



Standard Specification for Transducers, Pressure and Differential, Pressure, Electrical and Fiber-Optic¹

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1. Scope

1.1 This specification covers the requirements for pressure and differential pressure transducers for general applications.

1.2 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only. Where information is to be specified, it shall be stated in SI units.

1.3 *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.*

1.4 Special requirements for naval shipboard applications are included in Supplementary Requirements S1, S2, and S3.

2. Referenced Documents

2.1 ASTM Standards:

D 3951 Practice for Commercial Packaging²

2.2 ANSI/ISA Standards:

ANSI/ISA S37.1 Electrical Transducer Nomenclature and Terminology³

2.3 ISO Standard:

ISO 9001 Quality System—Model for Quality Assurance in Design/Development, Production, Installation, and Servicing⁴

3. Terminology

3.1

Terms marked with (ANSI/ISA S37.1) are taken directly from ANSI/ISA S37.1 (R-1982) and are included for the convenience of the user. *Definitions*—Terminology consistent with

ANSI/ISA S37.1 shall apply, except as modified by the definitions listed as follows:

3.1.1 *absolute pressure*—pressure measured relative to zero pressure (vacuum). (ANSI/ISA S37.1)

3.1.2 *ambient conditions*—conditions such as pressure and temperature of the medium surrounding the case of the transducer. (ANSI/ISA S37.1)

3.1.3 *burst pressure*—the maximum pressure applied to the transducer sensing element without rupture of the sensing element or transducer case as specified.

3.1.4 *calibration*—the test during which known values of measurands are applied to the transducer and corresponding output readings are recorded under specified conditions. (ANSI/ISA S37.1)

3.1.5 *common mode pressure*—the common mode pressure is static line pressure applied simultaneously to both pressure sides of the transducer for the differential pressure transducer only.

3.1.6 *differential pressure*—the difference in pressure between two points of measurement. (ANSI/ISA S37.1)

3.1.7 *environmental conditions*—specified external conditions, such as shock, vibration, and temperature, to which a transducer may be exposed during shipping, storage, handling, and operation. (ANSI/ISA S37.1)

3.1.8 *error*—the algebraic difference between the indicated value and the true value of the measurand. (ANSI/ISA S37.1)

3.1.9 *fiber-optic pressure transducer*—a device that converts fluid pressure, by means of changes in fiber-optic properties, to an output that is a function of the applied measurand. The fiber-optic pressure transducer normally consists of a sensor head, optoelectronics module, and connectorized fiber-optic cable.

3.1.10 *hysteresis*—the maximum difference in output, at any measurand value within the specified range, when the value is approached first with increasing and then with decreasing measurand. (ANSI/ISA S37.1)

3.1.11 *insulation resistance*—the resistance measured between insulated portions of a transducer and between the insulated portions of a transducer and ground when a specified dc voltage is applied under specified conditions.

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² *Annual Book of ASTM Standards*, Vol 15.09.

³ Available from American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.

⁴ Available from International Organization for Standardization, Case Postale 56, Geneva, Switzerland CH-1211.

3.1.12 *line pressure*—the pressure relative to which a differential pressure transducer measures pressure.

(ANSI/ISA S37.1)

3.1.13 *operating environmental conditions*—environmental conditions during exposure to which a transducer must perform in some specified manner.

(ANSI/ISA S37.1)

3.1.14 *optical*—involving the use of light-sensitive devices to acquire information.

3.1.15 *optical fiber*—a very thin filament or fiber, made of dielectric materials, that is enclosed by material of lower index of refraction and transmits light throughout its length by internal reflections.

3.1.16 *optoelectronics module*—a component of the fiber-optic pressure transducer that contains the optical source and detector, and signal conditioner devices necessary to convert the sensed pressure to the specified output signal.

3.1.17 *output*—electrical or numerical quantity, produced by a transducer or measurement system, that is a function of the applied measurand.

3.1.18 *overpressure*—the maximum magnitude of measurement that can be applied to a transducer without causing a change in performance beyond the specified tolerance.

3.1.19 *pressure cycling*—the specified minimum number of specified periodic pressure changes over which a transducer will operate and meet the specified performance.

3.1.20 *pressure rating*—the maximum allowable applied pressure of a differential pressure transducer.

3.1.21 *process medium*—the measured fluid (measurand) that comes in contact with the sensing element.

