EXHIBIT 152
PART 5

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Standard Test Methods for Analyses of Metals in Refuse-Derived Fuel by Atomic Absorption Spectroscopy[1]

This standard is issued under the fixed designation E 885; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 These test methods cover the determination of metals in solution by atomic absorption spectroscopy (AAS).

1.2 The following sections outline the operating parameters for the individual metals:

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1.3 Detection limits, sensitivity, and optimum ranges of the test methods will vary with the various makes and models of atomic absorption spectrophotometers. The data shown in Table 1 provide some indication of the actual concentration ranges measurable by direct aspiration and using furnace techniques. In the majority of instances, the concentration range shown in the table by direct aspiration may be extended much lower with scale expansion and conversely extended upwards by using a less sensitive wavelength or by rotating the burner head. Detection limits by direct aspiration may also be extended through concentration of the sample or through solvent extraction techniques, or both. Lower concentrations may also be determined using the furnace techniques. The concentration ranges given in Table 1 are somewhat dependent on equipment such as the type of spectrophotometer and furnace accessory, the energy source, and the degree of electrical expansion of the output signal.

1.4 When using the furnace techniques, the analyst should be cautioned as to possible chemical reactions occurring at elevated temperatures that may result in either suppression or enhancement of the analysis element. To ensure valid data with furnace techniques, the analyst must examine each matrix for interference effects (see 6.2) and if detected, treat accordingly using either successive dilution, matrix modification or method of standard additions (see 10.5).

1.5 Where direct aspiration atomic absorption techniques do not provide adequate sensitivity, in addition to the furnace procedure, reference is made to specialized procedures such as gaseous hydride method for arsenic and selenium, the cold-vapor technique for mercury and the chelation-extraction procedure for selected metals.

1.6 *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* For hazard statement, see 8.4 and 17.2.3.

2. Referenced Documents

2.1 *ASTM Standards:*

D 1193 Specification for Reagent Water[2]

D 3223 Test Method for Total Mercury in Water[2]

E 926 Test Methods of Preparing Refuse-Derived Fuel (RDF) Samples for Analyses of Metals[3]

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[1] These test methods are under the jurisdiction of ASTM Committee D-34 on Waste Management and are the direct responsibility of Subcommittee D34.08 on Thermal Treatment.

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[2] *Annual Book of ASTM Standards*, Vol 11.01.

[3] *Annual Book of ASTM Standards*, Vol 11.04.

TABLE 1 Atomic Absorption Concentrations[A]

Metal	Direct Aspiration			Furnace Technique[B,C]	
	Detection Limit, mg/L	Sensitivity, mg/L	Optimum Concentration Range, mg/L	Detection Limit, µg/L	Optimum Concentration Range, µg/L
Aluminum	0.1	1	5 to 50	3	20 to 200
Antimony	0.2	0.5	1 to 40	3	20 to 300
Arsenic[D]	0.002	. . .	0.002 to 0.02	1	5 to 100
Barium (*P*)	0.1	0.4	1 to 20	2	10 to 200
Beryllium	0.005	0.025	0.05 to 2	0.2	1 to 30
Cadmium	0.005	0.025	0.05 to 2	0.1	0.5 to 10
Calcium	0.01	0.08	0.2 to 7	. . .	. . .
Chromium	0.05	0.25	0.5 to 10	1	5 to 100
Cobalt	0.05	0.2	0.5 to 5	1	5 to 100
Copper	0.02	0.1	0.2 to 5	1	5 to 100
Iron	0.03	0.12	0.3 to 5	1	5 to 100
Lead	0.1	0.5	1 to 20	1	5 to 100
Lithium	. . .	0.035	. . .	. . .	. . .
Magnesium	0.001	0.007	0.02 to 0.5	. . .	. . .
Manganese	0.01	0.05	0.1 to 3	0.2	1 to 30
Mercury[E]	0.0002	. . .	0.0002 to 0.01	. . .	. . .
Molybdenum (*P*)	0.1	0.4	1 to 40	1	3 to 60
Nickel (*P*)	0.04	0.15	0.3 to 5	1	5 to 100
Potassium	0.01	0.04	0.1 to 2	. . .	. . .
Selenium[D]	0.002	. . .	0.002 to 0.02	2	5 to 100
Silver	0.01	0.06	0.1 to 4	0.2	1 to 25
Sodium	0.002	0.015	0.03 to 1	. . .	. . .
Tin	0.8	4	10 to 300	5	20 to 300
Titanium (*P*)	0.4	2	5 to 100	10	50 to 500
Vanadium (*P*)	0.2	0.8	2 to 100	4	10 to 200
Zinc	0.005	0.02	0.05 to 1	0.05	0.2 to 4

[A] The concentrations shown are not contrived values and should be obtainable with any satisfactory atomic absorption spectrophotometer.

[B] For furnace sensitivity values consult instrument operating manual.

[C] The listed furnace values are those expected when using a 20 µL injection and normal gas flow except in the case of arsenic and selenium where gas interrupt is used. The symbol (*p*) indicates the use of pyrolytic graphite with the furnace procedure.

[D] Gaseous hydride method.

[E] Cold vapor technique.

3. Descriptions of Terms Specific to This Standard

3.1 *detection limit*—detection limits can be expressed as either an instrumental or method parameter. The limiting factor of the former using acid water standards would be the signal to noise ratio and degree of scale expansion used; while the latter would be more affected by the sample matrix and preparation procedure used.

3.1.1 The Scientific Apparatus Makers Association (SAMA) has approved the following definition: The detection limit is that concentration of an element which would yield an absorbance equal to twice the standard deviation of a series of measurements of a solution, the concentration of which is distinctly detectable above, but close to blank absorbance measurement.

3.1.2 The detection limit values listed in Table 1 and on individual metal methods are to be considered minimum working limits achievable with the procedures outlined in these test methods.

3.2 *optimum concentration range*—a range defined by limits expressed in concentration, below which scale expansion must be used and above which curve correction should be considered. The range will vary with the sensitivity of the instrument and the operating condition employed.

3.3 *sensitivity*—the concentration in milligrams of metal per litre that produces an absorption of 1 %.

4. Summary of Test Methods

4.1 In direct aspiration atomic absorption spectroscopy, a sample is aspirated and atomized in a flame. The light beam from a hollow cathode lamp whose cathode is made of the element to be determined is directed through the flame into a monochromator, and into a detector that measures the amount of light absorbed. Absorption depends upon the presence of free unexcited ground state atoms in the flame. Since the wavelength of the light beam is characteristic of only the metal being determined, the light energy absorbed by the flame is a measure of the concentration of that metal in the sample. This principle is the basis of atomic absorption spectroscopy.

4.2 Pretreatment of a solid sample is necessary for complete dissolution of the metals and complete breakdown of organic material prior to analysis (see Methods E 926). This process may vary because of the metals to be determined and the nature of the sample being analyzed.

4.3 When using the furnace technique in conjunction with an atomic absorption spectrophotometer, a representative aliquot of the sample is placed in the graphite tube in the furnace, evaporated to dryness, charred, and atomized. As a greater percentage of available atoms are vaporized and dissociated for absorption in the tube than the flame, the use of small sample volumes or detection of low concentrations of elements is possible. The principle is essentially the same as with direct aspiration atomic absorption except a furnace, rather than a flame, is used to atomize the sample. Radiation from a given excited element is passed through the vapor containing ground state atoms of that element. The intensity of the transmitted radiation decreases in proportion to the amount of the ground state element in the vapor. The metal atoms to be measured are placed in the beam of radiation by increasing the temperature of the furnace, thereby causing the injected specimen to be volatilized. A monochromator isolates the characteristic radiation from the hollow cathode lamp, and a photosensitive device measures the attenuated transmittal radiation.

5. Significance and Use

5.1 Metals in solution may be readily determined by atomic absorption spectroscopy (AAS). The method is simple, rapid, and applicable to a large number of metals in solution. Solid type samples may be analyzed after proper treatment.

6. Interferences

6.1 *Direct Aspiration:*

6.1.1 The most troublesome type of interference in atomic absorption spectrophotometry is usually termed "chemical" and is caused by lack of absorption of atoms bound in molecular combination to the flame. This phenomenon can occur when the flame is not sufficiently hot to dissociate the molecule, as in the case of phosphate interference with magnesium, or because the dissociated atom is immediately oxidized to a compound that will not dissociate further at the temperature of the flame. The addition of lanthanum will overcome the phosphate interference in the magnesium, calcium, and barium determinations. Similarly, silica interference in the determination of manganese can be eliminated by the addition of calcium.

6.1.2 Chemical interferences may also be eliminated by separating the metal from the interfering material. While complexing agents are primarily employed to increase the sensitivity of the analysis, they may also be used to eliminate or reduce interferences.

6.1.3 Highly dissolved solids in the sample being aspirated may result in an interference from nonatomic absorbance such as light scattering. If background correction is not available, a nonabsorbing wavelength should be checked. Preferably, high solid content solutions should be extracted (see 6.1.1 and 11.2).

6.1.4 Ionization interferences occur where the flame temperature is sufficiently high to generate the removal of an electron from a neutral atom, giving a positive charged ion. This type of interference can generally be controlled by the addition, to both standard and sample solutions, of a large excess of an easily ionized element.

6.1.5 Although quite rare, spectral interference can occur when an absorbing wavelength of an element present in the sample but not being determined falls within the width of the absorption line of the element of interest. The results of the determination will then be erroneously high, due to the contribution of the interfering element to the atomic absorption signal. Also, interference can occur when resonant energy from another element in a multi-element lamp or a metal impurity in the lamp cathode falls within the bandpass of the slit setting and that metal is present in the sample. This type of interference may sometimes be reduced by narrowing the slit width.

6.2 *Flameless Atomization:*

6.2.1 Although the problem of oxide formation is greatly reduced with furnace procedures because atomization occurs in an inert atmosphere, the technique is still subject to chemical and matrix interferences. The composition of the sample matrix can have a major effect on the analysis. It is those effects that must be determined and taken into consideration in the analysis of each different matrix encountered. To help verify the absence of matrix or chemical interference, use the following procedure. Withdraw from the sample two equal aliquots. To one of the aliquots, add a known amount of analyte and dilute both aliquots to the same predetermined volume. (The dilution volume should be based on the analysis of the undiluted sample. Preferably, the dilution should be 1:4 while keeping in mind the optimum concentration range of the analysis. Under no circumstances should the dilution be less than 1:1). The diluted aliquots should then be analyzed and the unspiked results multiplied by the dilution factor should be compared to the original determination. Agreement of the results (within ± 10 %) indicates the absence of interference. Comparison of the actual signal from the spike to the expected response from the analyte in an aqueous standard should help confirm the finding from the dilution analysis. Those samples that indicate the presence of interference should be treated in one or more of the following ways.

6.2.1.1 The samples should be successively diluted and reanalyzed to determine if the interference can be eliminated.

6.2.1.2 The matrix of the sample should be modified in the furnace. Examples are the addition of ammonium nitrate to remove alkali chlorides, ammonium phosphate to retain cadmium, and nickel nitrate for arsenic and selenium analysis **(1)**.[4] The mixing of hydrogen with the inert purge gas has also been used to suppress chemical interference. The hydrogen acts as a reducing agent and aids in molecular dissociation.

6.2.1.3 Analyze the sample by method of standard additions while noting the precautions and limitations of its use (see 10.5).

6.2.2 Gases generated in the furnace during atomization may have molecular absorption bands encompassing the analytical wavelength. When this occurs, either the use of background correction or choosing an alternate wavelength outside the absorption band should eliminate this interference. Background correction can also compensate for nonspecific broad band absorption interference.

6.2.3 Interference from a smoke-producing sample matrix can sometimes be reduced by extending the charring time at a higher temperature or using an ashing cycle in the presence of air. Care must be taken, however, to prevent loss of the analysis element.

6.2.4 Samples containing large amounts of organic materials should be oxidized by conventional acid digestion prior to being placed in the furnace. In this way, broad-band absorption will be minimized.

6.2.5 From anion-interference studies in the graphite furnace it is generally accepted that nitrate is the preferred anion. Therefore, nitric acid is preferable for any digestion or solubilization step. If another acid in addition to HNO_3 is required, a minimum amount should be used. This applies particularly to hydrochloric and to a lesser extent to sulfuric and phosphoric acids.

6.2.6 Carbide formation resulting from the chemical environment of the furnace has been observed with certain

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[4] The boldface numbers in parentheses refer to the list of references at the end of these test methods.

elements that form carbides at high temperatures. Molybdenum may be cited as an example. When this takes place, the metal will be released very slowly from the carbide as atomization continues. For molybdenum, one may be required to atomize for 30 s or more before the signal returns to baseline levels. This problem is greatly reduced, and the sensitivity increased with the use of pyrolytically-coated graphite.

6.2.7 Ionization interferences have to date not been reported with furnace techniques.

6.2.8 For comments on spectral interference see 6.1.5.

6.2.9 Contamination of the sample can be a major source of error because of the extreme sensitivities achieved with the furnace. The sample-preparation work area should be kept scrupulously clean. All glassware should be cleaned as directed. Pipet tips have been known to be a source of contamination. If suspected, they should be acid soaked with 1:5 HNO_3 and rinsed thoroughly with tap and deionized water. The use of a better grade pipet tip can greatly reduce this problem. It is very important that special attention be given to reagent blanks in both analysis and the correction of analytical results. Lastly, pyrolytic graphite, because of the production process and handling, can become contaminated. As many as five to possibly ten high temperature burns may be required to clean the tube before use.

7. Apparatus

7.1 *Atomic Absorption Spectrophotometer*—Single or dual channel, single- or double-beam instrument having a grating monochromator, photomultiplier detector, adjustable slits, a wavelength range from 190 to 800 nm, and provisions for interfacing with a strip-chart recorder.

7.2 *Burner*—The burner recommended by the particular instrument manufacturer should be used. For certain elements the nitrous oxide burner is required.

7.3 *Hollow Cathode Lamps*—Single-element lamps are to be preferred but multi-element lamps may be used. Electrodeless discharge lamps may also be used when available.

7.4 *Graphite Furnace*—Any furnace device capable of reaching the specified temperatures is satisfactory.

7.5 *Strip Chart Recorder*—A recorder is strongly recommended for furnace work so that there will be a permanent record, and any problems with the analysis such as drift, incomplete atomization, losses during charring, changes in sensitivity, etc., can be easily recognized.

7.6 *Pipets*—Microliter with disposable tips. Sizes can range from 5 to 100 µL as required.

7.7 *Pressure-reducing Valves*—The supplies of fuel and oxidant shall be maintained at pressures somewhat higher than the controlled operating pressure of the instrument by suitable valves.

7.8 *Separatory Flasks*—250 mL, or larger, for extraction with organic solvents.

7.9 *Glassware*—All glassware, linear polyethylene, polypropylene or Teflon containers, including sampling bottles, should be washed and rinsed in the following order: washed with detergent; rinsed with tap water, 1:1 nitric acid, tap water, 1:1 hydrochloride acid, tap water, and deionized distilled water.

7.10 *Borosilicate Glass Distillation Apparatus.*

8. Reagents and Materials

8.1 *Purity of Reagents*—Reagent grade chemicals shall be used in all tests. Unless otherwise indicated, it is intended that all reagents shall conform to the specifications of the Committee on Analytical Reagents of the American Chemical Society, where such specifications are available.[5] Other grades may be used, provided it is first ascertained that the reagent is of sufficiently high purity to permit its use without lessening the accuracy of the determination.

8.2 *Purity of Water*—Unless otherwise indicated, references to water shall be understood to mean reagent water as defined by Type II of Specification D 1193.

8.3 *Deionized Distilled Water*—Prepare by passing distilled water through a mixed bed of cation and anion exchange resins. Use deionized distilled water for the preparation of all reagents, calibration standards, and as dilution water.

8.4 *Nitric Acid* (concentrated)—If metal impurities are found to be present, distill reagent grade nitric acid in a borosilicate glass distillation apparatus, or use a spectrograde acid.

NOTE 1: **Precaution**—Perform distillation in hood with protective sash in place.

8.4.1 *Nitric Acid* (1:1)—Prepare a 1:1 dilution with deionized, distilled water by adding the concentrated acid to an equal volume of water.

8.5 *Hydrochloric Acid* (1:1)—Prepare a 1:1 solution of reagent grade hydrochloric acid and deionized distilled water. If metal impurities are found to be present, distill this mixture from a borosilicate glass distillation apparatus or use a spectrograde acid.

8.6 *Stock Standard Metal Solutions*—Prepare as directed in 10.1 and under the individual metal procedures. Commercially available stock standard solutions may be used.

8.7 *Calibration Standards*—Prepare a series of standards of the metal by dilution of the appropriate stock metal solution to cover the concentration range desired.

8.8 *Fuel and Oxidant*—Commercial grade acetylene is generally acceptable. Air may be supplied from a compressed air line, a laboratory compressor, or from a cylinder of compressed air. Reagent grade nitrous oxide is also required for certain determinations. Standard, commercially available argon and nitrogen are required for furnace work.

8.9 *Special Reagents for the Extraction Procedure:*

8.9.1 *Pyrrolidine Dithiocarbamic Acid (PDCA)*[6]—Prepare by adding 18 mL of analytical reagent grade pyrrolidine to 500 mL of chloroform in a litre flask.[7] Cool and add 15 mL of carbon disulfide in small portions and with swirling. Dilute to 1 L with chloroform. The solution can be used for several months if stored in a brown bottle in a refrigerator.

8.9.2 *Ammonium Hydroxide, 2N*—Dilute 3 mL concen-

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[5] *Reagent Chemicals, American Chemical Society Specifications*, American Chemical Society, Washington, DC. For suggestions on the testing of reagents not listed by the American Chemical Society, see *Analar Standards for Laboratory Chemicals*, BDH Ltd., Poole, Dorset, U.K., and the *United States Pharmacopeia and National Formulary*, U.S. Pharmaceutical Convention, Inc. (USPC), Rockville, MD.

[6] The name pyrrolidine dithiocarbamic acid (PDCA), although commonly referenced in the scientific literature is ambiguous. From the chemical reaction of pyrrolidine and carbon disulfide a more proper name would be 1-pyrrolidine carbodithioic acid, PCDA (CAS Registry No. 25769-03-3).

[7] An acceptable grade of pyrrolidine may be obtained from the Aldrich Chemical Co., 940 West St. Paul Ave., Milwaukee, WI 53233.

trated NH_4OH to 100 mL with deionized distilled water.

8.9.3 *Bromphenol Blue Indicator* (1 g/L)—Dissolve 0.1 g bromphenol blue in 100 mL of 500 % ethanol or isopropanol.

8.9.4 *HCL* (2.5 % v/v)—Dilute 2 mL redistilled HCl to 40 mL with deionized distilled water.

9. Sample Handling and Preservation

9.1 See Methods E 926 for sample handling and preservation procedures.

10. Preparation of Standards and Calibration

10.1 *Stock Standard Solutions,* are prepared from high purity metals, oxides, or nonhygroscopic reagent grade salts using deionized distilled water and redistilled nitric or hydrochloric acids. (See individual analysis sheets for specific instruction.) Sulfuric or phosphoric acids should be avoided as they produce an adverse effect on many elements. The stock solutions are prepared at concentrations of 1000 mg of the metal per litre. Commercially available standard solutions may also be used.

10.2 *Calibration Standards,* are prepared by diluting the stock metal solutions at the time of analysis. For best results, calibration standards should be prepared fresh each time an analysis is to be made and discarded after use. Prepare a blank and at least four calibration standards in graduated amounts in the appropriate range. The *calibration standards* should be prepared using the same type of acid or combination of acids and at the same concentration as will result in the samples following processing. Beginning with the blank and working toward the highest standard, aspirate the solutions and record the readings. Repeat the operation with both the calibration standards and the samples a sufficient number of times to secure a reliable average reading for each solution. Calibration standards for furnace procedures should be prepared as described on the individual sheets for that metal.

10.3 Where the sample matrix is so complex that viscosity, surface tension, and components cannot be accurately matched with standards, the method of standard addition must be used. This technique relies on the addition of small, known amounts of the analysis element to portions of the sample, the absorbance difference between those, and the original solution giving the slope of the calibration curve. The method of standard addition is described in greater detail in 10.5.

10.4 For those instruments that do not read out directly in concentration, a calibration curve is prepared to cover the appropriate concentration range. Usually, this means the preparation of standards that produce an absorption of 0 to 80 %. The correct method is to convert the percent absorption readings to absorbance and plot that value against concentration. The following relationship is used to convert absorption values to absorbance:

$$\text{absorbance} = \log (100/\%\ T) = 2 - \log(\%\ T)$$

where:

$\%\ T = 100 - \%$ absorption

As the curves are frequently nonlinear, especially at high absorption values, the number of standards should be increased in that portion of the curve.

10.5 *Method of Standard Additions:*

10.5.1 In this test method, equal volumes of sample are added to a deionized distilled water blank and to three standards containing different known amounts of the test element. The volume of the blank and the standards must be the same. The absorbance of each solution is determined and then plotted on the vertical axis of a graph, with the concentrations of the known standards plotted on the horizontal axis. When the resulting line is extrapolated back to zero absorbance, the point of interception of the abscissa is the concentration of the unknown. The abscissa on the left of the ordinate is scaled the same as on the right side, but in the opposite direction from the ordinate. An example of a plot so obtained is shown in Fig. 1.

10.5.2 The method of standard additions can be very useful. For the results to be valid, the following limitations must be taken into consideration:

10.5.2.1 The absorbance plot of sample and standards must be linear over the concentration range of concern. For best results the slope of the plot should be nearly the same as the slope of the aqueous standard curve. If the slope is significantly different (more than 20 %) caution should be exercised.

10.5.2.2 The effect of the interference should not vary as the ratio of analyte concentration to sample matrix changes, and the standard addition should respond in a similar manner as the analyte.

10.5.2.3 The determination must be free of spectral interference and corrected for nonspecific background interference.

11. General Procedure for Analysis by Atomic Absorption

11.1 *Direct Aspiration*—Differences between the various makes and models of satisfactory atomic absorption spectrophotometers prevent the formulation of detailed instructions applicable to every instrument. The analyst should follow the manufacturer's operating instructions for his particular instrument. In general, after choosing the proper hollow cathode lamp for the analysis, allow the lamp to warm up for a minimum of 15 min unless operated in a double beam mode. During this period, align the instrument, position the monochromator at the correct wavelength, select the proper monochromator slit width, and adjust the hollow cathode current according to the manufacturer's recommendation. Subsequently, light the flame and regulate the flow of fuel and oxidant, adjust the burner and nebulizer flow rate for maximum percent absorption and stability, and balance the photometer. Run a series of standards of the element under analysis and construct a calibration curve by plotting the concentrations of the standards against the absorbance. For those instruments which read directly in concentration set the curve corrector to read out the proper concentration. Aspirate the samples and determine the concentrations either directly or from the calibration curve. Standards must be run each time a sample or series of samples are run.

11.1.1 *Calculation for Direct Determination of Liquid Samples*—Read the metal value in mg/L from the calibration curve or directly from the readout system of the instrument.

11.1.1.1 If dilution of sample was required:

$$\text{mg/L metal in sample} = A\left(\frac{C + B}{C}\right)$$

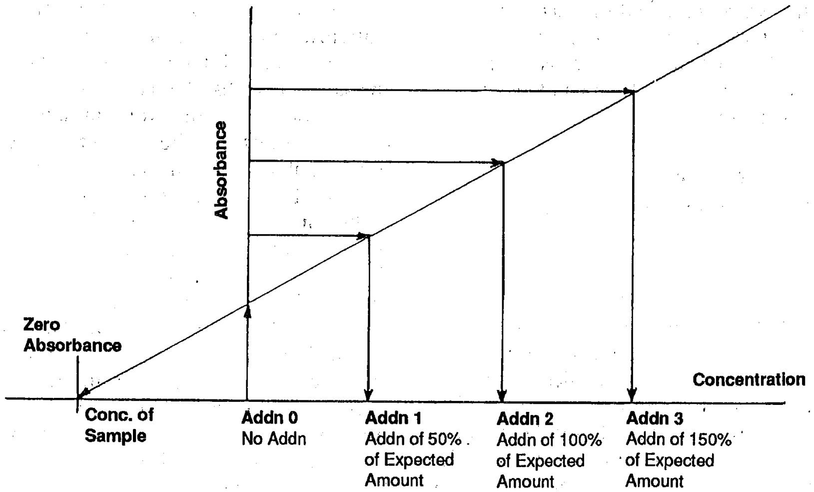

FIG. 1 Standard Addition Plot

where:
A = mg/L of metal in diluted aliquot from calibration curve,
B = mL of deionized distilled water used for dilution, and
C = mL of sample aliquot.

11.1.2 For solid samples: report all concentrations as mg/kg dry weight.

11.1.2.1 Dry sample:

$$\text{mg metal/kg sample} = \frac{A \times V}{D}$$

where:
A = mg/L of metal in processed sample from calibration curve,
V = final volume of the processed sample in mL, and
D = weight of dry sample in grams.

11.1.2.2 Wet sample:

$$\text{mg metal/kg sample} = \frac{A \times V}{W \times P}$$

where:
A = mg/L of metal in processed sample from calibration curve,
V = final volume of the processed sample in mL,
W = weight of wet sample in grams, and
P = percent solids.

11.2 *Special Extraction Procedure*—When the concentration of the metal is not sufficiently high to determine directly, or when considerable dissolved solids are present in the sample, certain metals may be chelated and extracted with organic solvents. Ammonium pyrrolidine dithiocarbamate (APDC)[8] in methyl isobutyl ketone (MIBK) is widely used for this purpose and is particularly useful for zinc, cadmium, iron, manganese, copper, silver, lead and chromium^{+6}. Trivalent chromium does not react with APDC unless it has first been converted to the hexavalent form (**2**). This procedure is described under method for chromium (chelation extraction). Aluminum, beryllium, barium and strontium also do not react with APDC. While the APDC-MIBK chelating-solvent system can be used satisfactorily, it is possible to experience difficulties.

NOTE 2—Certain metal chelates, manganese-APDC in particular, are not stable in MIBK and will redissolve into the aqueous phase on standing. The extraction of other metals is sensitive to both shaking rate and time. As with cadmium, prolonged extraction beyond 1 min, will reduce the extraction efficiency, whereas 3 min of vigorous shaking is required for chromium. Also, when multiple metals are to be determined either larger sample volumes must be extracted or individual extractions made for each metal being determined. The acid form of APDC-pyrrolidine dithiocarbamic acid prepared directly in chloroform as described by Lakanen has been found to be most advantageous (**3**). In this procedure the more dense chloroform layer allows for easy combination of multiple extractions which are carried out over a broader pH range favorable to multielement extraction. Pyrrolidine dithiocarbamic acid in chloroform is very stable and may be stored in a brown bottle in the refrigerator for months. Because chloroform is used as the solvent, it may not be aspirated into the flame. The procedure described in 11.2.1 is suggested.

11.2.1 *Extraction Procedure with Pyrrolidine Dithiocarbamic Acid (PDCA) in Chloroform:*

11.2.1.1 Transfer 200 mL of sample into a 250-mL separatory funnel, add 2 drops bromphenol blue indicator solution (8.9.3) and mix.

11.2.1.2 Prepare a blank and sufficient standards in the same manner and adjust the volume of each to approximately 200 mL with deionized distilled water. All of the metals to be determined may be combined into single solutions at the appropriate concentration levels.

11.2.1.3 Adjust the pH by addition of 2N NH_4OH solution (8.9.2) until a blue color persists. Add HCl (8.9.4) dropwise until the blue color just disappears; then add 2.0 mL HCl (8.9.4) in excess. The pH at this point should be 2.3. (The pH adjustment may be made with a pH meter instead of using indicator.)

11.2.1.4 Add 5 mL of PDCA-chloroform reagent (8.9.1) and shake vigorously for 2 min. Allow the phases to separate and drain the chloroform layer into a 100-mL beaker.

NOTE 3—If hexavalent chromium is to be extracted, the aqueous phase must be readjusted back to a pH of 2.3 after the addition of

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[8] The name ammonium pyrrolidine dithiocarbamate (APDC) is somewhat ambiguous and should more properly be called ammonium, 1-pyrollidine carbodithioate (APCD), CAS Registry No. 5108-96-3.

PDCA-chloroform and maintained at that pH throughout the extraction. For multielement extraction, the pH may be adjusted upward after the chromium has been extracted.

11.2.1.5 Add a second portion of 5 mL PDCA-chloroform reagent (8.7.1) and shake vigorously for 2 min. Allow the phases to separate and combine the chloroform phase with that obtained in 11.2.1.4.

11.2.1.6 Determine the pH of the aqueous phase and adjust to 4.5.

11.2.1.7 Repeat 11.2.1.4 again combining the solvent extracts.

11.2.1.8 Readjust the pH to 5.5, and extract a fourth time. Combine all extracts and evaporate to dryness on a steam bath.

11.2.1.9 Hold the beaker at a 45° angle, and slowly add 2 mL of concentrated distilled nitric acid, rotating the beaker to effect thorough contact of the acid with the residue.

11.2.1.10 Place the beaker on a low temperature hotplate or steam bath and evaporate just to dryness.

11.2.1.11 Add 2 mL of nitric acid (1:1) to the beaker and heat for 1 min. Cool, quantitatively transfer the solution to a 10-mL volumetric flask and bring to volume with distilled water. The sample is now ready for analysis.

11.2.2 Prepare a calibration curve by plotting absorbance versus the concentration of the metal standard (μg/L) in the 200-mL extracted standard solution. To calculate sample concentration read the metal value in μg/L from the calibration curve or directly from the readout system of the instrument. If dilution of the sample was required use the following equation:

$$\text{mg/L metal in sample} = Z\left(\frac{C+B}{C}\right)$$

where:

Z = μg/L of metal in diluted aliquot from calibration curve,
B = mL of deionized distilled water used for dilution, and
C = mL of sample aliquot.

11.3 *Furnace Procedure*—Furnace devices (flameless atomization) are a most useful means of extending detection limits. Because of differences between various makes and models of satisfactory instruments, no detailed operating instructions can be given for each instrument. Instead, the analyst should follow the instructions provided by the manufacturer of his particular instrument and use as a guide the temperature settings and other instrument conditions listed on the individual analysis sheets which are recommended for the Perkin-Elmer HGA-2100.[9] In addition, the following points may be helpful.

11.3.1 With flameless atomization, background correction becomes of high importance especially below 350 nm. This is because certain samples, when atomized, may absorb or scatter light from the hollow cathode lamp. It can be caused by the presence of gaseous molecular species, salt particles, or smoke in the sample beam. If no correction is made, sample absorbance will be greater than it should be, and the analytical result will be erroneously high.

11.3.2 If during atomization all the analyte is not volatilized and removed from the furnace, memory effects will occur. This condition is dependent on several factors such as the volatility of the element and its chemical form, whether pyrolytic graphite is used, the rate of atomization and furnace design. If this situation is detected through blank burns, the tube should be cleaned by operating the furnace at full power for the required time period as needed at regular intervals in the analytical scheme.

11.3.3 Some of the smaller size furnace devices, or newer furnaces equipped with feedback temperature control employing faster rates of atomization, can be operated using lower atomization temperatures for shorter time periods than those listed in this manual.[10]

11.3.4 Although prior digestion of the sample in many cases is not required providing a representative aliquot of sample can be pipeted into the furnace, it will provide for a more uniform matrix and possibly lessen matrix effects.

11.3.5 Inject a measured microlitre aliquot of sample into the furnace and atomize. If the concentration found is greater than the highest standard, the sample should be diluted in the same acid matrix and reanalyzed. The use of multiple injections can improve accuracy and help detect furnace pipetting errors.

11.3.6 To verify the absence of interference, follow the procedure as given in part 6.2.1.

11.3.7 A check standard should be run approximately after every 10 sample injections. Standards are run in part to monitor the life and performance of the graphite tube. Lack of reproducibility or significant change in the signal for the standard indicates that the tube should be replaced. Even though tube life depends on sample matrix and atomization temperature, a conservative estimate would be that a tube will last at least 50 firings. A pyrolytic-coating would extend that estimate by a factor of 3.

11.3.8 *Calculation*—For determination of metal concentration by the furnace: Read the metal value in μg/L from the calibration curve or directly from the readout system of the instrument.

11.3.8.1 If different size furnace injection volumes are used for samples rather than for standards, calculate as follows:

$$\text{μg/L of metal in sample} = Z\left(\frac{S}{U}\right)$$

where:

Z = μg/L of metal read from calibration curve or readout system,
S = μL volume standard injected into furnace for calibration curve, and
U = μL volume of sample injected for analysis.

11.3.8.2 If dilution of sample was required but sample injection volume was the same as for the following standard:

$$\text{μg/L of metal in sample} = Z\left(\frac{C+B}{C}\right)$$

where:

Z = μg/L metal in diluted aliquot from calibration curve,

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[9] The Perkin-Elmer HGA-2100 available from Perkin-Elmer Corp., Instruments Division, Main Ave., Norwalk, CT 06858 has been found suitable.

[10] Instrumentation Laboratories Model 555 available from Instrumentation Laboratory, Inc., Analytical Instrumentation Division, Jonspin Road, Wilmington, MA 01887; Perkin-Elmer Models HGA2200 and HGA7613; and Varian Model CRA-90 available from Varian Associates, Inc., 611 Hansen Way, Palo Alto, CA 94303 have been found suitable.

B = mL of deionized distilled water used for dilution, and
C = mL of sample aliquot.

11.3.9 For solid samples, report all concentrations as mg/kg dry weight.

11.3.9.1 *Dry sample:*

$$\text{mg metal/kg sample} = \frac{\left(\frac{Z}{1\,000}\right)V}{D}$$

where:
Z = µg/L of metal in processed sample from calibration curve (see 11.3.8.1),
V = final volume of processed sample in millilitres, and
D = weight of dry sample in grams.

11.3.10 *Wet sample:*

$$\text{mg metal/kg sample} = \frac{\left(\frac{Z}{1\,000}\right)V}{W \times P}$$

where:
Z = µg/L of metal in processed sample from calibration curve (see 11.3.8.1),
V = final volume of processed sample in millilitres,
W = weight of wet sample in grams, and
P = percent solids.

12. Aluminum—Direct Aspiration

12.1 *Requirements:*

12.1.1 *Optimum Concentration Range*, 5 to 50 mg/L using a wavelength of 309.3 nm (see Notes 4 and 5).

12.1.2 *Sensitivity*, 1 mg/L.

12.1.3 *Detection Limit*, 0.1 mg/L.

NOTE 4—The following lines may also be used:
308.2 nm Relative Sensitivity 1
396.2 nm Relative Sensitivity 2
394.4 nm Relative Sensitivity 2.5

NOTE 5—For concentrations of aluminum below 0.3 mg/L, the furnace procedure is recommended.

12.2 *Preparation of Standard Solution:*

12.2.1 *Stock Solution*—Carefully weigh 1.000 g of aluminum metal (analytical reagent grade). Add 15 mL of concentrated HCl to the metal, cover the beaker, and warm gently. When solution is complete, transfer quantitatively to a 1 L-volumetric flask and make up to volume with deionized distilled water. 1 mL = 1 mg Al (1000 mg/L).

12.2.2 *Potassium Chloride Solution*—Dissolve 95 g potassium chloride (KCl) in deionized distilled water and make up to 1 L.

12.2.3 Prepare dilutions of the stock solution to be used as calibration standards at the time of analysis. The *calibration standards* should be prepared using the same type of acid and at the same concentration as that of the sample being analyzed either directly or after processing. To each 100 mL of standard and sample alike add 2.0 mL potassium chloride solution.

12.3 *General Instrumental Parameters:*

12.3.1 *Aluminum Hollow Cathode Lamp.*

12.3.2 *Wavelength*—309.3 nm.

12.3.3 *Fuel*—Acetylene.

12.3.4 *Oxidant*—Nitrous oxide.

12.3.5 *Type of flame*—Fuel rich.

12.4 *Analysis Procedure*—For analysis procedure and calculation, see "Direct Aspiration," 11.1.

12.5 *Interferences*—Aluminum is partially ionized in the nitrous oxide-acetylene flame. This problem may be controlled by the addition of an alkali metal (potassium, 1000 µg/mL) to both sample and standard solutions.

13. Aluminum—Furnace Technique

13.1 *Requirements:*

13.1.1 *Optimum Concentration Range*, 20–200 µg/L (see Note 6).

13.1.2 *Detection Limit*, 3 µg/L.

NOTE 6—The above concentration values and instrument conditions are for a Perkin-Elmer HGA-2100, based on the use of a 20-µL injection, continuous flow purge gas and nonpyrolytic graphite.

13.2 *Preparation of Standard Solution:*

13.2.1 *Stock Solution*—Prepare as described under "direct aspiration method."

13.2.2 Prepare dilutions of the stock solution to be used as calibration standards at the time of analysis. Also use these solutions for "standard additions."

13.2.3 Dilute the calibration standard to contain 0.5 % (v/v) HNO_3.

13.3 *General Instrument Parameters:*

13.3.1 *Drying Time and Temperature*—30 s at 125°C.

13.3.2 *Ashing Time and Temperature*—30 s at 1300°C.

13.3.3 *Atomizing Time and Temperature*—10 s at 2700°C.

13.3.4 *Purge Gas Atmosphere*—Argon.

13.3.5 *Wavelength*—309.3 nm.

13.3.6 Other operating parameters should be set as specified by the particular instrument manufacturer (see Notes 7 and 8).

NOTE 7—Background correction may be required if the sample contains high dissolved solids.

NOTE 8—It has been reported that chloride ion and that nitrogen used as a purge gas suppress the aluminum signal. Therefore, the use of halide acids and nitrogen as a purge gas should be avoided.

13.4 *Analysis Procedure*—For the analysis procedure and the calculation, see "Furnace Procedure" 11.3 (see Notes 9 and 10).

NOTE 9—For every sample matrix analyzed, verification is necessary to determine that the method of standard additions is not required (see 6.2.1).

NOTE 10—If the method of standard additions is required, follow the procedure given earlier in 10.5.

14. Antimony—Direct Aspiration

14.1 *Requirements:*

14.1.1 *Optimum Concentration Range*, 1 to 40 mg/L using a wavelength of 217.6 nm (see Note 11).

14.1.2 *Sensitivity*, 0.5 mg/L.

14.1.3 *Detection Limit*, 0.2 mg/L.

NOTE 11—For concentrations of antimony below 0.35 mg/L, the furnace procedure is recommended.

14.2 *Preparation of Standard Solution:*

14.2.1 *Stock Solution*—Carefully weigh 2.7426 g of antimony potassium tartrate (analytical reagent grade) and dissolve in deionized distilled water. Dilute to 1 L with deionized distilled water. 1 mL = 1 mg Sb (1000 mg/L).

14.2.2 Prepare dilutions of the stock solution to be used as calibration standards at the time of analysis. The *calibration*

standards should be prepared using the same type of acid and at the same concentration as that of the sample being analyzed either directly or after processing.

14.3 *General Instrumental Parameters:*

14.3.1 *Antimony Hollow Cathode Lamp.*

14.3.2 *Wavelength*—217.6 nm.

14.3.3 *Fuel*—Acetylene.

14.3.4 *Oxidant*—Air.

14.3.5 *Type of Flame*—Fuel Lean.

14.4 *Analysis Procedure*—For analysis procedure and calculation, see "Direct Aspiration," 11.1.

14.5 *Interferences:*

14.5.1 In the presence of lead (1000 mg/L), a spectral interference may occur at the 217.6-nm resonance line. In this case the 231.1-nm antimony line should be used.

14.5.2 Increasing acid concentrations decrease antimony absorption. To avoid this effect, the acid concentration in the samples and in the standards should be matched.

15. Antimony—Furnace Technique

15.1 *Requirements:*

15.1.1 *Optimum Concentration Range*, 20–300 µg/L (see Note 12).

15.1.2 *Detection Limit*, 3 µg/L.

NOTE 12—The concentration values and instrument conditions are for a Perkin-Elmer HGA-2100, based on the use of a 20-µL injection, continuous flow purge gas and non-pyrolytic graphite. Smaller sized furnace devices or those employing faster rates of atomization can be operated using lower atomization temperatures for shorter time periods than the recommended settings.

15.2 *Preparation of Standard Solution:*

15.2.1 *Stock Solution*—Prepare as described under "direct aspiration method."

15.2.2 Prepare dilutions of the stock solution to be used as calibration standards at the time of analysis. Also use these solutions for "standard additions."

15.2.3 Dilute the calibration standard to contain 0.2 % (v/v) HNO_3.

15.3 *General Instrument Parameters:*

15.3.1 *Drying Time and Temperature*—30 s at 125°C.

15.3.2 *Ashing Time and Temperature*—30 s at 800°C.

15.3.3 *Atomizing Time and Temperature*—10 s at 2700°C.

15.3.4 *Purge Gas Atmosphere*—Argon.

15.3.5 *Wavelength*—217.6 nm.

15.3.6 Other operating parameters should be set as specified by the particular instrument manufacturer (see Notes 13 and 14).

NOTE 13—The use of background correction is recommended.

NOTE 14—Nitrogen may also be used as the purge gas.

15.4 *Analysis Procedure*—For the analysis procedure and the calculation, see "Furnace Procedure" 11.3 (see Notes 15, 16, and 17).

NOTE 15—If chloride concentration presents a matrix problem or causes a loss previous to atomization, add an excess of 5 mg of ammonium nitrate to the furnace and ash using a ramp accessory or with incremental steps until the recommended ashing temperature is reached.

NOTE 16—For every sample matrix analyzed, verification is necessary to determine that the method of standard additions is not required (see 6.2.1).

NOTE 17—If the method of standard additions is required, follow the procedure given in 10.5.

16. Arsenic—Furnace Technique

16.1 *Requirements:*

16.1.1 *Optimum Concentration Range*, 5–100 µg/L (see Note 18).

16.1.2 *Detection Limit*, 1 µg/L.

NOTE 18—The above concentration values and instrument conditions are for a Perkin-Elmer HGA-2100, based on the use of a 20-µL injection, continuous flow purge gas and non-pyrolytic graphite. Smaller size furnace devices or those employing faster rates of atomization can be operated using lower atomization temperatures for shorter time periods than the above recommended settings.

16.2 *Preparation of Standard Solution:*

16.2.1 *Stock Solution*—Dissolve 1.320 g of arsenic trioxide, As_2O_3 (analytical reagent grade) in 100 mL of deionized distilled water containing 4 g NaOH. Acidify the solution with 20 mL concentrated HNO_3 and dilute to 1 L. 1 mL = 1 mg As (1000 mg/L).

16.2.2 *Nickel Nitrate Solution*, 5 %—Dissolve 24.780 g of ACS reagent grade $Ni(NO_3)_2 \cdot 6H_2O$ in deionized distilled water and make up to 100 mL.

16.2.3 *Nickel Nitrate Solution*, 1 %—Dilute 20 mL of the 5 % nickel nitrate to 100 mL with deionized distilled water.

16.2.4 *Working Arsenic Solutions*—Prepare dilutions of the stock solution to be used as calibration standards at the time of analysis. Withdraw appropriate aliquots of the stock solution, add 1 mL of concentrated HNO_3, 2 mL of 30 % H_2O_2 and 2 mL of the 5 % nickel nitrate solution. Dilute to 100 mL with deionized distilled water.

16.3 *Sample Preparation:*

16.3.1 Transfer 100 mL of well-mixed sample to a 250-mL Griffin beaker. Add 2 mL of 30 % H_2O_2 and sufficient concentrated HNO_3 to result in an acid concentration of 1 % (v/v). Heat for 1 h at 95°C or until the volume is slightly less than 50 mL.

16.3.2 Cool and bring back to 50 mL with deionized distilled water.

16.3.3 Pipet 5 mL of this digested solution into a 10 mL volumetric flask, add 1 mL of the 1 % nickel nitrate solution and dilute to 10-mL with deionized distilled water. The sample is now ready for injection into the furnace.

NOTE 19—If solubilization or digestion is not required, adjust the HNO_3 concentration of the sample to 1 % (v/v) and add 2 mL of 30 % H_2O_2 and 2 mL of 5 % nickel nitrate to each 100 mL of sample. The volume of the calibration standard should be adjusted with deionized distilled water to match the volume change of the sample.

16.4 *General Instrument Parameters:*

16.4.1 *Drying Time and Temperature*—30 s at 125°C.

16.4.2 *Ashing Time and Temperature*—30 s at 1100°C.

16.4.3 *Atomizing Time and Temperature*—10 s at 2700°C.

16.4.4 *Purge Gas Atmosphere*—Argon.

16.4.5 *Wavelength*—193.7 nm.

16.4.6 Other operating parameters should be set as specified by the particular instrument manufacturer.

NOTE 20—The use of background correction is recommended.

16.5 *Analysis Procedure*—For the analysis procedure and the calculation, see "Furnace Procedure" 11.3.

NOTE 21—For every sample matrix analyzed, verification is necessary to determine that the method of standard additions is not required (see 6.2.1).

NOTE 22—If the method of standard additions is required, follow the procedure given in 10.5.

17. Arsenic Gaseous Hydride Method

17.1 *Scope and Application:* The gaseous hydride method determines inorganic arsenic when present in concentrations at or about 2 μg/L. The method is applicable to drinking water and most fresh and saline waters in the absence of high concentrations of chromium, cobalt, copper, mercury, molybdenum, nickel, and silver.

17.2 *Summary of Test Method:*

17.2.1 Arsenic in the sample is first reduced to the trivalent form using $SnCl_2$ and converted to arsine, AsH_3, using zinc metal. The gaseous hydride is swept into an argon-hydrogen flame of an atomic absorption spectrophotometer. The working range of the method is 2 to 20 μg/L. The 193.7 nm wavelength is used.

17.2.2 Organic arsenic must be converted to inorganic compounds.

NOTE 23: **Precaution**—Arsine is a toxic gas. Precautions should be made to keep the system closed to the atmosphere.

17.3 Except for the perchloric acid step, the procedure to be used for this determination is found in Standard Methods for the Examination of Water and Wastewater **(4)**.

18. Barium—Direct Aspiration

18.1 *Requirements:*

18.1.1 *Optimum Concentration Range*, 1–20 mg/L using a wavelength of 553.6 nm (see Note 24).

18.1.2 *Sensitivity*, 0.4 mg/L.

18.1.3 *Detection Limit*, 0.1 mg/L.

NOTE 24—For concentrations of barium below 0.2 mg/L, the furnace procedure is recommended.

18.2 *Preparation of Standard Solution:*

18.2.1 *Stock Solution*—Dissolve 1.7787 g barium chloride ($BaCl_2 \cdot 2H_2O$, analytical reagent grade) in deionized distilled water and dilute to 1 L. 1 mL = 1 mg Ba (1000 mg/L).

18.2.2 *Potassium Chloride Solution*—Dissolve 95 g potassium chloride, KCl, in deionized distilled water and make up to 1 L.

18.2.3 Prepare dilutions of the stock barium solution to be used as calibration standards at the time of analysis. To each 100 mL of standard and sample alike, add 2.0 mL potassium chloride solution. The *calibration standards* should be prepared using the same type of acid and the same concentration as that of the sample being analyzed either directly or after processing.

18.3 *General Instrumental Parameters:*

18.3.1 *Barium hollow cathode lamp.*

18.3.2 *Wavelength*—553.6 nm.

18.3.3 *Fuel*—Acetylene.

18.3.4 *Oxidant*—Nitrous oxide.

18.3.5 *Type of Flame*—Fuel rich.

18.4 *Analysis of Procedure*—For analysis procedure and calculation, see "Direct Aspiration," 11.1.

18.5 *Interferences:*

18.5.1 The use of nitrous oxide-acetylene flame virtually eliminates chemical interference. However, barium is easily ionized in this flame, and potassium must be added (1000 mg/L) to standards and samples alike to control this effect.

18.5.2 If the nitrous oxide flame is not available and acetylene-air is used, phosphate, silicon and aluminum will severely depress the barium absorbance. This may be overcome by the addition of 2000 mg/L lanthanum.

19. Barium—Furnace Technique

19.1 *Requirements:*

19.1.1 *Optimum Concentration Range*, 10 to 200 μg/L (see Note 25).

19.1.2 *Detection Limit*, 2 μg/L.

NOTE 25—The above concentration values and instrument conditions are for a Perkin-Elmer HGA-2100, based on the use of a 20-μL injection, continuous flow purge gas and pyrolytic graphite.

19.2 *Preparation of Standard Solution:*

19.2.1 *Stock Solution*—Prepare as described under "direct aspiration method."

19.2.2 Prepare dilutions of the stock solution to be used as calibration standards at the time of analysis. These solutions are also to be used for "standard additions."

19.2.3 The calibration standard should be diluted to contain 0.5 % (v/v) HNO_3.

NOTE 26—The use of halide acid should be avoided.

19.3 *General Instrument Parameters:*

19.3.1 *Drying Time and Temperature*—30 s at 125°C.

19.3.2 *Ashing Time and Temperature*—30 s at 1200°C.

19.3.3 *Atomizing Time and Temperature*—10 s at 2800°C.

19.3.4 *Purge Gas Atmosphere*—Argon.

NOTE 27—Because of possible chemical interaction, nitrogen should not be used as a purge gas.

19.3.5 *Wavelength*—553.6 nm.

19.3.6 *Other Operating Parameters*, should be set as specified by the particular instrument manufacturer.

19.4 *Analysis Procedure*—For the analysis procedure and the calculation, see "Furnace Procedure" 11.3.

NOTE 28—For every sample matrix analyzed, verification is necessary to determine that the method of standard additions is not required (see 6.2.1).

NOTE 29—If the method of standard additions is required, follow the procedure given in 10.5.

20. Beryllium—Direct Aspiration

20.1 *Requirements:*

20.1.1 *Optimum Concentration Range*, 0.05 to 2 mg/L using a wavelength of 234.9 nm (see Notes 30 and 31).

20.1.2 *Sensitivity*, 0.025 mg/L.

20.1.3 *Detection Limit*, 0.005 mg/L.

NOTE 30—The "aluminon colorimetric method" may also be used **(6)**. The minimum detectable concentration by this method is 5 μg/L.

NOTE 31—For concentrations of beryllium below 0.02 mg/L, the furnace procedure is recommended.

20.2 *Preparation of Standard Solution:*

20.2.1 *Stock solution*—Dissolve 11.6586 g beryllium sulfate, $BeSO_4$, in deionized distilled water containing 2 mL concentrated nitric acid and dilute to 1 L. 1 mL = 1 mg Be (1000 mg/L).

20.2.2 Prepare dilutions of the stock solution to be used as calibration standards at the time of analysis. The *calibration*

standards should be prepared using the same type of acid and at the same concentration as that of the sample being analyzed either directly or after processing.

20.3 *General Instrumental Parameters:*

20.3.1 *Beryllium Hollow Cathode Lamp.*

20.3.2 *Wavelength*—234.9 nm.

20.3.3 *Fuel*—Acetylene.

20.3.4 *Oxidant*—Nitrous oxide.

20.3.5 *Type of Flame*—Fuel-rich.

20.4 *Analysis Procedure:*

20.4.1 For analysis procedure and calculation, see "Direct Aspiration," 11.3.

20.5 *Interferences:*

20.5.1 Sodium and silicon at concentrations in excess of 1000 mg/L have been found to severely depress the beryllium absorbance.

20.5.2 Bicarbonate ion is reported to interfere; however, its effect is eliminated when samples are acidified to a pH of 1.5.

20.5.3 Aluminum at concentrations of 500 μg/L is reported to depress the sensitivity of beryllium **(5)**.

21. Beryllium—Furnace Technique

21.1 *Requirements:*

21.1.1 *Optimum Concentration Range*, 1 to 30 μg/L (see Note 32).

21.1.2 *Detection Limit*, 0.2 μg/L.

NOTE 32—The above concentration values and instrument conditions are for a Perkin-Elmer HGA-2100, based on the use of a 20-μL injection, continuous flow purge gas and non-pyrolytic graphite. Smaller sized furnace devices or those employing faster rates of atomization can be operated using lower atomization temperatures for shorter time periods than the above recommended settings.

21.2 *Preparation of Standard Solution:*

21.2.1 *Stock Solution*—Prepare as described under "direct aspiration method."

21.2.2 Prepare dilutions of the stock solution to be used as calibration standards at the time of analysis. Also use these solutions for "standard additions."

21.2.3 The calibration standard should be diluted to contain 0.5 % (v/v) HNO_3.

21.3 *General Instrumental Parameters:*

21.3.1 *Drying Time and Temperature*—30 s at 125°C.

21.3.2 *Ashing Time and Temperature*—30 s at 1000°C.

21.3.3 *Atomizing Time and Temperature*—10 s at 2800°C.

21.3.4 *Purge Gas Atmosphere*—Argon.

21.3.5 *Wavelength*—234.9 nm.

21.3.6 The operating parameters should be set as specified by the particular instrument manufacturer.

NOTE 33—The use of background correction is recommended.

NOTE 34—Because of possible chemical interaction and reported lower sensitivity, nitrogen should not be used as the purge gas.

21.4 *Analysis Procedure*—For the analysis procedure and the calculation see "Furnace Procedure," 11.3.

NOTE 35—For every sample matrix analyzed, verification is necessary to determine that the method of standard additions is not required (see 6.2.1).

NOTE 36—If the method of standard additions is required, follow the procedure given in 10.5.

22. Cadmium—Direct Aspiration

22.1 *Requirements:*

22.1.1 *Optimum Concentration Range*, 0.05 to 2 mg/L using a wavelength of 228.8 nm (see Note 37).

22.1.2 *Sensitivity*, 0.025 mg/L.

22.1.3 *Detection Limit*, 0.005 mg/L.

NOTE 37—For levels of cadmium below 20 μg/L, either the Special Extraction Procedure given in 11.2 or the furnace technique is recommended.

22.2 *Preparation of Standard Solution:*

22.2.1 *Stock Solution*—Carefully weigh 2.282 g of cadmium sulfate ($3CdSO_4 \cdot 8H_2O$, analytical reagent grade) and dissolve in deionized distilled water. 1 mL = 1 mg Cd (1000 mg/L).

22.2.2 Prepare dilutions of the stock solution to be used as calibration standards at the time of analysis. The *calibration standards* should be prepared using the same type of acid and at the same concentration as that of the sample being analyzed either directly or after processing.

22.3 *General Instrumental Parameters:*

22.3.1 *Cadmium Hollow Cathode Lamp.*

22.3.2 *Wavelength*—228.8 nm.

22.3.3 *Fuel*—Acetylene.

22.3.4 *Oxidant*—Air.

22.3.5 *Type of Flame*—Oxidizing.

22.4 *Analysis Procedure*—For analysis procedure and calculation, see "Direct Aspiration," 11.1.

23. Cadmium—Furnace Technique

23.1 *Requirements:*

23.1.1 *Optimum Concentration Range*, 0.5 to 10 μg/L (see Note 38).

23.1.2 *Detection Limit*, 0.1 μg/L.

NOTE 38—The above concentration values and instrument conditions are for a Perkin-Elmer HGA-2100, based on the use of a 20-μL injection, continuous flow purge gas and non-pyrolytic graphite. Smaller sized furnace devices or those employing faster rates of atomization can be operated using lower atomization temperatures for shorter time periods than the above recommended settings.

23.2 *Preparation of Standard Solution:*

23.2.1 *Stock Solution*: Prepare as described under "direct aspiration method."

23.2.2 *Ammonium Phosphate Solution* (40 %)—Dissolve 40 g of ammonium phosphate, $(NH_4)2HPO_4$ (analytical reagent grade) in deionized distilled water and dilute to 100 mL.

23.2.3 Prepare dilutions of the stock cadmium solution to be used as calibration standards at the time of analysis. To each 100 mL of standard and sample alike add 2.0 mL of the ammonium phosphate solution. The calibration standards should be prepared to contain 0.5 % (v/v) HNO_3.

23.3 *General Instrument Parameters:*

23.3.1 *Drying Time and Temperature*—30 s at 125°C.

23.3.2 *Ashing Time and Temperature*—30 s at 500°C.

23.3.3 *Atomizing Time and Temperature*—10 s at 1900°C.

23.3.4 *Purge Gas Atmosphere*—Argon.

23.3.5 *Wavelength*—228.8 nm.

23.3.6 Other operating parameters should be set as specified by the particular instrument manufacturer.

NOTE 39—The use of background correction is recommended.

23.4 *Analysis Procedure*—For the analysis procedure and the calculation see "Furnace Procedure," 11.3.

NOTE 40—Contamination from the work area is critical in cadmium analysis. Use of pipet tips which are free of cadmium is of particular importance.

NOTE 41—For every sample matrix analyzed, verification is necessary to determine that the method of standard additions is not required (see 6.2.1).

NOTE 42—If the method of standard additions is required, follow the procedure given in 10.5.

24. Cadmium—Direct Aspiration

24.1 *Requirements:*

24.1.1 *Optimum Concentration Range,* 0.2 to 7 mg/L using a wavelength of 422.7 nm (see Notes 43 and 44).

24.1.2 *Sensitivity,* 0.08 mg/L.

24.1.3 *Detection Limit,* 0.01 mg/L.

NOTE 43—Phosphate, sulfate and aluminum interfere but are masked by the addition of lanthanum. Since low calcium values result if the pH of the sample is above 7, both standards and samples are prepared in dilute hydrochloric acid solution. Concentrations of magnesium greater than 1000 mg/L also cause low calcium values. Concentrations of up to 500 mg/L each of sodium, potassium and nitrate cause no interference.

NOTE 44—The 239.9 nm line may also be used. This line has a relative sensitivity of 120.

24.2 *Preparation of Standard Solution:*

24.2.1 *Stock Solution*—Suspend 1.250 g of $CaCO_3$ (analytical reagent grade) dried at 180°C for 1 h before weighing, in deionized distilled water, and dissolve cautiously with a minimum of dilute HCl. Dilute to 1000 mL with deionized distilled water. 1 mL = 0.5 mg Ca (500 mg/L).

24.2.2 *Lanthanum Chloride Solution*—Dissolve 29 g of La_2O_3, slowly and in small portions, in 250 mL concentrated HCl (**Caution**—Reaction is violent). Dilute to 500 mL with deionized distilled water.

24.2.3 Prepare dilutions of the stock calcium solutions to be used as calibration standards at the time of analysis. To each 10 mL volume of calibration standard and sample alike, add 1.0 mL of the lanthanum chloride solution, that is, 20 mL of standard or sample + 2 mL $LaCl_3$ = 22 mL.

24.3 *General Instrumental Parameters:*

24.3.1 *Cadmium Hollow Cathode Lamp.*

24.3.2 *Wavelength*—422.7 nm.

24.3.3 *Fuel*—Acetylene.

24.3.4 *Oxidant*—Air.

24.3.5 *Type of Flame*—Reducing.

24.4 *Analysis Procedure*—For analysis procedure and calculation, see "Direct Aspiration," 11.1.

NOTE 45—Anionic chemical interferences can be expected if lanthanum is not used in samples and standards.

NOTE 46—The nitrous oxide-acetylene flame will provide two to five times greater sensitivity and freedom from chemical interferences. Ionization interferences should be controlled by adding a large amount of alkali to the sample and standards. The analysis appears to be free from chemical suppressions in the nitrous oxide-acetylene flame (7).

25. Chromium—Direct Aspiration

25.1 *Requirements:*

25.1.1 *Optimum Concentration Range:* 0.5 to 10 mg/L using a wavelength of 357.9 nm (see Notes 47 and 48).

25.1.2 *Sensitivity*—0.25 mg/L.

25.1.3 *Detection Limit*—0.05 mg/L.

NOTE 47—The following wavelengths may also be used:

359.3 nm Relative Sensitivity 1.4,
425.4 nm Relative Sensitivity 2,
427.5 nm Relative Sensitivity 3, and
428.9 nm Relative Sensitivity 4.

NOTE 48—For levels of chromium between 50 and 200 µg/L, where the air-acetylene flame cannot be used or for levels below 50 µg/L, either the furnace procedure or the extraction procedure is recommended.

25.2 *Preparation of Standard Solution:*

25.2.1 *Stock Solution:* Dissolve 1.923 g of chromium trioxide (CrO_3, reagent grade) in deionized distilled water. When solution is complete, acidify with redistilled HNO_3 and dilute to 1 L with deionized distilled water. 1 mL = 1 mg Cr (1000 mg/L).

25.2.2 Prepare dilutions of the stock solution to be used as calibration standards at the time of analysis. The *calibration standards* should be prepared using the same type of acid and at the same concentration as that of the sample being analyzed either directly or after processing.

25.3 *General Instrumental Parameters:*

25.3.1 *Chromium Hollow Cathode Lamp.*

25.3.2 *Wavelength*—357.9 nm.

25.3.3 *Fuel*—Acetylene.

NOTE 49—The fuel-rich air-acetylene flame provides greater sensitivity but is subject to chemical and matrix interference from iron, nickel, and other metals. If the analysis is performed in a lean flame the interference can be lessened but the sensitivity will also be reduced.

NOTE 50—The suppression of both Cr (III) and Cr (VI) absorption by most interfering ions in fuel rich air-acetylene flames is reportedly controlled by the addition of 1 % ammonium bifluoride in 0.2 % sodium sulfate (**8**). A 1 % oxine solution is also reported to be useful.

25.3.4 *Oxidant*—Nitrous oxide.

25.3.5 *Type of Flame*—Fuel rich.

25.4 *Analysis Procedure*—For analysis procedure and calculation, see "Direct Aspiration," 11.1.

26. Chromium—Furnace Technique

26.1 *Requirements:*

26.1.1 *Optimum Concentration Range,* 5 to 100 µg/L (see Note 51).

26.1.2 *Detection Limit,* 1 µg/L.

NOTE 51—The concentration values and instrument conditions are for a Perkin-Elmer HGA-2100, based on the use of 20 µL injection, continuous flow purge gas and non-pyrolytic graphite.

26.2 *Preparation of Standard Solution:*

26.2.1 *Stock Solution*—Prepare as described under "direct aspiration method."

26.2.2 *Calcium Nitrate Solution*—Dissolve 11.8 g of calcium nitrate, $Ca(NO_3)_2 \cdot 4H_2O$ (analytical reagent grade) in deionized distilled water and dilute to 100 mL. 1 mL = 20 mg Ca.

26.2.3 Prepare dilutions of the stock chromium solution to be used as calibration standards at the time of analysis. The calibration standards should be prepared to contain 0.5 % (v/v) HNO_3. To each 100 mL of standard and sample alike, add 1 mL of 30 % H_2O_2 and 1 mL of the calcium nitrate solution.

NOTE 52—Hydrogen peroxide is added to the acidified solution to convert all chromium to the trivalent state. Calcium is added to a level above 200 mg/L where its suppressive effect becomes constant up to 1000 mg/L.

26.3 *General Instrument Parameters:*

26.3.1 *Drying Time and Temperature*—30 s at 125°C.

26.3.2 *Ashing Time and Temperature*—30 s at 1000°C.

26.3.3 *Atomizing Time and Temperature*—10 s at 2700°C.

26.3.4 *Purge Gas Atmosphere*—Argon.

26.3.5 *Wavelength*—357.9 nm.

26.3.6 Other operating parameters should be set as specified by the particular instrument manufacturer.

NOTE 53—Background correction may be required if the sample contains high dissolved solids.

NOTE 54—Nitrogen should not be used as a purge gas because of possible CN band interference.

26.4 *Analysis Procedure*—For the analysis procedure and the calculation, see "Furnace Procedure" 11.3.

NOTE 55—Pipet tips have been reported to be a possible source of contamination.

NOTE 56—For every sample matrix analyzed, verification is necessary to determine that the method of standard additions is not required (see 6.2.1).

NOTE 57—If the method of standard additions is required, follow the procedure given in 10.5.

27. Chromium—Chelation-Extraction

27.1 *Scope*—This test method may be used to analyze samples containing from 1.0 to 25 µg of chromium per litre of solution.

27.2 *Summary of the Test Method:*

27.2.1 This test method is based on the chelation of hexavalent chromium with ammonium pyrrolidine dithiocarbamate (APDC) following oxidation of trivalent chromium. The chelate is extracted with methyl isobutyl ketone (MIBK) and aspirated into the flame of the atomic absorption spectrophotometer.

27.2.2 Hexavalent chromium may also be chelated with pyrrolidine dithiocarbamic acid in chloroform as described in 11.2.

27.3 *Interferences*—High concentrations of other reactive metals, as may be found in wastewaters, may interfere. The method is free from interferences from elements normally occurring in fresh water.

27.4 *General Instrumental Parameters:*

27.4.1 *Chromium Hollow Cathode Lamp.*

27.4.2 *Wavelength*—357.9 nm.

27.4.3 *Fuel*—Acetylene.

27.4.4 *Oxidant*—Air.

27.4.5 *Type of Flame*—Fuel rich (adjust for organic solvent).

27.5 *Reagents:*

27.5.1 *Ammonium Pyrrolidine Dithiocarbamate* (APDC) *Solution*—Dissolve 1.0 g APDC in dimineralized water and dilute to 100 mL. Prepare fresh daily.

27.5.2 *Bromphenol Blue Indicator Solution*—Dissolve 0.1 g bromphenol blue in 100 mL 50 % ethanol.

27.5.3 *Potassium Dichromate Standard Solution* (1.0 mL = 0.08 mg Cr)—Dissolve 0.2263 g dried analytical reagent grade $K_2Cr_2O_7$ in demineralized water, and make up to 1000 mL.

27.5.4 *Trivalent Chromium Stock Solution* (1.0 mL = 0.002 mg $Cr^{+}3$)—Pipet 5.00 mL of the potassium dichromate standard solution (5.3) into an Erlenmeyer flask. Add approximately 15 mg Na_2SO_3 and 0.5 mL concentrated HNO_3. Gently evaporate to dryness; strong heating reoxidizes the chromium. Add 0.5 mL concentrated HNO_3 and again evaporate to dryness to destroy any excess sulfite. Take up in 1 mL concentrated HNO_3 with warming and dilute to 200.00 mL with demineralized water.

27.5.5 *Trivalent Chromium Working Solution* (1.0 mL = 0.005 mg Cr^{+3})—Immediately before use, dilute 25.0 mL of trivalent chromium stock solution (27.5.4) to 100.0 mL with demineralized water.

27.5.6 *Potassium Permanganate* (0.1 N)—Dissolve 0.32 g potassium permanganate in 100 mL demineralized water.

27.5.7 *Sodium Azide* (0.1 %)—Dissolve 100 mg sodium azide in demineralized water and dilute to 100 mL.

27.5.8 *Methyl Isobutyl Ketone* (MIBK).

27.5.9 *Sodium Hydroxide Solution* (1 M)—Dissolve 40 g NaOH in demineralized water and dilute to 1 L.

27.5.10 *Sulfuric Acid* (0.12 M)—Slowly add 6.5 mL concentrated H_2SO_4 (sp gr 1.84) to demineralized water and dilute to 1 L.

27.6 *Procedure:*

27.6.1 Pipet a volume of sample containing less than 2.5 µg chromium (100 mL maximum) into a 200 mL volumetric flask, and adjust the volume to approximately 100 mL. The pH must be 2.0 or less. Add concentrated HNO_3 if necessary.

27.6.2 Acidify a litre of demineralized water with 1.5 mL concentrated HNO_3. Prepare a blank and sufficient standards using trivalent chromium, and adjust volumes to approximately 100 mL with the acidified demineralized water.

27.6.3 Add 0.1 N $KMnO_4$ dropwise to both standards and samples until a faint pink color persists.

27.6.4 Heat on a steam bath for 20 min. If the color disappears, add additional $KMnO_4$ solution dropwise to maintain a slight excess.

27.6.5 While still on the steam bath, add sodium azide solution dropwise until the $KMnO_4$ color just disappears. Heat for about 2 min between each addition and avoid adding any excess. Continue heating for 5 min after adding the last drop of sodium azide solution.

27.6.6 Transfer the flasks to a water bath and cool to room temperature.

27.6.7 Remove from the water bath and filter (through Whatman No. 40 filter paper or equivalent) any sample that has a brownish precipitate or coloration which may interfere with the pH adjustment.

27.6.8 Add 2.0 mL of 1 M NaOH and 2 drops bromphenol blue indicator solution. Continue the addition of 1 M NaOH dropwise to all samples and standards in which the indicator change from yellow to blue has not occurred. Add 0.12 M H_2SO_4 dropwise until the blue color just disappears, then add 2.0 mL in excess. The pH at this point will be 2.4.

27.6.9 The pH adjustment to 2.4 may also be made with a pH meter instead of using an indicator.

27.6.10 Add 5.0 mL APDC solution and mix. The pH should then be approximately 2.8.

27.6.11 Add 10.0 mL MIBK and shake vigorously for 3 min.

27.6.12 Allow the layers to separate and add demineralized water until the ketone layer is completely in the neck of the flask.

27.6.13 Aspirate the ketone layer, record the instrument reading for each sample and standard against the blank. Repeat, and average the duplicate results.

27.7 *Calculations:*

27.7.1 Determine the µg/L Cr in each sample from a plot of the instrument readings of standards. A working curve must be prepared with each set of samples. Report Cr concentrations as follows:

27.7.1.1 Less than 10 µg/L, nearest µg/L, and

27.7.1.2 10 µg/L and above, two significant figures.

27.7.2 Calculate the mg metal per kg of samples as outlined in 11.2.

28. Chromium, Hexavalent—Chelation–Extraction

28.1 *Scope:*

28.1.1 This test method may be used to analyze samples containing from 1.0 to 25 µg of chromium per litre of solution.

28.2 *Summary of Test Method:*

28.2.1 This method is based on the chelation of hexavalent chromium with ammonium pyrrolidine dithiocarbamate (APDC) and extraction with methyl isobutyl ketone (MIBK). The extract is aspirated into the flame of the atomic absorption spectrophotometer.

28.2.2 Hexavalent chromium may also be chelated with pyrrolidine dithiocarbamic acid in chloroform as described in 11.2. A pH of 2.3 must be maintained throughout the extraction.

28.2.3 The diphenylcarbazide colorimetric procedure as found in "Standard Methods for the Examination of Water and Wastewater" may also be used **(9)**.

28.3 *Sample Handling and Preservation:*

28.3.1 Stability of hexavalent chromium is not completely understood at this time. Therefore, the chelation and extraction should be carried out as soon as possible.

28.3.2 To retard the chemical activity of hexavalent chromium, the sample should be transported and stored until time of analysis at 4°C.

28.4 *Interferences:*

28.4.1 High concentrations of other reactive metals, as may be found in wastewaters, may interfere. The method is free from interferences from elements normally occurring in fresh water.

28.5 *General Instrumental Parameters:*

28.5.1 *Chromium hollow cathode lamp.*

28.5.2 *Wavelength*—357.9 nm.

28.5.3 *Fuel*—Acetylene.

28.5.4 *Oxidant*—Air.

28.5.5 *Type of Flame:* Fuel-rich (adjust for organic solvent).

28.6 *Reagents:*

28.6.1 *Ammonium Pyrrolidine Dithiocarbamate (APDC) Solution*—Dissolve 1.0 g APDC in demineralized water and dilute to 100 mL. Prepare fresh daily.

28.6.2 *Bromphenol Blue Indicator Solution*—Dissolve 0.1 g bromphenol blue in 100 mL 50 % ethanol.

28.6.3 *Chromium Standard Solution I* (1.0 mL = 100 µg Cr)—Dissolve 0.2829 g pure, dried $K_2Cr_2O_7$ in demineralized water and dilute to 1000 mL.

28.6.4 *Chromium Standard Solution II* (1.0 mL = 10.0 µg Cr)—Dilute 100 mL chromium standard solution I to 1000 mL with demineralized water.

28.6.5 *Chromium Standard Solution III* (1.0 mL = 0.10 µg Cr)—Dilute 10.0 mL chromium standard solution II to 1000 mL with demineralized water.

28.6.6 *Methyl Isobutyl Ketone* (MIBK).

28.6.7 *Sodium Hydroxide Solution* (1 M)—Dissolve 40 g NaOH in demineralized water and dilute to 1 L.

28.6.8 *Sulfuric Acid* (0.12 M)—Slowly add 6.5 mL concentrated H_2SO_4 (sp gr 1.84) to demineralized water and dilute to 1 L.

28.7 *Procedure:*

28.7.1 Pipet a volume of sample containing less than 2.5 µg chromium (100 mL maximum) into a 200-mL volumetric flask, and adjust the volume to approximately 100 mL.

28.7.2 Prepare a blank and sufficient standards, and adjust the volume of each to approximately 100 mL.

28.7.3 Add 2 drops bromphenol blue indicator solution. (The pH adjustment to 2.4 may also be made with a pH meter instead of using an indicator.)

28.7.4 Adjust the pH by addition of 1 M NaOH solution dropwise until a blue color persists. Add 0.12 M H_2SO_4 dropwise until the blue color just disappears in both the standards and sample. Then add 2.0 mL of 0.12 M H_2SO_4 in excess. The pH at this point should be 2.4.

28.7.5 Add 5.0 mL APDC solution and mix. The pH should then be approximately 2.8.

28.7.6 Add 10.0 mL MIBK and shake vigorously for 3 min.

28.7.7 Allow the layers to separate and add demineralized water until the ketone layer is completely in the neck of the flask.

28.7.8 Aspirate the ketone layer, and record the scale reading for each sample and standard against the blank. Repeat and average the duplicate results.

28.8 *Calculations:*

28.8.1 Determine the µg/L Cr^{+6} in each sample from a plot of scale readings of standards. A working curve must be prepared with each set of samples. Report Cr^{+6} concentrations as follows: Less than 10 µg/L, nearest µg/L; 10 µg/L and above, two significant figures.

28.8.2 Calculate the mg metal per kg of sample as outlined in 11.2.

29. Cobalt—Direct Aspiration

29.1 *Requirements:*

29.1.1 *Optimum Concentration Range*—0.5 to 5 mg/L using a wavelength of 240.7 nm (see Note 58).

29.1.2 *Sensitivity*—0.2 mg/L.

29.1.3 *Detection Limit*—0.05 mg/L.

NOTE 58—For levels of cobalt below 100 µg/L, either the special extraction procedure (11.2), or the furnace technique is recommended.

29.2 *Preparation of Standard Solution:*

29.2.1 *Stock Solution*—Dissolve 4.307 g of cobaltous chloride, $CoCl_2 \cdot 6H_2O$ (analytical reagent grade), in deionized distilled water. Add 10 mL of concentrated nitric acid and dilute to 1 L with deionized distilled water. 1 mL = 1 mg Co (1000 mg/L).

29.2.2 Prepare dilutions of the stock cobalt solution to be used as calibration standards at the time of analysis. The *calibration standards* should be prepared using the same type of acid and at the same concentration as that of the sample being analyzed either directly or after processing.

29.3 *General Instrumental Parameters:*

29.3.1 *Cobalt Hollow Cathode Lamp.*

29.3.2 *Wavelength*—240.7 nm.

29.3.3 *Fuel*—Acetylene.

29.3.4 *Oxidant*—Air.

29.3.5 *Type of Flame*—Oxidizing.

29.4 *Analysis Procedure*—For analysis procedure and calculation, see "Direct Aspiration," 11.1.

30. Cobalt—Furnace Technique

30.1 *Requirements:*

30.1.1 *Optimum Concentration Range*, 5–100 μg/L (see Note 59).

30.1.2 *Detection Limit*, 1 μg/L.

NOTE 59—The above concentration values and instrument conditions are for a Perkin-Elmer HGA-2100, based on the use of a 20 μL injection, continuous flow purge gas and nonpyrolytic graphite. Smaller sized furnace devices or those employing faster rates of atomization can be operated using lower atomization temperatures for shorter time periods than the above recommended settings.

30.2 *Preparation of Standard Solution:*

30.2.1 *Stock Solution*—Prepare as described under "direct aspiration method."

30.2.2 Prepare dilutions of the stock solution to be used as calibration standards at the time of analysis. These solutions are also to be used for "standard additions."

30.2.3 The calibration standard should be diluted to contain 0.5 % (v/v) HNO_3.

30.3 *General Instrument Parameters:*

30.3.1 *Drying Time and Temperature*—30 s at 125°C.

30.3.2 *Ashing Time and Temperature*—30 s at 900°C.

30.3.3 *Atomizing Time and Temperature*—10 s at 2700°C.

30.3.4 *Purge Gas Atmosphere*—Argon.

30.3.5 *Wavelength*—240.7 nm.

30.3.6 Other operating parameters should be set as specified by the particular instrument manufacturer.

NOTE 60—The use of background correction is recommended.

NOTE 61—Nitrogen may also be used as the purge gas but with reported lower sensitivity.

30.4 *Analysis Procedure*—For the analysis procedure and the calculation, see "Furnace Procedure" 11.3.

NOTE 62—For every sample matrix analyzed, verification is necessary to determine that the method of standard additions is not required (see 6.2.1).

NOTE 63—If the method of standard additions is required, follow the procedure given earlier in 10.5.

31. Copper—Direct Aspiration

31.1 *Requirements:*

31.1.1 *Optimum Concentration Range*, 0.2–5 mg/L using a wavelength of 324.7 nm (see Notes 64 and 65).

31.1.2 *Sensitivity*, 0.1 mg/L.

31.1.3 *Detection Limit*, 0.02 mg/L.

NOTE 64—For levels of copper below 50 μg/L, either the Special Extraction Procedure, given in 11.2 or the furnace technique is recommended.

NOTE 65—Numerous absorption lines are available for the determination of copper. By selecting a suitable absorption wavelength, copper samples may be analyzed over a very wide range of concentration. The following lines may be used:

327.4 nm Relative Sensitivity 2,
216.5 nm Relative Sensitivity 7, and
222.5 nm Relative Sensitivity 20.

31.2 *Preparation of Standard Solution:*

31.2.1 *Stock Solution*—Carefully weigh 1.00 g of electrolyte copper (analytical reagent grade). Dissolve in 5 mL redistilled HNO_3, and make up to 1 L with deionized distilled water. Final concentration is 1 mg Cu per mL (1000 mg/L).

31.2.2 Prepare dilutions of the stock solution to be used as calibration standards at the time of analysis. The *calibration standards* should be prepared using the same type of acid and at the same concentration as that of the sample being analyzed either directly or after processing.

31.3 *General Instrumental Parameters:*

31.3.1 *Copper Hollow Cathode Lamp.*

31.3.2 *Wavelength*—324.7 nm.

31.3.3 *Fuel*—Acetylene.

31.3.4 *Oxidant*—Air.

31.3.5 *Type of Flame*—Oxidizing.

31.4 *Analysis Procedure*—For analysis procedure and calculation, see "Direct Aspiration", 11.1.

32. Copper—Furnace Technique

32.1 *Requirements:*

32.1.1 *Optimum Concentration Range*, 5 to 100 μg/L (see Note 66).

32.1.2 *Detection Limit*, 1 μg/L.

NOTE 66—The above concentration values and instrument conditions are for a Perkin-Elmer HGA-2100, based on the use of a 20-μL injection, continuous flow purge gas and non-pyrolytic graphite. Smaller sized furnace devices or those employing faster rates of atomization can be operated using lower atomization temperatures for shorter time periods than the above recommended settings.

32.2 *Preparation of Standard Solution:*

32.2.1 *Stock Solution*—Prepare as described under "direct aspiration method."

32.2.2 Prepare dilutions of the stock solution to be used as calibration standards at the time of analysis. These solutions are also to be used for "standard additions."

32.2.3 The calibration standard should be diluted to contain 0.5 % (v/v) HNO_3.

32.3 *General Instrument Parameters:*

32.3.1 *Drying Time and Temperature*—30 s at 125°C.

32.3.2 *Ashing Time and Temperature*—30 s at 900°C.

32.3.3 *Atomizing Time and Temperature*—10 s at 2700°C.

32.3.4 *Purge Gas Atmosphere*—Argon.

32.3.5 *Wavelength*—324.7 nm.

32.3.6 Other operating parameters should be set as specified by the particular instrument manufacturer.

NOTE 67—Background correction may be required if the sample contains high dissolved solids.

NOTE 68—Nitrogen may also be used as the purge gas.

32.4 *Analysis Procedure*—For the analysis procedure and the calculation, see "Furnace Procedure" 11.3.

NOTE 69—For every sample matrix analyzed, verification is necessary to determine that the method of standard additions is not required (see 6.2.1).

NOTE 70—If the method of standard additions is required, follow the procedure given in 10.5.

33. Iron—Direct Aspiration

33.1 *Requirements:*

33.1.1 *Optimum Concentration Range*, 0.3 to 5 mg/L using a wavelength of 248.3 nm (see Notes 71 and 72).

NOTE 71—The following lines may also be used:

248.8 nm relative sensitivity 2,
271.9 nm relative sensitivity 4,
302.1 nm relative sensitivity 5,
252.7 nm relative sensitivity 6, and
372.0 nm relative sensitivity 10.

NOTE 72—For concentrations of iron below 0.05 mg/L, either the Special Extraction Procedure given in 11.2 or the furnace procedure, is recommended.

33.1.2 *Sensitivity*, 0.12 mg/L.

33.1.3 *Detection Limit*, 0.03 mg/L.

33.2 *Preparation of Standard Solution:*

33.2.1 *Stock Solution*—Carefully weigh 1.000 g of pure iron wire (analytical reagent grade) and dissolve in 5 mL redistilled HNO_3, warming if necessary. When solution is complete, make up to 1 L with deionized distilled water. 1 mL = 1 mg Fe (1000 mg/L).

33.2.2 Prepare dilutions of the stock solution to be used as calibration standards at the time of analysis. The *calibration standards* should be prepared using the same type of acid and at the same concentration as will result in the sample to be analyzed either directly or after processing.

33.3 *General Instrumental Parameters:*

33.3.1 *Iron Hollow Cathode Lamp.*

33.3.2 *Wavelength*—248.3 nm.

33.3.3 *Fuel*—Acetylene.

33.3.4 *Oxidant*—Air.

33.3.5 *Type of Flame*—Oxidizing.

33.4 *Analysis Procedure*—For analysis procedure and calculation, see "Direct Aspiration," 11.1.

34. Iron—Furnace Technique

34.1 *Requirements:*

34.1.1 *Optimum Concentration Range*—5 to 100 µg/L (see Note 73).

34.1.2 *Detection Limit*—1 µg/L.

NOTE 73—The concentration values and instrument conditions are for a Perkin-Elmer HGA-2100, based on the use of a 20 µL-injection, continuous flow purge gas, and nonpyrolytic graphite. Smaller sized furnace devices or those employing faster rates of atomization can be operated using lower atomization temperatures for shorter time periods than the recommended settings.

34.2 *Preparation of Standard Solution:*

34.2.1 *Stock Solution*—Prepare as described under "direct aspiration method."

34.2.2 Prepare dilutions of the stock solution to be used as calibration standards at the time of analysis. These solutions are also to be used for "standard additions."

34.2.3 The calibration standard should be diluted to contain 0.5 % (v/v) HNO_3.

34.3 *General Instrument Parameters:*

34.3.1 *Drying Time and Temperature*—30 s at 125°C.

34.3.2 *Ashing Time and Temperature*—30 s at 1000°C.

34.3.3 *Atomizing Time and Temperature*—10 s at 2700°C.

34.3.4 *Purge Gas Atmosphere*—Argon.

34.3.5 *Wavelength*—248.3 nm.

34.3.6 Other operating parameters should be set as specified by the particular instrument manufacturer.

NOTE 74—The use of background correction is recommended.

NOTE 75—Nitrogen may also be used as the purge gas.

34.4 *Analysis Procedure*—For the analysis procedure and the calculation, see "Furnace Procedure," 11.3.

NOTE 76—For every sample matrix analyzed, verification is necessary to determine that the method of standard additions is not required (see 6.2.1).

NOTE 77—If the method of standard additions is required, follow the procedure given in 10.5.

35. Lead—Direct Aspiration

35.1 *Requirements:*

35.1.1 *Optimum Concentration Range*, 1–20 mg/L using a wavelength of 283.3 nm (see Notes 78 and 79).

35.1.2 *Sensitivity*, 0.5 mg/L.

35.1.3 *Detection Limit*, 0.1 mg/L.

NOTE 78—For levels of lead below 200 µg/L, either the Special Extraction Procedure given in 11.2 or the furnace technique is recommended.

NOTE 79—The following lines may also be used:
217.0 nm Relative Sensitivity 0.4, and
261.4 nm Relative Sensitivity 10.

35.2 *Preparation of Standard Solution:*

35.2.1 *Stock Solution*—Carefully weigh 1.599 g of lead nitrate, $Pb(NO_3)_2$ (analytical reagent grade), and dissolve in deionized distilled water. When solution is complete, acidify with 10 mL redistilled HNO_3 and dilute to 1 L with deionized distilled water. 1 mL = 1 mg Pb (1000 mg/L).

35.2.2 Prepare dilutions of the stock solution to be used as calibration standards at the time of analysis. The *calibration standards* should be prepared using the same type of acid and at the same concentration as that of the sample being analyzed either directly or after processing.

35.3 *General Instrumental Parameters:*

35.3.1 *Iron Hollow Cathode Lamp.*

35.3.2 *Wavelength*—283.3 nm.

35.3.3 *Fuel*—Acetylene.

35.3.4 *Oxidant*—Air.

35.3.5 *Type of Flame*—Oxidizing.

35.4 *Analysis Procedure*—For analysis procedure and calculation, see "Direct Aspiration," 11.1.

NOTE 80—The analysis of this metal is exceptionally sensitive to turbulence and absorption bands in the flame. Therefore, some care should be taken to position the light beam in the most stable, center portion of the flame. To do this, first adjust the burner to maximize the absorbance reading with a lead standard. Then, aspirate a water blank and make minute adjustments in the burner alignment to minimize the signal.

36. Lead—Furnace Technique

36.1 *Requirements:*

36.1.1 *Optimum Concentration Range*, 5 to 100 µg/L (see Note 81).

36.1.2 *Detection Limit*, 1 µg/L.

NOTE 81—The above concentration values and instrument conditions are for a Perkin-Elmer HGA-2100, based on the use of a 20-µL injection, continuous flow purge gas and nonpyrolytic graphite. Smaller sized furnace devices or those employing faster rates of atomization can be operated using lower atomization temperatures for shorter time periods than the above recommended settings.

36.2 *Preparation of Standard Solution:*

36.2.1 *Stock Solution*—Prepare as described under "direct aspiration method."

36.2.2 *Lanthanum Nitrate Solution*—Dissolve 58.64 g of ACS reagent grade La_2O_3 in 100 mL concentrated HNO_3, and dilute to 1000 mL with deionized distilled water. 1 mL = 50 mg La.

36.2.3 *Working Lead Solution*—Prepare dilutions of the stock lead solution to be used as calibration standards at the time of analysis. Each calibration standard should contain 0.5 % (v/v) HNO_3. To each 100 mL of diluted standard, add 10 mL of the lanthanum nitrate solution.

36.3 *General Instrument Parameters:*

36.3.1 *Drying Time and Temperature*—30 s at 125°C.

36.3.2 *Ashing Time and Temperature*—30 s at 500°C.

36.3.3 *Atomizing Time and Temperature*—10 s at 2700°C.

36.3.4 *Purge Gas Atmosphere*—Argon.

36.3.5 *Wavelength*—283.3 nm.

NOTE 82—Greater sensitivity can be achieved using the 217.0-nm line, but the optimum concentration range is reduced. The use of a lead electrodeless discharge lamp at this lower wavelength has been found to be advantageous. Also a lower atomization temperature (2400°C) may be preferred.

36.3.6 Other operating parameters should be set as specified by the particular instrument manufacturer.

NOTE 83—The use of background correction is recommended.

36.4 *Analysis Procedure*—For the analysis procedure in the calculation see "Furnace Procedure," 11.3.

NOTE 84—To suppress sulfate interference (up to 1500 ppm) lanthanum is added as the nitrate to both samples and calibration standards (**10**).

NOTE 85—Since glassware contamination is a severe problem in lead analysis, all glassware should be cleaned immediately prior to use, and once cleaned, should not be open to the atmosphere except when necessary.

NOTE 86—For every sample matrix analyzed, verification is necessary to determine that the method of standard additions is not required (see 6.2.1).

NOTE 87—If the method of standard additions is required, follow the procedure given in 10.5.

37. Lithium—Direct Aspiration

37.1 *Requirements:*

37.1.1 *Optimum Concentration Range*—to 0.2 mg/L using a wavelength of 670.8 nm (see Note 88).

37.1.2 *Sensitivity*—0.035 mg/L.

NOTE 88—The following lines may also be used:
323.3 nm relative sensitivity 235, and
610.4 nm relative sensitivity 3600.

37.2 *Preparation of Standard Solution:*

37.2.1 *Stock Solution*—Dissolve 5.324 g of lithium carbonate, Li_2CO_3 in a minimum volume of (1+1) HCl and dilute to 1 L with deionized water. 1 mL = 1.00 mg Li (1000 mg/L).

37.2.2 Prepare dilutions of the stock lithium solution to be used as calibration standards at the time of analysis. The *calibration standards* should be prepared using the same type of acid and at the same concentration as that of the sample being analyzed either directly or after processing.

37.3 *General Instrumental Parameters:*

37.3.1 *Lithium Hollow Cathode Lamp.*

37.3.2 *Wavelength*—670.8 nm.

37.3.3 *Fuel*—Acetylene.

37.3.4 *Oxidant*—Air.

37.4 *Analysis Procedure*—For analysis procedure and calculations, see "Direct Aspiration," 11.1.

38. Magnesium—Direct Aspiration

38.1 *Requirements:*

38.1.1 *Optimum Concentration Range*, 0.02 to 0.5 mg/L using a wavelength of 285.2 nm (see Notes 89 and 90).

38.1.2 *Sensitivity*, 0.007 mg/L.

38.1.3 *Detection Limit*, 0.001 mg/L.

NOTE 89—The following line may also be used: 202.5 nm relative sensitivity 25.

NOTE 90—To cover the range of magnesium values normally observed in surface waters (0.1 to 20 mg/L), it is suggested that either the 202.5 nm line be used or the burner head be rotated. A 90° rotation of the burner head will produce approximately one-eighth the normal sensitivity.

38.2 *Preparation of Standard Solution:*

38.2.1 *Stock Solution*—Dissolve 0.829 g of magnesium oxide, MgO (analytical reagent grade), in 10 mL of redistilled HNO_3, and dilute to 1 L with deionized distilled water. 1 mL = 0.50 mg Mg (500 mg/L).

38.2.2 *Lanthanum Chloride Solution*—Dissolve 29 g of La_2O_3, slowly and in small portions in 250 mL concentrated HCl, (**Caution**—Reaction is violent), and dilute to 500 mL with deionized distilled water.

38.2.3 Prepare dilutions of the stock magnesium solution to be used as calibration standards at the time of analysis. These *calibration standards* should be prepared using the same type of acid and at the same concentration as that of the sample being analyzed directly or after processing. To each 10-mL volume of *calibration standard* and sample alike add 1.0 mL of the lanthanum chloride solution, that is, 20 mL of standard or sample +2 mL $LaCl_3$ = 22 mL.

38.3 *General Instrumental Parameters:*

38.3.1 *Magnesium Hollow Cathode Lamp.*

38.3.2 *Wavelength*—285.2 nm.

38.3.3 *Fuel*—Acetylene.

38.3.4 *Oxidant*—Air.

38.3.5 *Type of Flame*—Oxidizing.

38.4 *Analysis Procedure*—For analysis procedure and calculation, see "Direct Aspiration," 11.1.

NOTE 91—The interference caused by aluminum at concentrations greater than 2 mg/L is masked by addition of lanthanum. Sodium, potassium and calcium cause no interference at concentrations less than 400 mg/L.

39. Manganese—Direct Aspiration

39.1 *Requirements:*

39.1.1 *Optimum Concentration Range*, 0.1 to 3 mg/L using a wavelength of 279.5 nm (see Note 92).

39.1.2 *Sensitivity*, 0.05 mg/L.

39.1.3 *Detection Limit*, 0.01 mg/L.

NOTE 92—The following line may also be used: 403.1 nm Relative Sensitivity 10.

39.2 *Preparation of Standard Solution:*

39.2.1 *Stock Solution*—Carefully weigh 1.000 g of manganese metal (analytical reagent grade), and dissolve in 10 mL of redistilled HNO_3. When solution is complete, dilute to 1 L with 1 % (v/v) HCl. 1 mL = 1 mg Mn (1000 mg/L).

39.2.2 Prepare dilutions of the stock solution to be used as calibration standards at the time of analysis. The *calibration standards* should be prepared using the same type of acid and at the same concentration as that of the sample being analyzed either directly or after processing.

39.3 *General Instrumental Parameters:*

39.3.1 *Manganese hollow cathode lamp.*

39.3.2 *Wavelength*—279.5 nm.

39.3.3 *Fuel*—Acetylene.

39.3.4 *Oxidant*—air.

39.3.5 *Type of Flame*—oxidizing.

39.4 *Analysis Procedure*—For analysis procedure and calculation, see "Direct Aspiration," 11.1.

NOTE 93—For levels of manganese below 25 µg/L, either the furnace procedure or the Special Extraction Procedure given in 10.2 is recommended. The extraction is carried out at a pH of 4.5 to 5. The manganese chelate is very unstable and the analysis must be made without delay to prevent its solution in the aqueous phase.

40. Manganese—Furnace Technique

40.1 *Requirements:*

40.1.1 *Optimum Concentration Range,* 1 to 30 µg/L (see Note 94).

40.1.2 *Detection Limit,* 0.2 µg/L.

NOTE 94—The above concentration values and instrument conditions are for a Perkin-Elmer HGA-2100, based on the use of a 20-uL injection, continuous flow purge gas and nonpyrolytic graphite. Smaller sized furnace devices or those employing faster rates of atomization can be operated using lower atomization temperatures for shorter time periods than the above recommended settings.

40.2 *Preparation of Standard Solution:*

40.2.1 *Stock Solution*—Prepare as described under "direct aspiration method."

40.2.2 Prepare dilutions of the stock solution to be used as calibration standards at the time of analysis. These solutions are also to be used for "standard additions."

40.2.3 The calibration standard should be diluted to contain 0.5 % (v/v) HNO_3.

40.3 *General Instrument Parameters:*

40.3.1 *Drying Time and Temperature*—30 s at 125°C.

40.3.2 *Ashing Time and Temperature*—30 s at 1000°C.

40.3.3 *Atomizing Time and Temperature*—10 s at 2700°C.

40.3.4 *Purge Gas Atmosphere*—Argon.

40.3.5 *Wavelength*—279.5 nm.

40.3.6 Other operating parameters should be set as specified by the particular instrument manufacturer.

NOTE 95—The use of background correction is recommended.

NOTE 96—Nitrogen may also be used as the purge gas.

40.4 *Analysis Procedure*—For the analysis procedure and the calculation, see "Furnace Procedure" 11.3.

NOTE 97—For every sample matrix analyzed, verification is necessary to determine that the method of standard additions is not required (see 6.2.1).

NOTE 98—If the method of standard additions is required, follow the procedure given earlier in 10.5.

41. Mercury Cold Vapor Technique

41.1 *Scope and Application* (**11**):

41.1.1 In addition to inorganic forms of mercury, organic mercurials may also be present. These organo-mercury compounds will not respond to the cold vapor atomic absorption technique unless they are first broken down and converted to mercuric ions. Potassium permanganate oxidizes many of these compounds, but recent studies have shown that a number of organic mercurials, including phenyl mercuric acetate and methyl mercuric chloride, are only partially oxidized by this reagent. Potassium persulfate has been found to give approximately 100 % recovery when used as the oxidant with these compounds. Therefore, a persulfate oxidation step following the addition of the permanganate has been included to ensure that organo-mercury compounds, if present, will be oxidized to the mercuric ion before measurement. A heat step is required for methyl mercuric chloride when present in or spiked to a natural system. For distilled water the heat step is not necessary.

41.1.2 The range of the test method may be varied through instrument or recorder expansion, or both. Using a 100-mL sample, a detection limit of 0.2 µg Hg/L can be achieved. Concentrations below this level should be reported as <0.2.

NOTE 99—If additional sensitivity is required, a 200 mL sample with recorder expansion may be used provided the instrument does not produce undue noise. Using a Coleman MAS-50 with a drying tube of magnesium perchlorate and a variable recorder, 2 mv was set to read full scale. With these conditions, and distilled water solutions of mercuric chloride at concentrations of 0.15, 0.10, 0.05 and 0.025 µg/L, the standard deviations were ±0.027, ±0.006, ±0.01, and ±0.004. Percent recoveries at these levels were 107, 83, 84, and 96 %, respectively.

41.2 *Summary of Test Method:*

41.2.1 The flameless AA procedure is a physical method based on the absorption of radiation at 253.7 nm by mercury vapor. The mercury vapor passes through a cell positioned in the light path of an atomic absorption spectrophotometer. Absorbance (peak height) is measured as a function of mercury concentration and recorded in the usual manner.

41.3 *Sample Handling and Preservation:*

41.3.1 Until more conclusive data are obtained, samples should be preserved by acidification with nitric acid to a pH of 2 or lower immediately at the time of collection. If only dissolved mercury is to be determined, the sample should be filtered through an all glass apparatus before the acid is added. For total mercury, the filtration is omitted.

41.4 *Interference:*

41.4.1 Possible interference from sulfide is eliminated by the addition of potassium permanganate. Concentrations as high as 20 mg/L of sulfide as sodium sulfide do not interfere with the recovery of added inorganic mercury from distilled water.

41.4.2 Copper has also been reported to interfere; however, copper concentrations as high as 10 mg/L had no effect on recovery of mercury from spiked samples.

41.4.3 High chloride concentrations require additional permanganate (as much as 25 mL). During the oxidation step, chlorides are converted to free chlorine which will also absorb radiation of 253 nm. Care must be taken to ensure that free chlorine is absent before the mercury is reduced and swept into the cell. This may be accomplished by using an excess of hydroxylamine sulfate reagent (25 mL). In addition, the dead air space in the BOD bottle must be purged before the addition of stannous sulfate. Both inorganic and organic mercury spikes have been quantitatively recovered from sea water using this technique.

41.4.4 Interference from certain volatile organic materials that will absorb at this wavelength is also possible. A preliminary run without reagents should determine if this type of interference is present.

NOTE 100—The possibility of absorption from certain organic substances actually being present in the sample does exist. This is

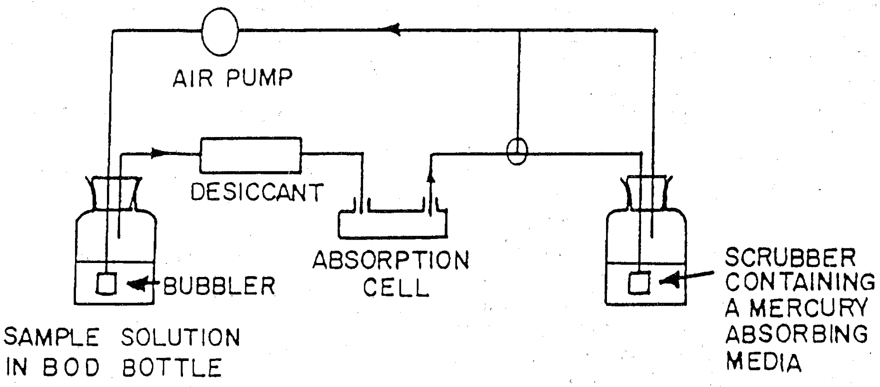

FIG. 2 Apparatus for Flameless Mercury Determination

mentioned only to caution the analyst of the possibility. A simple correction that may be used is as follows: If an interference has been found to be present, the sample should be analyzed both by using the regular procedure and again under oxidizing conditions only, that is without the reducing reagents. The true mercury value can then be obtained by subtracting the two values.

41.5 *Apparatus:*

41.5.1 Atomic Absorption Spectrophotometer; (See Note 101) Any atomic absorption unit having an open sample presentation area in which to mount the absorption cell is suitable. Instrument settings recommended by the particular manufacturer should be followed.

NOTE 101—Instruments designated specifically for the measurement of mercury using the cold vapor technique are commercially available and may be substituted for the atomic absorption spectrophotometer.

41.5.2 *Mercury Hollow Cathode Lamp*—argon filled, or equivalent.[11]

41.5.3 *Recorder*—Any multi-range variable speed recorder that is compatible with the UV detection system is suitable.

41.5.4 *Absorption Cell*—Standard spectrophotometer cells 10 cm long, having quartz end windows may be used. Suitable cells may be constructed from plexiglass tubing, 1 outside diameter by 4½ in. The ends are ground perpendicular to the longitudinal axis and quartz windows (1-in. diameter by 1/16-in. thickness) are cemented in place. The cell is strapped to a burner for support and aligned in the light beam by use of two 2 by 2 in. cards. One-inch diameter holes are cut in the middle of each card; the cards are then placed over each end of the cell. The cell is then positioned and adjusted vertically and horizontally to give the maximum transmittance.

41.5.5 *Air Pump*—Any peristaltic pump capable of delivering 1 L of air per minute may be used. A Masterflex pump with electronic speed control has been found to be satisfactory.

41.5.6 *Flowmeter*—Capable of measuring an air flow of 1 L per minute.

41.5.7 *Aeration Tubing*—A straight-glass frit having a coarse porosity. Tygon tubing is used for passage of the mercury vapor from the sample bottle to the absorption cell and return.

41.5.8 *Drying Tube*—6 by ¾ in. diameter tube containing 20 g of magnesium perchlorate (see Note 102). The apparatus is assembled as shown in Fig. 2.

NOTE 102—In place of the magnesium perchlorate drying tube, a small reading lamp with 60 W bulb may be used to prevent condensation of moisture inside the cell. The lamp is positioned to shine on the absorption cell maintaining the air temperature in the cell about 10.25°C above ambient.

41.6 *Reagents:*

41.6.1 *Sulfuric Acid, Concentrated*—Reagent grade.

41.6.1.1 *Sulfuric Acid,* 0.5 N—Dilute 14.0 mL of concentrated sulfuric acid to 1.0 L.

41.6.2 *Nitric Acid,* Concentrate—Reagent grade of low mercury content.

NOTE 103—If a high reagent blank is obtained, it may be necessary to distill the nitric acid.

41.6.3 *Stannous Sulfate*—Add 25 g stannous sulfate to 250 mL of 0.5 *N* sulfuric acid. This mixture is a suspension and should be stirred continuously during use. (Stannous chloride may be used in place of stannous sulfate.)

41.6.4 *Sodium Chloride-Hydroxylamine Sulfate Solution*—Dissolve 12 g of sodium chloride and 12 g of hydroxylamine sulfate in distilled water and dilute to 100 mL. (Hydroxylamine hydrochloride may be used in place of hydroxylamine sulfate.)

41.6.5 *Potassium Permanganate* (5 % solution, w/v)—Dissolve 5 g of potassium permanganate in 100 mL of distilled water.

41.6.6 *Potassium Persulfate* (5 % solution, w/v)—Dissolve 5 g of potassium persulfate in 100 mL of distilled water.

41.6.7 *Stock Mercury Solution*—Dissolve 0.1354 g of mercuric chloride in 75 mL of distilled water. Add 10 mL of concentrated nitric acid and adjust the volume to 100.0 mL. 1 mL = 1 mg Hg.

41.6.8 *Working Mercury Solution*—Make successive dilutions of the stock mercury solution to obtain a working standard containing 0.1 μg per mL. This working standard and the dilutions of the stock mercury solution should be prepared fresh daily. Acidity of the working standard should be maintained at 0.15 % nitric acid. This acid should be added to the flask as needed before the addition of the aliquot.

41.7 *Calibration:*

41.7.1 Transfer 0, 0.5, 1.0, 2.0, 5.0, and 10.0 mL aliquots of the working mercury solution containing 0 to 1.0 μg of mercury to a series of 300 mL BOD bottles. Add enough

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[11] Westinghouse WL-22847 available from any laboratory supply house has been found suitable.

distilled water to each bottle to make a total volume of 100 mL. Mix thoroughly and add 5 mL of concentrated sulfuric acid and 2.5 mL of concentrated nitric acid to each bottle. Add 15 mL of $KMnO_4$ solution to each bottle, and allow to stand at least 15 min. Add 8 mL of potassium persulfate to each bottle and heat for 2 h in a water bath maintained at 95°C. Cool and add 6 mL of sodium chloride-hydroxylamine sulfate solution to reduce the excess permanganate. When the solution has been decolorized wait 30 s, add 5 mL of the stannous sulfate solution and immediately attach the bottle to the aeration apparatus forming a closed system. At this point the sample is allowed to stand quietly without manual agitation. The circulating pump, which has previously been adjusted to a rate of 1 L per minute, is allowed to run continuously. (An open system where the mercury vapor is passed through the absorption cell only once may be used instead of the closed system.)

41.7.2 The absorbance will increase and reach maximum within 30 s. As soon as the recorder pen levels off; approximately 1 min, open the bypass valve and continue the aeration until the absorbance returns to its minimum value. Because of the toxic nature of mercury vapor, precaution must be taken to avoid its inhalation. Therefore, a bypass has been included in the system to either vent the mercury vapor into an exhaust hood or pass the vapor through some absorbing media such as follows:

(*a*) equal volumes of 0.1 M $KMnO_4$ and 10 % H_2SO_4, and
(*b*) 0.25 % iodine in a 3 % KI solution.

NOTE 104—Directions for the disposal of mercury-containing wastes are given in Test Method D 3223.[12]

41.7.3 Close the bypass valve, remove the stopper and frit from the BOD bottle and continue the aeration. Proceed with the standards and construct a standard curve by plotting peak height versus micrograms of mercury.

41.8 *Procedure:*

41.8.1 Transfer 100 mL, or an aliquot diluted to 100 mL, containing not more than 1.0 µg of mercury, to a 300-mL BOD bottle. Add 5 mL of sulfuric acid and 2.5 mL of concentrated nitric acid mixing after each addition. Add 15 mL of potassium permanganate solution to each sample bottle. For sewage, sample additional permanganate solution, if necessary, until the purple color persists for at least 15 min. Add 8 mL of potassium persulfate to each bottle and heat for 2 h in a water bath at 95°C. Cool and add 6 mL of sodium chloride-hydroxylamine sulfate to reduce the excess permanganate. After a delay of at least 30 s, add 5 mL of stannous sulfate and immediately attach the bottle to the aeration apparatus. Continue as described in 41.7.

41.9 *Calculation:*

41.9.1 Determine the peak height of the unknown from the chart, and read the mercury value from the standard curve.

41.9.2 Calculate the mercury concentration in the sample by the formula:

$$\mu g\ Hg/L = (\mu g\ Hg\ in\ aliquot)\left(\frac{1{,}000}{volume\ of\ aliquot\ in\ mL}\right)$$

41.9.3 Report mercury concentrations as follows: Below 0.2 µg/L, <0.2; between 1 and 10 µg/L, one decimal; above 10 µg/L, whole numbers.

42. Molybdenum—Direct Aspiration

42.1 *Requirements:*

42.1.1 *Optimum Concentration Range,* 1 to 40 mg/L using a wavelength of 313.3 nm (see Note 105).

42.1.2 *Sensitivity,* 0.4 mg/L.

42.1.3 *Detection Limit,* 0.1 mg/L.

NOTE 105—For concentrations of molybdenum below 0.2 mg/L, the furnace procedure is recommended.

42.2 *Preparation of Standard Solution:*

42.2.1 *Stock Solution*—Dissolve 1.840 g of ammonium molybdate $(NH_4)_6Mo_7O_{24}\cdot 4H_2O$ (analytical reagent grade) in deionized distilled water and dilute to 1 L. 1 mL = 1 mg Mo (1000 mg/L).

42.2.2 *Aluminum Nitrate Solution*—Dissolve 139 g aluminum nitrate, $Al(NO_3)_3\cdot 9H_2O$, in 150 mL of deionized distilled water; heat to effect solution. Allow to cool and make up to 200 mL.

42.2.3 Prepare dilutions of the stock molybdenum solution to be used as calibration standards at the time of analysis. The *calibration standards* should be prepared using the same type of acid and at the same concentration as that of the sample being analyzed either directly or after processing. To each 100 mL of standard and sample alike, add 2 mL of the aluminum nitrate solution.

42.3 *General Instrumental Parameters:*

42.3.1 *Molybdenum Hollow Cathode Lamp.*

42.3.2 *Wavelength*—313.3 nm.

42.3.3 *Fuel*—Acetylene.

42.3.4 *Oxidant*—Nitrous Oxide.

42.3.5 *Type of Flame*—Fuel rich.

42.4 *Analysis Procedure*—For analysis procedure and calculation, see "Direct Aspiration," 11.1.

42.5 *Interferences:*

42.5.1 With the recommended nitrous oxide-acetylene flame, interferences of calcium and other ions may be controlled by adding 1000 mg/L of a refractory metal such as aluminum **(12)**. This should be done to both samples and standards alike.

43. Molybdenum—Furnace Technique

43.1 *Requirements:*

43.1.1 *Optimum Concentration Range,* 3 to 60 µg/L (see Note 106).

43.1.2 *Detection Limit,* 1 µg/L.

NOTE 106—The concentration values and instrument conditions are for a Perkin-Elmer HGA-2100, based on the use of a 20-µL injection, continuous flow purge gas and pyrolytic graphite.

43.2 *Preparation of Standard Solution:*

43.2.1 *Stock Solution*—Prepare as described under "direct aspiration method".

43.2.2 Prepare dilutions of the stock solution to be used as calibration standards at the time of analysis. These solutions are also to be used for "standard additions".

43.2.3 The calibration standard should be diluted to contain 0.5 % (v/v) HNO_3.

43.3 *General Instrument Parameters:*

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[12] A specially treated charcoal that will absorb mercury vapor is also available from Barneby and Cheney, East 8th Ave. and North Cassidy St., Columbus, OH 43219, Catalog No. E580-13 or 580-22.

43.3.1 *Drying Time and Temperature*—30 s at 125°C.

43.3.2 *Ashing Time and Temperature*—30 s at 1400°C.

43.3.3 *Atomizing Time and Temperature*—15 s at 2800°C.

43.3.4 *Purge Gas Atmosphere*—Argon.

43.3.5 *Wavelength*—313.3 nm.

43.3.6 Other operating parameters should be set as specified by the particular instrument manufacturer.

NOTE 107—Background correction may be required if the sample contains high dissolved solids.

NOTE 108—The use of nitrogen as a purge gas is not recommended.

43.4 *Analysis Procedure*—For the analysis procedure and the calculation, see "Furnace Procedure," 11.3.

NOTE 109—For every sample matrix analyzed, verification is necessary to determine that the method of standard additions is not required (see 6.2.1).

NOTE 110—If the method of standard additions is required, follow the procedure given in 10.5.

44. Nickel—Direct Aspiration

44.1 *Requirements:*

44.1.1 *Optimum Concentration Range,* 0.3 to 5 mg/L using a wavelength of 232.0 nm (see Note 111).

44.1.2 *Sensitivity,* 0.15 mg/L.

44.1.3 *Detection Limit,* 0.04 mg/L.

NOTE 111—For levels of nickel below 100 µg/L, either the Special Extraction Procedure, given in 11.2, or the furnace technique is recommended.

44.2 *Preparation of Standard Solution:*

44.2.1 *Stock Solution*—Dissolve 4.953 g of nickel nitrate, $Ni(NO_3)_2 \cdot 6H_2O$ (analytical reagent grade) in deionized distilled water. Add 10 mL of concentrated nitric acid and dilute to 1 L with deionized distilled water. 1 mL = 1 mg Ni (1000 mg/L).

44.2.2 Prepare dilutions of the stock nickel solution to be used as calibration standards at the time of analysis. The *calibration standards* should be prepared using the same type of acid and at the same concentration as that of the sample being analyzed either directly or after processing.

44.3 *General Instrumental Parameters:*

44.3.1 *Nickel Hollow Cathode Lamp.*

44.3.2 *Wavelength*—232.0 nm.

44.3.3 *Fuel*—Acetylene.

44.3.4 *Oxidant*—Air.

44.3.5 *Type of Flame*—Oxidizing.

44.4 *Analysis Procedure*—For analysis procedure and calculation, see "Direct Aspiration", 11.1.

44.5 *Interferences*—The 352.4-nm wavelength is less susceptible to interference and may be used. The calibration curve is more linear at this wavelength; however, there is some loss of sensitivity.

45. Nickel—Furnace Technique

45.1 *Requirements:*

45.1.1 *Optimum Concentration Range,* 5 to 100 µg/L (see Note 112).

45.1.2 *Detection Limit,* 1 µg/L.

NOTE 112—The concentration values and instrument conditions are for a Perkin-Elmer HGA-2100, based on the use of a 20-µL injection, continuous flow purge gas and pyrolytic graphite. Smaller sized furnace devices or those employing faster rates of atomization can be operated using lower atomization temperatures for shorter time periods than the recommended settings.

45.2 *Preparation of Standard Solution:*

45.2.1 *Stock Solution*—Prepare as described under "direct aspiration method."

45.2.2 Prepare dilutions of the stock solution to be used as calibration standards at the time of analysis. These solutions are also to be used for "standard additions."

45.2.3 The calibration standard should be diluted to contain 0.5 % (v/v) HNO_3.

45.3 *General Instrument Parameters:*

45.3.1 *Drying Time and Temperature*—30 s at 125°C.

45.3.2 *Ashing Time and Temperature*—30 s at 900°C.

45.3.3 *Atomizing Time and Temperature*—10 s at 2700°C.

45.3.4 *Purge Gas Atmosphere*—Argon.

45.3.5 *Wavelength*—232.0 nm.

45.3.6 Other operating parameters should be set as specified by the particular instrument manufacturer.

NOTE 113—The use of background correction is recommended.

NOTE 114—Nitrogen may also be used as the purge gas.

45.4 *Analysis Procedure*—For the analysis procedure and the calculation, see "Furnace Procedure", 11.3.

NOTE 115—For every sample matrix analyzed, verification is necessary to determine that the method of standard additions is not required (see 6.2.1).

NOTE 116—If the method of standard additions is required, follow the procedure given in 10.5.

46. Potassium—Direct Aspiration

46.1 *Requirements:*

46.1.1 *Optimum Concentration Range*—0.1 to 2 mg/L using a wavelength of 766.5 nm (see Note 117).

46.1.2 *Sensitivity*—0.04 mg/L.

46.1.3 *Detection Limit*—0.01 mg/L.

NOTE 117—The 404.4-nm line may also be used. This line has a relative sensitivity of 500.

46.2 *Preparation of Standard Solution:*

46.2.1 *Stock Solution*—Dissolve 0.1907 g of KCl (analytical reagent grade), dried at 110°C, in deionized distilled water and make up to 1 L. 1 mL = 0.10 mg K (100 mg/L).

46.2.2 Prepare dilutions of the stock solution to be used as calibration standards at the time of analysis. The *calibration standards* should be prepared using the same type of acid and at the same concentration as that of the sample being analyzed either directly or after processing.

46.3 *General Instrumental Parameters:*

46.3.1 *Potassium Hollow Cathode Lamp.*

46.3.2 *Wavelength*—766.5 nm.

46.3.3 *Fuel*—Acetylene.

46.3.4 *Oxidant*—Air.

46.3.5 *Type of Flame*—Slightly oxidizing.

46.4 *Analysis Procedure*—For analysis procedure and calculation, see "Direct Aspiration", 11.1.

NOTE 118—In air-acetylene or other high temperature flames (>2800°C), potassium can experience partial ionization which indirectly affects absorption sensitivity. The presence of other alkali salts in the sample can reduce this ionization and thereby enhance analytical results. The ionization suppressive effect of sodium is small if the ratio of Na to K is under 10. Any enhancement due to sodium can be stabilized by adding excess sodium (1000 µg/mL) to both sample and standard solutions. If more stringent control of ionization is required, the addition of cesium should be considered. Reagent blanks should be analyzed to correct for potassium impurities in the buffer stock.

NOTE 119—To cover the range of potassium values normally observed in surface waters (0.1 to 20 mg/L), it is suggested that the burner head be rotated. A 90° rotation of the burner head provides approximately one-eighth the normal sensitivity.

47. Selenium—Furnace Technique

47.1 *Requirements:*

47.1.1 *Optimum Concentration Range*, 5 to 100 μg/L (see Note 120).

47.1.2 *Detection Limit*, 2 μg/L.

NOTE 120—The above concentration values and instrument conditions are for a Perkin-Elmer HGA-2100, based on the use of a 20-μL injection, continuous flow purge gas and non-pyrolytic graphite. Smaller sized furnace devices or those employing faster rates of atomization can be operated using lower atomization temperatures for shorter time periods than the above recommended settings.

47.2 *Preparation of Standard Solution:*

47.2.1 *Stock Selenium Solution*—Dissolve 0.3453 g of selenous acid (actual assay 94.6 % H_2SeO_3) in deionized distilled water and make up to 200 mL. 1 mL = 1 mg Se (1000 mg/L).

47.2.2 *Nickel Nitrate Solution, 5 %*—Dissolve 24.780 g of ACS reagent grade $Ni(NO_3)_2 \cdot 6H_2O$ in deionized distilled water and make up to 100 mL.

47.2.3 *Nickel Nitrate Solution,* 1 %—Dilute 20 mL of the 5 % nickel nitrate to 100 mL with deionized distilled water.

47.2.4 *Working Selenium Solution*—Prepare dilutions of the stock solution to be used as calibration standards at the time of analysis. Withdraw appropriate aliquots of the stock solution, add 1 mL of concentrated HNO_3, 2 mL of 30 % H_2O_2 and 2 mL of the 5 % nickel nitrate solution. Dilute to 100 mL with deionized distilled water.

47.3 *Sample Preparation:*

47.3.1 Transfer 100 mL of well-mixed sample to a 250-mL Griffin beaker, add 2 mL of 30 % H_2O_2 and sufficient concentrated HNO_3 to result in an acid concentration of 1 % (v/v). Heat for 1 h at 95°C or until the volume is slightly less than 50 mL.

47.3.2 Cool and bring back to 50 mL with deionized distilled water.

47.3.3 Pipet 5 mL of this digested solution into a 10 mL volumetric flask, add 1 mL of the 1 % nickel nitrate solution and dilute to 10 mL with deionized distilled water. The sample is now ready for injection into the furnace.

NOTE 121—If solubilization or digestion is not required, adjust the HNO_3 concentration of the sample to 1 % (v/v) and add 2 mL of 30 % H_2O_2 and 2 mL of 5 % nickel nitrate to each 100 mL of sample. The volume of the calibration standard should be adjusted with deionized distilled water to match the volume change of the sample.

47.4 *Instrument Parameters:*

47.4.1 *Drying Time and Temperature*—30 s at 125°C.

47.4.2 *Charring Time and Temperature*—30 s at 1200°C.

47.4.3 *Atomizing Time and Temperature*—10 s at 2700°C.

47.4.4 *Purge Gas Atmosphere*—Argon.

47.4.5 *Wavelength*—196.0 nm.

47.4.6 Other operating parameters should be set as specified by the particular instrument manufacturer.

NOTE 122—The use of background correction is recommended.

47.5 *Analysis Procedure*—For the analysis procedure and the calculation see "Furnace Procedure," 11.3.

NOTE 123—Selenium analysis suffers interference from chlorides (>800 mg/L) and sulfate (>200 mg/L). For the analysis of industrial effluents and samples with concentrations of sulfate from 200 to 2000 mg/L, both samples and standards should be prepared to contain 1 % nickel.

NOTE 124—For every sample matrix analyzed, verification is necessary to determine that the method of standard additions is not required (see 6.2.1).

NOTE 125—If the method of standard additions is required, follow the procedure given in 10.5.

48. Selenium—Gaseous Hydride

48.1 *Scope and Application*—The gaseous hydride method determines inorganic selenium when present in concentrations at or above 2 μg/L. The test method is applicable in the absence of high concentrations of chromium, cobalt, copper, mercury, molybdenum, nickel, and silver.

48.2 *Summary of Test Method*—Selenium in the sample is reduced from the +6 oxidation state to the +4 oxidation state by the addition of $SnCl_2$. Zinc is added to the acidified sample, producing hydrogen and converting the selenium to the hydride, SeH_2. The gaseous selenium hydride is swept into an argon-hydrogen flame of an atomic absorption spectrophotometer. The working range of the test method is 2 to 20 μg/L using the 196.0-nm wavelength.

48.3 *Discussion:*

48.3.1 In analyzing drinking water and most surface and ground waters, interferences are rarely encountered. Industrial waste samples should be spiked with a known amount of selenium to establish adequate recovery.

48.3.2 Organic forms of selenium must be converted to an inorganic form and organic matter must be oxidized before beginning the analysis. The oxidation procedure given in Procedure 4.1 of Method 206.5 should be used **(13)**.

48.4 References

48.4.1 Except for the perchloric acid step, the procedure to be used for this determination is found in *Standard Methods for the Examination of Water and Wastewater* **(14)**.

49. Silver—Direct Aspiration

49.1 *Requirements:*

49.1.1 *Optimum Concentration Range*, 0.1 to 4 mg/L using a wavelength of 328.1 nm (see Notes 126 and 127).

49.1.2 *Sensitivity*, 0.06 mg/L.

49.1.3 *Detection Limit*, 0.01 mg/L.

NOTE 126—For levels of silver below 30 μg/L, either the Special Extraction Procedure, given in 11.2 or the furnace procedure is recommended.

NOTE 127—The 338.2-nm wavelength may also be used. This has a relative sensitivity of 2.

49.2 *Preparation of Standard Solution:*

49.2.1 *Stock Solution*—Dissolve 1.575 g of $AgNO_3$ (analytical reagent grade) in deionized distilled water, add 10 mL concentrated HNO_3 and make up to 1 L. 1 mL = 1 mg Ag (1000 mg/L).

NOTE 128—Silver nitrate standards are light sensitive. Dilutions of the stock should be discarded after use as concentrations below 10 mg/L are not stable over long periods of time.

49.2.2 Prepare dilutions of the stock solution to be used as calibration standards at the time of analysis. The *calibration*

standards should be prepared using nitric acid and at the same concentration as that of the sample being analyzed either directly or after processing.

49.2.3 *Iodine Solution* (1 *N*)—Dissolve 20 g of potassium iodide, KI (analytical reagent grade) in 50 mL of deionized distilled water, add 12.7 g of iodine, I_2 (analytical reagent grade) and dilute to 100 mL. Store in a brown bottle.

49.2.4 *Cyanogen Iodide* (CNI) *Solution*—To 50 mL of deionized distilled water add 4.0 mL concentrated NH_4OH, 6.5 g KCN, and 5.0 mL of 1.0 *N* I_2 solution. Mix and dilute to 100 mL with deionized distilled water. Fresh solution should be prepared every 2 weeks.

49.3 *General Instrumental Parameters:*

49.3.1 *Silver Hollow Cathode Lamp.*

49.3.2 Wavelength—328.1 nm.

49.3.3 *Fuel*—Acetylene.

49.3.4 *Oxidant*—Air.

49.3.5 *Type of Flame*—Oxidizing.

49.4 *Analysis Procedure*—For the analysis procedure and the calculation, see "Direct Aspiration," 11.1.

NOTE 129—If absorption to container walls or the formation of AgCl is suspected, make the sample basic using concentrated NH_4OH and add 1 mL of (CNI) solution per 100 mL of sample. Mix the sample and allow to stand for 1 h before proceeding with the analysis.

50. Silver—Furnace Technique

50.1 *Requirements:*

50.1.1 *Optimum Concentration Range*—1 to 25 µg/L (see Note 130).

50.1.2 *Detection Limit*—0.2 µg/L.

NOTE 130—The concentration values and instrument conditions are for a Perkin-Elmer HGA-2100, based on the use of a 20-µL injection, continuous flow purge gas and nonpyrolytic graphite. Smaller sized furnace devices or those employing faster rates of atomization can be operated using lower atomization temperatures for shorter time periods than the above recommended settings.

50.2 *Preparation of Standard Solution:*

50.2.1 *Stock Solution*—Prepare as described under "direct aspiration method."

50.2.2 Prepare dilutions of the stock solution to be used as calibration standards at the time of analysis. These solutions are also to be used for "standard additions."

50.2.3 The calibration standard should be diluted to contain 0.5 % (v/v) HNO_3.

NOTE 131—The use of halide acids should be avoided.

50.3 *General Instrument Parameters:*

50.3.1 *Drying Time and Temperature*—30 s at 125°C.

50.3.2 *Ashing Time and Temperature*—30 s at 400°C.

50.3.3 *Atomizing Time and Temperature*—10 s at 2700°C.

50.3.4 *Purge Gas Atmosphere*—Argon.

50.3.5 *Wavelength*—328.1 nm.

50.3.6 Other operating parameters should be set as specified by the particular instrument manufacturer.

NOTE 132—Background correction may be required if the sample contains high dissolved solids.

50.4 *Analysis Procedure*—For the analysis procedure and the calculation, see "Furnace Procedure," 11.3 (see Notes 3, 5, 6, and 7).

NOTE 133—If adsorption to container walls or formation of AgCl is suspected, see the Direct Aspiration Method.

NOTE 134—For every sample matrix analyzed, verification is necessary to determine that the method of standard additions is not required (see 6.2.1).

NOTE 135—If the method of standard additions is required, follow the procedure given in 10.5.

51. Sodium—Direct Aspiration

51.1 *Requirements:*

51.1.1 *Optimum Concentration Range,* 0.03 to 1 mg/L using a wavelength of 589.6 nm (see Note 136).

51.1.2 *Sensitivity*, 0.015 mg/L.

51.1.3 *Detection Limit*, 0.002 mg/L.

NOTE 136—The 330.2 nm resonance line of sodium, which has a relative sensitivity of 185, provides a convenient way to avoid the need to dilute more concentrated solutions of sodium.

51.2 *Preparation of Standard Solution:*

51.2.1 *Stock Solution*—Dissolve 2.542 g of NaCl (analytical reagent grade), dried at 140°C, in deionized distilled water and make up to 1 L. 1 mL = 1 mg Na (1000 mg/L).

51.2.2 Prepare dilutions of the stock solution to be used as calibration standards at the time of analysis. The *calibration standards* should be prepared using the same type of acid and at the same concentration as that of the sample being analyzed either directly or after processing.

51.3 *General Instrumental Parameters:*

51.3.1 *Sodium Hollow Cathode Lamp.*

51.3.2 *Wavelength*—589.6 nm.

51.3.3 *Fuel*—Acetylene.

51.3.4 *Oxidant*—Air.

51.3.5 *Type of Flame*—Oxidizing.

NOTE 137—Low-temperature flames increase sensitivity by reducing the extent of ionization of this easily ionized metal. Ionization may also be controlled by adding potassium (1000 mg/L) to both standards and samples.

51.4 *Analysis Procedure*—For analysis procedure and calculation, see "Direct Aspiration," 11.1.

52. Tin—Direct Aspiration

52.1 *Requirements:*

52.1.1 *Optimum Concentration Range*, 10 to 300 mg/L using a wavelength of 286.3 nm (see Note 138).

52.1.2 *Sensitivity*, 4 mg/L.

52.1.3 *Detection Limit*, 0.8 mg/L.

NOTE 138—For concentrations of tin below 2 mg/L, the furnace procedure is recommended.

52.2 *Preparation of Standard Solution:*

52.2.1 *Stock Solution*—Dissolve 1.000 g of tin metal (analytical reagent grade) in 100 mL of concentrated HCl and dilute to 1 L with deionized distilled water. 1 mL = 1 mg Sn (1000 mg/L).

52.2.2 Prepare dilutions of the stock tin solution to be used as calibration standards at the time of analysis. The *calibration standards* should be prepared using the same type of acid and at the same concentration as that of the sample being analyzed either directly or after processing.

52.3 *General Instrumental Parameters:*

52.3.1 *Tin Hollow Cathode Lamp.*

52.3.2 *Wavelength*—286.3 nm.

52.3.3 *Fuel*—Acetylene.

52.3.4 *Oxidant*—Nitrous oxide.

52.3.5 *Type of Flame*—Fuel rich.

52.4 *Analysis Procedure*—For the analysis procedure and the calculation, see "Direct Aspiration," 11.1.

53. Tin—Furnace Technique

53.1 *Requirements:*

53.1.1 *Optimum Concentration Range*, 20 to 300 µg/L (see Note 139).

53.1.2 *Detection Limit*, 5 µg/L.

NOTE 139—The concentration values and instrument conditions are for a Perkin-Elmer HGA-2100, based on the use of a 20 µL injection, continuous flow purge gas and non-pyrolytic graphite. Smaller sized furnace devices or those employing faster rates of atomization can be operated using lower atomization temperatures for shorter time periods than the recommended settings.

53.2 *Preparation of Standard Solution:*

53.2.1 *Stock Solution*—Prepare as described under "direct aspiration method".

53.2.2 Prepare dilutions of the stock solution to be used as calibration standards at the time of analysis. These solutions are also to be used for "standard additions".

53.2.3 The calibration standard should be diluted to contain 2 % (v/v) HNO_3.

53.3 *Instrument Parameters:*

53.3.1 *Drying Time and Temperature*—30 s at 125°C.

53.3.2 *Ashing Time and Temperature*—30 s at 600°C.

53.3.3 *Atomizing Time and Temperature*—10 s at 2700°C.

53.3.4 *Purge Gas Atmosphere*—Argon.

53.3.5 *Wavelength*—224.6 nm.

53.3.6 Other operating parameters should be set as specified by the particular instrument manufacturer.

NOTE 140—The use of background correction is recommended.

NOTE 141—Nitrogen may also be used as the purge gas.

53.4 *Analysis Procedure*—For the analysis procedure and the calculation see "Furnace Procedure," 11.3.