3.1.22 *range*—measurand values, over which a transducer is intended to measure, specified by their upper and lower limits.

(ANSI/ISA S37.1)

3.1.23 *repeatability*—ability of a transducer to reproduce output readings when the same measurand value is applied to it consecutively, under the same conditions, and in the same direction.

(ANSI/ISA S37.1)

3.1.24 *response*—the measured output of a transducer to a specified change in measurand.

3.1.25 *ripple*—the peak-to-peak ac component of the dc output.

3.1.26 *sensing element*—that part of the transducer that responds directly to the measurand.

(ANSI/ISA S37.1)

3.1.27 *sensitivity factor*—the ratio of the change in transducer output to a change in the value of the measurand.

3.1.28 *sensor head*—the transduction element of the fiber-optic pressure transducer that detects fluid pressure by means of changes in optical properties.

3.1.29 *signal conditioner*—an electronic device that makes the output signal from a transduction element compatible with a readout system.

3.1.30 *static error band*—static error band is the maximum deviation from a straight line drawn through the coordinates of the lower range limit at specified transducer output, and the upper range limit at specified transducer output expressed in percent of transducer span.

3.1.31 *transducer*—device that provides a usable output in response to a specified measurand.

(ANSI/ISA S37.1)

3.1.32 *wetted parts*—transducer components with at least one surface in direct contact with the process medium.

4. Classification

4.1 *Designation*—Most transducer manufacturers use designations or systematic numbering or identifying codes. Once understood, these designations could aid the purchaser in quickly identifying the transducer type, range, application, and other parameters.

4.2 *Design*—Pressure transducers typically consist of a sensing element that is in contact with the process medium and a transduction element that modifies the signal from the sensing element to produce an electrical or optical output. Some parts of the transducer may be hermetically sealed if those parts are sensitive to and may be exposed to moisture. Pressure connections must be threaded with appropriate fittings to connect the transducer to standard pipe fittings or to other appropriate leak-proof fittings. The output cable must be securely fastened to the body of the transducer. A variety of sensing elements are used in pressure transducers. The most common elements are diaphragms, bellows, capsules, Bourdon tubes, and piezoelectric crystals. The function of the sensing element is to produce a measurable response to applied pressure or vacuum. The response may be sensed directly on the element or a separate sensor may be used to detect element response. The following is a brief introduction to the major pressure sensing technology design categories.

4.2.1 Electrical Pressure Transducers:

4.2.1.1 *Differential Transformer Transducer*—Linear variable differential transformers (LVDT) are variable reluctance devices. Pressure-induced sensor movement, usually transmitted through a mechanical linkage, moves a core within a differential transformer. Sensors are most commonly bellows, capsules, or Bourdon tubes. The movement of the core within the differential transformer results in a change in reluctance that translates to a voltage output. An amplifying mechanical linkage may be used to obtain adequate core movement.

4.2.1.2 *Potentiometric Transducer*—Pressure-induced movement of the sensing element causes movement of a potentiometer wiper resulting in a change in resistance which translates to a voltage output. A bellows or Bourdon tube is commonly used as the sensing element. An amplifying mechanical linkage may be used to obtain adequate wiper movement.

4.2.1.3 *Strain Gage Transducer*—Typical strain gage pressure transducers convert a pressure into a change in resistance due to strain which translates to a relative voltage output. Pressure-induced movement in the sensing element deforms strain elements. The strain elements of a typical strain gage pressure transducer are active arms of a Wheatstone Bridge arrangement. As pressure increases, the bridge becomes electrically unbalanced as a result of the deformation of the strain elements providing a change in voltage output.

4.2.1.4 *Variable Capacitance Transducer*—Variable capacitance pressure transducers sense changes in capacitance with changes in pressure. Typically, a diaphragm is positioned between two stator plates. Pressure-induced diaphragm deflection changes the circuit capacitance, which is detected and translated into a change in voltage output.

4.2.1.5 *Variable Reluctance Transducer*—Variable reluctance pressure transducers sense changes in reluctance with changes in pressure. Typically, a diaphragm is positioned between two ferric core coil sensors that when excited produce a magnetic field. Pressure-induced diaphragm deflection changes the reluctance, which is detected and translated to a change in voltage output.

4.2.1.6 *Piezoelectric Transducer*—Piezoelectric transducers consist of crystals made of quartz, tourmaline, or ceramic material. Pressure-induced changes in crystal electrical properties cause the crystal to produce an electrical output which is detected and translated to a change in voltage output.

4.2.2 *Fiber-Optic Pressure Transducers:*

4.2.2.1 *Fabry-Perot Interferometer*—Fabry-Perot interferometers (FPI) consist of two mirrors facing each other, the space between the mirrors being called the cavity length. Light reflected in the FPI is wavelength modulated in exact accordance with the cavity length. Pressure-induced movement of one of the mirrors causes a measurable change in cavity length and a phase change in the reflected light signal. This change is optically detected and processed.

4.2.2.2 *Bragg Grating Interferometer*—A Bragg grating is contained in a section about 1 cm long and acts as a narrow band filter that detects variation in the optical properties of the fiber. When the fiber is illuminated with an ordinary light source such as an LED, only a narrow band of light will be reflected back from the grating section of the fiber. If a pressure is applied to the grating section of the fiber, the grating period changes, and hence, the wavelength of the reflected light, which can be measured.

4.2.2.3 *Quartz Resonators*—Typically, a pair of quartz resonators are inside the pressure transducer. These are excited by the incoming optical signal. One resonator is load-sensitive and vibrates at a frequency determined by the applied pressure. The second resonator vibrates at a frequency that varies with the internal temperature of the transducer. Optical frequency signals from the resonators are transmitted back to the optoelectronics interface unit. The interface unit provides an output of temperature-compensated pressure.

4.2.2.4 *Micromachined Membrane/Diaphragm Deflection*—The sensing element is made on a silicon substrate using photolithographic micromachining. The deflection of this micromachined membrane is detected and measured using light. The light is delivered to the sensor head through an optical fiber. The light returning from the membrane is proportional to the pressure deflection of the membrane and is delivered back to a detector through an optical fiber. The fiber and the sensor head are packaged within a thin tubing.

4.3 *Types*—The following are common types of pressure and differential pressure transducers: pressure, differential; pressure (gage, absolute and sealed); pressure, vacuum; and pressure, compound.

4.4 *Process Medium*—The following are the most common types of process media: freshwater, oil, condensate, steam, nitrogen and other inert gases, seawater, flue gas and ammonia, and oxygen.

4.5 *Application*—The following is provided as a general comparison of different types of transducers and considerations for application.

4.5.1 *LVDT Transducer*—The sensor element may become complicated depending on the amount of motion required for core displacement. Careful consideration should be exercised when the application includes very low- or high-pressure measurement, overpressure exposure, or high levels of vibration. Careful consideration should also be exercised when measuring differential pressure of process media having high dielectric constants, especially liquid media. If the process media is allowed to enter the gap between the sensor element and core, accuracy may suffer. Frequency response may suffer depending on the type of mechanical linkage(s) used in the transducer.

4.5.2 *Potentiometric Pressure Transducer*—Potentiometric pressure transducers are generally less complicated than other designs. Careful consideration should be exercised when the application includes very low pressure measurement, overpressure exposure, high levels of vibration, stability and repeatability over extended periods of time, or extremely high resolution requirements. Frequency response may suffer depending on the type of mechanical linkage(s) used. Technological advances have yielded more reliable designs that are commonly used.

4.5.3 *Strain Gage Transducers*—Low-level output strain gage transducers are among the most common pressure transducers. They are available in very compact packages which lend well in applications in which size is critical. Strain gage transducers that demonstrate high degrees of accuracy and excellent frequency response characteristics are readily available. Careful consideration should be exercised when the application includes very low-pressure measurement, very low lag or delay, high vibration levels, extreme overpressure requirements, or critical stability over extended periods.

4.5.4 *Variable Capacitance Transducers*—Variable capacitance transducers are well suited to measure dry, clean gases at very low pressures with a high degree of accuracy. Careful consideration should be exercised when measuring differential pressure of process media having high dielectric constants, especially liquid media. If the process media is allowed to enter the gap between the diaphragm and stators, accuracy may suffer. Process media that alters the dielectric constant between the diaphragm and stators also alters the output of the transducer unless isolation devices such as membranes or oil fills are used.

4.5.5 *Variable Reluctance Transducers*—Variable reluctance transducers are well suited to measure most process media, especially if the core coil sensors are isolated from the process media. Variable reluctance transducers are well suited for applications that include high shock or vibration levels, extreme overpressure requirements, high degrees of accuracy, or critical stability over extended periods. Careful consideration should be exercised when evaluating size, weight, and cost. All reluctance devices are affected by strong magnetic fields.