NOTE 142—Tin analysis is sensitive to chloride concentration. If chloride concentration presents a matrix problem or causes a loss previous to atomization, add an excess of 5 mg of ammonium nitrate to the furnace and ash using a ramp necessary or with incremental steps until the recommended ashing temperature is reached. Extended ashing times have been reported to improve precision.

NOTE 143—For every sample matrix analyzed, verification is necessary to determine that the method of standard additions is not required (see 6.2.1).

NOTE 144—If the method of standard additions is required, follow the procedure given in 10.5.

54. Titanium—Direct Aspiration

54.1 *Requirements:*

54.1.1 *Optimum Concentration Range*, 5 to 100 mg/L using a wavelength of 365.3 nm (see Note 145).

54.1.2 *Sensitivity*, 2 mg/L.

54.1.3 *Detection Limit*, 0.4 mg/L.

NOTE 145—For concentrations of titanium below 1.0 mg/L, the furnace procedure is recommended.

54.2 *Preparation of Standard Solution:*

54.2.1 *Stock Solution*—Dissolve 4.008 g of titanium sulfate, $Ti_2(SO_4)_3$, in dilute HCl and make up to 1 L with deionized distilled water. 1 mL = 1 mg Ti (1000 mg/L).

54.2.2 *Potassium Chloride Solution*—Dissolve 95 g potassium chloride, KCl, in distilled water and make up to 1 L.

54.2.3 Prepare dilutions of the stock titanium solution to be used as calibration standards at the time of analysis. The *calibration standards* should be prepared using the same type of acid and at the same concentration as that of the sample being analyzed either directly or after processing. To each 100 mL of standard and sample alike, add 2 mL of potassium chloride solution.

54.3 *General Instrumental Parameters:*

54.3.1 *Titanium Hollow Cathode Lamp.*

54.3.2 *Wavelength*—365.3 nm.

54.3.3 *Fuel*—Acetylene.

54.3.4 *Oxidant*—Nitrous oxide.

54.3.5 *Type of Flame*—Fuel rich.

54.4 *Analysis Procedure*—For the analysis procedure and the calculation, see "Direct Aspiration," 11.1.

54.5 *Interferences*—A number of elements increase the sensitivity of titanium. To control this problem, potassium (1000 mg/L) must be added to standards and samples alike **(15)**.

55. Titanium Furnace Technique

55.1 *Requirements:*

55.1.1 *Optimum Concentration Range,* 50 to 500 µg/L (see Note 146).

55.1.2 *Detection Limit,* 10 µg/L.

NOTE 146—The above concentration values and instrument conditions are for a Perkin-Elmer HGA-2100, based on the use of a 20-µL injection, continuous flow purge gas and pyrolytic graphite.

55.2 *Preparation of Standard Solution:*

55.2.1 *Stock Solution*—Prepare as described under "direct aspiration method."

55.2.2 Prepare dilutions of the stock solution to be used as calibration standards at the time of analysis.

55.2.3 The *calibration standards* should be prepared using the same type of acid and at the same concentration as that of the sample being analyzed either directly or after processing.

55.3 *General Instrument Parameters:*

55.3.1 *Drying Time and Temperature*—30 s at 125°C.

55.3.2 *Ashing Time and Temperature*—30 s at 1400°C.

55.3.3 *Atomizing Time and Temperature*—15 s at 2800°C.

55.3.4 *Purge Gas Atmosphere*—Argon.

55.3.5 *Wavelength*—365.4 nm.

55.3.6 Other operating parameters should be set as specified by the particular instrument manufacturer.

NOTE 147—Background correction may be required if the sample contains high dissolved solids.

NOTE 148—Because of possible chemical interactions, nitrogen should not be used as the purge gas.

55.4 *Analysis Procedure*—For the analysis procedure and the calculation, see "Furnace Procedure," 11.3.

NOTE 149—For every sample matrix analyzed, verification is necessary to determine that the method of standard additions is not required (see 6.2.1).

NOTE 150—If the method of standard additions is required, follow the procedure given in 10.5.

56. Vanadium—Direct Aspiration

56.1 *Requirements:*

56.1.1 *Optimum Concentration Range*—2 to 100 mg/L using a wavelength of 318.4 nm (see Note 151).

56.1.2 *Sensitivity*—0.8 mg/L.

56.1.3 *Detection Limit*—0.2 mg/L.

NOTE 151—For concentrations of vanadium below 0.5 mg/L, the furnace procedure is recommended.

56.2 *Preparation of Standard Solution:*

56.2.1 *Stock Solution*—Dissolve 1.7854 g of vanadium pentoxide, V_2O_5 (analytical reagent grade) in 10 mL of concentrated nitric acid and dilute to 1 L with deionized distilled water. 1 mL = 1 mg V (1000 mg/L).

56.2.2 *Aluminum Nitrate Solution*—Dissolve 139 g aluminum nitrate, $Al(NO_3)_3 \cdot 9H_2O$, in 150 mL of deionized distilled water; heat to effect solution. Allow to cool and make up to 200 mL.

56.2.3 Prepare dilutions of the stock solution to be used as calibration standards at the time of analysis. The *calibration standards* should be prepared using the same type of acid and at the same concentration as that of the sample being analyzed either directly or after processing. To each 100 mL of standard and sample alike, add 2 mL of the aluminum nitrate solution.

56.3 *General Instrumental Parameters:*

56.3.1 *Vanadium Hollow Cathode Lamp.*

56.3.2 *Wavelength*—318.4 nm.

56.3.3 *Fuel*—Acetylene.

56.3.4 *Oxidant*—Nitrous oxide.

56.3.5 *Type of Flame*—Fuel rich.

56.4 *Analysis Procedure*—For the analysis procedure and the calculation, see "Direct Aspiration," 11.1.

56.5 *Interferences*—It has been reported that high concentrations of aluminum and titanium increase the sensitivity of vanadium. This interference can be controlled by adding excess aluminum (1000 ppm) to both samples and standards **(16)**.

57. Vanadium—Furnace Technique

57.1 *Requirements:*

57.1.1 *Optimum Concentration Range*, 10 to 200 µg/L (see Note 152).

57.1.2 *Detection Limit*, 4 µg/L.

NOTE 152—The above concentration values and instrument conditions are for a Perkin-Elmer HGA-2100, based on the use of a 20-µL injection, continuous flow purge gas and pyrolytic graphite. Smaller sized furnace devices or those employing faster rates of atomization can be operated using lower atomization temperatures for shorter time periods than the above recommended settings.

57.2 *Preparation of Standard Solution:*

57.2.1 *Stock Solution*—Prepare as described under "direct aspiration method."

57.2.2 Prepare dilutions of the stock solution to be used as calibration standards at the time of analysis. These solutions are also to be used for "standard additions."

57.2.3 The calibration standard should be diluted to contain 0.5 % (v/v) HNO_3.

57.3 *General Instrument Parameters:*

57.3.1 *Drying Time and Temperature*—30 s at 125°C.

57.3.2 *Ashing Time and Temperature*—30 s at 1400°C.

57.3.3 *Atomizing Time and Temperature*—15 s at 2800°C.

57.3.4 *Purge Gas Atmosphere*—Argon.

57.3.5 *Wavelength*—318.4 nm.

57.3.6 Other operating parameters should be set as specified by the particular instrument manufacturer.

NOTE 153—Background correction may be required if the sample contains high dissolved solids.

NOTE 154—Because of possible chemical interaction, nitrogen should not be used as the purge gas.

57.4 *Analysis Procedure*—For the analysis procedure and the calculation, see "Furnace Procedure," 11.3.

NOTE 155—For every sample matrix analyzed, verification is necessary to determine that the method of standard additions is not required (see 6.2.1).

NOTE 156—If the method of standard additions is required, follow the procedure given in 10.5.

58. Zinc—Direct Aspiration

58.1 *Requirements:*

58.1.1 *Optimum Concentration Range,* 0.05 to 1 mg/L using a wavelength of 213.9 nm (see Note 157).

58.1.2 *Sensitivity*, 0.02 mg/L.

58.1.3 *Detection Limit*, 0.005 mg/L.

NOTE 157—For concentrations of zinc below 0.01 mg/L, either the Special Extraction Procedure or the Furnace Procedure, is recommended.

58.2 *Preparation of Standard Solution:*

58.2.1 *Stock Solution*—Carefully weigh 1.00 g of zinc metal (analytical reagent grade) and dissolve cautiously in 10 mL HNO_3. When solution is complete make up to 1 L with deionized distilled water. 1 mL = 1 mg Zn (1000 mg/L).

58.2.2 Prepare dilutions of the stock solution to be used as calibration standards at the time of analysis. The *calibration standards* should be prepared using the same type of acid and at the same concentration as that of the sample being analyzed either directly or after processing.

58.3 *Instrumental Parameters:*

58.3.1 *Zinc Hollow Cathode Lamp.*

58.3.2 *Wavelength*—213.9 nm.

58.3.3 *Fuel*—Acetylene.

58.3.4 *Oxidant*—Air.

58.3.5 *Type of Flame*—Oxidizing.

58.4 *Analysis Procedure*—For analysis procedure and calculation, see "Direct Aspiration," 11.1.

NOTE 158—High levels of silicon may interfere.

NOTE 159—The air-acetylene flame absorbs about 25 % of the energy at the 213.9 nm line.

NOTE 160—The sensitivity may be increased by the use of low-temperature flames.

NOTE 161—Some sample container cap liners can be a source of zinc contamination. To circumvent or avoid this problem, the use of polypropylene caps is recommended.

59. Zinc—Furnace Technique

59.1 *Requirements:*

59.1.1 *Optimum Concentration Range*—0.2 to 4 µg/L (see Note 162).

59.1.2 *Detection Limit*—0.05 µg/L.

NOTE 162—The concentration values and instrument conditions are for a Perkin-Elmer HGA-2100, based on the use of a 20-µL injection, continuous flow purge gas and non-pyrolytic graphite. Smaller sized furnace devices or those employing faster rates of atomization can be operated using lower atomization temperatures for shorter time periods than the recommended settings.

59.2 *Preparation of Standard Solution:*

59.2.1 *Stock Solution*—Prepare as described under "Direct Aspiration Method."

59.2.2 Prepare dilutions of the stock solution to be used as calibration standards at the time of analysis. These solutions are also to be used for "standard additions."

59.2.3 The calibration standard should be diluted to contain 0.5 % (v/v) HNO_3.

59.3 *General Instrument Parameters:*

59.3.1 *Drying Time and Temperature*—30 s at 125°C.

59.3.2 *Ashing Time and Temperature*—30 s at 400°C.

59.3.3 *Atomizing Time and Temperature*—10 s at 2500°C.

59.3.4 *Purge Gas Atmosphere*—Argon.

59.3.5 *Wavelength*—213.9 nm.

59.3.6 Other operating parameters should be set as specified by the particular instrument manufacturer.

NOTE 163—The use of background correction is recommended.

NOTE 164—Nitrogen may also be used as a purge gas.

59.4 *Analysis Procedure*—For the analysis procedure and the calculation, see "Furnace Procedure," 11.3.

NOTE 165—The analysis of zinc by the graphite furnace is extremely sensitive and very subject to contamination from the work area, reagents, and pipet tips. Since all these factors affect the precision and accuracy, zinc should be analyzed by the direct aspiration procedure whenever possible.

NOTE 166—For every sample matrix analyzed, verification is necessary to determine that the method of standard additions is not required (see 6.2.1).

NOTE 167—If the method of standard additions is required, follow the procedure given in 10.5.

60. Precision and Bias

60.1 Precision and bias data for the methods described on RDF are not available at this time.

REFERENCES

(1) *Atomic Absorption Newsletter*, Vol 14, No. 5, Sept. and Oct., Perkin-Elmer Corp., Norwalk, CT, 1975, p. 127.

(2) *Atomic Absorption Newsletter*, Vol 6, 1967, p. 128.

(3) *Atomic Absorption Newsletter*, Vol 5, 1966, p. 17.

(4) *Standard Methods for the Examination of Water and Wastewater*, 14th Ed. Method 301A (VII), American Public Health Assn., American Water Works Assn. and Water Pollution Control Federation, 1975, p. 159.

(5) *Spectrochimica Acta*, Vol 22, Pergamon Press, 1966, p. 1325.

(6) *Standard Methods for the Examination of Water and Wastewater*, 14th Ed., 1975, p. 177.

(7) *Atomic Absorption Newsletter*, Vol 14, 1975, p. 29.

(8) *Talanta*, Vol 20, An International Journal of Analytical Chemistry, Pergamon Press, Inc. Journals Division, Maxwell House, Fairview Park, Elmford, NY 10523, 1973, p. 631.

(9) *Standard Methods for the Examination of Water and Wastewater*, 14th Ed., 1975, p. 192.

(10) *Atomic Absorption Newsletter*, Vol 15, No. 3, May and June 1976, p. 71.

(11) Kopp, J. F., Longbottom, M. C., and Lobring, L. B., "Cold Vapor Method for Determining Mercury," American Water Works Assoc., Vol 64, Jan. 1971, p. 20.

(12) *Analytical Chimica Acta*, Vol 44, Elsevier Scientific Publishing Co., Box 211, 1000 AE, Amsterdam, Netherlands, 1969, p. 437.

(13) *Standard Methods for the Examination of Water and Wastewater*, 14th Ed., 404B, 1975, p. 285.

(14) *Standard Methods for the Examination of Water and Wastewater*, 14th Ed., Method 301A (VII), 1975, p. 159.

(15) *Atomic Absorption Newsletter*, Vol 6, 1967, p. 86.

(16) *Talanta*, Oxford/NY, 1968, p. 871.

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Designation: E 1337 – 90 (Reapproved 1996)

Standard Test Method for Determining Longitudinal Peak Braking Coefficient of Paved Surfaces Using a Standard Reference Test Tire[1]

1. Scope

1.1 This test method covers the measurement of peak braking coefficient of paved surfaces using a standard reference test tire (SRTT) as described in Specification E 1136 that represents current technology passenger car radial tires. General test procedures and limitations are presented for determining peak braking coefficient independent of surface conditions. Actual surface test conditions are determined and controlled by the user at the time of test. Test and surface condition documentation procedures and details are specified. This measurement quantifies the peak braking coefficient at the time of test and does not necessarily represent a maximum or fixed value.

1.2 This test method utilizes a measurement representing the peak braking force on a braked test tire passing over a road surface. This test is conducted with a tire under a nominal vertical load at a constant speed while its major plane is parallel to its direction of motion and perpendicular to the pavement.

1.3 The measured peak braking coefficient obtained with the equipment and procedures stated herein may not necessarily agree or correlate directly with those obtained by other surface coefficient measuring methods.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

E 274 Test Method for Skid Resistance of Paved Surfaces Using A Full-Scale Tire[2]

E 556 Test Method for Calibrating a Wheel Force or Torque Transducer Using a Calibration Platform (User Level)[2]

E 867 Terminology Relating to Traveled Surface Characteristics[2]

E 1136 Specification for a Radial Standard Reference Test Tire[2]

F 377 Practice for Calibration of Braking/Tractive Measuring Devices for Testing Tires[3]

F 408 Test Method for Tires for Wet Traction in Straight-Ahead Braking, Using a Towed Trailer[3]

F 457 Method for Speed and Distance Calibration of a Fifth Wheel Equipped with Either Analog or Digital Instrumentation[3]

3. Terminology

3.1 *Definitions:*

3.1.1 *chirp test*—the progressive application of brake torque required to produce the maximum value of longitudinal braking force that will occur prior to wheel lockup, with subsequent brake release to prevent any wheel lockup (tire slide).

3.1.2 For other definitions pertaining to this standard, see Terminology E 867 and Method F 408.

3.2 *Descriptions of Terms:*

3.2.1 *braking force coefficient, tire*—the ratio of braking force to vertical load.

3.2.2 *braking force coefficient, tire, peak*—the maximum value, as defined in 12.2, of tire braking force coefficient that occurs prior to wheel lockup as the braking torque is progressively increased.

3.2.3 *braking force coefficient, tire, slide*—the value of the braking force coefficient obtained on a locked wheel.

3.2.4 *braking force, tire*—the negative longitudinal force resulting from braking torque application.

3.2.5 *braking torque*—the negatively directed wheel torque.

3.2.6 *longitudinal force, tire* (F_x)—the component of a tire force vector in the X' direction.

3.2.7 *tire-axis system*—the origin of the tire-axis system is the center of the tire contact. The X' axis is the intersection of the wheel plane and the road plane with a positive direction forward. The Z' axis is perpendicular to the road plane with a positive direction downward. The Y' axis is in the road plane, its direction being chosen to make the axis system orthogonal and right-hand (see Fig. 1 in Method F 408).

3.2.8 *tire forces*—the external forces acting on the tire by the road.

3.2.9 *torque wheel (T)*—The external torque applied to a tire from a vehicle about the wheel spin axis. Driving torque is positive wheel torque; braking torque is negative wheel torque.

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[1] This test method is under the jurisdiction of ASTM Committee E-17 on Vehicle-Pavement Systems and is the direct responsibility of Subcommittee E17.21 on Field Methods for Measuring Tire Pavement Friction.

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[2] *Annual Book of ASTM Standards*, Vol 04.03.

[3] *Annual Book of ASTM Standards*, Vol 09.02.

3.2.10 *vertical load* (F_z)—the downward vertical component of force between the tire and the road.

4. Summary of Test Method

4.1 The measurements are conducted with a standard reference test tire (Specification E 1136) mounted on a test trailer towed by a vehicle. The trailer contains a transducer, instrumentation, and actuation controls for the braking of the test tire. See 6.6 for trailer instrumentation.

4.2 The test apparatus is normally brought to a test speed of 40 mph (64 km/h). The brake is progressively applied until sufficient braking torque results to produce the maximum braking force that will occur prior to wheel lockup. Longitudinal force, vertical load, and vehicle speed are recorded with the aid of suitable instrumentation and data acquisition equipment.

4.3 The peak braking coefficient of the road surface is determined from the ratio of the maximum value of braking force to the simultaneous vertical load occurring prior to wheel lockup as the braking torque is progressively increased.

5. Significance and Use

5.1 Pavement surfaces have different traction characteristics, depending on many factors. Surface texture, binder content, usage, environmental exposure, and surface conditions (that is, wet, dry) are some of the factors.

5.2 The measured values represent peak braking coefficients for tires of the general type in operation on passenger vehicles, obtained with a towed test trailer on a prescribed road surface, under user defined surface conditions. Such surface conditions may include the water depth used to wet the road surface and the type of water application method. Variations in these conditions may influence the test results.

6. Apparatus

6.1 The apparatus consists of a tow vehicle and test trailer. The vehicle and trailer must comply with all legal requirements applicable to state laws when operated on public roads.

6.2 *Tow Vehicle*—The vehicle shall have the capability of maintaining a test speed of 40 mph (64 km/h) within ±0.5 mph (±0.8 km/h) even at maximum level of application of braking forces.

6.3 *Test Trailer*—The test wheel shall be equipped with a sufficient braking torque to produce the maximum value of braking test wheel longitudinal force at the conditions specified.

6.3.1 Each of the trailer wheels shall have a suspension capable of holding toe and camber changes to within ±0.05° with maximum vertical suspension displacements under both static and dynamic conditions.

6.3.2 The rate of brake application shall be sufficient to control the time interval between initial brake application and peak longitudinal force to be between 0.3 and 0.5 s.

6.4 *Vertical Load*—The trailer shall be of such a design as to provide a static load of 1031± 15 lbf (4586 ± 67 N) to the test wheel and on detachable trailers a static down load of 100 to 200 lbf (445 to 890 N) at the hitch point.

6.5 *Tire and Rim*—The test tire shall be the standard reference test tire (SRTT) for pavement tests, as specified in Specification E 1136, mounted on a suitable 14 by 6-in. rim.

6.5.1 When irregular wear or damage results from tests, or when wear or usage influences the test results, the use of the tire should be discontinued.

6.6 *Instrumentation*:

6.6.1 *General Requirements for Measuring System*—The instrumentation system shall conform to the following overall requirements at ambient temperatures between 40 and 100°F (4 and 38°C):

6.6.1.1 Overall system accuracy of ±1.5 % of applied load from 200 lbf (890 N) to full scale; for example, at 200 lbf (890 N), applied calibration force of the system output shall be determinable within ±3 lbf (±13 N).

6.6.1.2 The exposed portions of the system shall tolerate 100 % relative humidity (rain or spray) and all other adverse conditions, such as dust, shock, and vibrations which may be encountered in highway operations.

6.6.1.3 *Braking Forces*—The braking force measuring transducer shall measure longitudinal reaction force within a range between 0 and 2000 lbf (0 and 8.9 kN) generated at the tire-pavement interface as a result of brake application. The tire force-measuring transducer shall be of such design as to measure the tire-pavement interface force with minimum inertial effects. Transducers are recommended to provide an output directly proportional to force with hysteresis less than 1 % of the applied load, nonlinearity less than 1 % of the applied load up to the maximum expected loading, and sensitivity to any expected cross-axis loading or torque loading less than 1 % of the applied load. The force transducer shall be mounted in such a manner as to experience less than 1° angular rotation with respect to its measuring plane at the maximum expected loading.

6.6.1.4 *Vertical Load*—The vertical load measuring transducer shall measure the vertical load at the test wheel during brake application. The transducer shall have the same specifications as those described in 6.6.1.3.

NOTE 1—Other transducer systems may be used to determine peak braking coefficients if they can be shown to correlate with the force-measuring transducer system with the same overall accuracy.

6.6.1.5 *Vehicle Speed-Measuring Transducers*—Transducers such as "fifth wheel" or a free-rolling wheel coupled tachometer shall provide speed resolution and accuracy of ±1.5 % of the indicated speed or ±0.5 mph (±0.8 km/h), whichever is greater. Output shall be directly viewable by the driver and shall be simultaneously recorded. Fifth wheel systems shall conform to Method F 457.

6.6.1.6 *Signal Conditioning and Data Acquisition*—All signal conditioning and recording equipment shall provide linear output and shall allow data reading resolution to meet the requirements of 6.6.1.1.

6.6.1.7 All strain-gage transducers shall be equipped with resistance shunt calibration resistors or equivalent that can be connected before or after test sequences. The calibration signal shall be at least 50 % of the normal vertical load and shall be recorded.

6.6.1.8 A digital data acquisition system shall be employed to individually digitize the braking force, vertical load, and vehicle speed analog outputs. The braking force, vertical load, and test wheel speed input signals to be digitized shall be sampled (as close to simultaneous as possible to minimize phase shifting) at 100 samples per second for each channel from unfiltered analog signals. Vehicle speed can be analog filtered, if necessary, to remove noise since this is a steady-state signal.

NOTE 2—Experience indicates that data sampling at 100 samples per second of unfiltered analog skid trailer data will properly describe the significant frequencies. To prevent "aliasing," caution must be exercised in digitizing skid trailer data which contains any significant frequencies above 50 Hz or other types of analog data.

7. Hazards

7.1 The test vehicle, as well as all attachments to it, shall comply with all applicable state and federal laws. All necessary precautions shall be taken beyond those imposed by laws and regulations to ensure maximum safety of operating personnel and other traffic. No test shall be made when there is danger that dispersed water may freeze on the pavement.

8. Preparation of Apparatus

8.1 *Preparation of Test Tire*:

8.1.1 Trim the test tires to remove all protuberances in the tread area caused by mold air vents or flashes at mold junctions.

8.1.2 Test tires should be stored in such a location that they all have the same ambient temperature prior to testing and shield them from the sun to avoid excessive heating by solar radiation.

8.1.3 Mount the test tire on Tire and Rim Association (TRA) recommended rim[4] (6.5) by using conventional mounting methods. **Caution:** Assure proper bead seating by the use of a suitable lubricant. Excessive use of lubricant should be avoided to prevent slipping of the tire on the wheel rim.

8.1.4 Check the test tires for the specified inflation pressure at ambient temperature (cold), just prior to testing. The test tire inflation pressure shall be 35 ± 0.5 psi. (241 ± 3 kPa)

9. Calibration

9.1 *Vehicle Speed*—Calibrate the test vehicle speed indicator at the test speed by determining the time for traversing at constant speed a reasonably level and straight, accurately measured pavement of a length appropriate for the method of timing. Load the test trailer to its specified operating weight for this calibration. Record speed variations during a traverse with the test system. Make a minimum of three runs at each test speed to complete the calibration. Other methods of equivalent accuracy may be used. Calibration of a fifth wheel shall be performed in accordance with Method F 457.

10. Conditioning

10.1 *Pretest Tire Conditioning*:

10.1.1 Test tire pretest conditioning shall be performed to precondition all tires prior to initial testing. Pretest conditioning is to be done only once per tire and prior to any actual test measurements. This process is recommended because the new tire burnish effect may have an influence on the peak braking coefficient obtained and to minimize test variability caused by transient, non-preconditioned, tire braking performance.

10.1.2 Pretest tire conditioning shall be conducted on a dry and level surface. Each tire shall be chirped ten times at 20 mph (32 km/h) under test load.

10.2 *General Test Conditions*:

10.2.1 The test surface shall be free of loose material or foreign deposits.

10.2.2 Do not test when wind conditions interfere with wetted test repeatability. Test results may be influenced by wind speed, or direction, or both. The magnitude of this dependence is a function of the water depth, application procedures, and surface wind protection.

11. Procedure

11.1 Warm up electronic test equipment as required for stabilization.

11.2 Install an SRTT (Specification E 1136) in the test position of the test trailer. A tire with a similar loaded radius and high cornering properties should be used on the opposite side to level the axle and to minimize trailer yaw during brake torque applications.

11.3 Check and, if necessary, adjust the test trailer static weight on the test tire to the specified test load (see 6.4).

11.4 Check and adjust tire inflation pressure as required immediately before testing to specified value (see 8.1.4).

11.5 When testing on an externally wetted test surface, offset the trailer test wheel sufficiently to prevent "tracking" of the towing vehicle. Twelve to sixteen in. (305 to 406 mm) is suggested.

11.6 Record tire identification and other data, including date, time, ambient temperature, test surface temperature, tire durometer, test surface type, and water depth (if wetted surface is used). Measure the water depth with a variable height probe type device.

11.7 Record electrical calibration signals prior to and after testing each surface, or as needed to ensure valid data.

11.8 Perform pretest tire conditioning (10.1) if using a new tire.

11.9 Conduct test at the required test vehicle speed. It is recommended that peak braking coefficient measurement tests be conducted using the chirp test methodology to minimize tire damage due to tire sliding.

11.10 Make at least eight determinations of the peak braking coefficient evenly distributed over the test surface with the test system at the specified test speed.

11.11 *Lateral Positioning of Test Vehicle on Highway Surfaces*—Normally, testing shall be done in the center of either wheel track of a traffic lane on a highway. The specific details regarding lane and the wheel-path used should be provided when reporting the data.

11.12 *Test Speeds*:

11.12.1 The standard test speed shall be 40 mph (64 km/h), and tests shall normally be conducted at that speed. Where the legal maximum speed is less than 40 mph (64 km/h), the tests may have to be conducted at a lower speed. Where the legal speed is considerably in excess of 40 mph (64 km/h), tests may

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[4] Current recommendations available from the Tire and Rim Association, 3200 Market St., Akron, OH 44313.

be made at the prevailing traffic speed, but it is recommended that at the same locations, additional tests be made at 40 mph (64 km/h). Maintain test speeds within ±1 mph (1.5 km/h).

11.12.2 The test speed must be given when the peak braking coefficient is quoted. This may be done by adding the numerals of the actual test speed in miles per hour in parentheses to the coefficient, for example, 0.50(50) indicates the peak braking coefficient was obtained at a test speed of 50 mph (80 km/h).

12. Calculation

12.1 *Data Reduction*:

12.1.1 Digitally filter the digitized input analog signals of braking force, vertical load, and vehicle speed using a five point moving average technique.

12.1.2 *Digital Filtering Methodology*—Calculate an average value for the first five digital data points. Drop the first data point and add the sixth data point, calculate another five point average value. Repeat this procedure for all remaining data points. This sequence is done individually on all the above digitized input analog signals. The following example computations illustrate the method using one channel.

$$(pt1 + pt2 + pt3 + pt4 + pt5)/5 = PT1$$
$$(pt2 + pt3 + pt4 + pt5 + pt6)/5 = PT2$$
$$(pt3 + pt4 + pt5 + pt6 + pt7)/5 = PT3$$

A new set of data points (indicated by capital letters) are then defined to represent the filtered data for each channel (that is, Avg ptx = PTy).

PT1, PT2, PT3, etc. – braking force
PT1, PT2, PT3, etc. – vertical force

12.2 Determining and Calculating Peak Braking Coefficient.

12.2.1 The peak braking coefficient shall be determined for each run (brake application).

12.2.2 Using the digitally filtered data (PT1, PT2, PT3, etc.), scan the longitudinal channel and determine the highest absolute filtered value (PTy) prior to wheel lock up. Calculate an average peak braking force value using the highest filtered value (PTy) and one filtered point directly before (PTy_{-1}) and directly after it (PTy_{+1}). This three point average is the peak braking force value developed for this individual lock up.

12.2.3 Determine the vertical load value from its respective digitally filtered data that corresponds to the highest absolute value for braking force, from 12.2.2. Calculate an average vertical load value using this corresponding value and one point directly before and directly after it. This three point average is the vertical load value that corresponds to the average peak braking force for this individual lock up.

12.2.4 Calculate the peak braking coefficient by dividing the three point average peak braking force, determined from 12.2.2, by the three point average vertical load, as determined in 12.2.3. The peak braking coefficient should be reported to two (2) decimal places.

12.3 For each test (11.10) the mean and standard deviation for peak braking coefficient are calculated from the individual determinations.

13. Report

13.1 *Field Report*—The field report for each test section shall contain data on the following items:

13.1.1 Identify test procedure used,
13.1.2 Location and identification of test section,
13.1.3 Date and time of day,
13.1.4 Weather conditions,
13.1.5 Lane and wheel-path tested,
13.1.6 Speed of test vehicle (for each test),
13.1.7 Peak braking coefficient (for each test),
13.1.8 Water depth, if wetted surface is used, and
13.1.9 Ambient and surface temperature.

13.2 *Summary Report*—The summary report shall include, for each test section, data on the following items insofar as they are pertinent to the variables or combinations of variables under investigation:

13.2.1 Location and identification of test section,
13.2.2 Number of lanes and presence of lane separators,
13.2.3 Grade and alignment,
13.2.4 Pavement type, mix design of surface course, condition, and aggregate type (specific source, if available),
13.2.5 Age of pavement,
13.2.6 Average daily traffic,
13.2.7 Posted speed limit,
13.2.8 Date and time of day,
13.2.9 Weather conditions,
13.2.10 Lane and wheel-path tested,
13.2.11 Ambient and surface temperature, and
13.2.12 Average, high, and low peak braking coefficient for the test section and speed at which the tests were made. (If values are reported that were not used in computing the average, this fact should be reported.)

14. Precision and Bias

14.1 *Precision*—Data are not yet available for making a statement on the precision of this test method. When such data become available, a precision statement will be included in this test method.

14.2 *Bias*—There are no standards or references with which the results of this test can be compared. The function of the test as indicated above is to be able to make comparisons among road surfaces tested with the same tire. It is believed that the results of the test method are adequate for making such comparisons without an external reference for assessing accuracy. It must be noted that surface friction is affected by many variables such as environmental conditions, usage, age, surface contamination (externally applied water), etc., and measured values are only valid until one of these conditions significantly changes.

15. Recommendations for Tire Use and Operational Requirements

15.1 When irregular wear or damage results from tests, or when wear or usage influences the test results, the use of the tire should be discontinued.

NOTE 3—Test results such as measured braking force may be influenced by tire groove depth or tread hardness, or both. The magnitude of this dependence is a function of the water depth, pavement characteristics, test speed, tire aging effects, and break-in (preconditioning).

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Standard Specification for In-Service Care of Insulating Line Hose and Covers[1]

1. Scope

1.1 This specification covers the in-service care, inspection, testing, and use voltage of insulating line hose and covers for protection from electrical shock.

1.2 The following safety hazards caveat applies only to the test method portion, Section 7, of this specification: *This standard does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* Specific precautionary statements are given in Note 1.

2. Referenced Documents

2.1 *ASTM Standards:*

D 1049 Specification for Rubber Insulating Covers[2]

D 1050 Specification for Rubber Insulating Line Hose[2]

D 2865 Practice for Calibration of Standards and Equipment for Electrical Insulating Materials Testing[3]

F 819 Definitions of Terms Relating to Electrical Protective Equipment for Workers[2]

2.2 *ANSI Standards:*

C 84.1 Voltage Ratings for Electric Power Systems and Equipment (60 Hz)[4]

2.3 *IEEE Standard:*

IEEE Standard 4, Techniques for High Voltage Testing[5]

3. Terminology

3.1 *breakdown*—the electrical discharge or arc occurring between the electrodes and through the equipment being tested.

3.2 *bulk storage*— the storage of hose or covers together with one or more layers piled neatly, but without the benefit of spacers, supports, or special protective containers.

3.3 *cover*—an electrically insulated enclosure designed to be installed temporarily on various types of irregularly shaped electrical equipment to protect personnel and equipment working in the close proximity.

3.4 *designated person*—an individual who is qualified by experience or training to perform an assigned task.

3.5 *distorted*—physically changed from the natural and original shape, caused by stress of any type.

3.6 *electrical testing facility*—a location with qualified personnel, testing equipment, and procedures for the inspection and electrical testing of electrical insulating protective equipment.

3.7 *electrode*—the energized or grounded conductor portion of electrical test equipment which is placed near or in contact with the material or equipment being tested.

3.8 *flashover*—the electrical discharge or arc occurring between electrodes and over or around, but not through, the equipment being tested.

3.9 *hose*—an electrical insulating tube with a longitudinal slit designed to be installed temporarily on energized electrical wires.

3.10 *ozone*—a very active form of oxygen that may be produced by corona, arcing, or ultraviolet rays.

3.11 *ozone cutting and checking*—cracks produced by ozone in a material under mechanical stress.

3.12 *retest*—the tests given after the initial acceptance test, usually performed at regular periodic intervals or as required because of physical inspection.

3.13 *voltage, maximum use*—the a-c voltage (rms) classification of the protective equipment that designates the maximum nominal design voltage of the energized system that may be safely worked. The nominal design voltage is equal to phase-to-phase voltage on multiphase circuits.

3.13.1 If there is no multiphase exposure in a system area, and the voltage exposure is limited to phase (polarity on d-c systems) to ground potential, the phase (polarity on d-c systems) to ground potential shall be considered to be the nominal design voltage.

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[1] This specification is under the jurisdiction of ASTM Committee F-18 on Electrical Protective Equipment for Workers and is the direct responsibility of Subcommittee F18.25 on Insulating Cover-up Equipment.

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[2] *Annual Book of ASTM Standards*, Vol 10.03.

[3] *Annual Book of ASTM Standards*, Vol 10.02.

[4] Available from the American National Standards Institute, 1430 Broadway, New York, NY 10018.

[5] Available from Institute of Electrical and Electronics Engineers, Inc., 445 Hoes Lane, Piscataway, NJ 08854-4150.

3.13.2 If electrical equipment and devices are insulated, or isolated, or both, such that the multiphase exposure on a grounded wye circuit is removed, then the nominal design voltage may be considered as the phase-to-ground voltage on that circuit.

3.14 *voltage, maximum retest*—voltage, either a-c rms or d-c average, that is equal to the proof test voltage for new protective equipment.

3.15 *voltage, nominal design*—a nominal value consistent with the latest revision of ANSI C84.1, assigned to the circuit or system for the purpose of conveniently designating its voltage class.

3.16 *voltage, retest*— voltage, either a-c rms or d-c average, that used protective equipment must be capable of withstanding for a specific test period without breakdown.

4. Significance and Use

4.1 Compliance with this specification should continue to provide personnel with insulating line hose and covers of known and acceptable quality after initial acceptance in accordance with Specifications D 1050 and D 1049. The standards herein are to be considered as minimum requirements.

4.2 A margin of safety shall be provided between the maximum use voltage and their class proof voltage in accordance with Specifications D 1050 and D 1049, as shown in Table 1.

4.3 The user of this type of protective equipment shall be knowledgeable of and instructed in the correct and safe inspection and use of this equipment.

5. Classification

5.1 Line hose covered in this specification are designed as Type I or Type II; Class 0, Class 1, Class 2, Class 3 or Class 4; Style A, Style B, Style C or Style D. Covers covered in this standard are designated as Type I or Type II; Class 0, Class 1, Class 2, Class 3 or Class 4; Style A, Style B, Style C, Style D or Style E.

5.1.1 *Type I*—High-grade *cis*-1,4-polyisoprene rubber compound of natural or synthetic origin, properly vulcanized.

5.1.2 *Type II*—Ozone resistant, made of any elastomer or combination of elastomeric compounds.

5.1.3 The class designations are based on the electrical properties in Specifications D 1050 and D 1049.

TABLE 1 Voltage Requirements Line Hose and Covers

Class Designation of Hose and Covers	A-C Use Voltage, rms, max[A]	A-C Retest Voltage, rms	D-C Retest Voltage, avg
0	1000	5000	20 000
1	7500	10 000	40 000
2	17 000	20 000	50 000
3	26 500	30 000	60 000
4	36 000	40 000	70 000

[A] The maximum use voltage is based on the following equations:

1. Maximum use voltage = 0.95 a-c and d-c retest voltage– 2 000, Classes 1, 2, 3, and 4.
2. Maximum use voltage = 0.95 a-c and d-c reset voltage – 30 500, Classes 1, 2, 3, and 4.
3. Maximum use voltage 1 0.95 a-c and d-c retest voltage – 18 000, Class 0.

5.1.4 The style designations are based on the designs and descriptions in Specifications D 1050 and D 1049.

6. Washing and Inspection

6.1 The recommended sequence of washing and inspection of contaminated insulating line hose and covers is as follows:

6.1.1 Washing,

6.1.2 Drying,

6.1.3 Inspection,

6.1.4 Marking, and

6.1.5 Packing for storage and shipment.

6.2 The hose and covers may be washed with a soap, mild non-bleaching detergent, or a cleaner recommended by the equipment manufacturer. After washing, the hose and covers shall be rinsed thoroughly with water.

6.2.1 The cleaning agent shall not degrade the insulating qualities of the line hose and covers.

6.2.2 A commercial tumble-type washing machine may be used, where practicable, but caution must be observed to eliminate any interior surfaces or edges that will cut, abrade, puncture, or pinch the hose or covers.

6.3 The hose and covers shall be air dried. The air temperature shall not be over 150°F (65.5°C). They may be suspended to allow drainage and air circulation or dried in a commercial tumble-type automatic dryer. In an automatic dryer, caution must be observed to eliminate any ozone-producing lamps and interior surfaces that will cut, abrade, puncture, or pinch the hose and covers.

6.4 Insulating line hose and covers shall be given a detailed inspection over the entire inner and outer surface for punctures, cuts, severe ozone cutting, or any other obvious condition that would adversely affect performance.

6.5 The hose and covers shall be marked in accordance with Section 12.

7. Electrical Tests

7.1 Where the inspection specified in Section 6 indicates that there may be reason to suspect the electrical integrity of a line hose or cover, an electrical test shall be performed before reissuing the line hose or cover for service.

7.2 Both a-c and d-c voltage retest methods are included in this section and either or both methods may be selected for electrical test.

NOTE 1—**Precaution**: In addition to other precautions, it is recommended that the test apparatus be designed to afford the operator full protection in the performance of duties. Reliable means of de-energizing and grounding the high-voltage circuit should be provided. It is particularly important to incorporate positive means of grounding the high-voltage section of d-c test apparatus due to the likely presence of high-voltage capacitance charges at the conclusion of the test.

7.3 Any electrical retest shall be performed at normal room temperatures and on clean hose or covers at an electrical testing facility.

7.4 *Electrodes*:

7.4.1 The entire area of each hose and cover shall be tested, as nearly as practicable, between electrodes that apply the electrical stress uniformly over the test area without producing damaging corona or mechanical strain in the hose or cover. The electrodes shall be of such dimensions and so placed as to avoid flashover at the edges.

7.4.2 For hose, the inside electrode shall be a metal mandrel of the size in Table 2. The outer electrode should be a close-fitting wet sponge or wet fabric blanket, metal foil, or a smooth metal form; extending to within ½in. (13 mm) of the edge of the lip of the hose, and extending to a distance from the end of the hose as specified in Table 3. If the hose has a connector end, the form should extend to within ½ in. (13 mm) of the connector end. When Style C line hose is tested, the outer electrode may fit around the outside diameter of the hose, but not the extended lip (Note 2).

NOTE 2—These end clearances are intended to serve as a guide and under some conditions may have to be increased to prevent flashover.

7.4.3 For covers, the electrodes shall be one of those described in the following methods:

7.4.3.1 *Method 1 for Types I and II*—Water as inner and outer electrodes.

7.4.3.2 *Method 2 for Types I and II*—Wet sponge or wet felt inner electrode; and wet sponge, wet felt, or metal foil outer electrode.

7.4.3.3 *Method 3 for Type II*—Fixed form metal or metal foil inner or outer electrodes, or both.

NOTE 3—Method 3 electrodes shall not be used with Type I materials when testing with alternating current due to the possibility of corona cutting.

7.5 *A-C Test*:

7.5.1 *Voltage Supply and Regulation*—The voltage supply and control equipment should be of such size and design that, with the test specimens in the circuit, the crest factor (ratio of peak to mean effective) of the test voltage shall differ by not more than 5 % from that of a sinusoidal wave over the upper half of the range of the test voltage. The correct rms value of the sinusoidal voltage waveform applied to the hose or cover may be measured by one of the following methods:

7.5.1.1 A voltmeter used in conjunction with a calibrated instrument transformer connected directly across the high voltage circuit,

7.5.1.2 A calibrated electrostatic voltmeter connected directly across the high voltage circuit,

7.5.1.3 An a-c meter connected in series with appropriate high voltage type resistors directly across the high voltage circuit.

7.5.1.4 The accuracy of the voltage measuring circuit shall be ±2 % of full scale. To ensure the continued accuracy of the test voltage, as indicated by the test equipment voltmeter, the test equipment shall be calibrated at least annually in accordance with the latest revision of Practice D 2865 or IEEE Standard 4. The crest factor may be checked by the use of a peak reading voltmeter connected directly across the high-voltage circuit.

TABLE 2 Line Hose Test Mandrel Size

Hose Size, Inside Diameter, in. (mm)	Recommended Test Mandrel Size, Outside Diameter, in. (mm)
¼ (6.4)	3⁄16 (4.8)
⅝ (16)	9⁄16 (14.3)
1 (25)	15⁄16 (23.8)
1¼ (32)	1 3⁄16 (30)
1½ (38)	1¼ (31.8)
2 (51)	1¾ (44.4)
2½ (63.5)	2¼ (57.2)

TABLE 3 Flashover Clearances Between Electrodes[A]

Class Designation, Glove or Sleeve	A-C Retest		D-C Retest	
	in.	mm	in.	mm
0	3	76	3	76
1	3	76	4	102
2	5	127	6	152
3	7	178	8	203
4	10	254	12	305

[A] Flashover clearances are stated in terms of the shortest electrical air path between electrodes around the edge of the item being tested. In those cases where atmospheric conditions make the specified clearances impractical, the distance may be increased by the maximum of 2 in. (51 mm).

7.5.2 *A-C Retest*—Electrical retest of a hose or cover shall be in accordance with the requirements of Section 8.

NOTE 4—It is recommended that the retest voltage be applied initially at a low value and increased gradually at a constant rate-of-rise of approximately 1000 V/s a-c until the prescribed test voltage level is reached. Unless an electrical puncture has occurred already, the applied voltage should be reduced to at least half value at the end of the test period before opening the test circuit.

7.6 *D-C Test*:

7.6.1 *Voltage Supply and Regulation*:

7.6.1.1 The d-c test voltage can be obtained from a source capable of supplying a d-c voltage whose peak-to-peak a-c ripple component does not exceed 2 % of the average voltage value under no-load conditions.

7.6.1.2 The d-c test voltage shall be measured by a method that provides the average value of the voltage applied to the hose or cover. It is recommended that the voltage be measured by the use of a d-c meter connected in series with appropriate high-voltage type resistors across the high-voltage circuit, or by an electrostatic voltmeter of proper range. The accuracy of the voltage measuring circuit shall be within ±2 % of full scale. The test equipment shall be calibrated at least annually, in accordance with the latest revision of Practice D 2865 or the latest revision of IEEE Standard 4.

7.6.2 *D-C Retest*—Electrical retest of a hose or cover shall be in accordance with the requirements of Section 8.

NOTE 5—It is recommended the d-c retest voltage should be applied in the same manner as for a-c retest voltage, with the exception of a rate-of-rise of approximately 3000 V/s.

8. Rejection Criteria

8.1 Any hose or cover that fails to comply with the electrical retest requirements as indicated in this section shall be rejected.

8.2 Each hose or cover shall withstand the 60-Hz a-c retest voltage (rms value) or the d-c retest voltage (average value) specified in Table 1. The test voltage shall be applied continuously for not less than 1 min and not more than 3 min.

8.3 Any hose or cover that upon inspection is found to have punctures, deep cuts, severe corona or ozone cutting, contamination from injurious materials, or has lost its normal elasticity, shall be rejected.

8.4 Minor surface corona cutting or ozone checking need not be cause for rejection.

9. Precision and Bias

9.1 No statement is made about either the precision or the bias of the test methods in this specification for measuring the dielectric strength since the results merely state whether there is conformance to the criteria for success specified in the procedure.

10. Repairs

10.1 Hose and covers shall not be repaired. Hose may be used in shorter lengths if the defective portion is cut off.

11. Field Care, Inspection, and Storage

11.1 The field care and inspection of electrical insulating line hose and covers, performed by the individual, is an important requirement in providing protection from electrical shock. Defective or suspected defective line hose and covers shall not be used. They shall not be re-issued for use until they have been inspected and retested at an electrical testing facility, and meet the requirements of Section 8.

11.2 Before use and installation on energized conductors, devices, or equipment, line hose and covers shall be inspected visually for defects and at other times if there is cause to suspect any damage.

11.3 Line hose and covers shall be wiped clean of any oil, grease, or other damaging substances as soon as practicable. Line hose and covers whose surface becomes otherwise contaminated shall be set aside and cleaned in accordance with Section 6.

11.4 Loose bulk storage or packaging may be used for hose or covers in transit or in temporary holding operations provided such storage is limited to periods not in excess of 1 month, and there is not severe distortion.

11.5 Line hose and covers shall be stored without distortion and mechanical stress in a location as cool, dark, and dry as possible. They shall be stored or packaged in a suitable compartment or in containers such as boxes or bags. The area shall be as free as possible of ozone, chemicals, oils, solvents, damaging vapors and fumes, and away from electrical discharges and sunlight.

11.6 Line hose and covers shall not have any identifying adhesive tapes or labels applied to them by other than authorized personnel. Tape shall not be used to secure line hose and covers for shipment or storage.

11.7 Line hose and covers with any of the following defects shall not be used:

11.7.1 Holes other than factory produced openings on the top, sides, or lips of the line hose or covers, tears and punctures, serious cuts, and rope or wire burns that extend more than one third the depth of the thickness of the rubber.

11.7.2 Texture changes: swelling, softening, hardening, and becoming sticky or inelastic.

11.7.3 Other defects that damage the insulating properties.

11.8 Line hose and cover should be left in service on energized lines for minimum necessary periods of time as exposure may result in ozone checking, corona cutting, or excessive weathering.

12. Marking

12.1 If the hose and covers are not readily identifiable as to class, they shall be marked.

12.2 Hose or covers that have been rejected and are not suitable for electrical service shall be defaced, cut, or otherwise marked and identified to indicate that they are not to be used for electrical service.

CERTIFICATE

By Authority Of
THE UNITED STATES OF AMERICA
Legally Binding Document

By the Authority Vested By Part 5 of the United States Code § 552(a) and Part 1 of the Code of Regulations § 51 the attached document has been duly INCORPORATED BY REFERENCE and shall be considered legally binding upon all citizens and residents of the United States of America. *HEED THIS NOTICE*: Criminal penalties may apply for noncompliance.

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Standard Method for Testing Full Scale Advancing Spill Removal Devices[1]

1. Scope

1.1 This standard provides a method for determining performance parameters of full-scale advancing oil spill removal devices in recovering floating oil when tested in a controlled test facility.

1.2 *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of whoever uses this standard to consult and establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

D 88 Test Method for Saybolt Viscosity[2]

D 341 Viscosity-Temperature Charts for Liquid Petroleum Products[3]

D 445 Test Method for Kinematic Viscosity of Transparent and Opaque Liquids (and the Calculation of Dynamic Viscosity)[3]

D 1298 Test Method for Density, Relative Density (Specific Gravity), or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method[3]

D 2161 Method for Conversion of Kinematic Viscosity to Saybolt Universal Viscosity or to Saybolt Furol Viscosity[4]

D 2904 Practice for Interlaboratory Testing of a Textile Test Method that Produces Normally Distributed Data[5]

D 2905 Practice for Statements on Number of Specimens for Textiles[5]

D 2906 Practice for Statements on Precision and Bias for Textiles[5]

3. Summary of Method

3.1 The spill removal device may be tested in a wave/tow tank or other suitable facility with a controllable test environment. Controlled test variables include device velocity relative to the water velocity, oil properties and slick thickness, wave conditions, and pertinent device variables. It is essential that the device be operated in a steady-state condition during the sampling period when oil encounter rate, recovery rate, recovery efficiency, and device parameters are monitored, measured, and recorded.

4. Significance

4.1 This test method provides quantitative data in the form of oil recovery rates, throughput efficiencies, and oil recovery efficiencies under controlled test conditions. The data can be used for evaluating design characteristics of a particular advancing spill removal device or as a means of comparing two or more devices. Caution must be exercised whenever test data are used to predict performance in actual spill situations as the uncontrolled environmental conditions which affect performance in the field are rarely identical to conditions in the test tank. Other variables such as mechanical reliability, presence of debris, ease of repair, ease of deployment, required operator training, operator fatigue, seaworthiness, and transportability also affect performance in an actual spill but are not measured by this method. These variables should be considered along with the test data when making comparisons or evaluations of advancing spill removal devices.

5. Definitions

5.1 *oil recovery rate*—the volume of oil recovered by the device per unit of time.

5.2 *throughput efficiency*—the ratio, expressed as a percentage, of the volume of oil recovered to the volume of oil encountered.

5.3 *oil recovery efficiency*—the ratio, expressed as a percentage, of the volume of oil recovered to the volume of total fluids recovered.

5.4 *advancing oil spill removal device*—a device that removes spilled oil from the water surface when there is relative motion between the device and the water. The device may move through the surrounding fluid or it may be stationary and the surrounding fluid moved past the device.

5.5 *data collection period*—the period of time during a test run when the performance data is recorded.

5.6 *oil*—the fluid distributed on the water of the test facility and recovered by the spill removal device (see Section 8).

5.7 *oil encounter rate*—the volume of oil per unit time actively directed to the removal mechanism.

5.8 *oil slick thickness*—the average thickness of the oil slick encountered by the test device.

5.9 *full-scale equipment*—equipment of the size that is (or will be) available commercially.

6. Interferences

6.1 The table of results (see 13.1) shall address the possibility of test facility effects. For example, wall effects

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[1] This method is under the jurisdiction of ASTM Committee F-20 on Spill Control Systems and is the direct responsibility of Subcommittee F20.12, on Removal.

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[2] *Annual Book of ASTM Standards*, Vol 04.04.

[3] *Annual Book of ASTM Standards*, Vol 05.01.

[4] *Annual Book of ASTM Standards*, Vol 05.02.

[5] *Annual Book of ASTM Standards*, Vol 07.01.

may interfere hydrodynamically with the device's performance.

7. Test Facilities

7.1 At least two types of test facilities, a wave/tow tank and a current tank, may be used to conduct the test outlined in this method.

7.1.1 *Wave/Tow Tank*—A wave/tow tank has a movable bridge or other mechanism for towing the test device through water for the length of the facility. A wave generator may be installed on one end, or on the side of the facility, or both.

7.1.2 *Current Tank*—A current tank is a water-filled tank equipped with a pump or other propulsion system for moving the water through a test section where the test device is mounted. A wave generator may be installed on this type of test facility.

7.1.3 Other facilities, such as private ponds or flumes, may also be used, provided the test parameters can be suitably controlled and environmental regulations adhered to.

7.2 Ancillary systems for facilities include, but are not limited to, a distribution system for accurately delivering oils to the water surface, skimming systems to assist in cleaning the facility between tests, and adequate tankage for storing the test oils.

8. Test Oils

8.1 Three standard test oils for use with this test method are defined in Appendix X1. These oils cover a wide range of properties and are designated with respect to viscosity and specific gravity as light, medium, and heavy. These oils must be Newtonian fluids and may be crude, refined, or simulant.

8.2 If it is desired to use an oil with properties that do not correspond to a standard test oil, a statement must be made in the table of results (see 13.1) that a standard test oil was not used. This statement must discuss the effect of the nonstandard oil on test data with respect to the probable results using the most similar standard test oil.

8.3 The viscosity of oil varies greatly with temperature. Frequently test oils must be distributed in the test facility at temperatures different from the water temperature. When this occurs, the oil generally will approach the surface water temperature.

8.4 If oils that originally meet the conditions stated in Appendix X1 are reused, their properties may change and should be evaluated prior to reuse.

9. Safety Precautions

9.1 Test operations shall conform to established safety requirements for both test facility operations and oil handling. Particular caution must be exercised when handling flammable or toxic test oils.

10. Test Device

10.1 The test device shall be deployed in accordance with facility operating characteristics. The device must be operated in accordance with the manufacturer's specified operating instructions with respect to mechanical operations and established maintenance routines. Modifications to the device for testing purposes shall follow the manufacturer's recommendations and shall be recorded with the test results.

11. Calibration and Standardization

11.1 At the outset of the test, the independent or control test parameters are selected. Typical test variables include:

Test oils	light, medium, and heavy
Test speed	upper and lower limits and speed increments selected as appropriate
Oil slick thickness	appropriate increments for the device being tested
Wave conditions	wave characteristics of significant height, average length, and period and pattern may be varied as appropriate

12. Procedure

12.1 Prior to the test, select the operating parameters, such as tow speed, wave conditions, test oil, and oil distribution rate. Then prepare the facility and spill removal device for the test run. Occasionally, it may be necessary to preload the device with oil to achieve steady-state operation within a reasonable period of time. Any preload must be carefully measured and discharged into the device. Measure or note immediately prior to each test the following parameters describing ambient conditions:

12.1.1 Air temperature,

12.1.2 Water temperature near the surface,

12.1.3 Wind speed,

12.1.4 Wind direction relative to the test device, and

12.1.5 General weather conditions, for example, rain, overcast, sunny, etc.

12.2 Start the wave generator (if necessary), oil distribution system, tow mechanism or water flow, and the spill removal device to begin a test run. Direct the discharge flow of recovered fluid from the device into a holding tank or back into the test tank out of the device's sweep path during the transient start-up period. After steady-state operation is achieved, monitor the discharge flow to obtain performance data. The discharge may be pumped through a flow meter to obtain a flow rate and sampled periodically to obtain the oil-to-fluid ratio. Alternatively, the discharge may be diverted into calibrated sample tanks from which the flow rate and oil-to-fluid ratio may be determined. In either case, the data collection period begins when sampling starts and ends when sampling stops. During the data collection period or immediately thereafter, measure and record the following parameters:

12.2.1 Oil distribution rate,

12.2.2 Fluid recovery rate (oil and water),

12.2.3 Tow speed or current speed,

12.2.4 Wave characteristics,

12.2.5 Length of the data collection period,

12.2.6 Oil encounter rate, and

12.2.7 Operating parameters of the spill recovery device such as belt speed, weir setting, pump speed, etc.

12.3 At the completion of the data collection period, divert the discharge of the spill removal device back into the holding tank or test tank. Stop the wave generator, tow mechanism or water flow, oil distribution, and spill removal device. Analyze samples of the discharge to determine oil-to-fluid ratio. Analyze samples of the recovered test oil to determine the following:

12.3.1 Specific gravity,

12.3.2 Viscosity,

12.3.3 Surface tension,

12.3.4 Interfacial tension with respect to test tank water, and

12.3.5 Water content.

12.4 Perform the analyses in 12.3 at the surface water temperature or in such a way that the values of these parameters at the surface water temperature can be determined from the analytical data.

13. Calculation or Interpretation of Results

13.1 Prepare a table of results for the test run containing the following entries:

13.1.1 Test identification number.

13.1.2 Date and time of day.

13.1.3 Average speed (tow speed or current speed) during data collection period.

NOTE—This rate is averaged over the data collection period.

13.1.4 Test oil type (light, medium, heavy, or nonstandard).

13.1.5 Oil slick thickness.

13.1.6 For regular waves, include height, average period (or length), and whether head or following. For irregular waves, include significant height, significant frequency, spectral characteristics, and whether head or following.

13.1.7 Oil properties at test temperatures, including specific gravity, viscosity, surface tension, interfacial tension with tank water, and initial water content of oil.

13.1.8 Total volume of oil distributed during data collection period.

13.1.9 Total volume of oil encountered during data collection period.

13.1.10 Total volume of fluid (oil/water) recovered during data collection period.

13.1.11 Average oil distribution rate (see Note).

13.1.12 Average oil encounter rate (see Note).

13.1.13 Average fluid (oil/water) recovery rate (see Note).

13.1.14 Average oil recovery efficiency (see Note).

13.1.15 Average oil recovery rate (see Note).

13.1.16 Average throughput efficiency (see Note).

13.1.17 Ambient conditions, including air temperature, surface water temperature, wind speed, wind direction, and brief statement of weather conditions during test run.

13.1.18 Length of data collection period.

13.1.19 Volume of oil in device at beginning of data collection period.

13.1.20 Volume of oil in device at end of data collection period.

13.1.21 Operating parameters of the device such as belt speed, weir setting, pump speed, etc.

13.1.22 Brief discussion of interferences or limiting factors (see 6.1).

13.2 If any of the data required by 13.1 are not applicable to the device being tested, a statement must be included in the table of results describing the reasons for omitting the data.

14. Precision and Accuracy

14.1 Statistical measures of accuracy and precision may be determined that will indicate the reliability of test results as well as the degree of standardization in test procedures. Examples of procedures may be found in Appendix X2.

APPENDIXES

X1. STANDARD TEST OILS

X1.1 General

X1.1.1 The ranges of physical properties for standard test oils will be as outlined in X1.2 through X1.5.

X1.2 Viscosity

X1.2.1 *Light Oil*—3 to 10 cSt (mm^2/s) at 60°F (15.6°C).

X1.2.2 *Medium Oil*—100 to 300 cSt (mm^2/s) at 60°F (15.6°C).

X1.2.3 *Heavy Oil*—500 to 2000 cSt (mm^2/s) at 60°F (15.6°C).

X1.3 Specific Gravity

X1.3.1 *Light Oil*—0.83 to 0.88.

X1.3.2 *Medium Oil*—0.90 to 0.94.

X1.3.3 *Heavy Oil*—0.94 to 0.97.

X1.4 Surface Tension

X1.4.1 *All Oils*—24 to 34 dynes/cm (mN/m) with distilled water at 77°F (25°C).

X1.5 Interfacial Tension

X1.6 *All Oils*—26 to 32 dynes/cm (mN/m) with distilled water at 77°F (25°C).

X2. DETERMINATION OF PRECISION AND ACCURACY

X2.1 The following properties may be determined by the ASTM standards listed which are considered for use in this method for full scale advancing skimmers:

X2.1.1 *Viscosity*—Methods D 88 and D 445.

X2.1.2 *Specific Gravity*—Method D 1298.

X2.1.3 *Viscosity versus Temperature*—Standard D 341.

X2.1.4 *Viscosity Conversion*—Method D 2161.

X2.1.5 *Interlaboratory Testing*—Practice D 2904.

X2.1.6 *Number of Test Replicates*—Practice D 2905.

X2.1.7 *Precision and Accuracy*—Practice D 2906.

CERTIFICATE

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By the Authority Vested By Part 5 of the United States Code § 552(a) and Part 1 of the Code of Regulations § 51 the attached document has been duly INCORPORATED BY REFERENCE and shall be considered legally binding upon all citizens and residents of the United States of America. *HEED THIS NOTICE*: Criminal penalties may apply for noncompliance.

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Standard Guide for Collecting Skimmer Performance Data in Controlled Environments[1]

This standard is issued under the fixed designation F 631; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This standard provides a guide for determining performance parameters of full-scale oil spill removal devices in recovering floating oil when tested in controlled environments.

1.2 This guide involves the use of specific test oils that may be considered hazardous materials after testing is completed. It is the responsibility of the user of this guide to procure and abide by the necessary permits for disposal of the used test oil.

1.3 *This standard does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

D 97 Test Method for Pour Point of Petroleum Oils[2]

D 445 Test Method for Kinematic Viscosity of Transparent and Opaque Liquids (and the Calculation of Dynamic Viscosity)[2]

D 971 Test Method for Interfacial Tension of Oil Against Water by the Ring Method[2,3]

D 1298 Test Method for Density, Relative Density (Specific Gravity), or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method[2]

D 2983 Test Method for Low-Temperature Viscosity of Automotive Fluid Lubricants Measured by Brookfield Viscometer[4]

D 4007 Test Method for Water and Sediment in Crude Oil by the Centrifuge Method (Laboratory Procedure)[4]

F 625 Practice for Describing Environmental Conditions Relevant to Spill Control Systems for Use on Water[5]

F 808 Guide for Collecting Skimmer Performance Data in Uncontrolled Environments[5]

3. Terminology

3.1 *Definitions:*

3.1.1 *advancing skimmer*—a device that removes spilled oil from the water surface when there is relative motion between the device and the water. The device may move through the surrounding fluid or it may be stationary and the surrounding fluid moved past the device.

3.1.2 *data collection period*—the period of time during a test run when the performance data are recorded.

3.1.3 *full-scale equipment*—equipment of the size that is (or will be) available commercially.

3.1.4 *oil*—the fluid distributed on the water of the test facility and recovered by the spill removal device (see Section 8).

3.1.5 *oil encounter rate*—the volume of oil per unit time actively directed to the removal mechanism (m^3/h).

3.1.6 *oil recovery efficiency*—the ratio, expressed as a percentage, of the volume of oil recovered to the volume of total fluids recovered.

3.1.7 *oil recovery rate*—the volume of oil recovered by the device per unit of time (m^3/h).

3.1.8 *oil slick thickness*—the average thickness of the oil slick encountered by the test device (mm).

3.1.9 *throughput efficiency*—the ratio, expressed as a percentage, of the volume of oil recovered to the volume of oil encountered.

4. Significance and Use

4.1 This guide provides quantitative data in the form of oil recovery rates, throughput efficiencies, and oil recovery efficiencies under controlled test conditions. The data can be used for evaluating design characteristics of a particular spill removal device or as a means of comparing two or more devices. Caution must be exercised whenever test data are used to predict performance in actual spill situations as the uncontrolled environmental conditions that affect performance in the field are rarely identical to conditions in the test tank. Other variables such as mechanical reliability, presence of debris, ease of repair, ease of deployment, required operator training, operator fatigue, seaworthiness, and transportability also affect performance in an actual spill but are not measured by this guide. These variables should be considered along with the test data when making comparisons or evaluations of spill removal devices.

5. Summary of Guide

5.1 The spill removal device may be tested in a wave/tow tank or other facility that is suitable for controlling the appropriate test parameters. Significant testing results can be obtained using simple test tanks or ponds, particularly when calm water and low velocity advancing tests are desired as an economical means to screen and compare devices. Controlled test variables include relative velocity, oil properties

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[1] This guide is under the jurisdiction of ASTM Committee F-20 on Hazardous Substances and Oil Spill Response and is the direct responsibility of Subcommittee F20.12 on Removal.

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[2] *Annual Book of ASTM Standards*, Vol 05.01.

[3] *Annual Book of ASTM Standards*, Vol 10.03.

[4] *Annual Book of ASTM Standards*, Vol 05.02.

[5] *Annual Book of ASTM Standards*, Vol 11.04.

and slick thickness, wave conditions, and pertinent device variables. It is essential that the device be operated in a steady-state condition during the sampling period when oil encounter rate, recovery rate, recovery efficiency, and device parameters are monitored, measured, and recorded.

6. Interferences

6.1 The table of results (see 13.1) shall address the possibility of test facility effects. For example, wall effects may interfere hydrodynamically with the device's performance.

6.2 Care should be taken that any containment means that is not inherent in the skimming device does not affect the oil distribution to the device.

7. Test Facilities

7.1 Several types of test facilities can be used to conduct the test outlined in this guide.

7.1.1 *Wave/Tow Tank*—A wave/tow tank has a movable bridge or other mechanism for towing the test device through water for the length of the facility. A wave generator may be installed on one end, or on the side of the facility, or both.

7.1.2 *Current Tank*—A current tank is a water-filled tank equipped with a pump or other propulsion system for moving the water through a test section where the test device is mounted. A wave generator may be installed on this type of test facility.

7.1.3 Other facilities, such as private ponds or flumes, may also be used, provided the test parameters can be suitably controlled.

7.2 Ancillary systems for facilities include, but are not limited to, a distribution system for accurately delivering oils to the water surface, skimming systems to assist in cleaning the facility between tests, and adequate tankage for storing the test oils.

8. Test Oils

8.1 Test oils for use with this guide should be selected to fall within the parameters specified in Appendix X1. These oils may be crude, refined, or simulated.

8.2 If test oils vary significantly from the recommended ranges, the test report shall discuss the implications of such deviations on the performance of the device.

8.3 The viscosity of oil varies greatly with temperature. Frequently test oils must be distributed in the test facility at temperatures different from the water temperature. When this occurs, the oil generally will approach the surface water temperature.

8.4 If oils that originally meet the conditions stated in Appendix X1 are reused, their properties may change and should be evaluated prior to reuse.

9. Safety Precautions

9.1 Test operations shall conform to established safety (and regulatory) requirements for both test facility operations and oil handling. Particular caution must be exercised when handling flammable or toxic test oils.

10. Test Device

10.1 The test device shall be deployed in accordance with facility operating characteristics. The device must be operated in accordance with the manufacturer's specified operating instructions with respect to mechanical operations and established maintenance routines. Modifications to the device, in any modification from commercial design, shall be recorded with the test results.

11. Test Variables

11.1 At the outset of the test, the independent or control test parameters are selected. The test evaluator should include a discussion of the procedures that were used to establish calibration and standardization. Data should be expressed with an indication of variability. Typical test variables include:

Test oils	as stated in Appendix X1
Test speed	upper and lower limits and speed increments selected as appropriate within ±0.1 m/s
Oil slick thickness	1, 5, and 25 mm and other thicknesses as appropriate
Wave conditions	wave characteristics of significant height, average length, and average significant period and pattern may be varied as appropriate to the design of the skimmer
Wave height	0 mm, 150 mm, and 450 mm
Debris	Use various materials to simulate various forms of natural debris that may hinder skimmer operation. Recommended materials include: polypropylene rope, ½ in. diameter, cut into lengths ranging from 4 in. to 2 ft; softwood lumber, nominal dimensions 2 by 2 in., lengths ranging from 4 in. to 2 ft; foam sponges, nominal size 4 to 12 in; broken ice, nominal size 1 to 4 in. diameter; seaweed, lengths up to 5 ft; plastic or aluminum disposable containers (such as soda cans); sorbent pads, booms, or sheets; or other suitable materials. Use adequate number of pieces to produce concentrations at the skimmer inlet area corresponding to 50 % surface coverage.

12. Procedure

12.1 Prior to the test, select the operating parameters, such as tow speed (as applicable), wave conditions, test oil, and oil distribution rate. Then prepare the facility and spill removal device for the test run. Occasionally, it may be necessary to preload the device with oil to achieve steady-state operation within a reasonable period of time. Any preload must be carefully measured and discharged into the device. Measure or note immediately prior to each test the following parameters describing ambient conditions:

12.1.1 Air temperature (°C),

12.1.2 Water temperature near the surface (°C),

12.1.3 Wind speed (m/s),

12.1.4 Wind direction relative to the test device, and

12.1.5 General weather conditions, for example, rain, overcast, sunny, etc.

12.2 Start the wave generator (if necessary), oil distribution system, tow mechanism or water flow (if necessary), and the spill removal device to begin a test run. Direct the discharge flow of recovered fluid from the device into a holding tank or back into the test tank out of the device's sweep path during the transient start-up period. After steady-state operation is achieved, monitor the discharge flow to obtain performance data. The discharge may be pumped through a flowmeter to obtain a flow rate and sampled periodically to obtain the oil-to-fluid ratio. Alternatively, the discharge may be diverted into calibrated sample tanks from which the flow rate and oil-to-fluid ratio may be determined. In either case, the data collection period begins when sampling starts and ends when sampling stops. During the data collection period or immediately thereafter, measure and record the following parameters:

12.2.1 Oil distribution rate (m^3/h),

12.2.2 Fluid recovery rate (oil and water) (m^3/h),

12.2.3 Tow speed or current speed (m/s),

12.2.4 Wave characteristics (see Practice F 625 for environmental descriptors and classifications),

12.2.5 Length of data collection period,

12.2.6 Oil encounter rate (m^3/h), and

12.2.7 Operating parameters of the spill recovery device such as belt speed (m/s), weir setting (mm below fluid level), pump speed (r/min), etc.

12.3 At the completion of the data collection period, divert the discharge of the spill removal device back into the holding tank or test tank. Stop the wave generator, tow mechanism or water flow, oil distribution, and spill removal device. Depending on the degree and variability of changes in the oil properties, the test evaluator will determine the required schedule of analysis to provide representative samples. Analyze representative samples of the discharge to determine oil-to-fluid ratio. Analyze representative samples of the recovered test oil to determine the following:

12.3.1 Density (g/mL),

12.3.2 Viscosity (mm^2/s),

12.3.3 Surface tension (mN/m),

12.3.4 Interfacial tension with respect to test tank water (mN/m), and

12.3.5 Water content (percent of total mixture).

12.4 Perform the analyses in 12.3 at the surface water temperature or in such a way that the values of these parameters at the surface water temperature can be determined from the analytical data.

13. Report

13.1 Prepare a schematic diagram of the layout for the test series.

13.2 Prepare a table of results for the test run containing the following entries:

13.2.1 Test identification number.

13.2.2 Date and time of day.

13.2.3 Average speed (tow speed or current speed, m/s) during data collection period.

NOTE—This rate is averaged over the data collection period.

13.2.4 Test oil type.

13.2.5 *Oil slick thickness*—Calculation of slick thickness should include a brief discussion of the method used for measuring variation in the thickness, especially for heavy oils.

13.2.6 For regular waves, include height, average period (or length), and whether head or following. For irregular waves, include significant height, significant frequency, spectral characteristics, and whether head or following. Primary and secondary (reflected) wave basin characteristics shall be described.

13.2.7 Oil properties at test temperatures, including density, viscosity, surface tension, interfacial tension with tank water, and initial water content of oil.

13.2.8 Recovered oil properties as performed in 12.3.

13.2.9 Total volume of oil distributed during data collection period.

13.2.10 Total volume of oil encountered during data collection period.

13.2.11 Total volume of fluid (oil/water) recovered during data collection period.

13.2.12 Average oil distribution rate (see Note).

13.2.13 Average oil encounter rate (see Note).

13.2.14 Average fluid (oil/water) recovery rate (see Note).

13.2.15 Average oil recovery efficiency (see Note).

13.2.16 Average oil recovery rate (see Note).

13.2.17 Average throughput efficiency (see Note).

13.2.18 Ambient conditions, including air temperature, surface water temperature, wind speed, wind direction, and brief statement of weather conditions during test run.

13.2.19 Length of data collection period.

13.2.20 Volume of oil in device at beginning of data collection period.

13.2.21 Volume of oil in device at end of data collection period.

13.2.22 Operating parameters of the device such as belt speed, weir setting, pump speed, etc.

13.2.23 For tests conducted in the presence of debris, report the following:

13.2.23.1 Size and type of debris forms used;

13.2.23.2 Approximate concentration, expressed as surface coverage (percent);

13.2.23.3 Mode of debris handling, or processing, or both;

13.2.23.4 Effectiveness of debris handling, or processing, or both; and

13.2.23.5 When comparing results, specify reasons for performance degradation (if any), differentiating between oil encounter degradation and that of the skimming mechanism.

13.2.24 Brief discussion of interferences or limiting factors (see 6.1).

13.3 If any of the data required by 13.2 are not applicable to the device being tested, a statement must be included in the table of results describing the reasons for omitting the data.

13.4 Report qualitative comments on device operating parameters such as mechanical reliability, ease of repair, ease of deployment, required operator training, operator fatigue, seaworthiness, and transportability.

14. Keywords

14.1 oil; oil recovery; skimmer

APPENDIX

(Nonmandatory Information)

X1. STANDARD TEST OILS

X1.1 Values in Table X1.1 refer to test fluid properties at test temperatures. Test methods for fluid properties are specified as follows: viscosity, Test Methods D 445 and D 2983 (report shear rate for viscosity measurement, should be in the range of 1 to 10 s^{-1}); density, Test Method D 1298; interfacial tension, Test Method D 971; pour point, Test Method D 97. For all test oils (with the exception of emulsions), maximum sediment and water (BSW) of 0.1 % (see Test Method D 4007).

X1.2 Of the five viscosity ranges, numbers I, II, and IV are especially recommended as being indicative, respectively, of lightly weathered, moderately weathered, and significantly weathered crude oils.

X1.3 The following lists examples of hydrocarbon oils that could be used to fall within the specified ranges. This list is intended for guidance only; it should be noted that viscosities of all oils will vary greatly with both temperature and the specific product. Selected oils may be crude, refined, or simulated. In the case of crudes and light refined products, it is acceptable and may be desirable to pre-weather the oil in order to produce a desired viscosity, increase the oil's flash point to a safe level, and produce a more stable test fluid.

TABLE X1.1 Candidate Test Oils

NOTE—Test oils should be selected to fall within these five categories.

	Viscosity, mm^2/s	Density, g/mL	Oil-Air Interfacial Tension, mN/m	Oil-Water Interfacial Tension, mN/m	Pour Point, °C
I[A]	150 to 250	0.90 to 0.93	28 to 34	20 to 30	< -3
II[B]	1500 to 2500	0.92 to 0.95	30 to 40	20 to 30	< -3
III[C]	17 000 to 23 000	0.95 to 0.98	20 to 40	20 to 40	< 10
IV[D]	50 000 to 70 000	0.96 to 0.99	20 to 40	20 to 40	. . .
V[E]	130 000 to 170 000	0.96 to 0.99	20 to 40	20 to 40	. . .

[A] 1) Alaska North Slope crude oil, 10 to 15 % weathered by volume.
2) Fuel oil No. 4 (heavy); can be prepared by blending 40 % fuel oil No. 2 and 60 % fuel oil No. 6.

[B] Fuel oil No. 5; can be prepared by blending 20 to 25 % fuel oil No. 2 with 75 to 80 % fuel oil No. 6.

[C] Residual fuel oil (that is, fuel oil No. 6 prepared to above criteria).

[D] Residual fuel oil (that is, heavy cut of fuel oil No. 6).

[E] Emulsified crude oil, 50 to 80 % water content. The oil may be emulsified by blowing compressed air through water on which the oil is floating.

CERTIFICATE

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By the Authority Vested By Part 5 of the United States Code § 552(a) and Part 1 of the Code of Regulations § 51 the attached document has been duly INCORPORATED BY REFERENCE and shall be considered legally binding upon all citizens and residents of the United States of America. *HEED THIS NOTICE*: Criminal penalties may apply for noncompliance.

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An American National Standard

Standard Specification for Wrought Carbon Steel Sleeve-Type Pipe Couplings[1]

This standard is issued under the fixed designation F 682; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This specification covers wrought carbon steel sleeve-type pipe couplings suitable for joining carbon steel pipes.

1.2 Type I couplings are intended for use on all schedules of pipe in which the pipe wall thickness does not exceed the wall thickness of standard weight pipe. Type II couplings are intended for use on all schedules of pipe in which the pipe wall thickness does not exceed the wall thickness of extra strong pipe.

1.3 This specification does not cover cast steel couplings.

NOTE 1—The values stated in inch-pound units are to be regarded as the standard.

NOTE 2—See Appendix X1 for rationale used to develop this specification.

2. Referenced Documents

2.1 *ASTM Standards:*

A 53/A 53M Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated Welded and Seamless[2]

A 106 Specification for Seamless Carbon Steel Pipe for High-Temperature Service[2]

A 234/A234M Specification for Piping Fittings of Wrought Carbon Steel and Alloy Steel for Moderate and High Temperature Service[2]

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products[3]

E 59 Practice for Sampling Steel and Iron for Determination of Chemical Composition[4]

2.2 *Manufacturer's Standardization Society of the Valve and Fittings Industry Standard:*

MSS SP-25 Standard Marking System for Valves, Fittings, Flanges and Unions[5]

2.3 *ASME Boiler and Pressure Vessel Code:*

Section VIII Unfired Pressure Vessels[6]

Section IX Welding Qualifications[6]

2.4 *Federal Regulations:*

Title 46, Code of Federal Regulations (CFR), Shipping, Parts 41 to 69[7]

2.5 *ANSI Standards:*

B16.5 Pipe Flanges and Flange Fittings[8]

3. Classification

3.1 Couplings are furnished in two types as follows:

3.1.1 *Type I*—Couplings (see 1.2).

3.1.2 *Type II*—Couplings (see 1.2).

NOTE 3—Type II couplings may be used in place of Type I couplings for all schedules of pipe in which the pipe wall thickness does not exceed the wall thickness of standard weight piping through 18 in. or Schedule 40 piping through 16 in.

4. Ordering Information

4.1 Orders for material under this specification shall include the following information:

4.1.1 Quantity (number of couplings of each size and type),

4.1.2 Name of material (sleeve-type pipe couplings),

4.1.3 Size (nominal, see Table 1 and Table 2 and Fig. 1),

4.1.4 Type (see 3.1),

4.1.5 ASTM designation and date of issue.

5. Materials and Manufacture

5.1 *Materials*—The couplings shall be manufactured from material having a chemical composition conforming to the requirements of 7.1 and with the mechanical properties of Section 9.

5.2 *Manufacture*—The initial form of the raw material shall be at the discretion of the manufacturer except couplings shall not be machined from unformed plate. The material shall be such that the finished couplings conform to all of the specified requirements (see Appendix X2).

5.3 Couplings fabricated by welding shall be (*a*) made by welders, welding operators, and welding procedures qualified

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[1] This specification is under the jurisdiction of ASTM Committee F-25 on Ships and Marine Technology and is the direct responsibility of Subcommittee F25.13 on Piping Systems.

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[2] *Annual Book of ASTM Standards*, Vol 01.01.

[3] *Annual Book of ASTM Standards*, Vol 01.03.

[4] *Annual Book of ASTM Standards*, Vol 03.05.

[5] Available from Manufacturer's Standardization Society of the Valve and Fitting Industry, 1815 N. Fort Myer Dr., Arlington, Va 22209.

[6] Available from American Society of Mechanical Engineers, 345 E. 47th St., New York, NY 10017.

[7] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

[8] Available from American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.

TABLE 1 Dimensions for Type I Couplings (See Fig. 1)

Nominal Size, in.	Dimension A, Inside Diameter, in. (mm)[A]	Dimension B, Outside Diameter, in. (mm)[B]	Dimension C, Thickness, min, in. (mm)	Dimension D, Length, in. (mm)[C]
¼	0.589 (15.0)	0.875 (22.2)	0.143 (3.6)	1 (25)
⅜	0.724 (18.4)	0.992 (25.2)	0.134 (3.4)	1¼ (32)
½	0.889 (22.6)	1.201 (30.5)	0.156 (4.0)	1¼ (32)
¾	1.099 (27.9)	1.401 (35.6)	0.151 (3.8)	1½ (38)
1	1.364 (34.6)	1.710 (43.4)	0.173 (4.4)	1½ (38)
1¼	1.709 (43.4)	2.057 (52.2)	0.174 (4.4)	1½ (38)
1½	1.949 (49.5)	2.306 (58.6)	0.179 (4.5)	1½ (38)
2	2.424 (61.6)	2.807 (71.3)	0.192 (4.9)	1½ (38)
2½	2.924 (74.3)	3.444 (87.5)	0.260 (6.6)	1½ (38)
3	3.545 (90.0)	4.105 (104.3)	0.280 (7.1)	1½ (38)
3½	4.070 (103.4)	4.633 (117.7)	0.282 (7.2)	2 (51)
4	4.570 (116.1)	5.164 (131.2)	0.297 (7.5)	2 (51)
5	5.660 (143.8)	6.286 (159.7)	0.313 (8.0)	2 (51)
6	6.720 (170.7)	7.409 (188.2)	0.345 (8.8)	2 (51)
8	8.720 (221.5)	9.527 (242.0)	0.404 (10.3)	2½ (64)
10	10.880 (276.4)	11.875 (301.6)	0.498 (12.6)	2½ (64)
12	12.880 (327.2)	13.800 (350.5)	0.460 (11.7)	2½ (64)
14	14.140 (359.2)	15.050 (382.3)	0.455 (11.6)	2½ (64)
16	16.160 (410.5)	17.050 (433.1)	0.445 (11.3)	2½ (64)
18	18.180 (461.8)	19.050 (483.9)	0.435 (11.0)	2½ (64)

[A] Tolerances shall be (*1*) Sizes through 3 in. incl: +0.000, −0.010 in. (+0.000, −0.254 mm); (*2*) Sizes 3½through 10 in. incl: +0.030, −0.000 in. (+0.762, −0.000 mm); and (*3*) Sizes above 10 in.: +0.060, −0.000 in. (+1.524, −0.000 mm).

[B] Tolerances shall be (*1*) Sizes through 10 in. incl: +0.125, −0.000 in. (+3.175, −0.000 mm) and (*2*) Sizes above 10 in.: +1.000, −0.000 in. (+25.4, −0.000 mm).

[C] Tolerances for all sizes shall be +0.250, −0.000 in. (+6.4, −0.000 mm).

TABLE 2 Dimensions for Type II Couplings (See Fig. 1)

Nominal Size, in.	Dimension A, Inside Diameter, in. (mm)[A]	Dimension B, Outside Diameter, in. (mm)[B]	Dimension C, Thickness, min, in. (mm)	Dimension D, Length, in. (mm)[C]
¼	0.589 (15.0)	1.055 (26.8)	0.233 (5.9)	1 (25)
⅜	0.724 (18.4)	1.156 (29.4)	0.216 (5.5)	1¼ (32)
½	0.889 (22.6)	1.369 (34.8)	0.240 (6.1)	1¼ (32)
¾	1.099 (27.9)	1.557 (39.5)	0.229 (5.8)	1½ (38)
1	1.364 (34.6)	1.876 (47.7)†	0.256 (6.5)†	1½ (38)
1¼	1.709 (43.4)	2.221 (56.4)†	0.256 (6.5)†	1½ (38)
1½	1.949 (49.5)	2.469 (62.7)†	0.260 (6.6)†	1½ (38)
2	2.424 61.6)	2.986 (75.8)†	0.281 (7.1)†	1½ (38)
2½	2.924 (74.3)	3.648 (92.7)†	0.362 (9.2)†	1½ (38)
3	3.545 (90.0)	4.340 (110.2)†	0.398 (10.1)†	1½ (38)
3½	4.070 (103.4)	4.891 (124.2)†	0.411 (10.4)†	2 (51)
4	4.570 (116.1)	5.444 (138.3)	0.437 (11.1)	2 (51)
5	5.660 (143.8)	6.613 (168.0)	0.477 (12.1)	2 (51)
6	6.720 (170.7)	7.875 (200.0)	0.578 (14.7)	2 (51)
8	8.720 (221.5)	10.125 (257.2)	0.703 (17.8)	2½ (64)
10	10.880 (276.4)	12.150 (308.6)	0.635 (16.1)	2½ (64)
12	12.880 (327.2)	14.150 (359.4)	0.635 (16.1)	2½ (64)
14	14.140 (359.2)	15.400 (391.2)	0.630 (16.0)	2½ (64)
16	16.160 (410.5)	17.400 (442.0)	0.620 (15.7)	2½ (64)
18	18.180 (461.8)	19.400 (492.8)	0.610 (15.5)	2½ (64)

[A] Tolerances shall be (*1*) Sizes through 3 in. incl: +0.000, −0.010 in. (+0.000, −0.254 mm); (*2*) Sizes 3½through 10 in. incl: +0.030, −0.000 in. (+0.762, −0.000 mm); and (*3*) Sizes above 10 in.: +0.060, −0.000 in. (+1.524, −0.000 mm).

[B] Tolerances shall be (*1*) Sizes through 10 in. incl: +0.125, −0.000 in. (+3.175, −0.000 mm) and (*2*) Sizes above 10 in.: +1.000, −0.000 in. (+25.4, −0.000 mm).

[C] Tolerances for all sizes shall be +0.250, −0.000 in. (+6.4, −0.000 mm).

† Editorially corrected.

under the provisions of ASME Boiler and Pressure Vessel Code, Section IX; (*b*) heat treated in accordance with Section 6 of this specification; and (*c*) nondestructively tested as follows:

5.3.1 *Sizes 3-in. NPS and Below*—Radiographically examined throughout the entire length of each fabricated weld in accordance with Paragraph UW-51 of ASME Code, Section VIII.

5.3.2 *Sizes 3½-in. NPS Through 16-in. NPS*— No nondestructive tests required, and

5.3.3 *Sizes 18-in. NPS and Above*—Any method of nondestructive testing may be used provided the tests are conducted in accordance with the applicable parts of ASME Code, Section VIII.

6. Heat Treatment

6.1 *Couplings Made from Plate or Tubular Products*:

6.1.1 Couplings machined from tubular products need not be heat treated.

6.1.2 Hot-formed couplings upon which the final forming

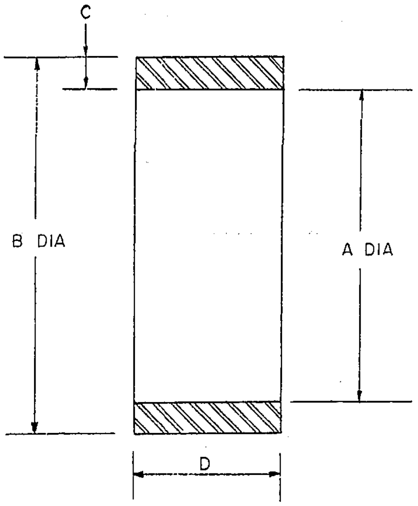

FIG. 1 Sleeve-Type Pipe Coupling

operation is completed at a temperature above 1150°F (621°C) and below 1800°F (982°C) need not be heat treated provided they are cooled in still air. If the manufacturer elects to heat treat such couplings it shall be by one of the procedures described in 6.3.

6.1.3 Hot-formed couplings finished at a temperature in excess of 1800°F (982°C) shall subsequently be annealed, normalized, or normalized and tempered.

6.1.4 Cold-formed couplings upon which the final forming operation is completed at a temperature below 1150°F (621°C) shall be normalized or shall be stress-relieved at 1100 to 1250°F (593 to 677°C) for 1 h/in. of thickness.

6.1.5 Couplings produced by fusion welding shall be postweld heat treated at 1100 to 1250°F (593 to 677°C), when the nominal wall thickness at the welded joint is ¾ in. or greater.

6.2 *Carbon Steel Couplings Made from Forgings*—Couplings made from forgings shall subsequently be annealed, normalized, or normalized and tempered.

6.3 *Heat Treatment Procedures*—Couplings after forming at an elevated temperature shall be cooled to a temperature below the critical range under suitable conditions to prevent injuries by too rapid cooling, but in no case more rapidly than the cooling rate in still air. Couplings that are to be heat treated shall be treated as follows:

6.3.1 *Full Annealing*—Couplings shall be uniformly reheated to a temperature above the transformation range and, after being held for a sufficient time at this temperature, cooled slowly to a temperature below the transformation range.

6.3.2 *Normalizing*—Couplings shall be uniformly reheated to a temperature above the transformation range and subsequently cooled in air at room temperature.

6.3.3 *Tempering and Postweld Heat Treatment*—Couplings shall be reheated to the prescribed temperature below the transformation range, held at temperature for not less than 1 h/in. of thickness at the thickest section, and cooled in the furnace or in still air.

7. Chemical Requirements

7.1 The couplings shall conform to the requirements as to chemical composition prescribed in Table 3.

7.2 Weld metal used in the construction of the couplings shall be mild steel analysis No. Al of Table QW-442, Section IX of the ASME Boiler and Pressure Vessel Code.

8. Product Analysis

8.1 Product analyses may be made by the purchaser from finished products representing each lot. The chemical composition thus determined shall conform to the requirements specified in Table 3.

8.2 In the event the couplings do not conform to the requirements specified in Table 3, referee analyses shall be made on additional couplings from the same lot in accordance with Practice E 59.

9. Mechanical Properties

9.1 The steel shall conform to the requirements as to tensile properties prescribed in Table 4.

9.2 The yield strength corresponding to a permanent offset of 0.2 % of the gage length of the specimen under load shall be determined.

9.3 Tension tests shall be made on material representative of and in the same condition of heat treatment as the finished coupling.

9.3.1 Records of the tension tests shall be certification that the material of the coupling meets the requirements of this specification provided the heat treatments are the same. If the raw material was not tested, the coupling manufacturer shall perform the required test on material representative of the finished coupling.

9.4 The tests required by this specification shall conform to those described in the latest issue of Test Methods and Definitions A 370.

10. Dimensions and Permissible Variations

10.1 The dimensions and permissible variations for sleeve couplings to this specification are prescribed in Table 1 and Table 2.

11. Workmanship, Finish, and Appearance

11.1 Sleeve couplings shall have a workmanlike finish, free of scale and injurious defects. Ends shall be finished square and without burrs.

12. Hydrostatic Testing

12.1 Hydrostatic testing is not required by this specification.

12.2 All couplings shall be capable of withstanding, without failure, leakage, or impairment of serviceability, a test pressure equal to that prescribed in the specification for the pipe with which the fitting is recommended to be used.

13. Product Marking

13.1 Identification marks consisting of the manufacturer's

TABLE 3 Chemical Requirements

	Composition, max, %
Carbon	0.30
Manganese	1.20
Phosphorus	0.05
Sulfur	0.06

TABLE 4 Tension Requirements

Tensile strength, min, ksi (MPa)	60 (414)
Yield Point, min, ksi (MPa)	35 (241)
Elongation in 2 in. or 50.8 mm, min, %	23

symbol or name, the ASTM designation number, type, and size shall be legibly stamped on each fitting, and in such a position as not to injure the usefulness of the fitting. SP-25 may be followed except the word "steel" shall not be substituted for the ASTM designation.

13.2 Where couplings are manufactured by an activity for its own use, the marking requirements of 13.1 do not pertain.

14. Keywords

14.1 carbon steel sleeve-type pipe couplings; couplings; pipe couplings; Type I couplings; Type II couplings

APPENDIXES

(Nonmandatory Information)

X1. RATIONALE USED FOR DEVELOPMENT OF SPECIFICATION F 682

X1.1 This specification has been developed to provide two types of couplings. Type I is for use on all schedules of pipe in which the pipe wall thickness does not exceed the wall thickness of standard weight pipe. Type II is for use on all schedules of pipe in which the pipe wall thickness does not exceed the wall thickness of extra strong pipe. Note 3 provides an option that allows the use of Type II couplings in place of Type I couplings, if desired.

X1.2 The design criteria for the couplings is based on CFR Title 46, Subpart 56.70-15(d)3 and 4 as follows:

X1.2.1 For couplings through 3-in. IPS, the clearance between the system pipe outside diameter and the sleeve coupling inside diameter has been held to a maximum of 0.080 in. when considering tolerances to allow these couplings to be used in Class I piping through 3 in. when not subjected to full radiography as allowed by CFR Title 46. The inside diameter of the coupling is therefore equal to the minimum outside diameter of the pipe to be joined +0.080 in. with a tolerance of +0.000, −0.010 in. This provides for a maximum diametral clearance of 0.080 in.

NOTE X1.1—The minimum outside diameter of the pipe was determined by subtracting the largest minus tolerance from either Specification A 53/A 53M (ABS Grades 1, 2, and 3) or Specification A 106 (ABS Grades 4 and 5).

X1.2.2 The coupling inside diameter and tolerance in sizes 3½ in. and above for use in Class II piping has been taken from ANSI B16.5, Table 9, for slip-on flanges.

X1.2.3 The minimum length of the coupling has been set at 1 in. This satisfies the USCG requirement of 3/8-in. minimum depth of pipe insertion when used in Class I piping.

X1.2.4 To meet the USCG requirement that "the fillet weld shall have a throat dimension of not less than the nominal thickness of the pipe or tubing being joined," a coupling outside diameter of not less than the nominal outside diameter of the system pipe plus two times 1.4 T has been used. (T = nominal pipe thickness.)

X1.2.5 Hoop stress calculations have been performed to ensure that the strength of the coupling is equal to or greater than that of pipe being joined.

X1.3 A tolerance of +0.125, −0.000 in. was established for the outside diameter of couplings through 10 in. and a tolerance of +1.000, −0.000 in. for couplings 12 in. and larger. This allows the use of commercially available tubular products without machining the outside diameter and limits the maximum outside diameter thereby allowing designers to determine the hole size which would be required to pass a coupling through a penetration.

X1.4 Testing heat treatment requirements have been taken from Specification A 234/A 234M as discussed with USCG G-MMT-2/82.

X1.4.1 Radiography requirements have been taken from CFR Title 46, Subpart 56.95 as discussed with USCG G-MMT-2/82.

X1.5 Although marking is not specifically required by USCG, "marking" has been included in the specification to allow for material control and segregation of the couplings in industry.

X2. TUBULAR RAW STOCK MATERIAL SIZES FOR MANUFACTURE OF COUPLINGS

X2.1 Tubular products listed in Table X2.1 may be used for the manufacture of couplings without machining the coupling outside diameter. Other tubular sizes as well as other wrought materials (that is, forging, bars, billets, plate, and so forth, see 5.2) may also be used provided all the requirements of this specification are satisfied.

TABLE X2.1 Tubular Products Used for Couplings

Nominal Size, in.	Type I Couplings	Type II Couplings
¼	0.875 OD × 0.563 ID	1.062 OD × 0.563 ID
⅜	¾ in. IPS Sch 160	1.188 OD × 0.688 ID
½	1 in. IPS Sch 160	1.375 OD × 0.875 ID
¾	1.500 OD × 1.062 ID	1¼ in. IPS XX Strong
1¼	1.750 OD × 1.250 ID	1½ in. IPS Sch 160
1½	2.125 OD × 1.625 ID	2.250 OD × 1.688 ID
1	2 in. IPS Sch 80	2.500 OD × 1.937 ID
2½	2½ in. IPS Sch 80	3.000 OD × 2.375 ID
2	3 in. IPS Sch 80	3.750 OD × 2.875 ID
3½	4.125 OD × 3.500 ID	4.375 OD × 3.500 ID
3	4.750 OD × 4.000 ID	5.000 OD × 4.000 ID
4	5.250 OD × 4.500 ID	5 in. IPS Sch 120
5	6.375 OD × 5.375 ID	6 in. IPS Sch 120
6	7.500 OD × 6.500 ID	8.000 OD × 6.500 ID
8	9.625 OD × 8.625 ID	10.250 OD × 8.500 ID
10	12.000 OD × 10.750 ID	12 in. IPS Sch 120
12	14 in. IPS Sch 60	16 in. IPS Sch 160
14	16 in. IPS Sch 100	16 in. IPS Sch 80
16	18 in. IPS Sch 80	18 in. IPS Sch 80
18	20 in. IPS Sch 80	20 in. IPS Sch 80

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Document Name: ASTM F715: Standard Test Methods for Coated Fabrics Used for Oil Spill Control and Storage

CFR Section(s): 33 CFR 154.106

Standards Body: American Society for Testing and Materials

Official Incorporator:
THE EXECUTIVE DIRECTOR
OFFICE OF THE FEDERAL REGISTER
WASHINGTON, D.C.

Designation: F 715 – 81 (Reapproved 1986)

Standard Methods of Testing Spill Control Barrier Membrane Materials[1]

This standard is issued under the fixed designation F 715; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 These methods cover laboratory-conducted performance tests for spill control barrier membrane materials.

1.2 *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

D 543 Test Method for Resistance of Plastics to Chemical Reagents[2]

D 751 Methods of Testing Coated Fabrics[3]

D 882 Test Methods for Tensile Properties of Thin Plastic Sheeting[2]

D 975 Specification for Diesel Fuel Oils[4]

D 1004 Test Method for Initial Tear Resistance of Plastic Film and Sheeting[2]

D 2261 Test Method for Tearing Strength of Woven Fabrics by the Tongue (Single Rip) Method (Constant-Rate-of-Extension Tensile Testing Machine)[5]

D 2262 Test Method for Tearing Strength of Woven Fabrics by the Tongue (Single Rip) Method (Constant-Rate-of-Traverse Tensile Testing Machine)[5]

2.2 *Federal Standard:*

Fed. Std. No. 191B Textile Test Methods[6]

2.3 *Military Specification:*

MIL-T-6396 C Tank, Fuel, Oil, Water-Alcohol, Coolant Fluid, Aircraft, Non-Self-Sealing, Removable, Internal[6]

3. Significance and Use

3.1 Membrane materials are subjected to these tests in order to provide data that reasonably relate to membrane response under the actual conditions of spill control barrier use.

3.2 Although these methods provide data on individual performance characteristics of membrane materials, all combinations of actual conditions of spill control barrier use are not simulated in this sequence of tests.

4. Base Line Tests

4.1 *Number of Specimens*—Subject seven specimens of spill control membrane materials to tests prescribed in 4.2 through 4.6. Perform all tests parallel and perpendicular to the axis of barrier when in use.

4.2 *Tensile Strength:*

4.2.1 *Supported Materials*—Fed. Std. No. 191B Method 5102 (cut strip), equivalent to Method D 751.

4.2.2 *Unsupported Materials*—Dumb Bell Sample, Method D 882, measured in pound-force per square inch.

4.3 *Tear Strength:*

4.3.1 *Supported Materials*—Fed Std No. 191B Method 5134 (tongue tear) equivalent to Methods D 2261 or D 2262. If standard sample does not achieve true tear or if fabric design requires roping to achieve high tear, sample size may be enlarged in order to achieve cord breakage, but all other procedures must be maintained. Such sample size change must be recorded in test results.

4.3.2 *Unsupported Materials*—Graves Method D 1004.

4.4 *Adhesion*—Fed Std. No. 191B Method 5970, after 5 days at 70°C in water, or Method D 751, after 5 days at 70°C in water.

4.5 *Puncture Resistance*—MIL-T-6396 C.

4.6 *Hydrostatic Resistance*—Fed. Std. No. 191B Method 5512 (Mullen Hydrostatic Test).

4.7 *Storage Life*—To be determined.

4.8 *Mildew*—Fed. Std. No. 191B Method 5762 (Mixed Cidal Spore Test).

5. Weather and Petroleum Sample Tests Related to Base Line Tests

5.1 *Specimen Preparation*—Subject samples of spill control barrier membrane material to the following preparations: weather resistance to be followed by resistance to petroleum products:

5.1.1 *Weather Resistance*—Fed. Std. No. 191B Method 5804, 500-h exposure.

5.1.2 *Resistance to Petroleum Products*—Method D 543, with 96-h exposure to No. 2 diesel stock as prescribed in Specification D 975, at ambient temperature.

5.2 *Weather and Petroleum Sample Test*—Perform each of the following tests within 1 h of the termination of the test in 5.1.2.

5.2.1 *Tensile Strength:*

5.2.1.1 *Supported Materials*—Same as base line test (4.2.1).

5.2.1.2 *Unsupported Materials*—Same as base line test (4.2.2).

5.2.2 *Tear Strength:*

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[1] These methods are under the jurisdiction of ASTM Committee F-20 on Hazardous Substances and Oil Spill Response and are the direct responsibility of Subcommittee F20.11 on Control.

Current edition approval Feb. 27, 1981. Published July 1981.

[2] *Annual Book of ASTM Standards*, Vol 08.01.

[3] *Annual Book of ASTM Standards*, Vol 09.02.

[4] *Annual Book of ASTM Standards*, Vol 05.01.

[5] *Annual Book of ASTM Standards*, Vol 07.01.

[6] Available from Naval Publications and Forms Center, 5801 Tabor Ave., Philadelphia, PA 19120.

5.2.2.1 *Supported Materials*—Same as base line test (4.3.1).

5.2.2.2 *Unsupported Materials*—Same as base line test (4.3.2).

5.2.3 *Adhesion*—Same as base line test (4.4). Samples shall be heat-sealed or cemented.

5.2.4 *Puncture Resistance*—Same as base line test (4.5).

5.2.5 *Hydrostatic Resistance*—Same as base line test (4.6).

5.3 *Interpretation of Results*—The results of each test in 5.2 shall be compared with the results of the same test in Section 4, and a percentage of change shall be noted.

6. Weather and Petroleum Sample Tests Followed by Hydrostatic Resistance, Related to Base Line Hydrostatic Test

6.1 *Specimen Preparation*—Use the three remaining samples from 5.1 for the tests in 6.2 and 6.3.

6.2 *Weather and Petroleum Sample Tests*—Perform each of the following tests within 1 h of the termination of the test in 5.1.2.

6.2.1 *Abrasion Resistance*—Fed. Std. No. 191B Method 5306 (Taber), using a H18 wheel and 1000-gf load, abraded 300 cycles.

6.2.2 *Low-Temperature Resistance*—Fed. Std. No. 191B Method 5874, at 2 h soak at −29°C with 2.5 kg mandrel roller weight.

6.2.3 *Flexibility*—To be determined.

6.3 *Hydrostatic Test*—Test for hydrostatic resistance in accordance with 4.6.

6.4 *Interpretation of Results*—The results of each test in 6.3 shall be compared with the results of 4.6, and a percentage of change shall be noted.

7. Precision and Bias

7.1 The precision and bias of test measurements are addressed in each individual test method cited in Sections 3, 4, and 5.

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Document Name: ASTM F715: Standard Test Methods for Coated Fabrics Used for Oil Spill Control and Storage

CFR Section(s): 33 CFR 155, Appendix B, 2.4

Standards Body: American Society for Testing and Materials

Official Incorporator:

THE EXECUTIVE DIRECTOR
OFFICE OF THE FEDERAL REGISTER
WASHINGTON, D.C.

Designation: F 715 – 95

Standard Test Methods for Coated Fabrics Used for Oil Spill Control and Storage[1]

1. Scope

1.1 These test methods cover laboratory-conducted performance tests for coated fabrics used in spill control barriers or in temporary storage devices.

1.2 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

D 86 Test Method for Distillation of Petroleum Products[2]
D 93 Test Methods for Flash Point by Pensky-Martens Closed Cup Tester[2]
D 97 Test Method for Pour Point of Petroleum Products[2]
D 129 Test Method for Sulfur in Pretroleum Products (General Bomb Method)[2]
D 130 Test Method for Detection of Copper Corrosion from Petroleum Products by the Copper Strip Tarnish Test[2]
D 287 Test Method for API Gravity of Crude Petroleum and Petroleum Products (Hydrometer Method)[2]
D 445 Test Method for Kinematic Viscosity of Transparent and Opaque Liquids (And the Calculation of Dynamic Viscosity)[2]
D 482 Test Method for Ash from Petroleum Products[2]
D 524 Test Method for Ramsbottom Carbon Residue of Petroleum Products[2]
D 543 Test Method for Resistance of Plastics to Chemical Reagents[3]
D 613 Test Method for Cetane Number of Diesel Fuel Oil[4]
D 664 Test Method for Acid Number of Petroleum Products by Potentiometric Titration[4]
D 751 Test Methods for Coated Fabrics[5]
D 975 Specification for Diesel Fuel Oils[2]
D 1149 Test Method for Rubber Deterioration—Surface Ozone Cracking in a Chamber[6]
D 1266 Test Method for Sulfur in Petroleum Products (Lamp Method)[2]
D 1298 Practice for Density, Relative Density (Specific Gravity), or a PI Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method[2]
D 1319 Test Method for Hydrocarbon Types in Liquid Petroleum Products by Fluorescent Indicator Adsorption[2]
D 1796 Test Method for Water and Sediment in Fuel Oils by the Centrifuge Method (Laboratory Procedure)[2]
D 2425 Test Method for Hydrocarbon Types in Middle Distillates by Mass Spectrometry[2]
D 2500 Test Method for Cloud Point of Petroleum Oils[2]
D 2644 Tolerances for Yarns Spun on the Woolen System[7]
D 3117 Test Method for Wax Appearance Point of Distillate Fuels[8]
D 4157 Test Method for Abrasion Resistance of Textile Fabrics (Oscillatory Cylinder Method)[9]
G 26 Practice for Operating Light-Exposure Apparatus (Xenon-Arc Type) With and Without Water for Exposure of Nonmetallic Materials[10]

2.2 *Federal Standard:*

Fed. Std. No. 191A Textile Test Methods[11]

2.3 *Military Specification:*

MIL-T-6396 E Tank, Fuel, Oil, Water-Alcohol, Coolant Fluid, Non-Self-Sealing, Removable, Internal[11]

3. Significance and Use

3.1 Membrane materials are subjected to these tests in order to provide data that reasonably relate to membrane response under the actual conditions of spill control barrier or storage device use.

3.2 Although these test methods provide data on individual performance of membrane materials, all combinations of actual conditions of spill control barrier or storage device use are not simulated in this sequence of tests.

4. Base Line Tests

4.1 *Number of Specimens*—Subject specimens of spill control membrane materials to the tests prescribed in 4.2 through 4.11. Perform all tests in the direction of both the warp and fill of the fabric. The number of specimens to be tested are as specified in the procedures referenced in 4.2 through 4.11.

4.2 *Mass and Thickness*—Test Methods D 751.

4.3 *Tensile Strength and Elongation at Break*—Test

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[1] These test methods are under the jurisdiction of ASTM Committee F-20 on Hazardous Substances and Oil Spill Response and are the direct responsibility of Subcommittee F20.11 on Control.

Current edition approval May 15, 1995. Published July 1995. Originally published as F 715 – 81. Last previous edition F 715 – 81 (1994)$^{\epsilon 1}$.

[2] *Annual Book of ASTM Standards*, Vol 05.01.

[3] *Annual Book of ASTM Standards*, Vol 08.01.

[4] *Annual Book of ASTM Standards*, Vol 05.04.

[5] *Annual Book of ASTM Standards*, Vol 09.02.

[6] *Annual Book of ASTM Standards*, Vol 09.01.

[7] *Annual Book of ASTM Standards*, Vol 07.01.

[8] *Annual Book of ASTM Standards*, Vol 05.02.

[9] *Annual Book of ASTM Standards*, Vol 07.02.

[10] *Annual Book of ASTM Standards*, Vol 14.02.

[11] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

TABLE 1 Detailed Requirements for Test Diesel Fuel Caterpillar 1G2/1H2

NOTE—Diesel fuels meeting the detailed requirements in Table 1 are available from Howell Hydrocarbons and Chemical Incorporated, 1201 South Sheldon Road, Channelview, TX 77530.

Property	ASTM Test Method	Requirement	
Flash point	D 93	140°F (60.0°C) min or legal	
Pour point	D 97	20°F (−7°C) max	
Cloud point	D 2500 or D 3117	Report	
Water and Sediment	D 1796	0.05 vol % max	
Ramsbottom carbon on 10 % residium	D 524	0.20 mass % max	
Ash	D 482	0.01 mass % max	
Distillation	D 86	IBP report 10 % report 50 % 500–530°F (260–277°C) 90 % 590–620°F (310–327°C) EP 650–690°F (343–366°C)	
Kinematic viscosity at 104°F (40.0°C)	D 445	2.0–4.0 cSt (2.0–4.0 mm^2/s)	
Total sulfur (must be natural)	D 2644 (Alt. D 129 or D 1266)	0.380–0.420 mass %	
Copper, corrosion (122°F, 50°C, 3 h)	D 130	No. 2 max	
Acid number (TAN-E)	D 664	0.15 mg KOH/g max	
Centane number	D 613	47.0–53.0	
Density	D 287 or D 1298	report	
API gravity	D 287 (Alt. D 1298)	33–35 API	
Cracked stocks		none	
Hydrocarbon types	D 1319	report	
Hydrocarbon types	D 2425	Component	mass %
		aliphatic paraffins	45.0–65.0
		monocycloparaffins, tetrocycloparaffins	report
		dicycloparaffins	0.0–15.0
		alkylbenzenes	5.0–10.0
		indans/tetralins, indenes	report
		napthalene	report
		napthalenes	5.0–15.0
		acenapthenes, acenapthylenes, tricyclic aromatics	report

Methods D 751 for Breaking Strength, Procedure A—Grab Test Method.

4.4 *Tear Strength*—Test Methods D 751 for Tearing Strength, Procedure B—Tongue Tear Method. If standard sample does not achieve true tear or if the fabric design requires roping to achieve high tear, sample size may be enlarged in order to achieve cord breakage, but all other procedures must be maintained. Such sample size change must be recorded in test results.

4.5 *Adhesion*—Test Methods D 751 after 5 days at 70°C in water.

4.6 *Puncture Resistance*—MIL-T-6396 E, procedure outlined in 4.6.17.

4.7 *Abrasion Resistance*—Test Method D 4157, abrade the specimen using a 2.72-kg (6-lb) dead weight load tension and a 2.72-kg (6-lb) dead weight load using extra coarse, 40 grit sandpaper as the abradant. Cycle continuously to exposure of threads.

4.8 *Seam Strength*—Test Methods D 751. Perform test with seam orientation as in device design.

4.9 *Seam Adhesion*—Repeat adhesion test (see 4.5) for specimens containing a seam.

4.10 *Blocking Resistance*—Test Methods D 751.

4.11 *Mildew*—Fed. Std. No. 191A, Method 5762 (Mixed Cidal Spore Test).

5. Weather and Petroleum Sample Tests Related to Base Line Tests

5.1 *Specimen Preparation*—Subject samples of spill control barrier or storage device membrane material to the following preparations: weather resistance to be followed by resistance to petroleum products:

5.1.1 *Weather Resistance*—Practice G 26, Test Method 2 (also referred to as Test Method B—Alternate Exposure to Light and Darkness and Intermittent Exposure to Water Spray), using deionized water and a 7000 watt xenon burner tube, 500-h exposure.

5.1.2 *Resistance to Petroleum Products*—Test Method D 543, with 96-h exposure to Diesel Fuel Grade No. 2, as prescribed in Specification D 975 and further meeting the specifications shown in Table 1 (Note). Conduct tests at ambient temperature.

5.2 *Weather and Petroleum Sample Tests*—Perform each of the following tests within 1 h of the termination of the test in 5.1.2.

5.2.1 *Tensile Strength*—Same as base line test (4.3).

5.2.2 *Tear Strength*—Same as base line test (4.4).

5.2.3 *Adhesion*—Same as base line test (4.5).

5.2.4 *Puncture Resistance*—Same as base line test (4.6).

5.2.5 *Abrasion Resistance*—Same as base line test (4.7).

5.2.6 *Seam Strength*—Same as base line test (4.8).

5.2.7 *Seam Adhesion*—Same as base line test (4.9).

5.2.8 *Blocking Resistance*—Same as base line test (4.10).

5.2.9 *Low Temperature Resistance*—Fed. Std. No. 191A, Method 5874, 2-h soak at −29°C with a 2.5-kg mandrel roller weight. Visually examine specimen and report signs of cracking or flaking. Do not perform hydrostatic resistance test.

5.2.10 *Ozone Resistance*—Test Method D 1149.

6. Precision and Bias

6.1 The precision and bias of test measurements are addressed in each individual test method cited in Sections 3, 4, and 5.

7. Keywords

7.1 barrier; coated fabrics; membrane materials; membranes; oil spill; spill control; storage devices; temporary storage devices

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Document Name: ASTM F722: Standard Specification for Welded Joints for Shipboard Piping Systems

CFR Section(s): 33 CFR 155.140

Standards Body: American Society for Testing and Materials

Official Incorporator:
THE EXECUTIVE DIRECTOR
OFFICE OF THE FEDERAL REGISTER
WASHINGTON, D.C.

Designation: F 722 – 82 (Reapproved 1998)

An American National Standard

Standard Specification for Welded Joints for Shipboard Piping Systems[1]

This standard is issued under the fixed designation F 722; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This specification covers typical details of welded joints commonly used in shipboard piping systems. These joints and other joints may be used provided the welding procedures used have been qualified in accordance with the applicable regulatory rules and regulations.

1.2 The values stated in inch-pound units are to be regarded as the standard.

2. Referenced Documents

2.1 *Federal Standards:*

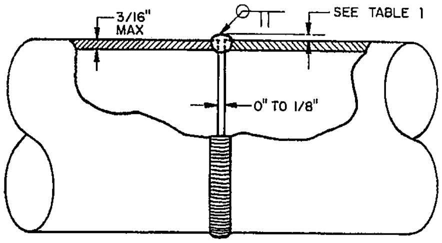
Code of Federal Regulations Title 46, Shipping, Parats 30 to 40[2]
Code of Federal Regulations Title 46, Shipping, Parts 41 to 69[2]
Code of Federal Regulations Title 46, Shipping, Parts 140 to 149[2]
Rules for Building and Classing Steel Vessels[3]

3. Application, Service, Limitations, and List of Weld Joint Details

3.1 Details of welded joints, including application, service, and limitation notes, are provided in the appropriate figures, as follows:

3.1.1 *Butt-Welded Joints for Pipes, Valves, Fittings, and Flanges*:

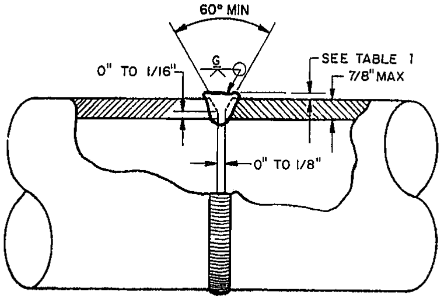
Fig. 1 Butt Joint, Square
Fig. 2 Butt Joint, V-Grooved
Fig. 3 Butt Joint, V-Grooved, Welded Both Sides
Fig. 4 Butt Joint, Double V-Grooved, Welded Both Sides
Fig. 5 Butt Joint, Compound Bevel V-Grooved, Welded Both Sides
Fig. 6 Butt Joint, V-Grooved, Miter Type
Fig. 7 Butt Joint, V-Grooved, Welded with Bevel End-Type Backing Ring
Fig. 8 Butt Joint, Compound Bevel V-Grooved, Welded with Bevel End-Type Backing Ring
Fig. 9 Butt Joint, V-Grooved Welded with Bevel End Lug-Type Backing Ring
Fig. 10 Butt Joint, V-Grooved, Welded with Square End-Type Backing Ring
Fig. 11 Butt Joint, V-Grooved, Welded with Consumable Insert Ring



1/8 in. = 3 mm
3/16 in. = 5 mm

Application—Class II piping
Systems or Service—For services such as gravity drains (including plumbing), vents, and overflows.
Remarks—1. Root of weld need not be ground.

FIG. 1 Butt Joint, Square



1/16 in. = 2 mm
1/8 in. = 3 mm
7/8 in. = 22 mm

Application—Class II piping
System or Service—All provided root of weld is visually inspected where possible to ensure complete weld penetration.
Remarks—1. For services such as vents, overflows, and gravity drains (including plumbing) the root of the weld need not be ground.

FIG. 2 Butt Joint, V-Grooved

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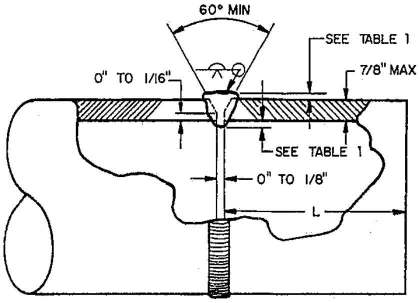
[1] This specification is under the jurisdiction of ASTM Committee F-25 on Ships and Marine Technology and is the direct responsibility of Subcommittee F25.13 on Piping Systems.

Current edition approved July 30, 1982. Published August 1982. Originally published as F 722 – 81. Last previous edition F 722 – 81.

[2] Available from Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402.

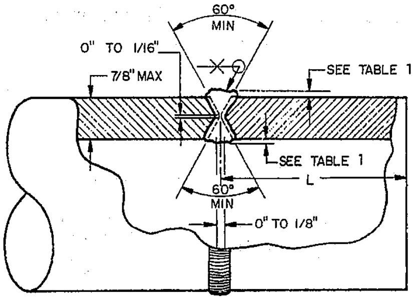
[3] Available from American Bureau of Shipping, 2 World Trade Center, 106th Floor, New York, NY 10048.



1⁄16 in. = 2 mm
1⁄8 in. = 3 mm
7⁄8 in. = 22 mm

Application—Class I and II piping above 2-in. NPS
System or Service—All
Remarks—1. Internal weld shall be made first and ground, chipped, or cleaned by some other means to assure sound welds.
2. The "L" dimension should be held to a minimum to facilitate welding and inspection on the inside surface of the pipe.

FIG. 3 Butt, Joint, V-Grooved, Welded Both Sides



1⁄16 in. = 2 mm
1⁄8 in. = 3 mm
7⁄8 in. = 22 mm

Application—Class I and II piping above 2-in. NPS
System or Service—All
Remarks—1. Internal weld shall be made first and ground, chipped, or cleaned by some other means to assure sound welds.
2. The "L" dimension should be held to a minimum to facilitate welding and inspection on the inside surface of the pipe.

FIG. 4 Butt Joint, Double V-Grooved, Welded Both Sides

Fig. 12 Butt Joint, Compound Bevel V-Grooved, Welded with Consumable Insert Ring

Fig. 13 Butt Joint, U-Grooved, Welded with Consumable Insert Ring

Fig. 14 Butt Joint, V-Grooved, Welded with Consumable Insert Ring

Fig. 15 Butt Joint, Socket Weld to Socket Weld Valve, Fitting or Flange Welded on Pipe Nipple

Fig. 16 Butt Joint, Transition between Unequal Inside and Outside Diameter Components

3.1.2 *Fillet Welded Joints for Valves, Fittings, and Flanges*:

Fig. 17 Fillet Welded Sleeve-Type Pipe Coupling

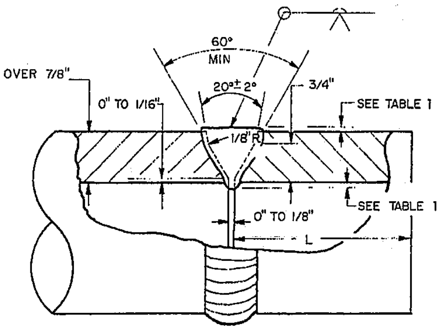
Fig. 18 Fillet Welded Socket Weld Fitting or Valve

Fig. 19 Fillet Welded Socket Weld-Flange

Fig. 20 Double Fillet Welded Slip-On Flange (Forged)

Fig. 21 Double Fillet Welded Slip-On Flange (Plate Type)

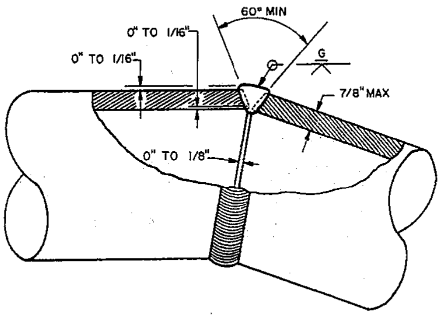
Fig. 22 Fillet Welded Slip-On Flange (Plate Type), Single Bevel



in.	1⁄16	1⁄8	3⁄4	7⁄8
mm	2	3	19	22

Application—Class I and II piping above 2-in. NPS
Systems or Service—All
Remarks—1. Internal weld shall be made first and ground, chipped, or cleaned by some other means to assure sound welds.
2. The "L" dimension should be held to a minimum to facilitate welding and inspection on the inside surface of the pipe.

FIG. 5 Butt Joint, Compound Bevel V-Grooved, Welded Both Sides



1⁄16 in. = 2 mm
1⁄8 in. = 3 mm
7⁄8 in. = 22 mm

Application—Class II piping where use will not cause objectionable pressure drop or turbulence.
System or Service—All provided root of weld is visually inspected where possible to ensure complete weld penetration.
Remarks—1. For services such as vents, overflows, and gravity drains (including plumbing), the root of the weld need not be ground.
2. Miter segments shall be designed in accordance with ANSI B31.1, paragraph 104.33, and 46 CFR 56.07-10(f).

FIG. 6 Butt Joint, V-Grooved, Miter Type

3.1.3 *Fabricated Joints*:

Fig. 23 Fillet Welded Internal Root Connection

Fig. 24 Fillet Welded External Root Connection

Fig. 25 Fillet Reinforced External Root Connection Single Bevel

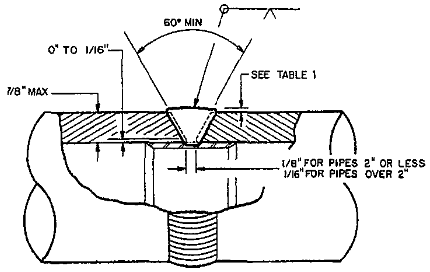
Fig. 26 Fillet Reinforced External Root Connection, Single Bevel, Welded Both Sides

Fig. 27 Fillet Reinforced External Root Connection, Single Bevel, Welded with Square End Backing Ring

Fig. 28 Fillet Reinforced Internal Root Connection, Single Bevel, Welded with Square End Backing Ring

3.1.4 *Outlet and Boss Connections*:

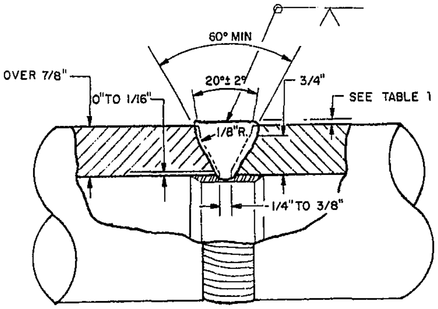
Fig. 29 Fillet Reinforced Boss Connection Without Pilot, Single Bevel



in.	1/16	1/8	3/16	7/8
mm	2	3	5	22

Application—Class I and II piping
System or Service—All, except as noted in remarks
Remarks—1. Backing ring may be tack-welded in place to facilitate fabrication.
2. When used in the following services, backing rings shall be removed.
(A) Lube oil service discharge piping from the lube oil pumps to the reduction gears, HP and LP turbines, and lube oil gravity tank.
(B) Superheated steam outlet piping from the main boilers to the HP and LP turbines and turbo generators and desuperheated steam from the main boilers to turbine driven main feed pumps.
(C) Central hydraulic systems.

FIG. 7 Butt Joint, V-Grooved, Welded with Bevel End-Type Backing Ring



in.	1/16	1/8	1/4	3/8	3/4	7/8
mm	2	3	6	10	19	22

Application—Class I and II piping
System or Service—All, except as noted in remarks
Remarks—1. Backing ring may be tack-welded in place to facilitate fabrication.
2. When used in the following services, backing rings shall be removed.
(A) Lube oil service discharge piping from the lube oil pumps to the reduction gears, HP and LP turbines, and lube oil gravity tank.
(B) Superheated steam outlet piping from the main boilers to the HP and LP turbines and turbo generators and desuperheated steam from the main boilers to turbine driven main feed pumps.
(C) Central hydraulic systems.

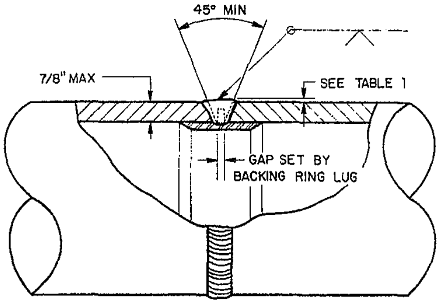
FIG. 8 Butt Joint, Compound Bevel V-Grooved, Welded with Bevel End-Type Backing Ring

Fig. 30 Fillet Reinforced Boss Connection with Pilot, Single Bevel

Fig. 31 Fillet Reinforced Boss Connection (Couplet) with Integral Backing Ring

Fig. 32 Fillet Reinforced External Root Connection, Single Bevel with Integrally Reinforced Outlet

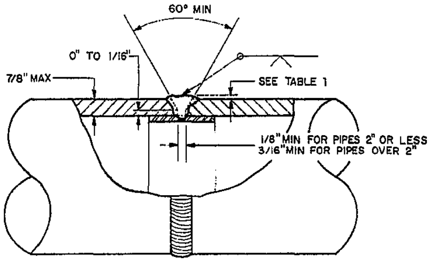
Fig. 33 Fillet Reinforced External Root Connection Welded Both Sides, Single Bevel with Integrally Reinforced Outlet



7/8 in. = 22 mm

Application—Class I and II piping
Systems or Service—All, except as noted in remarks
Remarks—1. Backing ring may be tack-welded in place to facilitate fabrication
2. When used in the following services, backing rings shall be removed.
(A) Lube oil service discharge piping from the lube oil pumps to the reduction gears, HP and LP turbines, and lube oil gravity tank.
(B) Superheated steam outlet piping from the main boilers to the HP and LP turbines and turbo generators and desuperheated steam from the main boilers to turbine driven main feed pumps.
(C) Central hydraulic systems.

FIG. 9 Butt Joint, V-Grooved Welded with Bevel End Lug-Type Backing Ring



in.	1/16	1/8	3/16	7/8
mm	2	3	5	22

Application—Class I and II piping
Systems or Service—All
Remarks—1. After welding, backing ring shall be machined flush with inside diameter of pipe or fitting.

FIG. 10 Butt Joint, V-Grooved, Welded with Square End-Type Backing Ring

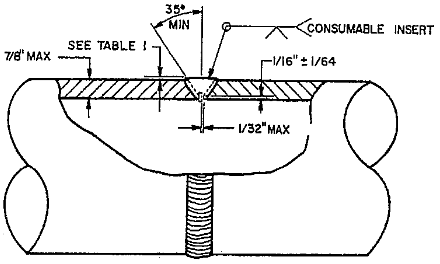
4. Piping Classifications and Butt Weld Reinforcements

4.1 Piping classifications in accordance with Subpart 56.04 of USCG Regulations apply to this specification. For definitions of ABS Group I and II Pipe Connections, see ABS Rules, Section 30, Paragraph 30.13.

4.2 Maximum thickness of butt weld reinforcements in accordance with Subpart 56.70, Table 56.70-15, of USCG Regulations are listed in Table 1.

5. Keywords

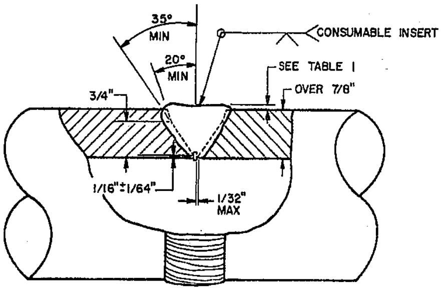
5.1 backing ring pipe welds; boss connections; flange welds; miter joint weld; pipe welds; root connections; sleeve pipe welds; socket welds; welded joints



in.	1⁄64	1⁄32	1⁄16	7⁄8
mm	0.4	1	2	22

Application—Class I and II piping
System or Service—All
Remarks—1. Internal misalignment of pipes shall not exceed 1⁄16 in. (2 mm).
2. Consumable insert ring shall be centered before welding.

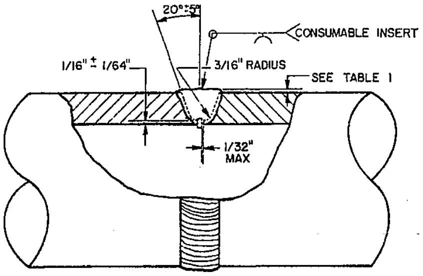
FIG. 11 Butt Joint, V-Grooved, Welded with Consumable Insert Ring



in.	1⁄64	1⁄32	1⁄16	3⁄4	7⁄8
mm	0.4	1	2	19	22

Application—Class I and II piping
System or Service—All
Remarks—1. Internal misalignment of pipes shall not exceed 1⁄16 in. (2 mm).
2. Consumable insert ring shall be centered before welding.

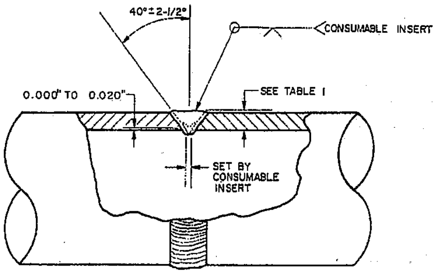
FIG. 12 Butt Joint, Compound Bevel V-Grooved, Welded with Consumable Insert Ring



in.	1⁄64	1⁄32	1⁄16	3⁄16
mm	0.4	1	2	5

Application—Class I and II Piping
System or Service—All
Remarks—1. Internal misalignment of pipes shall not exceed 1⁄16 in. (2 mm).
2. Consumable insert ring shall be centered before welding.

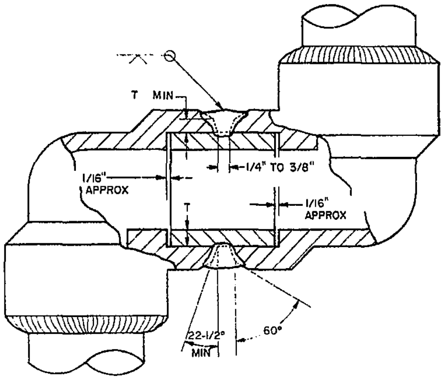
FIG. 13 Butt Joint, U-Grooved, Welded with Consumable Insert Ring



0.020 in. = 0.51 mm.

Application—Class I and II piping
System or Service—All
Remarks—1. Internal misalignment of pipes shall not exceed 1⁄32 in. (1 mm).
2. Consumable insert ring shall be centered before welding.

FIG. 14 Butt Joint, V-Grooved, Welded with Consumable Insert Ring



1⁄16 in. = 2 mm
1⁄4 in. = 6 mm
3⁄8 in. = 10 mm

Application—Fittings: See Fig. 18. Flanges: See Fig. 19.

System or Service—See Fig. 18 and Fig. 19.

Remarks—1. Size of weld shall be equal to or greater than "T."

2. For Class I piping, depth of insertion of the pipe nipple into the fitting shall not be less than 3⁄8 in. (10 mm).

3. Weld to be deposited in a minimum of two passes unless specifically approved otherwise in a special procedure qualification.

FIG. 15 Butt Joint, Socket Weld to Socket Weld Valve, Fitting or Flange Welded on Pipe Nipple

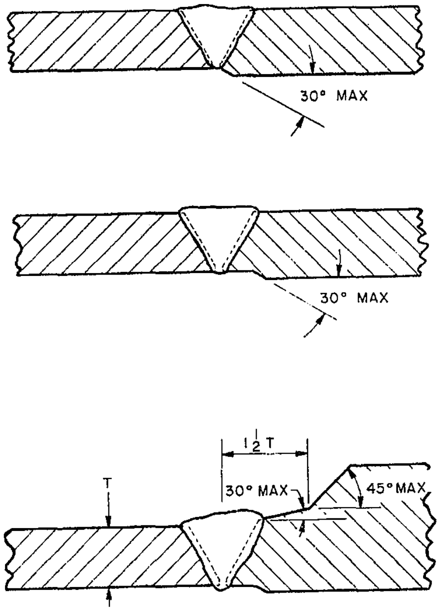
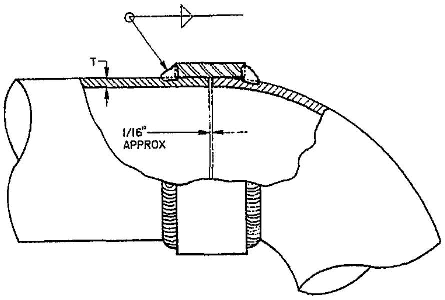


FIG. 16 Butt Joint, Transition Between Unequal Inside and Outside Diameter Components



1⁄16 in. = 2 mm

Application—Class I piping 3-in. NPS max where not subject to full radiography by 46 CFR Table 56.95-10. Class II piping all sizes.

Systems or Service—All

Remarks—1. Size of weld shall be 1.4 T min but not less than 1⁄8 in. (3 mm).

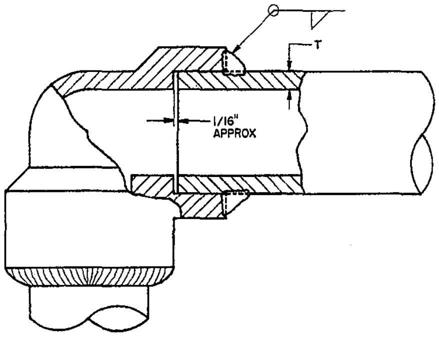
2. For Class I piping, depth of insertion of pipe, tube, or fitting in sleeve shall not be less than 3⁄8 in. (10 mm).

3. Weld to be deposited in a minimum of two passes unless specifically approved otherwise in a special procedure qualification.

4. For Class I piping, the inside diameter of the sleeve shall not exceed the outside diameter of the pipe, tube, or fitting by more than 0.080 in. (2.03 mm).

5. Couplings may be used with flat or beveled end pipes and fitting.

FIG. 17 Fillet Welded Sleeve-Type Pipe Coupling



1⁄16 in. = 2 mm

Application—Class I piping 3-in. NPS max where not subject to full radiography by 46 CFR Table 56.95-10. Class II piping all sizes.

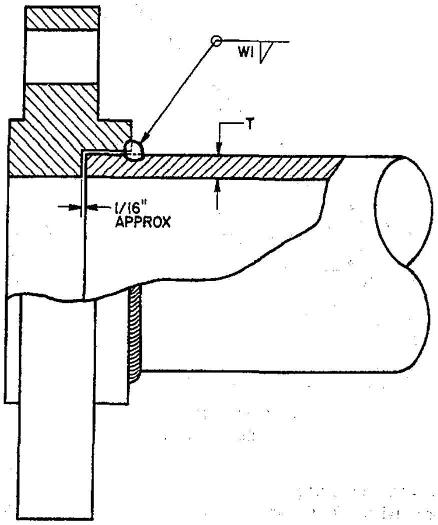
System or Service—All, except socket welds shall not be used where severe erosion or crevice corrosion is expected to occur.

Remarks—1. Size of weld shall be 1 1⁄4 T min but not less than 1⁄8 in. (3 mm).

2. For Class I piping, depth of insertion of pipe or tube into the fitting shall not be less than 3⁄8 in. (10 mm).

3. Weld to be deposited in a minimum of two passes unless specifically approved otherwise in a special procedure qualification.

FIG. 18 Fillet Welded Socket Weld Fitting or Valve



1⁄16 in. = 2 mm.

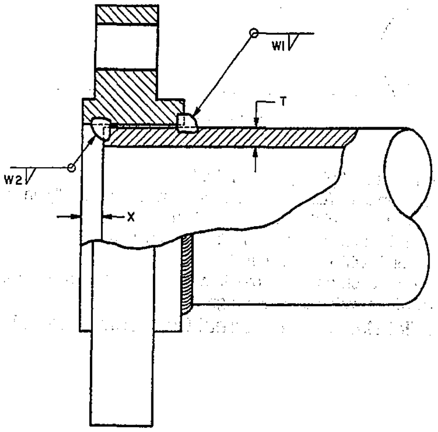
Application— Class I piping 3-in. NPS max for 600# and lower classes and 2½-in. NPS for 900 and 1500# classes. 3-in. size not permitted where subject to full radiography by 46 CFR Table 56.95-10. Class II piping all sizes.

System or Service—All, except socket welds shall not be used where severe erosion or crevice corrosion is expected to occur

Remarks—1. Size of Weld W1 shall be 1.4 T min. for Class II piping, size of weld may be limited to 17⁄32 in. (13 mm) max.

2. Weld to be deposited in a minimum of two passes unless specifically approved otherwise in a special procedure qualification.

FIG. 19 Fillet Welded Socket Weld Flange



Application—Class I and II piping not to exceed the service pressure temperature ratings for the 300# and lower classes. Slip-on flanges shall not be used on Class I piping where subject to full radiography by 46 CFR Table 56.95-10.

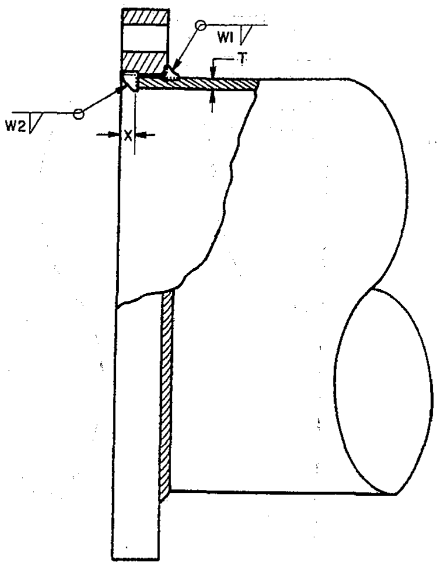
System or Service—All

Remarks—1. Size of Weld W1 shall be 1.4 T min. for Class II piping, size of weld may be limited to 17⁄32 in. (13 mm) max.

2. Size of Weld W2 shall be equal to "T" or ¼ in. (6 mm), whichever is smaller.

3. Dimension X shall be equal to T plus 1⁄16 in. (2 mm) min. for Class II piping, Dimension X may be limited to ⅜in. (10 mm).

FIG. 20 Double Fillet Welded Slip-on Flange (Forged)



Application—Class II piping not exceeding 150 psi (1034 kPa) or 450°F (232°C)

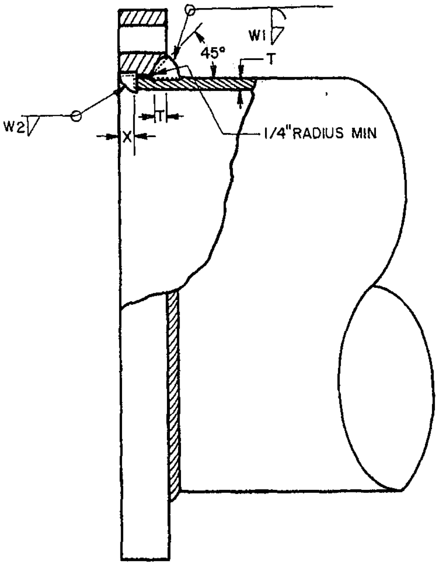
System or Service—All

Remarks—1. Size of Weld 8a W1 shall be 1.4 "T" min but may be limited to 17⁄32 in. (13 mm).

2. Size of Weld W2 shall be equal to "T" or ¼ in. (6 mm), whichever is smaller.

3. Distance X shall be T plus 1⁄16in. (2 mm) min but may be limited to ⅜in. (10 mm).

FIG. 21 Double Fillet Welded Slip-on Flange (Plate Type)



¼ in. = 6 mm

Application—Class II piping not exceeding 150 psi (1034 kPa) or 650°F (343°C)

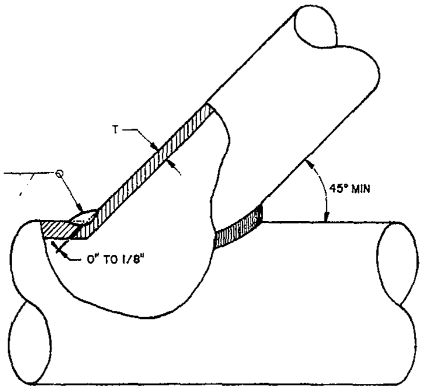
System or Service—All

Remarks—1. Size of Weld W1 shall be 1.4 "T" min but may be limited to $^{17}/_{32}$ in. (13 mm).

2. Size of Weld W2 shall be equal to "T" or ¼ in. (6 mm), whichever is smaller.

3. Distance X shall be "T" plus $^1/_{16}$ in. (2 mm) min but may be limited to ⅜ in. (10 mm).

FIG. 22 Fillet Welded Slip-on Flange (Plate-Type) Single Bevel



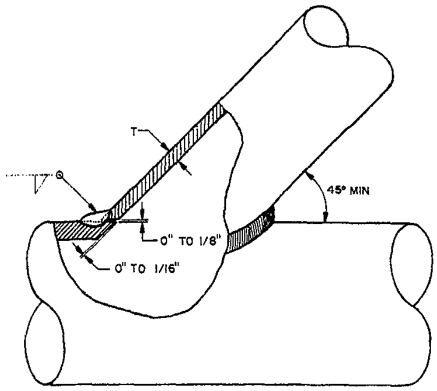
⅛ in. = 3 mm

Application—Class II piping

System or Service—For services such as vents, overflows, and gravity drains (including plumbing).

Remarks—1. Size of weld shall be T min.

FIG. 23 Fillet Welded Internal Root Connection



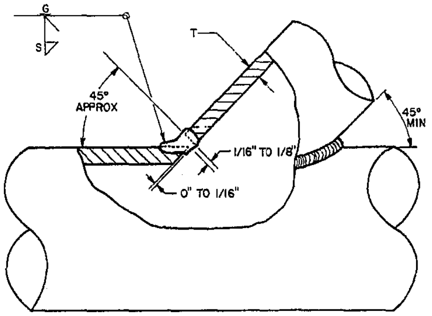
$^1/_{16}$ in. = 2 mm
⅛ in. = 3 mm

Application—Class II piping.

System or Service—For services such as vents, overflows, and gravity drains (including plumbing).

Remarks—1. Size of weld shall be T min.

FIG. 24 Fillet Welded External Root Connection



$^1/_{16}$ in. = 2 mm
⅛ in. = 3 mm

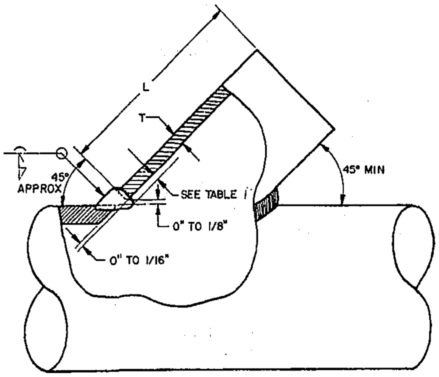
Application—Class II piping above 2-in. NPS.

System or Service—All, provided root of weld is visually inspected where possible to ensure complete weld penetration.

Remarks—1. Reinforcing fillet S shall have a minimum throat dimension of 0.7 T or ¼ in. (6 mm), whichever is smaller.

2. For services such as vents, overflows, and gravity drains (including plumbing), the root of the weld need not be ground.

FIG. 25 Fillet Reinforced External Root Connection Single Bevel



1⁄16 in. = 2 mm
1⁄8 in. = 3 mm

Application—Class I and II piping above 2-in. NPS

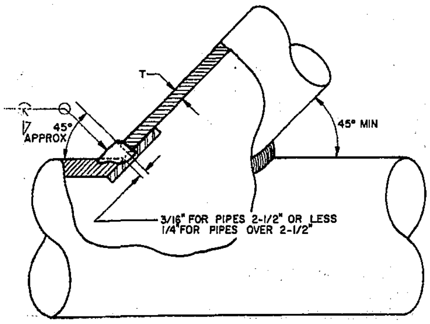
System or Service—All.

Remarks—1. Reinforcing fillet S shall have a minimum throat dimension of 0.7 T or 1⁄4 in. (6 mm), whichever is smaller.

2. Internal weld shall be made first and ground, chipped, or cleaned by some other means to assure sound welds.

3. The "L" dimension should be held to a minimum to facilitate welding and inspection on the inside surface of the pipe.

FIG. 26 Fillet Reinforced External Root Connection, Single Bevel, Welded Both Sides



3⁄16 in. = 5 mm
1⁄4 in. = 6 mm

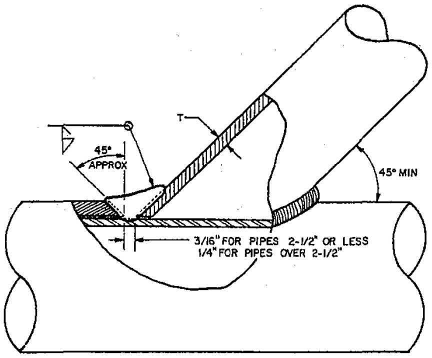
Application—Class I and II piping.

System or Service—All.

Remarks—1. Reinforcing fillet S shall have a minimum throat dimension of 0.7 T or 1⁄4 in. (6 mm), whichever is smaller.

2. After welding, backing ring shall be machined flush with inside diameter of pipe.

FIG. 27 Fillet Reinforced External Root Conn, Single Bevel, Welded with Square End Backing Ring



3⁄16 in. = 5 mm
1⁄4 in. = 6 mm

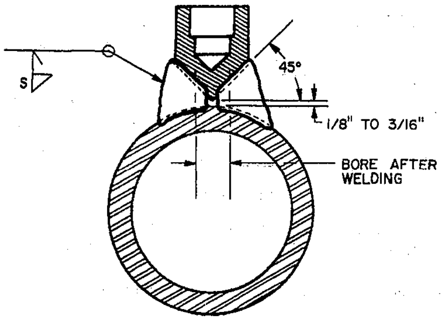
Application—Class I and II piping.

System or Service—All.

Remarks—1. Reinforcing fillet S shall have a minimum throat dimension of 0.7 T or 1⁄4 in. (6 mm), whichever is smaller.

2. After welding, backing ring shall be machined flush with inside diameter of pipe.

FIG. 28 Fillet Reinforced Internal Root Conn, Single Bevel, Welded With Square End Backing Ring



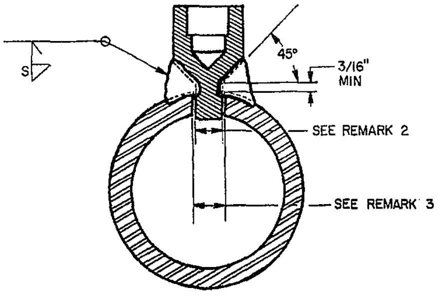
1⁄8 in. = 3 mm
3⁄16 in. = 5 mm

Application—Class I and II piping.

System or Service—All.

Remarks—1. Reinforcing fillet S shall have a minimum throat dimension of 1⁄4 in. (6 mm).

FIG. 29 Fillet Reinforced Boss Conn Without Pilot, Single Bevel



3⁄16 in. = 5 mm

Application—Class I and II piping.

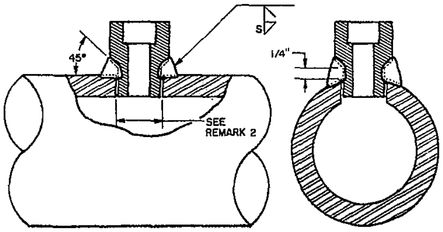
System or Service—All.

Remarks—1. Reinforcing fillet S shall have a minimum throat dimension of ¼ in. (6 mm).

2. Pilot hole shall be 1⁄32 in. (1 mm) larger than pilot diameter.

3. Final bore after welding shall be a minimum of ⅛ in. (3 mm) larger than pilot diameter.

FIG. 30 Fillet Reinforced Boss Conn with Pilot, Single Bevel



¼ in. = 6 mm

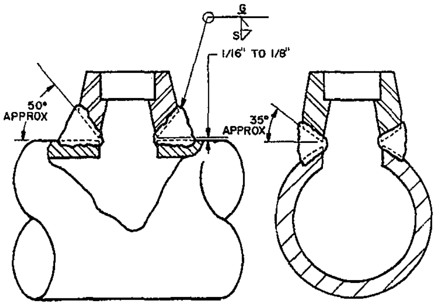
Application—Class I and II piping 2-in. NPS max.

System or Service—All, provided pressure does not exceed 1025 psi (7067 kPa) max or temperature does not exceed 750°F (399°C) max.

Remarks—1. Reinforcing fillet S shall have a minimum throat dimension of ¼ in. (6 mm).

2. Pilot hole diameter shall be equal to backing ring OD plus 1⁄32 in. (1 mm).

FIG. 31 Fillet Reinforced Boss Conn (Couplet) with Integral Backing Ring



1⁄16 in. = 2 mm
⅛ in. = 3 mm

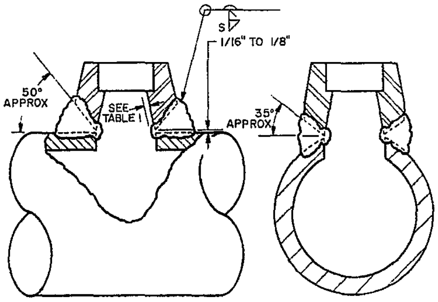
Application—Class II piping.

System or Service—All, provided root of weld is visually inspected where possible to ensure complete weld penetration.

Remarks—1. Reinforcing fillet S shall have a minimum throat dimension of ¼ in. (6 mm).

2. For services such as vents, overflows, and gravity drains (including plumbing), the root of the weld need not be ground.

FIG. 32 Fillet Reinforced External Root Conn, Single Bevel with Integrally Reinforced Outlet



Application—Class I and II piping.

System or Service—All.

Remarks—1. Reinforcing fillet S shall have a minimum throat dimension of ¼ in. (6 mm).

2. Internal weld shall be made first and ground, chipped, or cleaned by some other means to assure sound welds.

FIG. 33 Fillet Reinforced External Root Conn Welded Both Sides, Single Bevel with Integrally Reinforced Outlet

TABLE 1 Maximum Butt Weld Reinforcement, in. (mm)

NOTE 1—For double-welded butt joints, this limitation on reinforcement given above applies separately to both inside and outside surfaces of the joint.

NOTE 2—For single-welded butt joints, the reinforcement limits given above apply to the outside surface of the joint only.

NOTE 3— The thickness of weld reinforcement is based on the thickness of the thinner of the materials being joined.

NOTE 4—The weld reinforcement thicknesses must be determined for the higher of the abutting surfaces involved.

NOTE 5—For boiler external piping, use the column titled "above 750°F" for weld reinforcement thicknesses.

NOTE 6—See 4.2.

Nominal Wall Thickness of Pipe or Tube, in.	Maximum Operating Temperature of Piping System, °F (°C)				
	0 to 350 (−18 to 177)	to	350 to 750 (177 to 399)	to	Above 750 (399)
Up to 1/8	3/16 (5)		3/32 (2)		1/16 (2)
Over 1/8 to 3/16	3/16 (5)		1/8 (3)		1/16 (2)
Over 3/16 to 1/2	3/16 (5)		5/32 (4)		1/16 (2)
Over 1/2 to 1	3/16 (5)		3/16 (5)		3/32 (2)
Over 1 to 2	1/4 (6)		1/4 (6)		1/8 (3)
Over 2	greater of 1/4 (6) or 1/8 the width of the weld		greater of 1/4 (6) or 1/8 the width of the weld		5/32 (4)

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CFR Section(s): 33 CFR 154, Appendix C, 6.3.1

Standards Body: American Society for Testing and Materials

APPROVED

Official Incorporator:
THE EXECUTIVE DIRECTOR
OFFICE OF THE FEDERAL REGISTER
WASHINGTON, D.C.

Designation: F 808 – 83 (1988)$^{\epsilon 1}$

Standard Guide for Collecting Skimmer Performance Data in Uncontrolled Environments[1]

This standard is issued under the fixed designation F 808; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

$^{\epsilon 1}$NOTE—Sections 3 and 4 were renumbered editorially in April 1988.

1. Scope

1.1 This guide describes methods for collecting data to measure the performance of skimmers in removing (recovering) oil slicks in uncontrolled environments (that is, other than in a controlled test facility).

2. Referenced Documents

2.1 *ASTM Standards:*

D 1298 Test Method for Density, Relative Density (Specific Gravity), or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method[2]

D 1331 Test Methods for Surface and Interfacial Tension of Solutions of Surface-Active Agents[3]

D 1746 Test Method for Transparency of Plastic Sheeting[4]

D 1796 Test Method for Determination of Water and Sediment in Fuel Oils by the Centrifuge Method (Laboratory Procedure)[5]

D 2983 Test Method for Low-Temperature Viscosity of Automotive Fluid Lubricants Measured by Brookfield Viscometer[6]

3. Definitions

3.1 *data collection period*—that period of time during which performance data are recorded.

3.2 *oil recovery efficiency*—the ratio of the oil recovery rate (water-free oil) to the oil slick recovery rate (in percent).

NOTE 1—The data from this calculation may not be indicative of performance of the skimmer if the floating oil is contaminated (for example with water, as in a mousse or emulsion, or with debris or ice easily ingested by the skimmer).

3.3 *oil recovery rate*—the volume of water-free oil removed from the water surface by the skimmer, per unit time.

3.4 *oil slick*—the oily fluid encountered by the skimmer. (Most real oil slicks are actually composed of various proportions of pure oil, water-in-oil (W/O) emulsionn, and oil-in-water (O/W) emulsions. Therefore, efficiencies and other performance criteria must be differentiated between those based on the oil slick itself, and those based on only the water-free oil contained within the oil slick.)

3.5 *oil slick encounter rate*—that volume of oil slick per unit time actively directed to the skimmer.

3.6 *oil slick recovery efficiency*—the ratio of the oil slick recovery rate to the total volumetric rate of fluids recovered (in percent).

3.7 *oil slick recovery rate*—the volume of oil slick removed from the water surface by the skimmer, per unit time.

3.8 *oil slick thickness*—the thickness of the oil slick encountered by the skimmer.

3.9 *skimmer*—a device that removes oil slicks or free oil from the water surface. The device may move through the surrounding fluid or it may be relatively stationary.

3.10 *storage efficiency*—the ratio of the oil slick recovery rate to the mean volumetric rate of oil and emulsion (excluding free water) delivered to storage. Most oil skimmers have at least a tendency to further emulsify the recovered oil and water through the action of pumping, belt squeezing, or other processing techniques. If the resulting emulsion is fairly stable, excessive storage capacity in the on-board or external tanks may be required to accommodate the increased volume of oily waste. A measure of the emulsification tendency of a skimmer can be expressed as the Storage Efficiency as defined herein. For example, if a skimmer picked up 80 gal/min of oil and stable emulsion plus 20 gal/min of underlying water (oil slick recovery efficiency of 80 %) but transferred 90 gal/min of oil and stable emulsion to storage plus 10 gal/min of free water (which is subsequently pumped back overboard), the storage efficiency would be (80/90 gal per min) × 100 = 89 %. As the storage efficiency would depend to some extent on the amount of settling time allowed, and on the height and area of the liquid column in the settling vessel, any measurement of the storage efficiency must specify these parameters. Thus, a skimmer with a poor oil slick recovery efficiency (picks up considerable water), but with a good storage efficiency (does not emulsify the water picked up), may present no more storage capacity problems than a skimmer with a good oil slick recovery efficiency, if the free water can be discharged back overboard.

3.11 *throughput efficiency*—the ratio of the oil recovery rate (water-free oil) to the total volumetric rate of water-free oil encountered by the skimmer (in percent).

4. Significance and Use

4.1 The data provided by the methods described herein

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[1] This guideline is under the jurisdiction of ASTM Committee F-20 on Hazardous Substances and Oil Spill Response and is the direct responsibility of Subcommittee F20.12 on Removal.

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[2] *Annual Book of ASTM Standards*, Vol 05.01.

[3] *Annual Book of ASTM Standards*, Vol 15.04.

[4] *Annual Book of ASTM Standards*, Vol 08.02.

[5] *Annual Book of ASTM Standards*, Vol 05.01.

[6] *Annual Book of ASTM Standards*, Vol 05.02.

can enable performance measurements to be made of the type obtained in a controlled test facility. However, the quality and accuracy of the data will depend on the type of environment in which the data are taken, and the type of instruments available. Such data will, therefore, be unlikely to compare in accuracy and reproducibility to similar data obtained in a controlled test facility.

4.2 The data will be significant if all of them are taken at approximately the same time and in the immediate vicinity of the skimmer. All data should be recorded as a function of time for later correlation with other events.

4.3 The situations in which this guide applies include both accidental and planned spills in natural waterways where equipment is to be evaluated under field conditions.

4.4 The guidelines provided will enable personnel at oil spills to determine the effectiveness of skimmers under field conditions as well as to gage the quantity of material recovered. Such information could also be useful in improving future skimmer designs.

4.5 Each datum can usually be obtained by more than one method, and the method used will depend on the degree of preparedness of the equipment user, the time available to take the measurement, and the general conditions under which the skimmer is used. The methods suggested for obtaining data are listed in order of preference. The method actually used to obtain the data should be described.

ENVIRONMENTAL CONDITIONS

5. General

5.1 Environmental conditions existing at the time of testing in the vicinity of the skimmer are important for both manufacturers and users in assessing the capabilities of the equipment. The following sections consider measurement techniques for important environmental conditions.

6. Wave Height

6.1 *Instrumented Buoy*—Instrumented buoys, although relatively sophisticated, generally provide the most accurate wave data, and are therefore preferred over other wave height measurement methods.

6.1.1 *Free-Floating Buoy*—One type of instrumented buoy that contains accelerometers and electronics to convert vertical motions of the buoy into recordable signals. Signals can be recorded as a function of time within the buoy, or transmitted to a boat or ship by means of cable or radio. Some buoys can be towed at skimmer speed to collect data in the immediate vicinity of the skimmer. The results generally require analysis of the recorded data at a later time to obtain accurate statistical data on wave heights and periods. Both swell waves and wind-driven waves are measured.

6.1.2 *Spar Buoy*—Another type of instrumented buoy that remains relatively stationary with respect to the waves and swell, and uses pressure, acoustic, or other types of wave-height sensors. These buoys are generally not towed, but signal processing characteristics are similar to other instrumented buoys.

6.2 *Simple Spar Buoy*—A simple free-floating spar boy (not instrumented) constructed of a long buoyant pole with a weight at one end, and painted with stripes at measured intervals, can be used for estimates of wave heights. The buoy should be made long in comparison to the expected wind-driven wave height so that it remains relatively stationary vertically. By observing the heights of a series of waves against the painted stripes, statistical information on wave heights can be determined. Swell waves will not be observed unless the buoy is extremely long, but in general, swell waves are not significant to a skimmer's performance unless the skimmer is incorporated into a relatively large vessel.

6.3 *Visual Estimate*—Experienced observers may be able to estimate a characteristic wave height that experience has shown to be approximately the average of the highest one-third of the waves ("significant" wave height). Long swell heights are usually estimated separately. The use of a background, such as a dock, offshore structure, large ship, or other relatively stable reference point may help an observer to judge the wave heights more accurately.

7. Wave Length, Period, and Direction

7.1 *Wave Recording*—The data from devices such as described in 6.1 can be obtained to compute wave periods and statistical wave lengths. The use of statistical wave data provides more accurate information than the other methods listed below. It is best interpreted by trained individuals. Wave direction cannot be determined with a single-wave recording instrument.

7.2 *Visual Estimate*—Experienced observers may be able to estimate a characteristic wave length and period, that is related to the "significant" wave described in 6.3. A visual background such as a large ship, jetty, or similar structure in the immediate vicinity of the skimmer, would be helpful in improving the estimate. Wave propagation direction can be estimated with the aid of a compass, and will generally be in the approximate direction toward which the wind is blowing.

8. Skimmer Forward Velocity (Towed or Self-Propelled)

8.1 *Chip Log*—A wood chip or similar floating object is dropped overboard and the time for the chip to traverse a known distance along the hull is measured. This distance divided by the time interval gives a good estimate of the skimmer speed relative to the surface at that particular moment. Several measurements should be taken during the data collection period to obtain an average skimmer speed. As long as the chip log is not affected by the presence of the ship's hull (turbulence, boundary layer effects, wake, etc.), it will give a good estimate of velocity on the surface where the oil is present.

8.2 *Current Meter*—Various types of current meters are available that can provide an accurate measure of forward velocity in the 0 to 3-m/s range common to most skimmers. The meter can be fixed to, or towed by the skimmer, or the skimmer-towing vessel. The meter output can be recorded as a function of time throughout the data collection period. The velocity measured will be relative to the water surface as opposed to the land or the bottom, and therefore will automatically take into account natural currents in the waterway. Note, however, that current speed on the surface (as measured by a chip log) may be different than the current a short distance below the surface, where a current meter typically would be positioned.

8.3 *Towing Vessel Speedometer*—The speedometer on the towing vessel, or on a vessel moving at the same speed as the skimmer, can give a reliable velocity estimate if the speedometer is properly calibrated for low speeds, and is properly maintained; if not, inaccuracy can be high. Other ship speed estimates, such as screw rpm correlations are generally less reliable.

9. Skimmer Motion Relative to Waves

9.1 *Wave Probe*—Various types of wave-measuring instruments (capacitance probes, acoustic devices, resistance probes, pressure sensors) can be attached to larger skimmers near the point where relative motion is critical, such as near a weir lip, oil intake point, etc. The output can be recorded continuously during the data collection period, and statistical relative motion information can be calculated at a later time. Oil coating of the sensor can be a problem with some devices. In general, the relative vertical motions are the most significant to skimmer performance, whether generated by pitching or heaving; therefore, instrumenting for separate measurements of pitch and heave would not normally be necessary. The use of measuring instruments, if they are properly calibrated and not subjected to oil coating or fouling, can provide the most accurate and complete record of skimmer motions.

9.2 *Visual or Photographic Estimates*—Relative motion data can be obtained by observing the water level changes *at the point of interest* on the skimmer. It may be helpful to paint or affix a measurement scale (grid, yardstick, etc.). A movie record will facilitate future analysis. (A clock in the field of view would be helpful.) The direction of the skimmer relative to the average wave propagation direction can be estimated visually with the aid of a compass.

10. Skimmer Velocity Relative to the Oil Slick

10.1 For unconfined slicks this is the same as the skimmer forward velocity, as determined in Section 8. Where substantial holdup has occurred immediately in front of the skimmer (boom systems and skimmer with herding arms) the slick may be moving at nearly the same speed as the skimmer, relative to the water. For use in encounter rate calculations in accordance with Section 9.2, where the slick thickness immediately in front of the skimmer is used, the slick-to-skimmer relative velocity immediately in front of the skimmer is needed, and is determined as follows:

10.2 *Chip Log or Current Stick*—The distance that the floating object moves relative to the skimmer, divided by the observed time interval will yield the desired velocity. A current stick must not be deep enough to be influenced by the water under the slick, nor be tall enough to be influenced by the wind. This approach is most feasible with manned skimmers where the observer can get close to the object.

11. Wind Speed and Direction

11.1 *Anemometer*—This can give wind speed and, in some models, direction, which can be recorded continuously. Various types are available and most larger vessels have these instruments on board. Although shipboard anemometers can provide more accurate data than the other methods described below, they are generally not as accurate as weather station instruments.

11.2 *Hand-Held Wind Speed Meter*—An inexpensive, hand-held meter is available that uses a rotameter principle to give instantaneous wind-speed readings. It is sensitive to wind direction and moisture contamination but can be useful in estimating average wind speeds. Average wind direction must be estimated by observation, with the aid of a compass.

11.3 *Visual Estimate*—Experienced observers can often estimate average wind velocities using the Beaufort criteria for Sea State. However, because the Beaufort wind velocity-Sea State correlation is a function of the duration and length of travel of the wind over the water (fetch), the wind speed estimate is relatively subjective. Average wind direction is estimated as in 11.2.

12. Surface Water Temperature

12.1 *Thermometer*—An accurate thermometer placed in the water, or in a freshly drawn water sample, will give good results.

13. Air Temperature

13.1 *Thermometer*—Hand-held thermometer, or outside-mounted ship's thermometer.

14. General Weather Description

14.1 A general weather description should include approximate degree and type of cloud cover, degree and type of precipitation (rain, snow, hail, fog), visibility, extent of whitecap formation on waves, general weather condition (fair, stormy, etc.). The description should cover the entire duration of the data collection period.

15. Current Speed and Direction (Relative to Bottom)

15.1 Speed can be determined by various types of current meters, with or without direction indication. Chips or current sticks, measured relative to a fixed object (buoy, platform, pile, etc.) are also useful.

OIL SLICK CONDITIONS

16. General

16.1 Data on the oil slick will be among the least precise data that can be collected, due to the difficulty in conducting representative sampling. All sampling should be performed in the vicinity of the skimmer.

16.2 At most spills, data on the oil slick properties will not be available until some time after the samples have been taken, because of the analysis procedures required. Therefore, a thorough sampling program is necessary.

17. Required Critical Data

17.1 *Oil Type and Source*—This information can usually be obtained from the spiller or government agencies tasked with identifying the oil. Several 1-L samples of the oil slick may be useful for identification purposes later if the type and source information is not available from others. A suitable preservative will be necessary.

17.2 *Oil Viscosity at Skimming Temperature:*

17.2.1 *Viscometer*—A Brookfield viscometer, a similar laboratory-type viscometer, or other suitable devices can be used with oil slick samples collected from the vicinity of the skimmer if fluid is non-newtonian. The samples should be tightly sealed to prevent evaporation, and free water should be excluded. Samples should be tested at skimming temperature (see 17.5), or at least at two or three other temperatures so that an estimate of viscosity at the skimmer can be made (excessive heating must be avoided, however, as emulsion properties may change). Samples should be tested as soon as possible in their original state to minimize property changes due to emulsion settling, photodegradation, etc. (see Test Method D 2983). A laboratory viscometer will give the most controlled, accurate, and reproducible viscosity measurement and therefore is the preferred method. However, if a delay in measurement is anticipated, one of the other following methods may be preferred for expediency.

17.2.2 *Falling Ball*—A rapid and expedient method of estimating viscosity is to drop a sphere through a thick layer of oil, and record the length of time for the ball to traverse the layer.

17.2.2.1 The following equation can be used to determine viscosity:

$$u = 13\ 830\ d^2\ (S_{\text{ball}} - S_{\text{oil}}))/(U)$$

where:

u = viscosity in centipoise,
d = ball diameter in inches,
S = specific gravity (relative to fresh water), and
U = ball falling velocity, inches per second (thickness of oil layer traversed/time to traverse).

This equation is accurate if the Reynolds number (Re) is one or less, that is,

$$\text{Re} = (645\ d\ U\ S_{\text{oil}})/(u)$$

17.2.2.2 If, after conducting a test and determining a viscosity, one checks and finds that *Re* is greater than one, another ball of smaller diameter or lower specific gravity, or both, should be used. Different specific gravities result from different ball materials (for example, copper BB, $S = 8.91$; steel ball bearing, $S = 7.87$; glass or marble ball, $S = 2.4$ to 2.8). A new ball diameter, *d*new, should be selected such that:

$$d_{\text{new}} - d_{\text{old}} \times [Re_{\text{old}}\ S_{\text{ball}} - S_{\text{oil new}}]/[(S_{\text{ball}} - S_{\text{oil}})_{\text{old}}]$$

17.2.2.3 If the next try with the new ball still gives a Reynolds number greater than one, the above process can be repeated.

17.2.2.4 The container used to hold the oil should have the following features:

(*a*) Diameter should be greater than 20 times the ball diameter to keep error to less than 10 %;

(*b*) Oil thickness should be sufficient to permit a falling time of at least 3 s (to minimize stop watch errors), and preferably more; and

(*c*) Container should give some indication of when traversing of the oil layer is completed (a glass bottom; glass walls with a water layer below the oil so that the ball can be observed leaving the oil layer; a metal bottom that will provide a sound when the ball touches it; a glass container with marks on the side for translucent oils; etc.).

17.2.2.5 In addition, the ball should be released at the oil surface (not above it), as this method depends upon the ball reaching a steady-state (terminal) velocity quickly. At least three measurements should be averaged to obtain a mean sample viscosity. Calibrating the apparatus with a fluid of known viscosity (similar to the sample) will give a better idea of the errors, and can be used to develop a correction factor for the data. The oil temperature should be recorded. (Note that laboratory-quality falling-ball viscometer are available commercially, as is an inexpensive field-type version for translucent oils of up to 400 cp viscosity.)

17.2.3 *Eye Dropper*—another simple and rapid expedient for estimating viscosity is to allow the oil to flow by gravity through an eye dropper or similar device and measure the time of flow. The tubes should be precalibrated with fluids of known viscosity, or else data can be taken at the scene and then the tubes calibrated later. Water, diesel fuel, and motor oils are common fluids that could be used for on-scene calibration. With viscous oils or emulsions, larger diameter tubes may be necessary to minimize flow time. As an alternative, an Ostwald viscometer or suitable cup viscometer can be used. This type uses the same principle as the tube, but they are carefully made (of glass) for various viscosity ranges, and can be purchased already calibrated. Temperature compensation is difficult, and a fresh sample at a known temperature should be tested. At least three tests should be made and the results (time intervals) averaged to obtain a mean value. All free water should be excluded.

17.3 *Oil/Water Content of Oil Slick:* This is determined from periodic grab samples of the oil slick (free water excluded). Each sample may be allowed to settle in a transparent, cylindrical vessel until separation of oil, W/O emulsion, and O/W emulsion phases have occurred. Then, the volume of each phase can be measured and analyzed for oil and water content using the extraction technique described in Test Method D 1746. With this technique, a motor-driven or hand-crank centrifuge is usually required to assist the separation, although in many cases a sufficiently accurate measurement can be obtained (within 2 to 3 %) without a centrifuge. One hundred millilitre samples should be sufficient. (Alternatively, the original sample can be mixed thoroughly and a composite sample analyzed for oil and water content by Test Method D 1796.) If gravity settling indicates that no emulsion is present, use of the extraction technique will be unnecessary. The fraction of oil in the slick is computed by summing the oil quantities in each phase and dividing by the total sample volume.

17.4 *Slick Thickness* (for example, at entrance to skimmer or free slick—location must be identified):

17.4.1 *Thickness Multiplying Samplers:*

17.4.1.1 Two versions of this type of device have been used. The "cookie cutter" is an inverted funnel or cone attached to a clear acrylic graduated cylinder with an air valve at the top. The device is manually pushed through the surface slick and the collected oil thickness is multiplied by the area ratio of the conic section as the sample is pushed into the cylinder. The air valve is then closed so that the oil layer thickness (in the cylinder) can be read off by raising the cylinder above the slick surface. Between measurements, the insides have to be swabbed with kerosene. This system is most easily used from a Zodiac-type boat (to place the operator nearer the surface). Two sizes would be useful: (*1*) a ten-to-one funnel for slicks 5 to 50 mm thick; and (*2*) a one-to-one funnel for slicks 50 to 500 mm thick. About one sample per minute can be read. Error is estimated to be about 10 %, neglecting sample variability due to real thickness variance.

17.4.1.2 A second variation is a rectangular floating "box", open on one side, so that when it is floated on the water surface the inside will flood part way with a small, representative area of the slick and underlying water. The box is constructed so that when the open end is closed off and it is quickly lifted out of the water and turned on its end (open side up), the slick will be compressed into a much smaller horizontal area, similar to the "cookie cutter" principle, therefore multiplying the actual thickness by the ratio of the original to "new" slick surface areas. Because the box can be constructed of clear plastic, a calibrated scale can be imprinted on the side for direct reading. With a 5:1 multiplying ratio, a slick thickness of 0.5 mm or greater can be determined. Operational problems are similar to the "cookie cutter" concept. These methods are generally preferred over the other methods below because of their simplicity, accuracy, speed of operation (instant results), and general applicability.

17.4.2 *Oleophilic Sorbent Blanket*—Oil slicks on the order of 0.2 to 2.0 mm thick can be monitored by oleophilic sorbent blankets, which have a preferential affinity for oil in the presence of water. Typical blankets made of 80 pores per inch (ppi), fully-reticulated polyurethane foam; thickness of ¼-in.; and platform areas between 1 to 16 square feet have been used successfully in previous full-scale oil spill trials. The blankets are simply cast on "representative" portions of the slick, allowed to remain on the surface for a fixed time period (about 20 s), and then recovered. Water and oil are extracted by means of a mechanical wringer, and stored for later assay in pre-labeled containers (or the whole blanket can be stored in a plastic Ziplock bag). The system is compact, lightweight, portable, can be used with any conventional small workboat, and is not affected by adverse weather conditions. No particular training is required for system use, although it is imperative that the sampling boat be professionally helmed and that other vessels not cut through the slick ahead of the sampling boat. Sampling frequency is limited to about one per minute. The method is somewhat viscosity sensitive, although for viscous oils a larger pore size (40, 20, or even 10 ppi) might be used to advantage.

17.4.3 *Electronic Devices:*

17.4.3.1 A wide variety of electronic instrumentation has been used to measure slick thickness in the laboratory and the field, including the following:

(*a*) Conductivity probes,
(*b*) Capacitative probes,
(*c*) Inductive probes,
(*d*) Acoustic thickness gauges,
(*e*) Acoustic interface sensors, and
(*f*) Viscosity sensors.

17.4.3.2 All of these techniques have proven less than satisfactory. They share several or all of the following deficiencies:

(*a*) Inability to measure very thin slicks accurately, particularly in waves,

(*b*) Problems with coating of sensors with oil,

(*c*) Difficulty in resolving the frequently ill-defined oil slick/water interface, and

(*d*) Poor at-sea reliability.

17.4.3.3 Potential advantages of electronic systems are as follows:

(*a*) Continuous readings possible,
(*b*) Remote readout possible,
(*c*) Data could be recorded automatically, and
(*d*) Personnel need not be in the vicinity of the instrument.

17.4.4 *Measuring Sticks*—Two variations of this approach have been used. Such methods are suitable for only thick slicks, such as the pool of oil collected by an oil boom.

17.4.4.1 *Thieving Paste*—This is a paste-like material that is spread onto a measuring stick, and is used to detect the presence of water in the bottom of fuel tanks. It is useful only where transparent oils (light oils, gasoline) are encountered, and where wave action is not severe. The coated measuring stick is thrust down into the oil, and the depth of penetration is noted on the stick. When the stick is withdrawn, the paste will have changed color where it was in contact with water. The difference between the penetration depth and the color change is the slick thickness. A small boat is necessary to perform this check. Oil-in-water emulsions may not be detected.

17.4.4.2 *Floating Measuring Stick*—This is a measuring stick that extends below the oil-water interface, and is floated vertically in the oil slick with the aid of a stable buoyant float. The measurement must be taken from below the interface by a diver. By marking the stick with distinctive markings, the slick thickness can be read by the diver some distance from the stick. A series of these sticks, separated from each other by lengths of line, can be used to measure a slick thickness profile. Such devices are relatively independent of wave conditions.

17.5 *Slick Temperature:*

17.5.1 *Direct Measurement*—Dip an accurate thermometer into the oil slick or into a freshly drawn sample from the vicinity of the skimmer.

17.5.2 *Indirect Measurement*—In most cases, if the slick is thin and has been on the water for some time, the water temperature (Section 12) will suffice for an estimate of the oil temperature.

17.6 *Measurement of Oil Slick Width*—A measurement of the oil slick width is necessary for calculating the oil slick encounter rate (see Section 24). To permit this calculation, the slick width should be measured at the same point that the slick thickness (17.4) and velocity relative to the skimmer (Section 10) are measured. This may be in the free slick, or in the thickened region in front of the skimmer if a containment boom is being utilized. The width must be measured perpendicular to the surface velocity direction.

17.6.1 *Observations*—Aerial photographs of the slick and skimmer together (for reference) provide perhaps the best means of estimating the width. However, good contrast is needed to distinguish areas where no slick exists. As slicks can be thin, patchy and irregular, both the slick thickness and width measurements may be subject to considerable error. Other methods, such as infrared photography, and direct observe estimates, can be helpful in corroborating the measurements obtained through aerial photography. For small spills, direct observe estimates alone may suffice.

17.6.2. *Distance Line*—When containment booms are used, a rope of known length may be stretched across the mouth of the boom and attached to the tow points. The length of the rope will be the required slick width measurement if slick thickness and velocity data are also measured at the rope. Problems with this technique are that the rope may interfere with traffic, and the slick may be quite discontinuous at this point.

17.7 *Debris Description*—An estimate of the quantity and type of debris (as a function of time) encountered by the skimmer should be made. Debris includes seaweed, dead fish, sorbents, twigs, tree limbs, leaves, garbage, etc.

17.8 *Oil Slick Specific Gravity*—This can be measured using an appropriate hydrometer (Test Method 1298) in the field or in the laboratory. The temperature should be noted. (See 17.2.1 for sampling considerations.)

18. Recommended Additional Data

18.1 These quantities may be difficult to quantify accurately, especially where emulsions and thin slicks are involved.

18.2 *Oil Slick Surface Tension*—This is best performed in the laboratory (Test Methods D 1331) using a sample of freshly recovered oil slick (see 17.2.1 for sampling considerations). The test temperature should be noted, and results at the skimmer ambient temperature should be obtained, if possible. Results are subject to error if emulsions are present.

18.3 *Oil/Water Interfacial Tension*—This is best performed in the laboratory (Test Methods D 1331) using samples of freshly recovered oil slick and pure water, taken separately from the vicinity of the skimmer. Alternatively, a composite oil-water sample can be used, although the presence of an emulsion at the interface can result in unreliable measurements. For comparison with other data, oil (or water-in-oil emulsion) and distilled water should be used in addition to other measurements. The test temperature should be noted, and results at the skimmer ambient temperature should be obtained, if possible.

18.4 *General Description of Slick Continuity*—Items for consideration are as follows:

18.4.1 Dimensions and shape of oil patches or windows;

18.4.2 The presence of sheen, black oil, or other color characteristics of the slick encountered by the skimmer, as a function of time;

18.4.3 Frequency of encounter of slicks (time in slick, time between slicks);

18.4.4 Presence and frequency of tar balls, rafts, emulsion patches, debris; and

18.4.5 any other observations (odors, etc.)

18.5 *Slick Boundary Conditions*

18.5.1 Items for consideration include the presence of boundaries such as pilings, beaches (including characteristics such as rocks, rip-rap, slope, etc.); docks and piers; ships and other vessels; and containment barriers.

18.5.2 The absence of any boundaries should also be noted as well as the number of sides restricted (compass bearings and chart locations may be appropriate).

18.5.3 Other obstructions such as the spacing of pilings, etc., that affect the ability of the skimmer to maneuver should be noted.

18.5.4 Vertical restrictions can also be important, as in the case of low piers or shallow water.

18.5.5 Items such as marsh grass (or marshes themselves), floating debris, and sorbent can also be considered as slick boundaries.

18.6 *Photographs*—Color photographs of the slick should be taken, if possible. Aerial photographs and other imagery methods (infrared, etc.) are also useful in describing slick geometry and characteristics. The effects of sea state and wind can also be revealed by photographs.

RECOVERED FLUID CONDITIONS

19. Required Critical Data

19.1 *Recovery Rate of Total Fluid as a Function of Time*—This should be measured with a calibrated flow meter suitable for the fluid being recovered. Selection of a proper flow meter is difficult, however. Typical instruments are generally subject to variances in physical properties (such as viscosity, density, conductivity, etc.), particularly when recovering combined oil, water, and emulsion fluids which can vary from moment to moment in composition. A positive displacement type meter is perhaps the best, but these too may present problems in size and weight, continuous readout capability, and pressure drop. A more cumbersome alternative to a positive displacement meter is to measure the time to collect a known volume of the pumped fluid in a separate container, and then calculate an average flow rate. If pumping is periodic (as from a sump), a short-term mean pumping rate should be computed for use in steady-state rate calculations.

19.2 *Total Amount of Fluid Collected*—This should be determined from the dimensions of the volume of fluid collected in the receiver(s). Less desirably, a collection rate versus time curve (from 19.1) can be integrated to obtain an estimated volume collected. Recovered water pumped back overboard from storage should be determined also.

19.3 *Amount of Debris Recovered*—This should include a breakdown by type, if feasible, and the frequency or rate of collection.

19.4 *Oil/Water Content of Recovered Fluid:*

19.4.1 *Determined From Periodic Samples of the Recovery Pump Output*—These samples should be collected from the line leading to the storage tanks (on-board or external). Each sample should be allowed to settle in a transparent container of constant diameter for a period of time (the time period should be recorded; approximately 10 min may be sufficient for the bulk of the settling to occur). The volumes of pure oil, W/O emulsion, O/W emulsion, and pure water phases should be recorded. Samples of each oil-containing phase should then be extracted (Test Method D 1796) for determination of the oil and water content. One hundred millilitre samples will usually be sufficient. (Alternatively, the entire sample in the settling container can be re-mixed and a single sample taken to determine the total amount of oil and water by Test Method D 1796.)

19.4.2 *Determined From the Total Volume of Recovered Fluid Collected*—In this case, the entire tank contents are treated as the "settling container" in 19.4.1, and the procedure described therein is followed. The alternative approach of re-emulsifying the entire tank contents for extracting a single composite sample will be virtually impossible, however. **CAUTION:** This approach is valid only if no free water is separated from the tank contents and pumped overboard before the contents are analyzed (that is, if the tanks do not include a separator function). Also, location of interfaces between phases in skimmer tanks may be very difficult and subject to considerable inaccuracy. If the tanks are large compared to the recovery rate, analysis of the tank contents probably will not represent steady-state skimming performance.

20. Recommended Data

20.1 *Viscosity of Recovered Fluid*—See 17.2 for methods. Separate phases in the settled samples are best measured separately. Actual conditions, including technique used and temperature, should be stated.

20.2 *Specific Gravity of Recovered Fluid*—See 17.8 for method. The same consideration of settled samples described in 20.1 should be applied.

20.3 *Interfacial and Surface Tensions of Recovered Fluid*—See Sections 18.2 and 18.3 for methods.

SKIMMER CONTROL SETTINGS

21. General

21.1 A recording of skimmer performance variables is intended to provide documentation on the way the skimmer was operated. Preferably, each skimmer would be operated at maximum efficiency all the time; however, this is unreasonable to expect. A description of the factors influencing the skimmer operating conditions is therefore recommended.

22. Critical Data

22.1 All data should be recorded as a function of time in order to relate it to oil collection data. The ability to obtain some of these data will depend on installed instrumentation existing on the skimmer.

22.2 Critical data to be taken include the following as appropriate:

22.2.1 Pump rate.

22.2.2 Engine speed.

22.2.3 Speed of oil slick pickup device (sorbent belt, disk, etc.).

22.2.4 Weir depth.

22.2.5 Hydraulic fluid flow rate and pressure.

22.2.6 Pneumatic flow rate and pressure.

22.2.7 Electrical current and voltage.

22.2.8 Door openings, gill door settings, ramps, etc.

22.2.9 Other controllable parameters that affect skimmer performance (boom hookup, hoses, tanks, etc.). Provide sketches as appropriate.

22.2.10 Description of performance-limiting skimmer problems (mechanical, electrical, etc.) encountered during testing.

22.2.11 Significant noncontrollable factors (tank volumes, separator functioning, location of sample points, etc.).

CALCULATION

23. General

23.1 Throughput efficiency and recovery rate are the two most commonly calculated results of skimming tests in controlled environments. For uncontrolled environments, where conditions may be rapidly changing, these efficiencies should be calculated at several times during operations. The appropriate time upon which to base an efficiency calculation is when all of the input data were obtained during a quasi-steady state operating period.

24. Oil Slick Encounter Rate (OSER)

$$\text{OSER} = \text{oil slick thickness (17.4)} \times \text{oil slick width (17.6)} \times \text{skimmer velocity relative to the oil slick (Section 11)}$$

25. Oil Encounter Rate (OER)

$$\text{OER} = \frac{\text{oil slick encounter rate (Section 24)} \times \text{sum of oil volumes in oil, W/O emulsion and O/W emulsion phases in oil slick sample (17.3)}}{\text{total volume of oil slick sample (17.3)}}$$

26. Oil Recovery Rate (ORR)

$$\text{ORR} = \frac{\text{sum of oil content in oil, W/O emulsion and O/W emulsion phases in recovered fluid sample (19.4.1)}}{\text{total volume of recovered fluid sample (19.4.1)} \times \text{mean pumping rate of total fluid to storage (19.1)}}$$

27. Oil Slick Recovery Rate (OSRR)

$$\text{OSRR} = \frac{\text{total volume of oil slick sample (17.3)}}{\text{sum of oil volumes in oil, W/O emulsion, and O/W emulsion phases in slick oil sample (17.3)} \times \text{oil recovery rate (Section 26)}}$$

28. Oil Slick Throughput Efficiency (OSTE)

$$\text{OSTE} = \frac{\text{oil slick recovery rate (Section 27)}}{\text{oil slick encounter rate (Section 23)}} \times 100\ \%$$

29. Throughput Efficiency (TE)

$$\text{TE} = \frac{\text{oil recovery rate (Section 26)}}{\text{oil encounter rate (Section 25)}} \times 100\ \%$$

NOTE 2—This value should be the same as 8.6

30. Oil Slick Recovery Efficiency (OSRE)

$$\text{OSRE} = \frac{\text{oil slick recovery rate (Section 27)}}{\text{total fluid recovery rate (19.1)}} \times 100\ \%$$

31. Recovery Efficiency (RE)

$$\text{RE} = \frac{\text{oil recovery rate (Section 26)}}{\text{total fluid recovery rate (19.1)}} \times 100\ \%$$

32. Storage Efficiency (SE)

$$\text{SE (10 min)} = \frac{\text{oil slick recovery rate (Section 27)}}{\text{mean pumping rate of total fluid to storage} \times \text{fraction of free water in settling container after 10 min settling (9.4.1)}} \times 100\ \%$$

NOTE 3—Storage efficiencies based on any convenient settling time basis may be computed.

GEOGRAPHICAL DESCRIPTION OF OPERATIONS AREA

33. Report

33.1 The report should include data, calculations, photography, and other observations.

33.2 Nautical charts or maps of the slick region should be provided. These should be marked to show the position and velocity direction of the skimmer, current, wind, and oil slick at the times that the data were collected. The point of origin of the slick should also be indicated.

34. Data Sheets

34.1 A data sheet format is given in Table 1. This includes all of the data discussed above, and can be used as a checklist to ensure that significant data are obtained.

TABLE 1 Data Sheet for Skimmer Testing in Uncontrolled Environments

Conditions	Time Recorded	Method/ Equipment Used
Environmental Conditions:		
Wave height (Section 6)		
Wave length and direction (Section 7)		
Skimmer forward velocity (relative to the water) (Section 8)		
Skimmer velocity (relative to the oil slick (Section 10)		
Skimmer motion relative to waves (Section 9)		
Wind speed (Section 11)		
Wind direction (Section 11)		
Surface water temperature (Section 12)		
Air temperature (Section 13)		
Current speed and direction (relative to the bottom) (Section 15)		
General weather description (14.1)		
Oil Slick Conditions (Where applicable):		
Oil type and source (17.1)		
Oil viscosity at skimming temperature (17.2)		
Oil/water content of oil slick (17.3)		
Slick thickness (at entrance to skimmer (17.4)		
Slick thickness (free slick) (17.4)		
Slick temperature (17.5)		
Oil slick surface tension (18.2)		
Oil/water interfacial tension (18.3)		
Oil slick specific gravity (17.8)		
Oil slick width (17.6)		
Debris description (17.7)		
General description of slick continuity (18.4)		
Slick boundary conditions (18.5)		
Recovered Fluid Conditions:		
Recovery rate (19.1)		
Total amount collected (19.2)		
Oil/water content (19.4)		
Viscosity (20.1)		
Specific gravity (20.2)		
Debris amount (19.3)		
Skimmer Control Settings (As Applicable):		
Pump rate		
Engine speed		
Speed of oil slick pickup device		
Weir depth		
Hydraulic fluid flow rate/pressure		
Pneumatic flow rate/pressure		
Electrical current/voltage		
Door openings, etc.		
Other controllable parameters		
Description of performance limiting variables		
Significant non-controllable variables		
Calculated Results:		
Oil slick encounter rate		
Oil encounter rate		
Oil recovery rate		
Oil slick recovery rate		
Oil slick throughput efficiency		
Throughput efficiency		
Oil slick recovery efficiency		
Recovery efficiency 4.2		
Storage efficiency		
Geographical Description of Operations Area: Listcharts prepared, and attach		
Photographs, Describe and attach		

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This Document Posted By Public.Resource.Org, Inc., a California Nonprofit Organization.

Not Affiliated Or Authorized by ASTM or by the United States Government

Document Name: ASTM F1003: Standard Specification for Searchlights on Motor Lifeboats

CFR Section(s): 46 CFR 199.175(a)(28)(i)

Standards Body: American Society for Testing and Materials

APPROVED

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THE EXECUTIVE DIRECTOR
OFFICE OF THE FEDERAL REGISTER
WASHINGTON, D.C.

Designation: F 1003 – 86 (Reapproved 1992)

An American National Standard

Standard Specification for Searchlights on Motor Lifeboats[1]

This standard is issued under the fixed designation F 1003; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers searchlights for motor lifeboats.

1.2 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

1.3 The following precautionary caveat pertains only to the test method portion, Section 7, of this specification: *This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*.

2. Referenced Documents

2.1 *ASTM Standard:*

B 117 Test Method of Salt Spray (Fog) Testing[2]

2.2 *Military Standard:*

MIL-STD-105D Sampling Procedures and Tables for Inspection by Attributes[3]

3. Descriptions of Terms Specific to This Standard

3.1 *lot*—a manufacturer's production run for a specific type of searchlight.

3.2 *order batch*—size of a specific contract or purchase order taken from the lot.

3.3 *production testing*—testing performed during a lot run of specific searchlights.

4. Materials and Manufacture

4.1 *Material:*

4.1.1 All materials used in the construction of these searchlights shall be of a quality suitable for the purpose intended and shall conform to the requirements of this specification.

4.1.2 The searchlight shall be constructed of brass, copper-alloy, an equivalent corrosion-resistant material, or a material that when tested in accordance with Method B 117 for 200 h, does not show signs of pitting, cracking, or deterioration.

4.1.3 Plastic, when used, shall be of a suitable thermoplastic or thermosetting material so molded as to produce a dense solid structure, uniform in texture, finish and mechanical properties.

5. Requirements

5.1 The height of the searchlight from the base to the top of the light shall not exceed 19 in. (483 mm).

5.2 The housing of the searchlight shall be capable of free movement of at least 60° above and 45° below the horizontal, and be able to rotate 360° in the horizontal plane. There shall be a means provided to lock the searchlight in any desired position without the use of tools (vertically and horizontally).

5.3 The searchlight shall be capable of illuminating a light colored object at night at 55 ft (180 m). The searchlight shall project a beam of light of not less than 5.5 ft (18 m) in diameter at a distance of 55 ft from the light source. The edge of the beam shall be a point where the intensity of the light is 10 % of the maximum intensity. The light source shall have a candlepower rating of no less than 350 000 cd.

5.4 The searchlight shall be capable of being operated for not less than 3 h of continuous use and 6 h of intermittent use.

5.5 The lamp utilized in the searchlight shall be of the incandescent, quartz, or other type which would allow for instant start. The lamps shall be rated for 12 V.

5.6 Each searchlight shall be watertight. The searchlight shall show no leakage of water following the test method prescribed in 7.1.

5.7 Each searchlight shall be wired with a 6-ft (2-m) length of rubber jacketed hard service flexible cord, unless otherwise specified in 8.3. The conductor size shall be no less than 16 AWG. The cable entry into the searchlight shall be sealed with a watertight bushing and packing gland. A suitable clamping device shall be installed in the area where the cables enter the gland to prevent any force being exerted on the gland or connections. The free end of this cord shall be dead-ended unless otherwise specified in 8.3.

5.8 Each searchlight shall be provided with a handle or handgrip to allow for ease of maneuvering the light into various positions.

6. Workmanship, Finish, and Appearance

6.1 Searchlights shall be of sturdy construction, and free from mechanical, electrical, or other imperfections or defects which materially affect appearance or which may affect quality, reliability, or serviceability.

6.2 The finished searchlight shall not contain rough edges, burrs, or other disfigurations and shall be clean, free from rust, tool marks, and other injurious defects.

7. Test Methods

7.1 *Watertightness*—The searchlight shall be submerged

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[1] This specification is under the jurisdiction of ASTM Committee F-25 on Shipbuilding and is the direct responsibility of Subcommittee F25.10 on Electrical, Electronics, and Automation.

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[2] *Annual Book of ASTM Standards*, Vols 02.05 and 03.02.

[3] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

in a saltwater solution (1.04 sp gr) to a depth of 3 ft (0.9 m) of 60°F (16°C) for 2 h. The light will then be subjected to the tests of 7.2.1 and be in perfect working order.

7.2 *Environmental:*

7.2.1 *Operational Test*—The searchlight shall be operated continuously for 3 h at rated voltage in an ambient temperature of 77°F (25°C) and be operational after being subjected to the watertightness test of 7.1. The searchlight shall then be operated intermittently. The intermittent time periods shall be 15 min "ON" and 5 min "OFF" for a total 6-h period. These tests shall be repeated three times.

7.2.2 *Impact:*

7.2.2.1 *Test Conditions*—The searchlight shall be placed in a cold chamber at −40 ± 5°F (−40 ± 3°C) for 2 h. With the searchlight stabilized at this temperature, it shall be immediately subjected to the low- and high-impact tests specified in 7.2.2.2 and 7.2.2.3. The point of impact shall be applied to the outside of the case at a point midway between the ends of the case at 4 points 90° apart and the back plate.

7.2.2.2 *Low Impact*—The searchlight shall be subjected to a 12 in.·lbf (1.3 J) impact using a 1-lb (0.5-kg) steel ball at each of the points of impact specified in 7.2.2.1. The searchlight shall then be subjected to the watertightness test (see 7.1). There shall be no evidence of breakage from impact and no evidence of moisture shall be found in the case.

7.2.2.3 *High Impact*—The searchlight, after passing the low-impact test, shall be again placed in the cold chamber at −40 ± 5°F (−40 ± 3°C) for 2 h and then immediately subjected to a 20 in.·lbf (2.3 J) impact using a 1-lb (0.5-kg) steel ball at each of the points of impact specified in 7.2.2.1. There shall be no evidence of damage to the case or the lens.

7.3 *Test for Light Projection*—The beam spread of the searchlight shall be shown to meet the calculations contained in the IES Lighting Handbook.[4] This test shall be conducted at rated voltage.

7.4 *Switch Endurance*—The contact switch mechanism of the searchlight shall be tested by operating the switch for 25 000 continuous cycles. A cycle shall consist of movements from "OFF" position through the full "ON" and "FLASHING" positions and back to "OFF" position. The switch shall be operated under normal electrical load conditions, and the lamp and battieres shall be replaced as often as required to ensure that the switch mechanism is operating under normal load throughout the 25 000 cycles. Burning out of bulbs and batteries during the test shall not constitute failure of this test. Failure of the switch to complete 25 000 cycles shall constitute failure of this test.

7.5 The searchlight, when mounted to a lifeboat, shall be able to withstand a vertical drop test of the lifeboat with forces of 10 *g* and a side impact test of the lifeboat with forces of 20 *g*.

8. Packaging and Package Marking

8.1 *Product Marking*—Each searchlight conforming to all the requirements in this specification shall be marked with the name, brand or trademark of the manufacturer, this ASTM specification number, and any other information as may be specified in the contract or purchase order.

8.2 *Packaging*—Unless otherwise specified by the customer in the contract or purchase order, the searchlight shall be packaged, packed, and marked in accordance with the manufacturer's commercial practice to ensure acceptance and safe delivery by the carrier for the mode of shipping and handling.

8.3 Details pertaining to the cable, cable terminations, and voltage should be provided by the procuring agency in the contract or purchase order.

9. Quality Assurance

9.1 *Responsibility for Inspection*—Unless otherwise specified in the contract or purchase order, the producer is responsible for the performance of all inspection and requirements as specified herein. Except as otherwise specified in the contract or purchase order, the producer may use his own or any other facilities suitable for the performance of the inspection requirements specified herein. The purchaser reserves the right to perform any of the inspections set forth in the specification where such inspections are deemed necessary to assure the searchlights conform to the prescribed requirements.

9.2 The producer shall perform the necesary inspection and tests to assure that an S-4 inspection level, in accordance with MIL-STD-105D, is provided. An Acceptable Quality Level (AQL) of 1 % defective for the operational test and the switch leakage test, and an AQL of 4 % for any of the other requirement or test specified shall be provided. Sample testing shall be in accordance with Table 1.

TABLE 1 Sample Testing

Production	Paragraph	Order Batch	Paragraph
Watertightness	7.1	Light projection	7.3
Operation	7.2.1	Operation	7.2.1
Impact	7.2.2		
Light projection	7.3		
Switch endurance	7.4		

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[4] IES Lighting Handbook (Vol 1, Section 20), is available from Illuminating Engineering Society, 345 E. 47th St., New York, NY 10017.

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Document Name: ASTM F1006: Standard Specification for Entrainment Separators for Use in Marine Piping Applications

CFR Section(s): 46 CFR 56.60-1(b)

Standards Body: American Society for Testing and Materials

APPROVED

Official Incorporator:

THE EXECUTIVE DIRECTOR
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WASHINGTON, D.C.

ASTM Logo Removed

Designation: F 1006 – 86 (Reapproved 1997)

An American National Standard

Standard Specification for Entrainment Separators for Use in Marine Piping Applications[1]

This standard is issued under the fixed designation F 1006; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification provides the minimum requirements for the pressure-temperature rating, testing, and making of pressure containing vessels for entrainment separators.

1.2 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

1.3 The following safety hazards caveat pertains only to the test methods portion, Section 6, of this specification: *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ANSI Standards:*

B 2.1 Pipe Threads (Except Dryseal)[2]
B 16.1 Cast Iron Pipe Flanges and Flanged Fittings[2]
B 16.3 Malleable Iron Threaded Fittings, Class 150 and 300[2]
B 16.4 Cast Iron Threaded Fittings, Class 125 and 250[2]
B 16.5 Steel Pipe Flanges and Flanged Fittings[2]
B 16.11 Forged Steel Fittings, Socket Welding and Threaded[2]
B 16.15 Cast Bronze Threaded Fittings, Class 150 and 300[2]
B 16.24 Bronze Flanges and Flanged Fittings, Class 150 and 300[2]
B 16.25 Buttwelding Ends[2]
B 16.31 Nonferrous Pipe Flanges[2]

2.2 *ASME Standards:*

SA 278 Cast Gray Iron Pressure Vessels[3]
SA 395-60 Cast Ductile Iron[3]
Boiler and Pressure Vessel Code, Section VIII[3]
Boiler and Pressure Vessel Code, Section II[3]

2.3 *Manufacturer's Standardization Society of the Valve and Fittings Industry Standard:*

MSS SP-51 150 LB Corrosion Resistant Cast Flanges and Flanged Fittings[4]

2.4 *Military Standard:*

MIL-F-1183 Fittings Tube, Bronze, Cast (Silver Brazings)[5]

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *entrainment separator*—a mechanical device inserted in a pipeline which by centrifugal force, baffles, or other means will separate a liquid from a gas (vapor).

3.1.2 *hydrostatic test*—the act of filling an entrainment separator vessel with water and applying internal pressure to all parts of the vessel.

3.1.3 *master gage*—the calibrated gage used to verify the accuracy of the test gage. This gage shall be recalibrated traceable to the National Bureau of Standards.

3.1.4 *pressure rating*—the maximum working pressure of an entrainment separator when operated at a specific temperature.

3.1.5 *proof test*—the act of filling an entrainment separator vessel with water and applying internal pressure to all parts of the vessel for the purpose of causing yielding of the vessel and bursting of the vessel.

3.1.6 *temperature ratings*—minimum and maximum temperatures at which the entrainment separator may be operated while at specific pressures.

3.1.7 *test gage*—the pressure gage that is used to check the internal pressure of the entrainment separator. The test gage shall be calibrated at least annually or at any time it is suspected to be in error by a calibrated master gage.

4. Materials and Manufacture

4.1 The pressure-temperature ratings established under this specification are based upon the manufacturer's usage of high quality materials produced under regular control of chemical and physical properties by a recognized process. The manufacturer shall be prepared to submit certification of compliance, verifying that his product has been so produced and that it has been manufactured from material with chemical and physical properties at least equal to the requirements of the appropriate standard or specification listed in 4.3 of this specification or Section II of the ASME Boiler and Pressure Vessel Code.

4.2 For materials not having values of allowable stress tabulated in Section VIII Division I of the ASME Boiler and Pressure Vessel Code, allowable stresses shall be determined in accordance with the procedures outlined in Appendix P of Section VIII, Division 1 of the ASME Boiler and Pressure Vessel Code.

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[1] This specification is under the jurisdiction of Committee F-25 on Ships and Marine Technology and is the direct responsibility of Subcommittee F25.13 on Piping Systems.

Current edition approved July 25, 1986. Published September 1986.

[2] Available from American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.

[3] Available from American Society of Mechanical Engineers, 345 E. 47th St., New York, NY 10017.

[4] Available from Manufacturer's Standardization Society of the Valve and Fittings Industry, 127 Park St., N.E. Vienna, VA 22180.

[5] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

4.3 Materials of construction shall be suitable for the service intended.

4.4 Bolting materials shall be at least equal to those listed in Table 1B of ANSI B16.5. Bolting materials shall not be used beyond temperature limits specified in the governing codes.

5. Requirements

5.1 Entrainment separators covered in this specification shall be designed according to the lowest pressure-temperature rating of any individual component, or as established by proof tests.

5.2 The design pressure-temperature of entrainment separators covered in this specification will be established by the manufacturer using one of the following methods:

5.2.1 Design calculations in accordance with the requirements prescribed in the ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, Part UG of Subsection A and the applicable part of Subsection C.

5.2.2 Proof test in accordance with the requirements of UG 101 (m), UCI-101, or UCD-101 of Section VIII, Division 1 of the ASME Boiler and Pressure Vessel Code.

5.2.3 Where any part of the entrainment separator vessel cannot be designed within the scope of the ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, Design Section, the pressure-temperature rating must be determined through proof and hydrostatic tests using the following formulas to determine the allowable operating limits of pressure and temperature. Operator safety should be considered when conducting these tests.

$P = (P_{HT}/4) \times (S_1/S_2)$ (For Steel Vessels)
$P = (P_{HT}/4) \times (T_1/T_2)$ (For Cast Iron Vessels)

where:
P = maximum allowable working pressure (psig) at design temperature,
P_{HT} = hydrostatic test pressure (psig) at test temperature,
S_1 = stress value at design temperature (psi),
S_2 = stress value at test temperature (psi),
T_1 = specified minimum tensile strength (psi), and
T_2 = actual tensile strength test specimen (psi).

5.2.3.1 Stress values S_1 and S_2 are determined from Section VIII, of the ASME Boiler and Pressure Vessel Code.

5.2.3.2 The value of P_{HT} to be used in determining the maximum allowable working pressure shall be the maximum pressure to which the entrainment separator was subjected to without permanent deformation or rupture.

5.2.3.3 Test water temperature[6] and entrainment separator temperature must be at equilibrium before hydrostatic test pressure is applied.

5.2.3.4 All possible air pockets must be purged while the entrainment separator vessel is being filled with water. Adequate vents shall be provided at all high points of the vessel.

5.2.3.5 External equipment not to be pressurized with the entrainment separator should be isolated or disconnected before applying the hydrostatic test pressure.

5.2.3.6 Hydrostatic test pressure shall be applied gradually to the entrainment separator and held stationary at each increment for a sufficient time in order that visual inspection can be made for leaks or deformation of the vessel. The final value of hydrostatic test pressure that is not in conflict with 5.2.3.2 is called P_{HT}.

5.3 Pressure-temperature rating and construction of all pipe connections shall be in accordance with the following standards or specifications: ANSI B2.1, ANSI B16.1, ANSI B16.3, ANSI B16.4, ANSI B16.5, ANSI B16.11, ANSI B16.15, ANSI B16.24, ANSI B16.25, ASME SA-278, ANSI B16.31, MSS SP-51, and MIL-F-1183.

6. Test Methods

6.1 All entrainment separators must be pressure tested in accordance with the following:

6.1.2 Each entrainment separator shall be tested by subjecting it to an internal hydrostatic test procedure, which at every point in the separator is at least equal to 1.5 times the maximum allowable working pressure, multiplied by the lowest ratio of the stress value for the design temperature.

$$\text{Test Pressure} = 1.5 \times \text{maximum allowable pressure} \times \frac{\text{stress value at test temperature}}{\text{stress value at design temperature}}$$

6.1.2.1 The hydrostatic test pressure shall be held stationary for a suitable time necessary for observation and inspection of the separator. The minimum time of test shall be no less than 1 min.

6.1.2.2 A test gage, as defined in this specification (see Section 3) shall be connected directly to the entrainment separator.

6.1.2.3 For compliance with ASME Codes leading to ASME certification proceed with steps as outlined in Section VIII, Division 1 of the ASME Boiler and Pressure Vessel Code for Standard Hydrostatic Tests.

7. Packaging and Package Marking

7.1 Each entrainment separator shall have a securely attached nameplate or other permanent marking indicating the following:

7.1.1 Manufacturer's name and trademark,
7.1.2 Pressure-temperature rating,
7.1.3 Manufacturer's serial number,
7.1.4 Year built,
7.1.5 Size (end connection pipe size),
7.1.6 Flow direction,
7.1.7 National board number, where applicable,
7.1.8 ASME code stamp, where applicable, and
7.1.9 ASTM designation and year of issue.

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[6] Test water temperature to be no less than 60°F (10°C), but not to exceed 125°F (52°C).

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Document Name: ASTM F1007: Standard Specification for Pipe-Line Expansion Joints of the Packed Slip Type for Marine Application

CFR Section(s): 46 CFR 56.60-1(b)

Standards Body: American Society for Testing and Materials

APPROVED

Official Incorporator:

THE EXECUTIVE DIRECTOR
OFFICE OF THE FEDERAL REGISTER
WASHINGTON, D.C.

Designation: F 1007 – 86 (Reapproved 1996)$^{\epsilon 1}$

An American National Standard

Standard Specification for Pipe-Line Expansion Joints of the Packed Slip Type for Marine Application[1]

This standard is issued under the fixed designation F 1007; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

$^{\epsilon 1}$ NOTE—Keywords were added editorially in November 1996.

1. Scope

1.1 This specification covers the design, manufacturing, and testing of packed slip type expansion joints utilized in pipe lines for accommodating axial thermal growth or contraction from the pipe-line carrying fluid.

1.2 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

2. Referenced Documents

2.1 *ASTM Standards:*

A 53 Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated Welded and Seamless[2]

A 216/A 216M Specification for Steel Castings, Carbon, Suitable for Fusion Welding, for High-Temperature Service[3]

A 285/A 285M Specification for Pressure Vessel Plates, Carbon Steel, Low- and Intermediate-Tensile Strength[4]

B 650 Specification for Electrodeposited Engineering Chromium Coatings on Ferrous Substrates[5]

2.2 *ANSI Standards:*

B 16.5 Steel Pipe Flanges and Flanged Fittings[6]

B 16.25 Buttwelding Ends[6]

B 31.1 Power Piping[6]

2.3 *ASME Standards:*

Section V Nondestructive Examination[7]

Section VIII, Division 1 Pressure Vessels[7]

Section IX Welding and Brazing Qualifications[7]

2.4 *AISI Standard:*

C-1018 Carbon Steel[8]

3. Classification

3.1 The expansion joints shall be of the following types, styles, classes and forms:

3.1.1 *Type I*—Injectable semi-plastic packing type, designed for injecting packing under full line pressure.

3.1.2 *Style I*—Internally-externally guided with guides integral with stuffing box.

3.1.3 *Style II*—Internally-externally guided with guides integral with stuffing box and with low-friction inserts at the guide surfaces.

3.1.4 *Class I*—Single joint, single slip.

3.1.5 *Class II*—Double joint, double slip.

3.1.6 *Form I*—Weld end.

3.1.7 *Form II*—Flanged end.

3.1.8 *Form III*—Other.

4. Ordering Information

4.1 Expansion joints shall meet all the requirements of the latest issue of this specification. Where possible, the expansion joint shall be the manufacturer's standard commercial product. Additional or superior features that are not prohibited by this specification but which are a part of the manufacturer's standard product, shall be included with the expansion joint being offered. A standard commercial product is a product that has been sold or is currently being offered for sale on the commercial market through advertisements or manufacturer's catalogs, or brochures, and represents the latest production model.

4.2 Purchase order or inquiry for expansion joints to this specification shall specify the following:

4.2.1 Title, number, and latest revision of this specification.

4.2.2 Style, class, and form required.

4.2.3 Materials, other than standard as specified (see Section 8).

4.2.4 Service conditions shall specify the following:

4.2.4.1 Maximum and minimum operating temperature, (°F).

4.2.4.2 Maximum operating pressure, (psig).

4.2.4.3 Fluid handled.

4.2.4.4 Corrosive conditions, if applicable.

4.2.5 Total axial expansion or contraction.

4.2.6 ANSI pressure class, facing and drilling for flanged end joint and pipe schedule or wall thickness of ends for weld end joint.

4.2.7 If base is required for support or main anchor on Class I expansion joint.

4.2.8 Drain connection, if required.

4.2.9 Service connection if required, noting location and type of connection.

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[1] This specification is under the jurisdiction of Committee F-25 on Ships and Marine Technology and is the direct responsibility of Subcommittee F25.13 on Piping Systems.

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[2] *Annual Book of ASTM Standards*, Vol 01.01.

[3] *Annual Book of ASTM Standards*, Vol 01.02.

[4] *Annual Book of ASTM Standards*, Vol 01.04.

[5] *Annual Book of ASTM Standards*, Vol 02.05.

[6] Available from American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.

[7] Available from American Society of Mechanical Engineers, 345 E. 47th St., New York, NY 10017.

[8] Available from American Iron and Steel Institute, 1000 N.W. 16th St., Washington, DC 20036.

4.2.10 Slip protectors, if required.

4.2.11 Adjustment rods for field extension or compression of the slip if required.

4.2.12 If hot-dip galvanizing of parts is required.

4.2.13 Spare parts, accessories, and special tools, if required.

4.2.14 Hydrostatic testing and test pressure, if required.

4.2.15 Radiographic or other nondestructive testing of weld joints if required.

5. Materials and Manufacture

5.1 *Materials:*

5.1.1 Materials of construction shall conform to the requirements as specified in this specification (see Section 8) and shall be new and free from defects that would adversely affect the performance of individual components or assemblies.

5.1.2 As specified in this specification and as required, the expansion joint shall be provided with flanged or welded end connections, limit stops, stuffing boxes with integral guides, base, drain connection, service connection, slip protectors, and adjustment rods.

5.2 *Manufacture:*

5.2.1 *General*—Unless otherwise required by this specification, the manufacturer's standard shop practices for the fabrication of the expansion joint is acceptable, provided these practices conform to the requirements and recommendations of this specification.

5.2.2 *All Welding*—Welding procedure qualifications, welder performance qualification, welding materials, preheat, and post weld heat treatment if required, shall be in accordance with ANSI B31.1 and ASME Code Section IX.

5.2.3 *Identification*—Each completed expansion joint shall have a name plate made from a corrosion resistant material permanently attached showing as a minimum the following:

5.2.3.1 Manufacturer's model number and joint size,

5.2.3.2 Design pressure and design temperature range,

5.2.3.3 Nominal traverse or movement per slip,

5.2.3.4 Type of packing and service fluid, and

5.2.3.5 Date of manufacture.

6. Joint Descriptions

6.1 *Styles:*

6.1.1 *Style I*—The slip of the expansion joint shall be guided with the body of the expansion joint by internal and external guides that are integral with the stuffing box. Semi-plastic packing shall be injected into the stuffing box and may be contained within the stuffing box chamber by ring type packing. All packing shall be of the self-lubricating type. The expansion joint and semi-plastic packing shall be suitable for the safe injection of the packing under full line pressure to stop leakage. Provisions for packing injection shall be by devices located radially about the stuffing box and designed to permit a maximum evacuation of packing at the bottom of the packing device when the injector is fully engaged. The number of devices with injectors for each stuffing box shall be in accordance with the manufacturer's standard practice. The design of the packing injection devices shall be such as to ensure no blowback of injectable packing or the service fluid when injecting packing under full line pressure.

6.1.2 *Style II*—The expansion joint shall be the same as Style I except low friction corrosion resistant material or inserts shall be used for internal and external guiding to prevent slip scoring from pipe misalignment, or vibration and to prevent corrosion of the guide surfaces.

6.2 *Classes:*

6.2.1 *Class I*—The expansion joint shall have slip at only one end of the joint. Class I expansion joints may or may not require a base.

6.2.2 *Class II*—The expansion joint shall have slip at both ends of the joint. Class II expansion joints shall require a base.

6.3 *Forms:*

6.3.1 *Form I—Welded End:* The expansion joint shall have provisions at each end of the Joint for field welding to the adjoining pipe line.

6.3.2 *Form II—Flanged End:* The expansion joint shall have flanges at each end of the joint for bolting to the mating flanges of the adjoining pipe line.

6.3.3 *Form III*—The expansion joint shall have other end connections as specified for attaching to the adjoining pipe line.

7. Design

7.1 The expansion joint shall be designed to conform to applicable sections of the latest edition of ANSI B31.1 and other applicable documents as noted in Section 2.

7.2 *Compresson Force*—Unless otherwise specified, the force to compress or extend the slip of the expansion joint shall not exceed 1000 lbf/in. (175 100 N/m) of nominal pipe diameter.

8. Construction

8.1 *Slip*—The slip shall be manufactured from steel pipe conforming to Specification A 53, Grade B, or a rolled and welded cylinder from Specification A 285/A 285M, Grade C plate, or equal with the longitudinal weld seam 100 % radiographed. The minimal wall thickness of the pipe or rolled cylinder shall be equivalent to Schematic 80 pipe for all sizes to 14 in. (356 mm), inclusive and Schematic 60 for sizes 16 to 24 in. (406 to 610 mm) to preclude slip collapse due to external loading of the injectable packing. Heavier wall pipe may be required for expansion joints subjected to pressures above 600 psig and for pipe sizes above 24 in. (610 mm) diameter.

8.1.1 *Chrome Plate*—The slip of the expansion joints shall be chrome plated with engineering chrome in accordance with Specification B 650, Class 50.

8.2 *Stuffing Box*—The stuffing box with integral internal and external guides shall be machined from Specification A 53, Grade B Pipe, or AISI C-1018 seamless tubing or cast steel in accordance with A 216/A 216M, Grade WCB. A rolled and welded cylinder from Specification A 285/A 285M, Grade C plate, or equal may be used provided the longitudinal weld seam is 100 % radiograph examined in accordance with ANSI B31.1 and ASME Code Section V.

8.3 *Traverse Chamber*—This chamber, also referred to as the "E.J. Body," shall be machined from Specification A 53, Grade B seamless steel pipe having a wall thickness suitable for the design service conditions. A rolled and welded cylinder from Specification A 285/A 285M, Grade C, or equal steel plate of suitable thickness for the design service conditions may also be used if the longitudinal weld seam is 100 % radiograph inspected to ANSI B31.1 and ASME Code Section V.

8.4 *End Connections*—The end connections of the expansion joint (see Section 6) shall be flanged, weld end, combination of both or others as specified. Flanges shall conform to ANSI B16.5 and be of the size, material, pressure class, and facing specified. Weld ends shall be beveled for welding to conform to ANSI B16.25 and be of the size, material and nominal wall thickness as specified for the mating pipe.

8.4.1 *Body End Connection for Class I Expansion Joints:*

8.4.1.1 *Form I—Weld End:* The reduction of the body size to the pipe line size shall be accomplished by a formed reduction of the traverse chamber (body) or by a reducer butt welded to the traverse chamber (body) that meets the requirements of ANSI B31.1 and the ASME Code Section VIII, Division 1.

8.4.1.2 *Form II—Flanged End:* Forged flanges shall be attached to the body by butt welding only and shall be in accordance with the requirements of ANSI B31.1 and the ASME Code Section VIII, Division 1.

8.5 *Limit Stops*—Limit stops may be of the external or internal type manufactured from a suitable material and designed to withstand the full line pressure thrust load in the event of a pipeline anchor failure.

8.6 *Internal and External Guides*—See 8.2.

8.6.1 *Low Friction Internal and External Guides*—The low friction internal and external guides or inserts shall be made from noncorrosive materials with appropriate differential hardness to also prevent scoring or binding of the slip.

8.7 *Base:*

8.7.1 *Expansion Joint Without a Service Connection*—When a base is specified for Class I expansion joints, the base shall be designed for use as a main anchor. Class II expansion joints shall have a base that is suitable as an intermediate anchor. The base shall be of cast or fabricated steel that conforms to the applicable ASTM standard and shall be suitably attached to the joint and drilled in accordance with the manufacturer's standard practice.

8.7.2 *Expansion Joint With a Service Connection*—Class I and Class II expansion joints with a service connection shall be provided with a main anchor base and all anchor loading data (forces and moments) shall be made available to the manufacturer to assure adequate anchor design. The base shall be of cast or fabricated steel that conforms to the applicable ASTM standard and shall be suitably attached to the joint and drilled in accordance with the manufacturer's standard practice.

8.8 *Service Connection*—Unless otherwise specified, a service connection, when required shall be the manufacturer's standard design and shall meet the applicable requirements of the ASTM, ANSI, and ASME Codes. The service connection shall be supplied with end connections as specified (See 8.5).

8.9 *Drain Connection*—When required, a drain connection shall be attached to the body of the expansion joint and shall be the manufacturer's standard unless otherwise specified. The drain connection shall meet the requirements for fitting connections as specified in ANSI B31.1.

8.10 *Packing*—Unless otherwise specified, the packing shall be the manufacturer's standard type packing and shall be suitable for the specified service conditions.

8.11 *Other Materials of Construction*—Where the expansion joint is to transfer corrosive fluids, or be installed in a corrosive atmosphere, corrosive resistant materials as specified may be substituted for the carbon steel components, especially the sliding slip.

9. Drawing Requirements

9.1 *Drawings*—When specified, dimensional sketches or drawings sufficiently detailed to describe the expansion joint to be supplied, shall be submitted with bid proposals. The inch-pound system of measurements shall be used to dimension drawings. Drawings shall note that the design of the components or products is in full compliance with this specification.

10. Cleaning and Surface Preservation

10.1 *Cleaning*—The internal and external surfaces of the expansion joint shall be cleaned of dirt, oil, grease, and other foreign material using a suitable cleaning solvent. Extreme care shall be utilized to ensure the interior is free of any slag, steel chips, or other similar materials that could lodge between the slip and the body and score the slip surface.

10.2 *Surface Preservation*—Unless specified, no preservation will be required on the internal surface of the expansion joint. All external surfaces except the chrome plated slip surface, flanged faces, and weld bevel surfaces shall be painted in accordance with the manufacturer's standard practice. Weld end joint surfaces for field welding shall be coated with "deoxaluminate" preservative.

11. Packaging and Package Marking

11.1 All openings shall be suitably sealed to protect the opening connection surfaces and prevent entrance of foreign materials.

11.2 Unless otherwise specified, the exposed chrome plated surface of the slips shall be protected in accordance with the manufacturer's standard practice.

11.3 Unless otherwise specified, the completed expansion joints shall be suitably attached with steel strapping or hold down bolting, to wood skids or crates in accordance with standard commercial practice for domestic shipments.

12. Quality Assurance

12.1 *Inspection*—Unless otherwise specified the contractor shall perform inspections as required to assure compliance with this specification. The procuring agency may establish inspection requirements, and it is the contractor's responsibility to provide access to his facilities for the procuring agency's inspection of material, work in process, and quality assurance testing or results as required.

12.2 *Material Certification*—Certified material test reports or certificates of compliance shall be required for all pressure retaining material. To maintain traceability, all pressure retaining material shall be metal stamped or otherwise suitably marked with heat treat numbers or other identification codes. If metal stamping is used, the indentations shall not exceed $\frac{1}{32}$ in. (0.8 mm) or infringe on minimum wall thickness. A round-nose, low-impression type stamping die shall be used.

12.3 *Nondestructive Testing*—When required all nondestructive testing shall be performed by qualified personnel in accordance with qualified acceptable procedures.

12.3.1 *Radiography*—Radiographic examination of welds shall be in accordance with ANSI B31.1 and Secton V of the ASME Code.

12.3.2 *Visual Examination, Magnetic Particle, and Liquid Penetrant Examination*—Whenever required, these examinations shall be in accordance with ANSI B31.1 and Section V of the ASME Code.

13. Keywords

13.1 axial thermal growth; expansion joint; fluid pipe line; marine technology; packed slip expansion joint; pipe line; ship

CERTIFICATE

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By the Authority Vested By Part 5 of the United States Code § 552(a) and Part 1 of the Code of Regulations § 51 the attached document has been duly INCORPORATED BY REFERENCE and shall be considered legally binding upon all citizens and residents of the United States of America. *HEED THIS NOTICE*: Criminal penalties may apply for noncompliance.

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An American National Standard

Standard Specification for Flashlights on Vessels[1]

This standard is issued under the fixed designation F 1014; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense. Consult the DoD Index of Specifications and Standards for the specific year of issue which has been adopted by the Department of Defense.

1. Scope

1.1 This specification covers three types of flashlights (see Section 4).

1.2 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

1.3 The following precautionary caveat pertains only to the test method portion, Section 9, of this specification: *This standard does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *Military Standard:*

MIL-STD-105D Department of Defense Standard; Sampling Procedures and Tables for Inspection by Attributes[2]

2.2 *UL Standard:*

UL Standard No. 783[3]

3. Terminology

3.1 *Descriptions of Terms Specific to This Standard:*

3.1.1 *lot*—a manufacturers production run for a specific type of flashlight.

3.1.2 *order batch*—the size of a specific contract or purchase order taken from the lot.

3.1.3 *production testing*—the testing performed during a lot run of specific flashlights.

4. Classification

4.1 The three types of flashlights covered in this specification are classified as follows:

4.1.1 *Type I*—Flashlights for use in lifeboats and liferafts.

4.1.2 *Type II*—Flashlights for use in hazardous locations where fire or explosion hazards may exist due to the presence of flammable gases or vapors, flammable liquids, combustible dust, or ignitable fibers or flyings.

4.1.3 *Type III*—Flashlights for use in lifeboats and liferafts and suitable for hazardous locations.

4.2 Type I flashlights shall be manufactured in accordance with Sections 2 through 11. Type II flashlights shall meet the requirements in Sections 11 and 12. Type III flashlights shall meet the requirements in Sections 2 through 12.

5. Materials and Manufacture

5.1 *Materials*—All materials used in the construction of these flashlights shall be of a quality suitable for the purpose intended and shall conform to the requirements of this specification.

5.2 *Manufacture*—Plastic, when used, shall be a suitable thermoplastic or thermosetting material so molded as to produce a dense solid structure, uniform in texture, finish, and mechanical properties.

6. General Requirements

6.1 Each flashlight shall be a three-cell light.

6.2 Each flashlight shall provide a concentrated beam of light. When used in this specification, a concentrated beam of light is light projected in a nearly parallel beam and is used to illuminate objects at considerable distances.

6.3 The flashlight shall show no leakage of water and shall be in perfect working order following the test prescribed in 9.2.

6.4 The proportions and design of each flashlight shall be such that the assembled unit complete with lamp and cells shall be capable of withstanding, without breakage or material distortion of any part and without upsetting the lamp focus, the test specified in 9.6. Damage of lamp filament or shifting of filament within the lamp as a result of this test shall not be cause for rejection of the flashlight if the flashlight operates when the spare lamp is used.

6.5 Each flashlight must be furnished with two lamps. One of these lamps is a spare and must be contained within the body of the flashlight, either in the end cap or reflector head area.

6.6 All metal parts of each flashlight shall be made of corrosion-resistant material. All copper or copper-alloy parts coming in contact with rubber shall not corrode or disintegrate the rubber.

6.7 The construction of each flashlight shall be such that a metallic contact outside the case cannot close the battery circuit and cause the light to come on.

6.8 Each flashlight shall be provided with means to prevent it from rolling.

7. Physical Requirements

7.1 *Dimensions*—Each flashlight shall not exceed 11½ in.

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[1] This specification is under the jurisdiction of ASTM Committee F-25 on Shipbuilding and is the direct responsibility of Subcommittee F25.10 on Electrical, Electronics, and Automation.

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[2] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

[3] Available from Underwriters Laboratories, 333 Pfingsten Rd., Northbrook, IL 60062.

(292 mm) in length and shall have a lens ring diameter of no more than 2½ in. (63.5 mm).

7.2 *Case, Lens Head Ring, and End Cap:*

7.2.1 The flashlight case must be suitable to receive three commercial D-size dry cells. The exterior of the flashlight shall have molded flutes or ribs to provide a satisfactory gripping surface when wet. Cells must be held in the case under sufficient pressure to ensure good contact and to prevent breaking of the circuit when the flashlight is tested in accordance with 9.1.2. The flashlight must be constructed so that the cells are readily replaceable.

7.2.2 The case, ring, and cap, need not be made of the same material but cooperating threaded surfaces should be of the same type material.

7.3 *Lens*—The lens shall be of good quality, laminated, shatter-proof glass or clear plastic, free from bubbles, striae, wrinkles, or other defects and blemishes that would affect the light distribution. The lens shall be secured to the lens head ring by a suitable retaining ring or other device so as to prevent it from being dropped when the lens head ring is unscrewed.

7.4 *Reflector*—The reflector may be of metal or plastic and must have sufficient rigidity so as not to become distorted when the flashlight is completely assembled with cells and lamp. It must have an essentially parabolic reflecting surface, highly polished and resistant to corrosion and discoloration. The reflector shall be 1¾ ± ¼ in. (44 ± 6 mm) in diameter.

7.5 *Lamps*—The lamps shall be appropriate for use with alkaline or carbon-zinc batteries. Each lamp must have a lamp life of at least 15 h at the rated battery voltage.

7.6 *Lamp Holder*—The lamp shall be firmly positioned in the reflector. It shall be so positioned that the lamp, when assembled in the holder, shall have its filament located at the focus of the reflector, with the accuracy necessary to produce a concentrated beam of light as specified in 9.7. It shall have sufficient rigidity so as not to become distorted when the flashlight is completely assembled with cells and lamp. Means shall be provided to protect the lamp from damage by battery impact and for conveniently removing and replacing the lamp. The mounting adjustment shall have sufficient stability to retain the focal adjustment of the lamp under a condition of vibration, and when the flashlight is tested in accordance with 9.1.2.

7.7 *Switch*—The switch shall be conveniently located and securely attached to the flashlight. It shall be provided with a permanent "ON" position, a manually operable signaling or "FLASHING" position, and a locked "OFF" position. It shall be provided with means to prevent accidental closing of the lamp circuit. The switch parts and switch contact strip shall be adequately insulated so that it will be impossible for metal-clad cells to close a circuit when the switch is on the "OFF" position. The flashlight shall be designed with a switch guard. Contact springs shall be of phosphor bronze, spring brass, or other corrosion-resistant equivalent material.

7.8 *Suspension Member*—Each flashlight shall be equipped with a suitable suspension ring or clip. The ring or clip shall be tested as specified in 9.8.

8. Workmanship

8.1 Flashlights shall be of sturdy construction and free of mechanical, electrical, or other imperfections or defects that materially affect appearance or that may affect quality, reliability, or serviceability. The finished flashlight shall not contain rough edges, burrs, blemishes, or other disfigurements and shall be clean, free from rust, toolmarks, pits, and other injurious defects.

8.1.1 Threaded parts shall be smooth and close fitting and shall be capable of being easily moved by hand relative to each other. Threaded parts shall not jump or change adjustment when being put together or when subjected to the tests in Section 9.

9. Test Methods

9.1 *Switches:*

9.1.1 *Switch Leakage*—With the lamp and reflector removed, insert fresh batteries into the flashlight. Connect a voltmeter across the switch and battery or the switch and battery contacts, as appropriate, in such a way as to read the battery voltage through the switch. With the switch in the "OFF" position, read the voltage. Any distinguishable deflection of the meter hand when the meter is set in the voltage range, nearest the battery voltage, shall constitute failure of this test.

9.1.2 *Operation*—Insert batteries into the flashlight and operate the switch five times in each of the three switch positions. Shake the flashlight vigorously in each "ON" and "FLASHING" switch position. The flashlight must not go off when shaken vigorously while the switch is in the "ON" or "FLASHING" position.

9.1.3 *Switch Endurance*—Test the contact switch mechanism of the flashlight by operating the switch for 25 000 continuous cycles. A cycle shall consist of movements from "OFF" position through the full "ON" and "FLASHING" positions and back to "OFF" position. Operate the switch under normal electrical load conditions, and replace the lamp and batteries as often as required to ensure that the switch mechanism is operating under normal load throughout the 25 000 cycles. Burning out of bulbs and batteries during the test shall not constitute failure of this test. Failure of the switch to complete 25 000 cycles shall constitute failure of this test.

9.2 *Watertightness*—Test the flashlight as follows:

9.2.1 Submerge the assembled flashlight in a salt water solution (1.04 sp gr) under a head of 1 ft (0.3 m) for a period of 24 h at a water temperature of 65°F (18°C). Remove the flashlight and wipe off the excess water. The total water absorption shall not exceed 5 % weight. The flashlight shall be capable of being disassembled and reassembled without undue difficulty upon completion of the test and shall be in perfect working order.

9.3 *Impact:*

9.3.1 *Test Conditions*—Place the flashlight, without batteries installed, in a cold chamber at −40 ± 5°F (−40 ± 3°C) for 2 h. With the flashlight stabilized at this temperature, immediately subject it to the low- and high-impact test specified in 9.3.2 and 9.3.3. Apply the point of impact to the following:

9.3.1.1 The outside of the flashlight case at a point midway between the ends of the case on a side 90° from the switch, 9.3.1.2 The switch (in the "ON" position and in the "OFF" position),

9.3.1.3 The lens cap, and

9.3.1.4 The end cap.

9.3.2 *Low Impact*—Subject the flashlight to a 12-lbf·in. (1.4 N·m) impact using a 1-lb (0.4-kg) steel ball at each of the points of impact specified in 9.3.1. Provided the flashlight remains intact, next subject the flashlight to the watertightness test (see 9.2). There shall be no evidence of breakage from impact or moisture in the case.

9.3.3 *High Impact*—After the flashlight passes the low-impact test, again place the flashlight in the cold chamber at −40°F ± 5°F (−40 ± 3°C) for 2 h, and then immediately subject it to a 20 lbf·in. (2.3 N·m) impact using a 1-lb (0.4-kg) steel ball at each of the points of impact specified above. There shall be no evidence of damage to the case, the lens, or the end cap.

9.4 *Environmental:*

9.4.1 *Heat and Humidity*—Place the flashlight, with dry cells, on a horizontal surface and subject to dry heat at 150 ± 5°F (65.6 ± 3°C) for 16 h, followed by an 85 ± 5 % relative humidity at 100 ± 2°F (38 ± 1°C) for 6 h. The flashlight shall be compared with untested flashlights for dimensional stability, crazing of surface, and then tested to determine that the flashlight operates in accordance with 9.1.2.

9.5 *Corrosion*—Subject the flashlights, without dry cells, to salt spray for 200 h. Then wash the flashlight with fresh water, dry, and then test to determine that the flashlight operates in accordance with 9.1.2. There shall be no evidence of corrosion.

9.6 *Rough Use*—Drop the flashlight, complete with dry cells, lamps, and lens, 5 ft (1.5 m) in free fall onto a vinyl-asbestos tiled concrete floor. Drop the flashlight twice in a horizontal position upon the switch, with the switch in the "ON" position, twice in a horizontal position upon the switch, with the switch in the "OFF" position, twice in a vertical position upon the head of the flashlight, and upon the base of the flashlight. Do not tighten parts once the test has begun. There shall be no evidence of damage to any part of the flashlight. Then test the flashlight in accordance with 9.1.3.

9.7 *Light Projection*—The flashlight must project a concentrated beam of light not less than 5 in. (127 mm) nor more than 11 in. (279 mm) in diameter when located 5 ft (1.524 m) from a screen. The plane of the screen must be perpendicular to the optical axis of the flashlight.

9.8 *End Cap Ring*—The end cap ring shall support a weight of 25 lb (11.3 kg) for 1 min without evidence of distortion.

10. Marking, Packaging, and Packing

10.1 *Product Marking*—Each flashlight conforming to all the requirements in this specification shall be marked with the name, brand, or trademark of the manufacturer, this ASTM specification number, the type of flashlight (Type I, Type II, or Type III), and any other information as may be specified in the contract or purchase order.

10.2 Unless otherwise specified by the customer in the contract or purchase order, the flashlight shall be packaged, packed, and marked in accordance with the manufacturer's commercial practice to ensure acceptance and safe delivery by the carrier for the mode of shipping and handling.

TABLE 1 Sample Testing

Production	Order Batch
1. Switch leakage (9.1.1)	1. Switch leakage (9.1.1)
2. Operation (9.1.2)	2. Operation (9.1.2)
3. Switch endurance (9.1.3)	3. Rough use (9.6)
4. Watertightness (9.2)	4. Light projection (9.7)
5. Impact (9.3)	5. End cap ring (9.8)
6. Heat and humidity (9.4.1)	
7. Corrosion (9.5)	
8. Rough use (9.6)	
9. Light projection (9.7)	
10. End cap ring (9.8)	

11. Quality Assurance Provisions

11.1 Unless otherwise specified in the contract or purchase order, the producer is responsible for the performance of all inspection and requirements as specified herein. Except as otherwise specified in the contract or purchase order, the producer may use his own or any other facilities suitable for the performance of the inspection requirements specified herein. The purchaser reserves the right to perform any of the inspections set forth in this specification where such inspections are deemed necessary to ensure that the flashlights conform to the prescribed requirements.

11.2 The producer shall perform the necessary inspection and tests to ensure that an S-4 inspection level, in accordance with MIL-STD-105D, is provided. An Acceptable Quality Level (AQL) of 1 % defective for the operational test and the switch leakage test, and an AQL of 4 % for any of the other requirements or tests specified shall be provided. Sample testing shall be in accordance with Table 1.

12. Flashlights for Use in Hazardous Locations on U.S. Flag Merchant Vessels

12.1 Details such as dimensions, construction criteria, battery configuration, and voltage shall be provided by the procuring agency in the contract or purchase order.

12.2 Flashlights that are to be used in hazardous locations shall conform to the requirements of Underwriters Laboratories (UL) Standard No. 783, or equivalent standard, and to the following requirements.

12.3 Flashlights that are to be used in hazardous locations shall be listed by an independent testing laboratory that is concerned with product evaluation, that maintains periodic inspection of production of listed flashlights, and whose listing states that the flashlight has been tested and found suitable for use in the hazardous location specified (that is, Class and Group designation). The testing laboratory must be acceptable to the appropriate regulatory bodies or the procurement agency.

12.4 Flashlights that have been listed by a testing laboratory meeting the criteria in 12.3 shall affix a label, symbol, or other identifying mark to the flashlight that shall indicate that the flashlight is suitable for use in the hazardous location.

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Document Name: ASTM F1020: Standard Specification for Line-Blind Valves for Marine Applications

CFR Section(s): 46 CFR 56.60-1(b)

Standards Body: American Society for Testing and Materials

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WASHINGTON, D.C.

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An American National Standard

Standard Specification for Line-Blind Valves for Marine Applications[1]

This standard is issued under the fixed designation F 1020; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

$^{\epsilon 1}$ NOTE—Keywords were added editorially in November 1996.

1. Scope

1.1 This specification provides the minimum requirements for design fabrication, pressure rating, and testing for line-blind valves.

1.2 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

1.3 The following safety hazards caveat pertains only to the test methods portion, Section 5, of this specification: *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standard:*

A 53 Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated Welded and Seamless[2]

2.2 *ANSI Standards:*

B16.5 Pipe Flanges and Flanged Fittings, Steel-Nickel Alloy and Other Special Alloys[3]

B31.1 Power Piping[3]

2.3 *MSS Standards:*

SP-6 Finish for Contact Faces of Pipe Flanges and Connecting End Flanges of Valves and Fittings[4]

SP-25 Marking System for Valves, Fittings, Flanges, and Unions[4]

SP-55 Quality Standard for Steel Castings for Valves, Flanges and Fittings, and Other Piping Components (Visual Method)[4]

2.4 *ASME Standard:*

ASME Boiler and Pressure Vessel Code, Sections II, VIII, IX[5]

3. Descriptions of Terms Specific to This Standard

3.1 *blank*—a solid one-piece circular unit inserted into a pipeline to prevent flow.

3.2 *line-blind valve*—an assembly consisting of a spectacle plate, bolting, and body, the purpose of which is to provide a convenient means to align a piping system to an open or positively closed configuration. The assembly is designed to provide a simplified method of changing over the flow control spectacle plate without the necessity of plate removal from the valve body.

3.3 *spectacle plate,* (*also spectacle blind*)—a figure-eight shaped unit with one end open for flow and the other solid to prevent flow.

4. Materials and Manufacture

4.1 *Materials:*

4.1.1 Materials for spectacle plates, bolting, and body shall be those contained in ASME Section II. For the purpose of stress calculations, ASME Section VIII values shall be used.

4.1.2 All welding shall be done with procedures and welders qualified in accordance with ASME Section IX; and 80 % weld efficiency factor shall be used.

4.1.3 All castings shall be visually inspected and acceptable in accordance with MSS-SP-55.

4.2 *Manufacture:*

4.2.1 The spectacle plate shall be designed in accordance with ANSI B31.1, paragraph 104.5.3.

4.2.2 The calculations of 4.2.3 and 4.2.4 shall ensure that a line blind is designed for the gasket material, of all that can be used with the line blind being designed, that imposes the most critical bolt-load conditions as a result of its gasket factor, m, and gasket or joint-contact-surface unit seating load, y.

4.2.3 The bolting shall be either of the following:

4.2.3.1 Modify the external loads in accordance with Section 6 as determined using ASME Section VIII, Division 1, Appendix 2.

4.2.3.2 The equivalent in cross-section to that of ANSI B16.5 flange bolting of equivalent nominal size and pressure.

4.2.3.3 In no case shall bolts have a nominal diameter less than ½ in. (12.7 mm).

4.2.3.4 The material class shall be an approved ANSI B16.5 material or equal in tensile strength.

4.2.3.5 Cast bolting shall be x-rayed or have an 80 % efficiency factor applied.

4.2.4 The body shall be calculated using ASME Section VIII, Division 1, Appendix 2 with consideration for the size and material of bolting in the appendix, the bolt load satisfying Note 2 of paragraph 2-5 of Appendix 2.

4.2.5 The spectacle plate and mating body facings shall be in accordance with MSS-SP-6.

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[1] This specification is under the jurisdiction of ASTM Committee F-25 on Ships and Marine Technology and is the direct responsibility of Subcommittee F25.13 on Piping Systems.

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[2] *Annual Book of ASTM Standards*, Vol 01.01.

[3] Available from American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.

[4] Available from Manufacturer's Standardization Society of the Valve and Fittings Industry, Inc., 127 Park St., N.E. Vienna, VA 22180.

[5] Available from American Society of Mechanical Engineers, 345 E. 47th St., New York, NY 10017.

5. Testing

5.1 Each valve body shall be hydrostatically tested to the shell test pressure in accordance with ANSI B16.5, Table 3. A valve supplied to the WOG standard shall be tested up to the nearest ANSI Class.

5.2 Each valve shall be tested for leakage at pressure 1.5 times the cold water rating of the valve rounded upward to the next higher 25 psi (170 kPa) increment. Acceptance criteria shall be that no leakage occurs during a 10-min "hold time" at pressure.

6. Calculations

6.1 Bolting calculations from ASME Section VIII, Division 1, Appendix 2 shall be modified to account for an externally applied load due to piping. Add to the minimum required bolt load for the operating conditions, W_{m1}, an external moment bolt load, H_x, such that the modified total cross-sectional area of the bolts shall be as follows:

$$A'_{m1} = (W_{m1} + H_x)/S_b$$

where:

$H_x = SZ/d_b$,

$Z = \Pi((D_o^4 - D_i^4)/D_o)/32$,

$D_i = D_o - 2t_p$,

$t_p = PD_o/(2(0.875)(S))$, but not less than 0.25 in. (6.4 mm), and

$d_b = C/\Pi + 2((G_o^3 - G_i^3)/(G_o^2 - G_i^2))3\Pi$.

6.1.1 All terms are identical to those defined in ASME Section VIII, Appendix 2 with the addition of the following:

6.1.1.1 A'_{m1} = modified total cross-sectional area of bolts at root of thread or section of least diameter under stress, required for the operating conditions, square inch. (square millimetre).

6.1.1.2 H_x = external moment of bolt load, lbf (N).

6.1.1.3 0.875 = assumed pipe wall tolerance factor.

6.1.1.4 S = ASME allowable stress of the pipe material at design temperature, psi (kPa), (for purposes of meeting this specification, 15 000 psi (103.4 MPa) from Specification A 53, Grade B, Type S shall be acceptable).

6.1.1.5 Z = section modulus of pipe shell, cubic inches (cubic millimetres).

6.1.1.6 D_o = nominal outside diameter of pipe, inches (millimetres).

6.1.1.7 D_i = calculated inside diameter of pipe, inches (millimetres).

6.1.1.8 t_p = calculated pipe wall thickness, inches (millimetres).

6.1.1.9 d_b = moment arm of external moment on bolts and gasket, inches (millimetres).

6.1.1.10 G_o = outside diameter of contact surface of gasket, inches (millimetres).

6.1.1.11 G_i = inside diameter of contact surface of gasket, inches (millimetres).

6.2 The selection of bolts to be used shall be made such that the actual total cross-sectional area of bolts, A_b, will not be less than A_m, where A_m is taken as the greater of A'_{m1} and A_{m2}.

7. Product Marking

7.1 Each valve must have the following markings in accordance with MSS-SP-25:

7.1.1 Manufacturer's name and trademark.

7.1.2 Appropriate pressure class.

7.1.3 Size of end connection.

7.1.4 ASTM designation of materials.

7.1.5 ASTM designation and year of issue of this specification.

8. Keywords

8.1 blind valve; line-blind valve; marine technology; piping system; ship; valve

CERTIFICATE

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Document Name: ASTM F1120: Standard Specification for Circular Metallic Bellows Type Expansion Joints for Piping Applications

CFR Section(s): 46 CFR 56.60-1(b)

Standards Body: American Society for Testing and Materials

APPROVED

Official Incorporator:

THE EXECUTIVE DIRECTOR
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WASHINGTON, D.C.

Standard Specification for Circular Metallic Bellows Type Expansion Joints for Piping Applications[1]

1. Scope

1.1 This specification establishes the minimum requirements for the mechanical design, manufacture, inspection, and testing of circular metallic bellows-type expansion joints used to absorb the dimensional changes resulting from piping thermal expansion or contraction, as well as the movement of terminal equipment and supporting structures.

1.2 Additional or better features, over and above the minimum requirements set by this specification, are not prohibited by this specification.

1.3 The layout of many piping systems provides inherent flexibility through natural changes in direction so that any displacements produce primarily bending or torsional strains, within acceptable limits. Where the system lacks this inherent flexibility the designer should then consider adding flexibility through the use of metallic bellows-type expansion joints.

1.4 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

2. Referenced Documents

2.1 *ANSI Standards:*
B16.5 Pipe Flanges and Flanged Fittings[2]
B16.25 Butt Welding Ends[2]
B31.1 Power Piping Code[2]
2.2 *ASME Standards:*
Section VIII, Division 1, Pressure Vessels[3]
Section IX, Welding and Brazing Qualifications[3]
2.3 *EJMA Standard:*
Standards of the Expansion Joint Manufacturer's Association[4]
2.4 *Pipe Fabrication Institute Standard:*
ES-3 Fabrication Tolerances[5]

3. Terminology Definitions

3.1 Expansion joint definitions shall be in accordance with those in the EJMA standards.

3.2 *double expansion joint*—expansion joint consisting of two bellows joined by a common connector.

3.3 *Discussion*—The common connector is anchored to some rigid part of the installation by means of an anchor base. The anchor base may be attached to the common connector either at installation or at time of manufacture. Each bellows acts as a single expansion joint and absorbs the movement of the pipe section in which it is installed independently of the other bellows.

3.4 *gimbal expansion joint*—expansion joint designed to permit angular rotation in any plane by the use of two pairs of hinges affixed to a common floating gimbal ring.

3.5 *Discussion*—The gimbal ring, hinges, and pins are designed to restrain the thrust of the expansion joint as a result of internal pressure and extraneous forces, where applicable.

3.6 *hinged expansion joint*—expansion joint containing one bellow designed to permit angular rotation in one plane only by the use of a pair of pins through hinge plates attached to the expansion joint ends.

3.7 *Discussion*—The hinges and hinge pins are designed to restrain the thrust of the expansion joint as a result of internal pressure and extraneous forces. Hinged expansion joints should be used in sets of two or three to function properly.

3.8 *pressure balanced expansion joint*—expansion joint designed to absorb axial movement or lateral deflection, or both, while restraining the pressure thrust by means of tie devices interconnecting the flow bellows with an opposed bellows also subjected to line pressure.

3.9 *Discussion*—This type of expansion joint is intended for use where a change of direction occurs in a run of piping. The flow end of a pressure balanced expansion joint sometimes contains two bellows separated by a common connector, in which case it is called a universal pressure balanced expansion joint.

3.10 *single expansion joint*—simplest form of expansion joint, consisting of single bellows construction, designed to

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[1] This specification is under the jurisdiction of ASTM Committee F-25 on Ships and Marine Technology and is the direct responsibility of Subcommittee F25.13 on Piping Systems.

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[2] Available from American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.

[3] Available from American Society of Mechanical Engineers, 345 E. 47th St., New York, NY 10017.

[4] Available from Expansion Joint Manufacturer's Association, 25 N. Broadway, Tarrytown, NY 10591. The Standards of the Expansion Joint Manufacturer's Association are a collection of standards developed by this industry and published in one volume, herein called EJMA Standards.

[5] Available from Pipe Fabrication Institute, 1326 Freeport Rd., Pittsburgh, PA 15238.

absorb all movement of the pipe section in which it is installed.

3.11 *swing expansion joint*—expansion joint designed to absorb lateral deflection or angular rotation, or both, in one plane.

3.12 *Discussion*—Pressure thrust and extraneous forces are restrained by the use of a pair of swing bars, each of which is pinned to the expansion joint ends.

3.13 *universal expansion joint*—expansion joint containing two bellows joined by a common connector for the purpose of absorbing any combination of axial movement, lateral deflection, and angular rotation.

3.14 *Discussion*—Universal expansion joints are usually furnished with control rods to distribute the movement between the two bellows of the expansion joint and stabilize the common connector.

4. Ordering Information

4.1 An expansion joint is a unique product and must be specifically designed for the intended service. It is the responsibility of the piping system designer to supply sufficient engineering data necessary for the complete design. The information compiled by the piping system designer must be complete and contain all pertinent data detailing the conditions under which the expansion joint is expected to operate.

4.2 Orders for each expansion joint shall include the following information:

4.2.1 Title, designation number, and latest revision of this specification.

4.2.2 *Size*—The nominal pipe diameter or specific ducting diameter.

4.2.3 *Type of Expansion Joint*—single, double, universal, guided, hinged, gimbal, swing, or pressure balanced.

4.2.4 *Flow Characteristics*:

4.2.4.1 *Flow Medium*—indicate whether the medium is gas or liquid.

4.2.4.2 Flow velocity, medium density, or viscosity, or combination thereof.

4.2.4.3 Flow direction.

4.2.5 *Pressure in psig (N/mm^2)*—design, operating, and test pressures.

4.2.6 *Temperature in °F (°C)*—design, operating, and installation temperatures.

4.2.7 *Movement*—axial (extension, compression); lateral (single plane, multiplane); angular; torsional (to be avoided). Differentiate between start-up, operational, or field installation tolerance movements.

4.2.8 *Materials*—Material types (including that for the bellows) shall be specified by the purchaser (see 5.1 for material restrictions).

4.2.9 *Internal Liner*—Liner shall be specified when needed because of flow velocity or other flow conditions. Specific criteria for liners is shown in Section C-3 of the EJMA Standards (see 6.6).

4.2.10 *External Cover*—To protect personnel having close access to the bellows, when thermal insulation is to be added in the field, or when external mechanical damage is possible (see 6.5).

4.2.11 *End Fittings*—The type of end connections such as flanged, threaded, or others to match the mating piping or terminal equipment.

4.2.12 *Accessories*—Specify what accessories are required and the conditions under which they operate. Consider items such as insulation lugs, tie, limit, or control rods, pantographic linkages, trunions, gimbals, drains, purge connections, anchor bases, and interply monitoring devices.

4.2.13 *Dimensional Limitations*—If space limitations exist, specify the maximum overall length, maximum outside diameter, minimum inside diameter, and installation tolerances.

4.2.14 *Operating Forces*—Specify calculated bellows spring forces and pressure thrust forces if they are required for subsequent anchor design or other piping systems analysis. If there are maximum allowable values, these must also be specified.

4.2.15 *Installation Position*—horizontal, vertical (flow up or down). Specify if liner drainage holes are required.

4.2.16 *Cycle Life Requirements*—Specify an anticipated number of thermal cycles over the intended life of the expansion joint.

4.2.17 *Testing Requirements*—Specify testing requirements in addition to the hydrostatic test required by 9.4 (for example, vacuum testing, testing at operating temperature).

4.2.18 *Inspection Requirements*—Specify inspection requirements in addition to the inspection required by Section 9 (that is, radiographic, fluorescent penetrant, or mass spectrometer).

4.2.19 *Piping Code Requirements*—Specify any piping or design code that must be used as the basis for design in addition to those specified in 5.2.

4.2.20 *Special Requirements*—Specify the magnitude of special system conditions such as vibration, shock, or hydraulic surge.

4.2.21 *Shipping Requirements*—Specify whether special packing is required including protection for extended outside storage, export handling, or special lifting considerations for heavy or large assemblies.

4.2.22 *Piping Drawing*—In addition to specifying the above information it would be beneficial to provide a drawing of the proposed piping system.

4.2.23 *Supplementary Requirements*—Specify any additional requirements not identified herein.

4.3 Fig. 1 and Fig. 2 should be used as a guide in ordering expansion joints to this specification.

5. Materials and Manufacture

5.1 *Materials*:

5.1.1 Pressure-containing parts shall be manufactured from material specifications and grades listed in Section VIII, Division 1, of the ASME Code or ANSI B31.1. End connection material shall have in service properties similar to the bellows material. Flanges shall meet ANSI B16.5.

5.1.2 All other materials of construction shall be of the type specified by the user and shall conform to an ASTM or ASME material specification. Materials not identified by the ordering data shall be of the manufacturer's standard and of the same quality used for the intended purpose in commercial practice.

5.1.3 Materials used shall be free from defects that would adversely affect the performance of the expansion joint.

COMPANY:	DATE / /
	SHEET OF
PROJECT:	INQUIRY NO.
	JOB NO.

ITEM NO./EJ TAG NO.							
1	QUANTITY			EJMA PAGE REFERENCE			
2	NOMINAL SIZE/I.D./O.D. (IN.)						
3	EXPANSION JOINT TYPE			1			
4a	FLUID INFORMATION	MEDIUM GAS/LIQUID		5, 6, 147 77			
4b		VELOCITY (FT./SEC)					
4c		FLOW DIRECTION					
5	DESIGN PRESSURE, PSIG			6, 19, 83, 135			
6	TEST PRESSURE, PSIG						
7a	TEMPERATURE	DESIGN (°F)		6, 13			
7b		MAXIMUM/MINIMUM (°F)					
7c		INSTALLATION (°F)					
8a	MAXIMUM INSTALLATION MOVEMENT	AXIAL COMPRESSION (IN.)		6, 7, 8, 141			
8b		AXIAL EXTENSION (IN.)					
8c		LATERAL (IN.)					
8d		ANGULAR (DEG.)					
9a	MAXIMUM DESIGN MOVEMENTS	AXIAL COMPRESSION (IN.)		6, 7, 13, 47			
9b		AXIAL EXTENSION (IN.)					
9c		LATERAL (IN.)					
9d		ANGULAR (DEG.)					
9e		NO. OF CYCLES					
10a	OPERATING FLUCTUATIONS	AXIAL COMPRESSION (IN.)		84			
10b		AXIAL EXTENSION (IN.)					
10c		LATERAL (IN.)					
10d		ANGULAR (DEG.)					
10e		NO. OF CYCLES					
11a	MATERIALS OF CONSTRUCTION	BELLOWS		5, 6, 45			
11b		LINERS		77, 78			
11c		COVER		3, 7, 72			
11d		PIPE SPECIFICATION					
11e		FLANGE SPECIFICATION		3, 43			
12	RODS (TIE/LIMIT/CONTROL)			3, 4, 41			
13	PANTOGRAPHIC LINKAGE			4			
14	ANCHOR BASE (MAIN/INTERMEDIATE)			1, 2, 17			
15a	DIMENSIONAL LIMITATIONS	OVERALL LENGTH (IN.)					
15b		OUTSIDE DIAMETER (IN.)					
15c		INSIDE DIAMETER (IN.)					
16a	SPRING RATE LIMITATIONS	AXIAL (LBS./IN.)		54			
16b		LATERAL (LBS./IN.)					
16c		ANGULAR (IN.-LBS./DEG.)					
17	INSTALLATION POSITION HORIZ./VERT.			8, 141			
18a	QUALITY ASSURANCE REQUIREMENTS	BELLOWS WELD NDE	LONG. SEAM	133			
18b			ATTACH.				
18c		PIPING NDE					
18d		DESIGN CODE REQRD.					
18e		PARTIAL DATA REQRD.					
18f							
18g							
19	VIBRATION AMPLITUDE/FREQUENCY						

FIG. 1 Standard Expansion Joint Specification Sheet

Company ______________________________ Date ______________

______________________________ Proposal No. ______________

Project ______________________________ Inquiry/Job No. ______________

______________________________ Sheet ________ of ________

		ITEM NO.			
20.		PURGE, INSTRUMENTATION CONNECTION			
21a.	SPECIAL FLANGE DESIGN	FACING			
21b.		O.D. (IN.)			
21c.		I.D. (IN.)			
21d.		THICKNESS (IN.)			
21e.		B.C. DIAMETER (IN.)			
21f.		NO. HOLES			
21g.		SIZE HOLES			
21h.		HOLE ORIENTATION			

ISOMETRIC PIPING SKETCH:

FIG. 2 Supplemental Specification Sheet (To Be Used With Standard Expansion Joint Specification Sheet)

5.1.4 All material incorporated in the work covered by this specification shall be new. The use of rebuilt or used products is not allowed under this specification.

5.1.5 Materials for hinge or gimbal hardware, or other sliding parts, shall be chosen to minimize galling of the contacting parts.

5.2 *Manufacture*:

5.2.1 Expansion joints shall be designed and fabricated in accordance with requirements set forth in the ordering data and the EJMA Standards.

5.2.2 Nonstandard flanges shall be designed and fabricated in accordance with Appendix 2 of Section VIII, Division 1, of the ASME Code. Flanges machined from plate shall not be used at pressures exceeding 150 psi (1034 kPa) and temperatures exceeding 450°F (232°C). Hubbed flanges machined from plate or bar stock shall meet the requirements of Appendix 2, Paragraph 2-2(*d*) of Section VIII, Division 1, of the ASME Code.

5.2.3 All welding shall be accomplished in accordance with ANSI B 31.1.

5.2.4 Welding personnel and welding procedures shall be qualified in accordance with the applicable sections of Section IX of the ASME Code.

5.2.5 All fabrication details not covered by the referenced codes and standards shall be taken from the appropriate ANSI standard. If no standard applies, accepted industry practice shall govern.

5.2.6 The bellows shall be of tested and proven convolution geometry.

6. Other Requirements

6.1 The details of design, material supply, fabrication, and testing of the complete product are the responsibility of the manufacturer unless specific details are requested by the purchaser.

6.2 The specified normal operating movements (axial, lateral, and angular) shall be available concurrently. The specified lateral and angular movements shall be available on either side of the expansion joint centerline.

6.3 Internal sleeves, external covers, and all attached hardware shall be constructed so as not to interfere with adjacent parts when the joint is in the fully deflected position.

6.4 Universal expansion joints shall be designed and fabricated to be self-supporting and not require any external structure for the support of the center pipe spool piece and its contents.

6.5 Expansion joints to be installed in systems above 150°F (66°C) shall have an external cover. When external mechanical damage is possible, a cover shall be fabricated to protect the joint and personnel.

6.6 Internal sleeves shall be installed in expansion joints when the fluid velocity of the system, where the expansion joint is to be installed, is greater than the values listed in Section C-3.1 of the EJMA Standards and where the flow velocity exceeds 75 % of the velocity calculated using Section C-3.1.4 of the EJMA Standards.

7. Dimensions and Permissible Variations

7.1 Dimensional tolerances on completed expansion joint assemblies shall be in accordance with Section D-2.9 of the EJMA Standards and Standard ES-3 of the Pipe Fabricating Institute.

8. Workmanship, Finish, and Appearance

8.1 The quality of workmanship shall be such as to produce a product that is in accordance with the requirements of this specification and ensures the proper functioning of all parts of the unit.

8.2 The bellows shall be manufactured and carefully handled to prevent surface flaws or deep scratches from being generated. The surface condition of the completed joint assembly shall be free from injurious surface discontinuities and any contaminants that would affect the operation of the assembly.

8.3 On completion of fabrication, and before shipment, the manufacturer shall clean the inside and outside of the completed assembly of all loose scale, grease, dirt, sand, rust, weld spatter, cutting chips, and any other foreign matter by any suitable means. The inside of the assembly shall then be inspected for cleanliness. All openings where practicable shall be suitably closed to prevent the entrance of foreign matter after cleaning and during shipment. The use of chlorinated solvents is prohibited.

9. Inspection

9.1 The responsibility for quality control rests with the manufacturer. However, all phases of fabrication may be subject to review by a representative of the purchaser.

9.2 The inspector representing the purchaser shall have access at all times, while work on the contract of the purchaser is being performed, to all parts of the manufacturer's plant that concern the manufacture of the product ordered. The manufacturer shall afford the inspector all reasonable facilities to satisfy the inspector that the product is being furnished in accordance with this specification. Inspection shall be made at the place of manufacture before shipment, unless otherwise specified, and shall be scheduled not to interfere unnecessarily with the operations of the manufacturer. This requirement applies to all subcontractors.

9.2.1 Acceptance of a particular phase of manufacturer of an assembly by a purchaser's representative shall not be considered a waiver of any of the requirements of this specification and shall not relieve the manufacturer of the responsibility of furnishing a satisfactory product.

9.3 When the bellows is formed from a longitudinally butt-welded cylinder, the longitudinal weld(s) shall be 100 % liquid penetrant examined on the outside and inside surfaces (if accessible) before forming. Liquid penetrant examination on all accessible inside and outside weld surfaces shall be repeated after forming. All other welds essential to pressure containing or restraining shall be liquid penetrant examined. Ferromagnetic materials may be examined by magnetic particle inspection instead of liquid penetrant at the manufacturer's option. Liquid penetrant and magnetic particle inspection shall be in accordance with Section D-3.1.2 of the EJMA Standards.

9.4 All pressure retaining components shall be hydrostatically tested to 1.5 times their design pressure as outlined in Section D-3.1.6 of the EJMA Standards. Moment restraint, simulating piping rigidity, shall be used if necessary. The expansion joint shall be vented before hydrotest. Test pressure shall be held for 10 min.