4.5.6 *Piezoelectric Transducers*—Piezoelectric transducers are very effective in measuring changes in pressure. The piezoelectric crystals only produce an output when they

experience a change in load. With adequate signal conditioners they can also be used to perform static measurements.

4.5.7 Fiber-Optic Pressure Transducers—Fiber-optic pressure transducers can be used in virtually all applications. They are extremely sensitive and are beneficial for high resolution measurements. They are unaffected by electromagnetic interference and are recommended in applications where EMI is a problem. These transducers are by nature intrinsically safe and are especially applicable for hazardous environments.

4.6 Range—Each manufacturer of transducers advertises a standard operating range for their offered selections but there is no industry-wide standard of specific ranges for transducers. Ranges are available that cover applications from vacuums to 210 MPaG (30 000 psig). Refer to individual manufacturer recommendations on range best suited to each application or specify an exact range if the range is a critical characteristic.

4.7 Pressure Rating—Pressure rating applies only to differential pressure transducers. Differential pressure transducers must be selected with a pressure rating for the maximum media pressure to be encountered. The purchaser should refer to specific manufacturer guidance to ensure a transducer has the proper pressure rating for each intended application.

4.8 Power Supply—Power supplies furnish excitation to the transducer. Power supplies may include batteries; line-powered, electronically regulated, dc power supplies; or ac power directly from the power system.

4.9 Output—Output signals can be electrical or optical dependent on design. Output must be measurable and must correspond with pressure applied within the range of the transducer. Multiple output signals shall be provided when specified. One signal shall be designated as the prime and the other as supplemental.

4.10 Pressure Connection—The pressure connection is the opening of the transducer used to allow the process medium to reach the sensing element. Differential pressure transducers have two pressure connections, a high-pressure port and a low-pressure port.

5. Ordering Information

5.1 The purchaser should provide the manufacturer with all of the pertinent application data shown in accordance with 5.2. If special application operating conditions exist that are not shown in the acquisition requirements, they should also be described.

5.2 Acquisition Requirements—Acquisition documents should specify the following:

- 5.2.1 Title, number, and date of this specification,
- 5.2.2 Manufacturer's part number,
- 5.2.3 Range, pressure rating (differential only), power supply, output,
- 5.2.4 Mounting method (see 7.2),
- 5.2.5 Type of pressure connection (see 7.5),
- 5.2.6 Type of electrical connection (see 7.4),
- 5.2.7 When an electrical connection mating plug is not to be provided (see 7.4),
- 5.2.8 System process medium,
- 5.2.9 Prime output signal,
- 5.2.10 Supplemental output signal, if required,

5.2.11 System operating characteristics, such as pressure and flow rate,

5.2.12 Materials,

5.2.13 Environmental requirements, such as vibration and ambient temperature,

5.2.14 Quantity of transducers required,

5.2.15 Size and weight restrictions (see 7.7),

5.2.16 Critical service life requirements (see 8.1),

5.2.17 Performance requirements (see 8.2),

5.2.18 Special surface finish requirements (see 9.1),

5.2.19 Special cleaning requirements (see 9.2),

5.2.20 When certification is required (see Section 13),

5.2.21 Special marking requirements (see Section 14),

5.2.22 Special packaging or package marking requirements (see Section 15),

5.2.23 When ISO 9001 quality assurance system is not required (see 16.1), and

5.2.24 Special warranty requirements (see 16.2).

6. Materials and Manufacture

6.1 Sensing Elements—The materials for the sensing element and wetted parts shall be selected for long-term compatibility (see 8.1) with the process medium (see 4.4).

7. Physical Properties

7.1 Enclosure—If case sealing is required, the mechanism, materials, and process shall be described. The same should apply to the electrical connector. The long-term resistance to common process media should be stated. Resistance to cleaning solvents should likewise be stated. Unique or special enclosure requirements shall be specified in the acquisition requirements (see 5.2).

7.2 Transducer Mounting—Transducers are commonly mounted directly by their pressure connections or through the use of brackets or similar hardware. Mounting force or torque shall be specified if it tends to affect transducer performance. Mounting error shall be specified in terms of percent of full-scale output or within the static error band under specified conditions of mounting force or torque.