9.4.1 Unless otherwise specified, potable water is acceptable for hydrotesting.

9.4.2 All piping and bellows shall be thoroughly drained after hydrotesting.

9.4.3 Pneumatic testing may be substituted for hydrostatic testing at the manufacturer's option. When substituted, pneumatic testing shall be accomplished in accordance with Section 137.5 of ANSI B31.1.

9.5 A dimensional inspection of the completed expansion joint assemblies shall be performed in accordance with Section D-2.9 of the EJMA Standards and Standard ES-3 of the Pipe Fabricating Institute.

9.6 A visual examination of the completed expansion joint shall be made.

10. Rejection and Rehearing

10.1 Expansion joint assemblies or parts thereof indicating fabrication not in accordance with the manufacturing drawings and procedures, or this specification, shall be subject to rejection and shall be resolved in accordance with the manufacturer's quality assurance program (see Section 14).

10.2 All repairs shall be in accordance with the specified code and other applicable specifications.

10.3 Expansion joint assemblies or parts thereof accepted by the purchaser's representative at the place of manufacture that subsequently reveal imperfections not previously detected or which by subsequent tests or analysis show nonconformance with this specification are subject to rejection.

11. Certification

11.1 When specified in the purchase order or contract, the manufacturer's certification shall be furnished to the purchaser. It shall state that each expansion joint has been manufactured, tested, and inspected in accordance with this specification and the requirements have been complied with. When specified, a report of any test results shall be furnished.

11.2 When specified, certification of the conformance to the requirements of this specification may be made by a third party.

11.3 ASTM/ASME mill test reports are required for pressure retaining and containing components.

11.4 No records are required for pipe fittings or flanges provided they are made and marked in accordance with an acceptable standard (such as ANSI). Certificates of conformance are required when the markings are missing or are removed during fabrication.

12. Product Marking

12.1 Each expansion joint shall be provided with a permanently attached corrosion resistant nameplate indicating as a minimum the following information:

12.1.1 Manufacturer's name.

12.1.2 Manufacturer's model number.

12.1.3 *Design Conditions*—pressure, temperature, movements.

12.1.4 This specification number (indicating compliance thereto).

12.1.5 Purchaser's specified component item number, if ordered.

12.2 When an expansion joint is supplied with an internal liner, a permanent arrow indicating the direction of flow shall be plainly visible on the outside of the expansion joint.

12.3 Impression stamping directly on bellows material is not permitted.

13. Packaging and Shipping

13.1 The expansion joint shall be containerized or shipped on pallets with all materials strapped down and prepared for shipment in such a manner that the quality, cleanliness, and finish shall be maintained during shipment.

13.2 Yellow painted shipping bars shall be furnished to maintain proper shipping length and alignment, and designed not to interfere with the installation of the assembly. The shipping bars shall be removed after installation and before piping system test. Expansion joints with tie rods can be provided with tie rod spacers instead of shipping bars.

13.3 Installation instructions shall be supplied in a weatherproof envelope with each expansion joint assembly.

13.4 When the expansion joint is to be transported to the job site by ship, it should preferably be sent as below deck cargo.

13.5 All external surfaces shall be treated and painted in accordance with the manufacturer's standard practices, unless otherwise specified. Paint shall be suitable for service temperatures.

14. Quality Assurance

14.1 The manufacturer shall have a current certificate of authorization to manufacture ASME Section VIII, Division 1, Pressure Vessels to assure an adequate quality assurance program that is applicable to all phases of manufacturing, including materials supplied by subcontractors.

14.2 Nothing in this specification shall relieve the manufacturer of the responsibility for performing, in addition to the requirements of this specification, such analyses, tests, inspections, or other activities that the manufacturer considers necessary to ensure that the design, material, and workmanship are satisfactory for the service intended, or as may be required by common usage or good practice.

15. Keywords

15.1 expansion joint; metallic bellows-type expansion joints; piping systems; piping thermal contraction; piping thermal expansion

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements are for use when desired by the purchaser. Other requirements not identified in this specification may be included by agreement between the manufacturer and the purchaser.

S1. Documents for Approval and/or Records

S1.1 Manufacturing drawings.

S1.2 Welding procedures and qualifications.

S1.3 Applicable nondestructive examination procedures.

S1.4 Heat treatment procedures or temperature charts, or both.

S1.5 Complete engineering design analysis calculations for the metallic bellows or hardware, or both.

S1.6 ASME partial data forms.

S2. Qualification Testing

S2.1 When specified, the manufacturer shall furnish a first article test assembly to determine conformance with this specification. The test assembly shall consist of the bellows and appropriate end connections. Liners, covers, tie, limit or control rods, hinges, gimbal rings, and other similar devices need not be provided on the first article test unit, unless they are necessary for the performance of the specific test(s) verification.

S2.2 When specified, cyclic endurance testing (fatigue testing) shall be performed for the required number of complete cycles. The test shall be performed under pressure at ambient temperature and the assembly need be cycled in axial movement only.

S2.2.1 During the test, the pressure in the assembly shall be adjusted to simulate, as closely as possible, the maximum design pressure of the unit being qualified. The pressure may vary from this value during each cycle.

S2.2.2 A single test bellows can be used instead of a multiple bellows assembly being qualified.

S2.2.3 In determining the qualifying extension or compression, or both, the equivalent axial movement caused by lateral deflection and angular rotation shall be included. The equivalent axial movement shall be computed in accordance with the EJMA Standards and shall be algebraically added to the specified values of axial movement.

S2.3 The purchaser may require that the expansion joint be certified as passing shock requirements. The shock requirements shall be specified by the purchaser.

S2.3.1 The purchaser may require that the expansion joint be certified as passing vibration requirements. The vibration requirements shall be specified by the purchaser.

S2.3.2 When specified, other qualifying tests shall be performed on a first article test unit under the requirements of the purchaser's contract.

CERTIFICATE

By Authority Of
THE UNITED STATES OF AMERICA
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By the Authority Vested By Part 5 of the United States Code § 552(a) and Part 1 of the Code of Regulations § 51 the attached document has been duly INCORPORATED BY REFERENCE and shall be considered legally binding upon all citizens and residents of the United States of America. *HEED THIS NOTICE*: Criminal penalties may apply for noncompliance.

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Document Name: ASTM F1121: Standard Specification for International Shore Connections for Marine Fire Applications

CFR Section(s): 33 CFR 126.15(a)(5)

Standards Body: American Society for Testing and Materials

APPROVED

Official Incorporator:

THE EXECUTIVE DIRECTOR
OFFICE OF THE FEDERAL REGISTER
WASHINGTON, D.C.

Designation: F 1121 – 87 (Reapproved 1998)

An American National Standard

Standard Specification for International Shore Connections for Marine Fire Applications[1]

This standard is issued under the fixed designation F 1121; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers the design and manufacture of international shore connections to be used with marine fire fighting systems during an emergency when a stricken ship has a system failure.

1.2 International shore connections are portable universal couplings that permit connection of shipboard firemain systems between one ship and another or between a shore facility and a ship when their respective system threading is mismatched. Both the ship and the facility are expected to have a fitting such that in an emergency can be attached to their respective fire hose and bolted together to permit charging the ship's system. It must be portable to accommodate hose to hose connection and allow assistance from any position.

1.3 The international shore connection is required by international treaty[2,3] to be carried onboard all passenger and cargo vessels of 500 gross tons or more, regardless of firemain size, engaged in international voyages, and is recommended for all vessels that would be expected to render assistance. It is also intended to be provided at shore facilities that would be used to supply water to a ship's firemain system.

1.4 Fabrication either on board a vessel, in a shipyard, or other shore facility is not precluded by this specification.

1.5 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

2. Ordering Information

2.1 The purchase order or inquiry for an international shore connection shall include the following as applicable:

2.1.1 Material of construction.

2.1.2 Title, number, and latest revision of this specification.

2.1.3 Maximum operating pressure (psig) (when above 150 psig, see 4.2).

2.1.4 Preservation (coating) requirements (if any, see 7.2).

2.1.5 Diameter and threading to be provided in the coupling.

3. Materials and Manufacture

3.1 The international shore connection may be machined from forgings, castings, plate or bar stock, or may be fabricated out of more than one piece.

3.2 The material shall be brass, bronze, or other suitable corrosion-resistant material. When fabricated out of more than one piece, the flange may be steel and the coupling a corrosion-resistant material. Aluminum shall not be used.

3.3 Nuts, bolts, and washers shall be a corrosion-resistant material.

4. Other Requirements

4.1 *Design*:

4.1.1 The connection shall consist of a flat face flange and a threaded coupling. Threading shall be specified by the purchaser.

4.1.2 The dimensions of the international shore connection shall be in accordance with Fig. 1.

4.2 The maximum allowable working pressure (MAWP) shall be at least 150 psig (1 N/mm^2).

4.3 The international shore connection shall be supplied with four bolts, ⅝ in. (16 mm) in diameter, at least 2 in. (50 mm) in length, and threaded at least to within 1 in. (25 mm) of the bolt head.

4.3.1 The bolts shall be supplied with four corresponding nuts and eight washers.

4.4 The international shore connection shall be supplied with a flange gasket suitable for the MAWP and seawater service.

5. Workmanship, Finish, and Appearance

5.1 The quality of workmanship shall be such as to produce a product that is in accordance with the requirements of this specification. Completed units shall be free from imperfections or defects that materially affect appearance or that may affect serviceability.

6. Inspection

6.1 Each finished international shore connection shall be visually examined and dimensionally checked to ensure it

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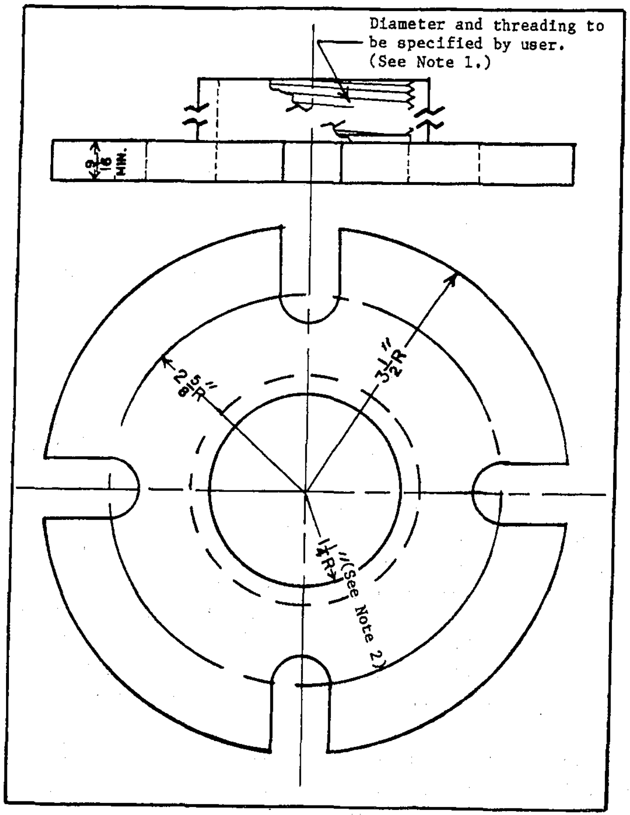
[1] This specification is under the jurisdiction of ASTM Committee F-25 on Ships and Marine Technology and is the direct responsibility of Subcommittee F25.13 on Piping Systems.

Current edition approved Dec. 31, 1987. Published February 1988.

[2] Amendments to the International Convention for the Safety of Life at Sea, Chapter II-2, Regulation 19, "International Shore Connection," 1974.

[3] International Maritime Organization Assembly Resolution A, XII 470, Jan. 4, 1987. This document is available from International Maritime Organization, 4 Albert Embankment, London, U.K. SE1 7SR.



NOTE 1—Fire hose coupling may be used.
NOTE 2—For 1½-in. fire hose coupling, the radius will be ¾ in.
NOTE 3—1 in. = 25.4 mm.

FIG. 1 International Shore Connection

corresponds to this specification.

7. Packaging and Preservation

7.1 Unless otherwise specified, the international shore connection shall be packaged for shipment in accordance with the manufacturer's standard commercial practice.

7.2 Preservation of the international shore connection, by the manufacturer or user, shall be satisfactory for preventing deterioration of the connection during long-term storage on vessels or at shore facilities.

8. Quality Assurance

8.1 The manufacturer shall use quality assurance procedures that assure manufacture of high quality international shore connections that are designed in accordance with this specification.

9. Keywords

9.1 fire fighting systems; international shore connections; hose-to-hose connection; marine fire applications; portable universal couplings; shipboard firemain systems; stricken ship

CERTIFICATE

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Not Affiliated Or Authorized by ASTM or by the United States Government

Document Name: ASTM F1122: Standard Specification for Quick Disconnect Couplings

CFR Section(s): 33 CFR 154.500(d)(3)

Standards Body: American Society for Testing and Materials

Official Incorporator:
THE EXECUTIVE DIRECTOR
OFFICE OF THE FEDERAL REGISTER
WASHINGTON, D.C.

Designation: F 1122 – 87 (Reapproved 1998)

An American National Standard

Standard Specification for Quick Disconnect Couplings[1]

1. Scope

1.1 This specification covers the manufacturing data required to produce a variety of styles and sizes of quick disconnect couplings for marine use that ensure interchangeability and safety of operation.

1.2 In general, quick disconnect couplings are hose and pipe end fittings that permit quick mechanical attachment by means other than bolted or threaded fittings. The method of attachment is a male coupling half (adapter) that fits into a female coupling half (coupler) of the same size. By closing attached cam handles, the coupling halves seal, permitting fluids to be transported under pressure through the quick disconnect coupling.

1.3 The values stated in this specification are in inch-pound units with SI units given in parentheses. The values of each system may not be exact equivalents. Therefore, each system should be considered separately.

1.4 The following safety hazards caveat pertains only to the test method described in this specification: *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ANSI Standards:*

B2.1 Pipe Threads[2]

B16.5 Pipe Flanges and Flanged Fittings, Steel-Nickel Alloy, and Other Special Alloys[2]

B16.24 Bronze Pipe Flanges and Flanged Fittings[2]

B16.42 Ductile Iron Pipe Flanges and Flanged Fittings[2]

B31.1 Power Piping Code[2]

2.2 *MSS Standards:*

MSS-SP-6 Standard Finish for Contact Faces of Pipe Flanges and Connecting End Flanges of Valves and Fittings[3]

MSS-SP-25 Standard Marking System for Valves, Fittings, Flanges, and Unions[3]

MSS-SP-55 Quality Standard for Steel Castings for Valves, Flanges, and Fittings and Other Piping Components (Visual Method)[3]

2.3 *ASME Standards:*

Section VIII, Division 1, Pressure Vessels[4]

Section IX, Welding and Brazing Qualifications[4]

3. Definitions of Terms Specific to This Standard

3.1 *adapter*—one half of a quick disconnect coupling that fits into the coupler and seals against an elastomer gasket positioned inside the coupler.

3.2 *cam handles*—handles that are assembled to the coupler half which by closing engages the adapter sealing the coupling.

3.3 *coupler*—one half of a quick disconnect coupling that receives the adapter. This half contains the sealing gasket and cam handles (see Fig. 1).

NOTE 1—See Fig. 2 for a description of typical coupler pipe fittings.

4. Classification

4.1 Quick disconnect couplings shall consist of the following types:

4.1.1 *Standard Class*—This type is to be designed for a 4:1 burst factor of safety.

4.1.2 *Class I*—This type is to be designed for a 5:1 burst factor of safety.

4.2 Both Standard Class and Class I will be called quick disconnect couplings in the body of this specification unless otherwise specified.

5. Ordering Information

5.1 Purchase orders for quick disconnect couplings under this specification shall include the following applicable information:

5.1.1 Class.

5.1.2 Size and type of each coupling half-end connection. (Example—2- by 1½-in. NPT).

5.1.3 ASTM material designation and date including alloy specifications for the following:

5.1.3.1 Adapter and coupler halves,

5.1.3.2 Cam handle, and

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[1] This specification is under the jurisdiction of ASTM Committee F-25 on Ships and Marine Technology and is the direct responsibility of Subcommittee F25.13 on Piping Systems.

Current edition approved Dec. 31, 1987. Published February 1988.

[2] Available from American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.

[3] Available from Manufacturers' Standardization Society of the Valve and Fittings Industry, Inc., 1815 N. Fort Myers Dr., Arlington, VA 22209.

[4] Available from American Society of Mechanical Engineers, 345 E. 47th St., New York, NY 10017.

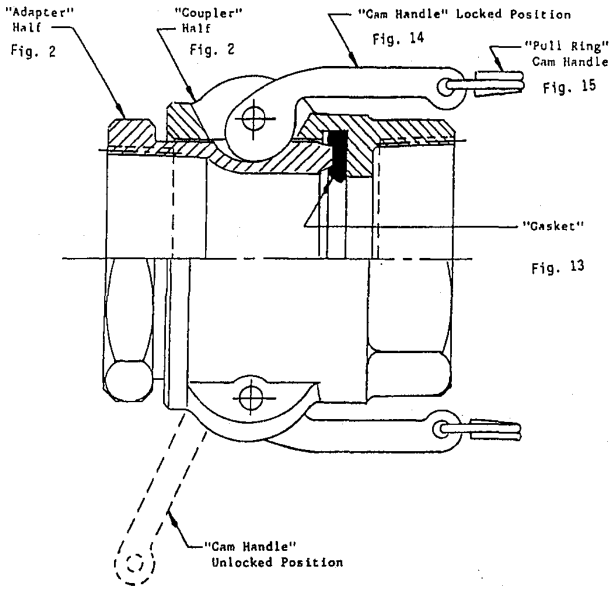


FIG. 1 Typical Coupler Assembly

5.1.3.3 Cam handle pivot pin.

5.1.4 Product or fluid in applicable system.

5.1.5 Shipping instructions.

5.1.6 Any special requirements, such as testing, coatings, and threads.

6. Materials and Manufacture

6.1 *Materials*:

6.1.1 Pressure-retaining parts shall be manufactured from material specifications and grades listed in Section VIII, Division 1, of the ASME Boiler and Pressure Vessel Code or ANSI B31.1.

6.1.2 All other materials of construction shall be of the type specified by the user and shall conform to ASTM, ASME, or Metal Power Industry Federation material specifications. Materials not identified by the ordering data shall be of the manufacturer's standard and of the same quality used for the intended purpose in commercial practice.

6.1.3 All material incorporated in the work covered by this specification shall be new. The use of rebuilt or used products are not allowed under this specification.

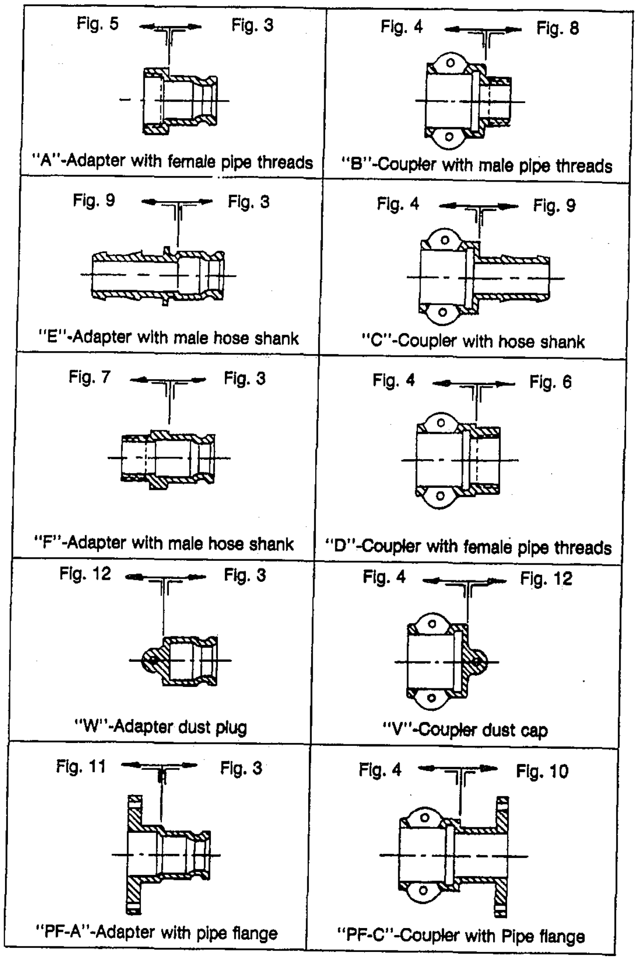
6.1.4 Gaskets are to be produced from a compressible elastomeric material and shall be compatible with the fluid to be transferred (see 5.1.4).

6.2 *Manufacture*:

6.2.1 Adapters and couplers are to be produced as castings or forgings. Cam handles may be produced by casting, forging, or sintered metal processes. Established commercial processing methods are to be used to produce these parts, provided chemical and physical properties are consistent with those cataloged for the specified materials.

6.2.2 Pipe threads on the service end of couplers or adapters, when specified, shall meet ANSI B2.1.

6.2.3 Flanges on the service end of couplers or adapters, when specified, shall meet ANSI B16.5, B16.24, or B16.42.



"A"-Adapter with female pipe threads

"B"-Coupler with male pipe threads

"E"-Adapter with male hose shank

"C"-Coupler with hose shank

"F"-Adapter with male hose shank

"D"-Coupler with female pipe threads

"W"-Adapter dust plug

"V"-Coupler dust cap

"PF-A"-Adapter with pipe flange

"PF-C"-Coupler with Pipe flange

FIG. 2 Adapter/Coupler Types (End Dimensional Data Located in Tables Indicated by Arrows)

6.2.4 Flanges shall be finish machined to specifications shown in MSS-SP-6.

6.2.5 Cam handles assembled to the coupler are to have a safety locking device to ensure against the handles being opened unintentionally or vibrating open. This locking device must require a separate, deliberate effort in the opening operation over the standard handle operation.

6.2.6 Cam handles shall be manufactured to contain the adapter within the coupler under rated pressure with no leakage occurring. The cam action shall not distort the couplers rendering the coupler unusable. The force required to close the cam handles shall be adequate to prevent leakage, but shall be easily attainable through hand operation by an average strength person. Handles should not need to be hammered closed.

6.2.7 Welding procedure qualifications, welder performance qualifications, and welding materials shall be in accordance with ANSI B 31.1 and Section IX of the ASME Code. Brazing or soldering shall not be used. Where radiography is required (see 12.1), all welds shall be butt welds.

7. Other Requirements

7.1 All couplings shall have a maximum allowable working pressure of not less than 150 psi (1034 kPa).

7.2 Maximum allowable working pressure (MAWP) for a Standard Class coupling shall be 25 % of its burst pressure.

7.3 Maximum allowable working pressure for a Class I coupling shall be 20 % of its burst pressure.

7.4 Burst pressure shall be determined in accordance with Section VIII, Division 1 of the ASME Code.

8. Dimensions

8.1 The dimensions and tolerances required to ensure interchangeability of adapter and coupler halves, of common sizes, shall be as given in Figs. 3-15.

8.2 Sizes as listed in the tables correspond to NPS for piping systems.

9. Workmanship, Finish, and Appearance

9.1 Couplings are to be produced with quality workmanship. Casting surface quality is to be in accordance with MSS-SP-55. Machined surfaces are to be finish machined to a 125-μin. (3175-μmm) (AA) finish or better with no porosity showing.

9.1.1 Couplings are to be free of burrs or sharp edges. Machined surfaces are to be free of nicks or scratches that may affect the sealing capabilities of the couplings.

9.1.2 Surfaces are to be sound with good appearance and true pattern. Internal surfaces, if not machined, shall be smooth, as expected from good quality casting, and free from any flaw that would render the part unsafe for its intended use.

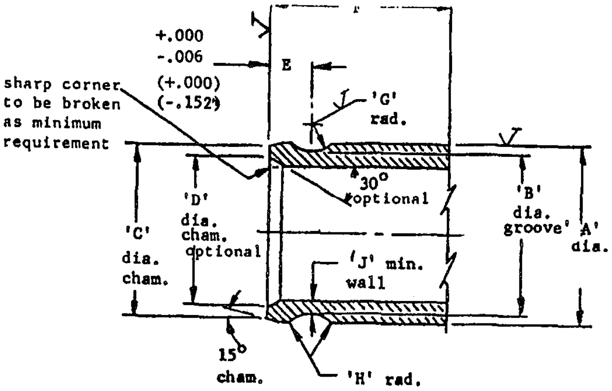
9.2 Cam handles are to be smooth, having no burrs or sharp edges. Cam closing surface is to be continuous, providing an increasing axial pull on mating adapter until proper seating against the gasket occurs.

9.3 Defective parts are not to be repaired by welding, brazing, or any other method, to fill porosity or other flaws in the casting.

9.4 Gaskets are to be produced having parallel sealing faces. Faces are not to contain any imperfections that will allow leakage to occur at working pressure.

10. Number of Tests

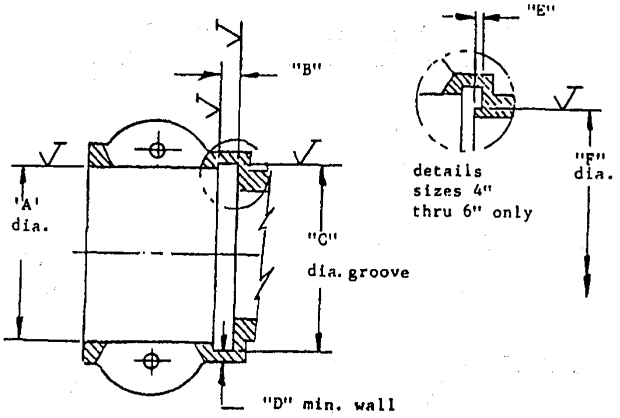
10.1 A prototype coupling of each size of each particular



Note 1—Unidentified tolerances; fractional = ±1⁄64 (±0.4), decimal = +0.000/−0.005 (+0.000/−0.127), angular = ±2° (±0.035 rad)

Size	Dimensions, in. (mm)								
	A	B	C	D	E	F	G	H	J
½	1.264 (32.1)	1.035 (26.3)	1 7⁄32 (31)	27⁄32 (21)	0.471 (12)	1 (25.4)	0.378 (9.6)	1⁄16 (1.6)	3⁄32 (2.4)
¾	1.264 (32.1)	1.035 (26.3)	1 7⁄32 (31)	31⁄32 (24.6)	0.471 (12)	1 (25.4)	0.378 (9.6)	1⁄16 (1.6)	3⁄32 (2.4)
1	1.446 (36.7)	1.144 (29)	1⅜ (34.9)	1 3⁄32 (27.8)	0.565 (14.3)	1 5⁄16 (33.3)	0.378 (9.6)	3⁄32 (2.4)	3⁄32 (2.4)
1¼	1.792 (45.5)	1.388 (35.2)	1 23⁄32 (43.6)	1¼ (31.7)	0.690 (17.5)	1 9⁄16 (39.7)	0.441 (11.2)	⅛ (3)	⅛ (3)
1½	2.105 (53.4)	1.690 (42.9)	2 1⁄32 (51.6)	1 9⁄16 (39.7)	0.690 (17.5)	1⅝ (41.3)	0.441 (11.2)	⅛ (3)	⅛ (3)
2	2.484 (63.1)	2.065 (52.4)	2 13⁄32 (61.1)	1 15⁄16 (49.2)	0.848 (21.5)	1⅞ (47.6)	0.441 (11.2)	⅛ (3)	⅛ (3)
2½	2.985 (75.8)	2.545 (64.6)	2⅞ (73)	2 7⁄16 (61.9)	0.848 (21.5)	1 15⁄16 (49.2)	0.441 (11.2)	⅛ (3)	5⁄32 (4)
3	3.604 (91.5)	3.202 (81.3)	3½ (88.9)	3 3⁄32 (78.6)	0.895 (22.7)	2 (50.8)	0.503 (12.8)	⅛ (3)	5⁄32 (4)
4	4.708 (119.6)	4.307 (109.4)	4 19⁄32 (116.7)	4⅛ (104.8)	0.895 (22.7)	2 1⁄16 (52.4)	0.503 (12.8)	⅛ (3)	7⁄32 (5.6)
5	5.728 (145.5)	5.312 (134.9)	5⅝ (142.9)	5⅛ (130.2)	0.897 (22.8)	2⅛ (54)	0.503 (12.8)	⅛ (3)	7⁄32 (5.6)
6	6.929 (176)	6.362 (161.6)	6 13⁄16 (173)	6 5⁄32 (156.4)	0.963 (24.5)	2¼ (57.1)	0.659 (16.7)	⅛ (3)	7⁄32 (5.6)

FIG. 3 Adapter End Dimensions



NOTE 1—Unidentified tolerances; fractional = ±1/64 (±0.4), angular = ±2° (±0.035 rad), decimal = ±0.005 (±0.127)

Size	Dimensions, in. (mm)					
	A	B	C	D	E	F
½	1.274 (32.3)	¼ (6.3)	1 27/64 (36.1)	3/32 (2.4)	. . .	. . .
¾	1.274 (32.3)	¼ (6.3)	1 27/64 (36.1)	3/32 (2.4)	. . .	. . .
1	1.464 (37.2)	9/32 (7.1)	1 19/32 (40.5)	3/32 (2.4)	. . .	. . .
1¼	1.810 (46)	9/32 (7.1)	2 (50.8)	⅛ (3)	. . .	. . .
1½	2.123 (53.9)	9/32 (7.1)	2¼ (57.1)	⅛ (3)	. . .	. . .
2	2.508 (63.7)	9/32 (7.1)	2 11/16 (68.3)	⅛ (3)	. . .	. . .
2½	3.009 (76.4)	9/32 (7.1)	3 3/16 (81)	5/32 (4)	. . .	. . .
3	3.628 (92.1)	9/32 (7.1)	3 25/32 (96)	5/32 (4)	. . .	. . .
4	4.732 (120.2)	9/32 (7.1)	4 15/16 (125.4)	7/32 (5.6)	3/32 (2.4)	3 29/32 (99.2)
5	5.752 (146.1)	9/32 (7.1)	5 31/32 (151.6)	7/32 (5.6)	3/32 (2.4)	4 51/64 (121.8)
6	6.948 (176.5)	9/32 (7.1)	7 9/64 (181.4)	7/32 (5.6)	3/32 (2.4)	5 29/32 (150)

FIG. 4 Coupler End Dimensions

design shall be tested to determine conformance to this specification.

10.2 Each coupling shall be tested as outlined in production testing of 11.2.

11. Test Methods

11.1 Prototype testing of each size of each particular design shall be as follows. Maintain the indicated test pressures for at least 1 min without leakage.

11.1.1 Pressure test to twice the MAWP after having been cycled (connected, closed, opened, and disconnected) three times.

11.1.2 Pressure test at MAWP while applying a moment of 1000 in.-lbs (113 N·M) to one coupling half attempting to twist it loose. Reapply MAWP after the moment is removed.

11.2 *Production Test*—Hydrostatically test each coupling to 1.5 times MAWP.

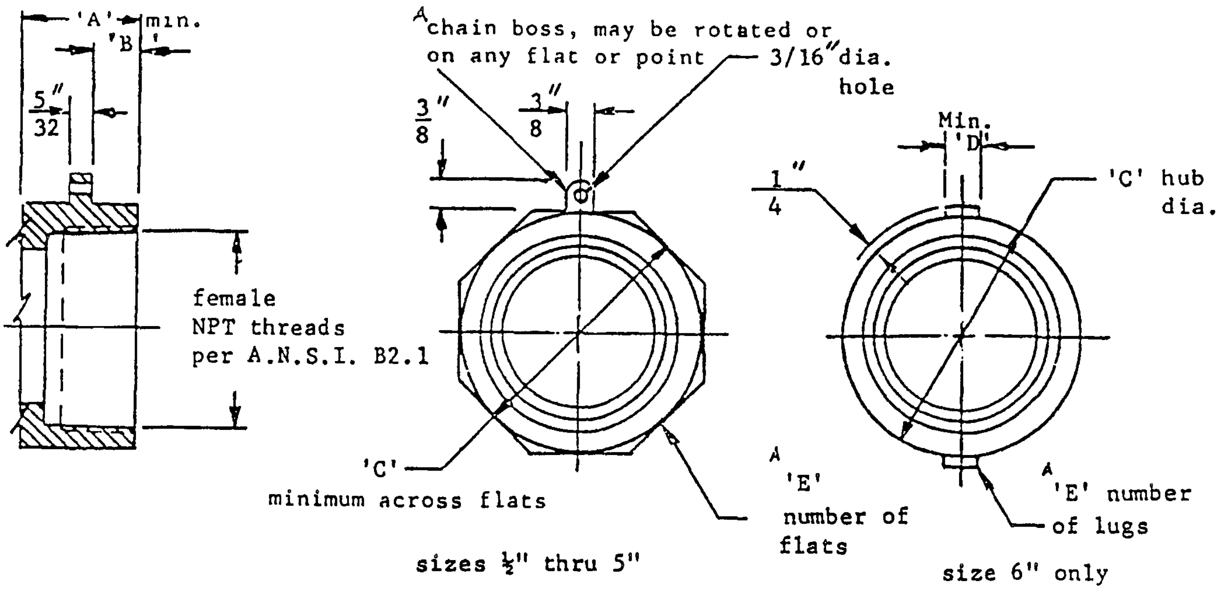
11.3 The test apparatus for 11.2 is to be a state-of-the-art device, designed to apply internal pressure to the coupling halves with gasket in place. Dye the fluid used to apply the hydrostatic pressure to facilitate observation of leakage should leakage occur.

12. Inspection

12.1 Nondestructive examination of welds shall be performed as required by ANSI B31.1. Additionally, 100 % radiography of all welds is required for couplings equal to or greater than 4-in. (100-mm) nominal diameter and when the nominal wall thickness is greater than 0.375 in. (9.4 mm).

12.2 The manufacturer is responsible for the inspection and testing of each coupling and assuring conformity to this specification. Samples selected for inspection, at least one coupling from each lot of 100 or fraction thereof, are to be dimensionally checked 100 % to verify adherence to this specification. Couplings having threads are to be inspected using proper thread gages. The entire lot of couplings is to be visually checked for porosity and other flaws that could adversely affect usability of this product.

12.3 The manufacturer shall afford the purchaser's inspector all reasonable facilities necessary to satisfy him that the material is being furnished in accordance with this specification. Inspection by the purchaser shall not interfere unnecessarily with the manufacturer's operations. All examinations and inspections shall be made at the place of manufacture,



Note 1—[A] Chain boss to be provided at the manufacturer's discretion; number of flats or lugs provided are at the manufacturer's discretion. Unidentified tolerances; fractional ±1/32 (±0.8)

Size	Dimensions, in. (mm)				
	A	B	C (minimum)	D (minimum)	E
½	9/16 (14.3)	7/32 (5.6)	1.259 (32)	. . .	8
¾	9/16 (14.3)	7/32 (5.6)	1.259 (32)	. . .	8
1	9/16 (14.3)	7/32 (5.6)	1.441 (36.6)	. . .	8
1¼	9/16 (14.3)	7/32 (5.6)	1.787 (45.4)	. . .	8
1½	9/16 (14.3)	7/32 (5.6)	2.100 (53.3)	. . .	8
2	9/16 (14.3)	7/32 (5.6)	2.479 (63)	. . .	8
2½	¾ (19)	5/16 (7.9)	2.980 (75.7)	. . .	8
3	¾ (19)	5/16 (7.9)	3.599 (91.4)	. . .	8
4	1 (25.4)	13/32 (10.3)	4.703 (119.5)	. . .	8
5	1 (25.4)	13/32 (10.3)	5.723 (145.4)	. . .	8
6	1 1/16 (27)	NA	6.924 (175.9)	¾ (19)	2

FIG. 5 Adapter Female Threads End

unless otherwise agreed upon.

12.4 Other tests, when agreed upon, shall be made from material of the lots covered in the order.

13. Certification

13.1 When specified in the purchase order or contract, the manufacturer's certification shall be furnished to the purchaser stating that the samples representing each lot have been manufactured, tested, and inspected in accordance with this specification and the requirements have been met. When specified in the purchase order or contract, a report of the test results shall be furnished.

14. Product Marking

14.1 Each adapter and coupler shall be marked in accordance with MSS-SP-25 including the following:

14.1.1 ASTM designation of this specification.

14.1.2 "Cl I" if it is a Class I adapter or coupler.

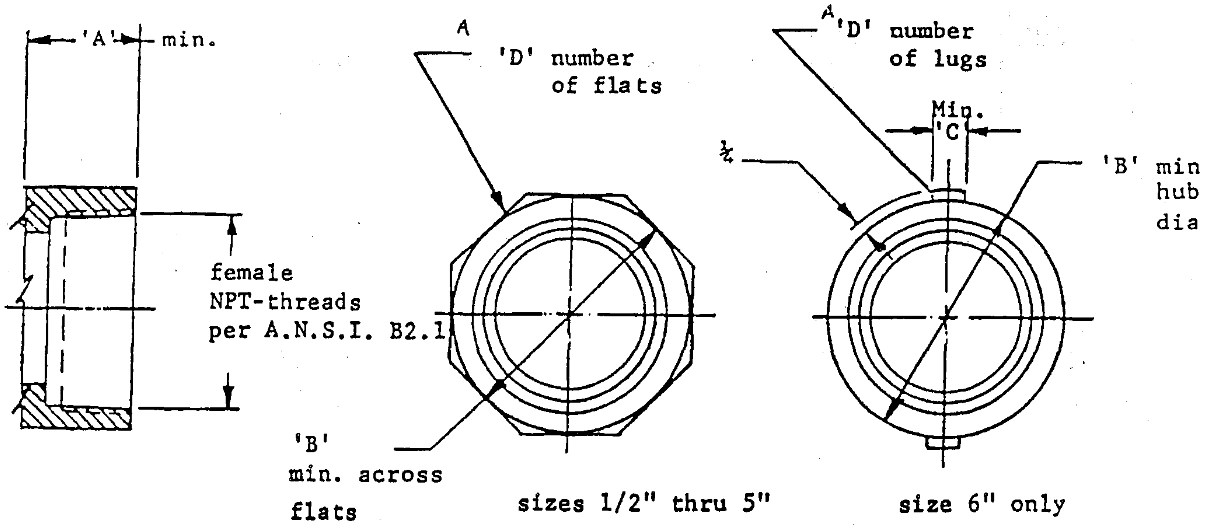
15. Packaging and Package Marking

15.1 The couplings shall be packed according to the manufacturer's standard practice, providing reasonable care to prevent lost or damaged parts in shipment.

15.2 Containers and packages shall be marked or tagged to adequately identify the contents or purchaser's order number.

16. Quality Assurance

16.1 The manufacturer of the quick disconnect couplings shall maintain the quality of the couplings that are designed,

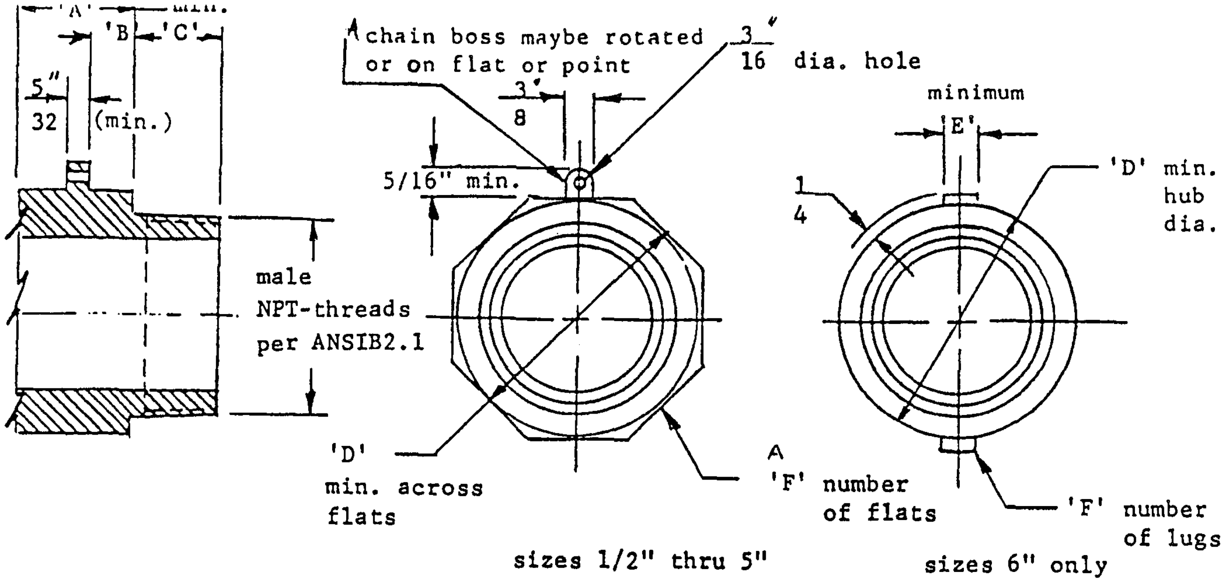


NOTE 1—^{A} Number of flats or lugs provided is at the manufacturer's discretion.
Unidentified tolerance; fractional ±1⁄32 (±0.8)

Size	Dimensions, in. (mm)			
	A	B (minimum)	C (minimum)	D
½	43⁄64 (17.1)	1 3⁄16 (30.2)	. . .	8
¾	¾ (19)	1 ¼ (37.7)	. . .	8
1	¾ (19)	1 ½ (38.1)	. . .	8
1 ¼	¾ (19)	2 (50.8)	. . .	8
1 ½	⅞ (22.2)	2 9⁄32 (57.9)	. . .	8
2	⅞ (22.2)	2 ¾ (69.8)	. . .	8
2 ½	1 5⁄32 (29.4)	3 5⁄16 (84.1)	. . .	8
3	1 5⁄32 (29.4)	3 15⁄16 (100)	. . .	8
4	1 ⅜ (34.9)	4 15⁄16 (125.4)	. . .	8
5	1 ¾ (44.4)	6 (152.4)	. . .	8
6	1 ¼ (31.7)	7 3⁄16 (182.6)	¾ (19)	2

FIG. 6 Coupler Female Thread End

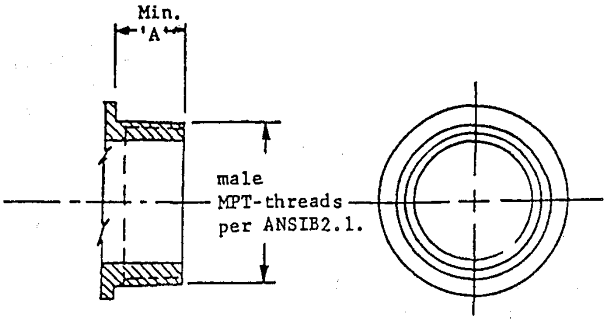
tested, and marked in accordance with this specification. At no time shall a coupling be sold with this specification designation that does not meet the requirements herein.



NOTE 1—[A] Chain boss and number of flats or lugs provided is at the manufacturer's discretion.
Unidentified tolerance; fractional ±1⁄32 (±0.8)

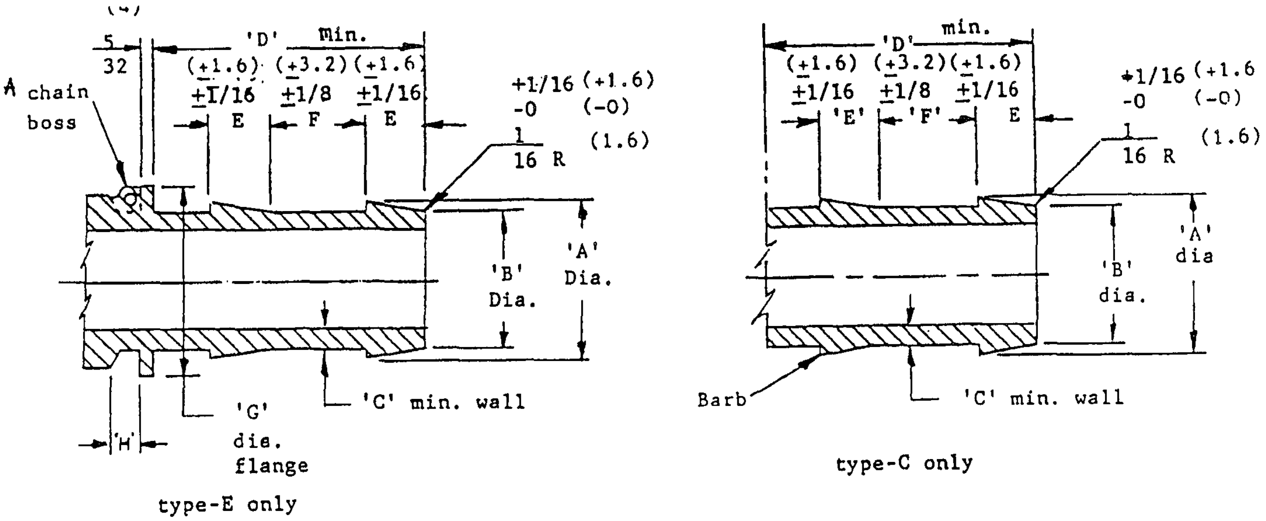
Size	Dimensions, in. (mm)					
	A	B	C (minimum)	D (minimum)	E (minimum)	F
½	9⁄16 (14.3)	13⁄64 (5.2)	5⁄8 (15.9)	(1.259) (32)	. . .	8
¾	9⁄16 (14.3)	13⁄64 (5.2)	5⁄8 (15.9)	1.259 (32)	. . .	8
1	9⁄16 (14.3)	13⁄64 (5.2)	7⁄8 (22.2)	1.441 (36.6)	. . .	8
1¼	(14.3)	13⁄64 (5.2)	7⁄8 (22.2)	1.787 (45.4)	. . .	8
1½	9⁄16 (14.3)	13⁄64 (5.2)	7⁄8 (22.2)	2.100 (53.3)	. . .	8
2	9⁄16 (14.3)	13⁄64 (5.2)	15⁄16 (23.8)	2.479 (63)	. . .	8
2½	¾ (19)	19⁄64 (7.5)	1 5⁄16 (33.3)	2.982 (75.7)	. . .	8
3	¾ (19)	19⁄64 (7.5)	1 7⁄16 (36.5)	3.599 (91.4)	. . .	8
4	1 (25.4)	27⁄64 (10.7)	1 9⁄16 (39.7)	4.703 (119.5)	. . .	8
5	1 (25.4)	27⁄64 (10.7)	1¾ (44.4)	5.723 (145.4)	. . .	8
6	1 (25.4)	. . .	1¾ (44.4)	6.924 (175.9)	¾ (19)	2

FIG. 7 Adapter Male Thread End



Size	Dimensions, in. (mm)
	A
½	⅝ (15.9)
¾	⅝ (15.9)
1	⅞ (22.2)
1¼	⅞ (22.2)
1½	⅞ (22.2)
2	15⁄16 (23.8)
2½	15⁄16 (33.3)
3	17⁄16 (36.5)
4	19⁄16 (39.7)
5	1¾ (44.4)
6	1¾ (44.4)

FIG. 8 Coupler Male Thread End



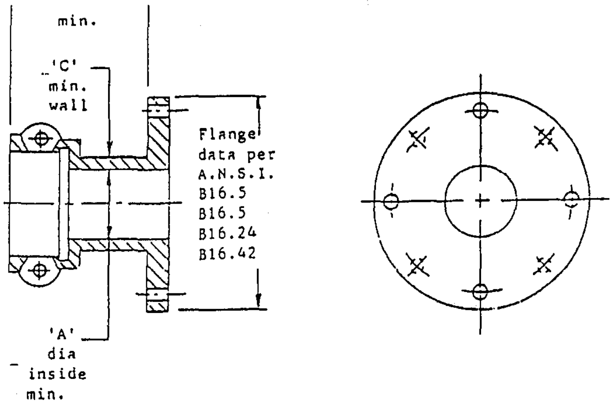
NOTE 1—^{A} Chain boss provided at the manufacturer's discretion.

NOTE 2—Additional barbs may be provided at the manufacturer's discretion.

Unidentified tolerance's = +1⁄32 (±0.8)

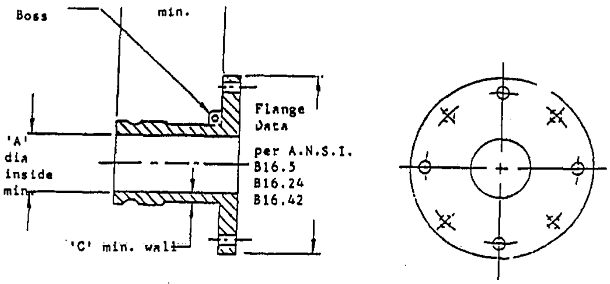
Size	Dimensions, in. (mm)							
	A	B	C	D	E	F	G	H
½	19⁄32 (15.1)	31⁄64 (12.3)	3⁄32 (2.4)	1 5⁄16 (33.3)	¼ (6.3)	¾ (19)	1¼ (31.7)	⅜ (9.5)
¾	27⁄32 (21.4)	47⁄64 (18.6)	3⁄32 (2.4)	2 (50.8)	¼ (6.3)	¾ (19)	1¼ (31.7)	⅜ (9.5)
1	1 5⁄64 (27.4)	63⁄64 (25)	3⁄32 (2.4)	2¼ (57.1)	⅜ (9.5)	¾ (19)	1⅝ (41.3)	7⁄16 (11.1)
1¼	1 11⁄32 (34.1)	1 15⁄64 (31.3)	⅛ (3)	2¼ (57.1)	⅜ (9.5)	13⁄16 (20.6)	2 (50.8)	7⁄16 (11.1)
1½	1 19⁄32 (40.5)	1 31⁄64 (37.7)	⅛ (3)	2⅜ (60.3)	⅜ (9.5)	13⁄16 (20.6)	2 5⁄16 (58.7)	7⁄16 (11.1)
2	2 3⁄32 (53.2)	1 31⁄32 (50)	⅛ (3)	2¾ (69.8)	⅜ (9.5)	1⅛ (28.6)	2 11⁄16 (68.3)	7⁄16 (11.1)
2½	2⅝ (66.7)	2 31⁄64 (63.1)	5⁄32 (4)	3⅛ (79.4)	7⁄16 (11.1)	1⅜ (34.9)	3 1⁄16 (81)	9⁄16 (14.3)
3	3⅛ (79.4)	2 31⁄32 (75.4)	5⁄32 (4)	4 (101.6)	½ (12.7)	1 9⁄16 (39.7)	3 25⁄32 (96)	9⁄16 (14.3)
4	4⅛ (104.8)	3 31⁄32 (100.8)	7⁄32 (5.6)	4¼ (107.9)	½ (12.7)	1¾ (44.4)	4⅞ (123.8)	9⁄16 (14.3)
5	5⅛ (130.2)	5 (127)	7⁄32 (5.6)	4½ (114.3)	½ (12.7)	1¾ (44.4)	6 9⁄16 (166.7)	⅝ (15.9)
6	6⅛ (155.6)	6 (152.4)	7⁄32 (5.6)	5½ (139.7)	½ (12.7)	2⅝ (66.7)	7⅛ (181)	¾ (19)

FIG. 9 Hose Shank End



Size	Dimensions, in. (mm)		
	A	B	C
½	11/16 (17.5)	2⅝ (66.7)	3/32 (2.4)
¾	13/16 (20.6)	2⅝ (66.7)	3/32 (2.4)
1	1 (25.4)	3 1/16 (77.8)	3/32 (2.4)
1¼	1 5/16 (33.3)	4 (101.6)	⅛ (3)
1½	1 9/16 (39.7)	4 (101.6)	⅛ (3)
2	1 15/16 (49.2)	4¼ (107.9)	⅛ (3)
2½	2 5/16 (58.7)	4¼ (107.9)	5/32 (4)
3	2⅞ (73)	4⅝ (117.5)	5/32 (4)
4	3½ (88.9)	4⅝ (117.5)	7/32 (5.6)
5	4⅜ (111.1)	5¼ (133.3)	7/32 (5.6)
6	5½ (139.7)	6⅝ (168.3)	7/32 (5.6)

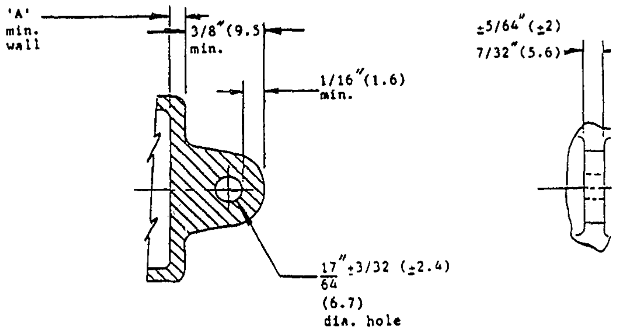
FIG. 10 Flanged Coupler ANSI Class 150



NOTE 1—Chain boss to be provided at the manufacturer's discretion.

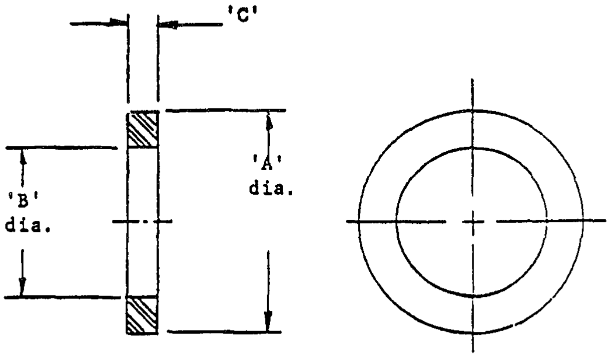
Size	Dimensions, in. (mm)		
	A	B	C
½	19/32 (15.1)	1¾ (44.4)	3/32 (2.4)
¾	11/16 (17.5)	1¾ (44.4)	3/32 (2.4)
1	13/16 (20.6)	2⅛ (54)	3/32 (2.4)
1¼	1'' (25.4)	2⅜ (60.3)	⅛ (3)
1½	1 9/32 (32.5)	2⅝ (66.7)	⅛ (3)
2	1 21/32 (42.1)	2¾ (69.8)	⅛ (3)
2½	2 1/16 (52.4)	2 13/16 (71.4)	5/32 (4)
3	2 11/16 (68.3)	2⅞ (73)	5/32 (4)
4	3 11/16 (93.4)	2⅞ (73)	7/32 (5.6)
5	4 11/16 (119.1)	3½ (88.9)	7/32 (5.6)
6	5 11/16 (144.5)	3½ (88.9)	7/32 (5.6)

FIG. 11 Flanged Adapter ANSI Class 150



Size	Dimensions, in. (mm)
	A
½	3/32 (2.4)
¾	3/32 (2.4)
1	3/32 (2.4)
1¼	1/8 (3)
1½	1/8 (3)
2	1/8 (3)
2½	5/32 (4)
3	5/32 (4)
4	7/32 (5.6)
5	7/32 (5.6)
6	7/32 (5.6)

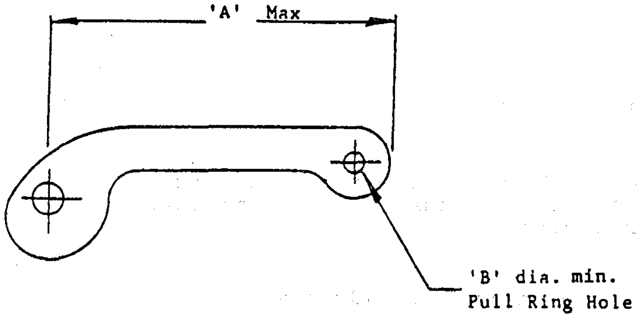
FIG. 12 Adapter Chain Boss End



NOTE 1—Unidentified Tolerance; Fractional = ±1/64 (±0.4)

Size	Dimensions, in. (mm)			Minimum Gasket Compression for Proper Sealing
	A	B	C	
½	1 3/8 (34.9)	7/8 (22.2)	7/32 (5.6)	0.030 (0.762)
¾	1 3/8 (34.9)	7/8 (22.2)	7/32 (5.6)	0.030 (0.762)
1	1 9/16 (39.7)	1 1/16 (27)	1/4 (6.3)	0.030 (0.762)
1¼	1 15/16 (49.2)	1 23/64 (34.5)	1/4 (6.3)	0.030 (0.762)
1½	2 3/16 (55.6)	1 5/8 (41.3)	1/4 (6.3)	0.030 (0.762)
2	2 5/8 (66.7)	2 (50.8)	1/4 (6.3)	0.030 (0.762)
2½	3 1/8 (79.4)	2 3/8 (60.3)	1/4 (6.3)	0.030 (0.762)
3	3 23/32 (94.5)	3 (76.2)	1/4 (6.3)	0.025 (0.635)
4	4 7/8 (123.8)	4 (101.6)	1/4 (6.3)	0.025 (0.635)
5	5 29/32 (150)	4 7/8 (123.8)	1/4 (6.3)	0.025 (0.635)
6	7 1/16 (179.4)	6 (152.4)	1/4 (6.3)	0.025 (0.635)

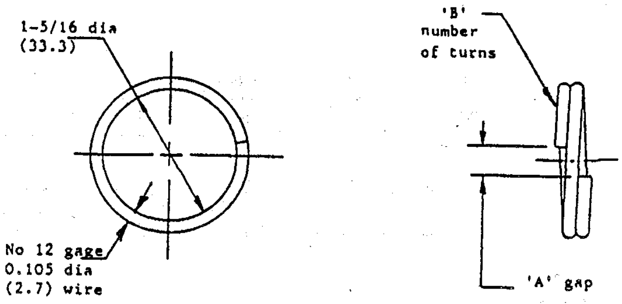
FIG. 13 Gasket



NOTE 1—Unidentified tolerance: fractional ±1⁄64 (±0.4)

Size	Dimensions, in. (mm)	
	A	B
½	1⅞ (47.6)	5⁄32 (4)
¾	1⅞ (47.6)	5⁄32 (4)
1″	1⅞ (47.6)	5⁄32 (4)
1¼	3 (76.2)	5⁄32 (4)
1½	3 (76.2)	5⁄32 (4)
2	3 (76.2)	5⁄32 (4)
2½	3 (76.2)	5⁄32 (4)
3	3¼ (82.5)	¼ (6.3)
4	3¼ (82.5)	¼ (6.3)
5	3¼ (82.5)	¼ (6.3)
6	4½ (114.3)	¼ (6.3)

FIG. 14 Cam Handle



NOTE 1—Unidentified tolerance: ±1⁄16 (±1.6); decimal ±0.002 (±0.05)

Size	Dimensions, in. (mm)	
	A	B
½	3⁄16 (4.8)	2
¾	3⁄16 (4.8)	2
1″	3⁄16 (4.8)	2
1¼	3⁄16 (4.8)	2
1½	3⁄16 (4.8)	2
2	3⁄16 (4.8)	2
2½	3⁄16 (4.8)	2
3	¼ (6.3)	3
4	¼ (6.3)	3
5	¼ (6.3)	3
6	¼ (6.3)	3

FIG. 15 Pull Ring, Cam Handle

CERTIFICATE

By Authority Of
THE UNITED STATES OF AMERICA
Legally Binding Document

By the Authority Vested By Part 5 of the United States Code § 552(a) and Part 1 of the Code of Regulations § 51 the attached document has been duly INCORPORATED BY REFERENCE and shall be considered legally binding upon all citizens and residents of the United States of America. *HEED THIS NOTICE*: Criminal penalties may apply for noncompliance.

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OFFICE OF THE FEDERAL REGISTER
WASHINGTON, D.C.

Designation: F 1123 – 87 (Reapproved 1998)

An American National Standard

Standard Specification for Non-Metallic Expansion Joints[1]

1. Scope

1.1 This specification provides the minimum requirements for construction, materials, performance, and dimensional requirements of arch-type non-metallic expansion joints.

1.2 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

1.3 The following safety hazards caveat pertains only to the test method described in this specification. *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

A 395 Specification for Ferritic Ductile Iron Pressure-Retaining Castings for Use at Elevated Temperatures[2]

D 1418 Practice for Rubber and Rubber Latices—Nomenclature[3]

2.2 *Federal Standard:*

Code of Federal Regulations, Title 30, Chapter I, Mine Safety and Health Administration[4]

2.3 *ANSI Standards:*

B16.1 Cast Iron Pipe Flanges and Flanged Fittings[5]

B16.5 Steel Pipe Flanges and Flanged Fittings[5]

B16.24 Bronze Flanges and Flanged Fittings[5]

3. Terminology

3.1 *Definitions:*

3.1.1 *floating metallic flange type*—expansion joint having the tube, fabric plies, and cover brought up from the joint body to form a bead.

NOTE 1—This bead is molded into a groove in the metallic flange. Retaining rings are not required with this design.

3.1.2 *integral rubber flange type*—expansion joint having the tube, fabric plies, and cover brought up from the joint body to form a rubber flange.

NOTE 2—Additional plies or other reinforcement may be used in the flange to meet service conditions. Retaining rings must be used with this design.

3.1.3 *maximum allowable working pressure (MAWP)*—manufacturer's recommended maximum continuous operating pressure (lb/in.^{2} (Pa)).

3.1.4 *non-metallic flanged expansion joint*—flexible connector fabricated from natural or synthetic rubber and fabrics, usually with metal reinforcement, to isolate vibration and noise and provide stress relief in piping systems caused by thermal changes and other system movements.

4. Ordering Information

4.1 Orders for products under this specification shall include the following information:

4.1.1 Inside diameter of connecting pipes (joint ID).

4.1.2 Face-to-face dimension that is the flange-to-flange dimension into which the expansion joint is to be installed.

4.1.3 Maximum and minimum operating pressure in pounds-force per square inch gage (pascals).

4.1.4 Maximum and minimum operating temperature in °F (°C).

4.1.5 Flange drilling in accordance with the appendix titled "Common Flange Dimension/Drilling Chart" of the *Technical Handbook on Rubber Expansion Joints and Flexible Pipe Connectors*[6] (herein referred to as the *Technical Handbook*) or in accordance with special customer requirements.

4.1.6 Fluid to be handled.

4.1.7 This ASTM specification designation.

4.1.8 Movement data requirements (including shock or vibratory excursions if applicable).

4.1.9 Design certification burst test if required (see 9.1).

4.1.10 Hydrostatic or special tests if required (see 9.2).

4.1.11 Certification of expansion joint if required (see Section 12).

4.1.12 Certified detailed drawing of the expansion joint if required (see 12.2).

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[1] This specification is under the jurisdiction of ASTM Committee F-25 on Ships and Marine Technology and is the direct responsibility of Subcommittee F25.13 on Piping Systems.

Current edition approved Dec. 31, 1987. Published February 1988.

[2] *Annual Book of ASTM Standards*, Vol 01.02.

[3] *Annual Book of ASTM Standards*, Vol 09.01.

[4] Available from Superintendent of Documents, Government Printing Office, Washington, DC 20402.

[5] Available from American Society of Mechanical Engineers, 345 E. 47th St., New York, NY 10017.

[6] The *Technical Handbook on Rubber Expansion Joints and Flexible Pipe Connections* is available from Fluid Sealing Association, 2017 Walnut St., Philadelphia, PA 19103.

5. Materials and Manufacture

5.1 Expansion joints shall be fabricated with an elastomeric tube reinforced with multiple plies of woven cloth or tire cord covered with synthetic rubber. The inner tube shall be a natural rubber, synthetic rubber, or blend of synthetic rubber that meets the requirements of this specification. The woven cloth or tire cord shall be nylon, polyester, fiberglass, or aramid. Cotton is not acceptable. The reinforcing fabric shall be impregnated with a compatible friction stock. Additional reinforcement to the fabric may be provided in the body of the expansion joint and may be solid metal rings or wire imbedded in the synthetic rubber. Tensile properties of the wire, if used, shall be as given in 5.2. Body rings, if used, must be welded before being installed in the expansion joint body. Welds must be 100 % penetration.

5.1.1 The list of elastomers used in expansion joints and rubber pipe in accordance with the *Technical Handbook*[6] lists acceptable natural rubber and synthetic elastomers for construction of non-metallic expansion joints.

5.2 Reinforcing wire shall have properties that allow the expansion joints to meet the requirements of this specification.

5.3 All expansion joints shall be manufactured with a cover of Hypalon or Neoprene (Chloroprene), in accordance with Practice D 1418. This cover material must consist of 100 % Hypalon or Chloroprene (not blended with any other elastomer) plus normal additives to provide for curing and a durometer between 50 and 75 on the Shore A Scale. Neoprene and Hypalon are selected as the best fire-retardant elastomer of the common types used for expansion joints. This material shall be certified flame resistant as outlined in 10.3.

5.4 *Integral Flanges*—The tube, fabric plies, and cover shall be brought up from the joint body to form an intregal flange. This rubber flange shall extend beyond the bolt holes of the retaining ring.

5.5 *Floating Metallic Flanges*—The metal flanges shall have a groove to accept the molded bead in the body at each end of the expansion joint bellows.

5.6 *Arches*—Arches may be either straight sided or long radius depending on the manufacturer's standard construction. The arch size and shape determine the movement capability of the joint. Minimum movement capability of single arch joints shall be in accordance with the *Technical Handbook*[6] table titled "Expansion Joint Movement Force/Spring Rate Capability.'' Movement capability information for multiple arch designs shall be available from the manufacturer.

5.7 *Metallic Flanges*:

5.7.1 Flanges shall be drilled in accordance with the *Technical Handbook*[6] appendix titled "Common Flange Dimension/Drilling Chart'' or in accordance with the customer order as required, to match the mating flanges.

5.7.2 Metallic flanges shall meet the material requirements and pressure-temperature ratings in accordance with ANSI B16.1, B16.5, or B16.24.

5.8 *Retaining Rings*—Retaining rings for the integral flange type are installed behind the flanges and are drilled to match the flange drilling. The sections supplied for each flange should be split at the bolt holes to ensure a proper seal at all points when the bolts are tightened. The edge next to the rubber flange shall be broken or bevelled to prevent cutting the rubber flanges. Retaining rings must be a minimum thickness of ⅜ in. (9.5 mm) and shall be made of steel or ductile iron. Carbon steel shall be galvanized. Ductile iron shall be in accordance with Specification A 395.

6. Other Requirements

6.1 All expansion joints shall be designed for a minimum burst pressure of four times the maximum allowable working pressure. The design shall be based on analytical or experimental test of expansion joints of similar construction, class, type, and size. The design shall be certified by tests if ordered (see 4.1.9).

6.2 *Performance Requirements*—Single arch expansion joint movement shall not exceed the limits of the *Technical Handbook*[6] table referred to in 5.6 unless the manufacturer certifies that a proposed design can exceed the listed minimum movement capability to meet a special requirement greater than the minimum listed. Multiple arch-joint movement shall be of the manufacturer's certified design.

6.3 *Pressure Rating*—Expansion joints shall be limited to the pressures listed in the table "Pressure Characteristics of Rubber Expansion Joints'' of the *Technical Handbook*[6].

7. Dimensions and Permissible Variations

7.1 Expansion joints shall be dimensioned in accordance with the *Technical Handbook*[6] table titled "Expansion Joint Movement/Force/Spring Rate Capability.''

8. Workmanship, Finish, and Appearance

8.1 *Tube*—The tube shall be free from cuts and breaks or severe abrasions. Small depressions and indentations are acceptable as long as the surface of the elastomer is not broken.

8.2 *Integral Rubber and Fabric Flange*:

8.2.1 The face of an integral rubber and fabric flange shall be free of cuts or obvious breaks and shall be covered with rubber. The most critical portion of the flange is from the inside diameter of the joint out to the bolt holes.

8.2.2 Bolt holes shall be drilled cleanly through the rubber flange. The retaining rings shall be checked for proper alignment with bolt holes.

8.2.3 The outer edge of the flange shall be sealed with rubber, so that moisture from the atmosphere cannot attack the reinforcing fabrics.

8.2.4 The surface of the rubber flange against which the retaining rings are installed shall be covered with rubber. The surface may be irregular and building form tooling marks are not objectionable.

8.3 *Expansion Joint Cover and Body*—The cover of a joint does not contribute to the strength of the joint. Its purpose is to keep fluids from the atmosphere or surroundings from being absorbed into the body plies of fabric. Surface blemishes, such as flash, nylon wrap markings, grooves, and other indentations in the cover, over the arch, or in the body area, are not harmful as long as the body fabric is not exposed.

9. Number and Type of Tests

9.1 *Prototype Test*:

9.1.1 When required by the purchaser, an expansion joint of each size and type shall be burst tested to determine its maximum allowable working pressure (see 10.1).

9.1.2 The outer covering material of the expansion joint shall be tested to determine its self-extinguishing characteristics (see 10.3).

9.2 *Production Test*—When required by the purchaser, an expansion joint shall be hydrostatically tested to 1.5 times its maximum allowable working pressure at its rated maximum operating temperature (see 10.2).

10. Test Methods

10.1 *Burst Test*—Fill each joint to be tested with water before the application of pressure, allowing all air in the joint to escape. Apply pressure at a uniform rate until failure of the joint occurs. Consider the pressure at which any fluid leakage first occurs as the bursting pressure of the joint. The maximum allowable working pressure of the joint shall be less than or equal to ¼ the bursting pressure determined by this test.

10.2 *Hydrostatic Test*—Fill each joint to be tested with water before the application of pressure, allowing all air in the joint to escape. Apply pressure at a uniform rate up to the test pressure. The joint shall show no sign of leakage at the test pressure.

10.3 *Flame Resistance Test*—Test four specimens of the joint, ½ by 6 in. (12.7 by 152.4 mm) by the thickness of the expansion joint, in accordance with 30 CFR 18.65(*b*) through (*d*). Consider the expansion joint flame resistant if the tests of the four specimens meet the test requirements in 30 CFR 18.65(*e*).

11. Inspection

11.1 Inspection of the material shall be agreed upon between the purchaser and the supplier as part of the purchase contract.

12. Certification

12.1 When specified in the purchase order or contract, the manufacturer's certification shall be furnished to the purchaser stating that samples representing each lot have been manufactured, tested, and inspected in accordance with this specification and the requirements have been met. When specified in the purchase order or contract, a report of the test results shall be furnished.

12.2 When specified in the purchase order or contract, a certified drawing detailing the expansion joint shall be provided.

13. Product Marking

13.1 Each expansion joint shall be permanently marked or tagged with the following information:

13.1.1 Manufacturer's name or trademark.

13.1.2 Nominal diameter.

13.1.3 Manufactured date (month and year).

13.1.4 Maximum allowable working pressure and temperature (psi/°F (Pa/°C)).

13.1.5 Face-to-face dimension.

13.1.6 ASTM designation and year of issue of this specification.

14. Quality Assurance

14.1 The manufacturer of the expansion joint shall maintain the quality of the joints that are designed, tested, and marked in accordance with this specification. At no time shall a joint be sold with this specification designation that does not meet the requirements herein.

15. Keywords

15.1 arch-type non-metallic expansion joints; expansion joints

CERTIFICATE

By Authority Of
THE UNITED STATES OF AMERICA
Legally Binding Document

By the Authority Vested By Part 5 of the United States Code § 552(a) and Part 1 of the Code of Regulations § 51 the attached document has been duly INCORPORATED BY REFERENCE and shall be considered legally binding upon all citizens and residents of the United States of America. ***HEED THIS NOTICE***: Criminal penalties may apply for noncompliance.

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Standard Practice for Selection and Application of Piping System Materials[1]

This standard is issued under the fixed designation F 1155; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice is intended as a guide to shipbuilders, shipowners, and design agents for use in the preparation of piping system material schedules for commercial ship design and construction.

1.2 The materials and limitations listed in Tables 1-28 meet the minimum requirements of the U.S. Coast Guard and the American Bureau of Shipping and should be considered to be the minimum acceptable materials in regard to material, design, and testing. This document is not intended to limit the selection of material strictly to those listed. Other equal or superior materials may be used provided that they are acceptable to the regulatory bodies and classification societies.

2. Referenced Documents

2.1 *ASTM Standards:*

A 53 Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated Welded and Seamless[2]

A 105/A105M Specification for Carbon Steel Forgings for Piping Applications[2]

A 106 Specification for Seamless Carbon Steel Pipe for High-Temperature Service[2]

A 134 Specification for Pipe, Steel, Electric-Fusion (Arc)-Welded (Sizes NPS 16 and Over)[2]

A 139/A 139M Specification for Electric-Fusion (Arc)-Welded Steel Pipe (NPS 4 and Over)[2]

A 178/A 178M Specification for Electric-Resistance Welded Carbon Steel and Carbon-Manganese Steel Boiler and Superheater Tubes[2]

A 179/A 179M Specification for Seamless Cold-Drawn Low-Carbon Steel Heat-Exchanger and Condenser Tubes[2]

A 181/A 181M Specification for Carbon Steel Forgings, for General-Purpose Piping[2]

A 182/A 182M Specification for Forged or Rolled Alloy-Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High-Temperature Service[2]

A 192/A 192M Specification for Seamless Carbon Steel Boiler Tubes for High-Pressure Service[2]

A 193/A 193M Specification for Alloy-Steel and Stainless Steel Bolting Materials for High-Temperature Service[2]

A 194/A 194M Specification for Carbon and Alloy Steel Nuts for Bolts for High-Pressure and High-Temperature Service[2]

A 213/A 213M Specification for Seamless Ferritic and Austenitic Alloy-Steel Boiler, Superheater, and HeatExchanger Tubes[2]

A 214/A 214M Specification for Electric-Resistance Welded Carbon Steel Heat-Exchanger and Condenser Tubes[2]

A 216/A 216M Specification for Steel Castings, Carbon, Suitable for Fusion Welding, for High-Temperature Service[3]

A 234/A 234M Specification for Piping Fittings of Wrought Carbon Steel and Alloy Steel for Moderate and High Temperature Service[2]

A 242/A 242M Specification for High-Strength Low-Alloy Structural Steel[4]

A 249/A 249M Specification for Welded Austenitic Steel Boiler, Superheater, Heat-Exchanger, and Condenser Tubes[2]

A 283/A 283M Specification for Low and Intermediate Tensile Strength Carbon Steel Plates[4]

A 307 Specification for Carbon Steel Bolts and Studs, 60 000 Psi Tensile Strength[5]

A 320/A 320M Specification for Alloy Steel Bolting Materials for Low-Temperature Service[2]

A 335/A 335M Specification for Seamless Ferritic Alloy-Steel Pipe for High-Temperature Service[2]

A 351/A 351M Specification for Castings, Austenitic, Austenitic–Ferritic (Duplex), for Pressure–Containing Parts[3]

A 387/A 387M Specification for Pressure Vessel Plates, Alloy Steel, Chromium-Molybdenum[4]

A 395 Specification for Ferritic Ductile Iron Pressure-Retaining Castings for Use at Elevated Temperatures[3]

A 515/A 515M Specification for Pressure Vessel Plates, Carbon Steel, for Intermediate- and Higher-Temperature Service[4]

A 536 Specification for Ductile Iron Castings[3]

A 563 Specification for Carbon and Alloy Steel Nuts[5]

B 61 Specification for Steam or Valve Bronze Castings[6]

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[1] This practice is under the jurisdiction of ASTM Committee F-25 on Ships and Marine Technology and is the direct responsibility of Subcommittee F25.13 on Piping Systems.

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[2] *Annual Book of ASTM Standards*, Vol 01.01.

[3] *Annual Book of ASTM Standards*, Vol 01.02.

[4] *Annual Book of ASTM Standards*, Vol 01.04.

[5] *Annual Book of ASTM Standards*, Vol 15.08.

[6] *Annual Book of ASTM Standards*, Vol 02.01.

B 62 Specification for Composition Bronze or Ounce Metal Castings[6]
B 88 Specification for Seamless Copper Water Tube[6]
B 466 Specification for Seamless Copper-Nickel Pipe and Tube[6]
B 467 Specification for Welded Copper-Nickel Pipe[6]
D 2996 Specification for Filament-Wound "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe[7]
D 2997 Specification for Centrifugally Cast "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe[7]
D 4024 Specification for Machine Made "Fiberglass" (Glass-Fiber-Reinforced Thermosetting Resin) Flanges[7]
F 682 Specification for Wrought Carbon Steel Sleeve-Type Pipe Couplings[8]
F 683 Practice for Selection and Application of Thermal Insulation for Piping and Machinery[8]
F 704 Practice for Selecting Bolting Lengths for Piping System Flanged Joints[8]
F 722 Specification for Welded Joints for Shipboard Piping Systems[8]
F 1476 Specification for Performance of Gasketed Mechanical Couplings for Use in Piping Applications[8]
F 1548 Specification for the Performance of Fittings for Use with Gasketed Mechanical Couplings Used in Piping Applications[8]

2.2 *ANSI Standards:*[9]
B16.5 Steel Pipe Flanges and Flanged Fittings
B16.9 Factor Made Wrought Steel Buttwelding Fittings
B16.10 Face to Face and End to End Dimensions of Valves
B16.11 Forged Steel Fittings, Socket Welding and Threaded
B16.15 Cast Bronze Threaded Fittings Class 125 and 250
B16.18 Cast Copper Alloy Solder Joint Pressure Fittings
B16.22 Wrought Copper and Copper Alloy Solder Joint Pressure Fittings
B16.24 Bronze Flanges and Flanged
B16.28 Wrought Steel Buttwelding Short Radius Elbows and Returns
B16.34 Valves Flanged, Threaded and Welding End
B16.42 Ductile Iron Pipe Flanges and Flanged Fittings
B18.2.1 Square and Hex Bolts and Screws Inch Series
B18.2.2 Square and Hex Nuts (Inch Series)
B31.1 Power Piping
B36.10 Welded and Seamless Wrought Steel Pipe
B36.19 Stainless Steel Pipe

2.3 *Manufacturer's Standardization Society of the Valve and Fitting Industry Standards:*[10]
SP-67 Butterfly Valves
SP-72 Ball Valves with Flanged or Butt-Welding Ends for General Service
SP-80 Bronze Gate, Globe, Angle and Check Valves
SP-83 Carbon Steel Pipe Unions, Socket-Welding and Threaded

2.4 *Other Documents:*
ASME Boiler and Pressure Vessel Code, Sections I and VIII[11]
ABS' Rules for Building and Classing Steel Vessels[12]
Title 46, Code of Federal Regulations, Parts 41 to 69[13]
NVIC 11-86; Guidelines Governing the Use of Fiberglass Pipe (FGP) on Coast Guard Inspected Vessels[13]
MIL-F-1183 Fittings, Pipe, Cast Bronze, Silver-Brazing[13]

3. General Requirements

3.1 Shipboard piping systems shall be in accordance with ANSI B31.1 except as modified by 46 CFR Part 56 of the U.S. Coast Guard regulations and Sections 36 and 44 of the ABS' Rules.

3.2 Piping systems shall be classed in accordance with 46 CFR 56.04.

3.3 Valves shall be in accordance with 46 CFR 56.20.

3.4 Valves for Class I systems shall be in accordance with 46 CFR 56.20-9(b) and if larger than 2-in. NPS shall not have socket weld ends.

3.5 Resilient seated valves shall be in accordance with 46 CFR 56.20-15.

3.6 Dimensions of ductile iron gate, globe, angle, and check valves shall be in accordance with ANSI B16.34 and shall use the adjusted pressure temperature ratings of ANSI B31.1, Appendix E.

3.7 Flanges for flanged valves and fittings and their companion flanges shall be in accordance with 46 CFR 56.25 and 56.30-10.

3.8 Bolting shall be in accordance with 46 CFR 56.25-20. Practice F 704 shall be used as a guide for determining flange bolting lengths.

3.9 Socket weld joints shall be in accordance with 46 CFR 56.30-5(c) and 56.30-10(b), Method 4, and shall not exceed 3-in. NPS for Class I and II-L service.

3.10 Threaded joints shall be in accordance with 46 CFR 56.30-20 and shall not exceed 2-in. NPS for Class I systems.

3.11 Flared, flareless, and compression tube fittings shall be limited to 2-in. OD or below and shall be in accordance with 46 CFR 56.30-25.3.12

3.12 Brazed socket type joints shall be in accordance with 46 CFR 56.30-30 and 56.75.

3.13 Gasketed mechanical couplings and fittings for use with gasketed mechanical couplings shall be in accordance with 46 CFR 56.30–35.

3.14 Flexible pipe couplings of the compression or slip-on types shall be in accordance with 46 CFR 56.30-40.

3.15 For restrictions on the use of welded tube and pipe, see 46 CFR 56.60-2(b).

3.16 Ferrous pipe used for saltwater service shall be protected against corrosion in accordance with 46 CFR 56.60-3(a).

3.17 All welding of Class I and II piping shall be in accordance with 46 CFR 56.70 and Specification F 722.

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[7] *Annual Book of ASTM Standards*, Vol 08.04.

[8] *Annual Book of ASTM Standards*, Vol 01.07.

[9] Available from American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.

[10] Available from Manufacturer's Standardization Society of the Valve and Fittings Industry, 127 Park St., N.E. Vienna, VA 22180.

[11] Available from American Society of Mechanical Engineers, 345 E. 47th St., New York, NY 10017.

[12] Available from American Bureau of Shipping, Book Order, 45 Eisenhower Dr., Paramus, NJ 07652.

[13] Available from Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402.

3.18 Thermal insulation for piping systems shall be in accordance with Practice F 683.

3.19 Fiberglass reinforced thermosetting epoxy resin pipe and fittings shall be in accordance with 46 CFR 56.60-25 and U.S. Coast Guard Navigation and Vessel Inspection Circular (NVIC) 11-86.

3.20 Fiberglass pipe shall not be used outboard of skin valves.

4. List of Tables

4.1 The tables are arranged in the following sequence:

5. Keywords

5.1 materials; piping systems; piping systems materials; ship construction; ship design

TABLE 1 Material Temperature Limitations[A]

Material	Material Specifications	Temperature Limit, °F, max
Corrosion resistant steel	ASTM A 194/A 194M GR[B] 8, 8C, 8T	1200
	ASTM A 194/A 194M GR 8F	800
	ASME SA312 TP[C] 316L	850
	ASME SA312 TP 304L	800
	ASTM A 351/A 351M GR CF3M	850
Chrome-molybdenum steel	ASTM A 182/A 182M GR F6a, F11	1100
	ASTM A 193/A 193M GR B16	1100
	ASTM A 193/A 193M GF B7	1000
	ASTM A 194/A 194 GR 4	900
	ASME SA217 GR WC6	1100
	ASTM A 234/A 234M GR WP11	1100
	ASTM A 335/A 335M GR P11	1100
	ASTM A 387/A 387M	1000
Carbon steel	ASTM A 53 TY[D] S	800[E]
	ASTM A 53 TY E	650
	ASTM A 105/A 105M	800[E]
	ASTM A 106	800[E]
	ASTM A 134 GR 285C (straight seam)	300
	ASTM A 134 GR 285C (spiral seam)	200
	ASTM A 139/A 139M GR B (straight seam)	300
	ASTM A 139/A 139M GR B (spiral seam)	200
	ASTM A 181/A 181M	800[E]
	ASTM A 194/A 194M GR 2H	800
	ASTM A 216/A 216M GR WCB	1000
	ASTM A 234/A 234M GR WPB	800
	ASTM A 307	400
	ASTM A 515/A 515M GR 70	800
Ductile iron	ASTM A 395	650
	A 536	450
Bronze	ASME SB61	550
	ASME SB62	406
Copper nickel alloy	ASME SB466 C70600	600
	ASME SB467 C70600	600
Copper	ASTM B 88 TY K or L	400
	ASME SB75	400
Glass reinforced plastic	ASTM D 2996 GR 1	225
	ASTM D 2997 GR 1	225
	ASTM D 4024 GR 1	225

[A] Maximum temperature limits per ANSI B31.1 for all material, except glass reinforced plastic, which is per NVIC 11-86 and Specification A 536 which is per 46 CFR 56.
[B] GR—grade.
[C] TP—tubular product.
[D] TY—type.
[E] Upon prolonged exposure to temperatures above 775°F, the carbide phase or carbon steel may be converted to graphite.

TABLE 2 Steam, Steam Drains, Boiler Blow, Superheater Safety Valve Escape Piping

Item	Type/Style	Material	Material Specification	Design Specification	Maximum Temperature 1100°F[A] Remarks/Limitations
Pipe	Seamless	CrMo[B] steel	ASTM A 335/A 335M GR[C] P11	ANSI B36.10	. . .
Takedown joints	Flanges: weld neck or socket weld	CrMo steel	ASTM A 182/A 182M GR F11	ANSI B16.5	. . .
Bolting	Bolts/bolt studs	CrMoV[D] steel	ASTM A 193/A 193M GR B16	ANSI B18.2.1	. . .
	Nuts	CMo[E] steel	ASTM A 194/A 194M GR 4	ANSI B18.2.2	. . .
Fittings	Flanged	CrMo steel	ASME SA217 GR WC6 or ASTM A 182/A 182M GR F11	ANSI B16.5	. . .
	Buttweld	CrMo steel	ASTM A 234/A 234M GR WP11	ANSI B16.9 or B16.28	. . .
	Socket weld	CrMo steel	ASTM A 182/A 182M GR F11	ANSI B16.11	. . .
Valves: gate, globe, angle, check	Flanged or buttweld	CrMo steel	ASME SA217 GR WC6 or ASTM A 182/A 182M GR F11	ANSI B16.34	Trim group 1[F]
	Socket weld	CrMo steel	ASTM A 182/A 182M GR F6a or GR F11	ANSI B16.34	. . .

[A] Consult applicable material and design specifications, and Table 1 where indicated, to establish pressure/temperature ratings.
[B] CrMo—chromium-molybdenum.
[C] GR—grade.
[D] CrMoV—chromium-molybdenum-vanadium.
[E] CMo—carbon-molybdenum.
[F] For trim group definition, refer to Table 28.

TABLE 3 Steam, Steam Drains, Feed, Condensate Boiler Blow Sampling and Compounding, Safety Valve Escape Piping

Item	Type/Style	Material	Material Specification	Design Specification	Maximum Temperature 775°F[A] Remarks/Limitations
Pipe	Seamless or electric resistance welded	Carbon steel	ASTM A 106 GR[B] B or A 53 GR B TY S or E	ANSI B36.10	A 53 GR B TY[C] E Limited to a design pressure of 350 psig. See also Table 1.
Takedown joints	Flanges: weld neck, socket weld or slip-on	Carbon steel	ASTM A 105/A 105M	ANSI B16.5	. . .
	Unions: socket weld	Carbon steel	ASTM A 105/A 105M	MSS-SP-83	. . .
Bolting	Bolts/bolt studs	CrMo[D] steel	ASTM A 193/A 193M GR B7	ANSI B18.2.1	. . .
	Nuts	Carbon steel	ASTM A 194/A 194M GR 2H	ANSI B18.2.2	. . .
Fittings	Flanged	Carbon steel	ASTM A 216/A 216M GR WCB or A 105/A 105M	ANSI B16.5	. . .
	Butt weld	Carbon steel	ASTM A 234/A 234M GR WPB	ANSI B16.9 or B16.28	. . .
	Socket weld	Carbon steel	ASTM A 234/A 234M GR WPB or A 105/A 105M	ANSI B16.11	. . .
Valves: gate, globe, angle, check	Flanged or buttweld	Carbon steel Carbon steel	ASTM A 216/A 216M GR WCB or A 105/A 105M	ANSI B16.34	Trim group 2[E]
	Socket weld		ASTM A 234/A 234M GR WPB or A 105/A 105M	ANSI B16.34	. . .

[A] Consult applicable material and design specifications, and Table 1 where indicated, to establish pressure/temperature ratings.
[B] GR—grade.
[C] TY—type.
[D] CrMo—chromium-molybdenum
[E] For trim group definition, refer to Table 28.

TABLE 4 Steam, Steam Drains, Feed, Condensate, Boiler Blow Sampling and Compounding, and Safety Valve Escape Piping

Item	Type	Style	Material Specification[A]	Design Specification	Maximum Temperature 406°F[B] Remarks/Limitations
Pipe	Seamless or electric resistance welded	Carbon steel	ASTM A 106 GR[C] B or A 53 GR B TY S or E	ANSI B36.10	A 53 GR B TY[D] E limited to a design pressure of 350 psig
Takedown joints	Flanges: weld neck, socket weld or slip-on	Carbon steel	ASTM A 105/A 105M	ANSI B16.5	. . .
	Unions: socket weld or threaded	Carbon steel	ASTM A 105/A 105M	MSS-SP-83	. . .
	Unions: threaded or brazed	Bronze	ASME SB61 or SB62	MIL-F-1183	. . .
Bolting	Bolts/bolt studs	Carbon steel	ASTM A 307 GR B	ANSI B18.2.1	. . .
	Nuts	Carbon steel	ASTM A 563 GR A	ANSI B18.2.2	. . .
Fittings	Flanged	Carbon steel	ASTM A 216/A 216M GR WCB or	ANSI B16.5	. . .
	Buttweld	Carbon steel	ASTM A 234/A 234M GR WPB	ANSI B16.9 or B16.28	. . .
	Socket weld	Carbon steel	ASTM A 234/A 234M GR WPB or A 105/A 105M	ANSI B16.11	. . .
	Sleeve couplings	Carbon steel	ASTM A 234/A 234M GR WPB	ASTM F 682	. . .
	Threaded or brazed	Bronze	ASME SB61 or SB62	MIL-F-1183	. . .
Valves: gate, globe, angle, check	Flanged	Ductile iron	ASTM A 395	ANSI B16.34	Trim group 3 and 4[E]
	Flanged or buttweld	Carbon steel	ASTM A 216/A 216M GR WCB or A 105/A 105M	ANSI B16.34	. . .
			ASTM A 105/A 105M	ANSI B16.34	
	Socket weld	Carbon steel	ASME SB61 or SB62	MSS-SP-80[F]	. . .
	Threaded or brazed	Bronze			. . .

[A] When combining dissimilar materials, galvanic corrosion can occur, especially in seawater systems, and should be considered.

[B] Consult applicable material and design specifications, and Table 1 where indicated, to establish pressure/temperature ratings.

[C] GR—grade.

[D] TY—type.

[E] For trim group definition, refer to Table 28.

[F] MSS-SP-80 valves limited to 75 % of valve design pressure.

TABLE 5 Gas Turbine and Diesel Exhaust Piping

Item	Type/Style	Material	Material Specification	Design Specification	Maximum Temperature 1100°F[A] Remarks/Limitations
Pipe	Seamless	CrMo steel[B]	ASTM A 335/A 335M GR[C] P11	ANSI B36.10	. . .
	Plate formed	CrMo steel	ASTM A 387/A 387M	Commercial[D]	. . .
Takedown joints	Flanges: weld neck or socket weld	CrMo steel	ASTM A 182/A 182M GR F11	ANSI B16.5	. . .
	Flanges: plate	CrMo steel	ASTM A 387/A 387M	Commercial[D]	. . .
Bolting	Bolts/bolt studs	CrMoV[E] steel	ASTM A 193/A 193M GR B16	ANSI B18.2.1	. . .
	Nuts	CMo[F] steel	ASTM A 194/A 194M GR 4	ANSI B18.2.2	. . .

[A] Consult applicable material and design specifications, and Table 1 where indicated, to establish pressure/temperature ratings.

[B] CrMo—chromium-molybdenum.

[C] GR—grade.

[D] Specific Coast Guard and ABS approval for design required.

[E] CrMoV—chromium-molybdenum-vanadium.

[F] CMo—carbon-molybdenum.

TABLE 6 Gas Turbine and Diesel Exhaust Piping

Item	Type/Style	Material	Material Specification	Design Specification	Maximum Temperature 775°F[A] Remarks/Limitations
Pipe	Seamless or electric resistance welded	Carbon steel	ASTM A 106 GR[B] B or A 53 GR B TY S or E	ANSI B36.10	See Table 1
Takedown joints	Flanges: weld neck, socket weld or slip-on	Carbon steel	ASTM A 105/A 105M	ANSI B16.5	. . .
	Flanges: plate	Carbon steel	ASTM A 515/A 515M GR 70	Commercial[C]	. . .
Bolting	Bolts/bolt studs	CrMo[D] steel	ASTM A 193/A 193M GR B7	ANSI B18.2.1	. . .
	Nuts	Carbon steel	ASTM A 194/A 194M GR 2H	ANSI B18.2.2	. . .
Fittings	Flanged	Carbon steel	ASTM A 216/A 216M GR WCB or A 105/A 105M	ANSI B16.5	. . .
	Buttweld	Carbon steel	ASTM A 234/A 234M GR WPB	ANSI B16.9 or B16.28	. . .

[A] Consult applicable material and design specifications, and Table 1 where indicated, to establish pressure/temperature ratings.
[B] GR—grade.
[C] Specific Coast Guard and ABS approval required.
[D] CrMo—chromium-molybdenum.

TABLE 7 Fresh Water for Auxiliary Machinery and Engine Cooling

Item	Type/Style	Material	Material Specification[A]	Design Specification	Maximum Temperature 240°F[B] Remarks/Limitations
Pipe	Seamless or electric resistance welded	Carbon steel	ASTM A 106 GR[C] B or A 53 GR B TY[D] S or E	ANSI B36.10	. . .
	Filament wound	FGP[E]	ASTM D 2996 GR 1	Commercial[F]	See Table 1 and NVIC 11-86[G]
	Centrifugally cast	FGP[E]	ASTM D 2997 GR1	Commercial[F]	
Takedown joints	Flanges: socket weld or slip-on	Carbon steel	ASTM A 105/A 105M	ANSI B16.5	. . .
	Unions: socket weld or threaded	Carbon steel	ASTM A 105/A 105M	MSS-SP-83	. . .
	Unions: threaded or brazed	Bronze	ASME SB61 or SB62	MIL-F-1183	. . .
	Flanges: adhesive bonded	GRP[H]	ASTM D 4024 GR 1	ASTM D 4024	. . .
	Gasketed mechanical couplings	Ductile iron	ASTM A 536	ASTM F 1476	. . .
Bolting	Bolts/bolt studs	Carbon steel	ASTM A 307 GR B	ANSI B18.2.1	. . .
	Nuts		ASTM A 563 GR A	ANSI B18.2.2	. . .
Fittings	Flanged	Carbon steel	ASTM A 216/A 216M GR WCB or A 105/A 105M	ANSI B16.5	. . .
	Buttweld	Carbon steel	ASTM A 234/A 234M GR WPB	ANSI B16.9 or B16.28	. . .
	Socket weld or threaded	Carbon steel	ASTM A 234/A 234M GR WPB or A 105/A 105M	ANSI B16.9 or B16.28	. . .
	Sleeve couplings	Carbon steel	ASTM A 234/A 234M GR WPB	ASTM F 682	. . .
	Threaded or brazed	Bronze	ASME SB61 or SB62	MIL-F-1183	. . .
	Adhesive bonded	GRP[H]	Commercial	Commercial[F]	. . .
	Used with gasketed mechanical couplings	Ductile iron	A 536	F 1548	. . .
Valves	Butterfly wafer or lug type	Ductile iron	ASTM A 395	MSS-SP-67	Trim group 4[I]
	Butterfly grooved end	Ductile iron	ASTM A 536	. . .	Trim group 4[I]
Valves: gate, globe, angle, check	Flanged	Ductile iron	ASTM A 395	ANSI B16.34	Trim group 4[I]
	Flanged or buttweld	Carbon steel	ASTM A 216/A 216M GR WCB or A 105/A 105M	ANSI B16.34	Trim group 3 and 4[I]
	Socket weld	Carbon steel	ASTM A 105/A 105M	ANSI B16.34	Trim group 3 and 4[I]
	Threaded or brazed	Bronze	ASME SB61 or SB62	MSS-SP-80[J]	Trim group 3 and 4[I]
	Grooved end	Ductile iron	ASTM A 536	. . .	Trim group 3 and 4[I]
Valves: ball	Flanged or buttweld	Carbon steel	ASTM A 216/A 216M GR WCB or A 105/A 105M or A 181/A 181M	MSS-SP-72	Trim group 3 and 4[I]

[A] When combining dissimilar materials, galvanic corrosion can occur especially in seawater systems, and should be considered.

[B] Consult applicable material and design specifications, and Table 1 where indicated, to establish pressure/temperature ratings.

[C] GR—grade.

[D] TY—type.

[E] FGP—fiberglass pipe.

[F] Specific Coast Guard and ABS approval required.

[G] For U.S. flag vessels in addition to classification society requirements.

[H] GRP—glass reinforced plastic.

[I] For trim group definition, refer to Table 28.

[J] MSS-SP-80 valves limited to 75 % of valve design pressure.

TABLE 8 Fresh Water, Hot and Cold Domestic, Air Conditioning, Sanitary

Item	Type/Style	Material	Material Specification[A]	Design Specification	Maximum Temperature 240°F[B] Remarks/Limitations
Pipe	Seamless	Copper	ASTM B 88 TY[C] K or L	ASTM B 88	Hard drawn. Must be annealed for pressures greater than 225 psig.
	Filament wound	FGP[D]	ASTM D 2996 GR[E] 1	Commercial[F]	See Table 1 and NVIC 11-86[G]
	Centrifugally cast	FGP[D]	ASTM D 2997 GR 1	Commercial[F]	See Table 1 and NVIC 11-86[G]
Takedown joints	Flanges: silbraze	Bronze	ASME SB62	ANSI B16.24	...
	Unions: brazed or threaded	Bronze	ASME SB61 or SB62	MIL-F-1183	...
	Flanges: adhesive bonded	GRP[H]	ASTM D 4024 GR 1	ASTM D 4024	...
	Gasketed mechanical couplings	Ductile iron[I]	ASTM A 536	ASTM F 1476	...
Bolting	Bolts/bolt studs	Carbon steel	ASTM A 307 GR B	ANSI B18.2.1	...
	Nuts	Carbon steel	ASTM A 563 GR A	ANSI B18.2.2	...
Fittings	Silbraze	Copper	ASME SB88 TY K or L	ANSI B16.22	...
	Adhesive bonded	GRP[H]	Commercial	Commercial[F]	...
	Used with gasketed mechanical couplings	Bronze	ASTM B 61 or B 62	ASTM F 1476	...
Valves	Butterfly wafer or lug	Ductile iron	ASTM A 395	MSS-SP-67	Trim group 4[J]
	Butterfly grooved end	Bronze	ASTM B 61 or B 62	...	Trim group 4[J]
Valves: gate, globe, angle, check	Flanged or brazed	Bronze	ASME SB61 or SB62	MSS-SP-80[K]	Trim group 4[J]
Valves: ball	Flanged	Bronze	ASME SB61 or SB62	MSS-SP-72	Trim group 4[J]

[A] When combining dissimilar materials galvanic corrosion can occur, especially in seawater systems, and should be considered.

[B] Consult applicable material and design specifications, and Table 1 where indicated, to establish pressure/temperature ratings.

[C] TY—type.

[D] FGP—fiberglass pipe.

[E] GR—grade.

[F] Specific Coast Guard and ABS approval required.

[G] For U.S. flag vessels in addition to classification society requirements.

[H] GRP—glass reinforced plastic.

[I] Acceptable when gasket isolates coupling housings from fluid.

[J] For trim group definition, refer to Table 28.

[K] MSS-SP-80 valves limited to 75 % of valve design pressure.

TABLE 9 Sea Water Circulating, Wet Firemain, and Distilling Plant Piping

Item	Type/Style	Material	Material Specification[A]	Design Specification	Maximum Temperature 150°F[B] Remarks/Limitations
Pipe	Seamless or welded	CNA[C] 90:10	ASME SB466 or SB467	ASME SB466 or SB467	
	Filament wound	FGP[D]	ASTM D 2996 GR[E] 1	Commercial[F]	See NVIC 11-86[G]
	Centrifugally cast	FGP[D]	ASTM D 2997 GR 1	Commercial[F]	See NVIC 11-86[G]
Takedown joints	Flanges: brazed	Bronze	ASME SB62	ANSI B16.24	. . .
	Unions: brazed	Bronze	ASME SB61 or SB62	MIL-F-1183	. . .
	Flanges: adhesive bonded	GRP[H]	ASTM D 4024 GR 1	ASTM D 4024	. . .
	Gasketed mechanical couplings	Ductile iron[I]	ASTM A 536	ASTM F 1476	. . .
Bolting	Bolts/bolt studs	Carbon steel	ASTM A 307 GR B	ANSI B18.2.1	. . .
	Nuts	Carbon steel	ASTM A 563 GR A	ANSI B18.2.2	. . .
Fittings	Flanged	Bronze	ASME SB61 or SB62	ANSI B16.24	. . .
	Buttweld or welding sleeve	CNA 90:10	ASME SB466 or SB467	810-1385880	. . .
	Brazed	Bronze	ASME SB61 or SB62	MIL-F-1183	. . .
	Adhesive bonded	GRP[H]	Commercial	Commercial[F]	. . .
	Used with gasketed mechanical couplings	Bronze	ASTM B 61 or B 62	ASTM F 1548	. . .
		CNA	ASTM B 466 or ASTM B 467	ASTM F 1548	. . .
Valves	Butterfly water or lug	Ductile iron[J]	ASTM A 395	MSS-SP-67	Trim group 6[K]
		Carbon steel[J]	ASTM A 216/A 216M GR WCB or A 105/A 105M		
	Butterfly grooved end	Bronze	ASTM B 61 or B 62	. . .	Trim group 4[K]
Valves: gate, globe, angle, check	Flanged Brazed	Bronze	ASME SB61 or SB62	MSS-SP-80[L]	Trim group 6[K]

[A] When combining dissimilar materials, galvanic corrosion can occur, especially in seawater systems, and should be considered.

[B] Consult applicable material and design specifications, and Table 1 where indicated, to establish pressure/temperature ratings.

[C] CNA—copper nickel alloy.

[D] FGP—fiberglass pipe.

[E] GR—grade.

[F] Specific Coast Guard and ABS approval required.

[G] For U.S. flag vessels in addition to classification society requirements.

[H] GRP—glass reinforced plastic.

[I] Acceptable when gasket isolates coupling housings from fluid.

[J] Not permitted with CNA piping.

[K] For trim group definition, refer to Table 28.

[L] MSS-SP-80 valves limited to 75 % of valve design pressure.

TABLE 10 Dry Fire Main, Foam, Sprinkling, Deckwash, Tank Cleaning Piping

Item	Type/Style	Material	Material Specification[A]	Design Specification	Maximum Temperature 200°F[B] Remarks/Limitations
Pipe	Seamless or electric resistance welded	Carbon steel	ASTM A 106 GR[C] B or A 53 GR B TY[D] S or E	ANSI B36.10	...
Takedown joints	Flanges: socket weld or slip-on	Carbon steel	ASTM A 105/A 105M	ANSI B16.5	...
	Unions: socket weld or threaded	Carbon steel	ASTM A 105/A 105M	MSS-SP-83	...
	Gasketed mechanical couplings	Ductile iron	ASTM A 536	ASTM F 1476	...
Bolting	Bolts/bolt studs	Carbon steel	ASTM A 307 GR B	ANSI B18.2.1	...
	Nuts	Carbon steel	ASTM A 563 GR A	ANSI B18.2.2	...
Fittings	Buttweld	Carbon steel	ASTM A 234/A 234M GR WPB	ANSI B16.9 or B16.28	...
	Socket weld	Carbon steel	ASTM A 234/A 234M GR WPB or A 105/A 105M	ANSI B16.11	...
	Sleeve coupling	Carbon steel	ASTM A 234/A 234M GR WPB	ASTM F 682	...
	Threaded	Bronze	ASME SB61 or SB62	ANSI B16.15	...
	Used with Gasketed mechanical couplings	Ductile iron	ASTM A 536	ASTM F 1548	...
Valves	Butterfly wafer or lug type	Ductile iron	ASTM A 395	MSS-SP-67	...
	Butterfly grooved end	Ductile iron	ASTM A 536	...	Trim group 4[E]
Valves: gate, globe, angle, check	Flanged	Ductile iron	ASTM A 395	ANSI B16.34	Trim group 4[E]
	Flanged or buttweld	Carbon steel	ASTM A 216/A 216M GR WCB or A 105/A 105M		Trim group 3[E]
	Socket weld	Carbon steel	ASTM A 234/A 234M GR WPB or A 105/A 105M	ANSI B16.34	...
	Flanged or threaded	Bronze	ASME SB61 or SB62	MSS-SP-80[F]	...
	Grooved end	Ductile iron	ASTM A 536	...	Trim group 3 and 4[E]

[A] When combining dissimilar materials, galvanic corrosion can occur, especially in seawater systems, and should be considered.

[B] Consult applicable material and design specifications, and Table 1 where indicated, to establish pressure/temperature ratings.

[C] GR—grade.

[D] TY—type.

[E] For trim group definition, refer to Table 28.

[F] MSS-SP-80 valves limited to 75 % of valve design pressure.

TABLE 11 Bilge, Clean Ballast, and Pump Priming Piping

Item	Type/Style	Material	Material Specification[A]	Design Specification	Maximum Temperature 100°F[B] Remarks/Limitations
Pipe	Seamless or electric resistance weld	Carbon steel	ASTM A 106 GR[C] B or A 53 GR B TY[D] S or E	ANSI B36.10	. . .
	Filament wound	FGP[E]	ASTM D 2996 GR 1	Commercial[F]	See NVIC 11-86[G]
	Centrifugally cast	FGP[E]	ASTM D 2997 GR 1	Commercial[F]	See NVIC 11-86[G]
Takedown joints	Flanges: slip-on or socket weld	Carbon steel	ASTM A 105/A 105M	ANSI B16.5	. . .
	Flanges: plate	Steel with NCA[H] facing	ASTM A 283/A 283M	ANSI B16.5	. . .
	Unions: socket weld or threaded	Carbon steel	ASTM A 105/A 105M	MSS-SP-83	. . .
	Flanges: adhesive bonded	GRP[I]	ASTM D 4024 GR 1	ASTM D 4024	. . .
	Gasketed mechanical couplings	Ductile iron	ASTM A 536	ASTM F 1476	. . .
Bolting	Bolts/bolt studs	Carbon steel	ASTM A 307 GR B	ANSI B18.2.1	. . .
	Nuts	Carbon steel	ASTM A 563 GR A	ANSI B18.2.2	. . .
Fittings	Buttweld	Carbon steel	ASTM A 234/A 234M GR WPB	ANSI B16.9 or B16.28	. . .
	Socket weld or threaded	Carbon steel	ASTM A 234/A 234M GR WPB or A 105/A 105M	ANSI B16.11	. . .
	Sleeve coupling	Carbon steel	ASTM A 234/A 234M GR WPB	ASTM F 682	. . .
	Adhesive bonded	GRP[I]	Commercial	Commercial[F]	. . .
	Used with gasketed mechanical couplings	Ductile iron	ASTM A 536	ASTM F 1548	. . .
Valves	Butterfly wafer or lug type	Ductile iron	ASTM A 395	MSS-SP-67	. . .
		Carbon steel	ASTM A 216/A 216M GR WCB or A 105/A 105M		
	Butterfly grooved end	Ductile iron	ASTM A 536	. . .	Trim group 4[J]
Valves: gate, globe, angle, check	Flanged	Ductile iron	ASTM A 395	ANSI B16.34	Trim group 3 and 4[J]
		Carbon steel	ASTM A 216/A 216M GR WCB or A 105/A 105M	ANSI B16.34	Trim group 3 and 4[J]
	Threaded or brazed	Bronze	ASME SB61 or SB62	MSS-SP-80[K]	Trim group 3 and 4[J]
	Grooved end	Ductile iron	ASTM A 536	. . .	Trim group 3 and 4[J]

[A] When combining dissimilar materials, galvanic corrosion can occur, especially in seawater systems, and should be considered.
[B] Consult applicable material and design specifications, and Table 1 where indicated, to establish pressure/temperature ratings.
[C] GR—grade.
[D] TY—type.
[E] FGP—fiberglass pipe.
[F] Specific Coast Guard and ABS approval required.
[G] For U.S. flag vessels in addition to classification society requirements.
[H] NCA—nickel copper alloy.
[I] GRP—glass-reinforced plastic.
[J] For trim group definition, refer to Table 28.
[K] MSS-SP-80 valves limited to 75 % of valve design pressure.

TABLE 12 Diesel and Lube Oil System Piping Fuel Oil Filling, Transfer, and Service Suction Piping

Item	Type/Style	Material	Material Specification	Design Specification	Maximum Temperature 200°F[A] Remarks/Limitations
Pipe	Seamless or electric resistance welded	Carbon steel	ASTM A 106 GR[B] B or A 53 GR B TY[C] S or E	ANSI B36.10	. . .
	Filament wound	FGP[D]	ASTM D 2996 GR 1	Commercial[E]	See NVIC 11-86[F]
	Centrifugally cast	FGP[D]	ASTM D 2997 GR 1	Commercial[E]	See NVIC 11-86[F]
Takedown joints	Flanges: weldneck, socket weld or slip-on	Carbon steel	ASTM A 105/A 105M	ANSI B16.5	. . .
	Unions: socket weld or threaded	Carbon steel	ASTM A 105/A 105M	MSS-SP-83	. . .
	Flanges: adhesive bonded	GRP[G]	ASTM D 4024 GR 1	ASTM D 4024	. . .
	Gasketed mechanical couplings	Ductile iron	ASTM A 536	ASTM F 1476	. . .
Bolting	Bolts/bolt studs	Carbon steel	ASTM A 307 GR B	ANSI B18.2.1	. . .
	Nuts	Carbon steel	ASTM A 563 GR A	ANSI B18.2.2	. . .
Fittings	Buttweld	Carbon steel	ASTM A 234/A 234M GR WPB	ANSI B16.9 or B16.28	. . .
	Socket weld or threaded	Carbon steel	ASTM A 234/A 234M GR WPB or A 105/A 105M	ANSI B16.11	. . .
	Sleeve couplings	Carbon steel	ASTM A 234/A 234M GR WPB	ASTM F 682	. . .
	Adhesive bonded	GRP[D]	Commercial	Commercial[E]	. . .
	Used with gasketed mechanical couplings	Ductile iron	ASTM A 536	ASTM F 1548	. . .
Valves	Butterfly wafer or lug	Ductile iron Carbon steel	ASTM A 395 ASTM A 216/A 216M GR WCB or A 105/A 105M	MSS-SP-67	Trim group 4 and 5[H]
	Butterfly grooved end	Ductile iron	ASTM A 536	. . .	Trim group 4[H]
Valves: gate, globe, angle, check	Flanged	Ductile iron Carbon steel	ASTM A 395 ASTM A 216/A 216M GR WCB or A 105/A 105M	ANSI B16.34	Trim group 4 and 5[H]
	Socket weld or threaded	Carbon steel	ASTM A 234/A 234M GR WPB or A 105/A 105M	ANSI B16.34	Trim group 3[H]
	Grooved end	Ductile iron	ASTM A 536	. . .	Trim group 3 and 4[H]

[A] Consult applicable material and design specifications, and Table 1 where indicated, to establish pressure/temperature ratings.
[B] GR—grade.
[C] TY—type.
[D] FGP—fiberglass pipe.
[E] Specific Coast Guard and ABS approval required.
[F] For U.S. flag vessel in addition to classification society requirements.
[G] GRP—glass reinforced plastic.
[H] For trim group definition, refer to Table 28.

TABLE 13 Fuel Oil Service Discharge Piping

Item	Type/Style	Material	Material Specification	Design Specification	Maximum Temperature 300°F[A] Remarks/Limitations
Pipe	Seamless	Carbon steel	ASTM A 106 GR[B] B or A 53 GR B TY[C] S	ANSI B36.10	. . .
Takedown joints	Flanges: weldneck, socket weld or slip-on	Carbon steel	ASTM A 105/A 105M	ANSI B16.5	. . .
	Unions: socket weld or threaded	Carbon steel	ASTM A 105/A 105M	MSS-SP-83	. . .
	Gasketed mechanical couplings	Ductile iron	ASTM A 536	ASTM F 1476	. . .
Bolting	Bolts/bolt studs	Carbon steel	ASTM A 307 GR B	ANSI B18.2.1	. . .
	Nuts	Carbon steel	ASTM A 563 GR A	ANSI B18.2.2	. . .
Fittings	Buttweld	Carbon steel	ASTM A 234/A 234M GR WPB	ANSI B16.9 or B16.28	. . .
	Socket weld or threaded	Carbon steel	ASTM A 234/A 234M GR WPB or A 105/A 105M	ANSI B16.11	. . .
	Sleeve couplings	Carbon steel	ASTM A 234/A 234M GR WPB	ASTM F 682	. . .
	Used with gasketed mechanical couplings	Ductile iron	ASTM A 536	ASTM F 1548	. . .
Valves	Butterfly grooved end	Ductile iron	ASTM A 536	. . .	Trim group 4[D]
Valves: gate, globe, angle, check	Flanged	Ductile iron	ASTM A 395	ANSI B16.34	Trim group 4 and 5[D]
		Carbon steel	ASTM A 216/A 216M GR WCB or A 105/A 105M		Trim group 3[D]
	Buttweld or socket weld	Carbon steel	ASTM A 234/A 234M GR WPB or A 105/A 105M	ANSI B16.34	. . .
	Grooved end	Ductile iron	ASTM A 536	. . .	Trim group 3 and 4[D]

[A] Consult applicable material and design specifications, and Table 1 where indicated, to establish pressure/temperature ratings.

[B] GR—grade.

[C] TY—type.

[D] For trim group definition, refer to Table 28.

TABLE 14 Cargo Oil and Vent Piping and Crude Oil Wash Piping

Item	Type/Style	Material	Material Specification	Design Specification	Maximum Temperature 200°F[A] Remarks/Limitations
Pipe	Seamless or electric resistance welded	Carbon steel	ASTM A 106 GR[B] B or A 53 GR B TY[C] S or E	ANSI B36.10	...
	Filament wound	FGP[D]	ASTM D 2996 GR 1	Commercial[E]	See NVIC 11-86[F]
	Centrifugally cast	FGP[D]	ASTM D 2997 GR 1	Commercial[E]	See NVIC 11-86[F]
Takedown joints	Flanges: weld neck, socket weld, or threaded	Carbon steel	ASTM A 105/A 105M	ANSI B16.5	...
	Unions: socket weld	Carbon steel	ASTM A 105/A 105M	MSS-SP-83	...
	Flexible couplings	Steel with resilient gasket	Commercial	Commercial[E]	...
	Flanges: adhesive bonded	GRP[G]	ASTM D 4024 GR 1	ASTM D 4024	...
	Gasketed mechanical couplings	Ductile iron	ASTM A 536	ASTM F 1476	...
Bolting	Bolts/bolt studs	Carbon steel	ASTM A 307 GR B	ANSI B18.2.1	...
	Nuts	Carbon steel	ASTM A 563 GR A	ANSI B18.2.2	...
Fittings	Flanged	Ductile iron	ASTM A 395	ANSI B16.42	...
		Carbon steel	ASTM A 216/A 216M GR WCB	ANSI B16.5	...
	Buttweld	Carbon steel	ASTM A 234/A 234M GR WPB	ANSI B16.9 or B16.28	...
	Socket weld	Carbon steel	ASTM A 234/A 234M GR WPB or A 105/A 105M	ANSI B16.11	...
	Sleeve coupling	Carbon steel	ASTM A 234/A 234M GR WPB	ASTM F 682	...
	Adhesive bonded	GRP[G]	Commercial	Commercial[E]	...
	Used with gasketed mechanical couplings	Ductile iron	ASTM A 536	ASTM F 1548	...
Valves	Butterfly wafer or lug	Ductile iron	ASTM A 395	MSS-SP-67	Trim group 4[H]
		Carbon steel	ASTM A 216/A 216M GR WCB or A 105/A 105M		Trim group 3[H]
	Butterfly grooved end	Ductile iron	ASTM A 536	...	Trim group 4[H]
Valves: gate, globe, angle, check	Flanged	Ductile iron	ASTM A 395	ANSI B16.34	Trim group 4[H]
		Carbon steel	ASTM A 216/A 216M GR WCB or A 105/A 105M		Trim group 3[H]
	Grooved end	Ductile iron	ASTM A 536	...	Trim group 3 and 4[H]

[A] Consult applicable material and design specifications, and Table 1 where indicated, to establish pressure/temperature ratings.
[B] GR—grade.
[C] TY—type.
[D] FGP—fiberglass pipe.
[E] Specific Coast Guard and ABS approval required.
[F] For U.S. flag vessel in addition to classification society requirements.
[G] GRP—glass reinforced plastic.
[H] For trim group definition, refer to Table 28.

TABLE 15 Steering Gear Fill and Drain Piping, and Telemotor Piping

Item	Type/Style	Material	Material Specification	Design Specification	Maximum Temperature 406°F[A] Remarks/Limitations
Pipe	Seamless	Copper	ASTM B 88 TY[B] K	ASTM B 88	Must be annealed for pressures over 225 psig
Takedown joints	Unions: brazed or threaded	Bronze	ASME SB61 or SB62	MIL-F-1183	...
Bolting	None required				
Fittings	Brazed or threaded	Bronze	ASME SB61 or SB62	ANSI B16.18	...
	Brazed	Copper	ASME SB75	ANSI B16.22	...
Valves: gate, globe, angle, check	Brazed or threaded	Bronze	ASME SB61 or SB62	MSS-SP-80[C]	Trim group[D]
Valves: ball	Flanged	Bronze	ASME SB61 or SB62	MSS-SP-72, Table 2	Trim group[D]

[A] Consult applicable material and design specifications, and Table 1 where indicated, to establish pressure/temperature ratings.
[B] TY—type.
[C] MSS-SP-80 valves limited to 75 % of valve design pressure.
[D] For trim group definition, refer to Table 28.

TABLE 16 Hydraulic Piping[A,B]

Item	Type/Style	Material	Material Specification[C]	Design Specification	Remarks/Limitations
Pipe	Seamless or electric resistance welded	Carbon steel	ASTM A 106, A 178/A 178M, A 179/A 179M, A 192/A 192M or A 214/A 214M	ANSI B36.10	. . .
		CRES[D]	ASTM A 213/A 213M or A 249/A 249M		
Takedown joints	Flanges: weldneck or socket weld	Carbon steel	ASTM A 105/A 105M	ANSI B16.5	. . .
	Unions: flared, flareless, compression	Carbon steel	Commercial	Commercial[E]	. . .
Bolting	Bolts/bolt studs	CrMo[F] steel	ASTM A 193/A 193M GR[G] B7	ANSI B18.2.1	. . .
	Nuts	Carbon steel	ASTM A 194/A 194M GR 2H	ANSI B18.2.2	. . .
Fittings	Buttweld	Carbon steel	ASTM A 234/A 234M GR WPB	ANSI B16.9 or B16.28	. . .
	Socket weld	Carbon steel	ASTM A 234/A 234M GR WPB or A 105/A 105M	ANSI B16.11	. . .
	Flared, flareless, compression	Carbon steel	Commercial	Commercial[E]	. . .
Valves: gate, globe, angle, check	Flanged or buttweld	Carbon steel	ASTM A 216/A 216M GR WCB or A 105/A 105M	ANSI B16.34	Trim group 2[H]
	Socket weld	Carbon steel	ASTM A 234/A 234M GR WPB or A 105/A 105M	ANSI B16.34	. . .
	Flared, flareless, compression	Carbon steel	Commercial	Commercial[E]	. . .
Valves: ball	Flanged	Bronze	ASME SB61 or SB62	MSS-SP-72	Trim group 3 and 4[H]

[A] This table does not apply to packaged hydraulic systems and equipment. For such applications, specific Coast Guard and ABS approval should be obtained.
[B] Consult applicable material and design specifications, and Table 1 where indicated, to establish pressure/temperature ratings.
[C] When combining dissimilar materials, galvanic corrosion can occur, especially in seawater systems, and should be considered.
[D] CRES—corrosion resistant steel.
[E] Specific Coast Guard and ABS approval required.
[F] CrMo—chromium-molybdenum.
[G] GR—grade.
[H] For trim group definition, refer to Table 28.

TABLE 17 Air Piping 150 psi and Below

Item	Type/Style	Material	Material Specification[A]	Design Specification	Maximum Temperature Ambient[B] Remarks/Limitations
Pipe	Seamless	Carbon steel	ASTM A 106 GR[C] B	ANSI B36.10	. . .
	Seamless	Copper	ASTM B 88 TY[D] K	ASTM B 88	. . .
	Filament wound	FGP[E]	ASTM D 2996 GR 1	Commercial[F]	See NVIC 11-86[G]
	Centrifugally cast	FGP[E]	ASTM D 2997 GR 1	Commercial[F]	See NVIC 11-86[G]
Takedown joints	Flanges: socket weld or slip-on	Carbon steel	ASTM A 105/A 105M	ANSI B16.5	. . .
	Unions: socket weld or threaded	Carbon steel	ASTM A 105/A 105M	MSS-SP-83	. . .
	Unions: brazed	Bronze	ASME SB61 or SB62	MIL-F-1183	. . .
	Flanges: adhesive bonded	GRP[H]	ASTM D 4024 GR 1	ASTM D 4024	. . .
	Gasketed mechanical couplings	Ductile iron	ASTM A 536	ASTM F 1476	. . .
Bolting	Bolts/bolt studs	Carbon steel	ASTM A 307 GR B	ANSI B18.2.1	. . .
	Nuts		ASTM A 563 GR A	ANSI B18.2.2	. . .
Fittings	Flanged	Carbon steel	ASTM A 216/A 216M GR WCB or A 105/A 105M	ANSI B16.34	. . .
	Buttweld		ASTM A 234/A 234M GR WPB	ANSI B16.9 or B16.28	. . .
	Socketweld		ASTM A 234/A 234M GR WPB or A 105/A 105M	ANSI B16.11	. . .
	Brazed	Bronze	ASME SB61 or SB62	MIL-F-1183	. . .
	Adhesive bonded	GRP[H]	Commercial[F]	Commercial[F]	. . .
	Sleeve coupling	Carbon steel	ASTM A 234/A 234M GR WPB	ASTM F 682	. . .
	Used with gasketed mechanical couplings	Ductile iron	ASTM A 536	ASTM F 1548	. . .
Valves	Butterfly grooved end	Ductile iron	ASTM A 536	. . .	Trim group 4[I]
Valves: gate, globe, angle, check	Flanged	Ductile iron	ASTM A 395	ANSI B16.34	Trim group 4[I]
		Carbon steel	ASTM A 216/A 216M GR WCB or A 105/A 105M		Trim group 3[I]
	Socket weld	Carbon steel	ASTM A 234/A 234M GR WPB or A 105/A 105M	ANSI B16.34	Trim group 3[I]
	Brazed or threaded	Bronze	ASME SB61 or SB62	MSS-SP-80[J]	Trim group 4[I]
	Grooved end	Ductile iron	ASTM A 536	. . .	Trim group 3 and 4[I]
Valves: ball	Flanged	Bronze	ASME SB61 or SB62	MSS-SP-72	Trim group 4[I]

[A] When combining dissimilar materials, galvanic corrosion can occur, especially in seawater systems, and should be considered.
[B] Consult applicable material and design specifications, and Table 1 where indicated, to establish pressure/temperature ratings.
[C] GR—grade.
[D] TY—type.
[E] FGP—fiberglass pipe.
[F] Specific Coast Guard and ABS approval required.
[G] For U.S. flag vessels in addition to classification society requirements.
[H] GRP—glass reinforced plastic.
[I] For trim group definition, refer to Table 28.
[J] MSS-SP-80 valves limited to 75 % of valve design pressure.

TABLE 18 Air Piping Above 150 psi

Item	Type/Style	Material	Material Specification	Design Specification	Maximum Temperature Ambient[A] Remarks/Limitations
Pipe	Seamless or electric resistance welded	Carbon steel	ASTM A 106 GR[B] B or A 53 GR B TY S or E	ANSI B36.10	A 53 GR B TY[C] E limited to a design pressure of 350 psig
Takedown joints	Flanges: weld neck, socket weld, or slip-on	Carbon steel	ASTM A 105/A 105M	ANSI B16.5	...
	Unions: socket weld or threaded	Carbon steel	ASTM A 105/A 105M	MSS-SP-83	...
	Gasketed mechanical couplings	Ductile iron	ASTM A 536	ASTM F 1476	...
Bolting	Bolts/bolt studs	Carbon steel	ASTM A 307 GR B	ANSI B18.2.1	...
	Nuts		ASTM A 563 GR A	ANSI B18.2.2	...
Fittings	Flanged	Carbon steel	ASTM A 216/A 216M GR WCB or A 105/A 105M	ANSI B16.5	...
	Buttweld		ASTM A 234/A 234M GR WPB	ANSI B16.9 or B16.28	...
	Socket weld or threaded		ASTM A 234/A 234M GR WPB or A 105/A 105M	ANSI B16.11	...
	Sleeve coupling		ASTM A 234/A 234M GR WPB	ASTM F 682	...
	Used with gasketed mechanical couplings	Ductile iron	ASTM A 536	ASTM F 1548	...
Valves	Butterfly grooved end	Ductile iron	ASTM A 536		Trim group 4[D]
Valves: gate, globe, angle, check	Flanged	Carbon steel	ASTM A 216/A 216M GR WCB or A 105/A 105M	ANSI B16.34	Trim group 3[D]
	Socket weld or threaded		ASTM A 234/A 234M GR WPB or A 105/A 105M	ANSI B16.34	...
	Grooved end	Ductile iron	ASTM A 536	...	Trim group 3 and 4[D]
Valves: ball	Flanged or buttweld	Carbon steel	ASTM A 216/A 216M GR WCB or A 105/A 105M or A 181/A 181M	MSS-SP-72	Trim group 3[D]

[A] Consult applicable material and design specifications, and Table 1 where indicated, to establish pressure/temperature ratings.

[B] GR—grade.

[C] TY—type.

[D] For trim group definition, refer to Table 28.

TABLE 19 Refrigeration Piping

Item	Type/Style	Material	Material Specification	Design Specification	Maximum Temperature 406°F[A] Remarks/Limitations
Pipe	Seamless	Copper	ASTM B 88 TY[B] K or L or ASME SB75	ASTM B 88 or ASME SB75	Must be annealed for pressures over 225 psig
Takedown joints	None				
Bolting	None				
Fittings	Brazed	Copper	ASTM B 88 TY K or L or ASME SB75	ANSI B16.22	...

[A] Consult applicable material and design specifications, and Table 1 where indicated, to establish pressure/temperature ratings.

[B] TY—type.

TABLE 20 CO_2, Halon, and Smoke Detection

Item	Type/Style	Material	Material Specification	Design Specification	Maximum Temperature 850°F[A] Remarks/Limitations
Pipe	Seamless or electric resistance welded	Carbon steel	ASTM A 106 GR[B] B or A 53 GR B TY[C] S	ANSI B36.10	See Table 1. Must be internally and externally protected from corrosion. CO_2 piping requires 6000-psig burst rating.
Takedown joints	Flanges: buttweld or socketweld	Carbon steel	ASTM A 105/A 105M	ANSI B16.5	...
	Unions: socket weld or threaded	Carbon steel	ASTM A 105/A 105M	MSS-SP-83	...
Bolting	Bolts/bolt studs	CrMo[D] steel	ASTM A 193/A 193M GR B7	ANSI B18.2.1	...
	Nuts	Carbon steel	ASTM A 194/A 194M GR 2H	ANSI B18.2.2	...
Fittings	Buttweld, socketweld or threaded	Carbon steel	ASTM A 234/A 234M GR WPB A 105/A 105M	ANSI B16.9 or B16.28	...
Valves: gate, globe, angle, check	Flanged or buttweld	Carbon steel	ASTM A 216/A 216M GR WCB or A 105/A 105M	ANSI B16.34	Trim group 2[E]
	Socket weld or threaded		ASTM A 234/A 234M GR WPB or A 105/A 105M	ANSI B16.34	...

[A] Consult applicable material and design specifications, and Table 1 where indicated, to establish pressure/temperature ratings.
[B] GR—Grade.
[C] TY—type.
[D] CrMo—chromium-molybdenum.
[E] For trim group definition, refer to Table 28.

TABLE 21 Sounding Tubes, Vents, and Overflows for Freshwater, Saltwater, and Oil

Item	Type/Style	Material	Material Specification[A]	Design Specification	Maximum Temperature 406°F[B] Remarks/Limitations
Pipe	Seamless or electric resistance welded	Carbon steel	ASTM A 106 GR[C] B or A 53 GR B TY[D] S or E	ANSI B16.10	...
	Filament wound	FGP[E]	ASTM D 2996 GR 1	Commercial[F]	See Table 1 and NVIC 11-86[G]
	Centrifugally cast	FGP[E]	ASTM D 2997 GR 1	Commercial[F]	
Takedown joints	Flanges: socket weld or slip-on	Carbon steel	ASTM A 105/A 105M	ANSI B16.5	...
	Unions: socket weld	Carbon steel	ASTM A 105/A 105M	MSS-SP-83	...
	Flanges: adhesive bonded	GRP[H]	ASTM D 4024 GR 1	ASTM D 4024	...
	Gasketed mechanical couplings	Ductile iron	ASTM A 536	ASTM F 1476	...
Bolting	Bolts/bolt studs	Carbon steel	ASTM A 307 GR B	ANSI B18.2.1	...
	Nuts		ASTM A 563 GR A	ANSI B18.2.2	...
Fittings	Buttweld	Carbon steel	ASTM A 234/A 234M GR WPB	ANSI B16.9 or B16.28	...
	Socket weld or threaded		ASTM A 234/A 234M GR WPB or A 105/A 105M	ANSI B16.11	...
	Sleeve couplings		ASTM A 234/A 234M GR WPB	ASTM F 682	...
	Adhesive bonded	GRP[H]	Commercial	Commercial[F]	...
	Used with gasketed mechanical couplings	Ductile iron	ASTM A 536	ASTM F 1548	...
Valves	Butterfly grooved end	Ductile iron	ASTM A 536		Trim group 4[I]
Valves: gate, globe, angle, check	Flanged	Ductile iron	ASTM A 395 A 105/A 105M	ANSI B16.34	Trim group 4[I]
	Socket weld		ASTM A 234/A 234M GR WPB or A 105/A 105M		Trim group 3[I]
	Brazed or threaded	Bronze	ASME SB61 or SB62	MSS-SP-80[J]	Trim group 4[I]
	Grooved end	Ductile iron	ASTM A 536		Trim group 3 and 4[I]

[A] When combining dissimilar materials, galvanic corrosion can occur, especially in seawater systems, and should be considered.
[B] Consult applicable material and design specifications, and Table 1 where indicated, to establish pressure/temperature ratings.
[C] GR—grade.
[D] TY—type.
[E] FGP—fiberglass pipe.
[F] Specific Coast Guard and ABS approval required.
[G] For U.S. flag vessels in addition to classification society requirements.
[H] GRP—glass reinforced plastic.
[I] For trim group definition, refer to Table 28.
[J] MSS-SP-80 valves limited to 75 % of valve design pressure.

TABLE 22 Waste, Soil, and Interior Deck Drains

Item	Type/Style	Material	Material Specification[A]	Design Specification	Maximum Temperature 240°F[B] Remarks/Limitations
Pipe	Seamless or electric resistance welded	Carbon steel	ASTM A 106 GR[C] B or ASTM A 53 TY[D] S or E	ANSI B36.10	. . .
	Filament wound	FGP[E]	ASTM D 2996 GR 1	Commercial[F]	See Table 1 and NVIC 11-86[G] FGP not permitted outboard of shell valve.
	Centrifugally cast	FGP[E]	ASTM D 2997 GR 1	Commercial[F]	
Takedown joints	Flanges: socket weld or threaded	Carbon steel	ASTM A 105/A 105M	ANSI B16.5	. . .
	Unions: socket weld or threaded			MSS-SP-83	. . .
	Flanges: adhesive bonded	GRP[H]	ASTM D 4024 GR 1	ASTM D 4024	. . .
	Gasketed mechanical couplings	Ductile iron	ASTM A 536	ASTM F 1476	. . .
Bolting	Bolts/bolt studs	Carbon steel	ASTM A 307 GR B	ANSI B18.2.1	. . .
	Nuts		ASTM A 563	ANSI B18.2.2	. . .
Fittings	Buttweld	Carbon steel	ASTM A 234/A 234M GR WPB	ANSI B16.9 or B16.28	. . .
	Socket weld or threaded		ASTM A 234/A 234M GR WPB or A 105/A 105M	ANSI B16.11	. . .
	Adhesive bonded	GRP[H]	Commercial	Commercial[F]	. . .
	Sleeve coupling	Carbon steel	ASTM F 682	ASTM F 682	. . .
	Used with gasketed mechanical couplings	Ductile iron	ASTM A 536	ASTM F 1548	. . .
Valves	Butterfly grooved end	Ductile iron	ASTM A 536	. . .	Trim group 4[I]
Valves: gate, globe, angle, check	Flanged	Ductile iron	ASTM A 395	ANSI B16.34	Trim group 4[I]
		Carbon steel	ASTM A 216/A 216M GR WCB or A 105/A 105M		Trim group 3[I]
	Brazed or threaded	Bronze	ASME SB61 or SB62	ANSI B16.24 MSS-SP-80[J]	Trim group 4[I]
	Grooved end	Ductile iron		ASTM A 536	Trim group 4[I]
Valves: ball	Flanged	Ductile iron	ASTM A 395	MSS-SP-72	Trim group 4[I]
		Bronze	ASME SB61 or SB62		

[A] When combining dissimilar materials, galvanic corrosion can occur, especially in seawater systems, and should be considered.
[B] Consult applicable material and design specifications, and Table 1 where indicated, to establish pressure/temperature ratings.
[C] GR—grade.
[D] TY—type.
[E] FGP—fiberglass pipe.
[F] Specific Coast Guard and ABS approval required.
[G] For U.S. flag vessels in addition to classification society requirements.
[H] GRP—glass reinforced plastic.
[I] For trim group definition, refer to Table 28.
[J] MSS-SP-80 valves limited to 75 % of valve design pressure.

TABLE 23 Weather Deck Drains, Main Deck, and Above

Item	Type/Style	Material	Material Specification	Design Specification	Maximum Temperature Ambient[A] Remarks/Limitations
Pipe	Seamless or electric resistance welded	Carbon steel	ASTM A 106 GR[B] B or A 53 GR B TY[C] S or E	ANSI B36.10	. . .
Takedown joints	Flanges: socketweld or slip-on	Carbon steel	ASTM A 105/A 105M	ANSI B16.5	. . .
	Unions: socket weld	Carbon steel	ASTM A 105/A 105M	MSS-SP-83	. . .
	Gasketed mechanical couplings	Ductile iron	ASTM A 536	ASTM F 1476	. . .
Bolting	Bolts/bolt studs	Carbon steel	ASTM A 307 GR B	ANSI B18.2.1	. . .
	Nuts		ASTM A 563 GR A	ANSI B18.2.2	. . .
Fittings	Buttweld	Carbon steel	ASTM A 234/A 234M GR WPB	ANSI B16.9 or B16.28	. . .
	Socket weld		ASTM A 234/A 234M GR WPB or A 105/A 105M	ANSI B16.11	. . .
	Sleeve couplings		ASTM A 234/A 234M GR WPB	ASTM F 682	. . .
	Used with gasketed mechanical couplings	Ductile iron	ASTM A 536	ASTM F 1548	. . .
Valves	Butterfly grooved end	Ductile iron	ASTM A 536	. . .	Trim group 4[D]
Valves: check	Flanged	Ductile iron	ASTM A 395	ANSI B16.34	Trim group 4[D]
		Carbon steel	ASTM A 216/A 216M GR WCB or A 105/A 105M		Trim group 3[D]
	Grooved end	Ductile iron	ASTM A 536	. . .	Trim group 3 and 4[D]

[A] Consult applicable material and design specifications, and Table 1 where indicated, to establish pressure/temperature ratings.
[B] GR—grade.
[C] TY—type.
[D] For trim group definition, refer to Table 28.

TABLE 24 Inert Gas-Generator or Uptakes to Scrubber

Item	Type/Style	Material	Material Specification	Design Specification	Maximum Temperature 840°F[A] Remarks/Limitations
Pipe	Fabricated duct	Alloy steel	ASTM A 242/A 242M TY[B] 1	Commercial[C]	. . .
Takedown joints	Flanges: welded	Alloy steel	ASTM A 242/A 242M TY 1	Commercial[C]	. . .
Bolting	Bolts	CrMoV[D] steel	ASTM A 193/A 193M GR[E] B 16	ANSI B18.2.1	. . .
	Nuts	CMo[F] steel	ASTM A 194/A 194M GR 4	ANSI B18.2.2	. . .
Fittings	Fabricated duct	Alloy steel	ASTM A 242/A 242M TY 1	Commercial[C]	. . .
Valves	Sliding gate	Carbon steel	Commercial[C]	Commercial[C]	Trim group 3[G]
Valves	Butterfly wafer or lug	Ductile iron	ASTM A 395	MSS-SP-67	Trim group 3[G]

[A] Consult applicable material and design specifications, and Table 1 where indicated, to establish pressure/temperature ratings.
[B] TY—type.
[C] Specific Coast Guard and ABS approval required.
[D] CrMoV—chromium-molybdenum-vanadium.
[E] GR—grade.
[F] CMo—carbon-molybdenum.
[G] For trim group definition, refer to Table 28.

TABLE 25 Inert Gas, Scrubber to Tanks

Item	Type/Style	Material	Material Specification[A]	Design Specification	Maximum Temperature 406°F[B] Remarks/Limitations
Pipe	Electric resistance welded	Carbon steel	ASTM A 134 GR[C] 285C or ASTM A 139/A 139M GR B	ANSI B36.10	. . .
	Seamless or electric resistance welded		ASTM A 106 GR B or A 53 GR B TY[D] S or E		
	Filament wound	FGP[E]	ASTM D 2996 GR 1	Commercial[F]	See Table 1 and NVIC 11-86[G]
	Centrifugally cast	FGP[E]	ASTM D 2997 GR 1	Commercial[F]	
Takedown joints	Flanges: weldneck socket weld or slip-on	Carbon steel	ASTM A 105/A 105M or A 181/A 181M CL 60	ANSI B16.5	. . .
	Flexible couplings	Steel with resilient gaskets	Commercial	Commercial[F]	. . .
	Flanges: adhesive bonded	GRP[H]	ASTM D 4024 GR 1	ASTM D 4024	. . .
Bolting	Bolts/bolt studs	Carbon steel	ASTM A 307 GR B	ANSI B18.2.1	. . .
	Nuts		ASTM A 563 GR A	ANSI B18.2.2	. . .
Fittings	Buttweld	Carbon steel	ASTM A 234/A 234M GR WPB	ANSI B16.9 or B16.28	. . .
	Socketweld or threaded		ASTM A 234/A 234M GR WPB or A 105/A 105M	ANSI B16.11	. . .
	Sleeve couplings		ASTM A 234/A 234M GR WPB	ASTM F 682	. . .
	Adhesive bonded	GRP[H]	Commercial	Commercial[F]	. . .
Valves	Butterfly wafer or lug	Ductile iron	ASTM A 395	MSS-SP-67	Trim group 8[I]
		Carbon steel	ASTM A 216/A 216M GR WCB or A 105/A 105M		Trim group 3[I]
Valves: gate, globe, angle, check	Flanged	Ductile iron	ASTM A 395	ANSI B16.34	Trim group 8[I]
		Carbon steel	ASTM A 216/A 216M GR WCB or A 105/A 105M		Trim group 3[I]
	Flanged, brazed, or threaded	Bronze	ASME SB61 or SB62	MSS-SP-80[J]	Trim group 8[I]

[A] When combining dissimilar materials, galvanic corrosion can occur, especially in seawater systems, and should be considered.
[B] Consult applicable material and design specifications, and Table 1 where indicated, to establish pressure/temperature ratings.
[C] GR—grade.
[D] TY—type.
[E] FGP—fiberglass pipe.
[F] Specific Coast Guard and ABS approval required.
[G] For U.S. flag vessels in addition to classification society requirements.
[H] GRP—glass reinforced plastic.
[I] For trim group definition, refer to Table 28.
[J] MSS-SP-80 valves limited to 75 % of valve design pressure.

TABLE 26 Liquified Natural Gas Systems Including Vapor Fuel, Inert Gas, and Nitrogen Service

Item	Type/Style	Material	Material Specification	Design Specification	Minimum Temperature 0°F[A] Remarks/Limitations
Pipe	Seamless or electric resistance welded	Carbon steel	ASTM A 106 GR[B] B or A 53 GR B TY[C] S or E	ANSI B36.10	. . .
Takedown joints	Flanges: weld neck, socket weld or slip-on	Carbon steel	ASTM A 105/A 105M	ANSI B16.5	. . .
Bolting	Bolts/bolt studs	Carbon steel	ASTM A 307 GR B	ANSI B18.2.1	. . .
	Nuts		ASTM A 563 GR A	ANSI B18.2.2	. . .
Fittings	Buttweld	Carbon steel	ASTM A 234/A 234M GR WPB	ANSI B16.9 or B16.28	. . .
	Socket weld		ASTM A 234/A 234M GR WPB or A 105/A 105M	ANSI B16.11	. . .
	Sleeve coupling		ASTM A 234/A 234M GR WPB	ASTM F 682	. . .
Valves	Butterfly wafer or lug	Carbon steel	ASTM A 216/A 216M GR WCB or A 105/A 105M	MSS-SP-67	. . .
Valves: gate, globe, angle, check	Flanged or buttweld	Carbon steel	ASTM A 216/A 216M GR WCB or A 105/A 105M	ANSI B16.34	Trim group 3[D]
	Socket weld		ASTM A 234/A 234M GR WPB or A 105/A 105M	ANSI B16.34	. . .

[A] Consult applicable material and design specifications, and Table 1 where indicated, to establish pressure/temperature ratings.
[B] GR—grade.
[C] TY—type.
[D] For trim group definition, refer to Table 28.

TABLE 27 Liquified Natural Gas Systems Including Cargo, Inert Gas, Nitrogen, and Cargo Tank Cooldown and Warm-Up Piping Below 0°F

Item	Type/Style	Material	Material Specification	Design Specification	Minimum Temperature –325°F[A] Remarks/Limitations
Pipe	Seamless or electric resistance welded	CRES[B]	ASME SA312 TP[C] 316L or 304L	ANSI B36.19	. . .
Takedown joints	Flanges: weld neck or socket weld	CRES	ASTM A 182/A 182M GR[D] 316L	ANSI B16.5	. . .
Bolting	Bolts/bolt studs	CRES	ASTM A 320/A 320M GR B8T, B8F, B8M, or B8C	ANSI B18.2.1	. . .
	Nuts		ASTM A 194/A 194M GR 8, 8C, 8F, or 8T	ANSI B18.2.2	. . .
Fittings	Buttweld	CRES	ASTM A 182/A 182M GR 316L or 304L; or A 351/A 351M GR CF3M	ANSI B16.9 or B16.28	. . .
	Socket weld		ASTM A 182/A 182M GR 316L or 304L; or A 351/A 351M GR CF3M	ANSI B16.11	. . .
Valves	Butterfly wafer or lug	CRES	ASTM A 182/A 182M GR 316L or 304L; or A 351/A 351M GR CF3M	MSS-SP-67	Trim group 7[E]
Valves: gate, globe, angle, check	Flanged, buttweld, or socket weld	CRES	ASTM A 182/A 182M GR 316L or 304L; or A 351/A 351M GR CF3M	ANSI B16.34	Trim group 7[E]

[A] Consult applicable material and design specifications, and Table 1 where indicated, to establish pressure/temperature ratings.
[B] CRES—corrosion resistant steel.
[C] TP—tubular product.
[D] GR—grade.
[E] For trim group definition, refer to Table 28.

TABLE 28 Valve Trim Groups[A]

Group	Trim	Material	Material Specification[B]	Remarks/Limitations
1	Stem	CRES[C]	ASTM A 182/A 182M GR[D]F6a	. . .
	Wedge/disk	CrMo[E]	ASTM A 182/A 182M GR F11	
	Seat ring	CrMo	ASTM A 182/A 182M GR F11 or ASME SA217 GR WC6	hard-faced seat
	Seat, integral	Same as valve body		
2	Stem, wedge/disk or seat ring	CRES	ASTM A 182/A 182M GR F6a	hard-faced seat
	Integral seats	Same as valve body		
3	Stem, wedge/disk or seat ring	CRES	ASTM A 182/A 182M GR F6a	hard-faced seat optional
	Seat integral	Same as valve body		
4	Stem, wedge/disc or seating	Bronze	ASME SB61 or SB62	. . .
	Seat integral	Same as valve body		
5	Stem, wedge/disk or seat ring	CRES	ASTM A 182/A 182M GR F6a	. . .
	Seat integral	Same as valve body		
6	Stem, wedge/disk or seat ring	NCA[F]	ASTM A 164[G]	. . .
7	Stem, wedge/disk or seat ring	CRES	ASTM A 182/A 182M GR F304L or F316L or ASTM A 351/A 351M GR CF3M	hard-faced seat optional
8	Stem	CRES	ASTM A 182/A 182M GR F6a	. . .
	Wedge/disk or seat ring	Bronze	ASME SB61 or SB62	. . .
	Integral seat	Same as valve body	. . .	. . .

[A] Consult applicable material and design specifications, and Table 1 where indicated, to establish pressure/temperature ratings.
[B] When combining dissimilar materials, galvanic corrosion can occur, especially in seawater systems, and should be considered.
[C] CRES—corrosion resistant steel.
[D] GR—grade.
[E] CrMo—chromium-molybdenum.
[F] NCA—nickel copper alloy.
[G] Discontinued.

CERTIFICATE

By Authority Of
THE UNITED STATES OF AMERICA

Legally Binding Document

By the Authority Vested By Part 5 of the United States Code § 552(a) and Part 1 of the Code of Regulations § 51 the attached document has been duly INCORPORATED BY REFERENCE and shall be considered legally binding upon all citizens and residents of the United States of America. *HEED THIS NOTICE*: Criminal penalties may apply for noncompliance.

Document Name: ASTM F1172: Fuel Oil Meters of the Volumetric Positive Displacement Type

CFR Section(s): 46 CFR 56.60-1(b)

Standards Body: American Society for Testing and Materials

APPROVED

Official Incorporator:

THE EXECUTIVE DIRECTOR
OFFICE OF THE FEDERAL REGISTER
WASHINGTON, D.C.

Standard Specification for
Fuel Oil Meters of the Volumetric Positive Displacement Type[1]

1. Scope

1.1 This specification provides the minimum requirements for the design, fabrication, pressure rating, marking, and testing for fuel oil meters (volumetric positive displacement type).

1.2 The values stated in inch-pound units are to be regarded as the standard. Metric (SI) units are provided for information only.

1.3 The following safety hazards caveat pertains only to the test method section of this specification. *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

F 722 Specification for Welded Joints for Shipboard Piping Systems[2]

2.2 *ANSI Standards:*[3]

B2.1 Pipe Threads
B16.1 Cast Iron Pipe Flanges and Flanged Fittings
B16.3 Malleable-Iron Screwed Fittings
B16.4 Cast-Iron Screwed Fittings
B16.5 Pipe Flanges and Flanged Fittings
B16.11 Forged Steel Fittings Socket-Welding and Threaded
B16.34 Valves, Flanged and Buttwelding End
B31.1 Power Piping

2.3 *Manufacturers' Standardization Society of the Valve and Fittings Industry:*[4]

MSS SP-25 Standard Marking System for Valves, Fittings, Flanges and Unions

2.4 *API Standard:*[5]

Code No. 1101 Measurement of Petroleum Liquid Hydrocarbons by Positive Displacement Meter

2.5 *American Society of Mechanical Engineers:*[6]

ASME Boiler and Pressure Vessel Code, Section VIII, Div. I, Pressure Vessels; Section IX, Welding and Brazing Qualifications

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *fuel oil meter (volumetric positive displacement type)*—device intended to indicate the volume of liquid fuel oil delivered to a fuel distribution system over a period of time.

3.1.2 *maximum allowable working pressure (MAWP)*—maximum system pressure to which a fuel oil meter may be subjected.

4. Ordering Information

4.1 Orders for products under this specification shall include the following applicable information:

4.1.1 Title, number, and date of this specification.
4.1.2 Operating pressure (psi) and temperature (°F).
4.1.3 End connection and size.
4.1.4 Maximum capacity required.
4.1.5 Type of fuel service.
4.1.6 Materials—external and internal.
4.1.7 Other test requirements.
4.1.8 Qualification test reports as required.

5. Materials and Manufacture

5.1 Fuel oil meter casings, as well as any pressure-retaining parts, shall be constructed of ferrous material as listed in Section VIII, Division 1 of the ASME Boiler and Pressure Vessel Code. All other parts shall be constructed of materials suitable for the service intended. Fasteners in contact with interior fluid shall be of corrosion-resistant steel.

5.2 Seals and associated parts shall be of materials suitable for the service and the fluid to be measured.

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[1] This specification is under the jurisdiction of ASTM Committee F-25 on Ships and Marine Technology and is the direct responsibility of Subcommittee F25.13 on Piping Systems.

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[2] *Annual Book of ASTM Standards*, Vol 01.07.

[3] Available from American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.

[4] Available from Manufacturer's Standardization Society of the Valve and Fittings Industry, 1815 N. Fort Myer Dr., Arlington, VA 22209.

[5] Available from American Petroleum Institute, 1801 K St., N.W., Washington, DC 20226.

[6] Available from American Society of Mechanical Engineers, 345 E. 47th St., New York, NY 10017.

5.3 *Manufacture*:

5.3.1 Fuel oil meters with end fittings in compliance with ANSI Standards B2.1, B16.1, B16.3, B16.4, B16.5, B16.11, or B16.34 as appropriate may be used within the pressure-temperature ranges permitted by the applicable standard provided the meter housing is satisfactory for these conditions.

5.3.2 Threaded fittings above two nominal pipe size (NPS) and socket welded flanges above 3 NPS shall not be used in fuel oil meters with a MAWP above 150 psig (1 N/mm^2) and for service above 150°F (65°C).

5.4 Welding procedure qualification, welder performance qualification, and welding materials shall be in accordance with ANSI B31.1 and Section IX of the ASME Code. Brazing or soldering shall not be used.

6. Other Requirements

6.1 *Components*:

6.1.1 The meter shall consist of a housing with measuring mechanism and a register with counter mechanism.

6.1.1.1 *Measuring Chamber*—The measuring chamber for all meters shall be so constructed as not to show distortion under maximum allowable working pressure in any manner, or to affect the sensitivity of the meter.

6.1.1.2 *Adjusting Device*—The meter shall be provided with an adjusting device for changing the registered quantity to attain desired calibration. The adjustment setting shall have provisions for locking and shall not change during the meter life except by manual readjustment. The adjusting device shall be noncyclical and shall permit adjustment without disassembly of the mechanism except for removal of adjusting device cover plate. The plate shall be sealed by means of a lead seal. The meter shall be capable of calibration adjustment over a minimum range of 5 %.

6.1.1.3 *Direction Marking of Meter*—Directions for positive and negative adjustment shall be permanently marked on the meter.

6.1.1.4 *Register*—The register shall be of the direct-reading type. The register shall have a nonsetback total indicator and a setback-type run indicator, so that individual runs can be registered without affecting the total of all runs, as shown on the total indicator. The total indicator shall have a minimum of eight figures, and the setback run indicator shall have a minimum of five figures. Reset digits shall have a minimum height of ½ in. (13 mm) and shall not be coated with fluorescent paint. The indicating register shall read in U.S. gallons of 231 in.^{3} (3.785 41 $\times$ 10^{-3} m^3) each. The register shall be isolated from the fluid.

6.1.1.5 *Register Face*—The register shall have a transparent, colorless plastic face of such size that all digits shall be easily read. Glass shall not be used.

6.2 *Rating, Design, and Fabrication*:

6.2.1 The maximum allowable working pressure-temperature rating (MAWP) for fuel oil meters conforming to this standard shall be established by at least one of the following methods:

6.2.1.1 Proof test in accordance with the requirements prescribed in Paragraph UG-101 of Section VIII of the ASME Code. If burst-type tests as outlined in Paragraph UG-101(m) are used, it is not necessary to rupture the component. In this case, the value of B to be used in determining the MAWP shall be the maximum pressure to which the component was subjected without rupture. Components that have been subjected to a hydrostatic proof test shall not be offered for sale.

6.2.1.2 The water temperature shall not exceed 125°F (52°C) during the test.

6.2.2 Design calculations are in accordance with the requirements prescribed in Section VIII, Division I of the ASME Code.

6.3 Where welded construction is used for the fabrication of pressure containing parts, welded joint design details shall be in accordance with Section VIII, Division 1 of the ASME Code and Specification F 722. Except for fillet welds, all welds shall be full penetration welds extending through the entire thickness of the shell.

6.4 Inlet and outlet connections consisting of welded flanges and fittings shall be in accordance with Specification F 722. When radiography is required (see 10.2), all welds shall be butt welds for Class I piping as required by Specification F 722, except packing cylinders, drains, and similar ancillary connections may be attached by fillet or socket welds.

6.5 *Capacity*—The maximum capacity of the meter shall be as specified by the manufacturer.

6.6 *Pressure Drop*—The maximum pressure drop between the meter inlet and outlet shall not exceed 5 psi (34 MPa) as certified by testing in accordance with 8.1.1.2.

6.7 *Error, Normal Flow*—For flow rate and calibration setting between 5 and 100 % of maximum capacity, the error of the meter shall not exceed 0.1 % for any one predetermined flow rate and accuracy setting.

6.8 *Maintainability*—The meter shall be so designed as not to require special tools for overhaul and repair.

7. Workmanship, Finish, and Appearance

7.1 Meter shall have all burrs or sharp edges removed and shall be cleaned of all loose metal chips and other foreign substances.

7.2 *Treatment and Painting*—The exterior surface of the meter shall be treated and painted in accordance with best commercial practice.

8. Number of Tests

8.1 *Qualification Tests*:

8.1.1 A representative fuel oil meter of each particular design shall be certified as having undergone the following qualification tests.

8.1.1.1 *Calibration and adjustment*:

The meter shall be tested in accordance with applicable sections of API Code 1101.

8.1.1.2 *Pressure drop*—Clean fluid at 35 Saybolt seconds Universal (SSU) shall be pumped through the meter at 100 % of manufacturer's rated capacity. After the flow rate has been stabilized, the measured pressure drop between the inlet and outlet of the meter shall not exceed 5 psi (34 MPa).

8.2 *Production Tests*:

8.2.1 The manufacturer shall production test each fuel oil meter by hydrostatic test methods as described in Section 9.

8.2.2 Each meter shall be calibration tested at mid range of flow capacity. The reading error shall not exceed 0.1 % at this flow rate.

9. Test Methods

9.1 *Hydrostatic Test*—Each fuel oil meter shall be given a hydrostatic shell test of at least 1½ times its maximum allowable working pressure.

9.1.1 The fluid temperature shall not exceed 125°F (52°C) during the hydrostatic test, and the fluid used should be nonflammable. Further, it should not cause rusting and should otherwise be compatible with the internal parts of the fuel oil meter.

9.1.2 The test arrangement shall be air free before pressurization.

9.1.3 The minimum duration of the shell test shall be 30 s at required pressure.

9.1.4 No visible leakage or structural damage shall show during the test.

10. Inspection

10.1 Each finished fuel oil meter shall be visually examined and dimensionally checked to ensure that the meter corresponds to this specification and is marked in accordance with Section 12.

10.2 *Nondestructive Examination of Welds*:

10.2.1 All welds shall be visually examined in accordance with ANSI B31.1.

10.2.2 Welded inlet and outlet connections that are equal to or greater than 4 NPS or greater than 0.375-in. nominal wall thickness which are in services greater than 150 psig (1 N/mm^2) and 150°F (65°C) shall be 100 % radiographically examined.

11. Certification

11.1 The pressure ratings established under this specification are based upon materials of high quality produced under regular control of chemical and physical properties by a recognized process. The manufacturer shall be prepared to certify that his product has been so produced and that the physical and chemical properties thereof, as proven by test specimens and nondestructive testing or as documented by certifications from the producer or recognized distributor of these materials, are at least equal to the requirements of the appropriate specifications.

11.2 When specified in the purchase order or contract, the manufacturer certification shall be furnished to the purchaser stating that samples representing each lot have been manufactured, tested, and inspected in accordance with this specification and the requirements have been met. When specified in the purchase order or contract, a report of the test results shall be furnished.

11.3 Certification of the MAWP shall be available to purchasers.

12. Product Marking

12.1 Each fuel oil meter shall be permanently marked with the following:

12.1.1 Manufacturer's name or trademark.

12.1.2 Maximum allowable working pressure—temperature rating (MAWP).

12.1.3 *Flow Direction*—The direction of flow through the meter shall be indicated by the words "inlet" and "outlet," a directional arrow, or both, stamped or embossed on the meter.

12.1.4 End fittings complying with a standard listed in 5.3.1 may be marked in accordance with the applicable requirements of MSS SP-25 for dimensional identification purposes if desired.

12.1.5 Size (end connection size), may be included at the option of the manufacturer.

12.1.6 ASTM designation of this specification.

13. Quality Assurance Provisions

13.1 The manufacturer of the fuel oil meter shall maintain the quality of the meters that are designed, tested, and marked in accordance with this specification. At no time shall a meter be sold that is marked with this standard designation that does not meet the requirements herein.

14. Keywords

14.1 fuel oil; fuel oil meters; meters; volumetric positive displacement meters

CERTIFICATE

By Authority Of
THE UNITED STATES OF AMERICA
Legally Binding Document

By the Authority Vested By Part 5 of the United States Code § 552(a) and Part 1 of the Code of Regulations § 51 the attached document has been duly INCORPORATED BY REFERENCE and shall be considered legally binding upon all citizens and residents of the United States of America. *HEED THIS NOTICE*: Criminal penalties may apply for noncompliance.

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An American National Standard

Standard Specification for Thermosetting Resin Fiberglass Pipe and Fittings to be Used for Marine Applications[1]

This standard is issued under the fixed designation F 1173; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers machine made reinforced thermosetting epoxy resin pipe and fittings nominal pipe size (NPS) 1 through 48 in. in diameter to be used in marine piping systems in which resistance to corrosion, aging, and deterioration from seawater, gas, chemicals, and sea environment is required.

1.2 When invoked by military or other procurement activities, MIL-P-24608 (SH) shall apply.

1.3 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

1.4 The dimensionless designator NPS has been substituted in this standard for such traditional terms as "nominal diameter," "size," and "nominal size."

1.5 The specific maximum temperature and pressure covered by this specification is 240°F (115.6°C) and 225 psi (15.5 bar).

1.6 The following safety hazards caveat pertains to the test methods portion, Section 11, of this specification. *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

D 257 Test Methods for dc Resistance or Conductance of Insulating Materials[2]

D 618 Practice for Conditioning Plastics and Electrical Insulating Materials for Testing[3]

D 883 Terminology Relating to Plastics[3]

D 1141 Specification for Substitute Ocean Water[4]

D 1599 Test Method for Short-Time Hydraulic Failure Pressure of Plastic Pipe, Tubing, and Fittings[5]

D 1600 Terminology of Abbreviated Terms Relating to Plastics[3]

D 1898 Practice for Sampling of Plastics[3]

D 2105 Test Method for Longitudinal Tensile Properties of "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe and Tube[5]

D 2310 Classification for Machine-Made "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe[5]

D 2924 Test Method for External Pressure Resistance of "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe[5]

D 2925 Test Method for Beam Deflection of "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe Under Full Bore Flow[5]

D 2996 Specification for Filament-Wound "Fiberglass" (Glass-Fiber-Reinforced Thermosetting Resin) Pipe[5]

D 2997 Specification for Centrifugally Cast "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe[5]

D 3567 Practice for Determining Dimensions of "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe and Fittings[5]

D 4024 Specification for Machine Made "Fiberglass" (Glass-Fiber-Reinforced Thermosetting Resin) Flanges[5]

D 4496 Test Method for dc Resistance or Conductance of Moderately Conductive Materials[6]

E 162 Test Method for Surface Flammability of Materials Using a Radiant Heat Source[7]

E 662 Test Method for Specific Optical Density of Smoke Generated by Solid Materials[7]

E 800 Guide for Measurement of Gases Present or Generated During Fires[7]

F 412 Terminology Relating to Plastic Piping Systems[5]

2.2 *ANSI Standards:*[8]

B16.1 Cast Iron Pipe Flanges and Flanged Fittings

B16.5 Steel Pipe Flanges, Flanges, Flanged Fittings

2.3 *ISO Standards:*[8]

13 Grey Iron Pipe, Special Castings and Grey Iron Parts for Pressure Main Lines

559 Welded or Seamless Steel Tubes for Water, Sewage and Gas

2.4 *Other Documents:*

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[1] This specification is under the jurisdiction of ASTM Committee F-25 on Shipbuilding and is the direct responsibility of Subcommittee F25.13 on Piping Systems.

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[2] *Annual Book of ASTM Standards*, Vol 10.01.

[3] *Annual Book of ASTM Standards*, Vol 08.01.

[4] *Annual Book of ASTM Standards*, Vol 11.02.

[5] *Annual Book of ASTM Standards*, Vol 08.04.

[6] *Annual Book of ASTM Standards*, Vol 10.02.

[7] *Annual Book of ASTM Standards*, Vol 04.08.

[8] Available from American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.

National Sanitation Foundation Standard 14[9]
MIL-P-24608 (SH) Pipe, Fittings, and Adhesive Kits, Glass Reinforced Thermosetting Epoxy Resin for Shipboard Piping Systems[10]
IMO Assembly Resolution A.753(18)[10]

3. Terminology

3.1 *Definitions*—Definitions are in accordance with Terminologies D 883 or F 412, and abbreviations are in accordance with Terminology D 1600, unless otherwise indicated.

3.2 *Descriptions of Terms Specific to This Standard:*

3.2.1 *maximum operating pressure*—the highest pressure that can exist in a system or subsystem under normal operating conditions. This pressure is determined by such influences as pump or compressor shut-off pressures, pressure regulating valve lockup (no flow) pressure, and maximum chosen pressure at the system source.

3.2.2 *representative piping system*—a system composed of a single manufacturer's pipes, fittings, joints, and adhesives that would normally be used by a customer or installer. If the system is conductive, any devices normally supplied by the manufacturer (either as electromechanical attachments or integrated into the composite structure) for electrical continuity or grounding are to be included as well.

4. Classification

4.1 *General:*

4.1.1 Pipe meeting this specification is classified by type, grade, and class similar to Classification D 2310.

4.1.2 Fittings meeting this specification are also classified by types (method of manufacture), grades (generic type of resin), and classes (joining system).

4.1.3 Joints meeting this specification are classified only as being conductive or non-conductive.

4.2 *Types:*

4.2.1 *Type I*—Filament-wound (pipe and fittings).

4.2.2 *Type II*—Centrifugally cast (pipe and fittings).

4.2.3 *Type III*—Molded (fittings only).

4.3 *Grades:*

4.3.1 *Grade I*—Epoxy/Epoxy Vinyl Ester resin (pipe and fittings).

4.3.2 *Grade II*—Polyester Resins (pipe and fittings).

4.3.3 *Grade III*—Customer Specified Thermosetting resin (pipe and fittings).

4.4 *Classes:*

4.4.1 *Pipe and Fittings Only:*

4.4.1.1 *Class A*—No liner.

4.4.1.2 *Class B*—Liner, reinforced.

4.4.1.3 *Class C*—Conductive, no liner.

4.4.1.4 *Class D*—Reinforced with conductive outer layer.

4.4.2 *Joining System:*

4.4.2.1 *Class E*—Non-conductive joint.

4.4.2.2 *Class F*—Conductive joint.

4.5 *Piping Systems*, including pipes, joints, and fittings, along with any applicable fire protection coatings or coverings shall meet at least one of the following three levels of full scale fire endurance.

4.5.1 *Level 1*—Piping systems must satisfy the acceptance criteria defined in Annex A4 and pass the fire endurance test method specified in Annex A4 for a duration of a minimum of one h.

4.5.2 *Level 2*—Piping systems must satisfy the acceptance criteria defined in Annex A4 and pass the fire endurance test method specified in Annex A4 for a duration of a minimum of 30 min.

4.5.3 *Level 3*—Piping systems must satisfy the acceptance criteria defined in Annex A5 and pass the fire endurance test method specified in Annex A5 for a duration of a minimum of 30 min.

4.5.4 Piping and insulation systems should not drip during full scale evaluations for levels 1, 2, or 3.

5. Ordering Information

5.1 When ordering pipe and fittings under this specification, the following should be specified:

5.1.1 Designation and date of this specification.

5.1.2 Type.

5.1.3 Grade.

5.1.4 Class.

5.1.5 NPS.

5.1.6 Manufacturer's identification (for example, part number, product's name, etc.).

5.1.7 Specific customer requirements, if any.

6. Materials and Manufacture

6.1 *Materials:*

6.1.1 *General*—The resins, reinforcements, colorants, fillers, and other materials, when combined as a composite structure, shall produce a pipe that shall meet the performance requirements of this specification.

6.1.2 *Joining Systems*—The joining system used shall be rated for the same design conditions as the pipe and fittings. This includes design for internal pressure, tensile strength, bending strength, electrical resistance, etc., as called for in Section 7.

6.2 *Manufacture:*

6.2.1 Pipe manufactured by the filament winding process shall be in accordance with Specification D 2996.

6.2.2 Pipe manufactured by the centrifugal casting process shall be in accordance with Specification D 2997.

6.2.3 Fittings shall be manufactured by the filament wound, molded, or centrifugally cast process, using thermosetting resin and glass reinforcement.

7. Performance Requirements

7.1 *General:*

7.1.1 The requirements of this section apply to all piping and piping systems independent of service or location.

7.1.2 The specification of the piping shall meet the performance guidelines that follow.

7.1.3 The structural wall of the piping system shall have sufficient strength to take account of the most severe coincident conditions of pressure, temperature, the weight of the piping itself, and any static and dynamic loads imposed by the design or environment. Once the structural wall

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[9] Available from the National Sanitation Foundation, 3475 Plymouth Rd., P.O. Box 1460, Ann Arbor, MI 48106.

[10] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

thickness is calculated, the corrosion liner is added to obtain the pipe's total wall thickness.

7.1.4 For the purpose of assuring adequate robustness for all piping systems, including open-ended piping, all pipe, fittings, and joints shall have a minimum structural wall thickness able to withstand loads due to transportation, handling, installation, personnel traffic, etc. This may require the pipe, fittings, and joints to have additional structural thickness than otherwise required by service considerations.

7.1.5 The performance requirements for any component of a piping system such as fittings and joints are the same as those requirements for the piping system they are installed in.

7.2 *Hydrostatic Strength:*

7.2.1 A piping system shall be designed for a maximum operating pressure not less than the maximum working pressure to be expected under operating conditions nor less than the highest set pressure of any safety valve or pressure relief device on the system, if fitted.

7.2.2 The maximum operating pressure for a pipe system shall be determined by dividing the short-term hydrostatic test failure pressure by a minimum safety factor of 4 or the long-term hydrostatic (>100,000 hours) test failure pressure by a minimum safety factor of 2.5, whichever is the lesser of the two. Special design cases, such as where pressure surges can not be accurately estimated or where dynamic loads cannot be accurately accounted for, may warrant safety factors in excess of these values, in some cases as great as 10:1. Either the short-term or the long-term hydrostatic test pressures, whichever is used, shall be verified experimentally or by a combination of testing and calculations to the satisfaction of the approving authority. In all designs, the maximum allowable internal pressure shall be based on the weakest part of the system, be it the pipe, fittings, and flanges or the joining method used.

7.2.2.1 The maximum operating pressure shall be based on the structural wall thickness, not the total wall thickness.

7.3 *External Pressure:*

7.3.1 External pressure shall be taken into account in the design of the piping system for any installation which may be subject to vacuum conditions inside the pipe or a pressure head acting on the outside of the pipe.

7.3.2 A piping system shall be designed for a maximum allowable external pressure not less than the sum of the maximum potential pressure head outside the pipe plus the design vacuum pressure. The maximum allowable external pressure for a piping system shall be determined by dividing the collapse test pressure by a minimum safety factor of 3. Special design cases, such as where pressure surges cannot be accurately estimated or where dynamic loads cannot be accurately accounted for, may warrant safety factors in excess of these values, in some cases as great as 10:1. The collapse test pressure shall be verified experimentally or by a combination of testing and calculation methods to the satisfaction of the approving authority.

7.3.2.1 The maximum allowable external pressure shall be based on the structural wall thickness, not the total wall thickness.

7.4 *Longitudinal Tensile Properties:*

7.4.1 The sum of the longitudinal stresses due to pressure, weight and other dynamic and sustained loads shall not exceed the maximum allowable stress in the longitudinal direction. Forces due to thermal expansion, contraction, and external loads, such as wind loads, seismic loads, etc., shall be considered when determining longitudinal stresses in the system. Internal shock, or pressure surge, commonly known as water hammer, shall also be considered when determining the stresses in the system.

7.4.2 The sum of the longitudinal stresses shall not exceed half of the nominal circumferential stress derived from the nominal internal pressure determined according to 2.2, unless the maximum allowable longitudinal stress is verified experimentally or by a combination of testing and calculation methods to the satisfaction of the approving authority.

7.4.2.1 The maximum allowable maximum longitudinal stress shall be based on the structural wall thickness, not the total wall thickness.

7.5 *Bending Strength:*

7.5.1 A piping system shall be designed for a maximum allowable bending stress not less than the sum of all bending stress due to dead weight, expansion loads, external loads, and any other static or dynamic loads imposed on the piping system.

7.5.2.1 The maximum allowable maximum bending stress shall be based on the structural wall thickness, not the total wall thickness.

7.6 *Beam Stiffness:*

7.6.1 The piping system shall be supported properly to limit the vertical deflection in any part of the piping system to 0.5 in. (12.7 mm).

7.6.2 The calculation of support spacing shall take into account the dead weight of the pipe and its fluid contents as well as any other static external loads.

7.6.2.1 The maximum allowable maximum support spacing shall be based on the structural wall thickness, not the total wall thickness.

7.7 *Temperature:*

7.7.1 The piping system shall meet the design requirements of these guidelines over the range of service temperatures it will experience.

7.7.2 The maximum working temperature should be at least 36°F (20°C) less than the minimum heat distortion temperature (determined according to ISO 75 method A, or equivalent) of the resin or plastic material. The minimum heat distortion temperature should not be less than 176°F (80°C).

7.7.3 Where high or low temperature services are encountered, special attention should be paid to material properties. Material properties such as strength, modulus, etc., will change with temperature, therefore, they shall be modified according to the pipe system's design temperature.

7.8 *Impact Resistance:*

7.8.1 A piping system shall have a minimum resistance to impact to the satisfaction of the approving authority. The impact resistance needs to satisfy all impact loading due to transportation and installation, not just under normal operation.

7.9 *Ageing:*

7.9.1 Before selection of a piping system material, the manufacturer shall confirm that the environmental effects including, but not limited to, ultraviolet rays, saltwater exposure, oil and grease exposure, temperature, and humidity, will not degrade the mechanical, electrical, or physical properties of the piping system material below the values necessary to meet these guidelines.

7.10 *Fatigue:*

7.10.1 In the cases where design loadings incorporate a significant cyclic or fluctuating component, fatigue shall be considered in the material selection process and taken into account in the installation design.

7.10.2 In addressing material fatigue, the designer may rely on experience with similar materials in similar service or only laboratory evaluation with mechanical test specimens. However, the designer is cautioned that small changes in the material composition may significantly affect fatigue behavior.

7.11 *Erosion Resistance:*

7.11.1 In the cases where fluid in the system has high flow velocities, abrasive characteristics, or where there are flow path discontinuities producing excessive turbulence, the possible effect of erosion shall be considered. If erosion can not be avoided then adequate measures shall be taken such as special liners, change of materials, etc.

7.12 *Fluid Absorption:*

7.12.1 Absorption of fluid by the piping system material shall not cause a reduction of mechanical, electrical, or physical properties of the material below that required by these guidelines.

7.13 *Material Compatibility:*

7.13.1 The piping material shall be compatible with the fluid being carried or in which it is immersed such that its design strength does not degenerate below that recognized by these guidelines. Where the reaction between the pipe material and the fluid is unknown, the compatibility should be demonstrated to the satisfaction of the approving authority.

7.14 *Potable Water Usage:*

7.14.1 The material, including pipe, fittings, and joints shall have no adverse effect on the health of personnel when used for potable water service. The material used for such purposes shall be to the satisfaction of the authority.

7.15 *Electrical Resistance*—Classes C and D pipe and fittings, and F joints and representative systems assembled from such components shall have a resistance per unit length not to exceed 1×10^5 Ω/meter (3.281×10^5 Ω/foot) when tested in accordance with 11.12.

7.16 *Static Charge Shielding*—Classes C and D pipe and fittings and F joints shall have a maximum resulting voltage not to exceed 100 V induced on the exterior surface of the pipe when tested in accordance with 11.13.

7.17 *Grounding Resistance*—Resistance to ground should not exceed 1×10^6 Ω when tested in accordance with 11.14.

7.18 *Flame Spread*—Piping shall have a flame spread index of 25 or less when tested in accordance with 11.9. Nominal 6-inch pipe should be cut into three 2-inch by 18-inch sections, measured along its chord and axially, respectively (19.5°) to approximate the flat 6 inch by 18 inch panel required in Test Method E 162. Edges of each of these sections should be cut so that they are completely flush (0.001″ gap maximum) to each other along the entire length of the sections. Where protective coatings or coverings are used, they shall also be tested while coated on or attached to the pipe sections. The outer surface should be orthogonal to the fire direction. The IMD Assembly Resolution A.753(18) is an alternative test method.

7.19 *Smoke Generation*—The maximum specific optical density under uncorrected flaming and nonflaming conditions for pipe should be 200 when tested in accordance with 11.10. 3 in. by 3 in., measured axially and along its chord (29° segment), square pieces should be cut from 12 in. pipe. Where protective coatings or coverings are used, they shall also be tested while coated or attached to the pipe sections. The outer surface should be orthogonal to the fire direction.

7.20 *Toxic Products of Combustion*—The following gases should have concentrations less than or equal to the limits listed in Table 1 when measured in accordance with Guide E 800 or equivalent during smoke generation (test 3). Samples should be drawn from the smoke chamber either at the point of maximum smoke concentration, or at the end of the test. The point of maximum smoke concentration, or at the end of the test. The point of maximum smoke concentration is explained in Guide E 800. For purposes of sampling, it may be defined as the point in time up to two minutes after the smoke concentration begins to decline or flatten out in a straight line. Burning of the pipe samples shall be done with Test Method E 662.

8. Other Requirements

8.1 *Flanges*—Fiberglass flanges for merchant vessels shall conform to Specification D 4024, ANSI B16.1, and ANSI B16.5.

8.2 *Potable Water Piping Systems*—Fiberglass pipe and fittings to be used on potable water systems must conform with National Sanitation Foundation Standard 14.

8.3 *Conductive Systems and Components:*

8.3.1 Conductive pipes, fittings, and joints meeting this specification and systems constructed thereof are preferred to be homogeneously conductive throughout.

8.3.2 Conductivity may be achieved through the use of conductive layers. In this case, the following applies:

8.3.2.1 Two conductive layers, as a minimum, are required—one on the interior and one on the exterior.

8.3.2.2 Conductive connections between the layers are required to equalize potential between the layers. The resistance of these connections shall meet the requirements of 7.15 and 7.17.

8.3.2.3 Test points must be included that are easily accessible on the exterior surface to permit measurement of the interior layer's resistance per unit length after installation. These test points must be electrically isolated from the exterior conductive layer.

8.3.2.4 The internal and external conductive layers, con-

TABLE 1 Gas Concentrations

Gas	Maximum Concentration (PPM)
CO	500
CO_2	15,000
HCl	20
HF	8
HCN	10
SO_2	10
NO_x	5
NH_3	200
$COCl_2$	1
H_2S	15

ductive connections, and test points shall be suitable for the system's intended service and have a lifetime expectation no less than the non-conductive materials of the system.

9. Dimensions and Tolerances

9.1 Dimensions and tolerances of pipe and fittings shall meet the requirements of Annex A6, unless otherwise agreed upon by the buyer and seller.

10. Workmanship, Finish, and Appearance

10.1 The pipe and fittings shall be free from defects including indentations, delaminations, bubbles, pinholes, foreign inclusions, cracks, porosity, and resin-starved areas which, due to their nature, degree, or extent, detrimentally affect the strength, serviceability, and conductivity (as applicable) of the pipe and fittings. The pipe and fittings shall be as uniform as commercially practicable in color, opacity, density, and other physical properties. The pipe and fittings shall be smooth and uniform. All pipe and fittings ends shall be cut at right angles to the axis of the pipe and any sharp edges removed. The bore of each fitting shall have a smooth uniform surface, and protrusion exceeding 1⁄16 in. (1.6 mm) of material into the internal fittings flow area shall be removed and blended with adjacent smooth surfaces.

11. Test Methods

11.1 *Conditioning*—Condition test specimens at 73 ± 4°F (23 ± 2°C) and 50 ± 5 % relative humidity for not less than 48 h prior to testing, in accordance with Procedure A of Practice D 618, for those tests in which conditioning is required and in all cases of disagreement.

11.2 *Test Conditions*—Conduct tests at ambient temperature and humidity, unless otherwise specified in the test method or in this specification.

11.3 *Sampling*—To determine conformance of the material to the hydrostatic strength requirements of 7.2, take samples of pipe at random on a monthly basis or on each production run, whichever is the most frequent. The rate of sampling for the other tests listed shall be in accordance with accepted statistical practice.

11.4 *Dimensions and Tolerances*—Determine wall thickness, length, diameter, and liner thickness in accordance with Practice D 3567.

11.5 *Hydrostatic Strength*—Determine hydrostatic strength in accordance with Test Method D 1599 (free ends test).

11.6 *Impact Resistance*—Determine impact resistance in accordance with the recommended test method in Annex A1.

11.7 *Beam Stiffness*—Test the pipe samples at a minimum temperature of 240°F (116°C) in accordance with Test Method D 2925. After determining *EI* from the test results, calculate the permissible simple span for ½ in. (25 mm) deflection. The calculated span after 1000 h at 240°F (116°C) shall not be less than those given by the manufacturer's literature, assuming the pipe to be full of water.

11.8 *External Pressure Resistance*—Test the pipe samples at 240°F (116°C) in accordance with Test Method D 2924. The failure pressure for the manufacturer's minimum wall thickness shall not be less than three times the rate of external pressure resistance published by the manufacturer's product specifications. Calculate the failure pressure for all pipe sizes of identical construction using the following equation:

$$P = \frac{8K't^3}{(OD - t)^3}$$

where:

P = pressure at collapse or leak, psi (kPa),
K' = KE, psi (kPa),
K = buckling scaling constant determined by Test Method D 2924,
E = circumferential modulus of elasticity as defined in Test Method D 2924,
t = minimum reinforced wall thickness, in. (mm), and
OD = outside diameter of pipe, in. (mm).

11.9 *Flame Spread*—Test samples cut from pipe in accordance with 7.18 and tested per Test Method E 162 or equivalent.

11.10 *Smoke Generation*—Test samples cut from pipe in accordance with 7.19 and tested per Test Method E 662 or equivalent.

11.11 *Toxic Products of Combustion*—Determine the toxic products of combustion during smoke generation test 3 of Test Method E 800 or equivalent.

11.12 *Electrical Resistance Per Unit Length*—Determine electrical resistance in accordance with the recommended test method in Annex A3.

11.13 *Static Charge Shielding Capability*—Determine static charge shielding capability in accordance with the recommended test method in Annex A2.

11.14 *Grounding Resistance*—Determine grounding resistance in accordance with the recommended test method in Annex A2.

11.15 *Longitudinal Tensile Properties*—Determine longitudinal tensile properties in accordance with Test Method D 2105.

12. Inspection and Sampling

12.1 Inspection and sampling of the material shall be in accordance with Practice D 1898 and agreed upon between the purchaser and the supplier as part of the purchase contract.

13. Certification

13.1 *General:*

13.1.1 A producer's certification shall be furnished to the purchaser stating that the material was manufactured, sampled, tested, and inspected in accordance with this specification and has been found to meet the requirements. A report of the test results shall be furnished.

13.2 If the supplier has in his possession bonafide test certification data acceptable to the purchaser, the purchaser may extend initial approval under 13.1 of this specification.

14. Product Marking

14.1 Pipe and fittings shall be marked with the name, brand or trademark of the manufacturer, NPS, weight (type, grade, and class), specification designation, and date and any other information that may be desired for a specific material.

15. Keywords

15.1 epoxy resin fittings; epoxy resin pipe; marine piping; nominal pipe size; thermoset epoxy resin pipe

ANNEXES

(Mandatory Information)

A1. TEST METHOD FOR IMPACT RESISTANCE OF FIBERGLASS PIPE AND FITTINGS BY MEANS OF A FALLING STEEL BALL

A1.1 Scope

A1.1.1 This test method covers the determination of the energy required to produce failure in fiberglass pipe and fittings under specified conditions of impact by means of a falling steel ball. Balls of differing diameter and weight may be used.

A1.2 Significance

A1.2.1 The testing procedures in this test method are applicable over a range of impact energies and ball diameters. The specific ball weight and diameter must be selected for each size and type of product.

A1.2.2 This test method is intended to represent service conditions wherein the product may be subjected to damage from impact by falling objects such as tools. Low-velocity impact, such as that caused by dropping a full length of pipe or fitting for a small distance onto a support surface, may not be accurately represented by this test method.

A1.3 Apparatus

A1.3.1 *General*—One type of impact tester is illustrated in Fig. A1.1.

A1.3.2 *Steel Ball*—Two different balls may be used. The ball designated A is 2.30 in. (58.4 mm) in diameter with a weight of 29.15 oz (826.5 g). The ball designated B has a diameter of 3.00 in. (76.2 mm) and a weight of 63.5 oz (1800 g). Other ball sizes may be used upon agreement between the buyer and the seller.

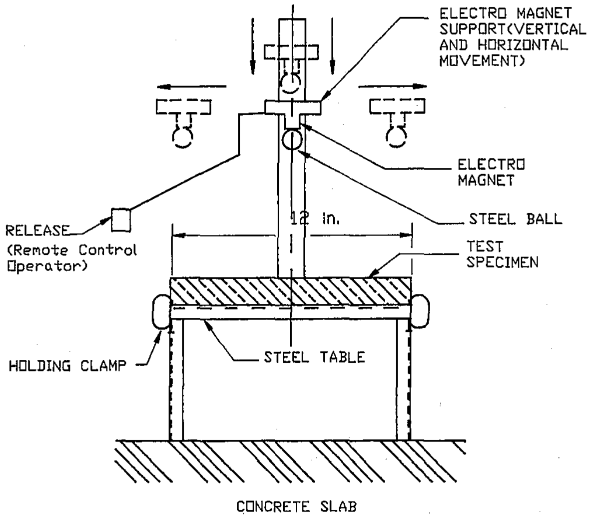

FIG. A1.1 Test Apparatus

A1.3.3 *Support Surface*—The test stand from which the ball is dropped shall be resting firmly on a concrete slab floor.

A1.3.4 *Vertical Drop*—A plump bob shall be used to ensure that the ball will drop squarely on the test specimen when released.

A1.3.5 Drop heights in increments of 1, 2, or 3 in. (25.4, 51, or 76 mm) are normally used. Means shall be provided to hold the ball at the appropriate drop heights above the test specimen as measured from the bottom of the ball to the surface of the specimen, to release the ball in a reproducible manner and to allow the ball to fall freely. Mechanical means may be used to catch the rebounding ball, or it may be caught by hand.

A1.3.6 *Specimen Holder:*

A1.3.6.1 For testing pipe, the specimen shall rest for its full length on a flat steel plate at least 0.5 in. (13 mm) thick.

A1.3.6.2 For testing fittings, a steel saddle plate curved to fit the part may be required to produce line bearing, as, for example, when the ball is being dropped onto the outer radius of a 90° elbow.

A1.3.6.3 Means shall be provided to clamp the specimen firmly into proper position at each end.

A1.4 Test Specimens

A1.4.1 The test specimens of pipe shall be equal in length to the nominal diameter but not less than 12-in. (305-mm) long. If impact resistance can vary along the pipe length, select test specimens from at least three widely spaced locations.

A1.4.2 Fittings shall be tested as a single unassembled unit.

A1.5 Number of Specimens

A1.5.1 The approximate starting point can usually be determined on one preliminary specimen.

A1.5.2 Sufficient specimens shall be used thereafter to produce a minimum of four drops at each of three different drop heights. Usable data are obtained only when, at a given drop height, at least one drop causes a failure and at least one drop does not cause a failure. If usable data are obtained at only one or two of the selected drop heights, reduce the drop height increments and continue testing within the range of heights yielding usable data.

A1.6 Conditioning

A1.6.1 The test specimens shall be conditioned at 73° + 4°F (23° + 3°C) for a minimum of 8 h prior to testing for those tests in which conditioning is required.

A1.6.2 Tests made at other temperatures shall be made in an enclosure maintained at the test temperature.

A1.7 Procedure

A1.7.1 Measure the dimensions of the test specimens in accordance with Practice D 3567. Include measurements of liner thickness and external coating thickness if applicable.

A1.7.2 Mount the specimen so the ball will strike no less than 3 in. (76 mm) from its end. The point of impact shall be at the top of the vertical diameter. Mark the point of impact and drop height on the outside of the specimen with a marking pen.

A1.7.3 Make preliminary tests to determine the approximate height of fall to produce failure in the particular pipe or fitting being tested. At this point it will usually not be necessary to cut the specimen in order to examine the inside surface.

A1.7.4 Select a ball weight and size that will produce failures between NPS 6 and 60. Using additional specimens test at three different drop heights that bracket the approximate height determined previously.

A1.7.5 Pipe less than NPS 2 in diameter are impacted twice at diametrically opposite points. Pipe NPS 2 or more in diameter can be impacted at each cross section a minimum of four times equally spaced around the circumference, using equal drop heights. As permitted by specimen diameter, additional drop points may be used with a circumferential spacing of 3 in. (76 mm). With a specimen 12 in. (305 mm) in length, drops may be made at three different cross sections (at the quarter points).

A1.7.6 For testing fittings, use diametrically opposite drop points or points in a line separated by a minimum of 3 in. (76 mm), depending on specimen geometry. For example, a 90° elbow may be laid on its side and tested at diametrically opposite points every 3 in. (76 mm) along its length, or it may be supported on a curved saddle plate and tested at points every 3 in. (76 mm) along its outer radius.

A1.7.6.1 Impact resistance of certain fittings will be a function of the fitting geometry at the point of impact. For example, testing on a 90° elbow may be limited to drops only on the outside radius when the test results reveal this as the critical area.

A1.7.7 A minimum of four impacts at each of three different drop heights which produce usable data are required (see A5.2).

A1.7.8 After a specimen has been impacted in as many places as permitted herein, cut the specimen lengthwise along its axis to examine the inside surface for failure. If a leakage test is to be performed on the impacted specimen, this can be carried out using water or air prior to cutting. The test pressure shall be 1½ times the rated pressure for the part.

A1.7.9 Swab the inside surface with fluorescent dye and use an ultraviolet light to detect failure. As an alternative, it may be possible to use other dyes or inks to high-light cracks.

A1.8 Definition of Failure

A1.8.1 Failure in the test specimen shall be shattering or any crack or split on the inside that was created by the impact which, when highlighted with dyes or inks, can be seen by the naked eye.

A1.8.2 Leaking of the specimen as a result of impact shall also be defined as failure. Because of difficulty in observing damage on the inside, failure in an unlined pipe or fitting will normally be defined as leakage in a pressure test.

A1.8.3 Damage to an external coating is not considered failure unless agreed upon between the buyer and the seller.

A1.9 Determination of Average and Standard Deviation

A1.9.1 Calculate the percentage of failures at each drop height.

A1.9.2 Plot the percentage of failures versus drop height on probability paper and draw a best-fit line representing the trend of the data. Read off the mean drop height, h_{50}, and drop height standard deviation $h_{50} - h_{15.9}$.

A1.9.3 Calculate the impact resistance as ball weight in pounds (newtons) times drop height in feet (meters). Calculate the standard deviation of impact resistance as ball weight times drop height standard deviation.

A1.10 Report

A1.10.1 Report the following information:

A1.10.1.1 Complete identification of the pipe or fitting tested including manufacturer's name and code, NPS, and average wall, liner, and coating thicknesses.

A1.10.1.2 Location of test specimens along pipe length, if applicable.

A1.10.1.3 Atmosphere in which the test was made and conditioning procedure.

A1.10.1.4 Ball diameter and weight.

A1.10.1.5 Average impact resistance in ft·lbf (N·m).

A1.10.1.6 Standard deviation in ft·lbf (N·m).

A1.10.1.7 Point of impact on fittings.

A1.10.1.8 Mode of failure (visible crack or leak) and appearance of impact area.

A1.10.1.9 Results of pressure test if applicable.

A1.10.1.10 Date of test.

A2. TEST METHOD FOR DETERMINING THE STATIC CHARGE SHIELDING CAPABILITY AND SYSTEM RESISTANCE OF REINFORCED THERMOSETTING RESIN PIPE, FITTINGS, AND JOINTS AFTER EXPOSURE TO VARIOUS CHEMICAL ENVIRONMENTS

A2.1 Scope

A2.1.1 This test method determines the static charge, if any, present on the exterior surface of a grounded fiberglass pipe, fitting, or joint when a charge is applied to the interior surface. It is also used to measure the resistance of the associated grounding techniques and to determine the effect of typical chemical exposures on the shielding capability of the pipe and grounding system.

A2.2 Summary of Test Methods

A2.2.1 *Grounding Resistance*—The test method consists of electrically isolating the pipe, fitting, or joint, then grounding the system using its associated grounding technique, and measuring the resistance of the system from an interior surface to a common ground.

A2.2.2 *Static Charge Shielding Capability*—This test method consists of applying a static charge to the interior

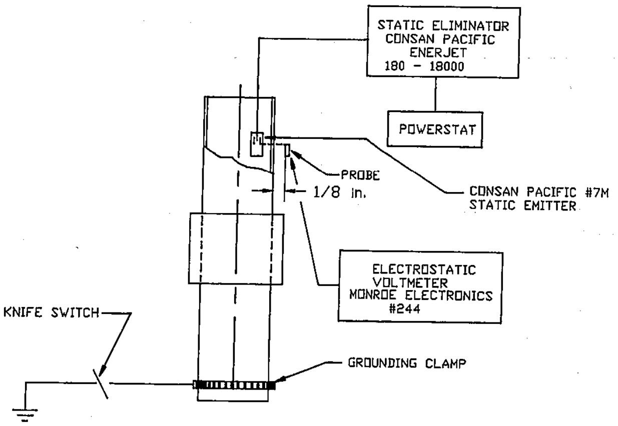

FIG. A2.1 Test Setup

surface of a grounded reinforced thermosetting resin pipe, fitting, or joint and then measuring the resulting voltage, if any, induced on the exterior surface.

A2.3 Test Equipment (see Fig. A2.1)

A2.3.1 *Static Generator*—An instrument capable of producing clouds of either negative or positive charges having a controlled voltage of 0 to 1000 V.[11]

A2.3.2 *Electrostatic Voltmeter*—An electrostatic voltmeter having a range of 0 to +3000 V and an accuracy of 0.1 %.[12]

A2.3.3 *Exposure Tank*—An exposure tank of nonmetallic construction and resistant to the test environment. It shall be maintained at a temperature of 60 to 80°F (15.6° to 26.7°C) throughout the duration of the test.

A2.3.4 *Oven*—An oven capable of being controlled to a temperature of 150° + 10°F (65.6° + 10°C).

A2.3.5 *Megohmmeter*—A megohmmeter having an accuracy of ±2 %.

A2.4 Test Specimens (see Fig. A2.2)

A2.4.1 *Specimen Size:*

A2.4.1.1 *Diameter*—Unless otherwise specified, the nominal diameter of the pipe, fitting, or joint tested shall be 2 in. (Fig. A2.2).

A2.4.1.2 *Length*—The length of the specimen shall be a minimum of seven times the nominal diameter of the pipe. To achieve this length, additional sections of conductive pipe shall be added as necessary, using the manufacturer's normally recommended assembly methods. If the additional sections are needed, resistance measurements shall be taken across the joints to ensure that the resistance per unit length does not exceed 1×10^5 ohms per meter (3.281×10^5 ohms per foot). The procedures in Annex A3 shall be used.

A2.5 Conditioning

A2.5.1 No special conditioning of the samples prior to initiation of the test is required.

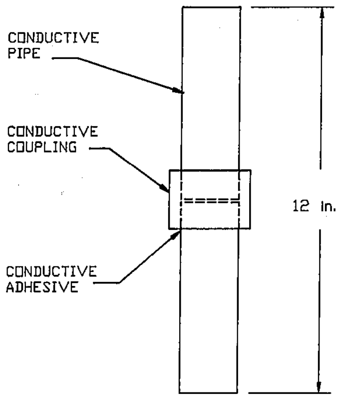

FIG. A2.2 Test Specimens

A2.6 Procedure

A2.6.1 Apply a suitable paint-on electrode around the interior circumference of the specimen on the end to which the grounding system will be installed. The distance of the electrode from the end of the specimen shall be greater than or equal to twice the specimen thickness. The width of the electrode shall be greater than four times the specimen wall thickness. Dimensional tolerances of the electrode with and its distance to the end shall not exceed ±10 % separately or combined. Allow the electrode to dry, then install the grounding clamp of the ground system on the exterior of the specimen at one end in accordance with the manufacturer's instructions. Any surface preparation shall not exceed that normally required when assembling a piping system using a fitting. If it is desired to compute surface or volume resistivity, then the procedures in Test Methods D 257 and D 4496 shall be adhered to.

A2.6.2 Position the specimen vertically on a nonconducting surface. Ground the specimen through the grounding system, and using the megohmmeter measure the resistance of the ground system from ground to a position on the interior surface of the electrode. The power applied should neither exceed 1W, nor should the electrification time exceed one min unless otherwise specified. Record the reading of the megohmmeter and its accuracy at that range.

A2.6.3 Thoroughly remove the electrode, then lower the static emitter into the interior of the pipe, fitting, or joint so that it is equidistant from each end. The emitter must be located as close to the interior surface of the pipe, fitting, or joint as possible.

A2.6.4 Approximately ⅛ in. (3.2 mm) from the exterior surface of the pipe, fitting or joint, and opposite the static emitter, position the probe from the electrostatic voltmeter. Fig. A2.1 shows a typical test setup.

A2.6.5 With the specimen ungrounded, turn the static eliminator on and adjust its output via a powerstat to obtain a voltage reading of 2500 permissible deviation (for example, +10 V) on the electrostatic voltmeter.

A2.6.6 Ground the test specimen by closing a switch connecting the test specimen to ground and record the residual voltage.

A2.6.7 If the effect of a chemical on the shielding charac-

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[11] A Static Eliminator has been found to meet these requirements.

[12] An instrument manufactured by Monroe Electronics, Model No. 244, has been found to meet this requirement.

teristics of the pipe, fitting, or joint and grounding technique is being studied, place the test specimen in a test tank so that it is completely immersed in the test fluid after initial measurement. Maintain the temperature of the bath at 60° to 80°F (15.6° to 26.7°C) throughout the duration of the test. Suggested test environments include but are not limited to (*1*) salt water per Specification D 1141, (*2*) gasoline, (*3*) Bunker C, and (*4*) 1 % sulfuric acid.

A2.6.8 At the end of 1, 3, 6, and 12 months, remove the test specimen from the bath and rinse thoroughly with tap water if the specimen has been exposed to a water-soluble product or a hydrocarbon solvent if the specimen has been exposed to a petroleum product.

A2.6.9 Wipe dry and place the test specimen in an oven at 150 + 10°F for a period of 2 h.

A2.6.10 At the end of 2 h, remove the specimen from the oven and allow it to cool to 70° to 80°F (21.1° to 26.7°C) in a 50 ± 5 % relative humidity environment for 60 ± 5 min before retesting.

A2.6.11 Repeat A2.6.1 through A2.6.6.

A2.6.12 Note the appearance of the test specimens and the condition of the grounding clamp.

A2.7 Report

A2.7.1 Report the following information:

A2.7.1.1 Manufacturer of pipe, fitting, or joint.

A2.7.1.2 Designation of product being tested.

A2.7.1.3 Description of the test sample including diameter of pipe, fitting, or joint and lengths of pipe extenders (when needed).

A2.7.1.4 Description of grounding details.

A2.7.1.5 Initial resistance reading of grounding system and accuracy and those before and after exposure periods of 1, 3, 6, and 12 months when the exposure periods are used.

A2.7.1.6 Test media.

A2.7.1.7 Initial exterior voltage readings before and after grounding and the exterior voltage reading before and after grounding following exposure periods of 1, 3, 6, and 12 months when the exposure periods are used.

A2.7.1.8 Appearance of test specimen.

A2.7.1.9 Date of test.

A3. TEST METHOD FOR DETERMINING THE ELECTRICAL RESISTANCE PER UNIT LENGTH OF FIBERGLASS PIPE, FITTINGS, AND JOINTS AND REPRESENTATIVE PIPING SYSTEMS AFTER EXPOSURE TO VARIOUS CHEMICAL ENVIRONMENTS

A3.1 Scope

A3.1.1 This test method covers the determination of the electrical resistance per unit length of conductive pipe, fittings, and joints in air before and after exposure to various chemical environments and the electrical resistance per unit length in air of a representative piping system assembled from such components. The components and systems are hereafter referred to in this Annex as the specimen.

A3.2 Summary of Test Method

A3.2.1 In this test method, the length of the potential current path is measured and then a potential difference of 1500 V is applied across the test specimen and a resistor of known value, which are connected in series. The voltage drop across the test specimen is then accurately measured and the resistance of the specimen calculated followed by calculation of resistance per unit length. Figure A3.1 shows a drawing of a typical test setup.

A3.3 Significance

A3.3.1 This test method is suitable for measuring resistance between 2 and 1 × 10^{10} Ω using an applied voltage of 1500 V.

A3.4 Test Equipment

A3.4.1 *Exposure Tank*—An exposure tank of nonmetallic construction and resistant to the environment being tested. It shall be maintained at a temperature of 60° to 80°F (15.6° to 26.7°C) throughout the duration of the test.

A3.4.2 *Oven*—An oven capable of being controlled to a temperature of 150° ± 10°F (66.6 ± 10°C).

A3.4.3 *Voltmeter*—A voltmeter capable of measuring dc voltages between 0.0001 and 1500 V with a resolution of 0.005 %.[13]

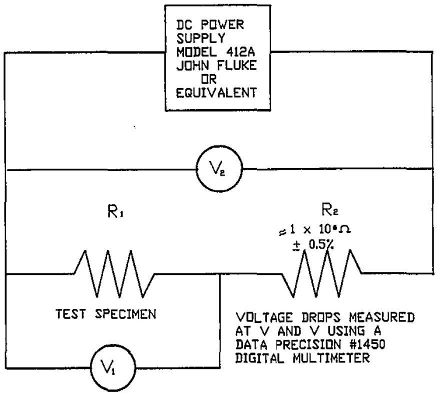

FIG. A3.1 Test Setup for Determining the Electrical Resistance of Fiberglass Pipe and Fittings

A3.4.4 *dc Power Supply*—A constant voltage dc power supply capable of supplying 1500 V at a current of 0.5 mA.

A3.4.5 *A 1* × *10*^{6} ± 0.5 % × 1 watt resistor.

A3.5 Test Specimens

A3.5.1 *Pipe, Fittings, and Joints:*

A3.5.1.1 *Diameter*—Unless otherwise specified, the nominal diameter of the pipe, fitting, or joint tested shall be 2 in.

A3.5.1.2 *Length*—The length of the specimen shall be six times the nominal diameter of the product plus two times the width of the grounding clamps. To achieve this length,

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[13] A Data Precision Model No. 1450 Digital Multimeter has been found satisfactory for this purpose.

additional sections of conductive pipe shall be added using the manufacturer's normally recommended assembly methods.

A3.5.2 *Representative Piping Systems:*

A3.5.2.1 *Diameter*—Unless otherwise specified the nominal diameter of the system tested shall be 2 inches.

A3.5.2.2 *Length*—The minimum length shall meet the requirements of A3.5.1.2.

A3.6 Conditioning

A3.6.1 No special conditioning of the specimens prior to initiation of the test is required.

A3.7 Procedure

A3.7.1 *Potential current path selection:*

A3.7.1.1 *Pipes, straight joints, adapters, couplings, plugs, caps, and bushings*—The path length shall be parallel to the centerline axis of the component and shall encompass the length of the component.

A3.7.1.2 *Elbows*—Two path lengths shall be established, one on the outer and one on the inner radius of curvature.

A3.7.1.3 *Crosses*—Six path lengths shall be established, one parallel to each of the longitudinal centerline axes and one along the shortest path from adjacent openings through each 90° bend.

A3.7.1.4 *Tees*—One path shall parallel the centerline axis opposite the interior opening. Two additional paths shall also be established, one along the shortest path from adjacent openings through each 90° bend.

A3.7.1.5 *Laterals*—Three paths shall be established, one parallel to the longitudinal centerline axis, one along the shortest distance between adjacent openings through the oblique angle, and one along the shortest distance between adjacent openings through the obtuse angle.

A3.7.1.6 *Representative piping systems*—The path length shall encompass the longest possible length that parallels the centerline axis of the system.

A3.7.1.7 If extenders are used, both lengths shall incorporate that portion of the extenders needed to meet specimen length requirements.

A3.7.1.8 For components and systems achieving conductivity through use of conductive layers, the resistance per unit length will be measured as follows:

(*a*) Separately through each conductive layer using the path selection criteria in paragraphs A3.7.1.1 through A3.7.1.7.

(*b*) Through the conductive connections between layers. The path length shall consist of the distance between the clamps plus the thickness of the non-conductive portion of the pipe, fitting, or joint. The path shall be measured from the interior of one end through the joint to the exterior of the opposite end.

(*c*) From the exterior part of the test point separately to the interior of each end of the pipe, joint, or fitting.

A3.7.2 *Sample Preparation*—Install the grounding clamps for each potential current path of interest in accordance with the manufacturer's recommendations. In the case of pipes having conductive layers, the recommendations will include methods/equipment that accommodate the separate resistance measurements of inner and outer conductive layers, conductive connections between layers, and resistance of interior layer test points. The surface preparation in any case shall not exceed that normally required when assembling a piping system using a fitting. The distance between the clamps should be six times the nominal diameter of the pipe, fitting, or joint when testing individual components and systems. If a specimen ends with an open flange, the grounding clamp will be installed on the face of the flange.

A3.7.3 Measure the lengths of the potential current paths of interest for test specimen including extenders (if used) and the thickness of any exposed flange faces.

A3.7.4 Isolate the test specimen from ground.

A3.7.5 Connect a 1 × 10^6 Ω – 1 W resistor in series with the test specimen.

A3.7.6 Apply a dc voltage of 1500 ± 0.1 V across the test specimen and resistor.

A3.7.7 Measure the voltage drop, V_1, across the test specimen. If immersion is not required, calculate the resistance in accordance with A3.7.14.

A3.7.8 If immersion is requested by the purchaser, place the specimens in the test tank so that they are completely immersed in the test fluid. Maintain the temperature of the bath at 60° to 80°F (15.5° to 26.7°C) throughout the duration of the test. Suggested test environments are: (1) Salt water per Specification D 1141, (2) Gasoline, (3) Bunker C, and (4) 1 % sulfuric acid.

A3.7.9 At the end of 1, 3, 6, and 12 months, remove the test specimens from the bath and rinse thoroughly with tap water if the test specimens have been exposed to a water soluble product or a hydrocarbon solvent if the specimens have been exposed to a petroleum product.

A3.7.10 Place the test specimens in an oven at 150° ± 10°F (66.6° ± 10°C) for a period of 2 h.

A3.7.11 At the end of 2 h, remove the specimens from the oven and allow them to cool to 70° to 80°F (21.1° to 26.7°C) in a 50 ± 5 % relative humidity environment for 60 ± 5 min before retesting.

A3.7.12 Remeasure the voltage drop across the specimens in accordance with A3.7.5 through A3.7.7.

A3.7.13 Note the appearance of the test specimens and the conditions of the clamps.

A3.7.14 Using the information obtained, calculate the resistance of the test specimen before and after exposure using the following equation:

$$\frac{V_1}{R_1} = \frac{V_2}{R_1 + R_2}$$

where:

V_1 = voltage drop across specimen,
R_1 = resistance of test specimen,
V_2 = line voltage (1500 V), and
R_2 = value of known resistor (1 × 10^6 Ω).

A3.7.15 Calculate the resistance per unit length for each of the potential current paths of interest on the specimen and its associated resistance.

A3.8 Report

A3.8.1 Report the following information:

A3.8.1.1 Manufacturer of the specimen.

A3.8.1.2 Designation of product being tested.

A3.8.1.3 Description of the specimen including the diameter and length for a pipe, fitting, or joint (including the lengths of extensions, if applicable) or a dimensioned sketch for a representative piping system. In both cases, placement of the grounding clamps and the potential current paths and their lengths shall be identified.

A3.8.1.4 Description of grounding clamps and grounding procedure.

A3.8.1.5 Test media.

A3.8.1.6 Initial resistance per unit length between clamps for each potential current path and resistance per unit length for each potential current path at 1, 3, 6, and 12 months if immersion testing was conducted.

A3.8.1.7 Appearance of test specimen if immersion testing was conducted.

A3.8.1.8 Date of test.

A4. TEST METHOD FOR FIRE ENDURANCE EVALUATION OF PLASTIC PIPING IN THE DRY CONDITION

A4.1 Scope

A4.1.1 This test method covers the determination of the fire endurance of thermosetting resin fiberglass pipe, fittings, and joints to be used in marine applications when empty. This test procedure is based on the IMO Assembly Resolution A.753(18) which is an alternative to this test. SI units shall be used in referee decisions.

A4.2 Significance

A4.2.1 This testing procedure in this test method is applicable over a range of temperatures up to 2012°F (1100°C). This temperature rise occurs in less than 1 hour, simulating a fully developed liquid hydrocarbon fire. This test is valid for pipe 1 in. to 48 in. nominal diameters for pressures up to 225 psi.

A4.3 Test Equipment

A4.3.1 *Furnace*—Test furnace with the capability to increase its temperature to 2012°F (1100°C) within 1 h while meeting the accuracy in A4.6.4.1. Furnace shall have a temperature gauge capable of measuring temperature ±2 %.

A4.3.2 *Thermocouples*—Two thermocouples capable of measuring up to 2012°F (1100°C).

A4.3.3 Nitrogen tank with regulator.

A4.4 Test Specimen

A4.4.1 The test specimen should be prepared with the joints, fittings, and fire protection coverings intended for use in the proposed application.

A4.4.2 The number of specimens shall be sufficient to test typical joints and fittings including joints between non-metal and metal pipes and fittings to be used.

A4.4.3 The ends of the specimen shall be closed with one end allowing pressurized nitrogen to be connected.

A4.4.4 The pipe ends and closures may be outside the furnace.

A4.4.5 The general orientation of the specimen should be horizontal and it should be supported by one fixed support with the remaining supports allowing free movement.

A4.4.6 The free length between supports should not be less than 8 times the pipe diameter.

A4.4.7 Full scale fire test shall be performed on 1, 2, 4, and 8 inch pipe systems. Above 8-inch, every third size of the manufacturer's product line shall be tested.

TABLE A4.1 Time/Mean Temperature Ramp of Furnace

Time	Mean Temperature
at the end of: 5 minutes:	≥945°C
at the end of: 10 minutes:	≥1033°C
at the end of: 15 minutes:	≥1071°C
at the end of: 30 minutes:	≥1098°C
at the end of: 60 minutes:	≥1100°C

A4.5 Test Conditions

A4.5.1 *Fire-Protective Coatings:*

A4.5.1.1 If the fire protective coating contains, or is liable to absorb, moisture the specimen should not be tested until the insulation has reached an air-dry condition. This condition is defined as equilibrium with an ambient temperature of 50 % relative humidity at 70 ± 10°F (20 ± 5°C).

A4.5.1.2 Accelerated conditioning is permissible provided the method does not alter the properties of component materials.

A4.5.1.3 Special samples shall be used for moisture content determination and conditioned with the test specimen. These samples should be so constructed as to represent the loss of water vapor from the specimen by having similar thickness and exposed faces.

A4.5.2 A nitrogen pressure inside the test specimen should be maintained automatically at 0.7 ± 0.1 bar during the test. Means should be provided to record the pressure inside the pipe and the nitrogen flow into and out of the specimen in order to indicate leakage.

A4.5.3 *Flame Temperature:*

A4.5.3.1 The exterior flame temperature shall be measured by means of two thermocouples mounted not more than 1 in. (2.5 cm) from the pipe near the center span of the assembly.

A4.5.3.2 The thermocouples shall be mounted on the horizontal plane at the level of the pipe.

A4.5.3.3 The test temperature shall be taken as the average of the two thermocouple readings.

A4.6 Procedure

A4.6.1 Measure the dimensions of the specimen in accordance with Practice D 3567. Include measurements of liner thickness and external coatings, if applicable.

A4.6.2 Place specimen in the furnace.

A4.6.3 Pressurize specimen with nitrogen maintaining the pressure in accordance with A4.5.2.

A4.6.4 Time/mean temperature ramp of furnace according to Table A4.1 is started.

A4.6.4.1 The accuracy of the furnace control should be as follows:

(*a*) During the first 10 min. of the test the area under the curve of mean furnace temperature vs. time should not vary by more than ±15 % of the area under the standard curve.

(*b*) During the first half hour of the test the area under the curve of mean furnace temperature vs. time should not vary by more than ±10 % of the area under the standard curve.

(*c*) For any ten minute period after the first half hour of the test the area under the curve of mean furnace temperature vs. time should not vary by more than ±5 % of the area under the standard curve.

(*d*) At any time after the first 10 min of the test the mean furnace temperature should not differ from the standard curve by more than ±100°C.

A4.6.5 The mean temperature and exterior flame temperature shall be recorded a minimum of once every 30 s.

A4.7 Acceptance Criteria

A4.7.1 No nitrogen leakage from the sample should occur during the test.

A4.7.2 *Hydrostatic Pressure:*

A4.7.2.1 After termination of the furnace test, the specimen together with fire protection coating, if any, should be allowed to cool in still air to ambient temperature and then test to the rated pressure of the pipe.

A4.7.2.2 The pressure should be held for a minimum of 15 min without leakage.

A4.7.2.3 Where practicable, the hydrostatic test should be conducted on bare pipe, that is pipe without any covering, including fire protection. This is to make any leakage readily apparent.

A4.8 Report

A4.8.1 Report the following information:

A4.8.1.1 Complete identification of the pipe or fitting tested including manufacturer's name and code.

A4.8.1.2 Description of fire-protective coating if applicable.

A4.8.1.3 Diameter of pipe, fitting or joint.

A4.8.1.4 Endurance time.

A4.8.1.5 Appearance of test specimen.

A4.8.1.6 Date of test.

A5. TEST METHOD FOR FIRE ENDURANCE TESTING OF WATER-FILLED PLASTIC PIPING

A5.1 Scope

A5.1.1 This test method covers the determination of the fire endurance of thermosetting resin fiberglass pipe, fittings and joints to be used in marine applications when in the wet condition. This test procedure is based on the IMO Assembly Resolution A.753(18) which is an alternative to this test. SI units shall be used in referee decisions.

A5.2 Summary of Test Method

A5.2.1 This test method subjects a pipe sample to a constant 36,011 Btu/(hr-ft·2) (113.6 kW/m·2) net flux to determine a pipe systems fire-endurance.

A5.3 Significance

A5.3.1 This test is valid for pipe 1 in. to 48 in. nominal diameters for pressures up to 225 psi. It will give a purchaser of fiberglass pipe the ability to determine the fire resistance of a fiberglass piping system when filled with water.

A5.4 Test Equipment

A5.4.1 *Sivert No. 2942 burner* or equivalent which produces an air mixed flame.

A5.4.1.1 The inner diameter of the burner heads should be 1.5 in. (29 mm) (see Fig. A5.1).

A5.4.1.2 The burner heads should be mounted in the same plane and supplied with gas from a manifold.

A5.4.1.3 If necessary, each burner should be equipped with a valve in order to adjust the flame height.

A5.4.1.4 The height of the burner stand should also be adjustable.

A5.4.1.5 It should be mounted centrally below the test pipe with the rows of burners parallel to the pipe's axis.

A5.4.1.6 The distance between the burner heads and the pipe should be maintained at 5 ± ⅜ in. (12.5 ± 1.0 cm) during the test.

A5.4.1.7 The free length of the pipe between its supports should be 31.5 ± 2 in. (0.80 ± 0.05 m).

A5.4.2 *Thermocouples*—Two thermocouples capable of

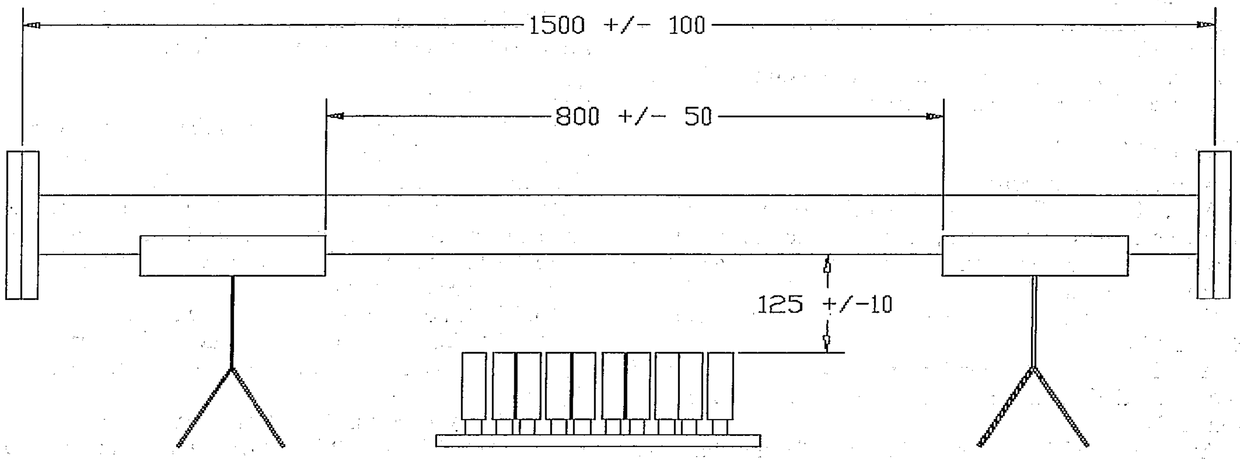


FIG. A5.1 Stand with Mounted Sample

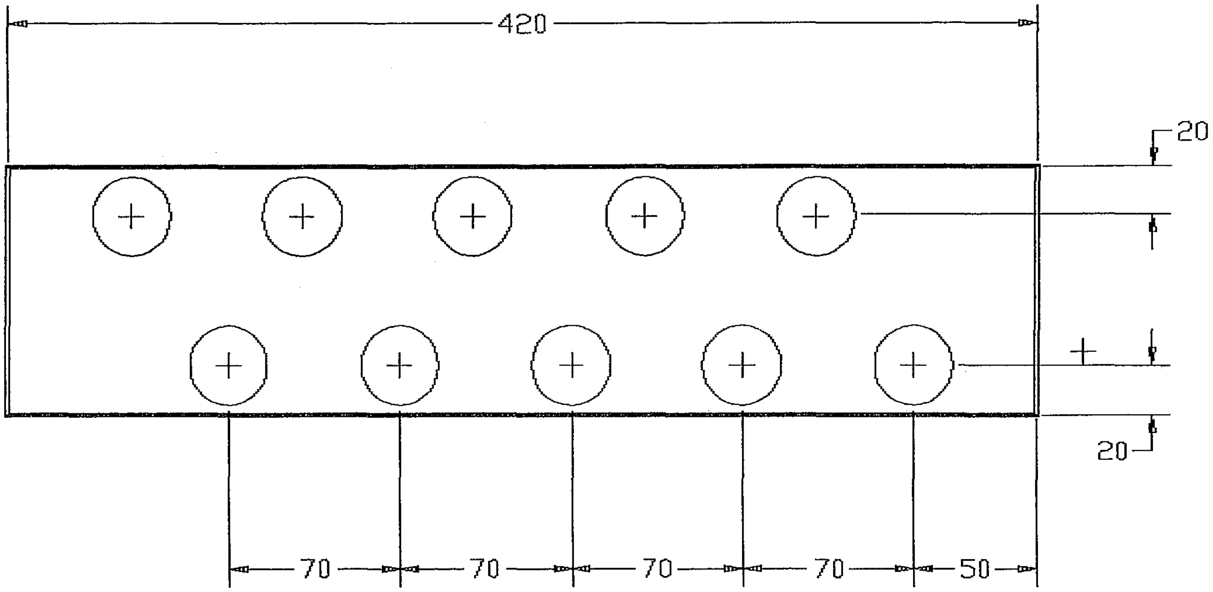


FIG. A5.2 Top View Burner Assembly

measuring up to 2012°F (1100°C).

A5.4.3 *Deaerated water.*

A5.4.4 *Thermometer*—To measure internal water temperature.

A5.4.5 *Pressure Gauge*—Capable of reading up to 5 bars (±5 %).

A5.4.6 *V-Shaped Pipe Supports.*

A5.5 Test Specimen

A5.5.1 *Specimen Length:*

A5.5.1.1 The test specimen should have a length of 59 in. (1.5 m).

A5.5.2 Test specimen should be pipe with permanent joints or fittings intended for use in marine applications.

A5.5.3 All joint types should be tested as they are the primary point of failure.

A5.5.4 The number of pipe specimens should be sufficient to test all typical joints and fittings.

A5.5.5 The ends of each specimen must be closed.

A5.5.6 One end should allow pressurized water to be connected.

A5.5.7 A pressure relief valve should be connected to one of the end closures of each specimen.

A5.6 Test Conditions

A5.6.1 *Fire-Protective Coatings:*

A5.6.1.1 If the fire-protective coating or covering contains, or is liable to absorb, moisture, the test specimen should not be tested until the insulation has reached an air-dry condition. This condition is defined as equilibrium with an ambient temperature of 50 % relative humidity at 70 ± 10°F (20 ± 5°C).

A5.6.1.2 Accelerated conditioning is permissible provided the method does not alter the properties of component materials.

A5.6.1.3 Special samples shall be used for moisture content determination and conditioned with the test specimen. These samples should be so constructed as to represent the loss of water vapor from the specimen by having similar thickness and exposed faces.

A5.6.2 The test should be carried out in a sheltered test site in order to prevent any draft influencing the test.

A5.6.3 Each pipe specimen should be completely filled with deaerated water and vented to exclude air bubbles.

A5.6.3.1 The water temperature should not be less than 59°F (15°C) at the start and should be measured continuously during the test.

A5.6.3.2 The water inside the sample should be stagnant and the pressure maintained at 3 ± 0.5 bar during the test.

A5.6.4 *Flame Temperature:*

A5.6.4.1 The exterior flame temperature shall be measured by means of two thermocouples mounted not more than 1 in. (2.5 cm) from the pipe near the center span of the assembly.

A5.6.4.2 The thermocouples shall be mounted on the horizontal plane at the level of the pipe.

A5.6.4.3 The test temperature shall be taken as the average of the two thermocouple readings.

A5.7 Procedure

A5.7.1 Measure the dimensions of the specimen in accordance with Practice D 3567. Include measurements of liner thickness and external coatings, if applicable.

A5.7.2 Place specimen on two V-shaped supports. The supports may consist of two stands as shown in Fig. A5.1.

A5.7.3 Pressurize specimen with water maintaining conditions in accordance with A6.3.

A5.7.4 *Burner Configuration for Constant Heat Flux:*

A5.7.4.1 For piping 6 ins. and less in diameter, the fire source should consist of two rows of 5 burners as shown in Fig. A5.2.

A5.7.4.2 A constant heat flux averaging 36,011 Btu/(hr-ft·2) (113.6 kW/m·2) (±10 %) should be maintained 5 ± ⅜ in. (12.5 ± 1.0 cm) above the centerline of the array.

(*a*) This flux corresponds to a pre-mix flame of propane with a fuel flow rate of 11.02 lb/hr (5 kg/hr) for a total heat release of 221,780 btu/hr (65 kW).

(*b*) The gas consumption should be measured with an accuracy of at least ±3 % in order to maintain a constant heat flux.

A5.7.4.3 For piping greater than 6 in. in diameter, one additional row of burners should be included for each 2 inch increase in pipe diameter.

(*a*) A constant heat flux averaging 36,011 Btu/(hr-ft·2) 113.6 kW/m·2 (±10 %) should still be maintained at the 5 ± ⅜ in. (12.5 ± 1.0 cm) height above the centerline of the burner array.

(*b*) The fuel flow should be increased as required to maintain the designated heat flux.

A5.7.5 Begin heat flux.

A5.7.6 Record test temperature, water temperature, water pressure at least once every 30 s.

A5.8 Acceptance Criteria

A5.8.1 No leakage from the sample(s) should occur except that slight weeping from the wall may be accepted.

A5.8.2 *Hydrostatic Pressure:*

A5.8.2.1 After termination of the burner regulation test, the test sample, together with the fire protection coating, if any, should be allowed to cool to ambient temperature and then tested to the rated pressure of the pipe.

A5.8.2.2 The pressure should be held for a minimum of 15 min and produce a leakage of less than 0.05 gpm (0.2 liters/min).

A5.8.2.3 Where practical, the hydrostatic test should be conducted on bare pipe that has had all of its coverings, including fire protection insulation removed, so that leakage will be readily apparent.

A5.9 Report

A5.9.1 Report the following information:

A5.9.1.1 Complete identification of the pipe, fitting or joint tested including manufacturer's name and code.

A5.9.1.2 Description of fire-protective coating if applicable.

A5.9.1.3 Diameter of pipe, fitting or joint.

A5.9.1.4 Endurance time.

A5.9.1.5 Appearance of test specimen.

A5.9.1.6 Date of test.

A6. DIMENSIONS AND TOLERANCES

A6.1 For Pipe

A6.1.1 *Diameter*—Pipe meeting this specification shall conform to the requirements in Table A6.1 or Table A6.2. Dimensions shall be determined in accordance with 11.4.

A6.1.2 *Wall Thickness*—The minimum wall thickness of pipe furnished under this specification shall not, at any point, be less than:

A6.1.2.1 Eighty-five percent of the nominal wall thickness published in the manufacturer's literature current at the time of purchase when measured in accordance with 11.4.

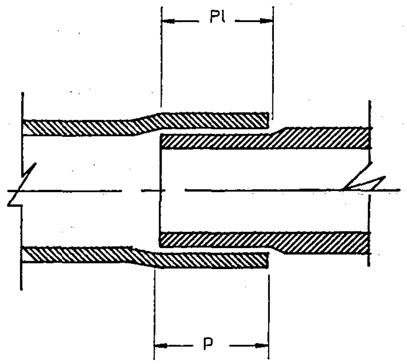
A6.1.2.2 The wall thickness determined using hydrostatic design basis in accordance with 7.2.

A6.1.3 *Liner thickness*—Except for unlined products, all pipe shall have a minimum liner thickness of 0.010 in. (0.254 mm) when measured in accordance with 11.4.

A6.1.4 *Length*—Pipe shall be in lengths as specified by

TABLE A6.1 Dimensions for Outside Diameter (OD) Series Pipe

Steel NPS	Outside Diameter	
	in., min	mm, min
1	1.31	33.4
1½	1.90	48.3
2	2.37	60.3
3	3.50	88.9
4	4.50	114.3
6	6.625	168.3
8	8.625	219.1
10	10.75	273.1
12	12.75	323.9
14	14.00	355.6
16	16.00	406.4
18	18.04	458.1
20	20.04	509.0
22	22.04	559.8
24	24.05	610.9
26	26.04	661.5
28	28.04	712.2
30	30.04	762.9
32	32.04	813.8
34	34.04	864.7
36	36.04	915.5



NPS	Minimum Socket Length, P in. (mm)	Minimum Spigot Length, P1 in. (mm)	Spigot Diameter	
			Minimum in. (mm)	Maximum in. (mm)
1	1.063 (27)	1.125 (29)	1.277 (32.4)	1.293 (32.8)
1½	1.250 (32)	1.125 (35)	1.876 (47.4)	1.883 (47.8)
2	1.813 (46)	2.000 (51)	2.330 (59.2)	2.346 (59.6)
3	1.813 (46)	2.000 (51)	3.450 (87.6)	3.466 (88.0)
4	1.813 (46)	2.000 (51)	4.430 (112.5)	4.446 (112.9)
6	2.250 (57)	2.375 (60)	6.544 (166.2)	6.560 (166.6)
8	2.500 (64)	2.625 (67)	8.544 (217.0)	8.560 (217.4)
10	2.750 (70)	2.875 (73)	10.680 (271.3)	10.696 (271.7)
12	3.000 (76)	3.125 (79)	12.684 (322.2)	12.700 (322.6)
14	3.500 (88)	3.625 (92)	13.945 (354.2)	13.970 (354.8)
16	4.000 (102)	4.125 (105)	15.909 (404.1)	15.925 (404.5)

NOTE 1—Fiberglass fittings and pipe can be connected by flanges or mechanical couplings, or both (that is, grooved or compression type).

FIG. A6.1 Standard Straight-Taper and Straight-to-Straight Joints

TABLE A6.2 Dimensions for Inside Diameter (ID) Series Pipe

Steel NPS	Inside Diameter	
	in.	mm
1	1.00 ± 0.06	25.4 ± 1.52
1½	1.50 ± 0.06	38.1 ± 1.52
2	2.00 ± 0.06	50.8 ± 1.52
3	3.00 ± 0.12	76.2 ± 3.05
4	4.00 ± 0.12	101.6 ± 3.05
6	6.00 ± 0.25	152.4 ± 6.35
8	8.00 ± 0.25	203.2 ± 6.35
10	10.00 ± 0.25	254.0 ± 6.35
12	12.00 ± 0.25	304.8 ± 6.35
14	14.00 ± 0.25	355.6 ± 6.35
16	16.00 ± 0.25	406.4 ± 6.35
18	18.00 ± 0.25	457.2 ± 6.35
20	20.00 ± 0.25	508.0 ± 6.35
22	22.00 ± 0.25	558.8 ± 6.35
24	24.00 ± 0.25	609.6 ± 6.35
26	26.00 ± 0.25	660.4 ± 6.35
28	28.00 ± 0.25	711.2 ± 6.35
30	30.00 ± 0.25	762.0 ± 6.35
32	32.00 ± 0.25	812.8 ± 6.35
34	34.00 ± 0.25	863.6 ± 6.35
36	36.00 ± 0.25	914.4 ± 6.35

the purchase order when measured in accordance with 11.4.

A6.2 For Fittings

A6.2.1 *Wall thickness*—The minimum wall thickness of fittings furnished under this specification shall not, at any point, be less than the pipe nominal wall thickness published in the manufacturer's literature current at the time of purchase when measured in accordance with 11.4.

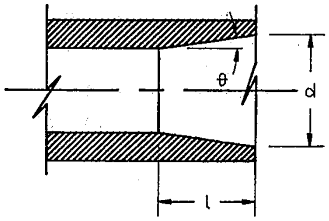
A6.2.2 Except for unlined products, the fittings shall have a minimum liner of 0.010 inches (0.254 mm) when measured in accordance with 11.4.

A6.2.3 *Length*—Lengths and tolerances are specified in Figs. A6.1 through A6.16.

NOTE 1—Outside diameters other than those listed in Table A6.1 or inside diameters as listed in Table A6.2 shall be permitted upon agreement between the manufacturer and the purchaser.

NOTE 2—Outside diameters approximate those for iron pipe size, ISO International Standard 559-1978, and for cast iron pipes, ISO International Standard 13-1978, as follows:

NOTE 3—Tolerances for 1 to 16 NPS in accordance with Specification D 2996 Figures. Tolerances for 18 to 36 NPS are ±1 % of the pipe outside diameter in accordance with ISO 559-1978.



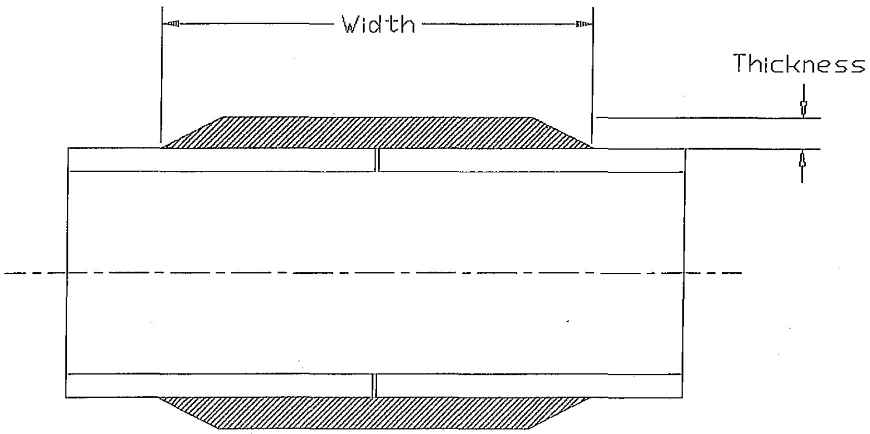
NPS	Socket Entrance Diameter, min, d, in. (mm)	Minimum Effective Bond Length, min, L, in. (mm)	Taper Angle Range ° (Degrees)
1	1.335 (34)	0.750 (19)	1 to 3
1½	1.910 (76)	0.750 (19)	1 to 3
2	2.375 (60)	1.000 (25)	1 to 2
3	3.500 (89)	1.125 (29)	1 to 2
4	4.500 (114)	1.250 (32)	1 to 2
6	6.600 (168)	1.500 (38)	1 to 2
8	8.635 (219)	2.000 (51)	1 to 2
10	10.700 (272)	2.125 (54)	1 to 2
12	12.670 (322)	2.250 (57)	1 to 2
14	14.400 (366)	2.500 (64)	1 to 2
16	16.460 (418)	2.500 (64)	1 to 2

NOTE 1—*Standard tapered socket.* In all cases, the base angle for bells (sockets) shall be the same as the angle for the pipe spigots (male tapers). The tolerances shall be set to ensure there is no gap between the end of the spigot and the bottom of the bell. The minor I.D. (diameter at the bottom) of the tapered socket shall always be less than the end dimension (the diameter at the end) of the pipe spigot to ensure that the spigot does not insert beyond the tapered portion of the bell. The insertion of the spigot into the bell shall be at least equal to the minimum allowable effective bond length (EBL) shown for Fig. A6.2. The minimum effective bond length is the minimum insertion length where the tapered spigot surfaces are in contact with the tapered bell surfaces. The tolerances shall be set to ensure that the effective bond length is at least equal to the values in Fig. A6.2. Angle tolerance for male tapers (spigots) and for female tapers (bells) shall not vary more than 0.25° i.e. the most extreme mismatch in a bonded joint must never exceed 0.5°. For all bonded joints, the angle for the spigot shall be equal to or less than the bell angle (preventing a gap between the end of the spigot and the bottom of the bell).

NOTE 2—Fiberglass fittings and pipe can be connected by flanges or mechanical couplings, or both (that is, grooved or compression type).

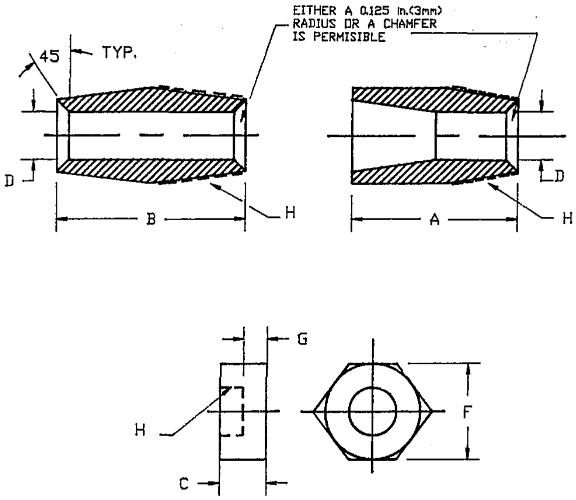
FIG. A6.2 Standard Taper-to-Taper Joint

A6.2.4 The lengths and tolerances of fittings not covered in Annex A6 must be agreed upon by the purchaser and the supplier.



NPS	Width, min, in.	Thickness, min, in.
2	3	0.125
3	3	0.125
4	3	0.125
6	4	0.175
8	4	0.175
10	6	0.2
12	6	0.25
14	8	0.25
16	19	0.25

FIG. A6.3 **Standard Butt-And-Wrap**



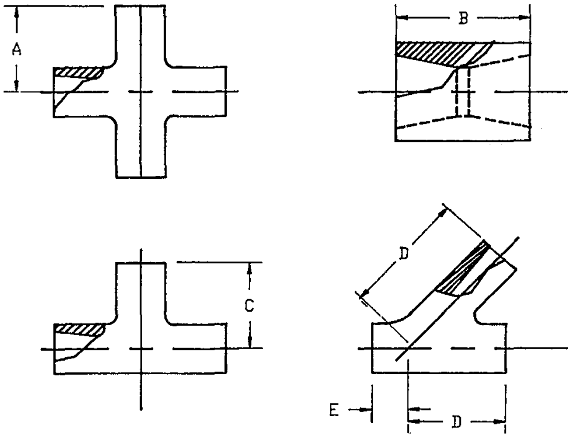
NPS	Overall Length, min			Minimum Internal Diameter D, in. (mm)	Width[A] Across Hex Flats F, in. (mm)	Minimum Thickness G, in. (mm)	Pipe Thread (IPS) H, in. (mm)	Taper[B] Angle Degrees °
	A, in. (mm)	B, in. (mm)	C, in. (mm)					
1	3.250 (83)	2.375 (60)	1.500 (38)	0.875 (22)	1.688 (43)	0.438 (11)	NPT	1 to 3
1½	3.250 (83)	2.500 (64)	1.750 (44)	1.500 (38)	2.438 (62)	0.500 (13)	NPT	1 to 3
2	4.000 (102)	3.500 (89)	2.000 (51)	1.890 (48)	3.000 (76)	0.563 (14)	NPT	1 to 2

[A] Width across hex flats tolerance +0.000 and −0.063 in. [+0.000 and −0.005 mm].

NOTE 1—Machining of threads shall be accordance with ANSI B2.1 for NPT threads.

NOTE 2—For tapered socket dimensions, see Fig. A6.2 and note 1, Fig. A6.2.

FIG. A6.4 **(A) Standard Adapter, Tapered Spigot × Male Pipe Thread; (B) Standard Adapter Tapered × Male Pipe Thread; and (C) Hexagonal Threaded Cap**

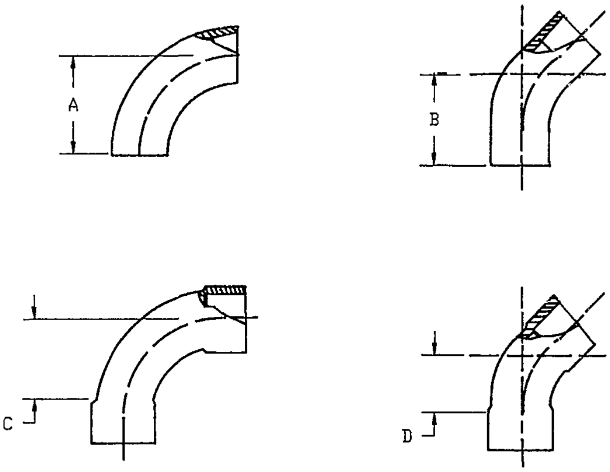


NPS	A, min, in. (mm)	B, min, in. (mm)	C, min, in. (mm)	D, min, in. (mm)	E, min, in. (mm)
1	2.500 (64)	2.500 (64)	2.500 (64)	3.625 (92)	2.250 (57)
1½	3.125 (79)	3.000 (76)	3.125 (79)	5.000 (127)	3.000 (76)
2	3.125 (79)	4.625 (117)	3.125 (79)	6.375 (162)	2.500 (64)
3	4.375 (111)	4.750 (121)	4.375 (111)	7.500 (191)	4.000 (102)
4	4.875 (124)	5.000 (127)	4.875 (124)	8.750 (222)	4.125 (105)
6	5.875 (149)	6.750 (171)	5.875 (149)	12.250 (311)	5.500 (140)
8	11.375 (289)	9.750 (248)	11.375 (289)	16.000 (406)	7.125 (181)
10	12.875 (327)	10.250 (260)	12.875 (327)	19.375 (492)	8.500 (216)
12	13.750 (349)	10.750 (273)	13.750 (349)	24.500 (622)	11.500 (292)
14	15.750 (400)	12.250 (311)	15.750 (400)	32.250 (819)	15.500 (394)
16	16.750 (425)	12.750 (324)	16.750 (425)	35.500 (902)	17.500 (445)

NOTE 1—For tapered socket dimensions, see Fig. A6.2 and note 1, Fig. A6.2.

NOTE 2—Fiberglass fittings and pipe can be connected by flanges or mechanical couplings, or both (that is, grooved or compression type).

FIG. A6.5 Taper-to-taper (A) Cross, (B) Coupling, (C) Tee, and (D) 45° Lateral

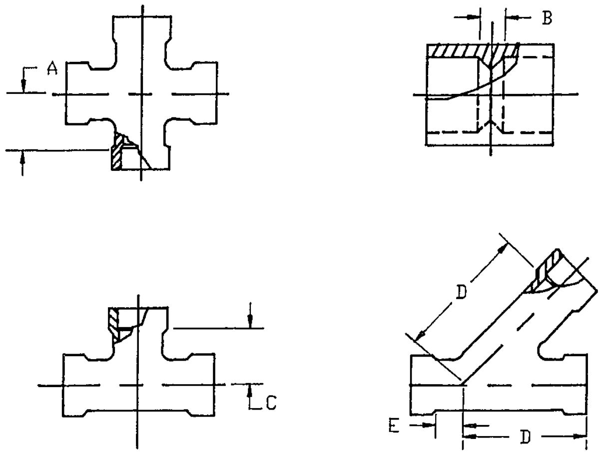


NPS	A, min, in. (mm)^A	B, min, in. (mm)^A	C, min, in. (mm)	D, min, in. (mm)
1	2.500 (64)	2.125 (54)	2.562 (65)	0.875 (22)
1½	3.125 (79)	2.625 (67)	3.188 (81)	0.125 (29)
2	3.125 (79)	2.375 (60)	3.000 (76)	1.375 (35)
3	4.375 (111)	3.505 (89)	4.500 (114)	2.000 (51)
4	4.875 (124)	3.625 (92)	6.000 (152)	2.500 (64)
6	5.875 (149)	4.125 (105)	9.000 (229)	3.750 (95)
8	11.375 (289)	7.875 (200)	12.000 (305)	5.000 (127)
10	12.875 (327)	8.375 (213)	15.000 (381)	6.250 (155)
12	13.750 (349)	9.250 (235)	18.000 (457)	7.500 (151)
14	15.750 (400)	10.000 (254)	14.125 (359)	4.750 (120)
16	17.000 (432)	10.625 (270)	15.125 (397)	5.375 (136)

[A] For tapered socket dimensions, see Fig. A6.2 and note 1, Fig. A6.2.

NOTE 1—Fiberglass fittings and pipe can be connected by flanges or mechanical couplings, or both (that is, grooved or compression type).

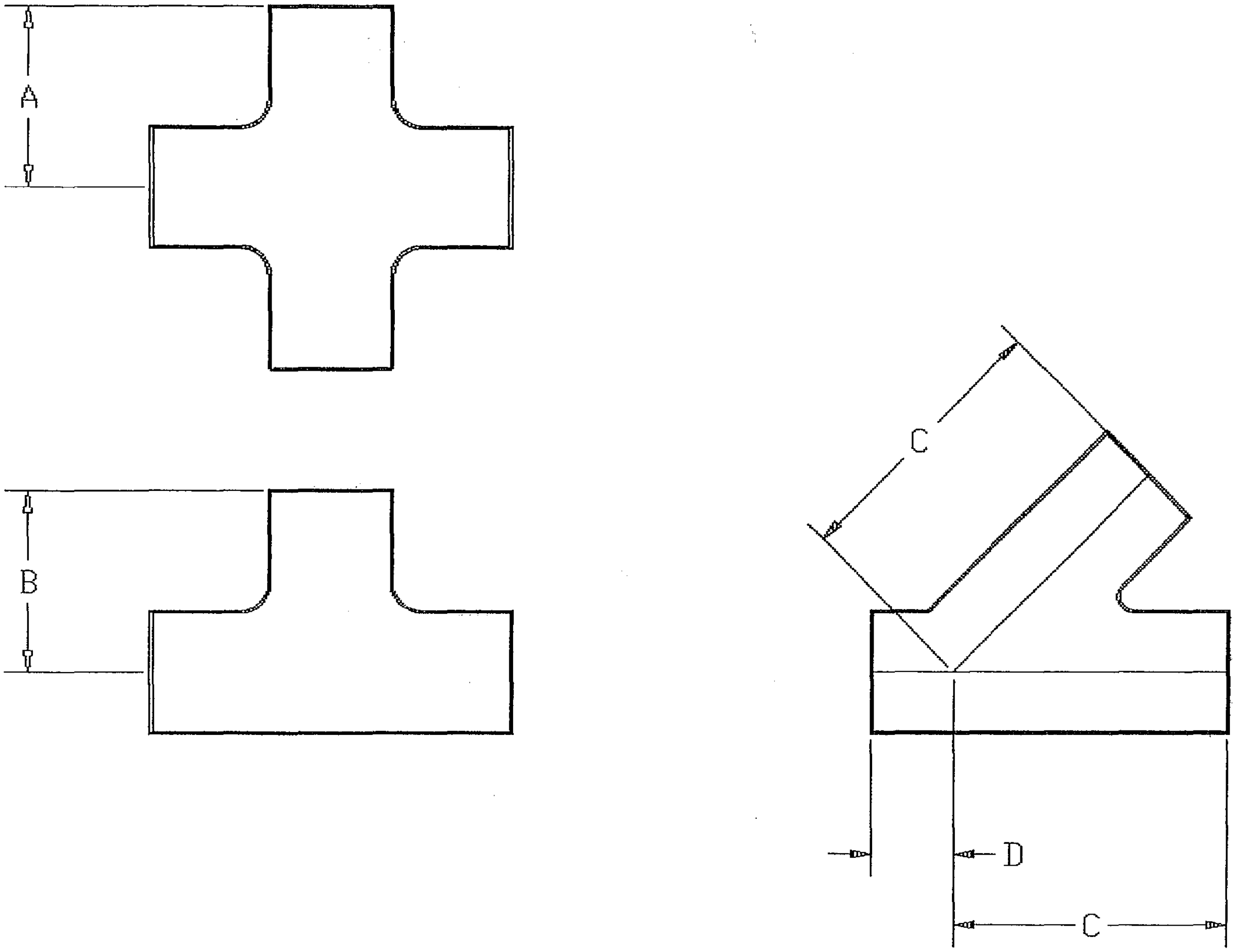
FIG. A6.6 Taper-to-Taper and Butt-Weld: (A) 90° Elbows and (B) 45° elbows; Straight-Taper and Straight-to-Straight (C) 90° Elbows and (D) 45° elbows



NPS	A, min, in. (mm)	B, min, in. (mm)	C, min, in. (mm)	D, min, in. (mm)	E, min, in. (mm)
1	1.063 (27)	0.375 (10)	0.063 (27)	3.000 (76)	1.000 (25)
1½	1.188 (30)	0.375 (10)	1.188 (30)	4.000 (102)	1.500 (38)
2	2.500 (64)	0.375 (10)	2.500 (64)	8.000 (203)	2.500 (64)
3	3.375 (86)	0.375 (10)	3.375 (86)	10.000 (254)	3.000 (76)
4	4.125 (105)	0.375 (10)	4.125 (105)	12.000 (305)	3.000 (76)
6	5.125 (143)	0.375 (10)	5.625 (143)	14.500 (368)	3.500 (89)
8	7.000 (178)	0.375 (10)	7.000 (178)	17.500 (445)	4.500 (114)
10	8.500 (216)	0.375 (10)	8.500 (216)	20.500 (521)	5.000 (127)
12	10.000 (254)	0.375 (10)	10.000 (254)	24.500 (622)	5.500 (140)
14	10.500 (267)	0.750 (19)	10.500 (267)	24.500 (622)	5.500 (140)
16	11.500 (292)	0.750 (19)	11.500 (292)	24.500 (622)	5.500 (140)

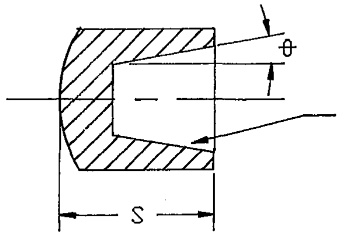
NOTE 1—Fiberglass fittings and pipe can be connected by flanges or mechanical couplings, or both (that is, grooved or compression type).

FIG. A6.7 Straight-Taper and Straight-to-Straight (A) Cross, (B) Coupling, (C) Tee, and (D) & (E) 45° Lateral



NPS	A, min, in.	B, min, in.	C, min, in.	D, min, in.
2	5	5	9	5
3	6	6	11	5
4	7	7	13	5
6	9	9	15	7
8	11	11	19	9
10	13	13	23	09
12	15	15	25	11
14	17	17	29	11
16	19	19	31	13

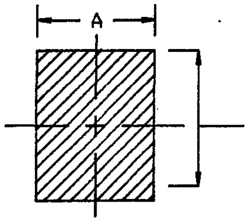
FIG. A6.8 Plain End (A) Cross, (B) Tee, and (C) & (D) 45° Lateral



NPS	Cap Length, S, min, in. (mm)
1	2.250 (57)
1½	2.375 (60)
2	2.500 (64)
3	3.000 (76)
4	3.500 (89)
6	4.625 (117)
8	6.500 (165)
10	7.000 (178)
12	8.750 (222)
14	10.500 (267)
16	11.500 (292)

NOTE 1—For tapered socket dimensions, see Fig. A6.2 and note 1, Fig. A6.2.

FIG. A6.9 End Cap: Taper-to-Taper



NPS	Plug Length, A, in. (mm)
1	1.188 (30)
1½	1.375 (35)
2	1.937 (49)
3	1.937 (49)
4	1.937 (49)
6	2.375 (60)
8	2.625 (67)
10	2.875 (73)
12	3.125 (79)
14	3.625 (92)
16	4.125 (105)

NOTE 1—For straight taper socket dimensions, see Fig. 1.

FIG. A6.10 Pipe Cap Fitting Plug: Straight-Taper

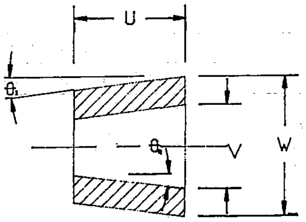
NPS	A, min, in. (mm)	B, min, in. (mm)[A]
1½ by 1	A = 2.5* (Outside Diameter – Inside Diameter)	1.250 (32)
2 by 1		2.500 (64)
2 by 1½		1.250 (32)
3 by 1½		3.000 (76)
3 by 2		2.120 (54)
4 by 2		3.000 (76)
4 by 3		2.880 (73)
6 by 3		3.810 (94)
6 by 4		3.690 (94)
8 by 4		5.440 (138)
8 by 6		3.880 (98)
10 by 6		4.620 (117)
10 by 8		4.120 (105)
12 by 8		5.880 (149)
12 by 10		5.380 (137)
14 by 10		16.620 (422)
14 by 12		16.620 (422)
16 by 12		18.620 (473)
16 by 14		18.880 (479)

[A] For straight taper joint, only.

NOTE 1—For tapered socket dimensions, see Fig. A6.2 and note 1, Fig. A6.2.

NOTE 2—Fiberglass fittings and pipe can be connected by flanges or mechanical couplings, or both (that is, grooved or compression type).

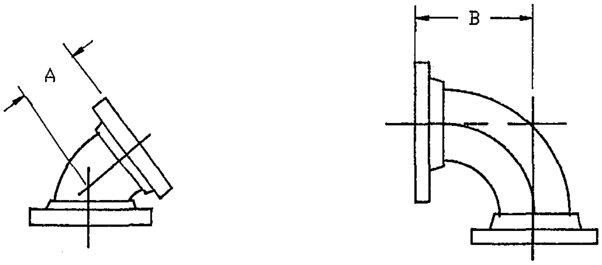
FIG. A6.11 Taper Body Reducer: (A) Taper by Taper and Plain end; (B) Straight-Taper and Straight by Straight



NPS	Bushing Length, min, U, in. (mm)
1½ by 1	1.125 (29)
2 by 1	1.375 (35)
2 by 1½	1.375 (35)
3 by 2	1.880 (41)
4 by 3	1.960 (67)
6 by 4	2.250 (57)
8 by 6	2.750 (70)
10 by 8	3.750 (95)
12 by 10	4.250 (108)
14 by 12	5.250 (133)
16 by 14	5.750 (146)

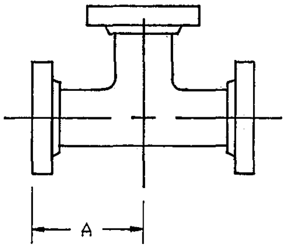
NOTE 1—For tapered socket dimensions, see Fig. A6.2 and note 1, Fig. A6.2. For external taper, see note 1, Fig. A6.2 (reference spigot design).

FIG. A6.12 Concentric Reducer Bushing: Taper-to-Taper



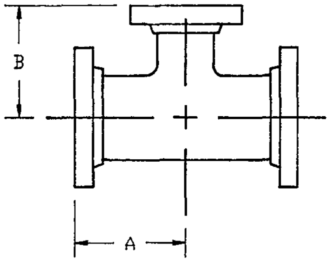
NPS	A, min, in. (mm)	B, min, in. (mm)
18	17.250 (438)	27.000 (432)
20	19.000 (483)	30.000 (762)
22	20.875 (530)	33.750 (857)
24	22.750 (578)	36.000 (914)
26	24.500 (622)	39.750 (1010)
28	26.375 (670)	42.750 (1086)
30	26.500 (673)	45.000 (1143)
32	30.000 (762)	48.750 (1238)
34	31.875 (810)	51.750 (1314)
36	29.000 (737)	54.000 (1372)

FIG. A6.13 (A) 45 Degree Flanged Elbow (B) 90 Degree Flanged Elbow



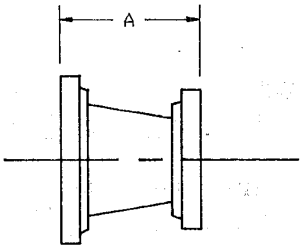
NPS	Center to Contact Surface "A", min, in. (mm)
18	22.500 (572)
20	24.750 (629)
22	27.000 (686)
24	29.250 (743)
26	31.500 (800)
28	33.750 (857)
30	35.500 (902)
32	38.250 (972)
34	40.500 (1029)
36	40.500 (1029)

FIG. A6.14 Tee Flanged



NPS	Center to Contact Surface	
	Main, A, min, in. (mm)	Branch, B, min, in. (mm)
18 by 18 by 8	22.500 (572)	17.026 (389)
10	22.500 (572)	18.026 (465)
12	22.500 (572)	18.067 (478)
14	22.500 (572)	20.005 (510)
16	22.500 (572)	21.005 (535)
20 by 20 by 10	24.750 (629)	19.026 (491)
12	24.750 (629)	19.067 (503)
14	24.750 (629)	21.005 (510)
16	24.750 (629)	22.005 (560)
18	24.750 (629)	23.500 (597)
24 by 24 by 12	29.250 (743)	22.026 (567)
14	29.250 (743)	23.005 (586)
16	29.250 (743)	24.005 (611)
18	29.250 (743)	25.500 (648)
20	29.250 (743)	25.500 (648)
22	29.250 (743)	26.750 (679)
26 by 26 by 14	31.500 (800)	24.000 (610)
16	31.500 (800)	25.000 (635)
18	31.500 (800)	26.500 (673)
20	31.500 (800)	27.750 (705)
22	31.500 (800)	29.000 (737)
24	31.500 (800)	30.250 (768)
28 by 28 by 16	33.750 (857)	26.000 (660)
18	33.750 (857)	27.500 (699)
20	33.750 (857)	28.750 (730)
28 by 28 by 22	33.750 (857)	30.000 (762)
24	33.750 (857)	31.250 (794)
26	33.750 (857)	32.500 (826)
30 by 30 by 18	35.500 (902)	28.500 (724)
20	35.500 (902)	29.750 (756)
22	36.000 (914)	31.000 (787)
24	35.500 (902)	32.250 (819)
26	36.000 (914)	33.500 (851)
28	36.000 (914)	34.750 (883)
32 by 32 by 20	38.250 (972)	30.750 (781)
22	38.250 (972)	32.000 (813)
24	38.250 (972)	33.250 (845)
26	38.250 (972)	34.500 (876)
28	38.250 (972)	35.750 (908)
34 by 34 by 22	40.500 (1029)	33.000 (838)
24	40.500 (1029)	34.250 (870)
26	40.500 (1029)	35.500 (902)
28	40.500 (1029)	36.750 (933)
30	40.500 (1029)	38.000 (965)
32	40.500 (1029)	39.250 (997)
36 by 36 by 24	40.500 (1029)	35.250 (895)
26	42.750 (1086)	36.500 (927)
28	42.750 (1086)	37.750 (959)
30	40.500 (1029)	39.000 (991)
32	42.750 (1086)	40.250 (1022)

FIG. A6.15 Reducer Tee Flanged



NPS	Center to Contact Surface "A", min, in. (mm)
18 by 14	19.000 (483)
16	19.000 (483)
20 by 16	20.000 (508)
18	20.000 (508)
22 by 18	22.000 (559)
20	22.000 (559)
24 by 20	24.000 (610)
22	24.000 (610)
26 by 22	26.000 (660)
24	26.000 (660)
28 by 24	28.000 (711)
26	28.000 (711)
30 by 26	30.000 (762)
28	30.000 (762)
32 by 28	32.000 (813)
30	32.000 (813)
34 by 30	34.000 (864)
32	34.000 (864)
36 by 30	35.000 (889)
32	36.000 (914)

FIG. A6.16 Reducer Flanged

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ASTM F1193-2006: Standard Practice for Quality, Manufacture, and Construction of Amusement Rides and Devices as required by:
Commonwealth of Virginia, 13 VAC 5-31-40(A)(2)
State of Indiana, 685 IAC 1-2-9
State of Florida, FAC 5F-8.0011

Designation: F 1193 – 06

Standard Practice for Quality, Manufacture, and Construction of Amusement Rides and Devices[1]

This standard is issued under the fixed designation F 1193; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice establishes the minimum requirements for a quality assurance program and the manufacturing of amusement rides and devices (including major modifications).

1.2 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

E 543 Practice for Agencies Performing Nondestructive Testing
F 770 Practice for Operation Procedures for Amusement Rides and Devices
F 853 Practice for Maintenance Procedures for Amusement Rides and Devices
F 1193 Practice for Amusement Ride and Device Manufacturer Quality Assurance Program and Manufacturing Requirements
F 1950 Specification for Physical Information to be Transferred With Used Amusement Rides and Devices
F 2291 Practice for Design of Amusement Rides and Devices

2.2 *AWS Standards:*[3]

As applicable.

2.3 *ASME Standards:*[4]

As applicable.

2.4 *ASNT Document:*[5]

Recommended Practice SNT-TC-1A Personnel Qualification and Certification in Nondestructive Testing

3. Significance and Use

3.1 The purpose of this practice is to provide the minimum manufacturing requirements for amusement rides and devices and to provide the minimum requirements for a written quality assurance program for an amusement ride or device manufacturer, or component supplier. This is not intended to include suppliers of off-the-shelf components (for example, fasteners, electrical wire, etc.).

4. Drawing Control Procedure

4.1 A procedure shall be in effect so that appropriate manufacturing drawings, their engineering revisions, and related documents are utilized.

5. Material and Component Control Procedure

5.1 A procedure shall be in effect so that materials, processes, and components, including raw materials, are in accordance with the engineering specifications.

5.1.1 This procedure shall provide the purchasing agent with all the information required to order appropriate material.

5.1.2 A receiving procedure shall be in effect so that incoming material and components are checked against the purchasing specifications.

5.1.3 A procedure shall be in effect so that material in stock can be properly identified for future use.

5.1.4 Documentation on any material, process, or components certified shall be filed for reference.

6. Manufacturing

6.1 Amusement ride and device components and systems shall be manufactured and assembled in accordance with the designer/engineer specified criteria.

6.2 Changes to the designer/engineer specified criteria shall be documented and approved by the designer/engineer or a

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[1] This practice is under the jurisdiction of ASTM Committee F24 on Amusement Rides and Devices and is the direct responsibility of Subcommittee F24.24 on Design and Manufacture.

Current edition approved March 1, 2006. Published March 2006. Originally approved in 1988. Last previous edition approved in 2005 as F 1193 – 05.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from The American Welding Society (AWS), 550 NW LeJeune Rd., Miami, FL 33126.

[4] Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Three Park Ave., New York, NY 10016-5990.

[5] Available from The American Society for Nondestructive Testing (ASNT), P.O. Box 28518, 1711 Arlingate Ln., Columbus, OH 43228-0518.

qualified engineer before components, subassemblies, or systems are placed into use.

6.3 *Quality Assurance Program*:

6.3.1 The manufacturer of an amusement ride or device shall have a written quality assurance program as specified in Practice F 1193 for use in conjunction with the design, manufacture, construction, modification, or reconditioning of the amusement ride or device.

6.3.2 Quality assurance documents, that is, material certifications, test reports, and inspection reports, shall be retained for a period of time as deemed appropriate by the manufacturers.

7. Inspection

7.1 A procedure shall be in effect so that appropriate inspections are made on manufactured parts and subassemblies, for conformance with the designer/engineer specified criteria.

7.2 A procedure shall be in effect so that appropriate inspections are made on purchased components.

7.3 A procedure shall be in effect so that completed subassemblies, or where practical, the assembled amusement rides or devices are inspected prior to delivery.

7.4 Non-conforming components found in 7.1, 7.2, or 7.3 shall be identified and evaluated. Disposition of the non-conforming components shall be one of the following:

7.4.1 The non-conforming component shall be scrapped or rejected, or

7.4.2 The non-conforming component shall be altered such that it cannot be used in the specific intended application for the component, or

7.4.3 The non-conforming component shall be reworked to bring it into compliance and re-inspected in conformance with 7.1, 7.2, or 7.3 of this practice.

7.4.4 The design of the non-conforming component shall be re-evaluated in accordance with 6.2 of this practice, and the drawing or documentation shall be modified or created to allow the component to be used as is.

8. Welding

8.1 Welding and welding procedures shall be in accordance with the appropriate American Welding Society (ANSI.AWS D1 specification) or the American Society of Mechanical Engineers, or other equivalent standard, and be performed by appropriately certified or qualified welders as required by the standard.

8.2 Documentation for certified or qualified welders shall be maintained.

9. Certification

9.1 Before a manufacturer ships an amusement ride or device, the manufacturer shall generate a document certifying that the amusement ride or device is in compliance with Practice F 1193. This certification shall be retained with other quality assurance documents for the amusement ride or device. When requested by an amusement ride or device-certifying authority, purchaser, or owner, the manufacturer shall provide a copy of this certification document.