7.3 External Configuration—The outline drawing shall show the configuration with dimensions in SI units (inch-pound units). The outline drawing shall include limiting dimensions for pressure and electrical connections if they are not specified. The outline drawing shall indicate the mounting method with hole size, center location, and other pertinent dimensions. Where threaded holes are used, thread specifications shall be provided.

7.4 Standard Electrical Connection—An electrical interface connector receptacle and mating plug shall be provided with each transducer unless otherwise specified in the contract (see 5.1). Optional possible electrical interface connections include pigtailed and terminal boards.

7.5 Pressure Connections—Pressure connections commonly consist of pipe thread, hose tube fittings, O-ring union, O-ring union face seal, and others.

7.6 Damping—The use of a media for damping in transducers shall be specified including the type, composition, and compatibility with transducer components and materials.

7.7 *Size and Weight*—The purchaser may have intended applications in which size and weight are limited. Size and weight restrictions shall be specified in the ordering information (see 5.2).

8. Performance Requirements

8.1 *Service Life*—The purchaser may have a minimum specified service life requirement that may be critical. Critical service life requirements shall be specified in the ordering information (see 5.2).

8.2 *Transducer Performance*—Performance tolerances are usually specified in percent of transducer output span. Critical performance requirements shall be specified in the ordering information (see 5.2). The following performance characteristics and environmental exposures may or may not be important to each purchaser's intended application: static error band, repeatability, hysteresis, sensitivity factor, ripple, warm-up time, steady-state supply voltage and frequency (ac), steady-state supply voltage (dc), response, transient supply voltage and frequency (ac), transient supply voltage (dc), temperature, humidity, overpressure, line pressure (differential only), salt spray, pressure cycling, insulation resistance, vibration, shock, burst pressure, output, enclosure, electromagnetic interference (EMI), common mode pressure (differential only), pressure rating (differential only), and power system harmonic distortion.

9. Workmanship, Finish and Appearance

9.1 *Finish and Appearance*—Any special surface finish and appearance requirements shall be specified in the ordering information (see 5.2).

9.2 *Transducer Cleaning*—Any special cleaning requirements shall be specified in the ordering information (see 5.2).

10. Number of Tests and Retests

10.1 *Test Specimen*—The number of test specimens to be subjected to first-article tests shall be specified and should depend on the transducer design. As guidance, if each range is covered by a separate and distinct design, a test specimen for each range should require testing. In instances in which a singular design series may cover multiple ranges and types, a minimum of three test specimens should be tested provided the electrical, optical, and mechanical similarities are approved by the purchaser. It is suggested that three units, one unit each representing the low, medium, and high ranges, be tested, regardless of design similarity.

10.1.1 *Low Range*—Less than 700 kPa (less than 100 lb/in.²).

10.1.2 *Medium Range*—700 kPa to less than 7 MPa (100 to less than 1000 lb/in.²).

10.1.3 *High Range*—7 MPa and greater (1000 lb/in.² and greater).

11. Test Methods

11.1 *Test Data*—All test data shall remain on file at the manufacturer's facility for review by the purchaser upon request. It is recommended that test data be retained in the manufacturer's files for at least three years, or a period of time acceptable to the purchaser and the manufacturer.

12. Inspection

12.1 *Classification of Inspections*—The inspection requirements specified herein are classified as follows:

12.1.1 First-article tests (see 12.2).

12.1.2 Conformance tests (see 12.3).

12.2 *First-Article Tests*—First-article test requirements shall be specified, where applicable. First-article test methods should be identified for each design and performance characteristic specified. Test report documentation requirements should also be specified.

12.3 *Conformance Tests*—Conformance testing shall be specified when applicable. Conformance testing shall be conducted on all units manufactured for delivery unless otherwise specified in the contract.

13. Certification

13.1 When specified in the acquisition requirements (see 5.2), the purchaser shall be furnished certification that samples representing each lot have been either tested or inspected as directed in this specification and the requirements have been met.

14. Product Marking

14.1 The purchaser specified product marking shall be listed in the acquisition requirements (see 5.2). The minimum data to be clearly marked on each transducer shall include the following:

14.1.1 Manufacturer's name,

14.1.2 Manufacturer's part number,

14.1.3 Serial number or lot number,

14.1.4 Date of manufacture,

14.1.5 Range,

14.1.6 Excitation voltage, and

14.1.7 Pressure rating (differential pressure transducers only).

14.2 For differential pressure transducers, the high- and low-pressure connections shall be clearly marked on the transducer body adjacent to the connections.