10. Information Requirements

10.1 The information given in 10.2 and 10.3–10.15.3 shall be included, where applicable, on the information plate as specified in 10.2, and in the documented operating and maintenance instructions to be furnished by the manufacturer or seller at the time of sale of each amusement ride or device.

10.2 *Information Plate*—A manufacturer-issued information plate, printed in English, shall be permanently affixed to the ride or device in a visible location, and shall be designed to remain legible for the expected life of the ride or device. The plate shall include, but not be restricted to, all applicable items listed in 10.2-10.2.8.

10.2.1 *Ride Serial Number*—A manufacturer-issued unique identifying number or code affixed to the ride in a permanent fashion.

10.2.2 *Ride Name and Manufacturer*—A manufacturer-issued unique identifying ride name, including the name of the manufacturer by city, state, and country.

10.2.3 *Ride Model Number*—A manufacturer-issued unique identifying number or code assigned to each manufactured type of ride having the same structural design or components.

10.2.4 *Date of Manufacture*—The date (month and year) determined by the manufacturer that the given ride or device met his required construction specifications.

10.2.5 *Ride Speed*—Maximum and minimum revolutions per minute, feet per second, or miles per hour, as applicable.

10.2.6 *Direction of Travel*—When the proper direction of travel is essential to the design operation of the ride, the manufacturer shall designate the direction of travel, including reference point for this designation.

10.2.7 *Passenger Capacity by Weight*—Maximum total passenger weight per passenger position and per ride.

10.2.8 *Passenger Capacity by Number*—Maximum total number of adult or child passengers per passenger position and per ride.

10.3 *Ride Duration*—The actual time the ride is in operation or a passenger is exposed to the elements of the ride functions, including passenger restrictions to maximum exposure time, shall be included.

10.4 *Recommended Balance of Passenger Loading or Unloading*—When passenger distribution is essential to the proper operation of the ride or device, the appropriate loading and unloading procedure with respect to weight distribution shall be provided.

10.5 *Environmental Restrictions*—Recommendations for operational restrictions relating to environmental conditions such as, but not limited to, wind, rain, salt corrosion, and extreme heat or cold.

10.6 *Recommended Passenger Restrictions*—Where applicable, any recommended passenger limitations such as, but not limited to, height passenger placement, or any other appropriate restrictions.

10.7 *Electrical Power Requirements*—Total electrical power required to properly operate the ride or device designated in watts and volts, including minimum and maximum voltage limits.

10.8 *Mechanical Power Requirements*—Minimum horsepower necessary to operate ride properly.

10.9 *Water Flow*—Minimum/maximum water flow rates.

10.10 *Static Information*—The following information shall be provided for the amusement ride or device when it is in a nonoperational state with no passengers: height, width, diameter, and weight.

10.11 *Dynamic Information*—The following information shall be provided for the amusement ride or device when it is in an operational state: height, width, diameter, and weight.

10.12 *Trailering Information*—Each trailer necessary for the transport of a portable amusement ride or device shall be provided with the following information: height, width, length, and weight.

10.13 *Fastener Schedule*—A manufacturer-issued schedule for the correct grade, torque, and placement of all fasteners used in the assembly, or erection, or both, of the ride or device.

10.14 *Load Distribution per Footing*—Maximum static loading and maximum dynamic loading of each footing of an amusement ride or device.

10.15 *Elements and Structures*—Provided the proposed owner/operator furnishes the manufacturer with necessary data concerning proposed installation and usage of the ride or device, the manufacturer shall provide to the proposed owner/operator a description of all structural interface between the ride or device and the owner/operator supports. This structural requirement definition shall include the following:

10.15.1 Maximum static design loads of each footing or equivalent structural connection,

10.15.2 Maximum dynamic design loads of each footing or equivalent structural connection, and

10.15.3 Any other structural interface design specification.

11. Operational Instruction Requirements

11.1 The manufacturer of an amusement ride or device shall provide, with delivery of each ride or device, documented, recommended operating instructions in the English language. These instructions shall include, but not be limited to the following:

11.1.1 Description of the ride or device operation, including the function and operation of its major components.

11.1.1.1 Description of the motion(s) of the ride or device during operation.

11.1.1.2 Description of the recommended passenger loading procedures during operation, including recommended seating, where applicable.

11.1.2 Recommended safety procedures and instructions, and information about safety equipment pertaining to patrons and ride or device operators and attendants.

11.1.2.1 Maximum total passenger weight and maximum number of passengers by carrier unit or ride total.

11.1.2.2 Description of the passenger restraint system, its recommended use and operation.

11.1.2.3 Ride or device operator and attendant safety check: recommended visual or other inspections to be performed by ride or device operators and attendants prior to and during each ride or device cycle.

11.1.2.4 Instructions to the patron: recommended information that should be made available to each patron of the ride or device.

11.1.2.5 Recommendations for operational restriction relating to environmental conditions such as wind, rain, or temperature fluctuation.

11.1.3 Manufacturer's recommended ride or device operating procedures, including the location of ride or device operators and attendants.

11.1.3.1 Description of the recommended, daily preopening inspection to be performed by ride or device operator(s) and attendants that is in addition to previously performed maintenance or other inspections.

11.1.3.2 Description of the recommended ride or device operator(s) and attendants positions and functions.

11.1.3.3 Description of the recommended series of steps, to be followed in a definite order, to complete the operation of the ride or device.

11.1.4 Manufacturer's recommended emergency procedures.

11.1.4.1 Recommended evacuation procedures for the ride or device.

11.1.4.2 Use of emergency power equipment, if provided with the ride or device.

11.1.4.3 Description of any emergency equipment that is provided with the ride or device, and its uses.

11.1.4.4 Description of any emergency procedure made necessary by an interruption of power, and restart procedures.

12. Testing Performance Requirements

12.1 *Developmental Testing Requirements*:

12.1.1 Where applicable, as determined by the manufacturer/designer, the following test procedures shall be developed and performed on a prototype amusement ride or device in order that the manufacturer/designer may determine the appropriateness for use, of not only the parts, but the entire system of a newly designed ride or device.

12.1.1.1 *Procedures to Verify Maximum Safe Design Loads*:

12.1.1.2 Procedures to verify such design characteristics as relevant deflections, loads, and forces that are placed on both the equipment and the passengers during operation of the ride or device,

12.1.1.3 A procedure to determine operational limits and restart criteria due to environmental conditions,

12.1.1.4 Procedures to allow the manufacturer to determine such factors as component variability and certification requirements of components, and

12.1.1.5 Any other procedures necessary to demonstrate a ride or device's appropriateness for its intended use.

12.2 *Installation Testing Requirements*:

12.2.1 This section of the guide covers those tests relevant not only to installation, but also includes post-modification and major modifications. The original manufacturer or supplier of an amusement ride or device shall also provide, where applicable, the following standard testing guides:

12.2.1.1 *Materials Testing*—Acceptable test procedures for the certification of all major structural components shall be provided. Where possible, this testing should be referenced to ASTM or to other commonly accepted industry standards.

12.2.1.2 *Erection/Modification Acceptance Testing*—Test procedures or criteria for the acceptance of such construction operations as welding and fastening shall be provided. Again, where possible, reference should be made to ASTM or to other currently accepted industry standards for this purpose.

12.2.1.3 *Performance Testing*—This should consist of a series of specified tests that can be used to determine that the newly erected ride or device conforms to the original design criteria.

12.3 *Operational Testing Requirements*:

12.3.1 The manufacturer of a ride or device shall develop specific operational tests along with minimum intervals for these tests to be performed that will allow the owner/operator of the ride or device to determine whether a given ride or device is operating within prescribed operational limits.

12.3.2 All operational tests, except those necessarily recommended subsequent to the sale because of information not reasonably available to the manufacturer at the time of sale, should be recommended to the owner/operator at the time of sale. All tests, whether recommended at the time of sale, or subsequent tests, shall meet the following criteria:

12.3.2.1 All tests shall have been satisfactorily performed by the manufacturer prior to sale.

12.3.2.2 The tests must be such that the ride, device, or element can reasonably be expected to pass during the expected design life, assuming recommended maintenance and operative procedures have been followed.

12.3.2.3 All tests must be reasonable and such that the owner/operator can reasonably be expected to be competent to perform or cause to be performed.

12.3.2.4 Any operational test including load testing performed on an amusement ride or device shall be completely nondestructive in nature. Overload testing exceeding the above limits shall be deemed inappropriate.

12.3.2.5 Any installation or operational testing conducted on an amusement ride or device shall be accomplished within the rated limits of the information provided by the manufacturer.

12.4 *Non-Destructive Testing Requirements*:

12.4.1 This section pertains to the nondestructive testing of amusement ride and device components as recommended by the manufacturer. These tests shall be performed by a qualified NDT inspector in accordance with Practice E 543 or ASNT Recommended Practice SNT-TC-1A, or both. It is not intended to preclude any other schedule of NDT, inspection, or testing.

12.4.1.1 Nondestructive testing (NDT) is the development and application of technical methods such as radiographic, magnetic particle, ultrasonic, liquid penetrant, electromagnetic, neutron radiographic, acoustic emission, visual, and leak testing to examine materials or components in ways that do not impair the future usefulness and serviceability in order to detect, locate, measure and evaluate discontinuities, defects, and other imperfections; to assess integrity, properties and composition; and to measure geometrical characters.

12.4.1.2 NDT shall be used to verify the integrity of components which due to their design, location, or installation, or combination thereof, cannot be adequately evaluated by other means.

12.4.1.3 A schedule for testing on a given ride or device component shall be defined in terms of hours, days, or other units of operation. The initial design shall be developed to expect a period between tests to be no more frequent than annually.

12.4.1.4 The manufacturer shall recommend components to be tested along with appropriate acceptance criteria. The manufacturer may recommend the test method but shall not specify how the testing is to be conducted except where certain procedures might endanger other components on the ride or device. Any changes or additions to these recommendations shall be communicated to all known owner/operators of the ride or device, and inspection agencies via manufacturers' bulletins. Tests shall meet the requirements of 12.3.2.1-12.3.2.3.

12.4.1.5 The manufacturer shall include in an appropriate section of the ride or device manual the list and location of components to be tested, recommending specific areas to test and the schedule by which they shall be tested in accordance with 12.4.1.4.

12.4.1.6 Components found to have relevant indications that do not meet the acceptance criteria shall be replaced or reconditioned in accordance with Practice F 1193.

12.4.1.7 Components found free of relevant indications that meet the acceptance criteria or have been reconditioned shall be further tested at the regular schedule in accordance with 12.4.1.3.

12.4.1.8 Within a reasonable time following a request by an owner/operator or inspection agency, the manufacturer of an amusement ride or device whose manual does not contain testing recommendations shall either provide a component listing or statement that no NDT is recommended on the ride or device as per the criteria outline of 12.4.1.2 When a manufacturer's list or statement is not available, it may be compiled by a registered professional engineer or engineering agency or by any individual qualified by training and experience to compile such a list or statement based upon the ride or device's specifications and history and using accepted engineering practices.

13. Maintenance Procedure Requirements (from Practice F 853)

13.1 The manufacturer of an amusement ride or device shall provide, with delivery of each ride or device, documented maintenance instructions in the English language. These instructions shall include, but not be limited to, the following:

13.1.1 Description of the ride or device operation, including the function and operation of its major components.

13.1.1.1 Description of the designed motion(s) of the ride or device during operation.

13.1.2 Description of the recommended procedures for installation, setup, disassembly, and transportation of an amusement ride or device.

13.1.3 Recommended lubrication procedures for the amusement ride or device.

13.1.3.1 Recommended types and specifications of lubricants.

13.1.3.2 Recommended frequency of lubrication.

13.1.3.3 A lubrication drawing, chart, or instruction, showing the location of lubrication points.

13.1.3.4 Recommended special method of lubrication, where applicable.

13.1.4 Description of the recommended daily, preopening inspection to be performed and identification of special care areas and recommended procedures for inspection and maintenance of these areas.

13.1.5 Description, including frequency, of recommended maintenance inspections and testing, other than daily preopening inspection.

13.1.5.1 Recommended wear limits or tolerances, where deemed necessary by the manufacturer.

13.1.5.2 Recommended operational tests, along with minimum intervals for these tests to be performed, that will allow the owner/operator of the ride or device to determine whether a given ride or device is operating within recommended prescribed operational limits.

13.1.5.3 Where applicable, recommended nondestructive testing along with appropriate acceptance criteria, including suggested frequency and the special parts of areas to be tested.

13.1.5.4 Tests recommended pursuant to 13.1.5 shall meet the following criteria:

(1) The tests shall have been performed satisfactorily by the manufacturer prior to the sale of the amusement ride or device,

(2) The test shall be a test that the amusement ride or device, or element, can reasonably be expected to pass during the expected life of the amusement ride or device, or element, assuming recommended maintenance and operating procedures have been followed, and

(3) The test shall be a test that is reasonable, and that the owner/operator can reasonably be expected to be competent to perform or cause to be performed.

13.1.6 Recommended specifications for the use of replacement fasteners, and recommended torque requirements for fasteners, where applicable. If appropriate, precautionary information will be provided relating to the continued use of fasteners that have been loosened or retorqued.

13.1.7 Schematics of electrical power, lighting, controls, and other systems, including location charts and manufacturer's troubleshooting guide, where applicable.

13.1.7.1 Description of recommended maintenance procedures for electrical components.

13.1.7.2 The name of the component manufacturer and appropriate identification number or specifications, or both, will be provided for electrical components used within the amusement ride or device.

13.1.7.3 Each electrical component used within the amusement ride or device will be assigned an individual identification number, symbol, or code to facilitate its location and identity on the electrical schematics.

13.1.8 Schematics of hydraulic and pneumatic systems, including recommended pressures, location of components, line specification, fitting specification, type of fluid, location chart, and manufacturer's troubleshooting guide.

13.1.8.1 Description of recommended maintenance procedures for hydraulic and pneumatic systems and components.

13.1.9 List of parts used in the assembly of the ride or device, or drawings showing component parts and their use.

13.1.10 Recommended procedures to be followed in the event of an extended period of non-operation or storage, or both.

13.1.11 Description of recommended assembly and disassembly techniques and procedures, pertaining to specific components, as deemed necessary by the manufacturer.

13.1.12 Recommended restrictions and special procedures, lubricants, materials, or equipment that may be necessary because of environmental conditions.

13.1.13 Other recommendations known to the manufacturer and specific to certain serial numbered rides or devices.

14. Manufacturer Supplemental Bulletin Requirements

14.1 Supplemental notification bulletins delivered by the manufacturer of an amusement ride or device to the owner/operator that were not provided at the time of sale and contain new information or newly recommended inspections or testing, or both, shall be consistent with the following criteria in order to carry the force and effect of this practice:

14.1.1 Modifications, procedures, testing, or inspections shall conform to Practices F 770, F 1193, and F 2291.

14.1.2 Modifications, procedures, testing, and inspections shall be reasonable, ethical, and consistent with the general manufacturing practices within the industry.

14.1.3 Supplemental notification bulletins when used shall have a page header that contains the following information, when available:

14.1.3.1 The name, address and telephone number of the issuing entity,

14.1.3.2 The date the bulletin is released,

14.1.3.3 The date the bulletin takes effect,

14.1.3.4 The period the bulletin recommends for completion,

14.1.3.5 The name of the original ride or device manufacturer,

14.1.3.6 The name of the ride or device,

14.1.3.7 The model number of the ride or device,

14.1.3.8 The serial numbers of the affected rides or devices,

14.1.3.9 The applicable dates of manufacture for the affected rides or devices,

14.1.3.10 A number that uniquely identifies the bulletin,

14.1.3.11 The number of the superseded bulletin, where applicable, and

14.1.3.12 The page number and number of total pages.

14.1.4 The first page shall contain, in large bold upper case letters, one of the following titles:

14.1.4.1 "SAFETY ALERT" for notifications that recommend immediate action (see Fig. A1.1),

14.1.4.2 "SERVICE BULLETIN" for notifications that do not recommend immediate action but do recommend future action (see Fig. A1.2), and

14.1.4.3 "NOTIFICATION" for notifications that do not necessarily recommend future action but are primarily for promulgation of information (see Fig. A1.3).

14.1.5 The first page shall contain a summary of the information contained in the body of the bulletin.

14.1.6 The first page shall summarize the reason(s) that prompted the release of the bulletin.

14.1.7 The first page shall list the recommended action to be taken, for example: Inspection, modification, part replacement, new parts, nondestructive testing, procedural change, manual revision, operational revision, etc.

14.1.8 The remainder of the first page and any supplemental pages shall contain text detailing the information being promulgated. Drawings and diagrams may be used for clarification where applicable.

14.1.9 The supplemental notification bulletin, when printed, shall be in black ink on white paper. The following colored ink may be used to print titles:

14.1.9.1 Red—for safety alert,

14.1.9.2 Blue—for service bulletins, and

14.1.9.3 Green—for notifications.

14.1.10 The supplemental notification bulletins shall follow the format provided in Annex A1.

15. Inspection Requirements

15.1 The manufacturer of an amusement ride or device shall provide the owner/operator with a written inspection procedure to be delivered with the ride or device. The document shall outline the inspections as contained in Practices F 1193 and F 770.

15.1.1 Any changes in the procedure prescribed in 15.1 deemed essential by the manufacturer due to information not available to the manufacturer at the time of delivery shall be communicated to all known owner/operators.

15.2 All inspections, whether recommended at the time of sale or subsequently, shall meet the following criteria:

15.2.1 Inspections are such that shall have been satisfactorily performed by the manufacturer.

15.2.2 Inspections are ones in which the ride or device or element can reasonably be expected to pass during the expected design life of the ride, device or element, assuming that recommended maintenance procedures have been followed; and

15.2.3 Inspections are reasonable and are such that the owner/operator can reasonably be expected to be competent to perform or cause to be performed.

15.3 Upon notification from an owner/operator of an incident involving a critical component, the manufacturer of an amusement ride or device shall promptly evaluate this information and disseminate his findings to the original owner/operator, along with any pertinent recommendations, to all known owner/operators.

16. Used Ride or Device Information Requirements (from Specification F 1950)

16.1 The original manufacturer of the used amusement ride or device being sold shall make available, upon request by the purchaser, owner, operational, and maintenance information along with updates, if any.

16.2 The original manufacturer of the used amusement ride or device being sold shall make available to the purchaser information regarding any major modifications made to the ride or device that the manufacturer authorized or otherwise performed on the ride or device.

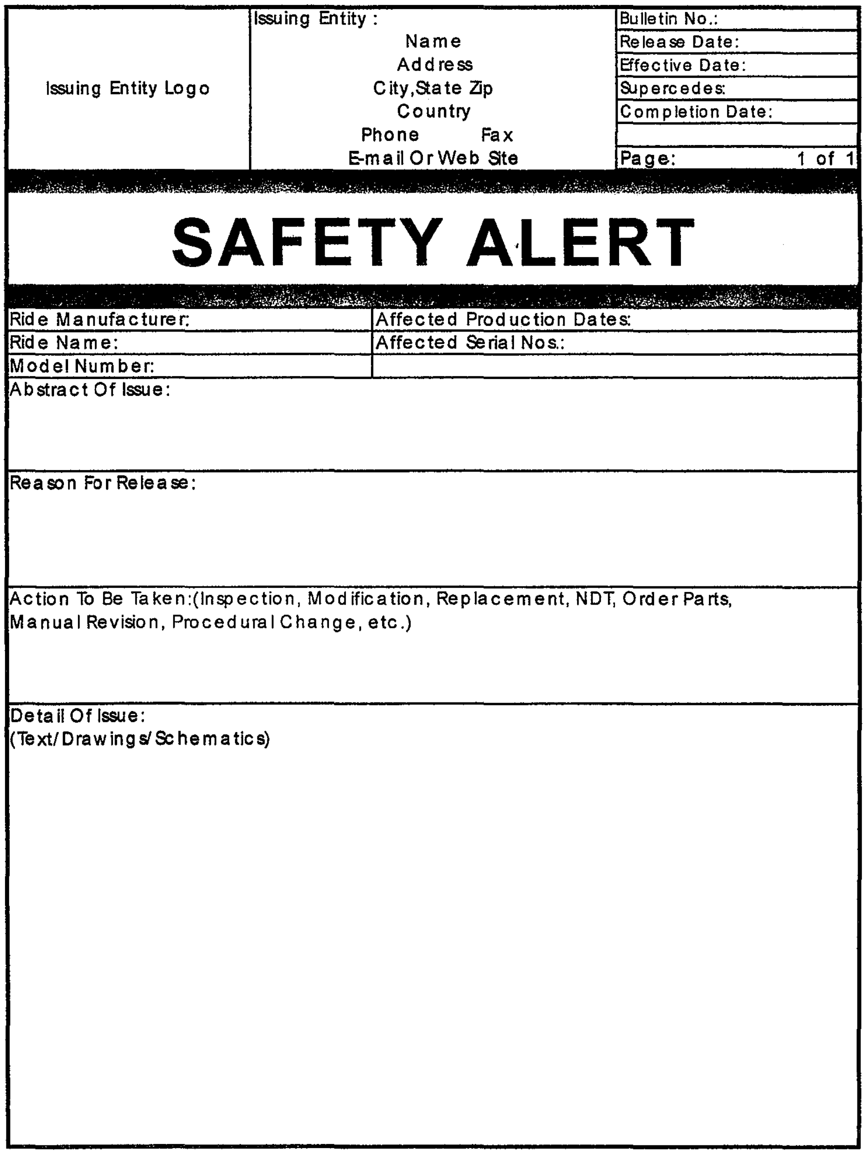
17. Keywords

17.1 amusement rides and devices; inspection; manufacturing; quality assurance; welding

ANNEX

(Mandatory Information)

A1. SUPPLEMENTARY NOTIFICATION BULLETINS FORMAT

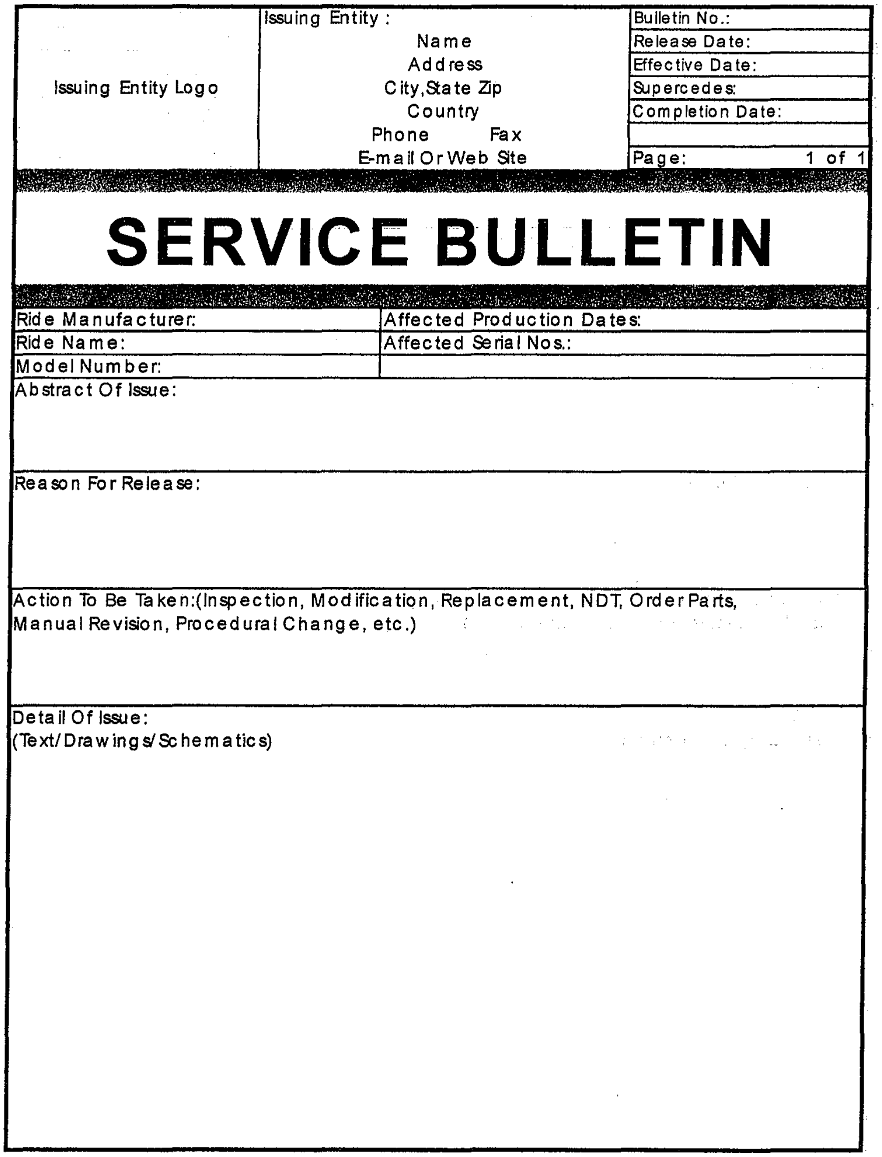


Issuing Entity Logo	Issuing Entity : Name Address City,State Zip Country Phone Fax E-mail Or Web Site	Bulletin No.: Release Date: Effective Date: Supercedes: Completion Date: Page: 1 of 1

SAFETY ALERT

Ride Manufacturer:	Affected Production Dates:
Ride Name:	Affected Serial Nos.:
Model Number:	
Abstract Of Issue:	
Reason For Release:	
Action To Be Taken:(Inspection, Modification, Replacement, NDT, Order Parts, Manual Revision, Procedural Change, etc.)	
Detail Of Issue: (Text/Drawings/Schematics)	

FIG. A1.1 Safety Alert Bulletin



Issuing Entity Logo	Issuing Entity : Name Address City,State Zip Country Phone Fax E-mail Or Web Site	Bulletin No.: Release Date: Effective Date: Supercedes: Completion Date: Page: 1 of 1

SERVICE BULLETIN

Ride Manufacturer:	Affected Production Dates:
Ride Name:	Affected Serial Nos.:
Model Number:	

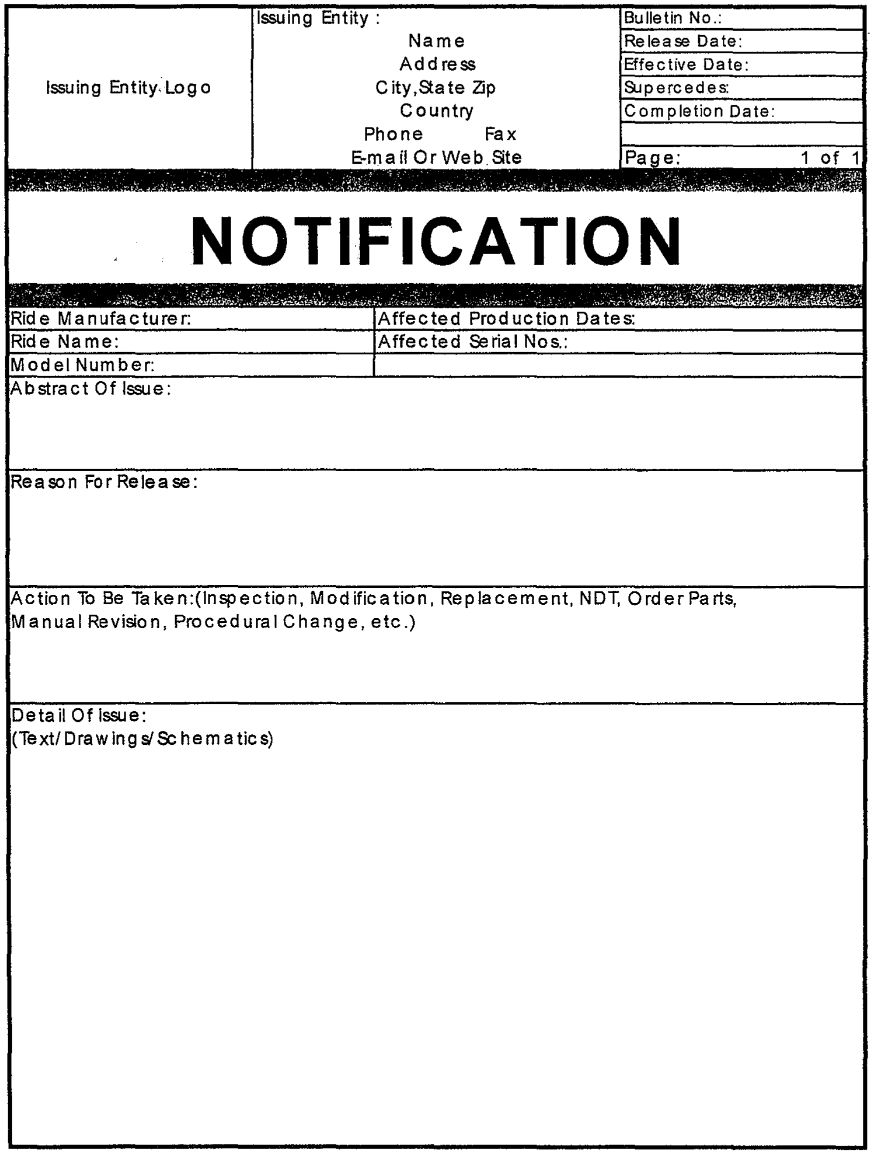
Abstract Of Issue:

Reason For Release:

Action To Be Taken:(Inspection, Modification, Replacement, NDT, Order Parts, Manual Revision, Procedural Change, etc.)

Detail Of Issue:
(Text/Drawings/Schematics)

FIG. A1.2 Service Bulletin



Issuing Entity Logo

Issuing Entity :
Name
Address
City,State Zip
Country
Phone Fax
E-mail Or Web Site

Bulletin No.:
Release Date:
Effective Date:
Supercedes:
Completion Date:
Page: 1 of 1

NOTIFICATION

Ride Manufacturer:
Affected Production Dates:
Ride Name:
Affected Serial Nos.:
Model Number:

Abstract Of Issue:

Reason For Release:

Action To Be Taken:(Inspection, Modification, Replacement, NDT, Order Parts, Manual Revision, Procedural Change, etc.)

Detail Of Issue:
(Text/Drawings/Schematics)

FIG. A1.3 Notification Bulletin

Issuing Entity Logo	Issuing Entity : Name Address City,State Zip Country Phone Fax E-mail Or Web Site	Bulletin No.: Release Date: Effective Date: Supercedes: Completion Date: Page: 2 of 2

Ride Manufacturer:	Affected Production Dates:
Ride Name:	Affected Serial Nos.:
Model Number:	
Detail Of Issue Continued:(Text/Drawings/Schematics)	

FIG. A1.3 Notification Bulletin *(continued)*

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Document Name:	ASTM F1199: Cast (All Temperatures and Pressures) and Welded Pipe Line Strainers (150 psig and 150 Degrees F Maximum)
CFR Section(s):	46 CFR 56.60-1(b)
Standards Body:	American Society for Testing and Materials

APPROVED

Official Incorporator:

THE EXECUTIVE DIRECTOR
OFFICE OF THE FEDERAL REGISTER
WASHINGTON, D.C.

Designation: F 1199 – 88 (Reapproved 1998)

An American National Standard

Standard Specification for Cast (All Temperatures and Pressures) and Welded Pipe Line Strainers (150 psig and 150°F Maximum)[1]

This standard is issued under the fixed designation F 1199; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This standard covers all cast strainers and welded strainers in services up to 150 psig and 150°F (1 MPa and 65°C). For welded strainers used in services above 150 psig and 150°F, see Specification F 1200.

1.2 This standard provides the minimum requirements for the design, fabrication, rating, marking, and testing of cast and welded pipe line strainers for services above 0°F (−18°C).

1.3 Strainers manufactured to this specification are acceptable for use in the marine environment.

1.4 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

1.5 The following safety hazards caveat pertains only to the test methods portion, Section 8, of this specification. *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

F 1200 Specification for Fabricated (Welded) Pipe Line Strainers (Above 150 psig and 150°F)[2]

2.2 *ANSI Standards:*[3]

B2.1 Pipe Threads
B16.1 Cast Iron Pipe Flanges and Flanged Fittings
B16.3 Malleable Iron Threaded Fittings
B16.4 Cast Iron Threaded Fittings
B16.5 Steel Pipe Flanges and Flanged Fittings
B16.11 Forged Steel Fittings, Socket-Welding and Threaded
B16.15 Cast Bronze Threaded Fittings
B16.24 Bronze Pipe Flanges and Flanged Fittings
B16.25 Buttwelding Ends
B31.1 Power Piping

2.3 *MSS Standards:*[4]

SP-51 150 lb Corrosion Resistant Cast Flanges and Flanged Fittings
SP-63 High Strength Wrought Welding Fittings

2.4 *ASME Standard:*[5]

ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, Pressure Vessels

3. Terminology

3.1 *Definitions:*

3.1.1 *basket or element*—the replaceable part in a strainer that performs the barrier separation of solid particles from flowing fluid. It is normally removable for cleaning and servicing and can be furnished in a wide variety of materials, particle size removal capability, straining area, and types of construction. Interchangeable baskets or elements are normally available for a given make, model, and size strainer.

3.1.2 *maximum allowable working pressure (MAWP)*—the highest internal pressure that the strainer can be subjected to in service. The maximum nonshock working pressure for which a strainer is rated by the manufacturer.

3.1.3 *maximum design temperature*—the maximum temperature for which a strainer is rated by the manufacturer.

3.1.4 *strainer*—a device which, when installed in a pipe line, provides a mechanical means of removing solids from a flowing liquid or gas by using a barrier element.

3.1.5 *straining open area*—the net effective open area of the clean element through which the fluid can pass.

4. Classification

4.1 Strainers may be classified into three general construction categories, simplex, duplex (or multiplex), and automatic (self-cleaning), as follows:

4.1.1 *Simplex*—A strainer consisting of a single basket or element chamber that normally requires the flow through the unit to be shut down before cleaning.

4.1.1.1 Classifications of simplex strainers based on port alignment relative to basket or element chamber are *Y*, *T*, *Z*, and others.

4.1.2 *Duplex* (or Multiplex)—A strainer usually consisting

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[1] This specification is under the jurisdiction of ASTM Committee F-25 on Ships and Marine Technology and is the direct responsibility of Subcommittee F25.13 on Piping Systems.

Current edition approved Dec. 30, 1988. Published February 1989.

[2] *Annual Book of ASTM Standards*, Vol 01.07.

[3] Available from American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.

[4] Available from American Society of Mechanical Engineers, 345 East 47th St., New York, NY 10017.

[5] Available from Manufacturers Standardization Society of the Valve and Fitting Industry, Inc., 1815 N. Fort Myer Dr., Arlington, VA 22209.

of at least two basket or element chambers separated by a valve (or valving) that permits continuous flow of fluid through one chamber while the other is accessible for cleaning.

4.1.3 *Automatic* (Self-Cleaning)—A strainer providing some means for back-flushing or cleaning of the straining element while the unit is in service. It can have one or more elements and may require periodic shutdown for maintenance and inspection.

4.2 Strainers may be further classified by pressure ratings and types of port connections, port alignments relative to unit center lines, cover closures, valve types (in duplex), types of baskets or elements, materials of construction, and other features of design.

5. Ordering Information

5.1 Orders for products under this specification shall include the following information as applicable. If a manufacturer's standardized product is being ordered, include all data needed by the manufacturer to define the product.

5.1.1 Make.
5.1.2 Model (simplex or duplex).
5.1.3 Port size.
5.1.4 Port connections.
5.1.5 Maximum allowable pressure/temperature rating.
5.1.6 Body and cover material.
5.1.7 Type of cover closure.
5.1.8 Basket (element) material.
5.1.9 Basket hole size.
5.1.10 Optional design features.
5.1.11 Certification (see 8.1.2.1 and Section 9).
5.1.12 This ASTM standard designation number.
5.1.13 Additional requirements or testing as contracted by the manufacturer and purchaser.

5.2 If a product is to be specified by performance criteria rather than model description, then the following should be specified:

5.2.1 Maximum allowable clean pressure loss at a given flow capacity of a given liquid at a given velocity.
5.2.2 Temperature and pressure.
5.2.3 Straining area.
5.2.4 Minimum basket rupture differential pressure (see 7.4).
5.2.5 Maximum valve seepage rates (see 7.3).
5.2.6 Certification (see 6.2, 8.1.2.1, and Section 9).
5.2.7 For self-cleaning strainers, specify basket cleaning effectiveness and endurance testing.

5.3 In general, the standard product description should not be mixed with the performance criteria because conflicting specifications can result (for example, maximum allowable pressure loss inconsistent with product size).

6. Materials and Manufacture

6.1 Strainer housings, as well as any pressure-retaining parts, including bolting used for pressure retention, shall be constructed of materials listed in Section VIII, Division 1 of the ASME Boiler and Pressure Vessel Code (hereafter called ASME Code) or ANSI/ASME B31.1. Bolts, screws, and fasteners in contact with interior fluid shall be of appropriate corrosion-resistant material.

6.2 The pressure ratings established under this specification are based on materials of high quality produced under regular control of chemical and mechanical properties by a recognized process. The manufacturer shall be prepared to submit a certificate of compliance verifying that his product has been so produced and that it has been manufactured from material whose chemical and mechanical properties are at least equal to the requirements of the appropriate standard or specification.

6.3 For materials not having values of allowable stress tabulated in Section VIII, Division 1 of the ASME Code, allowable stresses shall be determined in accordance with the procedures outlined in Subsection C and Appendix P of that section. Where it can be shown that the values of allowable stress listed for a particular material in one product form (because of similar chemistry, mechanical properties, heat treatment, and so forth) are applicable to the same material in an unlisted product form, the listed values of allowable stress may be used.

6.4 Seals and parts, other than pressure-retaining parts and bolting used for pressure retention, shall be of materials suitable for the service.

6.5 Users are cautioned against applications with fluids which may react chemically with any materials used in these products in contact with the fluid.

6.6 Cast iron shall be limited to services below 450°F (232°C). Cast iron fittings conforming to B16.1 and B16.4 are limited to Class 125 and Class 250.

7. Other Requirements

7.1 The maximum allowable working pressure (MAWP) and maximum design temperature (MAT) rating of strainers covered under this specification shall be established by at least one of the following methods:

7.1.1 Proof test in accordance with the requirements prescribed in paragraph UG-101 of Section VIII of the ASME Code. If burst-type tests as outlined in paragraph UG-101(m) are used, it is not necessary to rupture the component. In this case, the value of B to be used in determining the MAWP shall be the maximum pressure to which the component was subjected without rupture. Safety of personnel shall be given serious consideration when conducting proof tests. Components that have been subjected to a proof test shall not be offered for sale.

7.1.2 Design calculations in accordance with the requirements prescribed in Section VIII, Division 1 of the ASME Code.

7.1.3 Extensive and successful performance experience under comparable service conditions with similar materials may be used as a basis for rating provided all other provisions of this specification are met.

7.2 Pipe end connections for strainers shall be in accordance with one of the standards listed in 2.2 and 2.3 or as agreed upon between the purchaser and manufacturer (see 5.1.13). Threaded pipe connections shall be limited to the following pressures:

¾ in. (19 mm) NPS and below . . . 1500 psig (10.3 MPa) max
1 in. (25 mm) NPS and below . . . 1200 psig (8.27 MPa) max

2 in. (50 mm) NPS and below . . . 600 psig (4.14 MPa) max
3 in. (76 mm) NPS and below . . . 400 psig (2.76 MPa) max

7.3 Duplex (or multiplex) strainer valve seepage rates shall be minimized to prevent undue spillage of fluid under normal operating conditions while the element is being serviced or cleaned in accordance with the manufacturer's procedures. Maximum seepage rates with a specified liquid at a specified pressure and temperature may be as contracted by the manufacturer and purchaser (see 5.2.5), and provision may be made to include a test to determine acceptability before acceptance for a given application.

7.4 Baskets or elements shall withstand a minimum of 10-psi (0.069-MPa) differential pressure without rupturing or such other differential pressure as contracted by the manufacturer and purchaser (see 5.2.4) for the application involved.

8. Test Methods

8.1 Test all strainers by one of the following methods:

8.1.1 Conduct a hydrostatic test at 1½ times the 100°F (37°C) rated MAWP of the strainer. Perform the test with water or other liquid having a maximum viscosity of 40 SSU at 125°F (52°C) with a maximum pressure test temperature of 125°F. The minimum duration of the test shall be 15 s for strainers less than 2-in. (50-mm) nominal pipe size (NPS), 1 min for strainers 2½ through 8 in. (63 through 203 mm), and 3 min for larger sizes. The purpose of this test is to detect leaks and structural imperfections. No visible leakage is permitted.

8.1.2 Strainers 2-in. (50-mm) NPS and smaller with other than flanged connections may, at the option of the manufacturer, be air tested to the lesser of 1.2 times the MAWP or 80 psig (0.55 MPa). The minimum duration of the test shall be 15 s. Visually detectable leakage is not acceptable.

8.1.2.1 If this option is exercised, the manufacturer shall be able to certify that a prototype of the same size strainer was subjected to a hydrostatic test in accordance with 8.1.1.

9. Certification

9.1 When specified in the purchase order or contract, the manufacturer's certification shall be furnished to the purchaser stating that samples representing each lot have been manufactured, tested, and inspected in accordance with this specification and the requirements have been met. When specified in the purchase order or contract, a report of the test results shall be furnished.

10. Product Marking

10.1 Each strainer shall have a securely attached name plate or other permanent marking indicating:

10.1.1 Manufacturer's name or trademark.

10.1.2 Maximum allowable working pressure.

10.1.3 Size (end connection NPS size).

10.1.4 Direction of flow (by an arrow or the word "inlet," "outlet," or both).

10.1.5 ASTM designation of this specification.

11. Quality Assurance

11.1 The strainer manufacturer shall maintain the quality of the strainers that are designed, tested, and marked in accordance with this specification. At no time shall a strainer be sold indicating that it meets the requirements of this specification if it does not meet the requirements herein.

12. Keywords

12.1 automatic strainer; cast pipe line strainers; cast strainers; duplex strainer; simplex strainer; strainer; welded pipe line strainers; welded strainers

CERTIFICATE

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An American National Standard

Standard Specification for Fluid Conditioner Fittings in Piping Applications Above 0°F[1]

This standard is issued under the fixed designation F 1201; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification provides the minimum requirements for pressure-retaining components of fluid conditioner fittings. It addresses the pressure-retaining component design, fabrication, rating, marking, and testing.

1.2 This specification is not intended to override any of the present fluid conditioner fitting specifications specific to devices such as strainers, filters, and traps but should be used for devices for which a specific specification does not apply.

1.3 This specification provides sufficient requirements to allow a fluid conditioner fitting to be used in the marine environment.

1.4 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

1.5 The following precautionary caveat pertains only to the test methods portion, Section 7, of this specification. *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

D 93 Test Methods for Flash Point by Pensky-Martens Closed Cup Tester[2]
F 722 Specification for Welded Joints for Shipboard Piping Systems[3]

2.2 *ANSI Standards:*[4]

B2.1 Pipe Threads
B16.1 Cast Iron Pipe Flanges and Flanged Fittings
B16.3 Malleable Iron Threaded Fittings
B16.4 Cast Iron Threaded Fittings
B16.5 Pipe Flanges and Flanged Fittings
B16.11 Forged Steel Fittings, Socket-Welding and Threaded
B16.15 Cast Bronze Threaded Fittings
B16.24 Bronze Pipe Flanges and Flanged Fittings
B16.25 Buttwelding Ends
B31.1 Power Piping

2.3 *MSS Standards:*[5]

SP-44 Steel Pipe Flanges
SP-51 150 lb Corrosion Resistant Cast Flanges and Flanged Fittings
SP-61 Pressure Testing of Steel Valves
SP-67 Butterfly Valves

2.4 *ASME Standard:*[6]

ASME Boiler and Pressure Vessel Code: Section VIII, Division 1, Pressure Vessels
ASME Boiler and Pressure Vessel Code: Section IX, Welding and Brazing Qualifications

3. Terminology

3.1 *Definitions:*

3.1.1 *fluid conditioner fitting*—a device, other than a valve or pipe or pipe joining fitting, installed in a pressure piping system, that monitors or provides for the monitoring of the fluid, or otherwise operates on or alters the condition of the fluid.

3.1.2 *maximum allowable working pressure (MAWP)*—the highest internal pressure at the maximum design temperature that the fluid conditioner fitting can be safely subjected to in service.

3.1.3 *maximum design temperature*—the maximum temperature for which the fluid conditioner fitting is rated by the manufacturer.

3.1.4 *multiplex fluid conditioner fitting*—a fluid conditioner fitting that is made up of multiples of a single unit connected by either manifolding, piping, tubes, or valves.

4. Classification

4.1 *Class I*—Fluid conditioner fitting meeting the following requirements:

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[1] This specification is under the jurisdiction of ASTM Committee F-25 on Ships and Marine Technology and is the direct responsibility of Subcommittee F25.13 on Piping Systems.

Current edition approved December 30, 1988. Published February 1989.

[2] *Annual Book of ASTM Standards*, Vol 05.01.

[3] *Annual Book of ASTM Standards*, Vol 01.07.

[4] Available from American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.

[5] Available from Manufacturers Standardization Society of the Valve and Fitting Industry, 1815 N. Forth Myer Dr., Arlington, VA 22209.

[6] Available from American Society of Mechanical Engineers, 345 E. 47th St., New York, NY 10017.

Service	Pressure, psig (MPa)	Temperature, °F (°C)
Liquefied flammable gas	above 150 (1.03) . . . and . . .	above 0 (−18)
Fuels	above 150 (1.03) . . . or . . .	above 150 (66)
Liquids with a flash point[A] 150°F (66°C) or below	above 225 (1.55) . . . or . . .	above 150 (66)
Liquids with a flash point above 150°F (66°C)[B]	above 225 (1.55) . . . or . . .	above 400 (204)
Steam, gases, and vapors	above 150 (1.03) . . . or . . .	above 650 (343)
Water	above 225 (1.55) . . . or . . .	above 350 (177)

[A] Flash point measured in accordance with Test Methods D 93.

[B] Includes lubricating oils, hydraulic fluids, and heat transfer oils.

4.2 *Class II*—All other fluid conditioner fittings.

5. Materials and Manufacture

5.1 Pressure-retaining parts shall be constructed of materials listed in Section VIII, Division 1 of the ASME Boiler and Pressure Vessel Code (hereafter called the ASME Code) or ANSI B31.1. Nonmetallic materials may be used for pressure-retaining parts provided the material is suitable for the intended service and is compatible with the fluid to be conducted.

5.2 Fluid conditioner fittings intended for flammable service with nonmetallic materials or metallic materials having a solidus to liquidus temperature below 1700°F (927°C) shall pass the prototype fire test in 7.2.

5.3 Bolting materials shall be at least equal to those listed in Table 1 of ANSI B16.5 or Table 126.1 of ANSI B31.1. Bolts, screws, and fasteners in contact with interior fluid shall be compatible with the fluid. Carbon steel bolting shall not be used in services rated above 500°F (260°C).

5.4 Gaskets and seals shall be of materials suitable for the intended service.

5.5 The pressure ratings established under this specification are based on materials of high quality produced under regular control of chemical and mechanical properties by a recognized process. The manufacturer shall be prepared to submit a certificate of compliance verifying that his product has been so produced and that it has been manufactured from material whose chemical and mechanical properties are at least equal to the requirements of the appropriate specification.

5.6 For materials not having values of allowable stress tabulated in Section VIII, Division 1 of the ASME Code, allowable stresses shall be determined in accordance with the procedures outlined in Subsection C and Appendix P of that section. Where it can be shown that the values of allowable stress listed for a particular material in one product form (because of similar chemistry, physical properties, heat treatment, and so forth) are applicable to the same material in an unlisted product form, the listed values of allowable stress may be used.

5.7 Cast iron shall be limited to services below 450°F (232°C). Cast iron fittings conforming to B16.1 and B16.4 are limited to Class 125 and 250.

5.8 Users are cautioned to exercise care in the selection of materials, as some fluids may react chemically with some materials used in these products.

6. Other Requirements

6.1 The maximum allowable working pressure (MAWP) of fluid conditioner fittings covered under this specification shall be established by at least one of the following methods:

6.1.1 Proof test in accordance with the requirements prescribed in paragraph UG-101 of Section VIII, Division 1 of the ASME Code. If burst-type tests as outlined in paragraph UG-101(m) are used, it is not necessary to rupture the component. In this case, the value of *B* to be used in determining the MAWP shall be the maximum pressure to which the component was subjected without rupture.

6.1.2 Design calculations in accordance with the requirements prescribed in Section VIII, Division 1 of the ASME Code.

6.2 Where welded construction is used, weld joint design details shall be in accordance with Section VIII, Division 1 of the ASME Code except as noted in 6.3. Supplemental radiography requirements are presented in 7.3. Welders and weld procedures shall be qualified in accordance with Section IX of the ASME Code. Except for fillet welds, all welds shall be full penetration welds extending through the entire thickness of the shell.

6.3 Welds on fluid conditioner fittings greater than 6-in. (152-mm) internal diameter or 1.5-ft^3 (0.042-m^3) net internal volume and rated above 600 psi (4.14 MPa) or 400°F (204°C) shall be of the following types as listed in Table UW-12 of the ASME Code: Type (1) for Category A joints; Types (1) or (2) for Category B joints; and all Category C and D joints shall be full penetration welds extending through the entire thickness of the vessel wall or nozzle wall. Welded joint categories are defined under UW-3 of the ASME Code.

6.4 Post-weld heat treatment shall be in accordance with Section VIII, Division 1, except that fluid conditioner fittings greater than 6-in. (152-mm) internal diameter or 1.5-ft^3 (0.042-m^3) net internal volume, rated above 600 psi (4.14 MPa) or 400°F (204°C), and fabricated of carbon or low alloy steel, shall be post-weld, heat-treated regardless of thickness.

6.5 Inlet and outlet connections consisting of welded flange end fittings shall be in accordance with Specification F 722. Pipe end connections for fluid conditioner fittings shall be in accordance with one of the specifications listed in 2.2 or 2.3. Where radiography is required by 7.3.2, all welded inlet and outlet connections shall be butt-weld joints as required by Specification F 722 for Class 1 piping systems. Threaded inlet and outlet connections shall be in accordance with 6.6.

6.6 Threaded pipe connections shall be limited to the following services:

NPS ¾ in. (20 mm) and below . . . 1500 psig (10.3 MPa) max
NPS 1 in. (25 mm) and below . . . 1200 psig (8.27 MPa) max
NPS 2 in. (50 mm) and below . . . 600 psig (4.14 MPa) max
NPS 3 in. (80 mm) and below . . . 400 psig (2.76 MPa) max

6.7 Threaded pipe joints above nominal pipe size (NPS) 2 (50 mm) shall not be used in systems that require radiographic examination in 7.3.2.

6.8 For multiplex fluid conditioner fittings:

6.8.1 Piping and valves shall be in accordance with ANSI B31.1. Welded joints used in the interconnected piping shall be in accordance with Specification F 722 for equivalent class of pipe.

6.8.2 The maximum valve seat leakage shall not be greater than that allowed by MSS SP-61 or SP-67.

6.8.3 There shall be continuous fluid flow during changeover of the elements.

6.9 For a fluid conditioner fitting requiring cleaning or servicing, its construction shall facilitate cleaning and minimize fluid spillage.

6.10 All performance ratings assigned to a fluid conditioner fitting shall be confirmed by calculations or testing (see 7.4), or both, and certified by the manufacturer.

6.11 If an external protective device is required for the fluid conditioner fitting to pass the fire test in 7.2, the device shall sufficiently encase the fluid conditioner fitting to protect the fitting from a fire when it is installed in its normal position(s).

7. Test Methods

7.1 All fluid conditioner fittings shall be pressure tested by one of the following methods:

7.1.1 Conduct a hydrostatic test at 1½ times the 100°F (37°C) rated MAWP of the fluid conditioner fitting. Perform the test with water or other liquid having a maximum viscosity of 40 SSU at 125°F (52°C) with a maximum pressure test temperature of 125°F (52°C). The minimum duration of the test shall be 15 s for fluid conditioner fittings less than NPS 2 (50 mm), 1 min for fluid conditioner fittings NPS 2½ (63 mm) through 8 (203 mm), and 3 min for larger sizes. The purpose of this test is to detect leaks and structural imperfections. No visible leakage is permitted.

7.1.2 Class II fluid conditioner fittings of NPS 2 (50 mm) and smaller with other than flanged connections may, at the option of the manufacturer, be air tested to the lesser of 1.2 times the MAWP or 80 psig (0.55 MPa). The minimum duration of the test shall be 15 s. Visually detectable leakage is not acceptable.

7.1.2.1 Manufacturers exercising this option shall also certify that a prototype from each production lot of the same size fluid conditioner fitting was subjected to a hydrostatic test in accordance with 7.1.1.

7.2 Test a prototype of a fluid conditioner fitting design that requires a fire test in accordance with 5.2 as follows:

7.2.1 Position the fluid conditioner fitting 9 in. (230 mm) above the top edge of an open pan of heptane large enough to engulf the fluid conditioner fitting completely in the fire. The pan shall conform to the following minimum dimensions:

7.2.1.1 *Depth*, 1½ in. (38 mm).

7.2.1.2 *Width*, twice the width of the fluid conditioner fitting but no less than 8½ in. (220 mm).

7.2.1.3 *Length*, twice the length of the fluid conditioner fitting but no less than 14 in. (360 mm).

7.2.2 Add to the pan sufficient heptane to provide for a 2½-min burn.

7.2.3 Mount thermocouples so as to sense the flame temperature in the same plane and elevation as the fluid conditioner fitting assembly. Pressurize with water the fluid conditioner fitting to its MAWP during the burning portion of the test. Following ignition of the heptane, begin timing and monitor the temperature. The temperature shall reach a minimum of 1200°F (649°C) but shall not exceed 1350°F (732°C). If 1200°F (649°C) is not reached, repeat the test using a new specimen. If 1350°F (732°C) is exceeded, discard the results and repeat the test.

7.2.4 At the end of the 2½-min of fire exposure, extinguish the flame, relieve the pressure, and allow the water to flow through the assembly. With free flow established, pressurize the fluid conditioner fitting to its MAWP and hold for 30 s. Failure to establish a free flow, or any fluid leakage during fire exposure or the subsequent pressure test, shall constitute failure.

7.2.5 Mount in their normally installed position those fluid conditioner fittings that require external protective devices installed to pass the above fire test. Test in each position those fluid conditioner fittings that can be mounted in more than one position. A different fluid conditioner fitting may be used for each test. If it is possible for this protection to be separated from the fluid conditioner fitting body by purchasers or users, mark the body to indicate that this protection is required (see 9.2).

7.2.6 Test only the smallest and largest sizes of a particular fluid conditioner fitting design to certify the design as having passed the above fire test.

NOTE 1—Manufacturers are cautioned that the application of this test can be hazardous. It is recommended that it be performed by a qualified laboratory familiar with the conduct of this type test.

7.3 Inspect all welds as follows:

7.3.1 Visually examine all welds in accordance with ANSI B31.1.

7.3.2 Welded inlet and outlet connections of Class I fluid conditioner fittings, equal to or greater than 4-in. (100-mm) nominal diameter or 0.375-in. (9.5-mm) nominal wall thickness, shall be 100 % radiographically examined in accordance with UW-51 of the ASME Code.

7.3.3 For Class I multiplex fluid conditioner fittings, all butt-welds in interconnected piping greater than 4-in. (100-mm) nominal diameter or 0.375-in. (9.5-mm) nominal wall thickness shall be 100 % radiographically examined in accordance with UW-51 of the ASME Code.

7.3.4 Fluid conditioner fittings greater than 6-in. (152-mm) internal diameter or 1.5-ft^3 (0.042-m^3) net internal volume and rated above 600 psi (4.14 MPa) or 400°F (204°C) shall have all butt-welds fully radiographed in accordance with UW-51 of the ASME Code.

7.4 A prototype of each fluid conditioner fitting having designated performance ratings not confirmed by calculations shall be tested to verify the ratings. The test shall be of the manufacturer's specification practice and shall be suitable for the type, size, and capacity of the fluid conditioner fitting.

7.4.1 Test only that combination of sizes, capacities, and so forth, of a particular fluid conditioner fitting design to certify the ratings of a complete family of a fluid conditioner fitting of the design.

8. Certification

8.1 When specified in the purchase order or contract, the manufacturer's certification shall be furnished to the purchaser stating that samples representing each lot or prototypes have been manufactured, tested, and inspected in accordance with this specification and the requirements have been met. When specified in the purchase order or contract, a report of the test results shall be furnished.

9. Product Marking

9.1 Each fluid conditioner fitting shall have a securely attached name plate or other permanent marking indicating the following:

9.1.1 Manufacturer's name or trademark.

9.1.2 Maximum allowable working pressure and temperature as designed and tested (for example, 150 psi at 150°F).

9.1.3 Size (end connection NPS).

9.1.4 ASTM designation number of this specification.

9.1.5 Direction of flow (by an arrow or the word "inlet," "outlet," or both).

9.1.6 If radiographed in accordance with 7.3, an "X" shall be placed after the ASTM designation number.

9.2 If a removable protective device is installed to pass the fire test of 7.2.5, an "S" shall be placed after the ASTM designation number.

10. Quality Assurance

10.1 The fluid conditioner fitting manufacturer shall maintain the quality of the fluid conditioner fittings that are designed, tested, and marked in accordance with this specification. At no time shall a fluid conditioner fitting be sold indicating that it meets the requirements of this specification if it does not meet the requirements herein.

11. Keywords

11.1 fluid conditioner fittings; piping applications; pressure-retaining components

CERTIFICATE

By Authority Of
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By the Authority Vested By Part 5 of the United States Code § 552(a) and Part 1 of the Code of Regulations § 51 the attached document has been duly INCORPORATED BY REFERENCE and shall be considered legally binding upon all citizens and residents of the United States of America. *HEED THIS NOTICE*: Criminal penalties may apply for noncompliance.

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Document Name: ASTM F1271: Standard Specification for Spill Valves for Use in Marine Tank Liquid Overpressure Protection Applications

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An American National Standard

Standard Specification for Spill Valves for Use in Marine Tank Liquid Overpressure Protections Applications[1]

This standard is issued under the fixed designation F 1271; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

$^{\epsilon 1}$ NOTE—Section 13 was added editorially in December 1995.

1. Scope

1.1 This specification provides the minimum requirements for design, construction, performance, and testing of devices to prevent marine tank liquid overpressurization (hereafter called spill valves).

1.2 The spill valves provided in accordance with this specification will satisfy Regulation II-2/59.1.6 of the 1981 and 1983 Amendments to the International Convention for the Safety of Life at Sea, 1974 (SOLAS), which states: "Provision shall be made to guard against liquid rising in the venting system to a height which would exceed the design head of the cargo tank. This shall be accomplished by high level alarms or overflow control systems or other equivalent means, together with gaging devices and cargo tank filling procedures."

1.3 The spill valves are not intended for the venting of vapors or the relief of vapor overpressurization or underpressurization of marine tanks.

1.4 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

1.5 The following precautionary caveat pertains only to the test methods portion, Section 8, of this specification: *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

B 117 Test Method of Salt Spray (Fog) Testing[2]

F 722 Specification for Welded Joints for Shipboard Piping Systems[3]

2.2 *ANSI Standards:*[4]

B2.1 Pipe Threads

B16.1 Cast Iron Pipe Flanges and Flanged Fittings

B16.3 Malleable Iron Threaded Fittings

B16.4 Cast Iron Threaded Fittings

B16.5 Steel Pipe Flanges and Flanged Fittings

B16.11 Forged Steel Fittings, Socket-Welding and Threaded

B16.15 Cast Bronze Threaded Fittings

B16.24 Bronze Pipe Flanges and Flanged Fittings

B31.1 Power Piping

2.3 *Other Documents:*

ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, Pressure Vessels; Section IX, Welding and Brazing Qualifications[5]

Safety for Life at Sea Convention, Regulation II-2/59.1.6, Amendments 1981 and 1983[4]

46 CFR 153 Ships Carrying Bulk Liquid, Liquified Gas, or Compressed Gas Hazardous Materials[6]

3. Terminology

3.1 *Definition:*

3.1.1 *spill valve*—an independent device that automatically prevents liquid overpressurization of a tank by relieving liquid at a predetermined pressure set higher than the pressure reached in the tank when the tank vapor relieving device operates at its maximum design venting rate (based on a volumetric vapor volume 1.25 times the maximum design loading rate).

4. Ordering Information

4.1 Orders for spill valves in accordance with this specification shall include the following information, as applicable:

4.1.1 Nominal pipe size and end connections,

4.1.2 Product(s) in tank being protected by the spill valve,

4.1.3 Inspection and tests other than specified by this specification,

4.1.4 Required relieving pressure at maximum tank loading flow rate,

4.1.5 Set (opening) pressure,

4.1.6 Maximum tank design loading flow rate,

4.1.7 Inlet pressure drop resulting from the maximum tank design loading flow rate,

4.1.8 Back pressure of the spill valve discharge lines resulting from maximum tank design loading flow rate,

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[1] This specification is under the jurisdiction of ASTM Committee F-25 on Shipbuilding and is the direct responsibility of Subcommittee F25.13 on Piping Systems.

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[2] *Annual Book of ASTM Standards*, Vol 03.02.

[3] *Annual Book of ASTM Standards*, Vol 01.07.

[4] Available from American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.

[5] Available from the American Society of Mechanical Engineers, 345 E. 47th St., New York, NY 10017.

[6] Available from Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402.

4.1.9 Purchaser's inspection requirements (see 9.1),

4.1.10 Installation inclinations in excess of 2½° (see 6.6),

4.1.11 Purchaser's specifications for preventing the valve from leaking due to cargo sloshing, and

4.1.12 Additional requirements or testing as contracted by the manufacturer and the purchaser.

5. Materials

5.1 Materials of construction shall be suitable for the service intended and resistant to the attack by the liquid carried in the tank being protected (see 4.1.2). Table I of 46 CFR 153 specifies materials that may not be used in components that contact liquid or vapor of each hazardous liquid cargo.

5.2 Housings of spill valves, and all other parts or bolting, or both, used for pressure retention, shall be constructed of materials having a solidus melting point of greater than 1700°F (927°C) and be listed in ANSI B31.1 or Section VIII, Division 1 of the ASME Boiler and Pressure Vessel Code, except as noted in 5.5.

5.3 Corrosion-resistant materials shall be used for the following:

5.3.1 Housings, disks, spindles, and seats of valves.

5.3.2 Springs that actuate disks of valves. Springs plated with corrosion-resistant material are not acceptable.

5.4 Nonmetallic materials shall not be permitted except for gaskets, seals, bushings in way of moving parts, and valve diaphragms.

5.5 Bolting materials shall be at least equal to those listed in Table 1 of ANSI B16.5. Bolts, screws, and fasteners in contact with interior liquid shall be compatible with the liquid (see 4.1.2).

6. Other Requirements

6.1 Pressure-retaining housings shall be designed to withstand a hydrostatic pressure of at least 125 lb/in.^{2} (8.78 kg/cm^2) without rupturing or showing permanent distortion.

6.2 Housing shall have suitable pipe connections for the removal, maintenance, and testing of the spill valve.

6.2.1 Threaded or flanged pipe end connections shall comply with the applicable B 16 ANSI standards listed in 2.2 or as agreed upon by the manufacturer and the purchaser (see 4.1.12). Welded joints shall comply with Specification F 722.

6.3 The design of spill valves shall allow for ease of inspection and removal of internal elements for replacement, cleaning, or repair without removal of the spill valve.

6.4 All flat joints of the housing shall be machined true and shall provide for a joint having adequate metal-to-metal contact.

6.5 Where welded construction is used, welded joint design details, welding, and nondestructive testing shall be in accordance with Section VIII, Division 1 of the ASME Code and Specification F 722. Welders and weld procedures shall be qualified in accordance with Section IX of the ASME Code.

6.6 The spill valve shall be fully operable at static inclinations up to 2½° unless otherwise specified by the ordering information in Section 4.

6.7 Spill valves shall allow for efficient drainage of moisture without impairing their proper operation.

6.7.1 Where the design does not permit complete drainage of condensate through its connection to the tank, the housing shall be fitted with a plugged drain opening on the side of the atmospheric outlet of not less than nominal pipe size ½ in. (12 mm).

6.8 Housing, elements, and seal gasket materials shall be capable of withstanding the highest pressure and temperature to which the spill valve may be exposed under normal conditions.

6.9 Spill valves shall be vapor tight at pressures below the rated liquid relieving pressure.

6.10 Fastenings essential to the operation of the spill valve shall be protected against loosening.

6.11 Spill valves shall be designed and constructed to minimize the effect of fouling under normal conditions.

6.12 The spill valve shall not be provided with a means of positive closure. In installations where cargo sloshing is expected, the spill valve installation must be designed to preclude premature opening of the valve due to cargo sloshing. Also, the installation shall be designed so that it complies with applicable loadline and subdivision requirements.

6.13 Spill valves shall be capable of operating in freezing conditions.

6.14 Each of the free areas through the valve seat and through the valve discharge at maximum lift shall not be less than the cross-sectional area of the valve inlet connection.

6.15 Means shall be provided to check that any valve opens freely and does not remain lodged in the open position.

6.16 *Valve Disks:*

6.16.1 Valve disks shall be guided by a ribbed cage or other suitable means to prevent binding and ensure proper seating. Where valve stems are guided by bushings suitably designed to prevent binding and to ensure proper seating, the valves need not be fitted with ribbed cages.

6.16.2 Valve disks shall close tight against the valve seat by metal to metal contact; however, resilient seating seals may be provided if the design is such that the disk closes tight against the seat in case the seals are destroyed or in case they carry away.

6.16.3 Valve disks may be solid or hollow. The pressure at which the valve disks open fully at maximum flow rating shall not exceed 120 % of the set (opening) pressure.

6.17 Valves may be actuated by nonmetallic diaphragms.

6.17.1 Nonmetallic diaphragms are not allowed where failure results in unrestricted flow of flammable or toxic tank vapors to the atmosphere or in an increase in the pressure at which the valve normally releases.

6.18 Relief pressure adjusting mechanisms shall be permanently secured by lockwire, locknuts, or other suitable means.

6.18.1 Hollow portions of the valve used to vary the relieving pressure by adding or removing weight shall be watertight.

6.1.19 Spill valves shall not permit entrance of water when exposed to boarding seas.

7. Workmanship, Finish, and Appearance

7.1 Spill valves shall be of first class workmanship and free from imperfections that may affect their intended purpose.

7.2 Each finished spill valve shall be visually and dimensionally checked to ensure that the spill valve corresponds to this specification, is certified in accordance with Section 10, and is marked in accordance with Section 11.

8. Test Methods

8.1 *Prototype Tests:*

8.1.1 A prototype of the largest and smallest spill valve of each design, based on valve inlet connection size, shall be tested as specified in 8.1.5, 8.1.6, and 8.1.8 through 8.1.10. Additionally, all models shall be tested as specified in 8.1.7.

8.1.2 The spill valve shall have the dimensions of and most unfavorable clearances expected in production units.

8.1.3 Tests shall be conducted by a laboratory capable of performing the tests.

8.1.4 A test report shall be prepared by the laboratory that shall include:

8.1.4.1 Detailed drawings of the spill valve,

8.1.4.2 Types of tests conducted and results obtained,

8.1.4.3 Specific advice on approved attachments,

8.1.4.4 Types of liquid for which the spill valve is approved,

8.1.4.5 Drawings of the test rig,

8.1.4.6 The pressures at which the spill valve opens and closes and the efflux flow rate at various inlet pressures,

8.1.4.7 Records of all markings found on the prototype spill valve, and

8.1.4.8 A traceable report number.

8.1.5 *Corrosion Test*—A corrosion test shall be conducted in accordance with Test Method B 117. The valve shall be subjected to the test for a period of 240 h and allowed to dry for 48 h. There shall be no corrosion deposits that cannot be washed off.

8.1.6 *Hydrostatic Test*—A hydrostatic pressure test shall be conducted to show compliance with 6.1. The test shall be made with water or other liquid having a maximum viscosity of 40 SSU at 125°F (52°C) with a maximum pressure test temperature of 125°F (52°C). The minimum duration of the test shall be 1 min.

8.1.7 *Performance Tests*—Performance characteristics, including flow rates under various positive pressures, operating sensitivity, flow resistance, and velocity, shall be demonstrated by appropriate tests with a representative fluid.

8.1.8 *Freeze Test*—Simulate water sloshing on deck by spraying a prototype spill valve completely with water from all sides and below using a fully pressurized fire hose. Allow 3 min to drain off. Immediately immerse it in a freeze chamber prechilled to 20°F (−7°C). Hold it in a chamber for 2 h at this temperature. Immediately test the valve as in 8.1.7 to determine opening pressure while frozen. The unit passes the test if it opens within 10 % of its previously measured set (opening) pressure.

8.1.9 *Vapor Tightness Test*—Compliance with 6.9 shall be demonstrated by testing the spill valve with compressed air at 90 % of the spill valve set (opening) pressure. The test apparatus shall have a total volume of air (in cubic feet) equal to $5 \times D$, where D is the seat diameter of the spill valve, in inches (test volume may vary by ±10 %). The valve design shall be deemed satisfactory if the air leakage rate is such that the pressure drop is not more than 2 % in 2 h.

8.1.10 *Seaworthiness Test*—In a simulated installation, immerse the spill valve such that the seal is under 2 ft of water, minimum. Spray it for 10 min with a 2½-in. fire hose with a fully open ⅞-in. diameter nozzle at a pitot pressure of 80 psig measured at the open nozzle. Spray all parts of the valve, both immersed and non-immersed, from all angles. The hose nozzle shall not be located further than 10 ft from the spill valve during the course of this test. The valve design is sufficient if leakage through the housing or past the disk, or both, is no more than 1 oz.

8.1.11 After completion of all tests the device shall be disassembled and examined and no part of the device shall be damaged or show permanent deformation.

8.2 *Production Tests:*

8.2.1 Each finished spill valve is to be tested by a hydrostatic test conducted at 1½ times the rated relieving pressure of the spill valve, with the device secured closed. The test shall be made with water or other liquid having a maximum viscosity of 40 SSU at 125°F (52°C) with a maximum pressure test temperature of 125°F (52°C). The minimum duration of the test shall be 1 min. The purpose of this test is to detect leaks and structural imperfections. No visible leakage is permitted.

8.2.2 Before being shipped, each unit shall be tested as necessary to verify that it will function at its set (opening) pressure and that the disk moves freely and fully.

9. Inspection

9.1 The manufacturer shall afford the purchaser's inspector all reasonable facilities necessary to satisfy him that the material is being furnished in accordance with this specification. Inspection by the purchaser shall not interfere unnecessarily with the manufacturer's operations. All examinations and inspections shall be made at the place of manufacture, unless otherwise agreed upon.

10. Certification

10.1 Manufacturer's certification that a spill valve has been constructed in accordance with this specification shall be provided in an instruction manual. The manual shall include the following:

10.1.1 Installation instructions, including size of the inlet and outlet, approved location for installation, and maximum or minimum length of pipe, if any, between the spill valve and the atmosphere,

10.1.2 Operating instructions,

10.1.3 Maintenance requirements,

10.1.3.1 Instructions on how to determine when spill valve cleaning is required and the method of cleaning,

10.1.4 Copy of prototype test report (see 8.1), and

10.1.5 Product(s) that the valve is designed for or restricted to, or both.

11. Product Marking

11.1 Each spill valve shall be permanently marked indicating the following:

11.1.1 Manufacturer's name or trademark,

11.1.2 Style, type, model, or other manufacturer's designation for the spill valve,

11.1.3 Direction of flow through the spill valve,

11.1.4 Maximum rated flow,
11.1.5 ASTM designation of this specification,
11.1.6 Relief pressure setting at full flow rating,
11.1.7 Set (opening) pressure, and
11.1.8 Indication of proper orientation of valve, if critical.

12. Quality Assurance

12.1 Spill valves shall be designed, manufactured, and tested in a manner that ensures they meet the characteristics of the prototype tested in accordance with this specification.

12.2 The spill valve manufacturer shall maintain the quality of the spill valves that are designed, tested, and marked in accordance with this specification. At no time shall a spill valve be sold with this specification designation that does not meet the requirements herein.

13. Keywords

13.1 marine technology; overflow control systems; overpressurization; overpressure protection; ships; spill valves

CERTIFICATE

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An American National Standard

Standard Specification for Tank Vent Flame Arresters[1]

This standard is issued under the fixed designation F 1273; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

$^{\epsilon 1}$ NOTE—Keywords were added editorially in November 1996.

1. Scope

1.1 This specification provides the minimum requirements for design, construction, performance, and testing of tank vent flame arresters.

1.2 This specification is intended for flame arresters protecting systems containing vapors of flammable or combustible liquids where vapor temperatures do not exceed 60°C. The test media defined in 9.1.1 can be used except where arresters protect systems handling vapors with a maximum experimental safe gap (MESG) below 0.9 mm. Flame arresters protecting such systems must be tested with appropriate media (the same vapor or a media having a MESG no greater than the vapor). Various gases and their respective MESG are listed in Table 1.

NOTE 1—Flame arresters meeting this specification also comply with the minimum requirements of the International Maritime Organization, Maritime Safety Committee Circular No. 373 (MSC/Circ. 373/Rev. 1).

1.3 The values stated in either inch-pound or SI units are to be regarded as the standard. The values given in parentheses are for information only.

1.4 The following precautionary caveat pertains only to the test methods portions, Sections 8 and 9, of this specification: *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

1.5 *This standard should be used to measure and describe the properties of materials, products, or assemblies in response to heat and flame under controlled laboratory conditions and should not be used to describe or appraise the fire hazard or fire risk of materials, products, or assemblies under actual fire conditions. However, results of this test may be used as elements of a fire risk assessment which takes into account all of the factors which are pertinent to an assessment of the fire hazard of a particular end use.*

2. Referenced Documents

2.1 *ASTM Standards:*

F 722 Specification for Welded Joints for Shipboard Piping Systems[2]

F 1155 Practice for Selection and Application of Piping System Materials[2]

2.2 *ANSI Standard:*

B16.5 Pipe Flanges and Flanged Fittings[3]

2.3 *Other Documents:*

ASME Boiler and Pressure Vessel Code:

Section VIII, Division 1, Pressure Vessels;

Section IX, Welding and Brazing Qualifications[4]

International Maritime Organization, Maritime Safety Committee:

MSC/Circ. 373/Rev. 1–Revised Standards for the Design, Testing and Locating of Devices to Prevent the Passage of Flame into Cargo Tanks in Tankers[5]

International Electrotechnical Commission:

Publication 79-1–Electrical Apparatus for Explosive Gas Atmospheres[6]

3. Terminology

3.1 *Definitions:*

3.1.1 *flame arrester*—a device to prevent the passage of flame in accordance with a specified performance standard. Its flame arresting element is based on the principle of quenching.

3.1.2 *flame passage*—the transmission of a flame through a flame arrester.

3.1.3 *flame speed*—the speed at which a flame propagates along a pipe or other system.

3.1.4 *gasoline vapors*—a non-leaded petroleum distillate consisting essentially of aliphatic hydrocarbon compounds with a boiling range of approximately 65 to 75°C.

4. Classification

4.1 The two types of flame arresters covered in this specification are classified as follows:

4.1.1 *Type I*—Flame arresters acceptable for end-of-line applications.

4.1.2 *Type II*—Flame arresters acceptable for in-line applications.

5. Ordering Information

5.1 Orders for flame arresters under this specification shall

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[1] This specification is under the jurisdiction of ASTM Committee F-25 on Ships and Marine Technology and is the direct responsibility of Subcommittee F25.13 on Piping Systems.

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[2] *Annual Book of ASTM Standards*, Vol 01.07.

[3] Available from American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.

[4] Available from American Society of Mechanical Engineers, 345 E. 47th St., New York, NY 10017.

[5] Available from International Maritime Organization, 4 Albert Embankment, London SE1 7SR, England.

[6] Available from International Electrotechnical Commission, 1 rue de Varembe, Geneva, Switzerland.

TABLE 1 Gases and Their MESGs

Inflammable Gas or Vapor	Maximum Experimental Safe Gap	
	mm	in.
Methane	1.170	0.046
Blast furnace gas	1.193	0.047
Propane	0.965	0.038
Butane	1.066	0.042
Pentane	1.016	0.040
Hexane	0.965	0.038
Heptane	0.965	0.038
Iso-octane	1.040	0.041
Decane	1.016	0.040
Benzene	0.99	0.039
Xylene	1.066	0.042
Cyclohexane	0.94	0.037
Acetone	1.016	0.040
Ethylene	0.71	0.028
Methyl-ethyl-ketone	1.016	0.040
Carbon monoxide	0.915	0.036
Methyl-acetate	0.990	0.039
Ethyl-acetate	1.04	0.041
Propyl-acetate	1.04	0.041
Butyl-acetate	1.016	0.040
Amyl-acetate	0.99	0.039
Methyl alcohol	0.915	0.036
Ethyl alcohol	1.016	0.040
Iso-butyl-alcohol	0.965	0.038
Butyl-alcohol (Normal)	0.94	0.037
Amyl-alcohol	0.99	0.039
Ethyl-ether	0.864	0.034
Coal gas (H_2 57 %)	0.482	0.019
Acetylene	<0.025	<0.001
Carbon disulphide	0.203	0.008
Hydrogen	0.102	0.004
Blue water gas (H_2 53 % CO 47 %)	0.203	0.008
Ethyl nitrate	<0.025	<0.001
Ammonia	3.33	0.133
Ethylene oxide	~0.65	~0.026
Ethyl nitrite	0.922	0.038

include the following information, as applicable:

5.1.1 Type (I or II),

5.1.2 Nominal pipe size,

5.1.3 Each gas or vapor in the tank being protected by the flame arrester and the corresponding MESG,

5.1.4 Inspection and tests other than those specified by this specification,

5.1.5 Anticipated ambient air temperature range,

5.1.6 Purchaser's inspection requirements (see 10.1),

5.1.7 Description of installation (distance and configuration of pipe between the arrester and the atmosphere or potential ignition source) (see 8.2.4.2),

5.1.8 Materials of construction (see Section 6), and

5.1.9 Maximum flow rate and the design pressure drop for that maximum flow rate.

6. Materials

6.1 The flame arrester housing, and other parts or bolting used for pressure retention, shall be constructed of materials listed in Practice F 1155, or Section VIII, Division 1 of the ASME Boiler and Pressure Vessel Code.

6.1.1 Arrester, elements, gaskets, and seals shall be of materials resistant to attack by seawater and the liquids and vapors contained in the tank being protected (see 5.1.3).

6.2 Nonmetallic materials, other than gaskets and seals, shall not be used in the construction of pressure-retaining components of the flame arrester.

6.2.1 Nonmetallic gaskets and seals shall be noncombustible and suitable for the service intended.

6.3 Bolting materials, other than those in 6.1, shall be at least equal to those listed in Table 1 of ANSI B16.5.

6.4 The possibility of galvanic corrosion shall be considered in the selection of materials.

6.5 All other parts shall be constructed of materials suitable for the service intended.

7. Other Requirements

7.1 Flame arrester housings shall be gas tight to prevent the escape of vapors.

7.2 Flame arrester elements shall fit in the housing in a manner that will ensure tightness of metal-to-metal contacts in such a way that flame cannot pass between the element and the housing.

7.2.1 The net free area through flame arrester elements shall be at least 1.5 times the cross-sectional area of the arrester inlet.

7.3 Housings and elements shall be of substantial construction and designed for the mechanical and other loads intended during service. In addition, they shall be capable of withstanding the maximum and minimum pressures and temperatures to which the device may be exposed under both normal and the specified fire test conditions in Section 9.

7.4 Threaded or flanged pipe connections shall comply with the applicable B16 standards in Practice F 1155. Welded joints shall comply with Specification F 722.

7.5 All flat joints of the housing shall be machined true and shall provide for a joint having adequate metal-to-metal contact.

7.6 Where welded construction is used for pressure-retaining components, welded joint design details, welding, and nondestructive testing shall be in accordance with Section VIII, Division 1 of the ASME Code and Specification F 722. Welders and weld procedures shall be qualified in accordance with Section IX of the ASME Code.

7.7 The design of flame arresters shall allow for ease of inspection and removal of internal elements for replacement, cleaning, or repair without removal of the entire device from the system.

7.8 Flame arresters shall allow for efficient drainage of condensate without impairing their efficiency to prevent the passage of flame.

7.8.1 Where the design does not permit complete drainage of condensate through its connection to the tank, the housing shall be fitted with a plugged drain opening on the side of the atmospheric outlet of not less than ½ in. nominal pipe size (NPS ½).

7.9 All fastenings shall be protected against loosening.

7.10 Flame arresters shall be designed and constructed to minimize the effect of fouling under normal operating conditions.

7.11 Flame arresters shall be capable of operating over the full range of ambient air temperatures anticipated.

7.12 End-of-line flame arresters shall be so constructed as to direct the efflux vertically upward.

7.13 Flame arresters shall be of first class workmanship and free from imperfections that may affect their intended purpose.

7.14 Tank vent flame arresters shall show no flame passage when subjected to the tests in 8.2.4.

8. Prototype Tests

8.1 Tests shall be conducted by an independent laboratory capable of performing the tests. The manufacturer, in choosing a laboratory, accepts that it is a qualified independent laboratory by determining that it has (or has access to) the apparatus, facilities, personnel, and calibrated instruments that are necessary to test flame arresters in accordance with this specification.

8.1.1 A test report shall be prepared by the laboratory that shall include the following:

8.1.1.1 Detailed drawings of the flame arrester and its components (including a parts list identifying the materials of construction).

8.1.1.2 Types of tests conducted and results obtained,

8.1.1.3 Specific advice on approved attachments (see 8.2.4.1),

8.1.1.4 Types of gases or vapors for which the flame arrester is approved (see 5.1.3),

8.1.1.5 Drawings of the test rig,

8.1.1.6 Records of all markings found on the tested flame arrester, and

8.1.1.7 A report number.

8.2 One of each model Type I and Type II flame arrester shall be tested. Where approval of more than one size of a flame arrester model is desired, the largest and smallest sizes shall be tested. A change of design, material, or construction that may affect the corrosion resistance, endurance burn, or flashback capabilities of the flame arrester shall be considered a change of model.

8.2.1 The flame arrester shall have the same dimensions, configuration, and the most unfavorable clearances expected in production units.

8.2.2 A corrosion test shall be conducted. In this test, a complete arrester, including a section of pipe similar to that to which it will be fitted, shall be exposed to a 20 % sodium chloride solution spray at a temperature of 25°C for a period of 240 h and allowed to dry for 48 h. Following this exposure, all movable parts shall operate properly and there shall be no corrosion deposits that cannot be washed off.

8.2.3 Performance characteristics as declared by the manufacturer, such as flow rates under both positive and negative pressure, operating sensitivity, flow resistance, and velocity, shall be demonstrated by appropriate tests.

8.2.4 Tank vent flame arresters shall be tested for endurance burn and flashback in accordance with the test procedures in Section 9. The following constraints apply:

8.2.4.1 Where a Type I flame arrester is provided with cowls, weather hoods, deflectors, etc., it shall be tested in each configuration in which it is provided.

8.2.4.2 Type II arresters shall be specifically tested with the inclusion of all pipes, tees, bends, cowls, weather hoods, etc., which may be fitted between the arrester and the atmosphere.

8.2.5 Devices that are provided with a heating arrangement shall pass the required tests at the heated temperature.

8.2.6 After all tests are completed, the device shall be disassembled and examined, and no part of the device shall be damaged or show permanent deformation.

9. Test Procedures for Flame Arresters

9.1 *Media/Air Mixtures:*

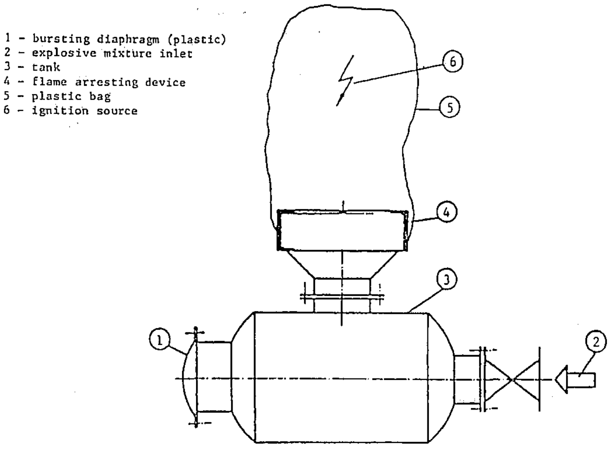

FIG. 1 Test Rig for Flash Back Test

9.1.1 For vapors from flammable or combustible liquids with a MESG greater than or equal to 0.9 mm, technical grade hexane or gasoline vapors shall be used for all tests in this section, except technical grade propane may be used for the flashback test in 9.2. For vapors with a MESG less than 0.9 mm, the specific vapor (or alternatively, a media with a MESG less than or equal to the MESG of the vapor) shall be used as the test medium in all Section 9 tests.

9.1.2 Hexane, propane, gasoline, and chemical vapors shall be mixed with air to form the most easily ignitable mixture.[7]

9.2 *Flashback Test:*

9.2.1 A flashback test shall be carried out as follows:

9.2.1.1 The test rig shall consist of an apparatus producing an explosive mixture, a small tank with a diaphragm, a prototype of the flame arrester, a plastic bag,[8] and a firing source in three positions (see Fig. 1).[9]

9.2.1.2 The tank, flame arrester assembly, and plastic bag enveloping the prototype flame arrester shall be filled so that this volume contains the most easily ignitable vapor/air mixture.[7] The concentration of the mixture should be verified by appropriate testing of the gas composition in the plastic bag. Three ignition sources shall be installed along the axis of the bag, one close to the flame arrester, another as far away as possible therefrom, and the third at the midpoint between these two. These three sources shall be fired in succession, one during each of the three tests. Flame passage shall not occur during this test.

9.2.1.3 If flame passage occurs, the tank diaphragm will burst and this will be audible and visible to the operator by the emission of a flame. Flame, heat, and pressure sensors may be used as an alternative to a bursting diaphragm.

9.3 *Endurance Burn Test:*

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[7] See IEC Publication 79-1.

[8] The dimensions of the plastic bag are dependent on those of the flame arrester. The plastic bag may have a circumference of 2 m, a length of 2.5 m, and a wall thickness of 0.05 m.

[9] In order to prevent remnants of the plastic bag from falling back onto the flame arrester being tested after ignition of the fuel/air mixture, it may be useful to mount a coarse wire frame across the flame arrester within the plastic bag. The frame should be constructed so as not to interfere with the test result.

9.3.1 An endurance burning test shall be carried out as follows:

9.3.1.1 The test rig referred to in 9.2.1.1 may be used, without the plastic bag. The flame arrester shall be so installed that the mixture emission is vertical. The mixture shall be ignited in this position.

9.3.1.2 Endurance burning shall be achieved by using the most easily ignitable test vapor/air mixture with the aid of a pilot flame or a spark igniter at the outlet. By varying the proportions of the flammable mixture and the flow rate, the arrester shall be heated until the highest obtainable temperature on the cargo tank side of the arrester is reached. The highest attainable temperature may be considered to have been reached when the rate of temperature increase does not exceed 0.5°C per minute over a 10 min period. This temperature shall be maintained for a period of 10 min, after which the flow shall be stopped and the conditions observed. If difficulty arises in establishing the highest attainable temperature, the following criteria shall apply. When the temperature appears to be approaching the maximum temperature, using the most severe conditions of flammable mixtures and flow rate, but increases at a rate in excess of 0.5°C per minute over a 10 min period, endurance burning shall be continued for a period of 2 h, after which the flow shall be stopped and the conditions observed. Flame passage shall not occur during this test.

10. Inspection

10.1 The manufacturer shall afford the purchaser's inspector all reasonable facilities necessary to ensure that the material is being furnished in accordance with this specification. All examinations and inspections shall be made at the place of manufacture, unless otherwise agreed upon.

10.2 Each finished flame arrester shall be visually and dimensionally checked to ensure that the device corresponds to this specification, is certified in accordance with Section 11, and is marked in accordance with Section 12. Special attention shall be given to checking the proper fit-up of joints (see 7.5 and 7.6).

11. Certification

11.1 Manufacturer's certification that a flame arrester has been constructed in accordance with this specification shall be provided in an instruction manual. The manual shall include the following, as applicable:

11.1.1 Installation instructions and a description of all configurations tested (see 8.2.4.1 and 8.2.4.2). Installation instructions to include manufacturer's recommended limitations based on all configurations tested.

11.1.2 Operating instructions.

11.1.3 Maintenance requirements.

11.1.3.1 Instructions on how to determine when flame arrester cleaning is required and the method of cleaning.

11.1.4 Copy of the test report (see 8.1.1).

11.1.5 Flow test data, including flow rates under both positive and negative pressures, operating sensitivity, flow resistance, and velocity.

11.1.6 The ambient air temperature range over which the device will effectively prevent the passage of flame.

NOTE 2—Other factors such as condensation and freezing of vapors should be evaluated at the time of equipment specification.

12. Product Marking

12.1 Each flame arrester shall be permanently marked indicating:

12.1.1 Manufacturer's name or trademark,

12.1.2 Style, type, model, or other manufacturer's designation for the flame arrester,

12.1.3 Size of the inlet and outlet,

12.1.4 Type of device (Type I or II),

12.1.5 Direction of flow through the flame arrester,

12.1.6 Test laboratory and report number,

12.1.7 Lowest MESG of gases for which the flame arrester is suitable,

12.1.8 Ambient air operating temperature range, and

12.1.9 ASTM designation F 1273.

13. Quality Assurance

13.1 Flame arresters shall be designed, manufactured, and tested in a manner that ensures they meet the characteristics of the unit tested in accordance with this specification.

13.2 The flame arrester manufacturer shall maintain the quality of the flame arresters that are designed, tested, and marked in accordance with this specification. At no time shall a flame arrester be sold with designation number F 1273 that does not meet the requirements herein.

14. Keywords

14.1 combustible liquid; flame arrester; flammable liquid; marine technology; ships; tank vent; tank vent flame arrester

CERTIFICATE

By Authority Of
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Legally Binding Document

By the Authority Vested By Part 5 of the United States Code § 552(a) and Part 1 of the Code of Regulations § 51 the attached document has been duly INCORPORATED BY REFERENCE and shall be considered legally binding upon all citizens and residents of the United States of America. *HEED THIS NOTICE*: Criminal penalties may apply for noncompliance.

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Standard Guide for Conducting a Stability Test (Lightweight Survey and Inclining Experiment) to Determine the Light Ship Displacement and Centers of Gravity of a Vessel[1]

This standard is issued under the fixed designation F 1321; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

INTRODUCTION

This guide provides the marine industry with a basic understanding of the various aspects of a stability test. It contains procedures for conducting a stability test in order to ensure that valid results are obtained with maximum precision at a minimal cost to owners, shipyards, and the government. This guide is not intended to instruct a person in the actual calculation of the light ship displacement and centers of gravity, but rather to be a guide to the necessary procedures to be followed to gather accurate data for use in the calculation of the light ship characteristics. A complete understanding of the correct procedures used to perform a stability test is imperative in order to ensure that the test is conducted properly and so that results can be examined for accuracy as the inclining experiment is conducted. It is recommended that these procedures be used on all vessels and marine craft.

1. Scope

1.1 This guide covers the determination of a vessel's light ship characteristics. The stability test can be considered to be two separate tasks; the lightweight survey and the inclining experiment. The stability test is required for most vessels upon their completion and after major conversions. It is normally conducted inshore in calm weather conditions and usually requires the vessel be taken out of service to prepare for and conduct the stability test. The three light ship characteristics determined from the stability test for conventional (symmetrical) ships are displacement (displ), longitudinal center of gravity (LCG), and the vertical center of gravity (KG). The transverse center of gravity (TCG) may also be determined for mobile offshore drilling units (MODUs) and other vessels which are asymmetrical about the centerline or whose internal arrangement or outfitting is such that an inherent list may develop from off-center weight. Because of their nature, other special considerations not specifically addressed in this guide may be necessary for some MODUs.

1.2 *This standard does not purport to address the safety problems, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Terminology

2.1 *Definitions:*

2.1.1 *inclining experiment*—involves moving a series of known weights, normally in the transverse direction, and then measuring the resulting change in the equilibrium heel angle of the vessel. By using this information and applying basic naval architecture principles, the vessel's vertical center of gravity (KG) is determined.

2.1.2 *light ship*—a vessel in the light ship condition (Condition I) is a vessel complete in all respects, but without consumables, stores, cargo, crew and effects, and without any liquids on board except that machinery fluids, such as lubricants and hydraulics, are at operating levels.

2.1.3 *lightweight survey*—this task involves taking an audit of all items which must be added, deducted, or relocated on the vessel at the time of the stability test so that the observed condition of the vessel can be adjusted to the light ship condition. The weight, longitudinal, transverse and vertical location of each item must be accurately determined and recorded. Using this information, the static waterline of the ship at the time of the stability test as determined from measuring the freeboard or verified draft marks of the vessel, the vessel's hydrostatic data, and the sea water density; the light ship displacement and longitudinal center of gravity can be obtained. The transverse center of gravity may also be calculated, if necessary.

3. Significance and Use

3.1 From the light ship characteristics one is able to calculate the stability characteristics of the vessel for all conditions of loading, and thereby determine whether the vessel satisfies the applicable stability criteria. Accurate results from a stability test may in some cases determine the future survival of the vessel and its crew, so the accuracy with which the test is conducted cannot be overemphasized. The condition of the vessel and the environment during the test is rarely ideal and consequently, the stability test is infrequently conducted exactly as planned. If the vessel isn't 100 % complete, the weather isn't perfect, there ends up being water or shipyard trash in a tank that was supposed to

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[1] This guide is under the jurisdiction of ASTM Committee F-25 on Shipbuilding and is the direct responsibility of Subcommittee F25.01 on Structures.

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be clean and dry, etc., then the person in charge must make immediate decisions as to the acceptability of variances from the plan. A complete understanding of the principles behind the stability test and a knowledge of the factors which affect the results is necessary.

4. Theory

4.1 *The Metacenter*—(See Fig. 1). The transverse metacenter (*M*) is based on the hull form of a vessel and is the point around which the vessel's center of buoyancy (*B*) swings for small angles of inclination (0 to 4° unless there are abrupt changes in the shape of the hull). The location of *B* is fixed for any draft, trim and heel, but it shifts appreciably as heel increases. The location of *B* shifts off the centerline for small angles of inclination, but its height above the molded keel (*K*) will stay essentially the same. The location of *M*, on the other hand, is essentially fixed over a range of heeling angles up to about 4°, as the ship is inclined at constant displacement and trim. The height of *M* above *K*, known as *KM*, is often plotted versus draft as one of the vessel's curves of form. If the difference from the design trim of the vessel is less than 1 % of its length, the *KM* can be taken directly from either the vessel's curves of form or hydrostatic tables. Because *KM* varies with trim, the *KM* must be computed using the trim of the ship at the time of the stability test when the difference from the design trim of the vessel is greater than 1 % of its length. Caution should be exercised when applying the "1 % rule of thumb" to ensure that excessive error, as would result from a significant change in the waterplane area during heeling, is not introduced into the stability calculations.

4.2 *Metacentric Height*—The vertical distance between the center of gravity (*G*) and *M* is called the metacentric height (*GM*). At small angles of heel, *GM* is equal to the initial slope of the righting arm (*GZ*) curve and is calculated using the relationship, $GZ = GM \sin \theta$. *GM* is a measure of vessel stability that can be calculated during an inclining experiment. As shown in Fig. 2, moving a weight (*W*) across the deck a distance (*x*) will cause a shift in the overall center of gravity (*G–G′*) of the vessel equal to $(W)(x)/\text{displ}$ and parallel to the movement of *W*. The vessel will heel over to a new equilibrium heel angle where the center of buoyancy (*B′*) will once again be directly under the center of gravity (*G′*). Because the angle of inclination during the inclining experiment is small, the shift in *G* can be approximated by $GM \tan \theta$ and then equated to $(W)(x)/\text{displ}$. Rearranging this equation slightly results in the following equation:

$$GM = \frac{(W)(x)}{(\text{displ})(\tan \theta)} \tag{1}$$

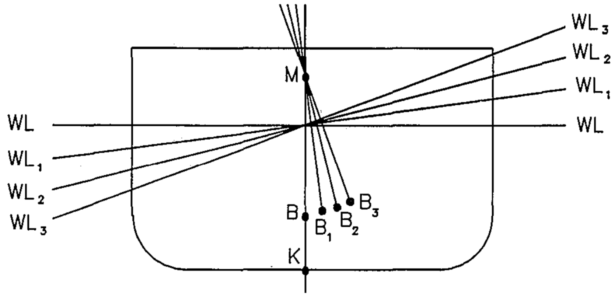


FIG. 1 Movement of the Center of Buoyancy

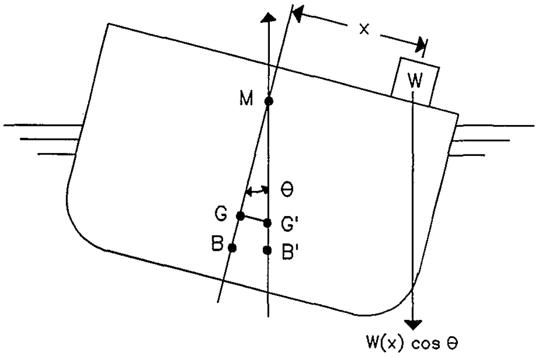


FIG. 2 Metacentric Height

Since *GM* and displ remain constant throughout the inclining experiment the ratio $(W)(x)/\tan \theta$ will be a constant. By carefully planning a series of weight movements a plot of tangents is made at the appropriate moments. The ratio is measured as the slope of the best represented straight line drawn through the plotted points as shown in Fig. 3, where three angle indicating devices have been used. This line does not necessarily pass through the origin or any other particular point, for no single point is more significant than any other point. A linear regression analysis is often used to fit the straight line.

4.3 *Calculating the Height of the Center of Gravity Above the Keel*—*KM* is known for the draft and trim of the vessel during the stability test. The metacentric height (*GM*), as calculated above, is determined from the inclining experi-

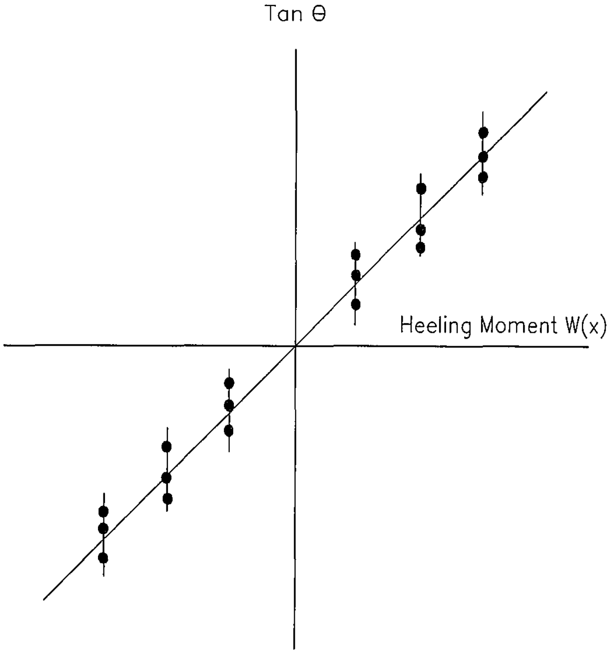


FIG. 3 A Typical Incline Plot

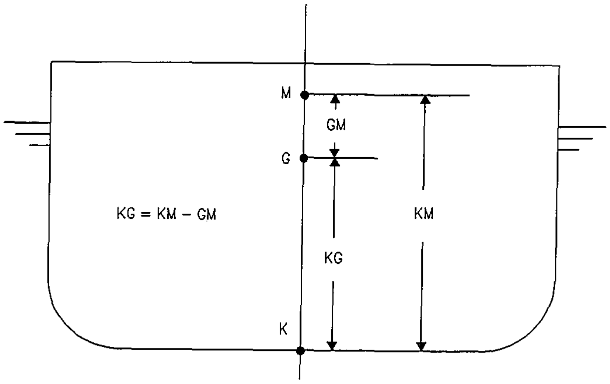


FIG. 4 Relationship between GM, KM, and KG

ment. The difference between the height *KM* and the distance *GM* is the height of the center of gravity above the keel (*KG*). See Fig. 4.

4.4 *Measuring the Angle of Inclination*—(See Fig. 5.) Each time an inclining weight (W) is shifted a distance (x), the vessel will settle to some equilibrium heel angle, θ. In order to accurately measure this angle (θ), pendulums or other precise instruments are used on the vessel. When pendulums are used, the two sides of the triangle defined by the pendulum are measured. Y is the length of the pendulum wire from the pivot point to the batten and Z is the distance the wire deflects from the reference position at the point along the pendulum length where transverse deflections are measured. Tangent θ is then calculated:

$$\tan \theta = Z/Y \qquad (2)$$

Plotting all of the readings for each of the pendulums during the inclining experiment aids in the discovery of bad readings. Since (W)(x)/tan θ should be constant, the plotted line should be straight. Deviations from a straight line are an indication that there were other moments acting on the vessel during the inclining. These other moments must be identified, the cause corrected, and the weight movements repeated until a straight line is achieved. Figures 6 through 9 illustrate examples of how to detect some of these other moments during the inclining, and a recommended solution for each case. For simplicity, only the average of the readings is shown on the inclining plots.

4.5 *Free Surface*—During the stability test, the inclining of the vessel should result solely from the moving of the inclining weights. It should not be inhibited or exaggerated by unknown moments or the shifting of liquids on board. However, some liquids will be aboard the vessel in slack tanks so a discussion of "free surface" is appropriate.

4.5.1 *Standing Water on Deck*—Decks should be free of water. Water trapped on deck may shift and pocket in a

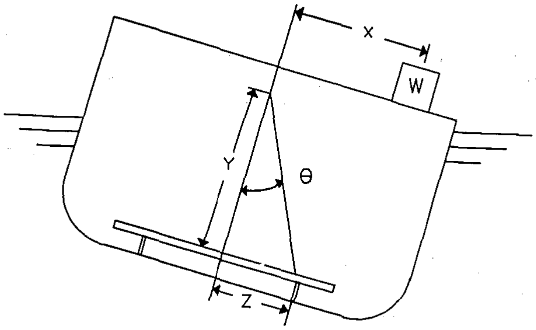
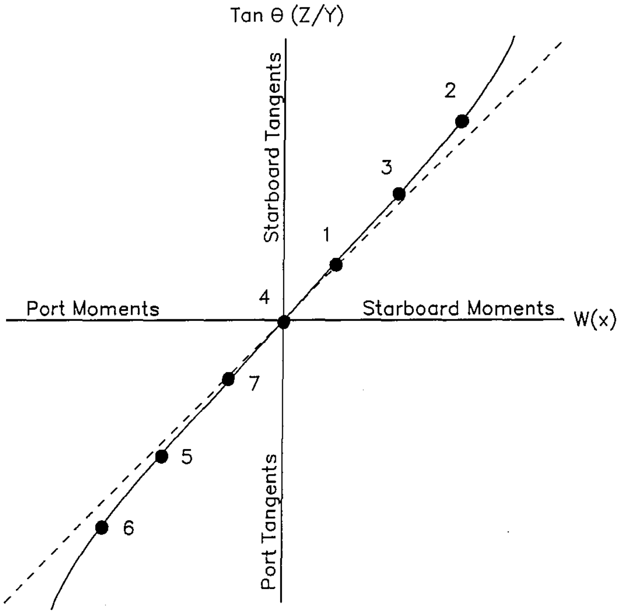
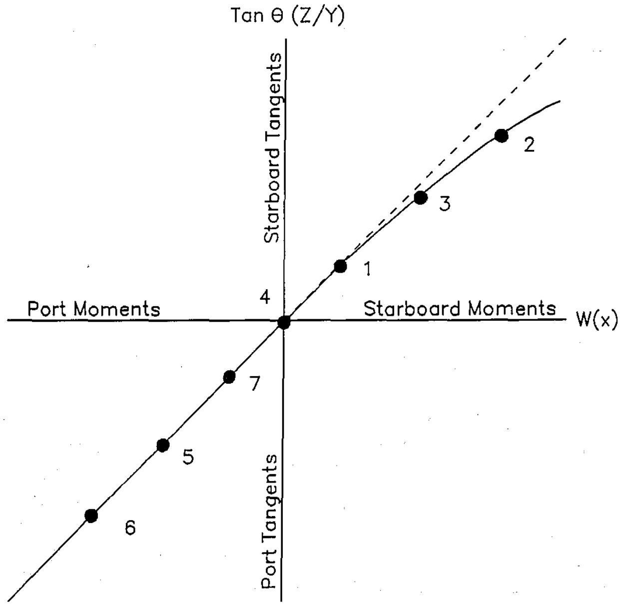


FIG. 5 Measuring the Angle of Inclination



NOTE—Re-check all tanks and voids and pump out as necessary; Re-do all weight movements and re-check freeboard and draft readings

FIG. 6 Excessive Free Liquids



NOTE—Take water soundings and check lines; re-do weight movements 2 and 3.

FIG. 7 Vessel Touching Bottom or Restrained by Mooring Lines

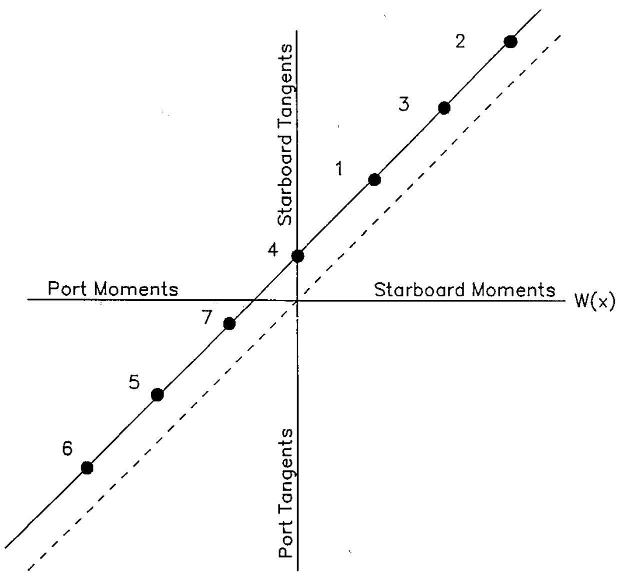
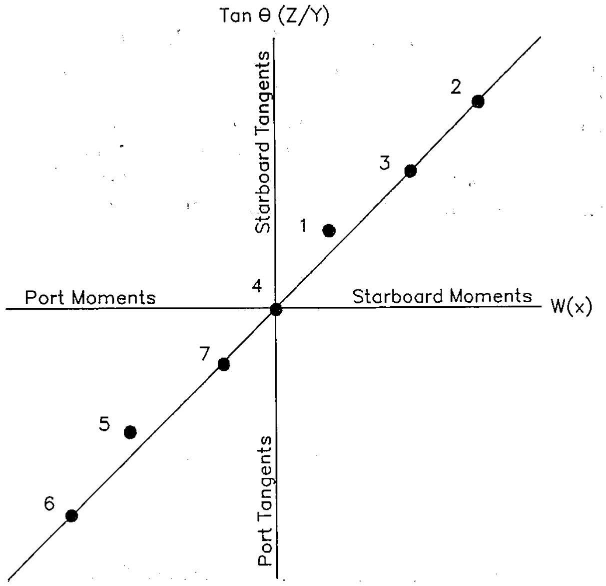


FIG. 8 Steady Wind From Port Side Came Up After Initial Zero Point Taken (Plot Acceptable)



NOTE—Re-do weight movements 1 and 5.

FIG. 9 Gusty Wind From Port Side

fashion similar to liquids in a tank.

4.5.2 *Tankage During the Inclining*—If there are liquids on board the vessel when it is inclined, whether in the bilges or in the tanks, it will shift to the low side when the vessel heels. This shift of liquids will exaggerate the heel of the vessel. Unless the exact weight and distance of liquid shifted can be precisely calculated, the *GM* from formula (1) will be in error. Free surface should be minimized by emptying the tanks completely and making sure all bilges are dry; or by completely filling the tanks so that no shift of liquid is possible. The latter method is not the optimum because air pockets are difficult to remove from between structural members of a tank, and the weight and center of the liquid in a full tank must be accurately determined in order to adjust the light ship values accordingly. When tanks must be left slack, it is desirable that the sides of the tanks be parallel vertical planes and the tanks be regular in shape (that is, rectangular, trapezoidal, etc.) when viewed from above, so that the free surface moment of the liquid can be accurately determined. The free surface moment of the liquid in a tank with parallel vertical sides can be readily calculated by the formula:

$$\text{Free surface (ft-tons)} = lb^3/12Q \qquad (3)$$

where:

l = length of tank, ft,

b = breadth of tank, ft, and

Q = specific volume of liquid in tank (ft^3/ton) (See Annex A3 for fuel oil conversions or measure Q directly with a hydrometer.).

Free surface correction is independent of the height of the tank in the ship, location of the tank, and direction of heel.

4.5.3 As the width of the tank increases, the value of free surface moment increases by the third power. The distance available for the liquid to shift is the predominant factor. This is why even the smallest amount of liquid in the bottom of a wide tank or bilge is normally unacceptable and should be removed prior to the inclining experiment. Insignificant amounts of liquids in V-shaped tanks or voids (for example, a chain locker in the bow), where the potential shift is negligible, may remain if removal of the liquid would be difficult or would cause extensive delays.

5. Preparations for the Stability Test

5.1 *General Condition of the Vessel*—A vessel should be as complete as possible at the time of the stability test. Schedule the test to minimize the disruption in the vessel's delivery date or its operational commitments. The amount and type of work left to be completed (weights to be added) affects the accuracy of the light ship characteristics, so good judgment must be used. If the weight or center of gravity of an item to be added cannot be determined with confidence, it is best to conduct the stability test after the item is added. Temporary material, tool boxes, staging, trash, sand, debris, etc. on board should be reduced to absolute minimum during the stability test.

5.2 *Tankage*—Include the anticipated liquid loading for the test in the planning for the test. Preferably, all tanks should be empty and clean, or completely full. Keep the number of slack tanks to a minimum. The viscosity of the fluid and the shape of the tank should be such that the free surface effect can be accurately determined.

5.2.1 *Slack Tanks:*

5.2.1.1 The number of slack tanks should normally be limited to one pair of port and starboard tanks or one centerline tank of the following:

(*a*) Fresh water reserve feed tanks,
(*b*) Fuel/diesel oil storage tanks,
(*c*) Fuel/diesel oil day tanks,
(*d*) Lube oil tanks,
(*e*) Sanitary tanks, or

(*f*) Potable water tanks.

5.2.1.2 To avoid pocketing, slack tanks should normally be of regular (that is, rectangular, trapezoidal, etc.) cross section and be 20 to 80 % full if they are deep tanks and 40 to 60 % full if they are double bottom tanks. These levels ensure that the rate of shifting of liquid remains constant throughout the heel angles of the stability test. If the trim changes as the vessel is inclined, then consideration must also be given to longitudinal pocketing. Slack tanks containing liquids of sufficient viscosity to prevent free movement of the liquids, as the vessel is inclined (such as Bunker C at low temperature), should be avoided since the free surface cannot be calculated accurately. A free surface correction for such tanks should not be used unless the tanks are heated to reduce viscosity. Communication between tanks should never be allowed. Cross connections, including those via manifolds, should be closed. Equal liquid levels in slack tank pairs can be a warning sign of open cross connections. A bilge, ballast, and fuel oil piping plan can be referred to, when checking for cross-connection closures.

5.2.2 *Pressed Up Tanks—Pressed up* means completely full with no voids caused by trim or inadequate venting. Anything less than 100 % full, for example, the 98 % condition regarded as full for operational purposes, is not acceptable. The vessel should be rolled from side to side to eliminate entrapped air before taking the final sounding. Special care should be taken when pressing fuel oil tanks to prevent accidental pollution. An example of a tank that would appear "pressed up," but actually contained entrapped air is shown in Fig. 10.

5.2.3 *Empty Tanks*—It is generally not sufficient to simply pump tanks until suction is lost. Enter the tank after pumping to determine if final stripping with portable pumps or by hand is necessary. The exceptions are very narrow tanks or tanks where there is a sharp deadrise, since free surface would be negligible. Since all empty tanks must be inspected, all manholes must be open and the tanks well ventilated and certified as safe for entry. A safe testing device should be on hand to test for sufficient oxygen and minimum toxic levels.

5.3 *Mooring Arrangements*—The importance of good mooring arrangements cannot be overemphasized. The arrangement selection will be dependent upon many factors. Among the most important are depth of water, wind, and current effects. Whenever possible the vessel should be moored in a quiet, sheltered area free of extraneous forces such as propeller wash from passing tugs, or sudden discharges from shore side pumps. The depth of water under the hull should be sufficient to ensure that the hull will be entirely free of the bottom. The tide conditions and the trim of the vessel during the test must be considered. Prior to the test, measure the depth of water and record in as many locations as necessary to ensure the vessel will not contact the bottom. If marginal, conduct the test during high tide or move the vessel to deeper water.

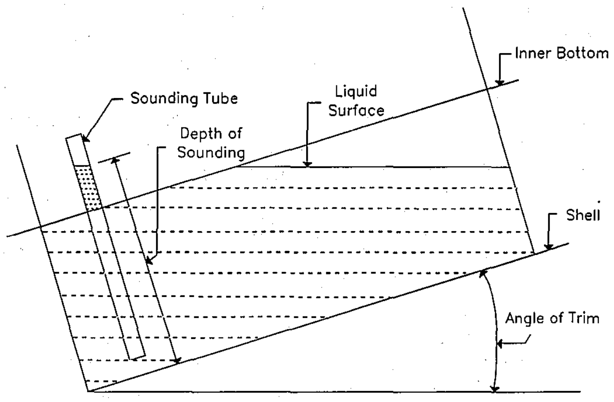


FIG. 10 Tank Containing Entrapped Air

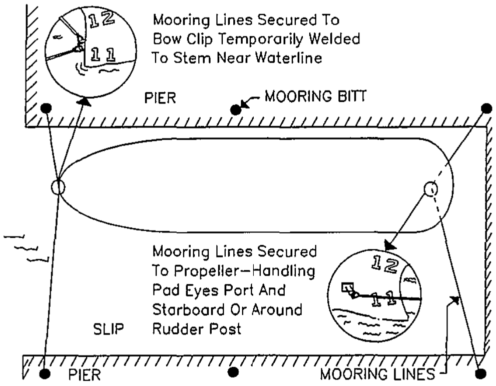


FIG. 11 The Preferred Mooring Arrangement

5.3.1 The vessel should be held by lines at the bow and the stern, attached to temporary pad eyes installed as close as possible to the centerline of the vessel and as near the waterline as practical. If temporary pad eyes are not feasible then lines can be secured to bollards or cleats, or both, on the deck. This arrangement requires that the lines be slackened when the ship is heeled away from the dock. The preferred arrangement is with the vessel lying in a slip where it can be moored as shown in Fig. 11. In this case, the lines can be kept taut to hold the vessel in place, yet allowing unrestricted heeling. Note, however, that wind or current, or both, may cause a superimposed heeling moment to act on the vessel throughout the test. For steady conditions this will not affect the results. Gusty wind or uniformly varying wind or current, or both, will cause these superimposed heeling moments to change, which may require additional test points to obtain a valid test. The need for additional test points can be determined by plotting test points as they are obtained.

5.3.2 Where the vessel can be moored to one side only, it is good practice to supplement the bow and stern lines with two spring lines in order to maintain positive control of the vessel, as shown in Fig. 12. The leads of the spring lines should be as long as practicable. Provide cylindrical camels between the vessel and the dock. All lines should be slack, with the vessel free of the pier and camels, when taking readings.

5.3.2.1 If the vessel is held off the pier by the combined effect of the wind and current, and the bow and stern lines are secured at centerline near the waterline, they can be taut. This is essentially the same as the preferred arrangement

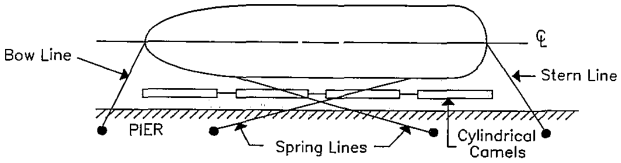


FIG. 12 An Acceptable Alternate Mooring Arrangement

described in 5.3.1. As in 5.3.1, varying wind or current, or both, will cause some distortion of the plot.

5.3.2.2 If the vessel is pressed against the camels by wind or current, or both, all lines should be slack. The cylindrical camels will prevent binding but again there will be an unavoidable superimposed heeling moment due to the ship bearing against the camels. This condition should be avoided but when used, give consideration to pulling the ship free of the dock and camels, and letting the ship drift as readings are taken.

5.3.2.3 Another acceptable arrangement is where the combined wind and current are such that the ship may be controlled by only one line at either the bow or the stern. In this case the control line need not be attached near the waterline, but it should be led from on or near the center line of the ship. With all lines but one slack, the ship is free to veer with the wind or current, or both, as readings are taken. This can sometimes be troublesome because varying wind or current, or both, can cause distortion of the plot.

5.3.3 If a floating crane is used for handling inclining weights it should not be moored to the ship.

5.3.4 Remove the access ramps. Power lines, hoses, etc. connected to shore should be at a minimum, and kept slack at all times.

5.4 *List and Trim*—In order to simplify calculations the vessel should be as close as possible to even list and design trim and have sufficient draft so that any abrupt changes in the waterplane will be avoided as the ship is inclined from side to side. If the vessel has a bow appendage, such as a bulbous bow or sonar dome, hard chine, or transom stern at the waterline, then give consideration to changing the draft or trim to ensure there is a minimum change in the waterplane area as the vessel is heeled from side to side. Trim different from design of up to 1 % of LBP (length between perpendiculars) is normally acceptable when using hydrostatic data calculated at design trim. Exercise caution when applying the "1 % rule of thumb" to ensure that excessive error, as would result from a significant change in the waterplane area during heeling, is not introduced into the stability calculations. With inclining weights in the initial position, up to ½° of list is acceptable. If the list exceeds this, use leveling weights to put the vessel in an acceptable condition.

5.5 *Test Weights*—The total weight used should be sufficient to provide a minimum inclination of 1° and a maximum of 4° of heel.

5.5.1 One approach that can be taken to estimate how much weight is needed follows:

5.5.1.1 Measure the maximum athwartships distance (x) that is available on deck to shift the weights as shown in Fig. 13.

5.5.1.2 Estimate the draft the vessel will be at for the stability test and find the corresponding displacement from the vessel's hydrostatic data.

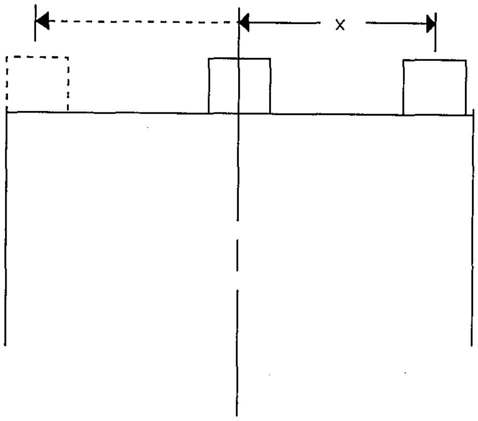


FIG. 13 Movement of the Test Weights

5.5.1.3 Estimate the GM of the vessel by estimating its center of gravity (KG) and subtracting that value from KM, obtained from the hydrostatic data for the appropriate draft;

$$GM = KM - KG \tag{3}$$

5.5.1.4 Estimate the total weight (W) required by the following formula:

$$W = \frac{GM\,(\tan\theta)\text{ displ}}{x} \tag{4}$$

where θ is the desired angle of inclination between 1 and 4°.

5.5.1.5 It would be prudent to have additional weights readily available to compensate for any inaccurate estimates.

5.5.2 Test weights should be compact and of such a configuration that the KG (vertical center of gravity) of the weights can be accurately determined. Weights, such as porous concrete, that can absorb significant amounts of moisture, should only be used if they were weighed just prior to the stability test or if recent weight certificates are presented. Mark each weight with an identification number and weight. For small vessels, drums completely filled with water may be used. Drums should normally be full and capped to allow accurate weight control.

5.5.2.1 Certify test weights using a certificated scale. Perform the weighing close enough in time to the stability test to ensure the measured weight is accurate. The time since weighing depends on the construction of the weight.

5.5.3 A crane of sufficient capacity and reach, or some other means, must be available during the stability test to shift weights on the deck in an expeditious and safe manner.

5.5.4 Take precautions to ensure that the decks are not overloaded during weight movements. If deck strength is questionable then perform a structural analysis to determine if existing framing can support the weight.

5.5.5 The test weights should be on board and in place prior to the scheduled time of the stability test.

5.6 *Pendulums:*

5.6.1 Use a minimum of three pendulums to allow identification of bad readings at any one pendulum station. They should each be located in an area protected from the wind. If this is not possible, then erect a screen around the exposed portions of the pendulums. Good locations for pendulums are ladder trunks, elevator shafts, hatchways, or any access way passing through decks.

5.6.2 The pendulums should be long enough to give a measured deflection, to each side of upright, of at least 6 in. Generally, this will require a pendulum length of at least 10 ft. Usually, the longer the pendulum the greater the accuracy of the test; however, if excessively long pendulums are used on a tender ship the pendulums may not settle down and the accuracy of the pendulums would then be questionable. On smaller vessels, where there is insufficient headroom to hang long pendulums, obtain the 6-in. deflection by increasing the test weight so as to increase the list. The typical inclination is between 2 and 3° but, in no case, should the maximum angle of list be greater than 4°. As shown in Fig. 14, the pendulums must be at least 87 in. long to get at least 6 in. of deflection without exceeding the 4° maximum heel.

5.6.3 If the pendulums are of different lengths, the possibility of collusion between station recorders is avoided. The pendulum wire should be piano wire or other monofilament material. The top connection of the pendulum should afford unrestricted rotation of the pivot point. An example is that of a washer with the pendulum wire attached suspended from a nail.

5.6.4 Provide a trough filled with a thick oil to dampen oscillations of the pendulum after each weight movement. It should be deep enough to prevent the pendulum weight from touching the bottom.

5.6.5 The use of a winged plumb bob at the end of the pendulum wire can also help to dampen the pendulum oscillations in the oil.

5.6.6 The battens should be smooth, light-colored wood, $\frac{1}{2}$ to $\frac{3}{4}$ in. thick, and should be securely fixed in position so that an inadvertent contact will not cause them to shift. The batten should be aligned close to the pendulum wire but not in contact with it.

5.6.7 The pendulums should be in place prior to the scheduled time of the stability test.

5.6.8 A typical satisfactory arrangement is shown in Fig. 15. The pendulums may be placed in any location on the vessel, longitudinally and transversely.

5.6.9 If the person conducting the test desires to substitute inclinometers or other measuring devices for the pendulums, complete prior testing of the measuring devices to verify their accuracy before actual substitution for the pendulums. It is recommended that the inclinometers or other measuring devices be used in conjunction with the pendulums instead of using only other devices and no pendulums.

5.7 *Communications Arrangements:*

5.7.1 One person at a central control station should have complete control over all personnel involved in the test.

5.7.2 There should be efficient two-way communications between central control and the weight handlers and between central control and each pendulum station.

5.7.3 Shelter the central control station from the elements, and have adequate lighting so that a plot of tangents versus heeling moments can be made during the test. It is desirable that the weight handlers be directly observed from the control station.

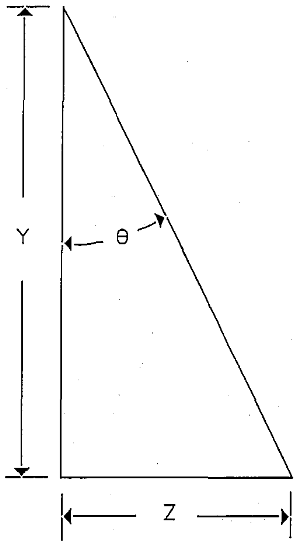
5.8 *Additional Requirements:*

5.8.1 Annex A1 contains additional requirements that must be met, if U.S. Coast Guard approval of the stability test is needed.

5.8.2 Annex A2 contains additional requirements that must be met for stability tests on U.S. Navy vessels.

6. Plans and Equipment Required

6.1 *Plans*—The person in charge of the inclining should



$\tan \theta = Z/Y$
$\tan 4° = 6 \text{ in.}/Y$
$Y = 6 \text{ in.}/\tan 4°$
$Y = 6 \text{ in.}/0.0699$
$Y = 87 \text{ in.}$
$\tan 3° = 6 \text{ in.}/Y$
$Y = 6 \text{ in.}/\tan 3°$
$Y = 6 \text{ in.}/0.0524$
$Y = 114 \text{ in.}$
$\tan 2° = 6 \text{ in.}/Y$
$Y = 6 \text{ in.}/\tan 2°$
$Y = 6 \text{ in.}/0.0349$
$Y = 172 \text{ in.}$

FIG. 14 Angle of Inclination versus Pendulum Length

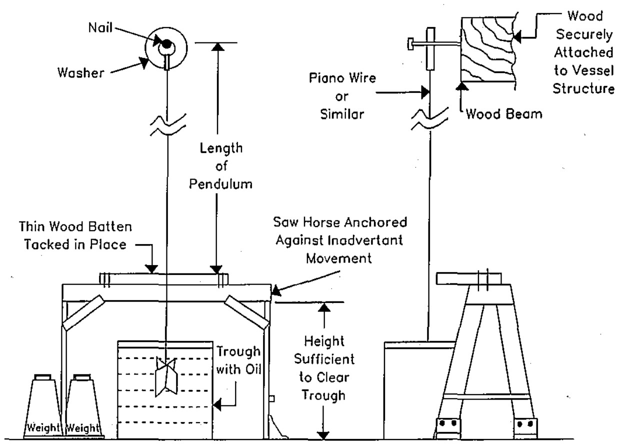


FIG. 15 Typical Satisfactory Pendulum Arrangement

have available a copy of the following at the time of the stability test:

6.1.1 Lines plan,

6.1.2 Curves of form (hydrostatic curves) or hydrostatic data,

6.1.3 General arrangement plan of decks, holds, inner bottoms, etc.,

6.1.4 Outboard profile,

6.1.5 Inboard profile,

6.1.6 Midship section,

6.1.7 Capacity plan showing capacities and vertical and longitudinal centers of gravity of cargo spaces, tanks, etc.,

6.1.8 Tank sounding tables,

6.1.9 Draft mark locations, and

6.1.10 Docking drawing with keel profile and draft mark corrections (if available).

6.2 *Equipment*—Besides the physical equipment necessary such as the inclining weights, pendulums, small boat, etc., the following are necessary and should be provided by or made available to the person in charge of the inclining:

6.2.1 Three engineering scales for measuring pendulum deflections (rules should be subdivided into at least tenths of an inch),

6.2.2 Three sharp pencils for marking pendulum deflections,

6.2.3 Chalk for marking the various positions of the inclining weights,

6.2.4 A sufficiently long measuring tape for measuring the movement of the weights and locating different items on board,

6.2.5 A sufficiently long sounding tape for sounding tanks and taking freeboard readings,

6.2.6 One or more specific gravity hydrometers, either 60°F/15°C (ASTM 125) or other, with range sufficient to cover 0.999 to 1.030, to measure the specific gravity of the water in which the vessel is floating (a quality hydrometer for measuring specific gravity of less than 1.000 may be needed in some locations),

6.2.7 Other hydrometers as necessary to measure the specific gravity of any liquids on board,

6.2.8 Graph paper to plot inclining moments versus tangents,

6.2.9 A straight edge to draw the measured waterline on the lines drawing,

6.2.10 A pad of paper to record data,

6.2.11 An explosion proof testing device to check for sufficient oxygen and absence of lethal gases in tanks and other closed spaces such as voids and cofferdams,

6.2.12 A thermometer, and

6.2.13 Draft tubes (if necessary).

7. Procedure

7.1 The inclining experiment, the freeboard/draft readings, and the survey, may be conducted in any order and still achieve the same results. If the person conducting the stability test is confident that the survey will show that the vessel is in an acceptable condition and there is the possibility of the weather becoming unfavorable, then it is suggested that the inclining be performed first and the survey last. If the person conducting the test is doubtful that the vessel is complete enough for the test, it is recommended that the survey be performed first since this could invalidate the entire test, regardless of the weather conditions. It is very important that all weights, the number of people on board, etc., remain constant throughout the test. Appendix X1 contains a stability test check list that can be used to make a quick check that the procedure is correctly followed.

7.1.1 *Initial Walk Through and Survey*—The person responsible for conducting the stability test should arrive on board the vessel well in advance of the scheduled time of the test to ensure that the vessel is properly prepared for the test. If the ship to be inclined is large, a preliminary walk through may need to be done the day preceding the actual incline. To ensure the safety of personnel conducting the walk through, and to improve the documentation of surveyed weights and deficiencies, at least two persons should make the initial walk through. Things to check include: all compartments are open, clean, and dry, tanks are well ventilated and gas free; movable or suspended items are secured and their position documented; pendulums are in place; weights are on board and in place; a crane or other method for moving weights is available; and the necessary plans and equipment are available. Before beginning the stability test, the person conducting the test should:

7.1.1.1 Consider the weather conditions. The combined adverse effect of wind, current, and sea may result in difficulties or even an invalid test due to the following:

(*a*) Inability to accurately record freeboards and drafts,

(*b*) Excessive or irregular oscillations of the pendulums, and

(*c*) Variations in unavoidable superimposed heeling moments.

In some instances, unless conditions can be sufficiently improved by moving the vessel to a better location, it may be necessary to delay or postpone the test. Any significant quantities of rain, snow, or ice must be removed from the vessel before the test.

7.1.1.2 Make a quick overall survey of the vessel to make sure the vessel is complete enough to conduct the test and to ensure that all equipment is in place.

7.1.1.3 Enter all empty tanks after it is determined that they are well ventilated and gas free to ensure that they are dry and free of debris. Ensure that any pressed up tanks are indeed full and free of air pockets.

7.1.1.4 Survey the entire vessel to identify all items which need to be added to the vessel, removed from the vessel, or relocated on the vessel to bring the vessel to the light ship condition. Each item must be clearly identified by weight and vertical and longitudinal location. If necessary, record also the transverse location. The inclining weights, the pendulums, any temporary equipment and dunnage, and the people on board during the stability test are all among the weights to be removed to obtain the light ship condition. The person calculating the light ship characteristics from the data gathered during the incline and survey or the person reviewing the stability test, or both, may not have been present during the test and must be able to determine the exact location of the items from the data recorded and the vessel's drawings. Any tanks containing liquids must be accurately sounded and the soundings recorded. Table 1 is an example of just a few typical entries from a survey.

(*a*) It is recognized that the weight of some items on board, or that are to be added, may have to be estimated. If this is necessary, it is in the best interest of safety to be on the safe side when estimating, so the following rules of thumb should be followed:

(1) When estimating weights to be added:
  - estimate high for items to be added high in the vessel, and
  - estimate low for items to be added low in the vessel.

(2) When estimating weights to be removed:
  - estimate low for items to be removed from high in the vessel, and
  - estimate high for items to be removed from low in the vessel.

(3) When estimating weights to be relocated:
  - estimate high for items to be relocated to a higher point in the vessel,
  - estimate low for items to be relocated to a lower point in the vessel.

7.1.2 *Freeboard/Draft Readings:*

7.1.2.1 Take freeboard/draft readings to establish the position of the waterline in order to determine the displacement of the vessel at the time of the stability test. It is recommended that at least five freeboard readings, approximately equally spaced, be taken on each side of the vessel or that all draft marks (forward, midship, and aft) be read on each side of the vessel. Take draft mark readings to assist in determining the waterline defined by freeboard readings, or to verify the vertical location of draft marks on vessels where their location has not been confirmed. The locations for each freeboard reading should be clearly marked. The longitudinal location along the vessel must be accurately determined and recorded since the (molded) depth at each point will be obtained from the vessel's lines. All freeboard measurements should include a reference note clarifying the inclusion of the coaming in the measurement and the coaming height.

7.1.2.2 Read draft and freeboard readings immediately before or immediately after the inclining test. Weights must be on board and in place and all personnel who will be on board during the test including those who will be stationed to read the pendulums, should be on board and in location during these readings. This is particularly important on small vessels. If readings are made after the test, maintain the vessel in the same condition as during the test. For small vessels, it may be necessary to counterbalance the list and trim effects of the freeboard measuring party. When possible, take readings from a small boat.

7.1.2.3 The mooring lines should be slack such that the vessel floats freely. A check should be made that the vessel is not resting on the bottom.

7.1.2.4 Determine the specific gravity of the flotation water at this time. Take samples from a sufficient depth of the water to ensure a true representation of the flotation water and not merely surface water, which could contain fresh water from run off of rain. Place a hydrometer in a water sample and read and record the specific gravity. For large vessels, it is recommended that samples of the flotation water be taken forward, midship, and aft and the readings averaged. For small vessels, one sample taken from midships should be sufficient. A conversion table from specific gravity to specific volume is contained in Annex A3. Take the temperature of the water and correct the measured specific gravity for deviation from the standard, if necessary. A correction to water specific gravity is not necessary if the specific gravity is determined at the inclining experiment site. Correction is necessary if specific gravity is measured when sample temperature differs from the temperature at the time of the inclining (for example, if check of specific gravity is done at the office).

7.1.2.5 A small boat should be available to aid in the taking of freeboard and draft mark readings. It should have low freeboard to permit accurate observation of the readings.

7.1.2.6 A draft mark reading may be substituted for a given freeboard reading at that longitudinal location if the height and location of the mark has been verified to be

TABLE 1 Typical Survey Entries

Items to Be Removed

Item	*Weight, lb*	*Vertical Center*	*Longitudinal Center*
Inclining weight No. 1	2400	3 ft above main deck	4.5 ft aft frame 50
Inclining weight No. 2	2640	3 ft above main deck	frame 50
Inclining Weight No. 3	2500	3 ft above main deck	4.5 ft forward frame 50
Inclining Weight No. 4	2350	3 ft above main deck	frame 51
Two men	370	3 ft above main deck	frame 63
Two men	370	3 ft above main deck	frame 90
Pendulum No. 1 (total setup and one man)	240	2.8 ft above bottom at centerline	3 ft forward of aft engine room bulkhead
Fuel oil tank No. 3P 8 ft 8 in. sounding	[A]	[A]	[A]
Potable water tk No. 1C 9 ft 3 in. sounding	[A]	[A]	[A]

Items to Be Added

Item	*Weight, lb*	*Vertical Center*	*Longitudinal Center*
Radio	200	5 ft above pilot deck	2 ft aft forward pilot house bulkhead
Antenna	85	15 ft above top of pilot house	frame 20
Towing cable	800	2.5 ft above main deck	8 ft forward frame 85
Rescue boat	120	4 ft above main deck	frame 60

Items to Be Relocated

Item	*Weight*	*From*		*To*	
		Vertical	*Longitudinal*	*Vertical*	*Longitudinal*
Liferaft	300	main deck	frame 50	01 deck	frame 65
Fire pump	220	main deck	frame 65	2 ft above shell	frame 40

[A] Can be determined later by the naval architect from drawings or sounding tables, or both.

accurate by a keel survey while the vessel was in drydock.

7.1.2.7 A device, such as a draft tube, can be used to improve the accuracy of freeboard/draft readings by damping out wave action.

7.1.2.8 The dimensions given on a vessel's lines drawing are normally molded dimensions. In the case of depth (D), this means the distance from the inside of the bottom shell to the inside of the deck plate. In order to plot the vessel's waterline on the lines drawing, convert the freeboard readings to molded drafts (d). See Fig. 16. If the freeboard is measured from the main deck to the waterline:

$$d = D + t - f \tag{5}$$

See Fig. 17. If the freeboard is measured from the top of the bulwark to the waterline:

$$d = D + t + b - f \tag{6}$$

Similarly, correct the draft mark readings from extreme (bottom of keel) to molded (top of keel) before plotting. Resolve any discrepancy between the freeboard/draft readings.

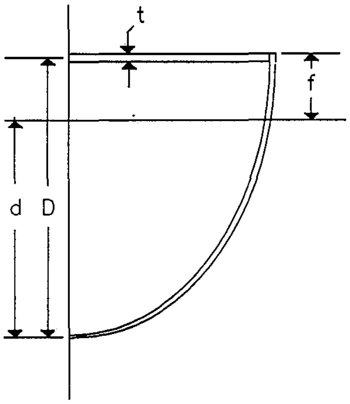
7.1.2.9 Calculate the mean draft (average of port and starboard reading) for each of the locations where freeboard/draft readings are taken and plotted on the vessel's lines drawing or outboard profile to ensure that all readings are consistent and together define the correct waterline. The resulting plot should yield either a straight line or a waterline which is either hogged or sagged. If inconsistent readings are obtained, retake the freeboards/drafts.

7.1.3 *The Inclining Experiment:*

7.1.3.1 Prior to any weight movements, check the following:

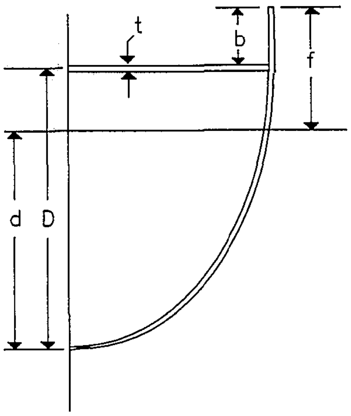
(*a*) Check the mooring arrangement to ensure that the vessel is floating freely. (Do this just prior to each reading of the pendulums.)

(*b*) Measure the pendulums and record their lengths. The pendulums should be aligned so that when the vessel heels, the wire will be close enough to the batten to ensure an accurate reading but will not come into contact with the batten. The typical satisfactory arrangement is shown in Fig. 15.



NOTE—where:
D = molded depth
d = molded draft
f = freeboard reading
t = deck thickness
b = bulwark height

FIG. 16 Converting Freeboards (Measured to the Main Deck) into Molded Drafts



NOTE—where:
D = molded depth
d = molded draft
f = freeboard reading
t = deck thickness
b = bulwark height

FIG. 17 Converting Freeboards (Measured to Top of Bulwark) into Molded Drafts

(*c*) Mark the initial position of the weights on the deck. This can be done by tracing the outline of the weights on the deck.

(*d*) The communications arrangement is adequate.

(*e*) All personnel are in place.

7.1.3.2 Run a plot during the test to ensure that acceptable data is being obtained. Typically, the abscissa of the plot will be heeling moment (weight times distance) and the ordinate will be the tangent of the heel angle (deflection of the pendulum divided by the length of the pendulum).

7.1.3.3 The standard test employs eight weight movements. Movement No. 8, a recheck of the zero point, may be omitted if a straight line plot is achieved after Movement No. 7.

7.1.3.4 The weight movements shown in Fig. 18 give a good spread of points on the test plot.

7.1.3.5 Once everything and everyone is in place, obtain the zero position and conduct the remainder of the experiment as quickly as possible, while maintaining accuracy and proper procedures, in order to minimize the possibility of a change in environmental conditions during the test.

7.1.3.6 Prior to each pendulum reading, each pendulum station should report to the control station when the pendulum has stopped swinging. Then, the control station will give a "standby" warning and then a "mark" command. When "mark" is given, the batten at each position must be marked at the location of the pendulum wire. If the wire was oscillating slightly, take the center of the oscillations as the mark. If any of the pendulum readers doesn't think the reading was a good one, the reader should advise the control station and the point should be retaken for all pendulum stations. Likewise, if the control station suspects the accuracy of a reading, it should be repeated for all the pendulum stations. Next to the mark on the batten should be written the number of the weight movement, such as zero for the

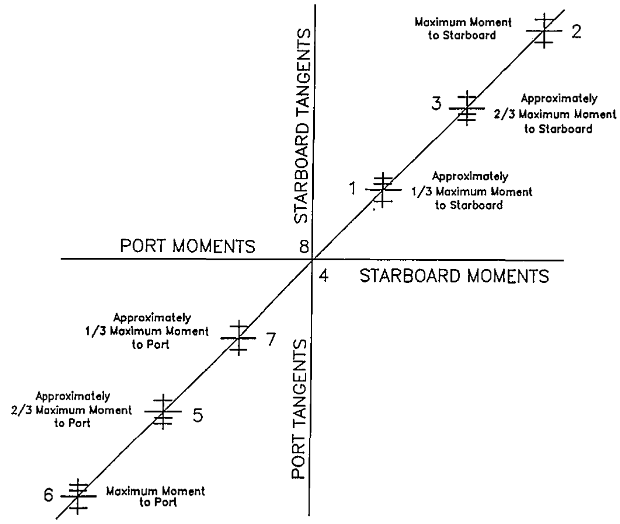


FIG. 18 Acceptable Spread of Test Points On Incline Plot

initial position and one through seven for the weight movements.

7.1.3.7 Make each weight movement in the same direction, normally transversely, so as not to change the trim of the vessel. After each weight movement, measure the distance the weight was moved (center to center) and calculate the heeling moment by multiplying the distance by the amount of weight moved. Calculate the tangent for each pendulum by dividing the deflection by the length of the pendulum. Plot the three resultant tangents on the graph. Provided there is good agreement among the pendulums with regard to the tan θ value, the average of the three pendulum readings may be graphed instead of plotting each of the readings.

7.1.3.8 If a straight line plot is achieved after the initial zero and six weight movements, the stability test is complete and the second check at zero may be omitted. If a straight line plot is not achieved, those weight movements that did not yield acceptable plotted points must be repeated or explained.

8. Report

8.1 Appendix X2 contains sample data sheets to record data during stability tests. It is suggested that these sheets be used so that no data is forgotten and so that the data is clear, concise, and consistent in form and format.

8.2. Appendix X3 contains sample sheets to aid in calculating the results of the stability test.

8.3 Alternatively, all calculations performed during the inclining and in preparation of the report may be carried out by a suitable computer program. Output generated by such a program may be used for presentation of all or partial data and calculations included in the test report if it is clear, concise, well documented, and generally consistent in form and content with the forms in Appendixes X2 and X3.

8.4 Annex A3 contains conversion factors to be used in changing specific gravity of fuel oil and water to specific volume.

9. Precision and Bias

9.1 The accuracy of the stability test is directly related to the accuracy of the measuring conditions at the time of the test. Many factors can influence the reliability of the information gained. The weather, the vessel loading, the mooring arrangements, the state of completion of the vessel, etc., can all significantly affect the final results of the test. Conditions during the measurement period should be such that readings can be recorded and then repeated to give consistent data. Make the required measurements, attempting to reach the following precision:

Freeboards	nearest ⅛ in.
Draft marks	nearest ⅛ in.
Pendulum lengths and readings	nearest 1⁄16 in. (0.05 in. on a 1⁄10 in. scale)
Survey weights	1 % of the weight (5 % for small items)
Tank soundings	nearest ⅛ in.

The precision used to read measurements does not guarantee the resulting overall accuracy of the test. If all procedures in this guide are followed, the test results should have satisfactory accuracy.

ANNEXES

(Mandatory Information)

A1. TO RECEIVE UNITED STATES COAST GUARD APPROVAL OF THE STABILITY TEST ON COMMERCIAL VESSELS THE FOLLOWING ADDITIONAL REQUIREMENTS SHOULD BE FOLLOWED

(In Amplification of the Regulations)

A1.1 *Prior Notification To The Coast Guard Marine Safety Center*—Written notification of the test must be sent to the Coast Guard Marine Safety Center (MSC) at least two weeks prior to the test. The MSC will make arrangements for an acceptable representative to witness the test.

A1.1.1 *Details of Notification*—Written notification should provide the following information:

A1.1.1.1 Identification of the vessel by name and shipyard hull number, if applicable.

A1.1.1.2 Date, time, and location of the test.

A1.1.1.3 Inclining weight data.

(*a*) Type,

(*b*) Amount (number of units and weight of each),

(*c*) Certification,

(*d*) Method of handling (that is, sliding rail or crane), and

(*e*) Anticipated maximum angle of heel to each side.

A1.1.1.4 *Pendulums*—Approximate location and length. (If a shipyard/naval architect desires to substitute inclinometers or other measuring devices for one or two of the three required pendulums, prior approval must be obtained from the MSC. The MSC might require that the devices be used in addition to the pendulums on one or more inclinings to verify their accuracy before allowing actual substitution for a pendulum.)

A1.1.1.5 Approximate trim.

A1.1.1.6 Condition of tanks.

A1.1.1.7 Estimated weights to deduct, to complete, and to relocate in order to place the vessel in its true light ship condition.

A1.1.1.8 Detailed description of any computer software to be used to aid in calculations during the inclining.

A1.1.1.9 Name and phone number of the person responsible for conducting the test.

A1.2 Alternate mooring arrangements will be considered if submitted for review prior to the test. Such arrangements should ensure that the vessel will be free to list without restraint for a sufficient period of time to allow the pendulums to damp out motion so that the readings can be recorded.

A1.3 Each of the test weights must be certified by a weigh-master's document and a copy provided to the Coast Guard representative. For small vessels, capped drums, completely filled with water may be used. In such cases, the weight should be verified in the presence of the Coast Guard representative using a recently calibrated scale.

A1.4 If bad weather conditions are detected early enough and the weather forecast does not call for improving conditions, the Coast Guard representative should be advised prior to departure from the office and an alternate date scheduled.

A1.5 An estimate of work items which will be outstanding at the time of the stability test should be included as part of any test procedure submitted to the MSC. This is required so that the Coast Guard representative can advise the shipyard/naval architect if in their opinion the vessel will not be sufficiently complete to conduct the stability test and that it should be rescheduled. If the condition of the vessel is not accurately depicted in the test procedure and at the time of the stability test the Coast Guard witness considers that the vessel is in such condition that an accurate stability test cannot be conducted, the witness may refuse to accept the test and require that a test be conducted at a later date.

A1.6 A certified marine chemist's certificate certifying that all fuel oil and chemical tanks are safe for human entry should be available, if necessary.

A1.7 If a computer program is used to perform calculations during the inclining, Coast Guard approval to use the program must be obtained prior to the test.

A1.8 Prior to departing the vessel, the person conducting the test and the Coast Guard representative should initial each sheet as an indication of their concurrence with the recorded data.

A1.9 A copy of the data should be forwarded to the MSC along with the stability test report.

A1.10 When completed, three copies of the stability test report should be submitted to the MSC for approval.

A1.11 The Coast Guard may alter or limit acceptance of any provision in this guide.

A1.12 When the American Bureau of Shipping is representing the Coast Guard during a stability test, the words, American Bureau of Shipping, should be substituted for the words, Coast Guard, and for the words, Marine Safety Center, in this annex.

A2. FOR STABILITY TESTS ON UNITED STATES NAVY (USN) VESSELS THE FOLLOWING ADDITIONAL REQUIREMENTS APPLY

A2.1 The inclining experiment shall be performed in accordance with the requirements set forth in Naval Ship's Technical Manual,[2] and as modified below. The stability test report shall be prepared on the forms described in the above technical manual.

A2.2 Photographs of topside arrangements including weather decks is required to document topside installations. Photographs of each draft mark reading are also required.

A2.3 A comprehensive survey of all compartments, tanks, and voids is required to determine the weight and center of

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[2] *NAVSEA 59086-C6-STM-000*, Chapter 096, "Weights and Stability," available from Commanding Officer, Naval Ships Weapon System Engineering Station, Code 5700, Port Hueneme, CA 93043.

gravity (vertical, longitudinal, and transverse) of all consumable loads, including personnel, ammunition, provisions, general stores, and liquids.

A2.4 Draft readings are required. Amidships marks should be read to determine hog or sag of ship. Projection draft marks and freeboard readings can be used to verify accuracy of draft mark readings.

A2.5 Inclining weights are moved transversely to produce at least two inclinations to port and two to starboard.

A2.6 Significant items of weight which are considered part of the lightship displacement but are subject to change or are readily removable are listed, as part of the report, by weight and center of gravity. These items include boats, armament, ballast, salvage gear, and yellow gear.

A2.7 It is desirable under most circumstances to incline the vessel at design trim. If however, the area of the waterplane will change substantially as the ship is heeled from side to side, then the trim should be altered, to minimize the change in the waterplane area during the incline. This may require that functions of wedges be calculated to correct for the trimmed conditions. The hydrostatics must be verified or recalculated, or both, if the as-trimmed waterplane area differs from the waterplane area at the design trim.

A2.8 The freeboard/draft mark readings must be taken simultaneously on both sides of the vessel, to ensure that any heel is properly recorded at the time of the stability test.

A2.9 The transverse center of gravity (TCG) must be determined for all ships.

A2.10 In presentation of incline results, incline plots are to be arranged such that the slope of the incline plot can be directly substituted into the *GM* formula as shown below.

$$GM = \frac{\text{slope}}{(\text{displ})}$$

where slope of the line from the incline plot equals the (rise/run). Heeling moments must be on the ordinate and tangents must be on the abscissa. Figure A2.1 gives an example of an acceptable plot.

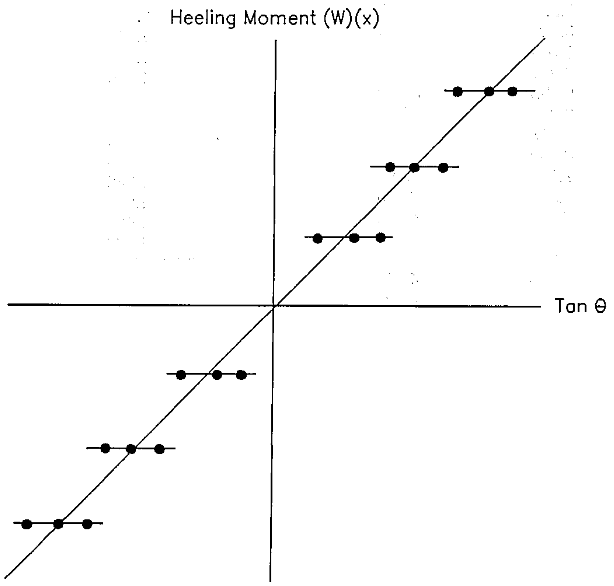

FIG. A2.1 Acceptable Orientation for Incline Plots on U.S. Navy Vessels

A3. CONVERSION TABLES FOR LIQUIDS

A3.1 Tables A3.1 and A3.2 are based on the weight of 1 gal of water in air against brass weights at 60°F and 30 in. mercury at 45° latitude at sea level and 50 % humidity. They were taken from the National Bureau of Standards Circular C-410.[3]

TABLE A3.1 Fuel Oil[A]

Degrees API	Specifiction Gravity	bbl/ton	ft^3/ton
10	1.0000	6.404	35.96
11	0.9930	6.449	36.21
12	0.9861	6.494	36.46
13	0.9792	6.540	36.72
14	0.9725	6.585	36.97
15	0.9659	6.630	37.22
16	0.9593	6.776	37.48
17	0.9529	6.720	37.73
18	0.9465	6.766	37.99
19	0.9402	6.811	38.24
20	0.9340	6.856	38.50
21	0.9279	6.901	38.75
22	0.9218	6.947	39.01
23	0.9159	6.992	39.26
24	0.9100	7.037	39.51
25	0.9042	7.082	39.76
26	0.8984	7.128	40.02
27	0.8927	7.174	40.28
28	0.8871	7.219	40.53
29	0.8816	7.264	40.78
30	0.8762	7.309	41.04

[A] Conversion Formula:

$$\text{Specific gravity} = \frac{141.5}{(131.5 + B)}$$

where B = degrees API.

TABLE A3.2 Water

Specific Gravity	ft^3/ton
0.999	35.99
1.000	35.96
1.001	35.92
1.002	35.88
1.003	35.85
1.004	35.81
1.005	35.78
1.006	35.74
1.007	35.71
1.008	35.67
1.009	35.63
1.010	35.60
1.011	35.56
1.012	35.53
1.013	35.49
1.014	35.46
1.015	35.42
1.016	35.39
1.017	35.35
1.018	35.32
1.019	35.28
1.020	35.25
1.021	35.22
1.022	35.18
1.023	35.15
1.024	35.11
1.025	35.08
1.026	35.04
1.027	35.01
1.028	34.98

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[3] Available from National Institute of Standards and Technology (NIST), Gaithersburg, MD 20899.

APPENDIXES

(Nonmandatory Information)

X1. STABILITY TEST CHECK LIST

X1.1 *Pre-Inclining:*

1. __________ Vessel is complete or nearly so.
   (*a*) No major structural sections or major items of equipment to be added or removed.
   (*b*) No tanks with liquids not shown in the inclining procedure.
   (*c*) No extraneous gear and personnel on board the vessel.
2. __________ Weather conditions are satisfactory.
   (*a*) No gusting winds. Steady light wind not causing motions is acceptable. Beam winds to be avoided. Wind speed normally acceptable if draft marks can be read.
   (*b*) No strong currents.
   (*c*) Not raining.
   (*d*) No waves. Ripples acceptable if can read freeboards to ⅛ in.
3. __________ Depth of water is greater than draft of vessel.
4. __________ All empty tanks should be opened and checked for liquids. All tanks containing liquids should be sounded for liquid levels. All tank levels should be recorded.
5. __________ Weight certificates obtained or the weights used for the inclining actually weighed using certified scales.
6. __________ Initial angle of heel is less than 0.5° and the trim difference from design is less than 1 % of the *LBP*. If more trim is allowed, as-trimmed hydrostatics must be used in calculations.

NOTE X1.1—In some cases, if trim is different from design, as-trimmed hydrostatics must always be used (that is, Navy inclines).

X1.2 *Freeboard/Draft Readings:*

1. __________ At least five (5) freeboard readings on each side at approximately the same intervals along the length at readily identifiable locations (for example, ends of deck houses). A verified draft mark reading may be substituted for a freeboard reading.
   (*a*) Each data point is to consist of:
      1. Freeboard reading (f) taken from the top of the bulwark to the point where the plumb bob touches the water.
      2. Bulwark height (b) reading at each location.
      3. Deck plating thickness (t) from the structural plan.
      4. Molded depth (D) at each location from the lines plan.
   (*b*) Molded Draft = molded depth plus bulwark height plus deck plating thickness minus freeboard reading ($d = D + b + t - f$).
2. __________ Draft mark readings:
   (*a*) Taken from a small boat.
   (*b*) Port and starboard; forward, midship, and aft.
   (*c*) Longitudinal locations from a known reference point.
3. __________ Plot of waterline (draft versus distance from forward perpendicular).
   (*a*) Note that draft readings are extreme (bottom of keel) while drafts from freeboard readings are molded (top of keel).
4. __________ Specific gravity of water (hydrometer reading) and water temperature readings.

X1.3 *Weight Movements:*

1. __________ Pendulums:
   (*a*) At least three (3); can be located on different decks and do not have to be on centerline.
   (*b*) Length of pendulums is measured from the pivot point to the top of the batten.
   (*c*) Pendulums should be of different lengths; to get required angle of deflection, pendulums need to be at least 10 ft long. The longer the better if sheltered from the wind. Pendulum unrestricted through maximum angle expected.
   (*d*) Thick oil in bucket to dampen movement of pendulums. Pendulums with dampers are recommended.
   (*e*) Pendulum support is fixed so it cannot be accidentally moved during the inclining.
2. __________ Battens:
   (*a*) Pencil marks placed on battens to record the position of the pendulum wires.
   (*b*) Batten is fixed so it can not be accidentally moved during the inclining.
   (*c*) Battens should never be reset once inclining begins and movements are being recorded.
3. __________ Weights:
   (*a*) Record initial position (vertical, transverse, longitudinal distances from known reference points such as distance above the deck, distance from the end of a deckhouse and distance from the centerline).
4. __________ Weight Movements:
   (*a*) At least three (3) to each side of the reference position.
   (*b*) Deflection of the pendulums at maximum moment should be at least six (6) inches to each side of the initial position.
   (*c*) Maximum angle of heel should not be greater than four (4) degrees; value of tangent must be less than 0.06993. Typical angle of heel should be between two (2) and three (3) degrees.
   (*d*) Moment equals weight times distance moved; calculated and summed for all weights moved for each movement.
   (*e*) Tangent equals pendulum deflection divided by pendulum length. When calculating the tangent, the deflection and the length must be in the same units (that is, inches or feet).
   (*f*) During each movement, ensure that:
      1. There are no taut mooring lines other than those attached to temporary pads on centerline;
      2. Pendulum weight is not touching side of bucket; and

3. Pendulum is not touching batten.

(*g*) Plot of moment-tangent curve:

1. Plot each tangent value calculated for each weight movement. The average of the three pendulum readings may be graphed instead of plotting each of the readings only if the tan θ values measured among the pendulums are consistent.

2. Plot must be a straight line but it doesn't have to pass through the origin.

3. Curved line means unaccounted for free surface, gusting winds or the vessel is touching the bottom and should not be accepted.

X1.4 *Post Inclining:*

1. __________ Check drafts/freeboards to ensure consistency with first measurements.

(*a*) Note that draft readings are extreme (bottom of keel) while drafts from freeboard readings are molded (top of keel).

2. __________ Survey tanks if drafts have changed.

X1.5 *Survey of Items to Be Added, Removed, or Relocated:*

1. __________ Record weight, vertical center of gravity, longitudinal center of gravity, and transverse center of gravity (if required) for each item. Weights become more critical as the size of the vessel becomes smaller.

2. __________ Typical weights to add:

(*a*) Liferafts/lifesaving equipment;
(*b*) Seating;
(*c*) Liquids in engines and other machinery;
(*d*) Paneling;
(*e*) CO_2 bottles/firefighting equipment;
(*f*) Fenders;
(*g*) Deck coverings/tiles and underlayments;
(*h*) Cables for winches;
(*i*) Lines and hawsers;
(*j*) Engineroom insulation;
(*k*) Ventilation ducts;
(*l*) Galley equipment (stoves and refrigerators);
(*m*) Mattresses;
(*n*) Paint (on surfaces to be painted);
(*o*) Dampers;
(*p*) Electronic equipment in the pilothouse;
(*q*) Masts and navigation lights.

3. __________ Typical weights to deduct:

(*a*) Inclining weights and pendulum set-up;
(*b*) Personnel on board;
(*c*) Liquids on board (in tanks and bilges but excluding liquids in engines and other machinery);
(*d*) Workers equipment;
(*e*) Scrap metal;
(*f*) Scaffolding;
(*g*) Dunnage.

4. __________ Typical weights to relocate:

(*a*) Paneling;
(*b*) Lifesaving equipment;
(*c*) Fenders and mooring equipment;
(*d*) Fire extinguishing equipment.

X2. SAMPLE DATA SHEETS

__________ Stability Test Rough Data __________

Description of Vessel:

Name __________

Type __________

Builder __________

Hull Number __________

Vessel inclined at __________

____

Date __________ Time __________

Test conducted by __________

Test witnessed by __________

Description of weather conditions __________

____

Specific gravity of water __________

Temperature of water __________

Weights certified by:

Weigh master (certificate attached) ☐

Reviewing authority ☐

FIG. X2.1 Stability Test Rough Data

Items to Be Added

Description	Weight	Vertical Center	Longitudinal Center	Transverse Center (if needed)

TANKS:

Description	Location	Sounding or Ullage	Specific Gravity/Density

FIG. X2.2 Items to be Added

Items to Be Removed

Description	Weight	Vertical Center	Longitudinal Center	Transverse Center (if needed)

TANKS:

Description	Location	Sounding or Ullage	Specific Gravity/Density

FIG. X2.3 Items to be Removed

Items to be Relocated

Description	Weight	From			To		
		Vertical Center	Longitudinal Center	Tranverse Center (if needed)	Vertical Center	Longitudinal Center	Tranverse Center (if needed)

FIG. X2.4 Items to be Relocated

Freeboard Readings

f = measured freeboard,
t = deck thickness,
D = molded depth from lines drawing,
b = measured bulwark height, and
d = calculated molded draft.

Without Bulwark or Side Shell Coaming
$d = D + t - f$

or

With Bulwark or Side Shell Coaming
$d = D + t + b - f$

Location		f	t	D	b	d
1.	P					
	S					
2.	P					
	S					
3.	P					
	S					
4.	P					
	S					
5.	P					
	S					
6.	P					
	S					
7.	P					
	S					
8.	P					
	S					

Draft Mark Readings

Location	Reading	Location	Reading
	P		P
	S		S
	P		P
	S		S
	P		P
	S		S

FIG. X2.5 **Freeboard Readings**

Ship at Time of Stability Test—Condition 0

Pendulums No. Location	Length to Batten Inches
1st	
2d	
3d	

Inclining Weights

Location ______________

Description ______________

Weight No.	Tons	Initial Position Port Feet	Initial Position Starboard Feet

	Weight		Distance from Initial Positions		Moment	Total Inclining Moment		Pendulum Deflections			Tangents	
	No.	Tons	Port Feet	Starboard Feet	Ft-Tons	Port Ft-Tons	Starboard Ft-Tons	No.	Port Inches	Starboard Inches	Port	Starboard
1st Trial								1st				
								2d				
								3d				
2d Trial								1st				
								2d				
								3d				
3d Trial								1st				
								2d				
								3d				
4th Trial								1st				
								2d				
								3d				
5th Trial								1st				
								2d				
								3d				
6th Trial								1st				
								2d				
								3d				
7th Trial								1st				
								2d				
								3d				
8th Trial								1st				
								2d				
								3d				

FIG. X2.6 Condition 0—Preliminary Report

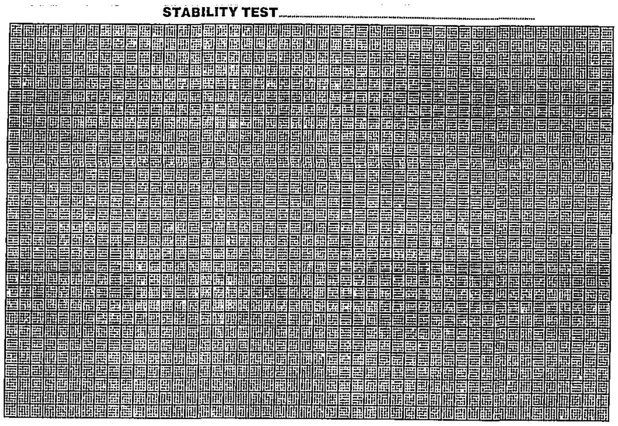

FIG. X2.7 Stability Test Graph—Preliminary Results

X3. STABILITY TEST DATA

Stability Test Data

Official Number ____________
Gross Tons ____________

DESCRIPTION OF VESSEL ____________

Type ____________
Builder ____________
Hull Number ____________ Date Built ____________
Hull ____________
____
____

Machinery ____________
____
____
____

Classed By ______ Inspected ☐ Safety Certificate ☐ Load Line ☐
Route: Ocean ☐ Coastwise ☐ Great Lakes ☐ Bays ☐ Rivers ☐
Specify Route, If Limited ____________

Owner ____________
Owner's Address ____________

Vessel Inclined At ____________
Date ____________ Time ____________
Test Requested By ____________

Plans Furnished By ____________
Offsets Measured By ____________
Curves of Form Computed By ____________

Test Conducted By ____________
Stability Calculations Made By ____________
Sister Vessels ____________

FIG. X3.1 Stability Test Data

Stability Test

Principal Dimensions

Length over all ____________ ft ______ in. (______ ft)
Length between perpendiculars which are at the extremities of ____________ waterline ____________ ft ______ in. (______ ft)
Length between draft marks, ____________ condition ____________ ft ______ in. (______ ft)
Breadth, extreme, at ____________ feet above base ____________ ft ______ in. (______ ft)
Breadth, molded, amidships at ____________ feet above base ____________ ft ______ in. (______ ft)
Breadth at load water line ____________ ft ______ in. (______ ft)
Depth amidships, from ____________ to ____________ ft ______ in. (______ ft)
Apparent full-load mean draft for stability { molded base ____________ ft ______ in. (______ ft)
Apparent full-load mean draft for stability { bottom of keel ____________ ft ______ in. (______ ft)
Displacement, sea water, tons (2240 lb), at above full-load draft ____________ tons
Freeboard amidships at above full-load draft ____________ ft ______ in. (______ ft)
Freeboard at low point of sheer (______ feet aft of amidships) ____________ ft ______ in. (______ ft)
Location of ports, in hull, which may affect stability ____________

General Information

Names and duties of official observers ____________
Designers represented by ____________
Builders represented by ____________
Owners represented by ____________
Weather, tide, and mooring conditions ____________
Condition of ship as to completeness and as to water in boilers, machinery, and bilges ____________
____

FIG. X3.2 Stability Test—Principle Dimensions

Stability Test

All tons used in this calculation are of ________ lb

Ship at Time of Stability Test—Condition 0

Sketch Showing Hog, Sag, Trim, Drag, and Location of Draft Marks, Freeboards, and Perpendiculars

Draft from draft marks when inclined
Forward ____________ ft ________ in.
Aft ____________ ft ________ in.
Amidships Port ________ ft ________ in.
Amidships Starboard ________ ft ________ in.

Distance between "curves of form" perpendiculars ____________ ft

Bottom of keel below base line ____________ in.

Molded Keel drafts corrected to "curves of form" perpendiculars for use in calculations
Forward ____________ ft
Aft ____________ ft
Mean of amidships P and S __ ft

Mean of forward and after drafts ____________ ft
Hog or sag ____________ ft
Trim forward, aft ____________ ft
Longitudinal center of floatation forward, aft ____________ ft
Molded Keel draft at center of flotation ____________ ft
Molded Keel draft at L.C.F. corrected for hog or sag ____ ft
Total displacement at above draft F.W., S. W. ____________ tons
Specific gravity of water ________ equals ________ ft^3/ton
Total displacement corrected for density ____________ tons

FIG. X3.3 Stability Test Sketch—Condition 0

Ship at Time of Stability Test—Condition 0

Pendulums		
No.	Location	Length to Batten
		in.
1st		
2d		
3d		

	Weight		Distance from Initial Positions		Moment	Total Inclining Moment		Pendulum Deflections			Tangents	
	No.		Port	Star-board		Port	Star-board	No.	Port	Star-board	Port	Star-board
		tons	ft	ft	ft-tons	ft-tons	ft-tons		in.	in.		
								1st				
1st Trial								2d				
								3d				
								1st				
2d Trial								2d				
								3d				
								1st				
3d Trial								2d				
								3d				
								1st				
4th Trial								2d				
								3d				
								1st				
5th Trial								2d				
								3d				
								1st				
6th Trial								2d				
								3d				
								1st				
7th Trial								2d				
								3d				
								1st				
8th Trial								2d				
								3d				

Inclining Weights

Location ______________

Description ______________

Weight		Initial Position	
No.		Port	Starboard
	tons	ft	ft

FIG. X3.4 Condition 0—Final Report

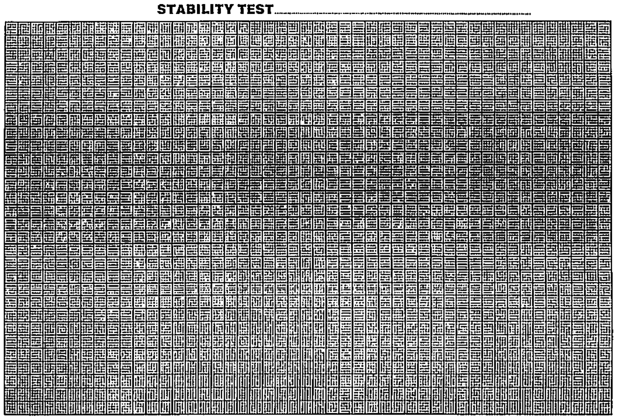

FIG. X3.5 Stability Test Graph—Final Results

Stability Test

Ship at Time of Stability Test—Condition 0

	From Hydrostatic Curves	From Independent Calculation
Corrected displacement	________ tons	________ tons
Mean virtual metacentric height obtained from plot of inclining moments versus tangents of angles of heel— $\frac{\text{moment}}{\text{displacement} \times \text{tangent}}$	________ ft	________ ft
Correction for free surface	________ ft[A]	________ ft
Mean metacentric height G. M. =	________ ft	________ ft
Transverse metacenter above the base line corresponding to draft at L. C. F. (corrected for hog or sag)	________ ft[B]	
Transverse metacenter above the base line corrected (for trim, and hog or sag)	________ ft	
C. G. above base line	________ ft	________ ft (from figure)
Longitudinal metacenter above C. G.	________ ft	
Moment to alter trim 1 foot, $\frac{\text{Longl. GM} \times \Delta}{\text{L}}$	________ ft-tons	
Trim by stern, bow	________ ft[B]	
Trimming lever = $\frac{\text{Trim} \times \text{moment to trim}}{\text{displacement}}$	________ ft	
L.C.B. forward, aft of amidships, which is ____ ft forward, aft of frame No.____	________ ft	
C. G. forward, aft of amidships	________ ft	________ ft (from figure)

Period of complete roll ________ s

Apparent radius of gyration of vessel—k = $\frac{T\sqrt{GM}}{1.108}$ ________ ft

Rolling Constant—C = $\frac{T\sqrt{GM}}{B}$ ________

[A] Water in bilges. The bilges should be entirely free of water; but should this be impossible, correction should be made in the derived *GM*. The details of this correction should form part of this report.

[B] If the trim is excessive, independent calculations should be made to obtain the positions of the center of buoyancy and transverse metacenter and the position of the center of gravity determined therefrom. These calculations should be incorporated in this booklet.

FIG. X3.6 Stability Test Results at Condition 0 from Hydrostatic Curves and Independent Calculation

Stability Test

Data for Tanks						C. G. Above base		C. G. Above from M. P.			
Liquid	Sounding	Net Inertia of Free Surface	Inertia, ft^3-ton	Items	Weight, tons	Lever	Vertical Moments, ft-tons	Feet Aft	After Moments, ft-tons	Feet Forward	Forward Moments, ft-tons

FIG. X3.7 Stability Test—Data for Tanks

Stability Test

Ship Light—Condition I

Ship complete in every respect, with water in boilers at steaming level and liquids in machinery and piping, but with all tanks and bunkers empty and no passengers, crew, cargo, stores, or baggage on board.

List of Major Equipment, etc., Included in Condition I as Shown
Ballast, boats, rafts, cargo booms, anchors, guns, armor, etc.

Items	Weight, tons	C.G. Above Base, ft	C.G. from M.P. Feet Forward	C.G. from M.P. Feet Aft
Fixed Ballast	______	______	______	______
______	______	______	______	______
______	______	______	______	______
______	______	______	______	______
______	______	______	______	______
______	______	______	______	______
______	______	______	______	______
______	______	______	______	______

Items	Displacement and Weight	C. G. Above Base		C.G. Above from M. P.			
	tons	Lever	Vertical Moments, ft-tons	Feet Aft	After Moments, ft-tons	Feet Forward	Forward Moments, ft-tons
Ship in Condition 0	______	______	______	______	______	______	______
Weight to Complete	______	______	______	______	______	______	______
Weight to Relocate	______	______	______	______	______	______	______
Weight to Remove	______	______	______	______	______	______	______
Ship in Condition I	______	______	______	______	______	______	______

Molded Keel—Draft at longitudinal center of flotation corresponding to above displacement for ______ water______ ft

Transverse metacenter above base at L.C.F. draft, uncorrected for trim ______________ ft

C.G. above base ______________ ft

Metacentric height, uncorrected for trim, G.M. ______________ ft

Metacentric height, corrected for G.M. ______________ ft

Longitudinal metacenter above C.G. at L.C.F. draft __________ ft

Moment to alter trim 1 foot at L.C.F. draft, $\frac{\text{longl GM} \times \Delta}{L}$ __________ ft-tons

C.B. of ship on even keel at L.C.F. draft, aft, forward f ℄ __________ ft

C.G. aft, forward of amidships __________ ft

Trimming lever __________ ft

Trim, aft, forward— $\frac{\text{displacement} \times \text{lever}}{\text{moment to trim}}$ __________ ft

L.C.F. aft, forward of amidships __________ ft

Difference between L.C.F. and amidships draft __________ ft

Molded draft amidships __________ ft

Draft on draft marks, forward __________ ft

Draft on draft marks, aft __________ ft

FIG. X3.8 **Ship Light—Condition I**

Stability Test

Ship in Condition ______________

Description of Condition	Items	Displacement and Weight	C. G. Above Base		C. G. Above from M. P.			
		tons	Lever	Vertical Moments, ft-tons	Feet Aft	After Moments, ft-tons	Feet Forward	Forward Moments, ft-tons
______	Ship in Condition ______	______	______	______	______	______	______	______
______	______	______	______	______	______	______	______	______
______	______	______	______	______	______	______	______	______
______	______	______	______	______	______	______	______	______
______	Total ______	______	______	______	______	______	______	______

______ Molded Keel—Draft at longitudinal center of flotation corresponding to above displacement for ______ water ______ ft

______ Transverse metacenter above base at L.C.F. draft, uncorrected for trim ______ ft

______ C.G. above base ______ ft

______ Metacentric height, uncorrected for free surface $\begin{bmatrix}\text{corrected for trim}\\ \text{uncorrected for trim}\end{bmatrix}$ G.M. ______ ft

Correction for free surface Metacentric height, corrected for free surface $\begin{bmatrix}\text{corrected for trim}\\ \text{uncorrected for trim}\end{bmatrix}$ G.M. ______ ft

Longitudinal metacenter above C.G. at L.C.F. draft ______ ft

Moment to alter trim 1 foot at L.C.F. draft, $\frac{\text{longl GM} \times \Delta}{L}$ ______ ft-tons

C.B. of ship on even keel at L.C.F. draft, aft, forward of amidships ______ ft

C.G. aft, forward of amidships ______ ft

Trimming lever ______ ft

Trim, aft, forward—$\frac{\text{displacement} \times \text{lever}}{\text{moment to trim}}$ ______ ft

Longitudinal center of floatation, aft, forward of amidships ______ ft

Difference between L.C.F. and amidships draft ______ ft

Molded draft amidships ______ ft

Draft on draft marks, forward ______ ft

Draft on draft marks, aft ______ ft

FIG. X3.9 Stability Test—Condition Description

Stability Test
Conclusive Remarks

NOTE—This sheet should be used for any explanations that may be required other than those covered by the notes on the previous sheets. In case the results of the stability test show that under certain conditions caution in loading and handling the vessel is necessary, particularly in regard to the effect of deck loads or free surface, a detailed statement to this effect should be made here.

FIG. X3.10 Stability Test—Conclusive Remarks

CERTIFICATE

By Authority Of
THE UNITED STATES OF AMERICA
Legally Binding Document

By the Authority Vested By Part 5 of the United States Code § 552(a) and Part 1 of the Code of Regulations § 51 the attached document has been duly INCORPORATED BY REFERENCE and shall be considered legally binding upon all citizens and residents of the United States of America. *HEED THIS NOTICE*: Criminal penalties may apply for noncompliance.

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WASHINGTON, D.C.

ASTM Logo Removed

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An American National Standard

Standard Specification for Shipboard Incinerators[1]

This standard is issued under the fixed designation F 1323; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers the design, manufacture, performance, operation, functioning, and testing of incinerators intended to incinerate garbage and other shipboard wastes generated during the ship's normal service (that is, maintenance, operational, domestic, and cargo-associated wastes).

1.2 This specification is a companion document to Guide F 1322.

1.3 This specification applies to those incinerator plants with capacities up to 1500 kW per unit.

1.4 Additional information is given in Appendixes Appendix X1-Appendix X5.

1.5 This specification does not apply to systems on special incinerator ships, for example, for burning industrial wastes such as chemicals, manufacturing residues, and so forth.

1.6 This specification does not address the electrical supply to the unit, nor the foundation connections and stack connections.

1.7 This specification does not cover emissions requirements.

1.8 *This standard does not purport to address all of the safety concerns associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* See 4.8.

2. Referenced Documents

2.1 *ASTM Standards:*

F 1322 Guide for Selection of Shipboard Incinerators[2]

2.2 *ANSI Standard:*

B 31.1 Power Piping[3]

ANSI/NFPA No. 70 National Electrical Code[3]

Article 430-7[3]

2.3 *ASME Boiler and Pressure Vessel Code:*

Section I, Power Boilers[4]

Section IX, Welding and Brazing Qualification[4]

2.4 *Underwriter's Laboratory Standards:*

UL 506 Standard for Specialty Transformers[5]

UL 814 Standard for Gas-Tube Signs and Ignition Cables[5]

2.5 *Safety of Life at Sea Convention:*

SOLAS 74 International Convention for the Safety of Life at Sea[3]

2.6 *Other Documents:*

International Convention for the Preventing of Pollution from Ships, 1973, as modified by the Protocol of 1978 (MARPOL 73/78)[6]

NOTE 1—Incinerators designed and manufactured in accordance with alternative standards must show compliance with this specification.

3. Terminology

3.1 *Definitions:*

3.1.1 *cargo-associated waste*—all materials that have become wastes as a result of use on board a ship for cargo stowage and handling. Cargo-associated waste includes but is not limited to dunnage, shoring pallets, lining and packing materials, plywood, paper, cardboard, wire, and steel strapping.

3.1.2 *cargo residues—for the purposes of this specification*, the remnants of any cargo material on board that cannot be placed in proper cargo holds (loading excess and spillage) or which remain in cargo holds and elsewhere after unloading procedures are completed (unloading residual and spillage). However, cargo residues are expected to be in small quantities.

3.1.3 *domestic waste*—all types of food wastes, sewage, and wastes generated in the living spaces on board the ship.

3.1.4 *fishing gear*—any physical device or part thereof or combination of items that may be placed on or in the water with the intended purpose of capturing, or controlling for subsequent capture, living marine or freshwater organisms.

3.1.5 *food wastes*—any spoiled or unspoiled victual substances, such as fruits, vegetables, dairy products, poultry, meat products, food scraps, food particles, and all other materials contaminated by such wastes, generated aboard ship, principally in the galley and dining areas.

3.1.6 *garbage*—all kinds of victual, domestic, and operational waste excluding fresh fish and parts thereof, generated during the normal operation of the ship and liable to be disposed of continuously or periodically. Those substances

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[1] This specification is under the jurisdiction of ASTM Committee F-25 on Ships and Marine Technology and is the direct responsibility of Subcommittee F25.06 on Marine Environmental Protection.

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[2] *Annual Book of ASTM Standards*, Vol 01.07.

[3] Available from the American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.

[4] Available from the American Society of Mechanical Engineers, 345 E. 47th St., New York, NY 10017.

[5] Available from Underwriter's Laboratories, Inc., 333 Pfingsten Rd., Northbrook, IL 60062.

[6] Available from the International Maritime Organization, 4 Albert Embankment, London SE1 7SR, UK.

which are defined or listed in Annexes, other than Annex V, to the International Convention for the Preventing of Pollution From Ships, 1973, as modified by the Protocol of 1978 (MARPOL 73/78) are excluded.

3.1.7 *incinerator*—shipboard facilities for incinerating solid wastes approximating in composition to household waste and liquid wastes arising from the operation of the ship, for example, domestic waste, cargo-associated waste, maintenance waste, operational waste, cargo residues, and fishing gear, and so forth. These facilities may be designed to use or not to use the heat energy produced.

3.1.8 *maintenance waste*—materials collected by the engine department and the deck department while maintaining and operating the ship, such as soot, machinery deposits, scraped paint, deck sweeping, wiping wastes, oily rags, and so forth.

3.1.9 *oily rags*—rags that have been saturated with oil as controlled in Annex I to the Convention. Contaminated rags are rags that have been saturated with a substance defined as a harmful substance in the other Annexes to the Convention.

3.1.10 *operational wastes*—all cargo-associated wastes and maintenance waste (including ash and clinkers) and cargo residues defined as garbage in 3.1.6.

3.1.11 *plastic*—a solid material that contains as an essential ingredient one or more synthetic organic high polymers and is formed (shaped) during either manufacture of the polymer or the fabrication into a finished product by heat or pressure, or both. Plastics have material properties ranging from hard and brittle to soft and elastic. Plastics are used for a variety of marine purposes including, but not limited to, packaging (vapor-proof barriers, bottles, containers, liners), ship construction (fiberglass and laminated structures, siding, piping, insulation, flooring, carpets, fabrics, paints and finishes, adhesives, electrical and electronic components), disposable eating utensils and cups, bags, sheeting, floats, fishing nets, strapping bands, rope, and line.

3.1.12 *ship*—a vessel of any type operating in the marine environment and includes hydrofoil boats, air-cushion vehicles, submersibles, floating craft, and fixed or floating platforms.

3.1.13 *waste*—useless, unneeded, or superfluous matter which is to be discarded.

4. Materials and Manufacture

4.1 Metal parts of the incinerator exposed to the combustion process shall be made of materials listed in Section I of the ASME Boiler and Pressure Vessel Code.

4.2 Where welded construction is used, welded joint design details, welding, and nondestructive testing of the combustion chamber shall be in accordance with Section I of the ASME Code. Welders and weld procedures shall be qualified in accordance with Section IX of the ASME Code.

4.3 Piping and piping components associated with incinerators for fuel, sludge, and liquid cargo residues shall comply with ANSI B31.1 for design and material requirements. Fuel oil pressure piping between service pumps and burners shall have a relief valve fitted which will discharge into the suction line or back into the tank. Pressure piping shall be of seamless steel with a thickness of at least Schedule 80. Short lengths of steel, or annealed copper nickel, nickel copper, or copper pipe and tubing may be used at the burners. The use of nonmetallic materials for fuel lines is prohibited. Valves and fittings may be threaded in sizes up to and including 2-in. normal pipe size (NPS) (60-mm outside diameter), but threaded unions are not to be used on pressure lines in sizes 1-in. NPS (33-mm outside diameter) and over.

4.4 All rotating or moving mechanical and exposed electrical parts shall be protected against accidental contact. All electrical devices shall be enclosed in drip-proof or watertight enclosures.

4.5 Refractory shall be resistant to thermal shocks and resistant to normal ship's vibration. The refractory design temperature shall be equal to the combustion chamber design temperature plus 20 % (see 5.1).

4.6 Incinerating systems shall be designed such that corrosion will be minimized on the inside of the systems.

4.7 In systems equipped for incinerating liquid wastes, safe ignition and maintenance of combustion shall be ensured, for example, by a supplementary burner using gas oil/diesel oil or equivalent.

4.8 The incinerating furnace may be charged with solid waste either by hand or automatically. In every case, fire dangers must be avoided and charging must be possible without danger to the operating personnel.

4.8.1 For instance, where charging is carried out by hand, a charging lock may be provided that ensures that the charging space is isolated from the fire box as long as the filling hatch is open.

4.8.2 Where charging is not affected through a charging lock, an interlock shall be installed to prevent the charging door from opening while the incinerator is in operation or while the furnace temperature is above 220°C.

4.9 Incinerators equipped with a feeding sluice shall ensure that the material charged will move from the sluice to the combustion chamber. Examples for accomplishing this are the use of a clear path down or a mechanical pusher.

4.10 Interlocks shall be installed to prevent ash removal doors from opening while burning is in progress or while the furnace temperature is above 220°C.

4.11 The incinerator shall be provided with a safe observation port of the combustion chamber to provide visual control of the burning process and waste accumulation in the combustion chamber. Neither heat, flame, nor particles shall be able to pass through the observation port. An example of a safe observation port is high-temperature glass with a metal closure.

4.12 *Electrical Requirements*:

4.12.1 *General*—Installation requirements shall apply to controls, safety devices, and burners on incinerators.

4.12.1.1 A disconnecting means capable of being locked in the open position shall be installed at an accessible location at the incinerator so that the incinerator can be disconnected from all sources of potential. This disconnecting means shall be an integral part of the incinerator or adjacent to it (see 6.1).

4.12.1.2 All uninsulated live metal parts and all rotating or moving parts that may cause injury shall be guarded to avoid accidental contact.

4.12.1.3 The electrical equipment shall be so arranged so that failure of this equipment will cause the fuel supply to be shut off.

4.12.1.4 The power supply to the electrical control system shall be from a two-wire branch circuit that has a grounded conductor; otherwise, an isolation transformer with a two-wire secondary shall be provided. When an isolation transformer is provided, one side of the secondary winding shall be grounded.

4.12.1.5 One side of all coils shall be electrically located in the grounded side of the circuit. All switches, contacts, and overcurrent devices shall be electrically located in the ungrounded or "hot" side of the circuit. All electrical contacts of every safety device installed in the same control circuit shall be electrically connected in series. However, special consideration shall be given to arrangements when certain devices are wired in parallel.

4.12.1.6 All electrical components and devices shall have a voltage rating commensurate with the supply voltage of the control system.

4.12.1.7 All electrical devices shall be at least NEMA Type 2 (Driptight). Electric equipment exposed to the weather shall be at least NEMA Type 4.

4.12.1.8 All electrical and mechanical control devices shall be of a type tested and accepted by a nationally recognized testing agency.

4.12.1.9 The design of the control circuits shall be such that limit and primary safety controls shall directly open a circuit that functions to interrupt the supply of fuel to combustion units.

4.12.2 *Overcurrent Protection*:

4.12.2.1 Conductors for interconnecting wiring that is smaller than the supply conductors shall be provided with overcurrent protection based on the size of the smallest interconnecting conductors external to any control box.

4.12.2.2 Overcurrent protection for interconnecting wiring shall be located at the point where the smaller conductors connect to the larger conductors. However, overall overcurrent protection is acceptable if it is sized on the basis of the smallest conductors of the interconnecting wiring.

4.12.2.3 Overcurrent protection devices shall be accessible and their function shall be identified.

4.12.3 *Motors*:

4.12.3.1 Motors exposed to dripping or spraying oil or water shall be of drip-proof construction. All motors shall be fully guarded as installed.

4.12.3.2 Motors shall be provided with a corrosion-resistant nameplate specifying information in accordance with NEC, Article 430-7.

4.12.3.3 Motors shall be provided with running protection by means of integral thermal protection, by overcurrent devices, or a combination of both in accordance with manufacturer's instructions that shall be based on the requirements of National Electrical Code, NFPA No. 70.

4.12.3.4 Motors shall be rated for continuous duty and shall be designed for an ambient temperature of 122°F (50°C) or higher.

4.12.3.5 All motors shall be provided with terminal leads or terminal screws in terminal boxes integral with, or secured to, the motor frames.

4.12.4 *Ignition System*:

4.12.4.1 When automatic electric ignition is provided, it shall be accomplished by means of either a high-voltage electric spark, a high-energy electric spark, or a glow coil.

4.12.4.2 Ignition transformers shall conform to requirements of the UL Standard 506.

4.12.4.3 Ignition cable shall conform to requirements of the UL Standard 814.

4.12.5 *Wiring*:

4.12.5.1 All wiring for incinerators shall be rated for the maximum operating temperature to which it may be exposed. Such wiring shall be in accordance with National Electrical Code, NFPA No. 70. All wiring between components shall have copper conductors not less than size No. 18 AWG and constructed in accordance with the National Electrical Code, NFPA No. 70.

4.12.5.2 All electrical wiring shall have a voltage rating commensurate with the voltage of the power supply.

4.12.5.3 Conductors shall be protected from physical damage where appropriate.

4.12.5.4 Conductors shall be sized on the basis of the rated current of the load they supply.

4.12.6 *Bonding and Grounding*:

4.12.6.1 Means shall be provided for grounding the major metallic frame or assembly of the incinerators.

4.12.6.2 Noncurrent carrying enclosures, frames, and similar parts of all electrical components and devices shall be bonded to the main frame or assembly of the boiler. Electrical components that are bonded by their installation do not require a separate bonding conductor.

4.12.6.3 When an insulated conductor is used to bond electrical components and devices, it shall show a continuous green color, with or without a yellow stripe.

5. Operating Requirements

5.1 The incinerator system shall be designed and constructed for operation with the following conditions:

Maximum combustion chamber temperature	2190°F (1200°C)
Minimum combustion chamber temperature	1560°F (850°C)
Preheat temperature of combustion chamber	1200°F (650°C)

For batch loaded incinerators, there are no preheating requirements. However, the incinerator shall be so designed that the temperature in the actual combustion space shall reach 1110°F (600°C) within 5 min after start.

Prepurge, before ignition	at least four air changes in the chamber(s) and stack, but not less than 15 s
Time between restarts	at least four air changes in the chamber(s) and stack, but not less than 15 s
Postpurge, after shutoff of fuel oil	not less than 15 s after the closing of the fuel oil valve
Incinerator discharge gases	min 6 % O_2 (measured in dry flue gas)

5.2 Outside surface of combustion chamber(s) shall be shielded from contact such that people would not be exposed to extreme heat (maximum 68°F (20°C) above ambient temperature) or direct contact of surface temperatures exceeding 140°F (60°C). Examples for alternatives to accomplish this are a double jacket with an air flow in between or an expanded metal jacket.

5.3 Incinerating systems are to be operated with underpressure (negative pressure) in the combustion chamber such that no gases or smoke can leak out to the surrounding areas.

5.4 The incinerator shall have warning plates attached in a prominent location on the unit, warning against unauthorized opening of doors to combustion chamber(s) during operation and against overloading the incinerator with garbage.

5.5 The incinerator shall have instruction plate(s) attached in a prominent location on the unit that clearly addresses the following:

5.5.1 Cleaning ashes and slag from the combustion chamber(s) and cleaning of combustion air openings before starting the incinerator (where applicable).

5.5.2 Operating procedures and instructions.

5.6 To avoid the buildup of dioxins, the flue gas should be shock-cooled to a maximum 660°F (350°C) within 2.5 m from the combustion chamber flue gas outlet.

6. Operating Controls

6.1 The entire unit shall be disconnected from all sources of electricity by means of one disconnect switch located near the incinerator (see 4.12.1.1).

6.2 There shall be an emergency stop switch located outside the compartment which stops all power to the equipment. The emergency stop switch shall also be able to stop all power to the fuel pumps. If the incinerator is equipped with an induced draft fan, the fan shall be capable of being restarted independently of the other equipment on the incinerator.

6.3 The control equipment shall be so designed that any failure of the following equipment will prevent continued operations and cause the fuel supply to be cut off.

6.3.1 *Safety Thermostat/Draft Failure*:

6.3.1.1 A flue gas temperature controller, with a sensor placed in the flue gas duct, shall be provided that will shut down the burner if the flue gas temperature exceeds the temperature set by the manufacturer for the specific design.

6.3.1.2 A combustion temperature controller, with a sensor placed in the combustion chamber, shall be provided that will shut down the burner if the combustion chamber temperature exceeds the maximum temperature.

6.3.1.3 A negative pressure switch shall be provided to monitor the draft and the negative pressure in the combustion chamber. The purpose of this negative pressure switch is to ensure that there is sufficient draft in the incinerator during operations. The circuit to the program relay for the burner shall be opened and an alarm activated before the negative pressure rises to atmospheric pressure. This is applicable to incinerators fitted with induced draft fans.

6.3.2 *Flame Failure/Fuel Oil Pressure*:

6.3.2.1 The incinerator shall have a flame safeguard control consisting of a flame-sensing element and associated equipment for shut down of the unit in the event of ignition failure and flame failure during the firing cycle. The flame safeguard control shall be so designed that the failure of any component will cause a safety shutdown and prevent automatic restarting.

6.3.2.2 The flame safeguard control shall be capable of closing the fuel valves in not more than 4 s after a flame failure.

6.3.2.3 The flame safeguard control shall provide a trial-for-ignition period of not more than 10 s during which fuel may be supplied to establish flame. If flame is not established within 10 s, the fuel supply to the burners shall be immediately shut off automatically. Where a light oil pilot is used, the flame safeguard control shall provide a trial-for-ignition period for the pilot of not more than 10 s. If flame is not established within 10 s, the fuel supply to the pilot shall be immediately shut off automatically.

6.3.2.4 Whenever the flame safeguard control has operated because of failure of ignition, flame failure, or failure of any component, manual reset of the flame safeguard control shall be required for restart.

6.3.2.5 Flame safeguard controls of the thermostatic type, such as stack switches and pyrostats operated by means of an open bimetallic helix, are prohibited.

6.3.2.6 If fuel oil pressure drops below that set by the manufacturer, a failure and lock out of the program relay shall result. This also applies to a sludge oil burner. (Applies where pressure is important for the combustion process or where a pump is not an integral part of the burner.)

6.3.3 *Motor Overload*—All motors shall be protected in all phases by a thermal overload relay or circuit breaker with thermal overload protection which must be reset manually (see 4.12.3.3).

6.3.4 If there is a loss of power to the incinerator control/alarm panel (not remote alarm panel), the system shall shut down.

6.4 *Fuel Supply*—Two fuel control solenoid valves shall be provided in series in the fuel supply line to each burner. On multiple burner units, a valve on the main fuel supply line and a valve at each burner will satisfy this requirement. The valves shall be connected electrically in parallel so that both operate simultaneously.

6.5 *Alarms*:

6.5.1 When a failure occurs, an audible alarm shall be automatically sounded. A visible indicator shall show what caused the failure. (Alarm may be provided by the user and indicator may cover more than one fault condition.)

6.5.2 Means shall be provided to silence the audible alarm. The visible indicators shall be designed so that, where failure is a safety related shutdown, manual reset is required.

6.6 After shutdown of the oil burner, the exhaust fan or ejector must continue to run until the fire box has cooled sufficiently. This does not apply in the case of an emergency manual trip.

7. Other Requirements

7.1 *Documentation*—A complete instruction and maintenance manual with drawings, electric diagrams, spare parts list, and so forth shall be furnished with each incinerator.

7.2 *Installation*—All devices and components shall, as fitted in the ship, be designed to operate when the ship is upright and when inclined at any angle of list up to and including 15° either way under static conditions and 22.5° under dynamic conditions (rolling) either way and simultaneously inclined dynamically (pitching) 7.5° by bow or stern.

7.3 *Incinerator*:

7.3.1 Incinerators are to be fitted with a pilot burner with sufficient energy to ensure a safe ignition and combustion. The combustion is to take place at sufficient negative pressure in the combustion chamber(s) to ensure no gases or smoke leaking out to the surrounding areas (see 6.3.1.3).

7.3.2 A driptray is to be fitted under each burner and under any pumps, strainers, and so forth that require occasional examination.

8. Tests

8.1 *Prototype Tests*—An operating test for the prototype of each design shall be conducted, with a test report completed indicating results of all tests. The tests shall be conducted to ensure that all of the control components have been properly installed and that all parts of the incinerator, including controls and safety devices, are in satisfactory operating condition. Tests shall include those described in8.3.

8.2 *Factory Tests*—For each unit, if preassembled, an operating test shall be conducted to ensure that all of the control components have been properly installed and that all parts of the incinerator, including controls and safety devices, are in satisfactory operating condition. Tests shall include those described in 8.3.

8.3 *Installation Tests*—An operating test after installation shall be conducted to ensure that all of the control components have been properly installed and that all parts of the incinerator, including controls and safety devices, are in satisfactory operating condition. The requirements for prepurge and time between restarts referred to in 5.1 shall be verified at the time of the installation test.

8.3.1 *Flame Safeguard*—The operation of the flame safeguard system shall be verified by causing flame and ignition failures. Operation of the audible alarm and visible indicator shall be verified. The shutdown times shall be verified.

8.3.2 *Limit Controls*—Shutdown as a result of the operation of the limit controls shall be verified.

8.3.2.1 *Oil Pressure Limit Control*—The lowering of the fuel oil pressure below the value required for safe combustion shall initiate a safety shutdown.

8.3.2.2 *Other Interlocks*—Other interlocks provided shall be tested for proper operation as specified by the unit manufacturer.

8.3.3 *Combustion Controls*—The combustion control shall be stable and operate smoothly.

8.3.4 *Programming Controls*—Programming controls shall be verified as controlling and cycling the unit in the intended manner. Proper prepurge, ignition, postpurge, and modulation shall be verified. A stopwatch shall be used for verifying intervals of time.

8.3.5 *Fuel Supply Controls*—The satisfactory operation of the two fuel control solenoid valves for all conditions of operation and shutdown shall be verified.

8.3.6 *Low-Voltage Test*—A low-voltage test shall be conducted on the incinerator unit to demonstrate satisfactorily that the fuel supply to the burners will be automatically shut off before an incinerator malfunction results from the reduced voltage.

8.3.7 *Switches*—All switches shall be tested to verify proper operation.

9. Inspections

9.1 The manufacturer shall afford the purchaser's inspector all reasonable facilities necessary to satisfy him that the material is being furnished in accordance with this specification. Inspection by the purchaser shall not interfere unnecessarily with the manufacturer's operations. All examinations and inspections shall be made at the place of manufacture, unless otherwise agreed upon.

10. Certification

10.1 Manufacturer's certification that an incinerator has been constructed in accordance with this specification shall be provided (by letter, certificate, or in the instruction manual).

11. Product Marking

11.1 Each incinerator shall be permanently marked indicating:

11.1.1 Manufacturer's name or trademark.

11.1.2 Style, type, model, or other manufacturer's designation for the incinerator.

11.1.3 Capacity to be indicated by net designed heat release of the incinerator in heat units per timed period; for example, British Thermal Units per hour, megajoules per hour, kilocalories per hour.

11.1.4 ASTM designation of this specification (F 1323).

12. Quality Assurance

12.1 Incinerators shall be designed, manufactured, and tested in a manner that ensures they meet the requirements of this specification.

12.2 The incinerator manufacturer shall maintain the production quality of the incinerators that are designed, tested, and marked in accordance with this specification. At no time shall an incinerator be sold with this standard designation that does not meet the requirements herein (see Certification).

APPENDIXES

(Nonmandatory Information)

X1. LOCATION REQUIREMENTS FOR INCINERATORS

X1.1 Incinerators for sludge oil may be installed in the engine room or in a separate room. Incinerators for garbage installed in the engine room should receive due attention to size and location of the incinerator. If the incinerator is installed in a separate room outside the engine room, bulkheads and decks of this room are to be A-class boundaries insulated in accordance with the requirements for Category A machinery spaces, as defined by SOLAS 1974, as amended in Chapter II-2, Regulation 3. This requirement shall apply regardless of the type of vessel construction used (that is, Methods IC, IIC, IIIC as defined in SOLAS II-2, Regulation 42) and regardless of whether the vessel is required to meet SOLAS or to be approved or certified by the cognizant government authority.

X1.2 On certified vessels or those meeting SOLAS, both fire detection and extinguishing systems must be approved by the cognizant government authority. Ventilation ducts shall be capable of being closed by means of fire dampers, controlled from outside the incinerator room, of sufficient construction to maintain the A-class boundary. Emergency stop of oil burner and oil-booster pumps shall also be arranged outside the room.

X1.3 Flue gas uptakes and surfaces of incinerators are not to be less than 500 mm from fuel, oil tanks, or accommodation bulkheads. Flue gas uptake and exhaust pipe are to be insulated and located well away from electrical installations and inflammable items. Exhaust pipes in the casing are to be led to the top of the funnel. Exhaust uptakes from incinerators, which are installed in separate rooms outside the engine room, are to be approved in each case.

X1.4 Incinerators and flue gas uptakes are to be located outside of hazardous areas as defined by the applicable rules.

X1.5 The flue lines of incinerating systems shall not open into the flues or exhaust lines of other equipment but must be arranged separately to the point of discharge.

X1.6 Garbage chutes shall comply with the same fire standards as incinerator rooms outside engine rooms.

X2. INCINERATORS INTEGRATED WITH HEAT RECOVERY UNITS

X2.1 The flue gas system, for incinerators in which the flue gas is led through a heat recovery unit (economizer), should be designed so that the incinerator can continue operation with the economizer coils dry. This may be accomplished with bypass dampers if needed.

X2.2 The incinerator unit should be equipped with a visual and audible alarm in case of loss of feed water.

X2.3 The gas side of the economizer should have equipment for proper cleaning. Sufficient access should be provided for adequate inspection of external heating surfaces.

X3. FLUE GAS TEMPERATURE

X3.1 When deciding upon the type of incinerator, consideration should be given as to what the flue gas temperature will be. The flue gas temperature can be a determining factor in the selection of materials for fabricating the stack. Special high-temperature material may be required for use in fabricating the stack when the flue gas temperatures exceed 775°F (413°C).

X4. DESIGN FOR FUTURE RETROFITS OF AIR EMISSION CONTROL EQUIPMENT

X4.1 Though not a requirement, it is recommended that incinerators be designed with an ability for future retrofits of air emission control equipment to accommodate emission standards for shipboard incinerators as they are developed.

X4.2 The Environmental Protection Agency (EPA) does not currently have emission standards for small shipboard incinerators as described in this specification. However, the EPA has indicated it intends to publish emission standards eventually. In addition, emission standards for state and local jurisdictions vary.

X4.3 Note that emission control equipment is unnecessary if the incinerator is only operated at sea, not in port or in coastal waters.

X5. SPARK ARRESTORS

X5.1 The incinerator should be so constructed or so equipped as not to permit from the exhaust the passage of spheres having a diameter larger than ½ in. (13.7 mm) nor block the passage of spheres having a diameter of less than ⅜ in. (9.5 mm).

X5.2 Means should be provided for securely attaching the spark arrestors to chimneys to provide adequate support and prevent movement of the arrestor.

X5.3 Means should be provided to replace spark screens.

CERTIFICATE

By Authority Of
THE UNITED STATES OF AMERICA
Legally Binding Document

By the Authority Vested By Part 5 of the United States Code § 552(a) and Part 1 of the Code of Regulations § 51 the attached document has been duly INCORPORATED BY REFERENCE and shall be considered legally binding upon all citizens and residents of the United States of America. ***HEED THIS NOTICE***: Criminal penalties may apply for noncompliance.

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Standard Test Method for
Air Cleaning Performance of a High-Efficiency Particulate Air Filter System[1]

1. Scope

1.1 This test method covers the procedure and equipment for measuring the penetration of test particles through high-efficiency particulate air (HEPA) filter systems using a laser aerosol spectrometer (LAS). This test method provides the capability of evaluating the overall effectiveness of HEPA filter systems consisting of one or two filter stages.

1.2 The aerosols used for testing have a heterodisperse size distribution in the submicrometer diameter range from 0.1 to 1.0 μm.

1.3 The purpose for conducting in-place filter testing by this test method is in the ability to determine penetration of multi-stage installations, without individual stage tests. Particle penetration as low as 10^{-8} can be measured by this test method. Also, the LAS provides a measure of penetration for discrete particle sizes.

1.4 Maximum penetration for an installed HEPA filter system is 5×10^{-4} for one filter stage, and 2.5×10^{-7} for two stages in series is recommended.

NOTE 1—Acceptance penetration criteria must be specified in the program, or owners specifications. The penetration criteria suggested in this test method is referenced in Ref (**1**).[2]

1.5 The values stated in SI units are to be regarded as the standard.

1.6 *This standard does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* Specific precautionary statements are given in Note 2.

2. Referenced Documents

2.1 *ASTM Standards:*

F 328 Practice for Determining Counting and Sizing Accuracy of an Airborne Particle Counter Using Near-Monodisperse Spherical Particulate Materials[3]

2.2 *Military Standard:*

MIL-STD 282 Military Standard Filter Units, Protective Clothing, Gas Mask Components, and Related Products: Performance Test Method[4]

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *diluter*—a device used to reduce the aerosol particle concentration to eliminate coincidence counting is in the LAS.

3.1.2 *dilution ratio*—the ratio of the undiluted aerosol particle concentration entering the diluter to the diluted portion of the particle concentration. Because diluters have inherent particle losses that may vary according to the particle size, the dilution ratio may not be constant with respect to size.

3.1.3 *laser aerosol spectrometer (LAS)*—a precision particle detector that allows single particle counting and sizing by the amount of scattered light from individual particles, where the signals can be grouped into categories corresponding to particle size.

3.1.4 *penetration*—the number of particles passing through the filter stage, to the number of particles challenging the upstream side of the filter stage. The penetration, or the challenge aerosol, may be associated for each particle size of interest.

4. Summary of Test Method

4.1 A challenge aerosol produced by Di(2-Ethylhexyl) Sebacate (DOS) or Di(2-Ethylhexyl) Phthalate (DOP) is injected upstream of the filter system and allowed to mix with the airstream. Using a LAS, samples of the aerosol are collected from the airstream through probes, both upstream and downstream of the filter system. With this test method, the penetration of the filter system can be calculated either as a function of particle size, or in a particular size of interest. Due to high particle concentrations that may be required to evaluate the performance of HEPA filter systems, it may become necessary to dilute the upstream sample to avoid errors due to coincidence counting by the LAS.

4.2 If a diluter is required, the diluter system is calibrated using lower particle counts of the same aerosol and using the LAS for the measurements (refer to Annex A1 for calibration).

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[1] This test method is under the jurisdiction of ASTM Committee D22 on Sampling and Analysis of Atmospheresand is the direct responsibility of Subcommittee D22.09on ISO TAG for ISO/TC 146.

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[2] The boldface numbers in parentheses refer to a list of references at the end of this standard.

[3] *Annual Book of ASTM Standards*, Vol 10.05.

[4] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

4.3 Heterodisperse submicrometer aerosols spanning the diameter range from 0.1 to 1.0 µm are used in the testing.

5. Significance and Use

5.1 This test method describes a procedure for determining the penetration of aerosols through a one- or twostage HEPA filter installation. Testing multiple filter stages as a single unit eliminates the need for: installation of auxiliary aerosol bypass ducts, installation of aerosol injection manifolds between filter stages, and entry of test personnel into contaminated areas. It provides for filter testing without interruption of plant processes and operation of ventilation systems.

5.2 The procedure is applicable for measuring penetrations requiring sensitivities to 0.1 µm.

5.3 A challenge concentration of 2.5×10^5 particles/cm^3(p/cm^3), is required for evaluation of one-filter stage, and 2×10^6 p/cm^3, or about 30 µg/L (assuming unit density), is required to properly evaluate a two-stage HEPA filter system as one unit.

5.4 This test method can determine the penetration of HEPA filters in the particle-size range from 0.1 to 0.2 µm where the greatest penetration of particles is likely to occur.

6. Apparatus

6.1 *LAS*[5]—The LAS is a particle detector for the purpose of sizing and counting single particles in a gas stream. Up to 3000 particles per second (p/s) can be counted with less than 10 % coincidence, or electronic loss at its maximum flow rate. The quantitative particle size distribution shall be a distribution by number, not mass, volume, or surface area.

6.2 The test aerosol should be in the diameter range from 0.1 to 1.0 µm.

6.3 The primary particle-size calibration of the LAS by the manufacturer shall be based on at least three sizes of monodisperse polystyrene latex spheres (PSLs), covering the dynamic range of the LAS. Calibration standards must be traceable to the National Institute of Standards and Technology (NIST).

6.4 Sample flow accuracy through the LAS of ±5 % is required, based on the manufacturer's specifications. (Refer to manufacturer's guide for altitude adjustments of the sample volume.)

6.5 The LAS must have the capability for producing a listing of the particle size distribution over the LAS range. A standard RS-232C interface signal for line printers, tape recorders, and computers is usually provided with the instrument.

6.6 For calibration aerosol having a median size two times the minimum detectable size of the LAS, the relative standard deviation of the particle size distribution indicated by the LAS, shall not be increased more than 10 % over the actual relative standard deviation of the calibration aerosol.

6.7 An aerosol diluter[6] is required to reduce the number of particles of the upstream sample to avoid significant coincidence counting losses in the LAS. The diluter must have minimum particle losses over the size range of interest and that the losses are constant with particle size. Calibration of the diluter is done with the LAS. The diluter calibration procedure is indicated in Annex A2. A schematic diagram of the diluter in calibration mode is shown in Fig. A2.1. The diluter calibration plot is presented in Fig. A2.2. A typical diluter with dimensions is illustrated in Fig. A2.3.

6.8 *Aerosol Generation*[7]—It is required that the generator produce a particle-size distribution covering the diameter range from 0.1 to 1.0 µm. It must have the capability of achieving up to 3000 p/s in gas streams when testing multiple-stage HEPA filter systems.

6.9 For streams where large volumes of aerosol are not required, an air-operated or small gas-thermal generator may be used.

6.10 Injection ports, or manifolds, must be provided for distributing the aerosol uniformly with the gas stream. Upstream and downstream probes are required to extract aerosol samples from inside the filter housing. The location of injection ports and sample collection probes or manifolds must be located in accordance with the requirements in Annex A3.

6.11 It is recommended that sample lines between the LAS, diluter, and the upstream and downstream probes be the same size and material, and the same length as practicable.

7. Reagent and Materials

7.1 *DOP or DOS*[8] is used as the liquid material to form test aerosols.

7.2 *Polystyrene Latex Spheres.*[9]

8. Calibration and Standardization

8.1 Perform the primary calibration of the LAS by the instrument manufacturer or by qualified personnel using acceptable standard methods in accordance with Ref (**2**). Perform calibrations at regular twelve-month intervals and following any repair or modification of the instrument. Place a label showing the due date of the next calibration on the instrument.

8.2 A check calibration by the operator is recommended periodically if the instrument is used continuously or is moved to a new test location requiring vehicle transportation or rough handling. The calibration check consists of testing the LAS with at least two sizes of PSLs. The LAS must correctly size the calibration aerosols and reproduce the spectral peak to within 0.05 µm. If the instrument cannot be adjusted to within those calibration limits, then it must be returned to the manufacturer for service and calibration. Annex A1 describes a procedure for calibration of the LAS.

8.3 *Aerosol Diluter*—It is recommended that the same aerosol used in the in-place testing be used for diluter calibration. If more than one dilution stage is required, each stage

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[5] Laser aerosol spectrometers are available from the following sources: Particle Measuring Systems, Inc., 1815 South 57th Court, Boulder, CO 80301, TSI Incorporated Particle Instruments Group, P.O. Box 64394, St. Paul, MN 55164, and Met One, Inc., 481 California Avenue, Grants Pass, OR 97526.

[6] Available from TSI Incorporated Particle Instrument Group, P.O. Box 64394 St. Paul, MN 55164.

[7] Aerosol generators are available from the following sources: Air Techniques Division of Hamilton Associates, Inc., Baltimore, MD 21207, Particle Measurements Systems, Inc., 1815 South 57th Court, Boulder, CO 80301 (Calibration), and Nuclear Consulting Services, Inc., P.O. Box 29151, Columbus, OH 43229.

[8] Di(2-Ethylhexyl) Phthalate (DOP) and Sebacate (DOS) are available from C.P. Hall Co., Chicago, IL 60635, and Nuclear Consulting Services, Inc., P.O. Box 29151, Columbus, OH 43229.

[9] Available from Duke Scientific Corp., Palo Alto, CA 94303.

must be calibrated independently. A procedure for calibration of the diluter using the LAS is outlined in Annex A2.

9. Procedure

9.1 An example of an in-place filter test system and sampling arrangement is illustrated in Fig. 1. Components include the gas-flow duct, filter housing with filters, the LAS, diluter, and aerosol generator.

9.2 *Aerosol Mixing Uniformity Tests*— Conduct these tests upon completion of initial installation and after any modifications or repair to the filter system. It is not required to conduct these tests each time the in-place test is performed. However, if aerosol mixing and sampling parameters are changed, then new air aerosol mixing uniformity tests are required. Refer to Annex A3 for procedure.

9.3 Measure the airflow of the test gas stream and the resistance across the filter stage following the procedure outlined in Annex A3.

9.4 Establish the arrangement of sample lines between the probes, the diluter, and LAS. Make the upstream and downstream sample lines as equal in length as practicable.

9.5 Because of expected low particle counts that can penetrate HEPA filter systems, it is necessary to measure the non-test particles in the gas stream to serve as background samples. With no aerosol generation and no sample dilution, use the LAS to sample the gas stream from the downstream sample probe only. Collect samples at this location for the same duration as will be required for the test aerosol. The background particle counts may vary depending on external leaks to the filter housing, but should not exceed 30 % of the expected test aerosol. If higher background particles are found than those suggested and if leaks in the filter housing are suspected, they must be plugged before testing can continue.

9.6 Generate the challenge aerosol at the suggested particle concentration, see 5.3.

NOTE 2—**Caution:** Avoid unnecessary loading of the filters by the test aerosols by injecting the aerosols only when ready to perform penetration measurements.

9.7 Collect samples from the upstream probe and establish the challenge particle count. This is accomplished by switching the sample line from the LAS to the diluter. Sampling periods are usually 20 s, refer to Annex A2.

9.8 Purge the sample collection system and zero the LAS before proceeding to the next step in the procedure. The purging procedure is described in A2.1.2 of Annex A2.

9.9 Accumulate two successive samples from the downstream location. Sampling time periods should be selected to yield net particle counts over background of at least 100. A10-min sampling period is usually sufficient. The difference between each set of samples shall not exceed 5 % of the larger count. If penetration of only one filter stage is being measured, shorter sampling times may be used because of higher particle counts. If significant penetration is experienced downstream of one-filter stage and coincidence counting is suspected in the LAS, then the diluter must be used in the sample line. See 6.1 and 6.7.)

10. Calculation

10.1 Calculate the penetration of the filter system for each discrete particle-size. The equation holds for each specific size particle diameter as:

$$P = \frac{C_d - C_b}{C_u D} \tag{1}$$

where:

P = penetration,

C_d = particle counts downstream,

C_b = particle counts of background,

C_u = particle counts upstream, and

D = dilution ratio.

10.2 To calculate the uncertainty of the upstream and downstream penetration measurements, a theoretical value was used in the following equation. The value is based on standard propagation-of-error techniques neglecting covariance terms and using Poisson statistics to estimate uncertainties. The equation is as follows:

$$CV_p = [(PNT_d)^{-1} + (D/(NT_u)) + CV_D^2]^{1/2} \tag{2}$$

where:

CV_p = coefficient of variation for penetration,

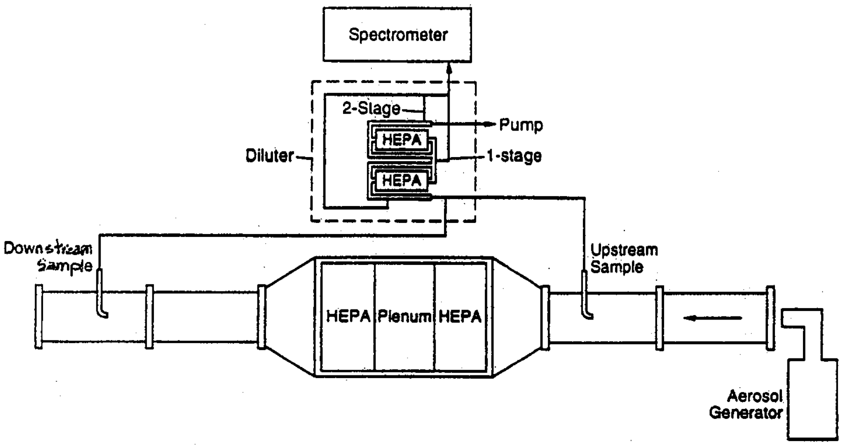

FIG. 1 Schematic Diagram of the In-Place Test Arrangement

P = aerosol number penetration,
N = undiluted upstream count rate, counts/s,
T_d = downstream counting time, s,
D = dilution ratio,
T_u = upstream counting time, s, and
CV_D = coefficient of variation for dilution ratio.

11. Report

11.1 The results of the testing shall contain, at a minimum, the following items:

11.2 Date of testing,

11.3 Identification of the filter system,

11.4 Penetration values, as a function of particle size,

11.5 The size for reporting the interval data may be either the minimum and maximum diameter for each interval or the geometric mean for the interval, and

11.6 Printed names and signatures of test personnel.

12. Precision and Bias

12.1 *Precision*—The precision of this test method for evaluating the air cleaning performance of a high efficiency particle air-filter system is being determined.

12.2 *Bias*—Since there is no reference material suitable for determining the bias for this test method, no statement on bias is being made.

13. Keywords

13.1 aerosol dilution; aerosol generator; average penetration; background particles; challenge aerosols; coincidence; compressed-air nebulizer; dilution ratio; fractional penetration; HEPA; laser aerosol spectrometer; test aerosols

ANNEXES

(Mandatory Information)

A1. LAS CALIBRATION

A1.1 The calibration procedure uses an aerosol having all particles of one size. Polystyrene latex spheres, (PSLs) are generated using a compressed-air nebulizer. The nebulizer is contained in a metal box with two chambers for diluting and drying the aerosol which contain an air-pressure regulator, dilution air control valve, and rotameter.

A1.2 A schematic view of the calibration generator is shown in Fig. A1.1. The aerosol generator must be connected to a compressed-air source that will allow the generator's pressure regulator to deliver 250 cm^3/s at standard temperature and pressure of air at 69-kPa pressure. The compressed-air source must not deliver any water droplets to the generator. If water is a concern, install a water trap before the generator. Connect the generator's output directly to sample inlet of the LAS. The nebulizer connects into a rubber stopper in the dilution chamber. The nebulizer has small internal passages for the air jet and the feed tube. These passages can become plugged if the PSL suspension is allowed to dry in the nebulizer. Upon completion of the calibration check, flush out the nebulizer with clean distilled water.

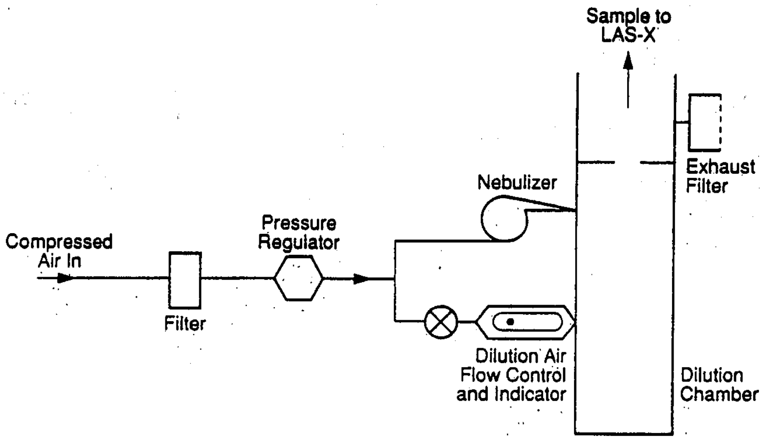

FIG. A1.1 Diagram of PSL Calibration Aerosol Generator

A2. DILUTER CALIBRATION

A2.1 The calibration of a diluter is very similar to that of the filter system penetration measurement. Refer to Fig. A2.1. However, generation of lower particle counts are required for the diluter calibration than for the actual penetration test. It is preferable, but not mandatory, to generate this aerosol in a flow system separate from the system housing of the in-place test to prevent unnecessary loading of the filters. If more than one diluter stage is required, each must be calibrated independently. An example of the diluter calibration plot is indicated in Fig. A2.2, Fig. A2.3. The diluter calibration procedure is as follows:

A2.1.1 Connect the diluter inlet to the flow system with a (HEPA-1) filter cartridge upstream of inlet duct and the diluter, and open Valves C and D. With this arrangement and no aerosol generation, accumulate a background sample with the LAS. Background particle counts are most likely due to leaks in the diluter system and must be eliminated before proceeding.

A2.1.2 Inject test aerosol upstream of the (HEPA-2) filter cartridge and allow a certain portion of the aerosol to bypass the filter by opening Valves A and B. Adjust Valve C to the desired dilution airflow in the diluter with the vacuum pump on. A typical dilution airflow of 250 cm^3/s and a ΔP across the capillary tube of 0.175 kPa are suggested for dilution ratios of 1200 to 1. Open Valve D and allow the LAS to sample the aerosol at the upstream side of the diluter to a level below which causes coincidence counting in the LAS (see 6.1). This sample arrangement establishes the challenge to the diluter. Position Valve D to purge and zero the LAS with filtered air (HEPA-3) before proceeding to the next section.

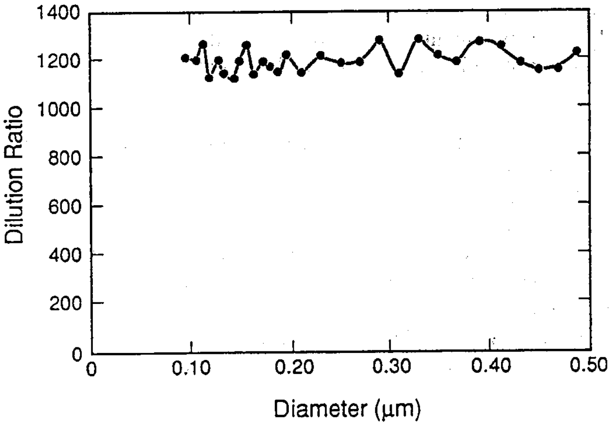

FIG. A2.2 Typical Aerosol Diluter Calibration Plot

A2.1.3 Position Valve D to sample the diluted aerosol at the downstream probe of the diluter and calculate the dilution ratio. The equation holds for each specific size particle diameter as:

$$D = \frac{C_u}{C_d} \tag{A2.1}$$

where:
D = dilution ratio,
C_u = upstream particle counts, and
C_d = downstream, or diluted particle counts.

A2.1.4 Only use the data for the particle size ranges where the dilution ratio remains constant and does not increase by more than 10 % for the overall distribution. Data for particles in sizes above and below that size are not to be used.

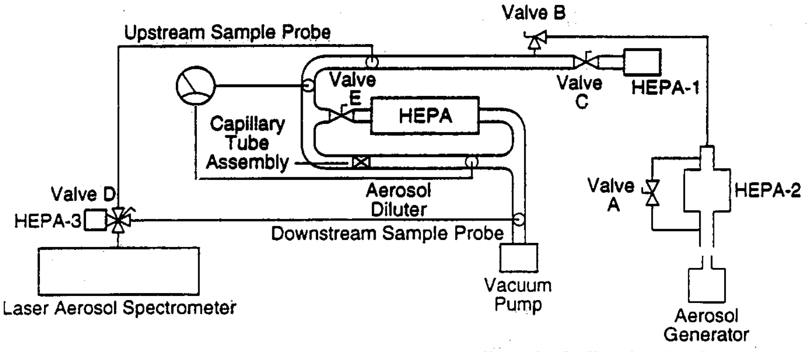

FIG. A2.1 Schematic Diagram of Aerosol Diluter in Calibration Mode

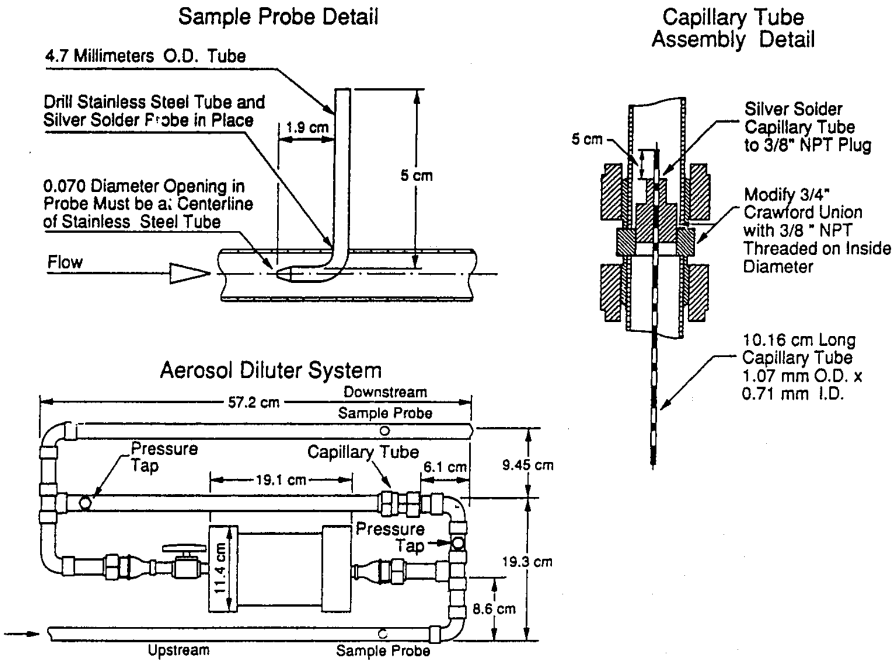

FIG. A2.3 Typical Aerosol Diluter with Dimensions

A3. AIRFLOW DISTRIBUTION AND AIR-TEST AGENT MIXING TESTS

A3.1 *Purpose*—Perform these tests to verify that the system design airflow is consistent with the fan furnished under actual field conditions at minimum and maximum filter pressure drop, and to verify that the airflow distribution across each HEPA filter stage is uniform at the design flow rates.

NOTE A3.1—These tests are to be performed only during acceptance or after extensive modification to the system, except for the airflow capacity and filter pressure drop test, that are required each time the in-place tests are performed.

A3.2 *Acceptance Criteria:*

A3.2.1 *Airflow Capacity Tests*—The system airflow shall be within ±10 % of the value specified in the test program or project specifications. Maximum housing component pressure drop airflows shall be ±10 % of the value specified in the test program or project specifications with the pressure drop greater than or equal to the maximum housing component pressure drop.

A3.2.2 *Airflow Distribution Tests*—No velocity readings shall exceed ±20 % of the calculated average. The minimum number of velocity measurements shall be one in the center of each filter. Make all measurements at equal distance away from the filters. It is recommended to conduct these measurements downstream of the filters to take advantage of the airflow distribution dampening effects of HEPA filters.

A3.2.3 *Air-Aerosol Mixing Uniformity Tests*—The purpose of this test is to verify that the challenge aerosol is introduced so as to provide uniform mixing in the airstream approaching the HEPA stage to be tested. When acceptable uniformity is achieved, an upstream sample taken in the same position that the uniformity data were obtained is defined as an acceptable single-point upstream sample. No reading shall exceed± 20 % of the calculated average reading.

APPENDIX

(Nonmandatory Information)

X1. RESULTS OF A ROUND-ROBIN TEST PROGRAM TO EVALUATE A MULTI-STAGE HEPA FILTER SYSTEM USING LASER AEROSOL SPECTROMETER (LAS)

X1.1 *Introduction:*

X1.1.1 The penetration of a two-stage high-efficiency particulate air HEPA filter system was measured by several laboratories using LASs. Single-stage HEPA filters are capable of removing 99.97 % for the particulate matter in air streams for particles having diameters greater than 0.3 µm. The purpose of this filter testing was to evaluate a new test method for determining the performance of two-stage HEPA filter systems. This test method involves challenge of the filters using an oil mist aerosol and subsequent measurements of aerosol penetration using a LAS. The current MIL-STD-282 standard applicable for single-stage filter systems measures the filter penetration at one particle size, approximately 0.3 µm in diameter, using a photometer-type detector. It requires that the challenge aerosol be 0.3 µm in diameter with a geometric standard deviation (σg) of 1.7 for testing. An existing method for in-place testing of HEPA filter systems, using a photometer for penetration measurements, specifies that 50 % of the aerosol be less than 0.7 µm with σg of 1.7. This test method places significant requirements on the test aerosol and yields little information about the dependence of penetration with particle size. The penetration measurements obtained by this test method depend on the challenge aerosol size distribution, the penetration of the filter, and the size response function of the photometer detector **(3)**.

X1.1.2 This test method presented here is an extension of the NE F3-4T **(4)** for in-place testing of HEPA filter systems for the Department of Energy nuclear industry. The main advantages of this test method are increased detection sensitivity, capability to measure the aerosol size distribution, and less required control over the challenge aerosol distribution. The increased sensitivity, achieved by the use of the LAS, allows multi-stage filter systems to be evaluated as a single unit.

X1.1.3 Penetrations as small as 4×10^{-8} can be measured. The typical photometer detector does not have the required sensitivity to measure such low penetrations. Using the LAS, both the challenge and penetrating aerosol size distributions can be measured down to 0.1 µm in diameter. More recent models extend this minimum size to 0.07 µm. With the additional size information, the filter penetration can be calculated either as a function of particle size or in a particular size of interest. This test method can determine the filter penetration of HEPA filters in the particle-size range from 0.1 to 0.2 µm where the greatest penetration is likely to occur. The only requirement on the challenge aerosol is that it lie in the range where the penetration is to be evaluated. Exact specification of its median diameter and standard deviation is not required.

X1.1.4 A major disadvantage to the LAS method is that the detection of aerosols of high concentration is subject to errors due to particle counting coincidence in the LAS. Coincidence errors are avoided by proper dilution of the challenge aerosol prior to sampling.

X1.1.5 This test method can also be used to evaluate the performance of single-stage filter systems. In these cases, lower concentrations of challenge aerosol can be used for testing than in the case of evaluations using the photometer detector.

X1.1.6 In the round-robin tests (RRT) reported here, a two-stage HEPA filter system was challenged with a heterodisperse oil mist aerosol having geometric median diameters ranging from 0.15 to 0.25 µm with a geometric standard deviation of 1.35 to 1.5. The measurements were accomplished with a LAS capable of counting and sizing particles with a 0.1 to 1.0-µm diameter. This test method describes the filtration system, the procedure used to determine penetration, and comparisons of results from the inter-laboratory evaluations.

X1.2 *Experimental Method:*

X1.2.1 The RRT filter system is illustrated in Fig. X1.1. Components included the gas stream flow duct with filters, the aerosol generator, the LAS, aerosol diluter, and pressure loss gages. Major steps associated with penetration measurements included, measuring the background downstream of the second filter stage, and particle-size distribution upstream and downstream of the filters. The test apparatus is designed to evaluate the performance of two standard 60 by 60 by 30-cm HEPA filters in series at 0.47-m^3/s airflow. For the purpose of testing by participating laboratories, upstream and downstream sample probes were each located in a removable 25-cm diameter duct. The upstream sample probe is located approximately eight duct diameters downstream of the aerosol injection position. The downstream sample probe is located eight duct diameters downstream from the second HEPA filter. These distances allow adequate mixing of the aerosol prior to sample extraction.

X1.2.2 The test aerosol was introduced into the duct at approximately eight duct diameters upstream of the sample probe. Aerosol generators used include the Air Techniques Inc., Model No. TDA-5A,[10] as well as modified Air Techniques thermal generators. All laboratories used Di(2-Ethylhexyl) Sebacate (DEHS) to produce the oil mist aerosol. The generators were capable of producing number concentrations in air of 2×10^{6} particles/cm^3(p/cm^3), or about 30 µg/L assuming unit density. High aerosol concentrations must be used so that the aerosol penetrating the dual HEPA system is greater than any background aerosol that may be leaking into the test duct after the second filter. The high concentration also allows the penetration measurements to be made in a reasonable amount

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[10] Available from Air Techniques Division of Hamilton Associates, Inc., Baltimore, MD 21207.

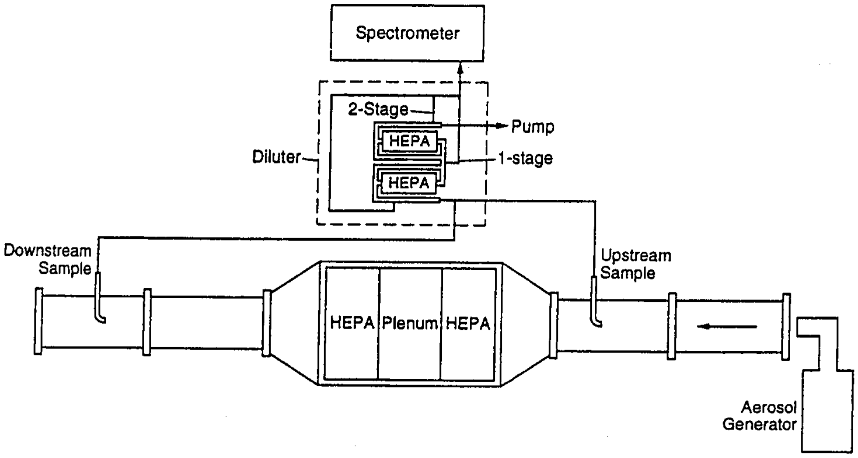

FIG. X1.1 Round-Robin Test Apparatus

of time. For example, with an upstream concentration of 2.5×10^{6} p/cm^3, a filter penetration of 4×10^{-8}, a LAS sample rate of 1.6 cm^3/s, and a downstream sample time of 600 s is required to accumulate 100 particle counts.

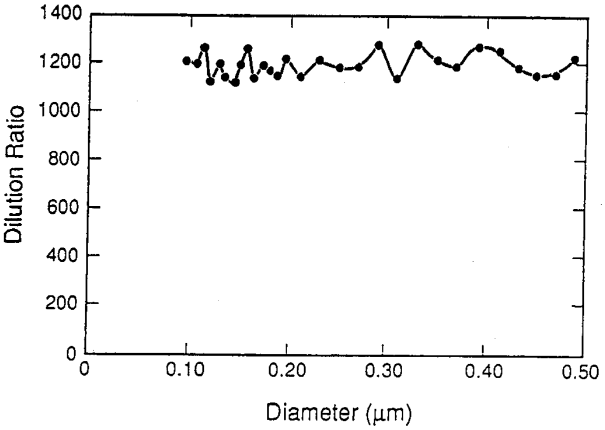

FIG. X1.2 Single-Stage Dilution Ratio, Laboratory 1

X1.2.3 Because of the high aerosol concentration used to challenge the filter system, the upstream aerosol sample must be diluted to prevent particle counting coincidence in the LAS. Particle count rates of greater than 3000 p/s must be avoided to prevent errors due to coincidence. Typically, aerosol dilution ratios of 1000 to 5000 are required. It is desirable that the diluter have minimum particle losses over the size range of interest and that those losses are constant with particle size. Calibration of the diluters can be done with the LAS using a reduced concentration of the same aerosol that is used in testing the filters. The diluter provided with the filter system allowed for either a one- or two-stage dilution. Each stage consisted of a capillary tube that allows a portion of the aerosol to pass while the rest of the air is filtered through a HEPA filter in parallel. A filtered dilution air flow of 250 cm^3/s was provided by an auxiliary pump. Dilutions of about 1000 to 1 can be achieved with a single stage. An example of a diluter calibration plot is shown in Fig. X1.2. The dilution ratio is nearly constant over the size range from 0.1 to 0.5 µm in diameter.

X1.2.4 Most of the testing was performed with the filter test apparatus under a negative pressure, that is with the air blower downstream of the filter unit. Because of this negative pressure, non-test particles can leak into the ducting from outside ambient environment. Since the concentration of test particles penetrating the filters is very low, it is necessary to ascertain the concentration of non-test particles in the system. This non-test or background concentration measurements is performed without aerosol generation and sampling with the LAS from the downstream probe. Sampling is maintained for the same time period as for the downstream aerosol test. It is desirable that the net downstream particle counts (downstream counts less background counts) be at least 100. Also, two successive sample accumulations are recommended and the difference of the two should not exceed 5 % of the larger count.

X1.2.5 The LASs used for the comparisons are capable of counting and sizing test aerosol particles from 0.1 to 1 µm in diameter. This range is adequate to determine the diameter at which maximum penetration occurs through HEPA filters at these flow conditions. The LASs used in the RRT included the Particle Measurement System 64-channel LAS-X model[5] for Laboratories 1 and 3, and a 32-channel ASASP-X for Laboratory 2. The LAS detects aerosol by the amount of scattered light from individual particles and sizes them by pulse height discrimination of the pulses. The LASs calibrated prior to the experiments, used monodisperse aerosol of polystyrene latex spheres (PSL). Minimum detectable sizes were between 0.09 to 0.11 µm in diameter. The LAS's calibrations using PSLs are presented in Fig. X1.3. The smallest sphere used during the calibration were within twice the lowest detectable size of the LAS. The LAS sampling rates ranged from 1.5 to 2 cm^3/s.

X1.2.6 In addition to slight differences in the aerosol generation and particle detection instrumentation used by each laboratory, there were some additional differences in the performance of testing by the laboratories. The dilution system provided with the filter system was inoperable at Laboratory 2 due to damage during shipment. Laboratory 2 testing was

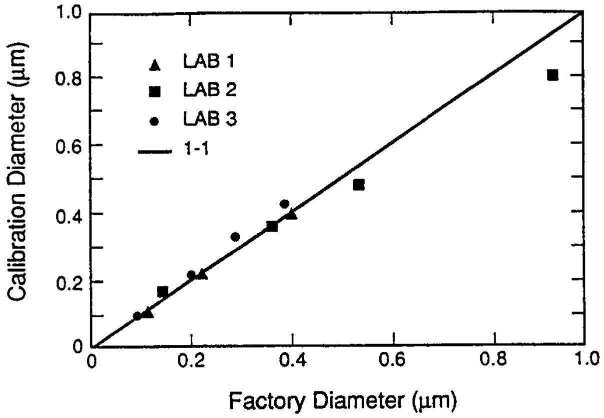

FIG. X1.3 LAS Calibration Using PSLs

accomplished with another two-stage aerosol diluter. The original filters in the system were first evaluated by Laboratories 1 and 2. When the filter system arrived at Laboratory 3, it was determined that the differential pressure across the filters was above the recommended level, therefore requiring filter replacement. The new set of filters were above the recommended change level of 0.14 kPa, therefore requiring filter replacement. The new set of filters in the RRT were tested by Laboratories 1 and 3. Laboratory 1 testing is denoted as "#1" for the first series of tests and "#2" after the filter replacement, respectively. Furthermore, some tests were performed in a pressurized operating mode by Laboratory 2 with the blower placed upstream of the system. The slight positive pressure in the system guaranteed that the penetrating particles are test particles.

X1.2.7 Calculate the penetration of the filter system for each discrete particle diameter. The equation holds for each specific particle diameter as follows:

$$P = \frac{C_d - C_b}{C_u D} \tag{X1.1}$$

and the coefficient of variation as:

$$\frac{\Delta P}{P} = \sqrt{\frac{1}{N_u} + \frac{(C_d + C_b)}{(C_d - C_b)^2} + \left(\frac{\Delta D}{D}\right)^2} \tag{X1.2}$$

where:

C_u = upstream concentration measured by LAS,
C_d = downstream concentration measured by LAS,
C_b = background concentration measured by LAS,
N_u = upstream particle counts,
D = dilution ratio,
ΔD = standard deviation for D, and
ΔP = standard deviation for P.

X1.2.7.1 N_u, ΔP, and ΔD are also functions of particle diameter. Error for the LAS sample volume and filter flow rate is not included in the expression for the coefficient of variation.

X1.3 *Results:*

X1.3.1 Table X1.1 lists a summary of the challenge aerosol characteristics and LAS sampling conditions for each series of tests. Four to seven penetration measurements were performed in each test series. The challenge aerosol count median diameters ranged from 0.15 to 0.25 µm and geometric standard deviation from 1.35 to 1.5. In a few tests the upstream particle concentration was somewhat less than the desired 2×10^{6} p/cm^3.

X1.3.2 A comparison between Laboratory 1 and Laboratory 3 penetration results across the two-stage filter system is shown in Fig. X1.4. Penetration results presented are the average of six tests for Laboratory 1 and nine tests for Laboratory 2. The Laboratory 2 results are the average of both positive and negative pressure testing. Very good agreement in penetration values were achieved for diameters greater than 0.2 µm. The maximum penetrations are 3.7×10^{-7} and 3.1×10^{-7} for Laboratory 1 and Laboratory 2, respectively. The diameter at which the maximum penetration occurs is approximately 0.17 µm in both cases. Previous investigators have found the diameter of maximum penetration to be between 0.1 to 0.2 µm for single-stage HEPA filters **(1, 6, 7)**. The competing particle capture mechanisms, diffusion, interception and impaction, cause the maximum in the penetration-size relation. The MIL-STD 282 acceptance criteria using the dioctyl phthalate 0.3-µm diameter aerosol with photometer detection is an efficiency of at least 99.97 % for HEPA filter media. The extrapolated penetration for a two-stage filter system, 9×10^{-8}, has been indicated at a diameter of 0.3 µm. It compares favorably with the penetration results from the LAS method.

X1.3.3 In Fig. X1.5 the same data is presented with bounds of ±1 standard deviation for each of the data sets at each particle size. The average penetration of each laboratory essentially lies within these bounds for the other. Differences in penetration are not statistically significant. Standard deviations

TABLE X1.1 Summary of Challenge Aerosol Characteristics and LAS Operation

Participants	Challenge Aerosol		Concentration	Particle counts/s	Dilution Ratio
	CMD (µm)[A]	σg	(10^6 p/cm^3)		
Laboratory 1, Set 1	0.147±0.008	1.45±0.03	2.2 to 4.0	1800 to 3500	1 200
Laboratory 2 Pos[B]	0.213±0.02	1.44±0.02	0.5 to 2.3	300 to 6000	1 000 to 10 000
Laboratory 2 Neg	0.254±0.002	1.46±0.004	2.7 to 4.3	600 to 1500	5 000 to 7 000
Laboratory 3	0.190±0.008	1.50±0.02	0.5 to 4.0	800 to 1300	1 500 to 40 000
Laboratory 1, Set 2	0.164±0.005	1.37±0.04	1.0 to 1.5	600 to 2500	1 000

[A] CMD = count medium diameter as measured by the LAS based on calibrations with PSLs.
[B] This test was conducted with the fan on the upstream side of the RRT filter system.

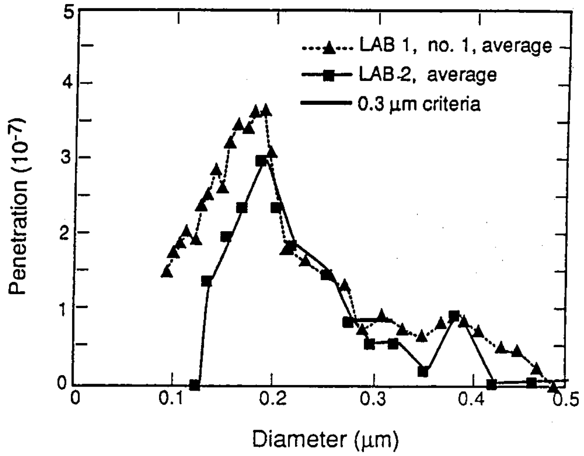

FIG. X1.4 Penetration Results, Laboratories 1 and 2, Two-Stage HEPA Filtration System

reported are about 30 to 60 % at diameter of maximum penetration. These can be explained in large part due to the low particle counts in each of the diameter ranges. Significant error in penetration can also be encountered due to errors in face velocity. An example of the magnitude of this error, as predicted by filtration theory, is presented in Fig. X1.6. At a face velocity of 2 cm/s, a variation of ±5 % in velocity can have associated errors of 30 to 40 % in penetration at the size of maximum penetration. In the current RRT, the method of flow measurements was left up to the participants.

X1.3.4 The comparison of measured penetration with the second set of filters is presented in Fig. X1.7. Higher penetrations were measured by Laboratory 3 for all particle sizes. Only the first test for Laboratory 3 is shown since the pressure drop across the single filter stage increased to 0.75 kPa as the test progressed. The penetration results for Laboratory 1 and 2 are an average of seven tests. The average results do not significantly differ from the Laboratory 3 test results.

X1.3.5 The penetration measurements made under positive and negative operating modes are compared in Fig. X1.9. The average of maximum penetrations are 2.4×10^{-7} and 4.0×10^{-7} for the positive and negative operation, respectively. However, the differences are not significant. Positive operation resulted in near zero background counts with downstream/background count ratios ranging from 30 to 300. Corresponding negative ratios range from 1.2 to 10. Even with considerable amount of background particle accumulation, credible penetration measurements can be made.

X1.3.6 In Fig. X1.8 two sets of average penetration data are compared with the single filtration theory. The theory includes the classical diffusion capture and the interception mechanisms according to Lee and Liu.

X1.4 *Discussion:*

X1.4.1 Using the LAS filter test method, filter systems having penetrations of 10^{-8} to 10^{-5} can be measured. The size of maximum penetration ranged from 0.12 to 0.18 µm in diameter. This is in agreement with both filtration theory and experimental measurements made on single-stage HEPA filter system. Penetration measurements can be achieved in a reasonable length of time and in the presence of aerosol leakage into the system from the external environment.

X1.4.2 The current RRT has indicated that it is feasible to perform penetration measurements on a 0.47-m^3/s rated airflow, two-stage HEPA filter system. It is desirable that future RRT involve a greater number of participants and a common measurement instrumentation. Possible additions to this test method should include specification of the diluter system purge times and a tolerance on the variation in the challenge concentration during testing. The LAS filter test method should continue to be pursued as a viable method for evaluating the performance of HEPA filters in-place having penetrations as low as 10^{-8}.

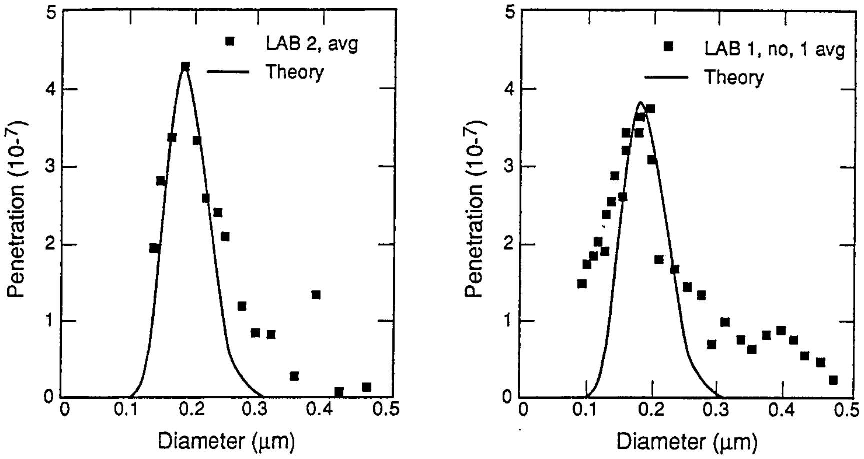

FIG. X1.8 Two Sets of Average Penetration Are Compared With the Single-Filter Filtration Theory

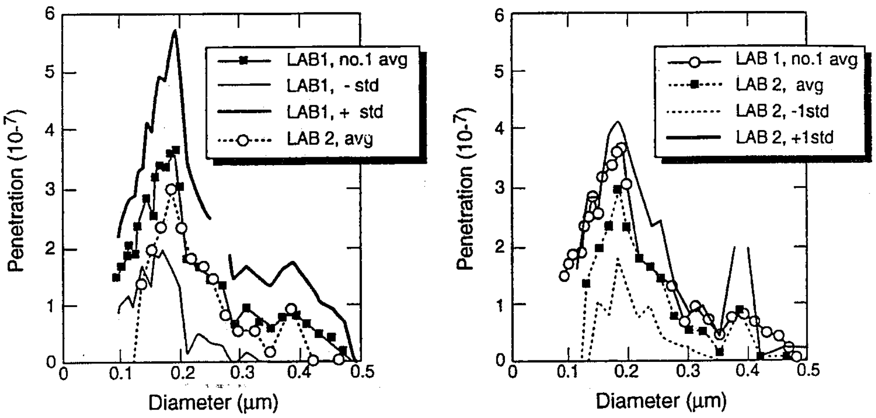

FIG. X1.5 A Plot Showing Average Penetration Measurements for Laboratories 1 and 2 Including Standard Deviation

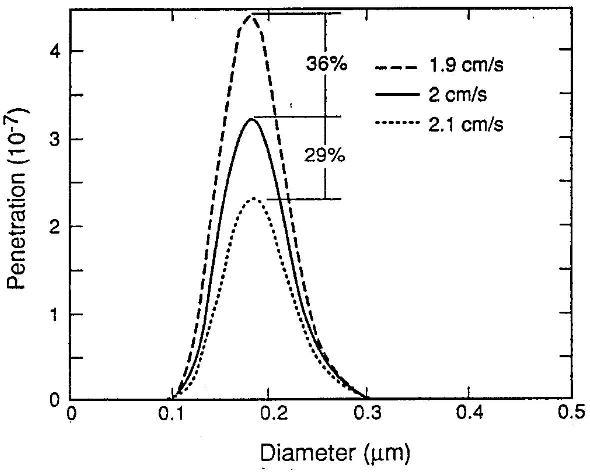

FIG. X1.6 Example of the Magnitude of This Error as Predicated by Filtration Theory

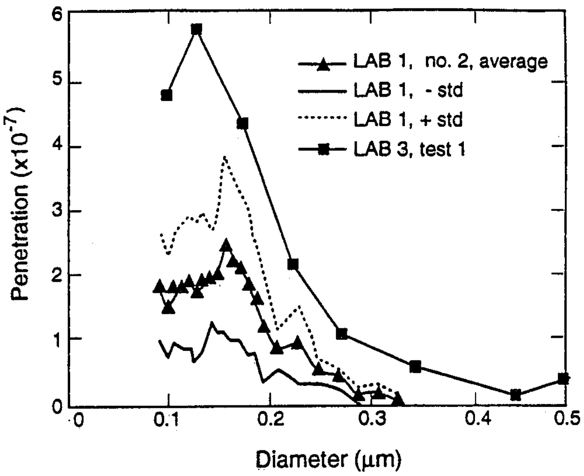

FIG. X1.7 Comparison of Measured Penetration With Second Set of Filters

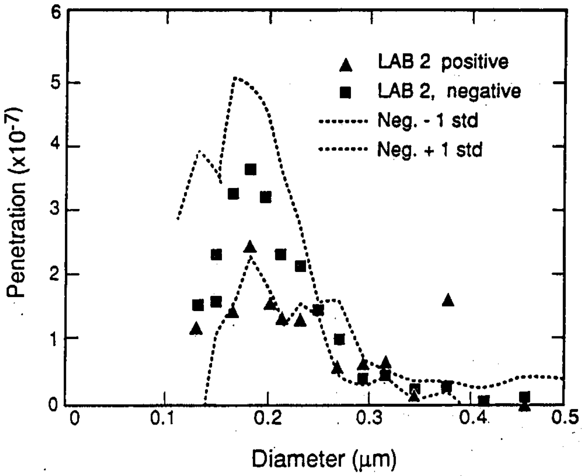

FIG. X1.9 Penetration Measurements Under Positive and Negative Operating Modes

REFERENCES

(1) *Nuclear Air Cleaning Handbook*, ERDA 76-21, National Technical Information Service, U.S. Department of Commerce, Springfield, VA 22161.

(2) *The Coefficient of Variation for Filter Penetration, ASTM STP 975*, ASTM, Philadelphia, PA, October 1986.

(3) Bierman, A. H., and Bergman, W., "Filter Penetration Measurements Using the Condensation Nucleus Counter and the Aerosol Photometer," *Journal of Aerosol Science*, Vol 19, No. 4, 1988, pp. 471–483.

(4) NE F3-41T, "In-Place Testing of HEPA Filter System by the Single-Particle, Particle-Size Spectrometer Method," U.S. Department of Energy, December 1986.

(5) Bergman, W., Biermann, A., Kahl, W., Lum, B., Bogdanoff, A., Hebard., H., Hall, M., Banks, D., Mazumber, M., and Johnson, J., "Electric Air Filtration: Theory Laboratory Studies, Hardware Development, and Field Evaluations," UCID-19952, Lawrence Livermore National Laboratory, 1983.

(6) Scripsick, R. C., Smitherman, R. L., and McNabb, S. A.," Operational Evaluation of the High Flow Alternative Filter Test System," *Proceedings of the 19th DOE/NRC Nuclear Air Cleaning Conference*, CONF-860820, May 1987.

(7) da Rosa, R. A., "Particle Size for Greatest Penetration of HEPA Filters and Their True Efficiency," UCRL-53311, Lawrence Livermore National Laboratory, 1982.

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Standard Specification for Fire Hose Nozzles[1]

This standard is issued under the fixed designation F 1546/F 1546M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers the design, manufacture and testing of fire hose nozzles intended for use with sea water or fresh water either in straight stream or adjustable spray patterns.

1.2 The values stated in SI units are to be regarded as the standard.

2. Referenced Documents

2.1 *ASTM Standards:*

A 313 Specification for Chromium-Nickel Stainless and Heat-Resisting Steel Spring Wire[2]

A 580/A 580M Specification for Stainless and Heat-Resisting Steel Wire[2]

A 582/A 582M Specification for Free-Machining Stainless and Heat-Resisting Steel Bars[3]

B 117 Practice for Salt Spray (Fog) Testing[4]

D 395 Test Methods for Rubber Property—Compression Set[5]

D 412 Test Methods for Vulcanized Rubber and Thermoplastic Rubbers and Thermoplastic Elastomers—Tension[5]

D 572 Test Method for Rubber Deterioration by Heat and Oxygen[5]

D 1193 Specification for Reagent Water[6]

2.2 *NFPA Standards:*

NFPA 1963 Standards for Screw Threads and Gaskets for Fire Hose Connections[7]

3. Terminology

3.1 *Definitions:*

3.1.1 *ball shut-off*—a spray nozzle configuration that stops the flow of water through the nozzle by rotating the ball through which the water flows so that the passage no longer aligns with the nozzle flow passage.

3.1.2 *break apart*—a feature that allows the nozzle tip to be disconnected from the nozzle body by virtue of a coupling identical to that on the hose end of the nozzle.

3.1.3 *constant flow rate spray nozzle*—an adjustable pattern nozzle in which the flow is delivered at a designed nozzle pressure. At the rated pressure, the nozzle will deliver a constant flow rate from straight stream through a wide angle pattern. This is accomplished by maintaining a constant orifice size during flow pattern adjustment.

3.1.4 *constant pressure (automatic) spray nozzle*—an adjustable pattern nozzle in which the pressure remains constant through a range of flows rates. The constant pressure provides the velocity for an effective stream reach at various flow rates. This is accomplished by means of a pressure-activated, self-adjusting orifice baffle.

3.1.5 *constant/select flow rate feature*—a nozzle feature that allows on-site adjustment of the orifice to change the flow rate to a predetermined value. The flow rate remains constant throughout the range of pattern selection from straight stream to wide angle spray.

3.1.6 *free swivel coupling*—a coupling between the nozzle and hose or between halves of a break-apart nozzle that is capable of being turned readily by hand; that is, a spanner wrench is not required to tighten the coupling to prevent leakage.

3.1.7 *flush*—a feature in a nozzle that allows the orifice to be opened so that small debris that might otherwise be trapped in the nozzle, causing pattern disruptions and flow variation, can pass through. When the flush feature is engaged, the nozzle pressure will drop and the pattern will deteriorate.

3.1.8 *lever-type control*—a control in which the handle operates along the axis of the nozzle.

3.1.9 *pistol grip*— a feature usually available as an attachment that allows a nozzle to be held like a pistol.

3.1.10 *rated pressure*—that pressure for which the nozzle is designed to operate at a specified flow rate(s).

3.1.11 *rotational-type control*—a control that rotates in a plane perpendicular to the axis of the nozzle.

4. Classification

4.1 Marine fire hose nozzles may be classified into four general construction types, as follows:

4.1.1 *Type I*—Pistol grip, lever-type control operated.

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[1] This specification is under the jurisdiction of ASTM Committee F-25 on Ships and Marine Technology and is the direct responsibility of Subcommittee F25.07 on General Requirements.

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[2] *Annual Book of ASTM Standards*, Vol 01.03.

[3] *Annual Book of ASTM Standards*, Vol 01.05.

[4] *Annual Book of ASTM Standards*, Vol 03.02.

[5] *Annual Book of ASTM Standards*, Vol 09.01.

[6] *Annual Book of ASTM Standards*, Vol 11.01.

[7] NFPA 1963 may be ordered by contacting the National Fire Protection Association, Batterymarch Park, Quincy, MA 02269.

4.1.2 *Type II*—Nonpistol grip, lever-type control operated.

4.1.3 *Type III*—Break apart, pistol grip, lever-type control operated.

4.1.4 *Type IV*—Break apart, nonpistol grip, lever-type control operated.

4.2 Nozzle types may be subdivided into three general classes, as follows:

4.2.1 *Class I*—Constant flow rate.

4.2.2 *Class II*—Constant/select flow rate.

4.2.3 *Class III*—Constant pressure.

4.3 Classes may be subdivided into two general sizes, as follows:

4.3.1 *Size 38 mm*, with free swivel base.

4.3.2 *Size 64 mm*, with free swivel base.

5. Ordering Information

5.1 The following shall be specified when ordering:

5.1.1 Quantity,

5.1.2 Type (see 4.1),

5.1.3 Class (see 4.2),

5.1.4 Size (see 4.3),

5.1.5 Material (see 6.1.2, 9.8.1 and 12)[8]

5.1.6 Thread type[9]

6. Material and Manufacture

6.1 *Materials*:

6.1.1 All nozzle components and parts must be durable and demonstrate satisfactory operation during all performance tests in Section 9.

6.1.2 The nozzle body and any metal used in the construction of any part of the nozzle shall be corrosion resistant. Copper alloys containing more than 15 % zinc are prohibited in all parts that are in contact with the fluid flow. No aluminum alloys may be used except for nozzles being operated exclusively with fresh water. No ferrous material may be used except for the Type 300 series stainless steel for wire and springs in accordance with Specifications A 313 or A 580/A 580M and for screws and pins in accordance with Specification A 582/A 582M.

6.1.3 All nonmetallic materials or synthetic elastomers used to form a seal or gasket shall have the following properties:

6.1.3.1 uniform dimensions,

6.1.3.2 be of such size, shape, and resiliency as to withstand ordinary usage and foreign matter carried by water, including petrochemical solvents and high alkaline solutions such as those used for cleaning nozzles (see 6.2), and

6.1.3.3 be able to withstand ozone and ultraviolet light exposure if used on the external portion of the nozzle.

6.1.4 All materials shall have tensile set of not more than 5 mm as determined in accordance with 6.2.1, and compression set not more than 15 % as determined in accordance with 6.2.2.

6.2 *Specific Requirements for Rubber Sealing Materials*:

6.2.1 *Tensile Strength, Ultimate Elongation, and Tensile Set Tests*:

6.2.1.1 Tensile strength, ultimate elongation, and tensile set shall be determined in accordance with Test Method D 412, Method A, except that, for tensile set determinations, the elongation shall be maintained for only 3 min, and the tensile set shall be measured 3 min after release of the specimen. The elongation of a specimen for a tensile set determination is to be such that the bench marks 25 mm apart become separated to a distance of 76 mm.

6.2.1.2 If a specimen breaks outside the bench marks, or if either the measured tensile strength or ultimate elongation of the specimen is less than the required value, an additional specimen shall be tested, and those results shall be considered final. Results of tests for specimens that break in the curved portion just outside the bench marks may be accepted if the measured strength and elongation values are within the minimum requirements.

6.2.2 *Compression Set Test*:

6.2.2.1 Type I specimens of the material shall be prepared and the test conducted in accordance with Test Methods D 395, Method B. The specimens shall be exposed for 22 h at 22°C.

6.2.3 *Accelerated Aging Test*:

6.2.3.1 Specimens shall be prepared in the same manner as for tensile strength and ultimate elongation and ultimate elongation tests, except for the bench marks 25 mm apart that shall be stamped on the specimen after the test exposure. The exposure shall be conducted in accordance with Test Method D 572.

6.2.3.2 All materials must retain not less than 70 % of the as-received tensile strength and ultimate elongation after the accelerated aging test.

6.2.4 Silicone rubber (rubber having polyorganosiloxane as its characteristic constituent) shall have a tensile strength of not less than 3.5 MPa and at least 100 % ultimate elongation as determined in accordance with 9.3.2.

6.2.5 Sealing material other than silicone rubber shall have a tensile strength of not less than 10 MPa and at least 200 % ultimate elongation as determined in accordance with 6.2.1.