15. Packaging and Package Marking

15.1 *Packaging of Product for Delivery*—The product should be packaged for shipment in accordance with Practice D 3951.

15.2 Any special packaging or package marking requirements for shipment or storage shall be identified in the ordering information (see 5.2).

16. Quality Assurance

16.1 *Quality System*—A quality assurance system in accordance with ISO 9001 shall be maintained to control the quality of the product being supplied effectively, unless otherwise specified in the acquisition requirements (see 5.2).

16.2 *Responsibility for Warranty*—Unless otherwise specified, the manufacturer is responsible for the following:

16.2.1 All materials used to produce a unit and

16.2.2 Workmanship to produce the unit.

16.3 Special warranty requirements shall be specified in the acquisition requirements (see 5.2).

17. Keywords

17.1 differential pressure transmitter; fiber-optic pressure transducer; miniature; optoelectronics module; pressure and differential pressure transducers; pressure transmitter; sensing element; sensor head; transduction element

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirement, established for U.S. naval shipboard application, shall apply when specified in the contract or purchase order. When there is conflict between this specification and this supplementary requirement, this supplementary requirement shall take precedence. This document supersedes MIL-T-24742, *Transducer, Pressure and Differential Pressure, Miniature (Electrical)*, for new ship construction.

S1. TRANSDUCERS, PRESSURE AND DIFFERENTIAL PRESSURE, MINIATURE (ELECTRICAL)

S1.1 Scope

S1.1.1 This supplement covers the requirements for miniature pressure and differential pressure transducers designed to meet the requirements for use onboard naval ships.

S1.1.2 The values stated in SI units are to be regarded as the standard. Inch-pound units are provided for information only. Where information is to be specified, it shall be stated in SI units.

S1.2 Referenced Documents

S1.2.1 ISO Standard:

6149-1 Connections for Fluid Power and General Use—Ports and Stud Ends with ISO 261 Threads and O-Ring Sealing—Part 1: Ports with O-Ring Seal in Truncated Housing⁴

S1.2.2 NEMA Standard:

250 Enclosures for Electrical Equipment (1000 Volts Maximum)⁵

S1.2.3 Military Standards:

MIL-S-901 Shock Tests, H.I. (High-Impact); Shipboard Machinery, Equipment and Systems, Requirements for⁶

MIL-STD-167-1 Mechanical Vibrations of Shipboard Equipment (Type I—Environmental and Type II—Internally Excited)⁶

MIL-STD-461 Electromagnetic Interference Characteristics of Subsystems and Equipment, Requirements for the Control of⁶

MIL-STD-1399, Section 300 Interface Standard for Shipboard Systems, Electric Power, Alternating Current⁶

MS3452 Connector, Receptacle, Electric, Box Mounting, Rear Release, Crimp Contact, AN Type⁶

MS3456 Connector, Plug, Electrical, Rear Release, Crimp Contact, AN type⁶

S1.3 Terminology

S1.3.1 Terminology is consistent with that of Section 3 and the referenced documents.

S1.4 Designation

S1.4.1 *Designation*—For this specification pressure transducers, designations shall be assigned in accordance with S1.5.1 and listed in the following below:

Example: F25XMS1-D-F-5-DC-2-N-M-100D

Specification	D	F	5	DC	2	N	M	100D
F25XMS1	Type	Application	Press Rating	Power Supply	Output	Press Conn	Mounting	Range
	S1.4.2	S1.4.3		S1.4.4	S1.4.5	S1.4.6	S1.4.7	S1.4.8
							S1.4.8	S1.4.9

S1.4.2 *Types*—The following designators have been established for the various types of transducers:

D—Pressure, differential

P—Pressure (gage, absolute and sealed)

V—Pressure, vacuum

C—Pressure, compound

S1.4.3 *Application*—The following application designations have been established for the corresponding process media:

F—Freshwater, oil, condensate, steam, nitrogen, and other inert gases

S—Seawater

G—Flue gas and ammonia

X—Oxygen

S1.4.4 *Pressure Rating*—The pressure rating shall be indicated by the designator for its numerical value for Type D transducers (“X” for Type P, V, and C transducers) and shall be limited to the following:

Designator	Rating, kPaG	Inch-Pound, psig
1	100	15
2	1 000	150
3	2 000	300
4	4 000	600
5	10 000	1500
6	20 000	3000
7	40 000	6000

S1.4.5 *Power Supply*—Transducers shall operate with either ac or dc input power, but not both. Designators shall be as follows:

S1.4.5.1 dc—Direct-current supply.