7. Configuration

7.1 All nozzles shall consist of the following components and design:

7.1.1 Nozzle body

7.1.2 Free swivel coupling

7.1.3 Shutoffs

7.1.4 Shutoff seats

7.1.5 Shutoff handle

7.1.6 Bumper guard

7.1.7 Seals

7.1.8 Flushing feature

7.1.9 Pistol grip (optional)

7.1.10 Break apart feature (optional)

7.2 Nozzles shall be provided with a lever-type control shutoff handle which shall be in the closed position when the handle is closest to the discharge end of the nozzle. Lever-type control of the flow rate must also be by means of the shutoff handle.

7.2.1 The inside clearances of the shutoff handle shall be a minimum of 75 mm wide by 25 mm high.

7.2.2 The shutoff handle shall be of such a size that the

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[8] Nozzle material should be galvanically compatible with the intended fire hose couplings.

[9] Threads should conform to a recognized industry standard such as NFPA 1963.

operator's hand in a fireman's glove and closed on the handle does not interfere with the operation of the shutoff handle in any position.

7.3 Spray pattern adjustment shall be by means of rotational controls. Rotational controls shall traverse from a wide angle spray pattern to narrow angle, to straight stream in a clockwise manner when viewed from the hose coupling end of the nozzle. The wide and narrow angle spray patterns shall be enhanced with an impinging action by means of a minimum of one and a maximum of two rows of fixed or rotating teeth concentric to the discharge orifice.

7.4 Nozzles shall have a capability of clearing or flushing debris from the nozzle without shutting down the hose line. This may be accomplished either through the full open nozzle position or through a flush feature of the nozzle.

7.4.1 If used, the flush feature shall have a separate control, incorporate a detent, or shall required increased force to operate, to indicate to the firefighter when the flush feature is being engaged.

7.5 All features and controls shall be operable by one hand of the operator while the other hand is holding the nozzle.

7.6 A bumper shall be provided at the discharge end of the nozzle for protection against physical damage. The nozzle stem shall not extend past the bumper in any of the flow positions including flush.

7.7 The pistol grip, if one is provided, shall have four finger notches on the tip side and the minimum span and width shall be suitable for use with a hand wearing a typical fireman's glove.

7.8 Couplings shall be of a free swivel type.

7.9 Each nozzle shall be provided with a resilient gasket fitted in the nozzle coupling recess. The gasket shall have dimensions in accordance with NFPA 1963. Type III and IV nozzles shall incorporate an additional gasket to accommodate the break-apart feature.

7.10 Nozzles for use with 38-mm hoses shall weigh not more than 4.53 kg. Nozzles for use with 64-mm hoses shall weigh not more than 5.9 kg.

7.11 Shutoff seats shall be self-adjusting or shall be adjustable without disassembly of the nozzle.

7.12 All features which incorporate a stop, detent, separate control, or increased force to engage shall be clearly labeled, including the open and shutoff positions, pattern selection, and flow rate selection.

8. Workmanship, Finish and Appearance

8.1 All parts and assemblies of the nozzle including castings, forgings, molded parts, stampings, bearings, machined surfaces and welded parts shall be clean and free from sand, dirt, fins, pits, spurs, scale, flux, and other foreign material. All exposed edges shall be rounded or chamfered.

9. Design Qualification Tests

9.1 Four first production run specimens shall be randomly selected and subjected to the tests described in 9.3 through 9.13 in sequential order.

9.2 The specimens shall exhibit no permanent deformation that interferes with their proper operation during any test.

9.3 Nonmetallic components shall be subjected to the following specific testing:

9.3.1 *Aging Exposure*:

9.3.1.1 Aging tests shall be performed before all other tests identified in this standard.

9.3.1.2 The specimens shall be subjected to air-oven aging for 180 days at 70°C and then allowed to cool at least 24 h in air at 25°C and 50 % relative humidity.

9.3.1.3 At the conclusion of the test, the specimens shall be inspected and all functions shall be operated to ensure they operate properly. Cracking, crazing, or any other condition that interferes with the proper operation of any specimen shall constitute failure of this test.

9.3.2 *Ultraviolet Light-Water Exposure*:

9.3.2.1 Nozzle designs with exposed nonmetallic parts shall be subjected to ultraviolet light and water for 720 h.

9.3.2.2 The ultraviolet light shall be obtained from two stationary enclosed carbon-arc lamps. The arc of each lamp is to be formed between two vertical carbon electrodes, 13 mm in diameter, located at the center of a revolvable vertical cylinder, 787 mm in diameter and 450 mm in height. Each arc is to be enclosed with a number PX Pyrex-glass globe.

9.3.2.3 The water shall conform to Type IV water in Specification D 1193.

9.3.2.4 The specimens are to be mounted vertically on the inside of the revolvable cylinder, arcing the lamps, and the cylinder continuously revolved around the stationary lamps at 1 revolution per minute. A system is to be provided so that each specimen in turn is sprayed with water as the cylinder revolves. During the operating cycle, each specimen is to be exposed to the light and water spray for 3 min and the light only for 17 min (total 20 min). The air temperature within the revolving cylinder of the apparatus during operations is to be maintained at 65°C.

9.3.2.5 At the conclusion of the test, the specimens shall be inspected and all functions shall be operated to ensure they operate properly. Cracking, crazing, or any other condition which interferes with the proper operation of any specimen shall constitute failure of this test.

9.4 *Discharge Calibration Test*:

9.4.1 Constant flow rate specimens shall flow the rated discharge, plus 10 %, minus 0 %, measured at rated pressure, through the entire range of pattern setting from straight stream to wide angle spray.

9.4.2 Constant/select flow rate specimens shall flow the rated discharge, plus 10 %, minus 0 %, measured at rated pressure, for each flow rate selection through the entire range of pattern setting from straight stream to wide angle spray.

9.4.3 Constant flow rate specimens and select flow rate specimens are to be installed on a piezometer fitting of the same size as the nominal inlet thread size, attached to a calibrated laboratory quality flow meter, and supplied with a source of pressurized water. The water flow rate in liters per minute is to be recorded through the full range of pattern selection.

9.4.4 Constant pressure specimens shall be tested beginning with the minimum rated flow. The pressure at this flow shall be recorded. The flow rate and nozzle pressure shall be monitored through the entire range of pattern selection from straight stream to wide angle spray. Any deviation over 2 % in flow rate or pressure shall constitute failure of this test. The flow rate shall be slowly increased to the maximum rated flow while the pressure is monitored. At the maximum rated flow, the flow rate and pressure shall be monitored throughout the entire range of pattern selection. Any deviation over 2 % in flow rate or pressure shall constitute failure of this test.

9.5 *Flow Pattern Test*:

9.5.1 Specimens shall develop discharge flow patterns varying from straight stream to wide angle spray while maintaining either constant flow rate or constant pressure.

9.5.2 The straight stream pattern setting shall provide a cohesive jet capable of delivering 90 % of the rated flow within a circle 400 mm in diameter at a distance of 8 m from the nozzle.

9.5.3 The spray pattern settings shall provide a full and uniform spray pattern of small droplets, and the spray pattern adjustments shall provide spray pattern angles ranging from 25° for narrow angle spray through at least 120° for wide angle spray at maximum flow rate.

9.6 *Flushing Test*:

9.6.1 The specimens shall be held vertically, discharge end down, and the controls placed in the flush position. A 7-mm ball must pass through each specimen without changes in the control position. The inability to pass the test ball will be considered failure of this test.

9.7 *Control Tests*:

9.7.1 *Lever-type controls*:

9.7.1.1 Not more than 80 N nor less than 35 N shall be required to open or close the shutoff handle against a minimum of 700-kPa nozzle inlet pressure.

9.7.1.2 The specimens shall be mounted in the closed position and subjected to a static pressure of 700 kPa. A dynomometer, which records the maximum force reading, shall be attached to the shutoff handle, where the handle would normally be held during operation. The shutoff handle shall be moved from the fully closed to fully open position for the full range of pattern adjustment. The maximum force shall be recorded. Next, the specimens shall be placed in the full flowing position and the inlet pressure shall be adjusted to 700 kPa. With this new pressure adjustment, the dynomometer shall be used when moving the shutoff handle through the full range of positions and maximum force again measured and recorded. The maximum force recorded in both directions shall not be greater than permitted in 9.7.1.1.

9.7.1.3 The specimens shall be mounted without any water pressure being applied and the shutoff handle shall be placed in a closed position. The handle shall be moved from the closed position and the force required to move the handle shall be measured with the dynomometer. The force to move the handle shall not be less than permitted in 9.7.1.1.

9.7.2 *Rotational-type controls*:

9.7.2.1 Designs incorporating rotational controls shall have the torque required to rotate the sleeve determined while the specimen inlet pressure is 700 kPa.

9.7.2.2 A length of twine or string, not to exceed 2-mm diameter, shall be wrapped around each specimen at the point where each specimen would normally be held while rotating the sleeve. The string shall be of sufficient length to wrap around each specimen at least six turns. The first two turns will overlap the starting end of the string, and the balance of the turns will not overlap any other turn. A force gauge, which records the maximum force reading, will be attached to a loop in the free end of the string.

9.7.2.3 The sleeve shall be rotated by pulling the force gauge perpendicular to the center of the axis of each specimen. As the pattern sleeve rotates, the string will unwind, so that the force always remains tangential to the sleeve.

9.7.2.4 The sleeve shall be rotated in either direction through the entire range of rotation and the maximum torque shall be calculated. The torque shall not be more than 2 N-m nor less than 0.5 N-m.

9.7.2.5 Free swivel-type couplings shall be tested in accordance with 9.7.2.2 through 9.7.2.4. The force required to rotate each specimen once the swivel is tightened onto a coupling shall be at least 50 N not less than 5 N greater than the force required to rotate the specimen controls.

9.8 *Corrosion Exposure*:

9.8.1 This test is not required for aluminum nozzles because of the restriction on their use in fresh water service only.

9.8.2 The specimens shall be supported vertically and exposed to salt spray as specified by Test Method B 117, Salt Spray (Fog) Testing, for 120 h.

9.8.3 After completion of the salt spray test, all controls shall operate without sticking or binding. There shall be no evidence of galvanic corrosion between dissimilar metals. For metallic specimens, this test shall be conducted immediately after the tests specified in 9.7.

9.9 *High Temperature Test*:

9.9.1 The specimens are to be conditioned at 60°C for 24 h. Immediately after being removed from the heating chamber, the specimens shall be tested for proper function of all controls. There shall be no binding, sticking, or malfunction of any function.

9.9.2 Within 3 min of removal from the heating chamber, the specimens shall be subjected to the Rough Usage Test in 9.11.

9.10 *Low Temperature Test*:

9.10.1 The specimens are to be conditioned at −37°C for 24 h. Immediately after being removed from the cooling chamber, the specimens shall be tested for proper operation. There shall be no binding, sticking, or malfunction of any function.

9.10.2 Within 3 min of removal from the cooling chamber, the specimens shall be subjected to the Rough Usage Test in 9.11.

9.11 *Rough Usage Test*:

9.11.1 Two of the four specimens shall be connected to a dry hose and dropped twice from a height of 2 m onto a concrete surface such that the point of impact is on the lever and twice such that the point of impact is on a side 90° from the lever. The same two specimens shall then be dropped twice from a height of 600 mm such that the point of impact is squarely on the discharge end of the nozzle. The two other specimens shall be connected to a wet hose and placed in the shutoff position. The static pressure shall be increased to 700 kPa. The test from the 2-m height shall be repeated. Specimens equipped with pistol grips shall also be dropped twice while unconnected so that the point of contact is on the grip.

9.11.2 Following the drop test, the specimens shall be examined for cracking, breaking, and deformation that interferes with their proper operation. Specimens developing cracks or broken sections or failing to operate properly are considered failed.

9.11.3 Following the drop tests, the specimens shall be subjected to the Leakage Test and Hydrostatic Pressure Test in accordance with 9.12 and 9.13, respectively.

9.12 *Leakage Test*:

9.12.1 The leakage test shall be conducted during the Hydrostatic Pressure Test.

9.12.2 At the point during the Hydrostatic Pressure Test in which the hydrostatic pressure is the greater of 4000 kPa or 1½ times the rated pressure, the shutoff shall be fully opened and closed. After the shutoff has been closed, the leakage shall be measured and recorded. The maximum leakage allowed through the discharge orifice is ½ mL per min. There shall be no leakage through any part of the specimens other than the discharge orifice.

9.12.3 The leakage shall be measured and recorded again when the specimens are subjected to the final hydrostatic pressure in 9.13. Increases in leakage shall not exceed 1 mL per min.

9.13 *Hydrostatic Pressure Test*:

9.13.1 The specimens shall be rigidly mounted in a closed position. The static pressure shall be increased to 350 kPa and held for 30 s. The static pressure shall be increased in 350-kPa increments and held for 30 s at each pressure to a maximum static pressure of 7000 kPa. The final pressure shall be held for 1 min without rupture of any specimen.

9.14 *Operator Protection Test*:

9.14.1 Each specimen shall be coupled to a hose and rigidly mounted at a height of 1 m to the center of the specimen body. The specimen may be slightly inclined to simulate the typical position during normal use. The pressure shall be increased to an inlet pressure of 700 kPa. The water must be clear and clean, such as that from a municipal water supply.

9.14.2 A cross or grid on which to mount radiometers shall be positioned 300 mm directly behind the specimen body. The structure shall be perpendicular to the vertical plane of the specimen.

9.14.3 Radiometers shall be mounted on the structure at a distance of 600 mm above the specimen, 300 mm to the right, 300 mm to the left, and 300 mm below the specimen.

9.14.4 A heat source, such as a grid, tree, or framework of natural gas nozzles, shall be positioned directly in front of the specimen. The heat source must be located at a horizontal distance from the specimen so that it will not be cooled when operating the specimen wide angle spray pattern.

9.14.5 The heat source shall be operated to obtain a heat flux value of at least 26 kW/m^2 measured by the radiometers. The specimen shall be set to the wide angle flow pattern, opened, and tested for each rated flow. The heat flux shall be recorded for each radiometer and the average calculated.

9.14.6 The average heat flux obtained during each test must be 5.7 kW/m^2 or lower, and no individual heat flux value may be greater than 8.0 kW/m^2.

9.15 *Horizontal Distance*:

9.15.1 The specimens shall be coupled to a hose, rigidly mounted at a height of 1 m in the open position. The flow pressure shall be set at 350 kPa.

9.15.2 The specimens shall be placed in the straight stream position. The specimens may be inclined to achieve the maximum reach. For 38-mm designs, the horizontal distance from the nozzle orifice to the center of the water pattern at its furthest point shall be at least 18 m. For 64-mm designs, this distance shall be at least 24 m.

9.15.3 The test shall be repeated with the inlet pressure increased to 700 kPa. For 38-mm designs, the horizontal distance from the nozzle orifice to the center of the water pattern at its furthest point shall be at least 27 m. For 64-mm designs, this distance shall be at least 36 m.

10. Quality Conformance Testing

10.1 *Sampling for Quality Conformance Testing*:

10.1.1 A quantity of completed specimens in accordance with Table 1 shall be randomly selected from each lot and subjected to the Discharge Calibration Test, Flow Pattern Test, and Leakage Test described in 9.4, 9.5 and 9.12, respectively. The Leakage Test shall be conducted using the rated pressure and the maximum leakage allowed through the discharge orifice is ¼ mL per min. If one or more defects are found in any specimen, the entire lot represented by the specimen shall be considered failed. If a lot is considered failed, the entire lot may be screened for the defective characteristic(s).

11. Certification

11.1 When specified in the purchase order or contract, the purchaser shall be furnished certification that samples from each lot have been tested and inspected as directed in this specification and the requirements have been met. When specified in the purchase order or contract, a report of the test results shall be furnished.

12. Product Marking

12.1 In addition to markings required by any other section, the name of the manufacturer, the manufacturer's model number, the size (see 4.3), the thread type, and ASTM specification designation shall be marked on each nozzle. Furthermore, all nozzles manufactured with aluminum alloys shall be marked with the phrase "F.W. Only." All required markings, whether embossed or attached, shall be permanent and legible.

13. Keywords

13.1 fire hose; fire protection; marine; nozzle; ship; shipboard equipment

TABLE 1 Sampling for Quality Conformance Testing

Lot Size	Sample Size
2–8	All
9–300	10 %–8 minimum
Over 301	5 %–30 minimum

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Standard Specification for the Performance of Fittings for Use with Gasketed Mechanical Couplings Used in Piping Applications[1]

This standard is issued under the fixed designation F 1548 ; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification defines classification, materials, test requirements, inspection certification, marking and packaging of fittings for use with gasketed mechanical couplings complying to Specification F 1476.

2. Referenced Documents

NOTE 1—See Table 1 for equivalency listing of applicable, equivalent specifications.

2.1 *ASTM Specifications:*

A 47 Specification for Ferritic Maleable Iron Castings[2]
A 48 Specification for Gray Iron Castings[2]
A 53 Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated Welded and Seamless[3]
A 153 Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware[4]
A 216 Specification for Steel Castings, Carbon Suitable for Fusion for High-Temperature Service[2]
A 234 Specification for Piping Fittings of Wrought Carbon Steel and Alloy Steel for Moderate and Elevated Temperatures[3]
A 312 Specification for Seamless and Welded Austenitic Stainless Steel Pipe[3]
A 403 Specification for Wrought Austenitic Stainless Steel Piping Fittings[3]
A 536 Specification for Ductile Iron Castings[2]
A 743 Specification for Castings, Iron-Chromium, Iron-Chromium-Nickel, Corrosion-Resistant for General Application[2]
B 26 Specification for Aluminum-Alloy Sand Castings[5]
B 75 Specification for Seamless Copper Tube[6]
B 210 Specification for Aluminum and Aluminum-Alloy Drawn Seamless Tubes[5]
B 369 Specification for Copper-Nickel Alloy Castings[6]
B 584 Specification for Copper-Alloy Sand Castings for General Applications[6]
B 633 Specification for Electrodeposited Coatings of Zinc on Iron and Steel[7]
F 1476 Specification for the Performance of Gasketed Mechanical Couplings for Use in Piping Applications[8]

2.2 *ANSI Standards:*[9]

B36.10 Welded and Seamless Wrought Steel Pipe
B36.19 Stainless Steel Pipe

2.3 *ANSI/AWWA Standards:*[9]

C151/A21.51 Ductile-Iron Pipe, Centrifugally Cast in Metal Molds or Sand-Lined Molds, for Water and Other Liquids
C606-87 Grooved and Shouldered Joints

2.4 *Military Standards:*[10]

MIL-A-8625 Anodic Coatings, for Aluminum and Aluminum Alloys
MIL-T-704 Treatment and Painting of Material
MIL-STD-45662 Calibration System Requirements

2.5 *British Standards:*[11]

BS 729 Specification for Hot Dip Galvanized Coatings on Iron and Steel Articles
BS 1400 Specification for Copper Alloy Ingots and Copper Alloy and High Conductivity Copper Castings
BS 1452 Specification for Flake Graphite Cast Iron
BS 1471 Specification for Wrought Aluminum and Aluminum Alloys for General Engineering Purposes—Drawn Tube
BS 1490 Specification for Aluminum and Aluminum Alloy Ingots and Castings for General Engineering Purposes
BS 1640 Pt. 1 Wrought Carbon and Ferritic Alloy Steel Fittings
BS 1640 Pt. 2 Wrought and Cast Austenitic Chromium—Nickel Steel Fittings
BS 1706 Method for Specifying Electroplated Coatings of Zinc and Cadmium on Iron and Steel
BS 2871 Specification for Copper and Copper Alloys—Tubes
BS 3071 Specification for Nickel—Copper Alloy Castings
BS 3100 Specification for Steel Castings for General Engineering Purposes
BS 3600 Specification for Dimensions of Steel Pipe for the Petroleum Industry

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[1] This practice is under the jurisdiction of ASTM Committee F-25 on Ships and Marine Technology and is the direct responsibility of Subcommittee 25.13 on Piping Systems.

Current edition approved August 15, 1994. Published October 1994.

[2] *Annual Book of ASTM Standards*, Vol 01.02.

[3] *Annual Book of ASTM Standards*, Vol 01.01.

[4] *Annual Book of ASTM Standards*, Vol 01.06.

[5] *Annual Book of ASTM Standards*, Vol 02.02.

[6] *Annual Book of ASTM Standards*, Vol 02.01.

[7] *Annual Book of ASTM Standards*, Vol 02.05.

[8] *Annual Book of ASTM Standards*, Vol 01.07.

[9] Available from American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.

[10] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

[11] Available from British Standards Institution, 2 Park Street, London W1A 2BS.

TABLE 1 Specification Equivalency Table

Spec. Ref. Number	U.S. Designation ASTM	British Standard	ISO Standard
1	A 47	6681	5922
2	A 48	1452	—
3	A 53	3601	—
4	A 153	729	1459, 1460, 1461
5	A 216	3100	—
6	A 234	1640 Pt. 1	—
7	A 312	3605	—
8	A 403	1640 Pt. 2	—
9	A 536	4772	2531, 4179, 8179
10	A 743	3100	—
11	B 26	1490	3522, 7722
12	B 75	2871	—
13	B 210	1471	290
14	B 369	3071	—
15	B 584	1400	—
16	B 633	1706	2081
	ANSI		
17	B36.10	3600	4200
18	B36.19	3600	4200
	ANSI/AWWA		
19	C151/A21.51	4772	2531, 4179, 8179
20	C606	—	—
	MILITARY STANDARDS		
21	MIL-A-8625	—	—
22	MIL-T-704	—	—
23	MIL-STD-45662	5781	—

BS 3601 Specification for Carbon Steel Pipes and Tubes with Specified Room Temperature Properties for Pressure Purposes
BS 3605 Austenitic Stainless Steel Pipes and Tubes for Pressure Purposes
BS 4772 Specification for Ductile Iron Pipes and Fittings
BS 5781 Measurement and Calibration System
BS 6681 Specification for Malleable Cast Iron

2.6 *International Standards Organization:*[12]

209 Composition of Wrought Products of Aluminum and Aluminum Alloys . . . Chemical Composition (Percent)
1459 Metallic Coatings—Protection Against Corrosion by Hot Dip Galvanizing—Guiding Principles
1460 Metallic Coatings—Hot Dip Galvanized Coatings on Ferrous Materials—Determination of the Mass Per Unit Area—Gravimetric Method
1461 Metallic Coatings—Hot Dipped Galvanized Coatings on Fabricated Ferrous Products—Requirements
2081 Metallic Coatings—Electroplated Coatings of Zinc on Iron or Steel
2531 Ductile Iron Pipes, Fittings and Accessories for Pressure Pipe Lines
3522 Cast Aluminum Alloys—Chemical Composition and Mechanical Properties
4179 Ductile Iron Pipes for Pressure and Non-Pressure Pipelines—Centrifugal Cement Mortar Lining—General Requirements
4200 Plain End Steel Tubes, Welded and Seamless—General Tables of Dimensions and Masses Per Unit Length
5922 Malleable Cast Iron
7722 Aluminum Alloy Castings Produced by Gravity, Sand, or Chill Casting, or by Related Processes—General Conditions for Inspection and Delivery
8179 Ductile Iron Pipes—External Zinc Coating

3. Terminology

3.1 *Definitions:*

3.1.1 *fabricated fitting*—a fitting constructed by welding together sections of pipe or tube.

3.1.2 *fitting*—a device used in a piping system to change pipe direction, size, split or combine flows, or adapt to other joining methods.

3.1.3 *grooved end*—type of fitting or pipe end having a groove for use with grooved mechanical couplings (Type I) as defined in F 1476.

3.1.4 *pipe*—hollow tubular product conforming to Table 1 Specification Reference Nos. 17, 18, 19 and 12, Nominal Dimensions, or O.D. tube.

3.1.5 *plain end*—type of fitting or pipe end for use with a gasketed mechanical coupling (Type II) that is plain end as defined in Specification F 1476.

3.1.6 *tangent*—a section of straight pipe or tube integral to or welded to the end(s) of a fitting.

3.1.7 *wrought fitting*—a fitting made by shaping or shaping and welding.

4. Classification

4.1 These fittings are classified into the following design types:

4.1.1 *Type I*—Grooved end.

4.1.2 *Type II*—Plain end.

5. Ordering Information

5.1 Orders for fittings under this specification shall include the following:

5.1.1 Specification designation, title, number and year of issue.

5.1.2 Quantity.

5.1.3 Size and appropriate suffix (Example 8 in. IPS, 76.1 mm O.D.).

5.1.4 Fitting description (90° Elbow, Tee, Cross, etc.).

5.1.5 Type (I, II)—Type I must include groove style (that is, Standard, End Seal,[13] AWWA Rigid, AWWA Flexible, or Copper).

5.1.6 Minimum pressure rating.

5.1.7 Material (ductile iron or steel, aluminum, copper nickel, copper, other, etc.) (see Section 6).

5.1.8 Finish (painted, galvanized, bare, plated, special coatings) (see Section 6).

5.1.9 Other requirements agreed to between purchaser and fitting manufacturer.

6. Materials and Manufacture

6.1 *Ferrous Materials*—Cast fittings shall be constructed of ductile iron in accordance with Table 1 Specification Reference 9 or Malleable Iron in accordance with Table 1 Specification Reference 1 or steel in accordance with Table 1 Specification Reference 5 or Cast Iron in accordance with

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[12] Available from ISO Central Secretariat; 1, rue de Varembe; Case postale 56; CH-1211 Geneve 20; Switzerland.

[13] End seal is a registered trademark of the Victaulic Company of America.

Table 1 Specification Reference 2. Wrought fittings shall be made in accordance with Table 1 Specification Reference 6. Fabricated fittings and tangents shall be constructed of steel in accordance with Table 1 Specification Reference 3.

6.1.1 Fitting shall be bare, coated with manufacturer's standard preparation and paint, hot-dip galvanized in accordance with Table 1 Specification Reference 4 or other finish as agreed upon between purchaser and manufacturer.

6.2 *Aluminum Alloy Materials*—Fittings shall be constructed of aluminum alloy in accordance with Table 1 Specification Reference 11. Fabricated fittings shall be made from pipe in accordance with Table 1 Specification Reference 13.

6.2.1 Finish for aluminum alloy fittings shall be bare, anodized in accordance with Table 1 Specification Reference 21, painted in accordance with Table 1 Specification Reference 22 or as otherwise agreed between purchaser and manufacturer.

6.3 *Iron-Chromium-Nickel, Corrosion Resistance Materials*—Fittings shall be constructed of iron-chromium-nickel alloy in accordance with Table 1 Specification Reference 10, or Table 1 Specification Reference 8. Welded tangents and fabricated fittings shall be in accordance with Table 1 Specification Reference 7.

6.3.1 Finish for iron-chromium-nickel shall be bare or as otherwise agreed between purchaser and manufacturer.

6.4 Copper or brass, cast fittings shall be constructed of brass in accordance with Table 1 Specification Reference 15. Wrought fittings shall be constructed of copper in accordance with Table 1 Specification Reference 12.

6.4.1 Finish for copper or brass fittings shall be bare or as otherwise agreed between purchaser and manufacturer.

6.5 Copper-nickel cast fittings shall be constructed of copper-nickel in accordance with Table 1 Specification Reference 14 as applicable.

6.5.1 Finish for copper-nickel fittings shall be bare or as otherwise agreed between purchaser and manufacturer.

6.6 *Other Materials*—Where other materials are required, the material, mechanical properties and finish of the products shall be as agreed upon by the fitting manufacturer and the purchaser.

6.7 *Material Quality:*

6.7.1 The material shall be of such quality and purity that the finished product shall have the properties and characteristics to meet the performance requirements of this standard.

6.7.2 The manufacturer is encouraged to use materials produced from recovered materials to the maximum extent practicable without jeopardizing the intended use. The term "recovered materials" means: "Materials which have been collected or recovered from solid waste and reprocessed to become a source of raw material, as opposed to virgin raw materials." Used or rebuilt products shall not be used.

7. Other Requirements

7.1 *Design Requirements:*

7.1.1 The design of the fittings may be qualified by mathematical analysis in accordance with piping codes agreed to by manufacturer and purchaser or by testing. Fittings that are tested shall be tested with gasketed mechanical couplings in accordance with the test requirements of Specification F 1476.

7.2 *Qualification Requirements:*

7.2.1 *Mathematical Analysis:*

7.2.1.1 A mathematical analysis, where appropriate, shall be performed as required by the governing piping code. Records of the analysis shall be available at the manufacturer's facility for inspection by the purchaser.

7.2.2 *Test:*

7.2.2.1 The fittings shall be tested, where appropriate, with gasketed mechanical couplings in accordance with the requirements of Specification F 1476. Unless otherwise noted herein, all requirements of Specification F 1476 apply. Records of successful tests shall be available at the manufacturer's facility for inspection by the purchaser.

7.2.3 Each type, pressure class, and material of fitting offered for sale must be qualified. Interpolation between qualified sizes is allowed as defined in Specification F 1476. Qualification of the fitting requires successful completion of the analysis or required testing. Each fitting design is only qualified for use with the GMC design on which it was tested or analyzed.

8. Dimensions, Mass and Permissible Variations

8.1 *Fitting Dimensions*—Fitting dimensions and tolerance shall be as specified by the manufacturer.

9. Workmanship, Finish and Appearance

9.1 All fitting surfaces shall be free from scale, blisters, fins, folds, seams, laps, burrs and cracks, which would affect the suitability for the intended service.

10. Certification

10.1 *Material Certification:*

10.1.1 A certification of compliance shall be obtained from the materials supplier, when applicable. This certificate shall state that applicable requirements for the raw material have been satisfied.

11. Inspection

11.1 *Terms of Inspection:*

11.1.1 Inspection of the fittings shall be in accordance with the manufacturer's standard inspection procedure or as agreed upon between the purchaser and the manufacturer or supplier as part of the purchase contract.

11.2 *Raw Material Inspection:*

11.2.1 Raw material shall be inspected for compliance with its material specification.

11.3 *Quality Conformance Inspection:*

11.3.1 Fitting samples shall be visually and dimensionally examined to verify compliance with the manufacturer's appropriate drawings.

11.4 *Process Control Inspection:*

11.4.1 Fittings shall be inspected throughout the entire manufacturing and processing cycle. Methods of inspection shall be in compliance with manufacturer's quality assurance procedures.

11.5 *Inspection Records:*

11.5.1 Inspection records shall be maintained by the manufacturer. The length of time on file shall be in accordance with the manufacturer's quality assurance procedures.

12. Product Markings

12.1 Each fitting shall be marked with the manufacturer's name or trademark, size, and markings traceable to the material and pressure rating.

13. Packaging

13.1 The fitting shall be boxed, crated, wrapped and otherwise protected during shipment and storage in accordance with manufacturer's standard practice. Care shall be taken to properly protect the fitting from damage during shipment and storage.

14. Keywords

14.1 fitting; grooved; marine; ship; tangent

CERTIFICATE

By Authority Of
THE UNITED STATES OF AMERICA
Legally Binding Document

By the Authority Vested By Part 5 of the United States Code § 552(a) and Part 1 of the Code of Regulations § 51 the attached document has been duly INCORPORATED BY REFERENCE and shall be considered legally binding upon all citizens and residents of the United States of America. *HEED THIS NOTICE*: Criminal penalties may apply for noncompliance.

Document Name: ASTM G21: Standard Practice for Determining Resistance of Synthetic Polymeric Materials to Fungi

CFR Section(s): 7 CFR 1755.910(d)(5)(iv)

Standards Body: American Society for Testing and Materials

APPROVED

Official Incorporator:

THE EXECUTIVE DIRECTOR
OFFICE OF THE FEDERAL REGISTER
WASHINGTON, D.C.

Designation: G 21 – 90

Standard Practice for Determining Resistance of Synthetic Polymeric Materials to Fungi[1]

This standard is issued under the fixed designation G 21; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense. Consult the DoD Index of Specifications and Standards for the specific year of issue which has been adopted by the Department of Defense.

1. Scope

1.1 This practice covers determination of the effect of fungi on the properties of synthetic polymeric materials in the form of molded and fabricated articles, tubes, rods, sheets, and film materials. Changes in optical, mechanical, and electrical properties may be determined by the applicable ASTM methods.

1.2 The values stated in SI units are to be regarded as the standard.

2. Referenced Document

2.1 *ASTM Standard:*

D 618 Methods of Conditioning Plastics and Electrical Insulating Materials for Testing[2]

3. Summary of Practice

3.1 The procedure described herein consists of (*1*) selection of suitable specimens for determination of pertinent properties, (*2*) inoculation of the specimens with suitable organisms, (*3*) exposure of inoculated specimens under conditions favorable to growth, (*4*) examination and rating for visual growth, and (*5*) removal of the specimens and observations or testing, either before cleaning or after cleaning and reconditioning.

NOTE 1—Since the procedure involves handling and working with fungi, it is recommended that personnel trained in microbiology perform the portion of the procedure involving handling of organisms and inoculated specimens.

4. Significance and Use

4.1 The resin portion of these materials is usually fungus-resistant in that it does not serve as a carbon source for the growth of fungi. It is generally the other components, such as plasticizers, cellulosics, lubricants, stabilizers, and colorants, that are responsible for fungus attack on plastic materials. It is important to establish the resistance to microbial attack under conditions favorable for such attack, namely, a temperature of 2 to 38°C (35 to 100°F) and a relative humidity of 60 to 100 %.

4.2 The effects to be expected are as follows:

4.2.1 Surface attack, discoloration, loss of transmission (optical).

4.2.2 Removal of susceptible plasticizers, modifiers, and lubricants, resulting in increased modulus (stiffness), changes in weight, dimensions, and other physical properties, and deterioration of electrical properties such as insulation resistance, dielectric constant, power factor, and dielectric strength.

4.3 Often the changes in electrical properties are due principally to surface growth and its associated moisture and to pH changes caused by excreted metabolic products. Other effects include preferential growths caused by nonuniform dispersion of plasticizers, lubricants, and other processing additives. Attack on these materials often leaves ionized conducting paths. Pronounced physical changes are observed on products in film form or as coatings, where the ratio of surface to volume is high, and where nutrient materials such as plasticizers and lubricants continue to diffuse to the surface as they are utilized by the organisms.

4.4 Since attack by organisms involves a large element of chance due to local accelerations and inhibitions, the order of reproducibility may be rather low. To assure that estimates of behavior are not too optimistic, the greatest observed degree of deterioration should be reported.

4.5 Conditioning of the specimens, such as exposure to leaching, weathering, heat treatment, etc., may have significant effects on the resistance to fungi. Determination of these effects is not covered in this practice.

5. Apparatus

5.1 *Glassware*—Glass vessels are suitable for holding specimens when laid flat. Depending on the size of the specimens, the following are suggested:

5.1.1 For specimens up to 75 mm (3 in.) in diameter, 150-mm (6-in.) covered Petri dishes.

5.1.2 For 75 mm (3 in.) and larger specimens, such as tensile and stiffness strips, large Petri dishes, trays of borosilicate glass, or baking dishes up to 400 by 500 mm (16 by 20 in.) in size, covered with squares of window glass.

5.2 *Incubator*—Incubating equipment for all test methods shall maintain a temperature of 28 to 30°C (82.4 to 86°C) and a relative humidity not less than 85 %. Automatic recording of wet- and dry-bulb temperature is recommended.

6. Reagents and Materials

6.1 *Purity of Reagents*—Reagent grade chemicals shall be used in all tests. Unless otherwise indicated, it is intended

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[1] This practice is under the jurisdiction of ASTM Committee G-3 on Durability of Nometallic Materials and is the direct responsibility of Subcommittee G03.04 on Biological Deterioration.

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[2] *Annual Book of ASTM Standards*, Vol 08.01.

that all reagents shall conform to the specifications of the Committee on Analytical Reagents of the American Chemical Society, where such specification are available.[3] Other grades may be used, provided it is first ascertained that the reagent is of sufficiently high purity to permit its use without lessening the accuracy of the determination.

6.2 *Purity of Water*—Unless otherwise indicated, references to water shall be understood to mean distilled water or water of equal purity.

6.3 *Nutrient-Salts Agar*[4]—Prepare this medium by dissolving in 1 L of water the designated amounts of the following reagents:

Potassium dihydrogen orthophosphate (KH_2PO_4)	0.7 g
Magnesium sulfate ($MgSO_4 \cdot 7H_2O$)	0.7 g
Ammonium nitrate (NH_4NO_3)	1.0 g
Sodium chloride (NaCl)	0.005 g
Ferrous sulfate ($FeSO_4 \cdot 7H_2O$)	0.002 g
Zinc sulfate ($ZnSO_4 \cdot 7H_2O$)	0.002 g
Manganous sulfate ($MnSO_4 \cdot H_2O$)	0.001 g
Agar	15.0 g
Potassium monohydrogen orthophosphate (K_2HPO_4)	0.7 g

Sterilize the test medium by autoclaving at 121°C (250°F) for 20 min. Adjust the pH of the medium by the addition of 0.01 *N* NaOH solution so that after sterilization the pH is between 6.0 and 6.5. Prepare sufficient medium for the required tests.

6.4 *Mixed Fungus Spore Suspension*:

NOTE 2—Since a number of other organisms may be of specific interest for certain final assemblies or components, such other pure cultures of organisms may be used if agreed upon by the purchaser and the manufacturer of the plastic. Reference (1) illustrates such a choice.

6.4.1 Use the following test fungi in preparing the cultures:

Fungi	ATCC No.[A]	MYCO No.[B]
Aspergillus niger	9642	386
Penicillium pinophilum[C]	11797	391
Chaetomium globosum	6205	459
Gliocladium virens	9645	365
Aureobasidium pullulans	15233	279c

[A] American Type Culture Collection, 12301 Parklawn Drive, Rockville, MD 20852.

[B] Mycological Services, Box 1056, Crawfordsville, IN 47933.

[C] Historically known as funiculosm.

Maintain cultures of these fungi separately on an appropriate medium such as potato dextrose agar. The stock cultures may be kept for not more than 4 months at approximately 3 to 10°C (37 to 50°F). Use subcultures incubated at 28 to 30°C (82 to 86°F) for 7 to 20 days in preparing the spore suspension.

6.4.2 Prepare a spore suspension of each of the five fungi by pouring into one subculture of each fungus a sterile 10-mL portion of water or of a sterile solution containing 0.05 g/L of a nontoxic wetting agent such as sodium dioctyl sulfosuccinate. Use a sterile platinum or nichrome inoculating wire to scrape gently the surface growth from the culture of the test organism.

6.4.3 Pour the spore charge into a sterile 125-mL glass-stoppered Erlenmeyer flask containing 45 mL of sterile water and 10 to 15 solid glass beads, 5 mm in diameter. Shake the flask vigorously to liberate the spores from the fruiting bodies and to break the spore clumps.

6.4.4 Filter the shaken suspension through a thin layer of sterile glass wool in a glass funnel into a sterile flask in order to remove mycelial fragments.

6.4.5 Centrifuge the filtered spore suspension aseptically, and discard the supernatant liquid. Resuspend the residue in 50 mL of sterile water and centrifuge.

6.4.6 Wash the spores obtained from each of the fungi in this manner three times. Dilute the final washed residue with sterile nutrient-salts solution (Note 3) in such a manner that the resultant spore suspension shall contain 1 000 000 ± 200 000 spores/mL as determined with a counting chamber.

6.4.7 Repeat this operation for each organism used in the test and blend equal volumes of the resultant spore suspension to obtain the final mixed spore suspension.

NOTE 3—Nutrient salts solution is identical with the composition for nutrient salts agar given in 6.3 except that the agar is omitted.

6.4.8 The spore suspension may be prepared fresh each day or may be held in the refrigerator at 3 to 10°C (37 to 50°F) for not more than 4 days.

7. Viability Control

7.1 With each daily group of tests place each of three pieces of sterilized filter paper, 25 mm (1 in.) square, on hardened nutrient-salts agar in separate Petri dishes. Inoculate these with the spore suspension by spraying the suspension from a sterilized atomizer[5] so that the entire surface is moistened with the spore suspension. Incubate these at 28 to 30°C (82 to 86°F) at a relative humidity not less than 85 % and examine them after 14 days' incubation. There shall be copious growth on all three of the filter paper control specimens. Absence of such growth requires repetition of the test.

8. Test Specimens

8.1 The simplest specimen may be a 50 by 50-mm (2 by 2-in.) piece, a 50-mm (2-in.) diameter piece, or a piece (rod or tubing) at least 76 mm (3 in.) long cut from the material to be tested. Completely fabricated parts or sections cut from fabricated parts may be used as test specimens. On such specimens, observation of effect is limited to appearance, density of growth, optical reflection or transmission, or manual evaluation of change in physical properties such as stiffness.

8.2 Film-forming materials such as coatings may be tested in the form of films at least 50 by 25 mm (2 by 1 in.) in size. Such films may be prepared by casting on glass and stripping after cure, or by impregnating (completely covering) filter paper or ignited glass fabric.

8.3 For visual evaluation, three specimens shall be inoculated. If the specimen is different on two sides, three specimens of each, face up and face down, shall be tested.

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[3] "Reagent Chemicals, American Chemical Society Specifications," Am. Chemical Soc., Washington, DC. For suggestions on the testing of reagents not listed by the American Chemical Society, see "Reagent Chemicals and Standards," by Joseph Rosin, D. Van Nostrand Co., Inc., New York, NY, and the "United States Pharmacopeia."

[4] Agar and nutrient-salts agar are obtainable from biological laboratory supply sources.

[5] DeVilbiss No. 163 atomizer or equivalent has been found satisfactory for this purpose.

NOTE 4—In devising a test program intended to reveal quantitative changes occurring during and after fungal attack, an adequate number of specimens should be evaluated to establish a valid value for the original property. If five replicate specimens are required to establish a tensile strength of a film material, the same number of specimens shall be removed and tested for each exposure period. It is to be expected that values of physical properties at various stages of fungal attack will be variable; the values indicating the greatest degradation are the most significant (see 4.4). The *ASTM Manual on Presentation of Data and Control Chart Analysis STP 15D,* may be used as a guide.

9. Procedure

9.1 *Inoculation*—Pour sufficient nutrient-salts agar into suitable sterile dishes (see 5.1) to provide a solidified agar layer from 3 to 6 mm (⅛ to ¼ in.) in depth. After the agar is solidified, place the specimens on the surface of the agar. Inoculate the surface, including the surface of the test specimens, with the composite spore suspension by spraying the suspension from a sterilized atomizer[5] with 110 kPa (16 psi) of air pressure so that the entire surface is moistened with the spore suspension.

9.2 *Incubation*—Cover the inoculated test specimens and incubate at 28 to 30°C (82 to 86°F) and not less than 85 % relative humidity for a minimum of 21 days, recording the growth each week.

NOTE 5—Covered dishes containing nutrient agar are considered to have the desired humidity. Covers on large dishes may be sealed with masking tape.

9.3 *Observation for Visible Effects*—If the test is for visible effects only, remove the three specimens from the incubator and judge them as follows:

Observed Growth on Specimens	Rating
None	0
Traces of growth (less than 10 %)	1
Light growth (10 to 30 %)	2
Medium growth (30 to 60 %)	3
Heavy growth (60 % to complete coverage)	4

NOTE 6—Traces of growth may be defined as scattered, sparse fungus growth such as might develop from (*1*) a mass of spores in the original inoculum, or (*2*) extraneous contamination such as fingermarks, insect feces, etc. Continous cobwebby growth extending over the entire specimen, even though not obscuring the specimen, should be rated as 2.

NOTE 7—Considerable physical change in plastics may occur without much visual growth, hence some measure of change in physical property selected from those cited in the Appendix is recommended.

9.4 *Effect on Physical, Optical, or Electrical Properties*—Wash the specimens free of growth, immerse in an aqueous solution of mercuric chloride (1+1000) for 5 min, rinse in tap water, air dry overnight at room temperature, and recondition at the standard laboratory conditions defined in Methods D 618, 23 ± 1°C (73 ± 2°F) and 50 ± 2 % relative humidity, and test according to the respective methods used on control specimens (see the Appendix).

NOTE 8—For certain electrical tests, such as insulation resistance and arc resistance, specimens may be tested in the unwashed, humidified condition. Test values will be affected by surface growth and its associated moisture.

10. Report

10.1 The report shall include the following:

10.1.1 Organisms or organism used,

10.1.2 Time of incubation (if progressive),

10.1.3 Visual rating of fungus growth according to 9.3, and

10.1.4 Tabulation of progressive change in physical, optical, or electrical property against time of incubation. Give the number of observations, the mean, and the maximum observed change.

REFERENCES

(1) Bagdon, V. J., Military Specification Mil-P-43018(CE), "Plastic Sheets: Polyethylene Terephthalate, Drafting, Coated," June 13, 1961.

(2) Baskin, A. D., and Kaplan, A. M., "Mildew Resistance of Vinyl-Coated Fabrics," *Applied Microbiology*, APMBA, Vol 4, No. 6, November 1956.

(3) Berk, S., "Effect of Fungus Growth on Plasticized Polyvinyl Chloride Films," *ASTM Bulletin*, ASTBA, No. 168, September 1950, p. 53 (TP 181).

(4) Berk, S., Ebert, H., and Teitell, L., "Utilization of Plasticizers and Related Organic Compounds by Fungi," *Industrial and Engineering Chemistry*, IECHA, Vol 49, No. 7, July 1957, pp. 1115–1124.

(5) Brown, A. E., "Problem of Fungal Growth on Synthetic Resins, Plastics, and Plasticizers," *Modern Plastics*, MOPLA, Vol 23, 1946, p. 189.

(6) Ross, S. H., "Biocides for a Strippable Vinyl Plastic Barrier Material," Report PB-151-119, U. S. Department of Commerce, Office of Technical Services.

APPENDIX

(Nonmandatory Information)

X1. TEST METHODS FOR EVALUATION OF EFFECT OF FUNGI ON SYNTHETIC POLYMERIC MATERIALS

X1.1 For evaluation of the effect of fungi on mechanical, optical, and electrical properties, the following ASTM and other test methods are recommended.

Property	Methods
Tensile strength	D 638, D 882, D 1708[A]
Stiffness	D 747[A] TAPPI Test Method T 451-M-45 Fed. Std. No 191, Method 5204 (Clark Stiffness Test) Fed. Std. No 191, Method 5206 (Cantilever Bend Method)
Hardness	D 785[A]
Optical transmission	E 308[A]
Haze	D 1003[A]
Water vapor transmission	E 96[A]
Dielectric strength	D 149[A]
Dielectric constant-power factor	D 150[A]
Insulation resistance	D 257[A]
Arc resistance	D 495[A]

[A] These designations refer to the following ASTM methods:
D 149, Test Method for Dielectric Breakdown Voltage and Dielectric Strength of Electrical Insulating Materials at Commercial Power Frequencies[2]
D 150, Test Methods for A-C Loss Characteristics and Dielectric Constant (Permittivity) of Solid Electrical Insulating Materials[2]
D 257, Test Methods for D-C Resistance or Conductance of Insulating Materials[2]
D 495, Test Method for High-Voltage, Low-Current, Arc Resistance of Solid Electrical Insulating Materials[2]
D 638, Test Method for Tensile Properties of Plastics[2]
D 747, Test Method for Stiffness of Plastics by Means of a Cantilever Beam[2]
D 785, Test Method for Rockwell Hardness of Plastics and Electrical Insulating Materials[2]
D 1003, Test Method for Haze and Luminous Transmittance of Transparent Plastics[2]
D 1708, Test Method for Tensile Properties of Plastics by Use of Microtensile Specimens[6]
E 96, Test Methods for Water Vapor Transmission of Materials in Sheet Form[7]
E 308, Rec. Practice for Spectrophotometry and Description of Color in CIE 1931 System[8]

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[6] *Annual Book of ASTM Standards*, Vol 08.02.
[7] *Annual Book of ASTM Standards*, Vols 08.03 and 15.09.
[8] *Annual Book of ASTM Standards*, Vol 06.01.

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Standard Practice for Exposing Nonmetallic Materials in Accelerated Test Devices that Use Laboratory Light Sources[1]

This standard is issued under the fixed designation G 151; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice provides general procedures to be used when exposing nonmetallic materials in accelerated test devices that use laboratory light sources. Detailed information regarding procedures to be used for specific devices are found in standards describing the particular device being used. For example, detailed information covering exposures in devices that use carbon-arc, xenon-arc, and fluorescent UV light sources are found in Practices G 23, G 26, and G 53, respectively.

NOTE 1—New performance based standards describing exposures in carbon-arc, xenon-arc, and fluorescent UV exposures are being developed by Subcommittee G 03.03.

1.2 This practice also describes general performance requirements for devices used for exposing nonmetallic materials to laboratory light sources. This information is intended primarily for producers of laboratory accelerated exposure devices.

NOTE 2—Certification of conformance to the performance requirements for new exposure devices generally is the responsibility of the manufacturer.

1.3 This practice provides information on the use and interpretation of data from accelerated exposure tests. Specific information about methods for determining the property of a nonmetallic material before and after exposure are found in standards describing the method used to measure each property. Information regarding the reporting of results from exposure testing of plastic materials is described in Practice D 5870.

NOTE 3—The Committee G-3 is developing standard guides for application of statistics to exposure test results and for addressing variability in exposure testing of nonmetallic materials.

NOTE 4—This standard is technically equivalent to ISO DIS 4892, Part 1.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

D 618 Practice for Conditioning Plastics and Electrical Insulating Materials for Testing[2]

D 3924 Specification for Standard Environment for Conditioning and Testing Paint, Varnish, Lacquer and Related materials[3]

D 5870 Practice for Calculating Property Retention Index of Plastics[3]

E 41 Terminology Relating to Conditioning[4]

E 171 Specification for Standard Atmospheres for Conditioning and Testing Flexible Barrier Materials[5]

E 585 Specification for Base-Metal Thermocouple Materials[6]

E 644 Test Methods for Testing Industrial Resistance Thermometers[6]

E 772 Terminology Relating to Solar Energy Conversion[7]

E 839 Test Methods for Sheathed Thermocouples and Sheathed Thermocouple Material[6]

G 7 Practice for Atmospheric Environmental Exposure Testing of Nonmetallic Materials[4]

G 23 Practice for Operating Light Exposure Apparatus (Carbon-Arc) Type With and Without Water for Exposure of Nonmetallic Materials[4]

G 24 Practice for Conducting Exposures to Daylight Filtered Through Glass[4]

G 26 Practice for Operating Light-Exposure Apparatus (Xenon-Arc) Type With and Without Water for Exposure of Nonmetallic Materials[4]

G 53 Practice for Operating Light- and Water-Exposure Apparatus (Fluorescent UV Condensation Type) for Exposure of Nonmetallic Materials[4]

G 113 Terminology Relating to Natural and Artificial Weathering Tests for Nonmetallic Materials[4]

G 130 Method for Calibration of Narrow- and Broad-Band Ultraviolet Radiometers Using a Spectroradiometer[4]

G 147 Practice for Conditioning and Handling of Nonmetallic Materials for Natural and Artificial Weathering Tests[4]

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[1] This practice is under the jurisdiction of ASTM Committee G-3 on Weathering and Durability and is the direct responsibility of Subcommittee G03.03 on Simulated and Controlled Exposure Tests.

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[2] *Annual Book of ASTM Standards*, Vol 08.01.

[3] *Annual Book of ASTM Standards*, Vol 06.01.

[4] *Annual Book of ASTM Standards*, Vol 14.02.

[5] *Annual Book of ASTM Standards*, Vol 15.09.

[6] *Annual Book of ASTM Standards*, Vol 14.03.

[7] *Annual Book of ASTM Standards*, Vol 12.02.

2.2 *ISO Standards:*

ISO 4892, Part 1 Plastics: Exposure to laboratory Light Sources–General Guidance[8]

ISO 9370 Plastics: Instrumental Determination of Radiant Exposure in Weathering Tests–General Guidance and Basic Test Method[8]

2.3 *CIE Documents:*

CIE Publication Number 85: 1989, Technical Report–Solar Spectral Irradiance[9]

3. Terminology

3.1 *Definitions*—The definitions given in Terminologies E 41, E 772, and G 113 are applicable to this practice.

4. Significance and Use

4.1 *Significance*:

4.1.1 When conducting exposures in devices that use laboratory light sources, it is important to consider how well the accelerated test conditions will reproduce property changes and failure modes associated with end-use environments for the materials being tested. In addition, it is essential to consider the effects of variability in both the accelerated test and outdoor exposures when setting up exposure experiments and when interpreting the results from accelerated exposure tests.

4.1.2 No laboratory exposure test can be specified as a total simulation of actual use conditions in outdoor environments. Results obtained from these laboratory accelerated exposures can be considered as representative of actual use exposures only when the degree of rank correlation has been established for the specific materials being tested and when the type of degradation is the same. The relative durability of materials in actual use conditions can be very different in different locations because of differences in UV radiation, time of wetness, relative humidity, temperature, pollutants, and other factors. Therefore, even if results from a specific exposure test conducted according to this practice are found to be useful for comparing the relative durability of materials exposed in a particular exterior environment, it cannot be assumed that they will be useful for determining relative durability of the same materials for a different environment.

4.1.3 Even though it is very tempting, calculation of an *acceleration factor* relating x h or megajoules of radiant exposure in a laboratory accelerated test to y months or years of exterior exposure is not recommended. These acceleration factors are not valid for several reasons.

4.1.3.1 Acceleration factors are material dependent and can be significantly different for each material and for different formulations of the same material.

4.1.3.2 Variability in the rate of degradation in both actual use and laboratory accelerated exposure test can have a significant effect on the calculated acceleration factor.

4.1.3.3 Acceleration factors calculated based on the ratio of irradiance between a laboratory light source and daylight, even when identical bandpasses are used, do not take into consideration the effects of temperature, moisture, and differences in spectral power distribution between the laboratory light source and daylight.

Note 5—If use of an acceleration factor is desired in spite of the warnings given in this practice, such acceleration factors for a particular material are only valid if they are based on data from a sufficient number of separate exterior and laboratory accelerated exposures so that results used to relate times to failure in each exposure can be analyzed using statistical methods. An example of a statistical analysis using multiple laboratory and exterior exposures to calculate an acceleration factor is described by J.A. Simms (1).[10]

4.1.4 There are a number of factors that may decrease the degree of correlation between accelerated tests using laboratory light sources and exterior exposures. More specific information on how each factor may alter stability ranking of materials is given in Appendix X1.

4.1.4.1 Differences in the spectral distribution between the laboratory light source and sunlight.

4.1.4.2 Light intensities higher than those experienced in actual use conditions.

4.1.4.3 Test conditions where specimens are exposed continuously to light when actual use conditions provide alternate periods of light and dark.

4.1.4.4 Specimen temperatures higher than those in actual conditions.

4.1.4.5 Exposure conditions that produce unrealistic temperature differences between light and dark colored specimens.

4.1.4.6 Exposure conditions, which produce very frequent cycling between high and low specimen temperatures, or which produce unrealistic thermal shock.

4.1.4.7 Unrealistically high or low levels of moisture.

4.1.4.8 Absence of biological agents or pollutants.

4.2 Use of accelerated tests with laboratory light sources.

4.2.1 Results from accelerated exposure tests conducted according to this standard are best used to compare the relative performance of materials. A common application is conducting a test to establish that the level of quality of different batches does not vary from a control material with known performance. Comparisons between materials are made best when the materials are tested at the same time in the same exposure device. Results can be expressed by comparing the exposure time or radiant exposure necessary to reduce the level of a characteristic property to some specified level.

4.2.1.1 It is strongly recommended that at least one control material be exposed with each test for the purpose of comparing the performance of the test materials to that of the control. Ideally, the control material should be of similar composition and construction and be chosen so that its failure modes are the same as that of the material being tested. It is preferable to use two controls, one with relatively good durability and one with relatively poor durability.

4.2.1.2 Sufficient replicates of each control material and each test material being evaluated are necessary in order to allow statistical evaluation of results. Unless otherwise specified, use a minimum of three replicates for all test and control

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[8] Available from American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.

[9] CIE

[10] The boldface numbers in parentheses refer to the list of references at the end of this standard.

materials. When material properties are measured using destructive tests, a separate set of specimens is needed for each exposure period.

4.2.2 In some applications, reference materials are used to establish consistency of the operating conditions in an exposure test. Reference materials, for example, blue wool test fabric, also may be used for the purpose of timing exposures.

4.2.2.1 In some cases, a reference material is exposed at the same time as a test material and the exposure is conducted until there is a defined change in property of the reference material. The test material then is evaluated. In some cases the results for the test material are compared to those for the reference material. These are inappropriate uses of reference materials when they are not sensitive to exposure stresses, which produce failure in the test material, or when the reference material is very sensitive to an exposure stress that has very little effect on the test material.

NOTE 6—Definitions for control and reference material that are appropriate to weathering tests are found in Terminology G 113.

NOTE 7—Subcommittee G03.01 is developing a standard practice for selecting and characterizing weathering reference materials used to establish consistency of operating conditions in a laboratory accelerated test.

4.3 Results from accelerated exposure tests only should be used to establish a pass/fail approval of materials after a specific time of exposure to a prescribed set of conditions when the variability in the exposure and property measurement procedure has been quantified so that statistically significant pass/fail judgments can be made.

5. Requirements for Laboratory Exposure Devices

5.1 *Light Source*:

5.1.1 The exposure device shall provide for placement of specimens and any designated sensing devices in positions which provide uniform irradiance by the light source.

NOTE 8—In some devices, several individual light sources are used simultaneously. In these devices, the term ***light source*** refers to the combination of individual light sources being used.

5.1.2 Manufacturers of exposure devices shall assure that the irradiance at any location in the area used for specimen exposures is at least 70 % of the maximum irradiance measured in this area. Procedures for measuring irradiance uniformity are found in Annex A1.

NOTE 9—During use, the irradiance uniformity in exposure devices can be affected by several factors, such as deposits, which can develop on the optical system and chamber walls. Irradiance uniformity also can be affected by the type and number of specimens being exposed. The irradiance uniformity as assured by the manufacturer is valid for new equipment and well defined measuring conditions.

5.1.3 Periodic repositioning of the specimens during exposure is not necessary if the irradiance at positions farthest from the center of the specimen area is at least 90 % of that measured at the center of the exposure area.

5.1.4 If irradiance at positions farthest from the center of the exposure area is between 70 and 90 % of that measured at the center, one of the following three techniques shall be used to used for specimen placement.

5.1.4.1 Periodically reposition specimens during the exposure period to ensure that each receives an equal amount of radiant exposure. The repositioning schedule shall be agreed upon by all interested parties.

5.1.4.2 Place specimens only in the exposure area where irradiance is at least 90 % of the maximum irradiance.

5.1.4.3 Randomly position replicate specimens within the exposure area that meets the irradiance uniformity requirements defined in 5.1.4

5.1.5 Replace lamps and filters according to the schedule recommended by the device manufacturer. Follow the apparatus manufacturer's instructions for lamp and filter replacement and for pre-aging of lamps or filters, or both.

5.1.6 CIE Publication No. 85-1989 provides data on solar spectral irradiance for typical atmospheric conditions, which can be used as a basis for comparing laboratory light sources with daylight. For example, global solar irradiance in the 300 to 2450 nm band is given as 1090 W/m^2 for relative air mass 1, with 1.42 cm precipitable water, and 0.34 cm of ozone (measured at a pressure of 1 atmosphere and temperature of 0°C). Table 1 shows a broad band condensed spectral irradiance for global solar radiation at this atmospheric condition in the UV, visible and infrared portions of the spectrum. This represents the maximum global solar irradiance that would be experienced by materials exposed on a horizontal surface at the equator near noon on a clear day at the spring or autumn equinox.

5.1.6.1 Direct radiation from xenon burners, open flame carbon arcs, and some fluorescent lamps contains considerable amounts of short wavelength ultraviolet radiation not present in daylight. With proper selection of filters for these light sources, much of the short wavelength light can be eliminated. Even when filters are used, however, a small, but significant, amount of this short wavelength (less than 300 nm) radiation often is present in the spectral distribution of the filtered light source. Fluorescent UV lamps can be selected to have a spectral output corresponding to a particular ultraviolet region of sunlight. The xenon arc, when appropriately filtered, produces radiation with a spectral power distribution that is a good simulation of average sunlight throughout the UV and visible region.

5.1.7 A radiometer, which complies with the requirements outlined in ISO 9370 may be used to measure irradiance, E, or the spectral irradiance, E, and the radiant exposure, H, or the spectral radiant exposure, H, on the specimen surface.

5.1.7.1 If used, the radiometer shall be mounted so that it receives the same irradiance as the specimen surface. If it is not positioned within the specimen plane, it shall be calibrated for irradiance at the specimen distance.

5.1.7.2 The radiometer shall be calibrated in the emission region of the light source used. Calibration of narrow or

TABLE 1 Spectral Global Irradiance (condensed from Table 4 of CIE Publication No. 85-1989)

Wavelength (nm)	Irradiance (Wm^{-2})	Percent Total (300-2450 nm)	Percent of UV and Visible (300-800 nm)
300-320	4.1	0.4	0.6
320-360	28.5	2.6	4.2
360-400	42.0	3.9	6.2
300-400	74.6	6.8	11.0
400-800	604.2	55.4	89.0
300-800	678.8	62.2	100.0
800-2450	411.6	37.8	...
300-2450	1090.4	100.0	...

broad-band ultraviolet radiometers with a spectroradiometer shall be conducted according to Method G 130. Calibration shall be checked according to the radiation measuring instrument manufacturer's instructions. A full calibration of the radiometer shall be conducted at least once/year. More frequent calibrations are recommended.

5.1.7.3 When measured, the irradiance in the wavelength range agreed upon by all interested parties shall be reported. Some apparatus provide for measuring irradiance in a specific wavelength range for example, 300–400 or 300–800 nm, or in a narrow bandpass centered around a single wavelength, for example, 340 nm.

5.2 *Temperature*:

5.2.1 The surface temperature of exposed materials depends primarily on the amount of radiation absorbed, the emissivity of the specimen, the thermal conduction within the specimen, and the heat transmission between specimen and air or specimen holder. Since it is not practical to monitor the surface temperature of individual test specimens, a specified black-panel sensor is used to measure and control temperature within the test chamber. It is strongly recommended that the black panel temperature sensor be mounted on a support within the specimen exposure area so that it receives the same radiation and cooling conditions as a flat test panel surface using the same support. The black panel also may be located at a fixed distance position different from the test specimens and calibrated for temperature in the specimen exposure area. This is not recommended, however, because black panels mounted at a fixed position away from the specimens may not indicate temperatures representative of the test specimens, even if they are calibrated to record temperature at positions within the specimen exposure area, due to differences in light intensity and movement of air.

5.2.2 Exposure devices shall use either an uninsulated black panel or an insulated black panel as black panel sensor. Requirements for each type are found in Annex A2.

5.2.3 The temperature indicated by the uninsulated black-panel or insulated thermometer depends on the irradiance of the laboratory light source and the temperature and speed of air moving in the test chamber. Uninsulated black-panel temperatures generally correspond to those for dark coatings on metal panels. Insulated black panel thermometer temperatures generally correspond to those for the exposed surface of dark samples with poor thermal conductivity. At conditions used in typical exposure tests, the temperature indicated by an insulated black panel thermometer will be 3-12°C higher than an uninsulated black panel thermometer. The response time for temperature changes is slightly slower for insulated black panel thermometers compared to uninsulated black panel thermometers.

5.2.3.1 At low irradiance, the difference between the temperature indicated by an uninsulated black panel or insulated black panel and the real specimen may be small. When light sources that emit very little infrared radiation are used, there generally will be very small difference in temperatures indicated by the two types of black panels or between light and dark colored specimens.

5.2.4 In order to evaluate the range of surface temperatures of the exposed specimens, the use of an uninsulated white panel or insulated white standard thermometer is recommended, in addition to the uninsulated black panel or insulated black panel thermometer. In some cases, temperature of either the uninsulated or insulated white panel thermometer may be used to specify exposure conditions. The uninsulated or insulated white panel shall be constructed in the same way as the corresponding uninsulated or insulated black panel thermometer, except for use of a white coating with a good resistance to aging. The reflectance of the white coating between 300 and 1000 nm shall be at least 90 % and at least 60 % between 1000 and 2500 nm.

5.2.5 Exposure devices which control temperature of a black or white temperature sensor shall be able to maintain temperature within± 3°C of the desired temperature. Manufacturers of exposure devices shall assure that the temperature of a black or white panel temperature sensor placed anywhere within the specimen exposure area shall be within ± 5 % of the desired centigrade temperature.

5.2.6 The test report shall indicate whether an insulated or uninsulated black or white panel was used. If either type of black or white panel thermometer is not positioned in the specimen exposure area, the exact position used shall be described in the test report.

NOTE 10—There can be differences in temperature indicated by a single type of black panel thermometer, depending on the specific design of the device supplied by different manufacturers. Work is being conducted within Subcommittee 6 ISO TC/61 to characterize the differences between the different types of temperature sensing devices and between temperature sensing devices of the same type.

5.2.7 If chamber air temperature is measured, the temperature sensing element shall be shielded from the light source and water spray. Exposure devices, which control temperature of chamber air shall be able to maintain temperature of chamber air within ± 3°C of the desired temperature.

5.2.8 Calibrate thermocouples according to instructions provided by the device manufacturer. If no instructions are provided by the device manufacture, sheathed thermocouples shall be calibrated according to Method E 839, and resistance thermometers used as the sensing element for black or white panel thermometers shall be calibrated according to Method E 644. Unless otherwise specified, devices used to measure temperature shall be calibrated at least annually. Wherever possible, calibrations should be traceable to a nationally recognized standards agency.

5.3 *Humidity and Wetting*:

5.3.1 The presence of moisture may have a significant effect on exposure tests. Any apparatus operated according to this standard, which attempts to simulate the effects of moisture, shall have means for providing moisture to specimens using one or more of the following methods: humidification of chamber air, formation of condensation, water spray, or immersion. The type and rate of material degradation can be affected significantly by the method used to provide moisture stress.

5.3.2 The purity of the water used for specimen wetting is very important. Without proper treatment to remove cations, anions, organics, and particularly silica, exposed specimens will develop spots or stains that do not occur in exterior exposures. It is strongly recommended that water used for specimen wetting contain maximum of 1 ppm solids and a maximum of 0.2 ppm silica. Distillation, or a combination of deionization and reverse osmosis can effectively produce water with the desired purity. If the water used for specimen wetting is above 1 ppm solids, the solids and silica levels must be reported. Recirculation of water used for specimen wetting is not recommended and must not be done unless the recirculated water meets the purity requirements listed above.

5.3.3 If specimens are found to have deposits or stains after exposure, the water purity must be checked to determine if it meets the purity requirements described in 5.3.2. On some occasions, exposed specimens can be contaminated by deposits from bacteria than can grow in the purified water used for specimen wetting. If bacterial contamination is detected, the entire system used for specimen wetting shall be flushed with a chlorinating solution, such as sodium hypochlorite and thoroughly rinsed prior to resuming exposures.

5.3.4 Although it does not always correlate with silica content, it is recommended that the conductivity of the water used for specimen wetting be monitored continuously and that exposures be stopped whenever the conductivity is above 5 µS/cm.

5.3.5 All components of the specimen wetting unit shall be fabricated from stainless steel, plastic, or other material that does not contaminate the water. If plastic materials are used, they shall not leach low molecular weight UV absorbing components into the water.

5.3.6 In devices where humidity within the test chamber is controlled, sensors used to determine humidity shall be placed within the test chamber air flow and shielded from direct radiation and water spray. When humidity is controlled, the measured relative humidity shall be within ± 5 % of the desired humidity.

5.3.6.1 Calibrate the sensors used to determine humidity according to the device manufacturer's instructions.

5.3.7 Any device intended to introduce wetting of specimens, for example, by spray or immersion, shall have means to program intervals with and without wetting.

NOTE 11—There is currently no generally accepted method for characterizing the uniformity or consistency of specimen wetting.

5.4 *Other Apparatus Requirements*—Although various apparatus designs are used in practice, each apparatus shall include the following:

5.4.1 Any device intended to provide light and dark cycles shall have means to program intervals with or without light. The time of each light and dark cycle shall be controlled to within ± 10 % of the shortest cycle time used. It is preferable to use cycle timers that are accurate and reproducible as possible. Optionally, means to provide a record of the length of light and dark cycles may be provided.

5.4.2 To fulfill the requirements of particular test procedures, the apparatus also may need to provide means to register or record the following operational parameters.

5.4.2.1 Line voltage;

5.4.2.2 Lamp voltage and where appropriate, lamp wattage;

5.4.2.3 Lamp current;

5.4.2.4 Temperature of uninsulated or insulated black or white panel thermometer;

5.4.2.5 Test chamber air temperature;

5.4.2.6 Test chamber relative humidity,

5.4.2.7 Water spray cycles;

5.4.2.8 Irradiance or radiant exposure, or both, over a specified spectral region; and,

5.4.2.9 Duration of exposure (radiation time and total, if different).

5.4.3 Follow the recommendations of the device manufacturer regarding calibration of devices used to record each operational parameter.

6. Test Specimens

6.1 *Form and Preparation*:

6.1.1 The dimensions of the test specimens normally are those specified in the appropriate test method for the property or properties to be measured after exposure. When the behavior of a specific type of article is to be determined, the article itself should be exposed whenever possible.

6.1.2 For some tests, specimens to be exposed may be cut from a larger sheet or part that is formed by extrusion, injection molding, or other process. The exact shape and dimensions of the specimens to be exposed will be determined by the specific test procedure used for measurement of the property of interest. The procedures used to machine or cut individual test specimens from a larger sheet or part may affect the results of the property measurement and the apparent durability. Therefore, the method used for specimen preparation shall be agreed upon by the interested parties and should be related closely to the method normally used to process the material in typical application.

6.1.3 Unless otherwise specified or required, do not cut individual test specimens for property measurement from larger specimens that have been exposed. The effects any cutting or machining operation may have on the properties of individual test specimens usually are much larger when the test specimens are cut from a large piece after exposure. This is especially true for materials that embrittle on exposure.

6.1.3.1 When test specimens are cut from an exposed sheet or larger part, they should be taken from an area that is at least 20 mm from the fixture holding the material or from the exposed specimen edges. In no circumstances shall any material from the exposed face be removed during the test specimen preparation.

6.1.4 When comparing materials in an exposure test, use test specimens that are similar in dimensions and exposed area.

6.2 *Number of Test Specimens*:

6.2.1 The number of test specimens for each test condition or exposure period shall be that specified in the appropriate test method for the property or properties to be measured after exposure.

6.2.2 Unless otherwise specified or required, use at least three replicate specimens where properties are measured using nondestructive tests and six replicate specimens where properties are measured using destructive tests.

6.2.3 When destructive tests are used to determine the properties being measured, the total number of test specimens required will be determined by the number of exposure periods used and whether unexposed file specimens are tested at the same time as exposed specimens.

6.2.4 Control materials with known durability should be included with each exposure test. It is recommended that control materials known to have relatively poor and good durability be used. Control materials are used for the purpose of comparing the performance of the test materials to the controls. Before laboratory to laboratory comparisons are made it is necessary to establish agreed upon control materials. The number of specimens of the control material should be the same as that used for test materials.

6.3 *Storage and Conditioning*:

6.3.1 Conditioning and handling of test, control, reference, and file specimens shall be according to Practice G 147.

6.3.2 If test specimens are cut or machined from larger pieces, they should be conditioned after machining according to Practice D 618, or Specifications D 3924, E 171. In some circumstances, it may be necessary to precondition the sheets prior to cutting or machining to facilitate specimen preparation. The properties of some materials are very sensitive to moisture content and the duration of conditioning may need to be longer than those specified in these standards, particularly where specimens have been exposed to climatic extremes.

6.3.3 Some materials will change color during storage in the dark, particularly after weathering. It is essential that color measurement or visual comparison be carried out as soon as possible after exposure once the exposed surface has dried.

7. Exposure Conditions and Procedure

7.1 Do not touch the surface of exposed specimens or optical components with bare skin because oils that are deposited may act as UV absorbers or contain contaminants which accelerate degradation.

7.2 Specific conditions and procedures for the exposure test depend upon on the type of device used and the material being tested. For carbon-arc, xenon-arc, and fluorescent UV exposures, these can be found in Practices G 23, G 26, and G 53 and in other standards which reference these practices.

7.2.1 Select material properties that exhibit a significant change during the exposure period in order to provide weathering performance discrimination among a series of materials.

7.2.2 Periodic evaluation of test and control materials is recommended to determine the variation in magnitude and direction of property change as a function of exposure time or radiant exposure.

7.2.2.1 The time or radiant exposure necessary to produce a defined change in a material property can be used to evaluate or rank the stability of materials. This method is preferred over evaluating materials after an arbitrary exposure time or radiant exposure.

7.3 Follow the procedures described in the appropriate standard for measuring properties on test specimens before and after exposure.

7.4 If nondestructive tests are used to measure properties of the materials being tested, properties of test specimens shall be measured before beginning the exposure. The same property then is measured on the test specimens after each exposure period. Care should be taken to make the property measurement after each exposure period in the same position on the test specimen.

NOTE 12—To monitor the response of the instrument used to measure the desired property, one can measure a calibration standard each time the test instrument is used.

7.5 If destructive tests are used to measure properties of the materials being tested, separate sets of test specimens will be needed for each exposure period. The property is measured on each set of exposed specimens. The value of the property after exposure may be compared to the property measured on an unexposed set of specimens measured prior to beginning the exposure. Alternatively, the property can be measured on a separate set of unexposed file specimens at the same time as the property of exposed specimens is measured. The results for the unexposed file specimens and from the exposed specimens can then be compared.

NOTE 13—Procedures and formulas for calculating the change in material property of test materials and reference materials after exposure can be found in Practice D 5870.

8. Test Report

8.1 The test report shall contain the following information;

8.1.1 Specimen description;

8.1.2 A full description of the specimens and their origin;

8.1.3 Compound details, cure time, and temperature where appropriate; and

8.1.4 Complete description of the method used for preparation of test specimens.

NOTE 14—If exposure tests are conducted by a contracting agency, specimens usually are identified by code number. In such cases, it is the responsibility of the originating laboratory to provide the complete specimen description when reporting results of the exposure test.

8.2 *Description of Exposure Test*—Description of the exposure device and light source including:

8.2.1 Type of device and light source;

8.2.2 Description of the filters used;

8.2.3 If required, mean and tolerance for irradiance at the specimen surface, including the bandpass in which the radiation was measured; and,

8.2.4 If required, mean and tolerance for wattage used for laboratory light source.

8.3 Type of black or white panel, or both thermometer used—Exact position of the black or white panel thermometer if it was not located in the test specimen exposure area.

8.4 If required, type of instrument used to measure humidity.

8.5 Complete description of exposure cycle used, including the following information for each light and dark period used:

8.5.1 Mean and tolerance limits for temperature recorded by the black panel thermometer;

8.5.2 Mean and tolerance limits for relative humidity of air passing over test specimens;

8.5.3 Time of water spray period and the conditions of water used for specimen spray, if used, including total solids and silica content if total solids is greater than 1 ppm;

8.5.4 Time of each light and dark period;

8.5.5 Mean and tolerance for white panel temperature, if applicable; and

8.5.6 Mean and tolerance for chamber air temperature, if applicable.

8.6 Description of method used to mount specimens in exposure frame, including a description of any material used as backing for test specimens.

8.7 Procedure for test specimen repositioning, if used.

8.8 Description of the radiometers used for measuring light dosage, if used.

8.9 *Test Results*:

8.9.1 Complete description of the test procedure used for measurement of any properties reported;

8.9.2 Results from property measurement on test specimens;

8.9.3 Results from property measurement on control specimens;

8.9.4 Results from property measurement on unexposed file specimens, if determined; and,

8.9.5 Exposure period (either time in hours, or radiant energy in Jm^2 and the bandpass in which it was measured).

8.10 The date of the test.

9. Precision and Bias

9.1 Precision and bias information can be found in relevant standards describing the specific type of exposure device.

10. Keywords

10.1 accelerated; durability; exposure; light; temperature; weathering; ultraviolet; UV-radiation

ANNEXES

(Mandatory Information)

A1. PROCEDURES FOR MEASURING IRRADIANCE UNIFORMITY IN SPECIMEN EXPOSURE AREA

A1.1 In devices that use a drum to hold specimens and rotate them around a light source, measure irradiance at a position in the specimen drum that is closest to the light source (position *A*) in Fig. A1.1 and at two positions within the specimen drum that are farthest from the light source (position *B*) in Fig. A1.1. The relationship between the irradiance at position *B* relative to the irradiance at position *A* shall be as follows:

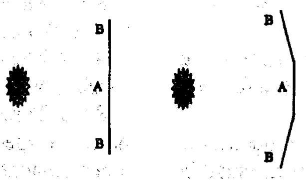
$$B \geq 0.7\,A \qquad \text{(A1.1)}$$

A1.2 In devices where specimens are positioned in a flat plane in front of a light source, measure irradiance at a position in the specimen plane that is closest to the light source (position *X* in Fig. A1.2) and in two opposite corners of the plane where test specimens are placed (position *Y* in Fig. A1.2). The relationship between the irradiance at position *Y* relative to the irradiance at position *X* shall be as follows:

$$Y \geq 0.7\,X \qquad \text{(A1.2)}$$

A1.3 If device design indicates that the maximum irradiance may not be at the center of the exposure area, the actual maximum irradiance shall be used for *A* or *X* in Eq A1.1 and Eq A1.2. Additional measurements of irradiance at other positions within the exposure area may also be made. In all cases, however, the irradiance measured at these positions shall be at least 70 % of the maximum irradiance.

A1.4 As an alternate to irradiance measurements, uniformity of irradiance may be determined by use of reference materials. The change in characteristic property of the reference material shall be known function preferably linear, of radiant exposure. Do not use reference materials, which show an induction time with little change in property as a function of radiant exposure. Fig. A1.3 is a typical plot of measured property as a function of radiant exposure for reference materials. Prior to using a reference material to determine uniformity of irradiance, repeatability of the property change for specimens of the reference material exposed at the same position must be determined. When reference materials are used, all specimens shall be from the same lot. Expose reference material specimens at the center of the exposure area and at positions farthest from the center. All specimens shall be exposed at the same time. Expose the reference specimens until there is a measurable change in the characteristic property being monitored. The change in measured property of the reference material at positions farthest from the center shall be at least 70 % of the change measured on the specimen exposed at the center.



Flat specimen drum   Canted specimen drum

FIG. A1.1 Measurement of Irradiance in Devices Using a Rotating Specimen Drum

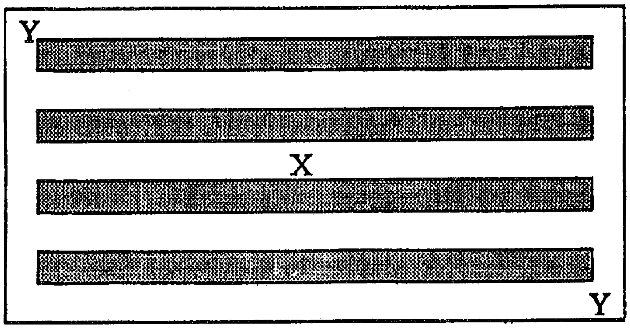
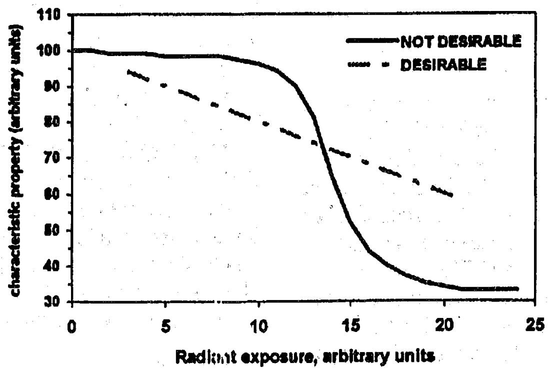


FIG. A1.2 Measuring Irradiance Uniformity in Device With a Flat Specimen Plane (Shaded Areas Indicate Light Sources)



Note 1—Typical plot of measured property for a reference material with a linear change with radiant exposure and a material that shows an induction period before measurable property change. Reference materials showing a linear change in property as a function of radiant exposure are desirable for use in characterizing irradiance uniformity.

FIG. A1.3 Typical Plot of Measured Property for Reference Materials

Note A1.1—Actual measurements of irradiance are preferred over use of reference materials because differences in property change between reference material specimens exposed at the extremes of the exposure and those exposed at the center may be affected significantly by differences in temperature or moisture conditions, or both, as well as differences in irradiance.

A2. REQUIREMENTS FOR UNINSULATED AND INSULATED BLACK PANEL THERMOMETERS

A2.1 Uninsulated black-panel thermometers consist of a plane (flat) metal plate that is resistant to corrosion. The surface of this plate that faces the light source shall be coated with a black layer which has good resistance to aging. The coated black plate shall absorb at least 90-95 % of all incident flux to 2500 nm. A thermal sensitive element shall be firmly attached to the center of the exposed surface. This thermal sensitive element can be a black-coated stem-type bimetallic dial sensor or a resistance sensor. The backside of the metal panel shall be open to the atmosphere within the exposure chamber.

A2.2 Insulated black panel thermometers consist of a plane (flat) stainless steel plate with a thickness of about 0.5 mm. The minimum dimensions for the stainless steel plate are 70 mm by 40 mm (**2**). The surface of this plate facing the light source shall be coated with a black layer which has good resistance to aging. The coated black plate shall absorb at least 90-95 % of all incident flux to 2500 nm. A platinum resistance sensor shall be attached in good thermal contact to the center of the plate on the side opposite the radiation source. This side of the metal plate shall be attached to 5 mm thick base plate made of unfilled polyvinylidene fluoride (PVDF). A small space sufficient to hold the platinum resistance sensor shall be machined in the PVDF base plate. The distance between the sensor and this recess in the PVDF plate is about 1 mm. The length and the width of the PVDF plate must be sufficient so that no metallic thermal contact exists between the black coated metal plate and the mounting holder into which it is fitted. The metallic mounts of the insulated black panel holder shall be at least 4 mm from the edges of the metal plate. Black standard thermometers which differ in construction are permitted, as long as the temperature of the alternate construction is within ± 1.0°C of the specified construction at all steady state temperature and irradiance settings the exposure device is capable of attaining. In addition, the time needed for an alternate black standard thermometer construction to reach steady state must be within 10 % of the time needed for the specified black standard thermometer to reach steady state.

NOTE A2.1—Insulated black panel thermometers are referred to as black standard thermometers in ISO 4892.

APPENDIX

(Nonmandatory Information)

X1. FACTORS THAT DECREASE DEGREE OF CORRELATION BETWEEN ACCELERATED TESTS USING LABORATORY LIGHT SOURCES AND ACTUAL USE EXPOSURES

X1.1 Differences in the spectral distribution or intensity between the laboratory light source and sunlight.

X1.1.1 Shorter than normal wavelength exposures are often used to obtain faster failure rates in laboratory accelerated exposure tests. For outdoor exposures, the cut-on for short wavelength UV radiation is generally considered to be about 300 nm. Exposures to UV radiation of wavelengths less than 300 nm, may produce degradation reactions, which do not occur when the material is used outdoors. If a laboratory light source used in an accelerated test contains UV radiation of wavelengths shorter than that found in the actual use condition, the mechanism of degradation and stability ranking of materials can be dramatically different in the accelerated test.

X1.1.2 It may not be necessary to simulate daylight over the entire spectrum, if radiation in a specific region is known to produce the type of degradation of interest in the materials being tested and does not alter stability ranking of materials. Laboratory light sources, which have a very strong emission in a narrow band relative to the rest of the ultraviolet or visible spectrum, however, may cause a particular reaction to be favored relative to others which may be very important (**3**). This type of light source also may not produce changes caused in exposures to daylight. Exposures to light sources, which only produce ultraviolet radiation may not produce color fade caused by visible radiation, and may cause polymer yellowing that is more pronounced than that produced in exposures to daylight.

X1.2 *Light Intensities Higher Than Those Experienced in Actual Use Conditions*—Light intensities higher than those experienced in actual use conditions typically are used in exposures to laboratory light sources in order to accelerate degradation. There are several reasons why the use of abnormally high irradiance can change the mechanism of material degradation relative to the conditions found in actual use environment. Some materials are more sensitive to changes in light intensity than others, so the use of abnormally high irradiance can alter the stability ranking of materials.

X1.2.1 In exterior exposures, polymers in an excited state caused by absorption of a high energy photon typically will decay to ground state before absorbing another high energy photon. In exposures to laboratory light sources with abnormally high light flux, however, the rate of photon absorption is so high that the material will often absorb a high energy photon when it is still in an excited state (**4**).

X1.2.2 Free radicals are formed in materials exposed to ultraviolet light. Reactions leading to degradation occur when the free radicals interact with the material. Free radicals also can recombine with other free radicals in reactions that do not lead to degradation. The high concentration of free radicals formed under high irradiance conditions results in a greater percentage of recombination due to the close proximity of the free radicals, particularly in polymers exposed at temperatures below their T_g (**5**).

X1.2.3 Oxygen diffusion can sometimes become rate limiting in polymer oxidation processes where abnormally high irradiance, or abnormally high specimen temperatures, are used for test acceleration (**6**). This can produce differences in the mechanism for degradation reactions and may cause an abnormal ratio of surface to bulk oxidation, which could result in unnatural color shifts or physical property changes.

X1.3 *Continuous Exposure to Light from a Laboratory Light Source Without Any Dark Periods*—Continuous exposure to light from laboratory light sources often is used in order to achieve accelerated degradation relative to actual use conditions. Continuous exposure to light, however, may eliminate critical dark reactions that occur in outdoor exposures or indoor use conditions where there are regular periods without light.

X1.4 *Specimen Temperatures That Are Abnormally High Relative to Actual Use Conditions*— Temperatures higher than those experienced in actual use conditions often are used to obtain faster degradation in laboratory accelerated tests. Some polymers are much more susceptible to degradation from thermal effects than others. For materials that are subject to the same rate and type of photodegradation, exposures at abnormally high temperatures may make a temperature sensitive material appear to be less durable compared to a less temperature sensitive material. In addition, exposures at temperatures above the glass transition temperature of polymers can alter dramatically the mechanism of degradation and stability ranking compared to exposures conducted at a temperature below the glass transition temperature. The black panel temperature used in a laboratory accelerated test should be maintained in a reasonable range, which usually is no higher than the maximum observed for the black panel in actual use conditions.

X1.5 *Exposure Conditions That Produce Unrealistically Large Temperature Differences Between Light and Dark Colored Specimens*—Some laboratory light sources produce large amounts of infrared radiation. In order to prevent overheating of specimens, the infrared radiation can be reduced using infrared absorbing or reflecting filters, or by passing large amounts of air through the specimen chamber to cool specimens. If measures to control the amount of infrared radiation reaching specimens being exposed are not sufficient, the temperature differences between light and dark colored specimens of the same material can be larger than would be seen in natural exposure. Some laboratory light sources produce very little or no infrared radiation. When these types of laboratory light sources are used, the difference between dark and light colored specimens may be less than that found in outdoor exposures.

X1.6 *Temperature Cycling Conditions That are Different from Those Found in Actual Use Conditions*—Abnormally high temperature cycling frequencies can produce mechanically-induced cracking or other degradation not seen in outdoor exposures. Exposure devices, which spray specimens with water when the light source is on, can produce an abnormally rapid change in temperature that also may produce cracking not produced in outdoor exposures.

X1.7 *Unrealistically High or Low Levels of Moisture*—Moisture is very important for producing degradation of many polymers. If the amount of moisture, or the way in which specimens are exposed to the effects of moisture in a laboratory accelerated test differs from the actual use environment, the mechanism and rate of degradation may be much different. This can have a significant effect on the stability ranking of materials.

X1.8 *Absence of Biological Agents or Pollutants*—Materials that are exposed in warm, wet locations often are subject to significant growth of biological agents, such as fungi, bacteria, and algae. Pollutants present in many exterior environments have a significant affect on the mechanism and rate of degradation for some plastics. If these effects are not included in a laboratory accelerated exposure test, the mechanism and stability ranking of materials may be significantly different than that found in exterior exposures.

References

(1) Simms, J.A. "Journal of Coatings Technology," ASTM, Vol 50, 1987, pp. 45-53.

(2) Boxhammer, J., Kockott, D., Trubiroha, P., "Black Standard Thermometer," Materialprüfung, Vol 35, 1993, p. 5.

(3) Searle, N.D.," Effect of Light Source Emissions on Durability Testing," *Symposium Accelerated and Outdoor Durability Testing of Organic Materials, ASTM STP 1202,* ASTM, 1993, p.

(4) Schnabel, W., "Polymer Degradation, Principles and Practical Applications," pp. 95–100, Macmillan Publishing Co., Inc., New York, NY 1981.

(5) Grassie, N., Scott, G., "Polymer Degradation and Stabilization," pp. 75–76, Cambridge University Press, New York, NY 1985.

(6) Clough, R.I., Gillen, K.T., "Physical Techniques for Profiling Heterogeneous Polymer Degradation," Polymer Stabilization and Degradation, ACS Symposium Series 280, Peter Klemchuk, Editor, American Chemical Society, Washington, D.C., 1985.

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Standard Practice for
Operating Fluorescent Light Apparatus for UV Exposure of Nonmetallic Materials[1]

This standard is issued under the fixed designation G 154; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice covers the basic principles and operating procedures for using fluorescent UV light, and water apparatus intended to reproduce the weathering effects that occur when materials are exposed to sunlight (either direct or through window glass) and moisture as rain or dew in actual usage. This practice is limited to the procedures for obtaining, measuring, and controlling conditions of exposure. A number of exposure procedures are listed in an appendix; however, this practice does not specify the exposure conditions best suited for the material to be tested.

NOTE 1—Practice G 151 describes performance criteria for all exposure devices that use laboratory light sources. This practice replaces Practice G 53, which describes very specific designs for devices used for fluorescent UV exposures. The apparatus described in Practice G 53 is covered by this practice.

1.2 Test specimens are exposed to fluorescent UV light under controlled environmental conditions. Different types of fluorescent UV light sources are described.

1.3 Specimen preparation and evaluation of the results are covered in ASTM methods or specifications for specific materials. General guidance is given in Practice G 151 and ISO 4892-1. More specific information about methods for determining the change in properties after exposure and reporting these results is described in ISO 4582.

1.4 The values stated in SI units are to be regarded as the standard.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

1.6 This standard is technically similar to ISO 4892-3 and ISO DIS 11507.

2. Referenced Documents

2.1 *ASTM Standards:*

D 3980 Practice for Interlaboratory Testing of Paint and Related Materials[2]

E 691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method[3]

G 53 Practice for Operating Light- and Water-Exposure Apparatus (Fluorescent UV-Condensation Type) for Exposure of Nonmetallic Materials[4]

G 113 Terminology Relating to Natural and Artificial Weathering Tests for Nonmetallic Materials[4]

G 151 Practice for Exposing Nonmetallic Materials in Accelerated Test Devices That Use Laboratory Light Sources[4]

2.2 *CIE Standard:*

CIE-Publ. No. 85: Recommendations for the Integrated Irradiance and the Spectral Distribution of Simulated Solar Radiation for Testing Purposes[5]

2.3 *ISO Standards:*

ISO 4582, Plastics—Determination of the Changes of Colour and Variations in Properties After Exposure to Daylight Under Glass, Natural Weathering or Artificial Light[6]

ISO 4892-1, Plastics—Methods of Exposure to Laboratory Light Sources, Part 1, Guidance[6]

ISO 4892-3, Plastics—Methods of Exposure to Laboratory Light Sources, Part 3, Fluorescent UV lamps[6]

ISO DIS 11507, Paint and Varnishes—Exposure of Coatings to Artificial Weathering in Apparatus—Exposure to Fluorescent Ultraviolet and Condensation Apparatus[6]

3. Terminology

3.1 *Definitions*—The definitions given in Terminology G 113 are applicable to this practice.

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[1] This practice is under the jurisdiction of ASTM Committee G3 on Weathering and Durability and is the direct responsibility of Subcommittee G03.03 on Simulated and Controlled Exposure Tests.

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[2] Discontinued 1998. See *1998 Annual Book of ASTM Standards,* Vol 06.01.

[3] *Annual Book of ASTM Standards*, Vol 14.02.

[4] *Annual Book of ASTM Standards*, Vol 14.04.

[5] Available from Secretary, U.S. National Committee, CIE, National Institute of Standards and Technology (NIST), Gaithersburg, MD 20899.

[6] Available from American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.

3.2 *Definitions of Terms Specific to This Standard*—As used in this practice, the term *sunlight* is identical to the terms *daylight* and *solar irradiance, global* as they are defined in Terminology G 113.

4. Summary of Practice

4.1 Specimens are exposed to repetitive cycles of light and moisture under controlled environmental conditions.

4.1.1 Moisture is usually produced by condensation of water vapor onto the test specimen or by spraying the specimens with demineralized/deionized water.

4.2 The exposure condition may be varied by selection of:

4.2.1 The fluorescent lamp,

4.2.2 The lamp's irradiance level,

4.2.3 The type of moisture exposure,

4.2.4 The timing of the light and moisture exposure,

4.2.5 The temperature of light exposure, and

4.2.6 The temperature of moisture exposure, and

4.2.7 The timing of a light/dark cycle.

4.3 Comparison of results obtained from specimens exposed in same model of apparatus should not be made unless reproducibility has been established among devices for the material to be tested.

4.4 Comparison of results obtained from specimens exposed in different models of apparatus should not be made unless correlation has been established among devices for the material to be tested.

5. Significance and Use

5.1 The use of this apparatus is intended to induce property changes associated with the end use conditions, including the effects of the UV portion of sunlight, moisture, and heat. These exposures may include a means to introduce moisture to the test specimen. Exposures are not intended to simulate the deterioration caused by localized weather phenomena, such as atmospheric pollution, biological attack, and saltwater exposure. Alternatively, the exposure may simulate the effects of sunlight through window glass. Typically, these exposures would include moisture in the form of condensing humidity.

NOTE 2—**Caution:** Refer to Practice G 151 for full cautionary guidance applicable to all laboratory weathering devices.

5.2 Variation in results may be expected when operating conditions are varied within the accepted limits of this practice. Therefore, no reference shall be made to results from the use of this practice unless accompanied by a report detailing the specific operating conditions in conformance with the Section 10.

5.2.1 It is recommended that a similar material of known performance (a control) be exposed simultaneously with the test specimen to provide a standard for comparative purposes. It is recommended that at least three replicates of each material evaluated be exposed in each test to allow for statistical evaluation of results.

6. Apparatus

6.1 *Laboratory Light Source*—The light source shall be fluorescent UV lamps. A variety of fluorescent UV lamps can be used for this procedure. Differences in lamp intensity or spectrum may cause significant differences in test results. A detailed description of the type(s) of lamp(s) used should be stated in detail in the test report. The particular testing application determines which lamp should be used. See Appendix X1 for lamp application guidelines.

NOTE 3—Do not mix different types of lamps. Mixing different types of lamps in a fluorescent UV light apparatus may produce major inconsistencies in the light falling on the samples, unless the apparatus has been specifically designed to ensure a uniform spectral distribution.

NOTE 4—Many fluorescent lamps age significantly with extended use. Follow the apparatus manufacturer's instructions on the procedure necessary to maintain desired irradiance (**1,2**).

6.1.1 Actual irradiance levels at the test specimen surface may vary due to the type or manufacturer of the lamp used, or both, the age of the lamps, the distance to the lamp array, and the air temperature within the chamber and the ambient laboratory temperature. Consequently, the use of a radiometer to monitor and control the radiant energy is recommended.

6.1.2 Several factors can affect the spectral power distribution of fluorescent UV lamps:

6.1.2.1 Aging of the glass used in some types of lamps can result in changes in transmission. Aging of glass can result in a significant reduction in the short wavelength UV emission of some lamp types,

6.1.2.2 Accumulation of dirt or other residue on lamps can affect irradiance,

6.1.2.3 Thickness of glass used for lamp tube can have large effects on the amount of short wavelength UV radiation transmitted, and

6.1.2.4 Uniformity and durability of phosphor coating.

6.1.3 *Spectral Irradiance*:

NOTE 5—Fluorescent UVA lamps are available with a choice of spectral power distributions that vary significantly. The more common may be identified as UVA-340 and UVA-351. These numbers represent the characteristic nominal wavelength (in nm) of peak emission for each of these lamp types. The actual peak emissions are at 343 and 350 nm, respectively.

6.1.3.1 *Spectral Irradiance of UVA-340 Lamps for Daylight UV*—The spectral power distribution of UVA-340 fluorescent lamps shall comply with the requirements specified in Table 1.

NOTE 6—The main application for UVA-340 lamps is for simulation of the short and middle UV wavelength region of daylight.

6.1.3.2 *Spectral Irradiance of UVA-351 Lamps for Daylight UV Behind Window Glass*—The spectral power distribution of UVA-351 lamp for Daylight UV behind Window Glass shall comply with the requirements specified in Table 2.

NOTE 7—The main application for UVA-351 lamps is for simulation of the short and middle UV wavelength region of daylight which has been filtered through window glass (**3**).

6.1.3.3 *Spectral Irradiance of UVB-313 Lamps*—The spectral power distribution of UVB-313 fluorescent lamps shall comply with the requirements specified in Table 2.

NOTE 8—Fluorescent UVB lamps have the spectral distribution of radiation peaking near the 313-nm mercury line. They emit significant amounts of radiation below 300 nm, the nominal cut on wavelength of global solar radiation, that may result in aging processes not occurring outdoors. Use of this lamp is not recommended for sunlight simulation. See Table 3.

TABLE 1 Relative Spectral Power Distribution Specification for UVA-340 Lamps for Daylight UV

Bandpass, nm	Fluorescent UVA-340 Lamp[A]	Sunlight[B]
Ultraviolet Wavelength Region Irradiance as a percentage of total irradiance from 260 to 400 nm		
260–270	0.0 %	0
271–280	0.0 %	0
281–290	0.0 %	0
291–300	< 0.2 %	0
301–320	6.2–8.6 %	5.6 %
321–340	27.1–30.7 %	18.5 %
341–360	34.2–35.4 %	21.7 %
361–380	19.5–23.7 %	26.6 %
381–400	6.6–7.8 %	27.6 %
Ultraviolet and Visible Wavelength Region Irradiance as a percentage of total irradiance from 300 to 800 nm[C]		
300–400	87.3 %[D]	11 %[E]
401–700	12.7 %[D]	72 %[E]

[A] UVA-340 data—The ranges given are based on spectral power distribution measurements made for lamps of different ages and operating at different levels of controlled irradiance. The ranges given are based on three sigma limits from the averages of this data.

[B] Sunlight data—The sunlight data is for global irradiance on a horizontal surface with a air mass of 1.2, column ozone 0.294 atm cm, 30 % relative humidity, altitude 2100 m (atmospheric pressure of 787.8 mb), and an aerosol represented by an optical thickness of 0.81 at 300 nm and 0.62 at 400 nm.

[C] Data from 701 to 800 nm is not shown.

[D] UVA-340 data—Because the primary emission of fluorescent UV lamps is concentrated in the 300- to 400-nm bandpass, there are limited data available for visible light emissions of fluorescent UV lamps. Therefore, the data in this table are based on very few measurements and are representative only.

[E] Sunlight data—The sunlight data is from Table 4 of CIE Publication Number 85, global solar irradiance on a horizontal surface with an air mass of 1.0, column ozone of 0.34 atm cm, 1.42-cm precipitable water vapor, and an aerosol represented by an optical thickness of 0.1 at 500 nm.

TABLE 2 Relative Spectral Power Distribution Specification for UVA-351 Lamps for Daylight UV Behind Window Glass

Bandpass, nm	Fluorescent UVA-351 Lamp[A]	Estimated Window Glass Filtered Sunlight[B]
Ultraviolet Wavelength Region Irradiance as a percentage of total irradiance from 260 to 400 nm		
260–270	0.0 %	0 %
271–280	0.0 %	0 %
281–290	0.0 %	0 %
290–300	< 0.1 %	0 %
301–320	0.9–3.3 %	0.1–1.5 %
321–340	18.3–22.7 %	9.4–14.8 %
341–360	42.7–44.5 %	23.2–23.5 %
361–380	24.8–28.2 %	29.6–32.5 %
381–400	5.8–7.6 %	30.9 –34.5 %
Ultraviolet and Visible Wavelength Region Irradiance as a percentage of total irradiance from 300 to 800 nm[C]		
300–400	90.1 %[D]	9.0–11.1 %[E]
401–700	9.9 %[D]	71.3–73.1 %[E]

[A] UVA-351 data—The ranges given are based on spectral power distribution measurements made for lamps of different ages and operating at different levels of controlled irradiance. The ranges given are based on three sigma limits from the averages of this data.

[B] Sunlight data—The sunlight data is for global irradiance on a horizontal surface with an air mass of 1.2, column ozone 0.294 atm cm, 30 % relative humidity, altitude 2100 m (atmospheric pressure of 787.8 mb), and an aerosol represented by an optical thickness of 0.081 at 300 nm and 0.62 at 400 nm. The range is determined by multiplying solar irradiance by the upper and lower limits for transmission of single strength window glass samples used for studies conducted by ASTM Subcommittee G03.02.

[C] Data from 701 to 800 nm is not shown.

[D] UVA-351 data—Because the primary emission of fluorescent UV lamps is concentrated in the 300- to 400-nm bandpass, there are limited data available for visible light emissions of fluorescent UV lamps. Therefore, the data in this table are based on very few measurements and are representative only.

[E] Sunlight data—The sunlight data is from Table 4 of CIE Publication Number 85, global solar irradiance on a horizontal surface with an air mass of 1.0, column ozone of 0.34 atm cm, 1.42-cm precipitable water vapor, and an aerosol represented by an optical thickness of 0.1 at 500 nm. The range is determined by multiplying solar irradiance by the upper and lower limits for transmission of single strength window glass samples used for studies conducted by ASTM Subcommittee G03.02.

6.2 *Test Chamber*—The design of the test chamber may vary, but it should be constructed from corrosion resistant material and, in addition to the radiant source, may provide for means of controlling temperature and relative humidity. When required, provision shall be made for the spraying of water on the test specimen for the formation of condensate on the exposed face of the specimen or for the immersion of the test specimen in water.

6.2.1 The radiant source(s) shall be located with respect to the specimens such that the uniformity of irradiance at the specimen face complies with the requirements in Practice G 151.

6.2.2 Lamp replacement, lamp rotation, and specimen repositioning may be required to obtain uniform exposure of all specimens to UV radiation and temperature. Follow manufacturer's recommendation for lamp replacement and rotation.

6.3 *Instrument Calibration*—To ensure standardization and accuracy, the instruments associated with the exposure apparatus (for example, timers, thermometers, wet bulb sensors, dry bulb sensors, humidity sensors, UV sensors, and radiometers) require periodic calibration to ensure repeatability of test results. Whenever possible, calibration should be traceable to national or international standards. Calibration schedule and procedure should be in accordance with manufacturer's instructions.

6.4 *Radiometer*—The use of a radiometer to monitor and control the amount of radiant energy received at the sample is recommended. If a radiometer is used, it shall comply with the requirements in Practice G 151.

6.5 *Thermometer*—Either insulated or un-insulated black or white panel thermometers may be used. The un-insulated thermometers may be made of either steel or aluminum. Thermometers shall conform to the descriptions found in Practice G 151.

6.5.1 The thermometer shall be mounted on the specimen rack so that its surface is in the same relative position and subjected to the same influences as the test specimens.

6.5.2 Some specifications may require chamber air temperature control. Positioning and calibration of chamber air temperature sensors shall be in accordance with the descriptions found in Practice G 151.

NOTE 9—Typically, these devices control by black panel temperature only.

6.6 *Moisture*—The test specimens may be exposed to moisture in the form of water spray, condensation, or high humidity.

6.6.1 *Water Spray*—The test chamber may be equipped with a means to introduce intermittent water spray onto the test specimens under specified conditions. The spray shall be uniformly distributed over the samples. The spray system shall

TABLE 3 Relative Spectral Power Distribution Specification for UVB-313 Lamps

Bandpass, nm	Fluorescent UVB-313 Lamp[A,B]	Sunlight[C]
Ultraviolet Wavelength Region[A] Irradiance as a percentage of total irradiance from 260 to 400 nm		
260–270	< 0.1 %	0
271–280	0.1–0.7 %	0
281–290	3.2–4.4 %	0
291–300	10.7–13.7 %	0
301–320	38.0–44.6 %	5.6 %
321–340	25.5–30.9 %	18.5 %
341–360	7.7–10.7 %	21.7 %
361–380	2.5–5.5 %	26.6 %
381–400	0.0–1.5 %	27.6 %
Ultraviolet and Visible Wavelength Region Irradiance as a percentage of total irradiance from 300 to 800 nm[D]		
300–400	88.5 %[E]	11 %[F]
401–700	11.5 %[E]	72 %[F]

[A] UVB-313 data—Some UVB lamps have measurable emittance at the 254-nm mercury line. This may affect test results for some materials.

[B] UVB-313 data—The ranges given are based on spectral power distribution measurements made for lamps of a different ages and operating at different levels of controlled irradiance. The ranges given are based on three sigma limits from the averages of this data. Lamps that meet this specification are available from different manufacturers. These lamps may have significantly different irradiance levels (that is, total light output), but still have the same relative spectral power distribution.

[C] Sunlight data—The sunlight data in for global irradiance on a horizontal surface with a air mass of 1.2, column ozone 0.294 atm cm, 30 % relative humidity, altitude 2100 m (atmospheric pressure of 787.8 mb), and an aerosol represented by an optical thickness of 0.081 to 300 nm and 0.62 at 400 nm.

[D] Data from 701 to 800 nm is not shown.

[E] UVB-313 data—Because the primary emission of fluorescent UV lamps is concentrated in the 300- to 400-nm bandpass, there is limited data available for visible light emissions of fluorescent UV lamps. Therefore, the data in this table are based on very low measurements and are representative only.

[F] Sunlight data—The sunlight data is from Table 4 of CIE Publication Number 85, global solar irradiance on a horizontal surface with an air mass of 1.0, column ozone of 0.34 atm cm, 1.42-cm precipitable water vapor, and an aerosol represented by an optical thickness of 0.1 at 500 nm.

be made from corrosion resistant materials that do not contaminate the water used.

6.6.1.1 *Spray Water Quality*—Spray water shall have a conductivity below 5 μS/cm, contain less than 1-ppm solids, and leave no observable stains or deposits on the specimens. Very low levels of silica in spray water can cause significant deposits on the surface of test specimens. Care should be taken to keep silica levels below 0.1 ppm. In addition to distillation, a combination of deionization and reverse osmosis can effectively produce water of the required quality. The pH of the water used should be reported. See Practice G 151 for detailed water quality instructions.

6.6.2 *Condensation*—The test chamber may be equipped with a means to cause condensation to form on the exposed face of the test specimen. Typically, water vapor shall be generated by heating water and filling the chamber with hot vapor, which then is made to condense on the test specimens.

6.6.3 *Relative Humidity*—The test chamber may be equipped with a means to measure and control the relative humidity. Such instruments shall be shielded from the lamp radiation.

6.7 *Specimen Holders*—Holders for test specimens shall be made from corrosion resistant materials that will not affect the test results. Corrosion resistant alloys of aluminium or stainless steel have been found acceptable. Brass, steel, or copper shall not be used in the vicinity of the test specimens.

6.8 *Apparatus to Assess Changes in Properties*—The necessary apparatus required by ASTM or ISO relating to the determination of the properties chosen for monitoring shall be used (see also ISO 4582).

7. Test Specimen

7.1 Refer to Practice G 151.

8. Test Conditions

8.1 Any exposure conditions may be used as long as the exact conditions are detailed in the report. Appendix X2 shows some representative exposure conditions. These are not necessarily preferred and no recommendation is implied. These conditions are provided for reference only.

9. Procedure

9.1 Identify each test specimen by suitable indelible marking, but not on areas used in testing.

9.2 Determine which property of the test specimens will be evaluated. Prior to exposing the specimens, quantify the appropriate properties in accordance with recognized ASTM or international standards. If required (for example, destructive testing), use unexposed file specimens to quantify the property. See ISO 4582 for detailed guidance.

9.3 *Mounting of Test Specimens*—Attach the specimens to the specimen holders in the equipment in such a manner that the specimens are not subject to any applied stress. To assure uniform exposure conditions, fill all of the spaces, using blank panels of corrosion resistant material if necessary.

NOTE 10—Evaluation of color and appearance changes of exposed materials shall be made based on comparisons to unexposed specimens of the same material which have been stored in the dark. Masking or shielding the face of test specimens with an opaque cover for the purpose of showing the effects of exposure on one panel is not recommended. Misleading results may be obtained by this method, since the masked portion of the specimen is still exposed to temperature and humidity that in many cases will affect results.

9.4 *Exposure to Test Conditions*—Program the selected test conditions to operate continuously throughout the required number of repetitive cycles. Maintain these conditions throughout the exposure. Interruptions to service the apparatus and to inspect specimens shall be minimized.

9.5 *Specimen Repositioning*—Periodic repositioning of the specimens during exposure is not necessary if the irradiance at the positions farthest from the center of the specimen area is at least 90 % of that measured at the center of the exposure area. Irradiance uniformity shall be determined in accordance with Practice G 151.

9.5.1 If irradiance at positions farther from the center of the exposure area is between 70 and 90 % of that measured at the center, one of the following three techniques shall be used for specimen placement.

9.5.1.1 Periodically reposition specimens during the exposure period to ensure that each receives an equal amount of radiant exposure. The repositioning schedule shall be agreed upon by all interested parties.

9.5.1.2 Place specimens only in the exposure area where the irradiance is at least 90 % of the maximum irradiance.

9.5.1.3 To compensate for test variability randomly position replicate specimens within the exposure area which meets the irradiance uniformity requirements as defined in 9.5.1.

9.6 *Inspection*—If it is necessary to remove a test specimen for periodic inspection, take care not to handle or disturb the test surface. After inspection, the test specimen shall be returned to the test chamber with its test surface in the same orientation as previously tested.

9.7 *Apparatus Maintenance*—The test apparatus requires periodic maintenance to maintain uniform exposure conditions. Perform required maintenance and calibration in accordance with manufacturer's instructions.

9.8 Expose the test specimens for the specified period of exposure. See Practice G 151 for further guidance.

9.9 At the end of the exposure, quantify the appropriate properties in accordance with recognized ASTM or international standards and report the results in conformance with Practice G 151.

NOTE 11—Periods of exposure and evaluation of test results are addressed in Practice G 151.

10. Report

10.1 The test report shall conform to Practice G 151.

11. Precision and Bias

11.1 *Precision*:

11.1.1 The repeatability and reproducibility of results obtained in exposures conducted according to this practice will vary with the materials being tested, the material property being measured, and the specific test conditions and cycles that are used. In round-robin studies conducted by Subcommittee G03.03, the 60° gloss values of replicate PVC tape specimens exposed in different laboratories using identical test devices and exposure cycles showed significant variability **(3)**. The variability shown in these round-robin studies restricts the use of "absolute specifications" such as requiring a specific property level after a specific exposure period **(4,5)**.

11.1.2 If a standard or specification for general use requires a definite property level after a specific time or radiant exposure in an exposure test conducted according to this practice, the specified property level shall be based on results obtained in a round-robin that takes into consideration the variability due to the exposure and the test method used to measure the property of interest. The round-robin shall be conducted according to Practice E 691 or Practice D 3980 and shall include a statistically representative sample of all laboratories or organizations that would normally conduct the exposure and property measurement.

11.1.3 If a standard or specification for use between two or three parties requires a definite property level after a specific time or radiant exposure in an exposure test conducted according to this practice, the specified property level shall be based on statistical analysis of results from at least two separate, independent exposures in each laboratory. The design of the experiment used to determine the specification shall take into consideration the variability due to the exposure and the test method used to measure the property of interest.

11.1.4 The round-robin studies cited in 11.1.1 demonstrated that the gloss values for a series of materials could be ranked with a high level of reproducibility between laboratories. When reproducibility in results from an exposure test conducted according to this practice have not been established through round-robin testing, performance requirements for materials shall be specified in terms of comparison (ranked) to a control material. The control specimens shall be exposed simultaneously with the test specimen(s) in the same device. The specific control material used shall be agreed upon by the concerned parties. Expose replicates of the test specimen and the control specimen so that statistically significant performance differences can be determined.

11.2 *Bias*—Bias can not be determined because no acceptable standard weathering reference materials are available.

12. Keywords

12.1 accelerated; accelerated weathering; durability; exposure; fluorescent UV lamps; laboratory weathering; light; lightfastness; non-metallic materials; temperature; ultraviolet; weathering

APPENDIXES

(Nonmandatory Information)

X1. APPLICATION GUIDELINES FOR TYPICAL FLUORESCENT UV LAMPS

X1.1 *General*

X1.1.1 A variety of fluorescent UV lamps may be used in this practice. The lamps shown in this section are representative of their type. Other lamps, or combinations of lamps, may be used. The particular application determines which lamp should be used. The lamps discussed in this Appendix differ in the total amount of UV energy emitted and their wavelength spectrum. Differences in lamp energy or spectrum may cause significant differences in test results. A detailed description of the type(s) of lamp(s) used shall be stated in detail in the test report.

X1.1.2 All spectral power distributions (SPDs) shown in this section are representative only and are not meant to be used to calculate or estimate total radiant exposure for tests in fluorescent UV devices. Actual irradiance levels at the test specimen surface will vary due to the type and/or manufacturer of the lamp used, the age of the lamps, the distance to the lamp array, and the air temperature within the chamber.

NOTE X1.1—All SPDs in this appendix were measured using a spectroradiometer with a double grating monochromator (1-nm band pass) with a quartz cosine receptor. The fluorescent UV SPDs were measured at the sample plane in the center of the allowed sample area. SPDs for sunlight were measured in Phoenix, AZ at solar noon at the summer solstice with a clear sky, with the spectroradiometer on an equatorial follow-the-sum mount.

X1.2 Simulations of Direct Solar UV Radiation Exposures

X1.2.1 *UVA-340 Lamps*—For simulations of direct solar UV radiation the UVA-340 lamp is recommended. Because UVA-340 lamps typically have little or no UV output below 300 nm (that is considered the "cut-on" wavelength for terrestrial sunlight), they usually do not degrade materials as rapidly as UVB lamps, but they may allow enhanced correlation with actual outdoor weathering. Tests using UVA-340 lamps have been found useful for comparing different nonmetallic materials such as polymers, textiles, and UV stabilizers. Fig. X1.1 illustrates the SPD of the UVA-340 lamp compared to noon, summer sunlight.

X1.2.2 *UVB-313 Lamps*—The UVB region (280 to 315 nm) includes the shortest wavelengths found in sunlight at the earth's surface and is responsible for considerable polymer damage. There are two commonly available types of UVB-313 lamps that meet the requirements of this document. These are known commercially as the UVB-313 and the FS-40. These lamps emit different amounts of total energy, but both peak at 313 nm and produce the same UV wavelengths in the same relative proportions. In tests using the same cycles and temperatures, shorter times to failure are typically observed when the lamp with higher UV irradiance is used. Furthermore, tests using the same cycles and temperatures with these two lamps may exhibit differences in ranking of materials due to difference in the proportion of UV to moisture and temperature.

NOTE X1.2—The Fig. X1.2 illustrates the difference between the lamps.

X1.2.2.1 All UVB-313 lamps emit UV below the normal sunlight cut-on. This short wavelength UV can produce rapid polymer degradation and often causes degradation by mechanisms that do not occur when materials are exposed to sunlight. This may lead to anomalous results. Fig. X1.2 shows the spectral power distribution (SPD) of typical UVB-313 lamps compared to the SPD of noon, summer sunlight.

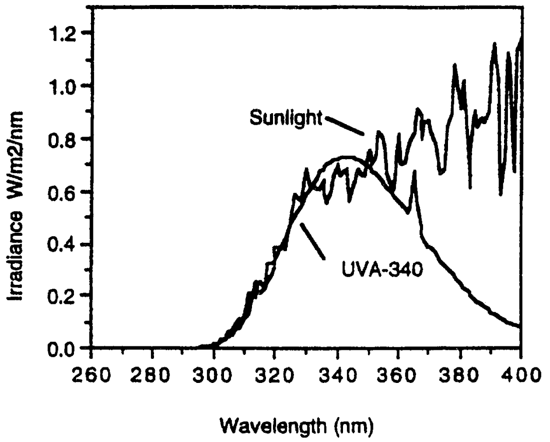

FIG. X1.1 Spectral Power Distributions of UVA-340 Lamp and Sunlight

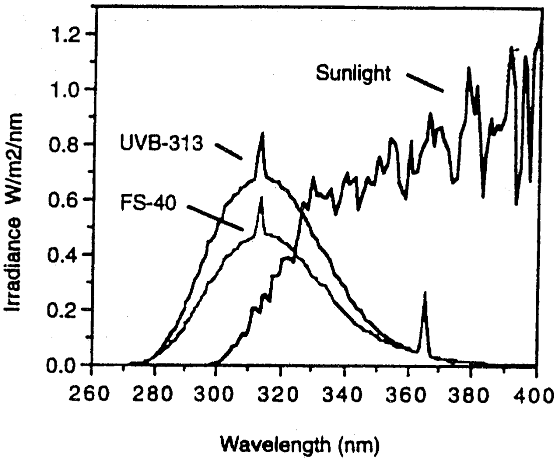

FIG. X1.2 Spectral Power Distributions of UVB Lamps and Sunlight

X1.3 Simulations of Exposures to Solar UV Radiation Through Window Glass

X1.3.1 *Filtering Effect of Glass*

Glass of any type acts as a filter on the sunlight spectrum (see Fig. X1.3). Ordinary glass is essentially transparent to light above about 370 nm. However, the filtering effect becomes more pronounced with decreasing wavelength. The shorter, more damaging UVB wavelengths are the most greatly affected. Window glass filters out most of the wavelengths below about 310 nm. For purposes of illustration, only one type of window glass is used in the accompanying graphs. Note that glass transmission characteristics will vary due to manufacturer, production lot, thickness, or other factors.

X1.3.2 *UVA-351 Lamps*

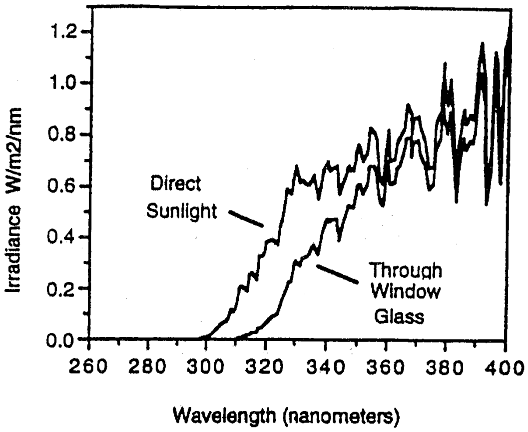

FIG. X1.3 Direct Sunlight and Sunlight Through Window Glass

For simulations of sunlight through window glass, UVA-351 lamps are recommended. The UVA-351 is used for these applications because the low end cut-on of this lamp is similar to that of direct sunlight which has been filtered through window glass (Fig. X1.4).

NOTE X1.3—UVB-313 lamps are not recommended for simulations of sunlight through window glass. Most of the emission of UVB-313 lamps is in the short wavelength UV that is filtered very efficiently by glass. Because of this, very little energy from this short wavelength region will reach materials in "behind glass" applications. This is because window glass filters out about 80 % of the energy from UVB-313 lamps, as shown in Fig. X1.5. As a result of filtering out these short wavelengths, its total effective energy is very limited. Further, because there is little longer wavelength energy, the glass-filtered UVB-313 is actually less severe than a UVA Lamp.

X1.4 Simulations of Exposures Where Glass or Transparent Plastic Forms Part of the Test Specimen

X1.4.1 *UVA-340 Lamps*

In some instances (for example, window sealants), glass or transparent plastic is part of the test specimen itself and normally acts as a filter to the light source. In these special cases, the use of UVA-340 lamps is recommended since the glass or plastic will filter the spectrum of the lamp in the same way that it would filter sunlight. Fig. X1.6 compares the spectral power distribution of sunlight filtered through window glass to the spectral power distribution of the UVA-340 lamp, both unfiltered and filtered through window glass.

NOTE X1.4—UBV-313 lamps are lamps not recommended for exposures where glass or transparent plastic forms part of the test specimen. See Note X1.3.

NOTE X1.5—UVA-351 lamps are not recommended for exposures where glass or transparent plastic forms part of the test specimen. This is because the UVA-351 has a special power distribution in the short wave UV region that is similar to sunlight that has already been filtered by window glass. As shown in Fig. X1.7, using this lamp through window glass or other transparent material further filters out the short wavelength UV and results in a spectrum that is deficient in the short wavelength UV.

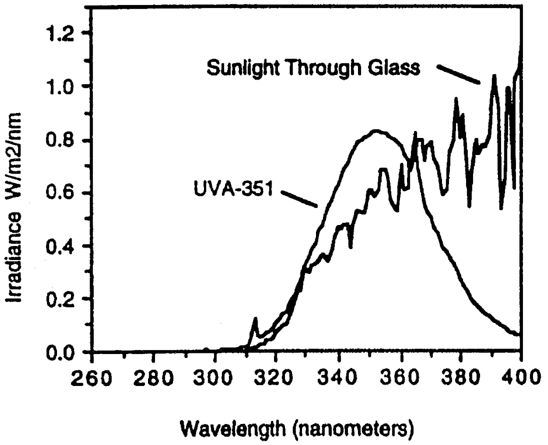

FIG. X1.4 Spectral Power Distributions of UVA-351 Lamp and Sunlight Through Window Glass

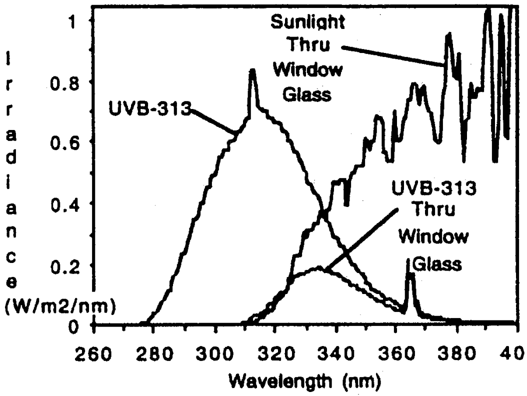

FIG. X1.5 Spectral Power Distributions of Unfiltered UVB-313 Lamp, UVB-313 Through Window Glass, and Sunlight Through Window Glass

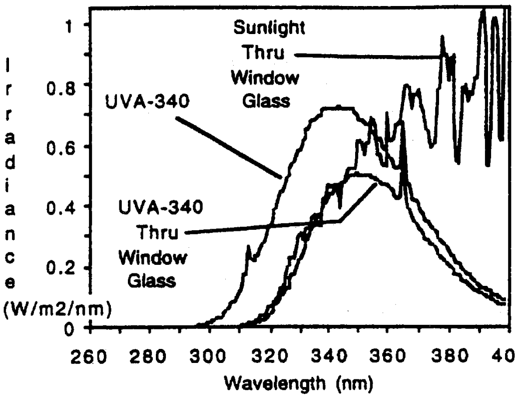

FIG. X1.6 Spectral Power Distributions of Unfiltered UVA-340 Lamp, UVA-340 Through Window Glass, and Sunlight Through Window Glass

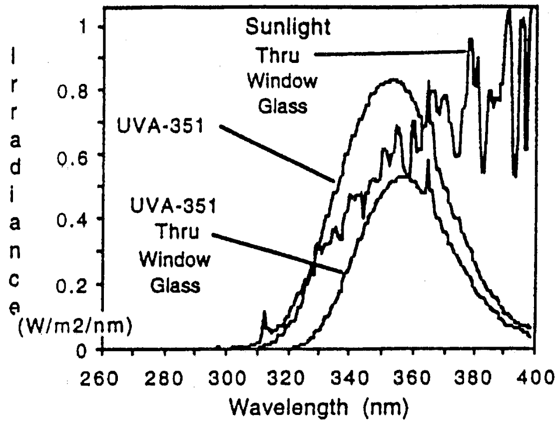

FIG. X1.7 Spectral Power Distributions of Unfiltered UVA-351 Lamp, UVA-351 Through Window Glass, and Sunlight Through Window Glass

X2. EXPOSURE CONDITIONS

X2.1 Any exposure conditions may be used, as long as the exact conditions are detailed in the report. Following are some representative exposure conditions. These are not necessarily preferred and no recommendation is implied. These conditions are provided for reference only (See Table X2.1).

NOTE X2.1—Cycle 1 is a commonly used exposure cycle for coatings and plastics. Cycle 2 has been widely used for coatings. Cycles 3 and 4 have been used for exterior automotive materials. Cycle 5 has been used for roofing materials. Cycle 6 has been used for high irradiance exposures of coatings and plastics. Cycle 7 has been used for thermal shock and for erosion testing of coatings for wood.

NOTE X2.2—When selecting programs of UV exposure followed by condensation, allow at least 2 h per interval to assure attainment of equilibrium.

NOTE X2.3—Surface temperature of specimens is an essential test quantity. Generally, degradation processes accelerate with increasing temperature. The specimen temperature permissible for the accelerated test depends on the material to be tested and on the aging criterion under consideration.

NOTE X2.4—Irradiance data shown is typical. Frequently, the irradiance is not controlled in this type of exposure device.

NOTE X2.5—The light output of fluorescent lamps is affected by the temperature of the air which surrounds the lamps. Consequently, in testers without feed-back-loop control of irradiance, the lamp output will decrease with increasing chamber temperature.

NOTE X2.6—Laboratory ambient temperature may have an effect on the light output of devices without feed-back-loop control of irradiance. Some fluorescent UV devices use laboratory ambient air to cool the lamps and thereby compensate for the drop in light output at higher exposure temperatures (see Note X2.5).

TABLE X2.1 Common Exposure Conditions

Cycle	Lamp	Typical Irradiance	Approximate Wavelength	Exposure Cycle
1	UVA-340	0.77 W/m^2/nm	340 nm	8 h UV at 60 (± 3) °C Black Panel Temperature; 4 h Condensation at 50 (± 3) °C Black Panel Temperature
2	UVB-313	0.63 W/m^2/nm	310 nm	4 h UV at 60 (± 3) °C Black Panel Temperature; 4 h Condensation at 50 (± 3) °C Black Panel Temperature
3	UVB-313	0.44 W/m^2/nm	310 nm	8 h UV at 70 (± 3) °C Black Panel Temperature; 4 h Condensation at 50 (± 3) °C Black Panel Temperature
4	UVA-340	1.35 W/m^2/nm	340 nm	8 h UV at 70 (± 3) °C Black Panel Temperature; 4 h Condensation at 50 (± 3) °C Black Panel Temperature
5	UVB-313	0.55 W/m^2/nm	310 nm	20 h UV at 80 (± 3) °C Black Panel Temperature; 4 h Condensation at 50 (± 3) °C Black Panel Temperature
6	UVA-340	1.35 W/m^2/nm	340 nm	8 h UV at 60 (± 3) °C Black Panel Temperature; 4 h Condensation at 50 (± 3) °C Black Panel Temperature.
7	UVA-340	1.35 W/m^2/nm	340 nm	8 h UV at 60 (± 3) °C Black Panel Temperature; 0.25 h water spray (no light), temperature not controlled; 3.75 h condensation at 50 (± 3) °C Black Panel Temperature
8	UVB-313	28 W/m^2	270 to 700 nm	8 h UV at 70 (± 3) °C Black Panel Temperature; 4 h Condensation at 50 (± 3) °C Black Panel Temperature

X2.2 For the most consistent results, it is recommended that apparatus without feed-back-loop control of irradiance be operated in an environment in which the ambient temperature is maintained between 18 and 27°C. Apparatus operated in ambient temperatures above or below this range may produce irradiances different from devices operated in the recommended manner.

NOTE X2.7—Fluorescent UV lamps emit relatively little infrared radiation when compared to xenon arc and carbon arc sources. In fluorescent UV apparatus, the primary heating of the specimen surface is by convection from heated air passing across the panel. Therefore, there is a minimal difference between the temperature of an insulated or uninsulated black or white panel thermometer, specimen surface, air in the test chamber, or different colored samples (**3**).

REFERENCES

(**1**) Mullen, P. A., Kinmonth, R. A., and Searle, N. D., "Spectral Energy Distributions and Aging Characteristics of Fluorescent Sun Lamps and Black Lights," *Journal of Testing and Evaluation*, Vol 3(1), 15–20, 1975.

(**2**) Fedor, G. R., and Brennan, P. J., "Irradiance Control in Fluorescent UV Exposure Testors," *Accelerated and Outdoor Durability Testing of Organic Materials, ASTM STP 1202*, American Society for Testing and Materials, 1993.

(**3**) Ketola, W., Robbins, J. S., "UV Transmission of Single Strength Window Glass," *Accelerated and Outdoor Durability Testing of Organic Materials. ASTM STP 1202*. Warren D. Ketola and Douglas Grossman, Editors, American Society for Testing and Materials, 1993.

(**4**) Fischer, R. M., "Results of Round-Robin Studies of Light- and Water-Exposure Standard Practices," *Accelerated and Outdoor Durability Testing of Organic Materials, ASTM STP 1202*. Warren K. Ketola and Douglas Grossman, Editors, American Society for Testing and Materials, 1993.

(**5**) Fischer, R. M., and Ketola, W. D., "Surface Temperatures of Materials in Exterior Exposures and Artificial Accelerated Tests," *Accelerated and Outdoor Durability Testing of Organic Materials, ASTM STP 1202*. Warren K. Ketola and Douglas Grossman, Editors, American Society for Testing and Materials, 1993.