S1.4.5.2 ac—Alternating-current supply.

S1.4.6 *Output*—The dc electrical signal output of the transducer shall be designated by the following designators:

2—4-20 mA

3—0-5 V

⁵ Available from National Electrical Manufacturers Association, 1300 N. 17th St., Suite 1847, Rosslyn, VA 22209.

⁶ Available from U.S. Government Standardization Documents Order Desk, 700 Robbins Ave., Philadelphia, PA 19111.

4—0-12 V
 5—0-3 mV
 6—0-200 μ V

S1.4.7 Pressure Connection—Transducer pressure sensing connection shall be as follows:

N—M12 $\times$ 1.5 (7/16-20 UNF-2B) (see S1.7.5)
 X—1/4 nps, 155-mm (6-in.) long pipe nipple (see S1.7.5)
 Z—Other

S1.4.8 Transducer Mounting—The transducer mounting method shall be designated as follows:

P—Pressure port connection
 M—Mounting plate

S1.4.9 Range—The pressure range of the transducer shall be designated by two parts. The first part shall be the designator for the upper range value. The second part shall be the designator for the upper range unit of measure (see S1.4.9.1). The transducer pressure ranges shall be in accordance with Table S1.1.

S1.4.9.1 Units—The units shall be designated by the corresponding letter designator and are limited to the following:

Letter	SI Units	Inch-Pound Units
V	kPaV—kiloPascals, vacuum	Hg—inches of mercury vacuum
A	kPaA—kiloPascals, absolute	psia—pounds per square inch, absolute
D	kPaD—kiloPascals, differential	psid—pounds per square inch, differential
G	kPaG—kiloPascals, gage	psig—pounds per square inch, gage
S	kPaS—kiloPascals, sealed at 101.4 kPaA	psis—pounds per square inch, sealed at 14.7 psia
W	kPaW—kiloPascals, water column	WC—inches of water column
N	KPaWD—kiloPascals, water column, differential	WCD—inches of water column, differential

S1.5 Ordering Information

S1.5.1 The purchaser shall provide the manufacturer with all of the pertinent application data in accordance with S1.5.2. If special application operating conditions exist that are not in the acquisition requirements, they shall also be described.

S1.5.2 Acquisition Requirements—Acquisition documents shall specify the following:

S1.5.2.1 Title, number, and date of this specification.

S1.5.2.2 Part designation.

S1.5.2.3 National Stock Number (NSN), if available.

TABLE S1.1 Range

Type D				Type P				Type C		Type V	
SI Units											
Differential Pressure Ranges, kPaD		Differential Pressure Water Column Ranges, kPaWD		Pressure Ranges, kPaG, kPaA or kPaS ^A		Water Column Ranges, kPaW		Compound Ranges, kPaV/kPaG		Vacuum Range, kPaV	
Range	Designator	Range	Designator	Range	Designator	Range	Designator	Range	Designator	Range	Designator
0-100	100	0-2.5	2	0-100	100	0-2.5	2	100/150	150	0-100	100
0-200	200	0-15	15	0-200	200	0-15	15	100/300	300		
0-400	400	0-40	40	0-350	350	0-40	40	100/900	900		
0-700	700	0-75	75	0-400	400	0-75	75	100/1500	1500		
0-1400	1400			0-700	700			100/2400	2400		
0-2800	2800			0-850	850			100/4000	4000		
0-4000	4K			0-1 400	1400						
				0-2 000	2K						
				0-4 000	4K						
				0-6 000	6K						
				0-7 000	7K						
				0-10 000	10K						
				0-20 000	20K						
				0-40 000	40K						
				0-70 000	70K						
Inch-Pound Units											
Differential Pressure Ranges, psid		Differential Pressure Water Column Ranges, WCD		Pressure Ranges, psig, psia, or psis ^A		Water Column Ranges, WC		Compound Ranges, Hg-0-psig		Vacuum Range, Hg	
Range	Designator	Range	Designator	Range	Designator	Range	Designator	Range	Designator	Range	Designator
0-15	100	0-10	2	0-15	100	0-10	2	30-0-15	150	0-30	100
0-30	200	0-60	15	0-30	200	0-60	15	30-0-30	300		
0-60	400	0-150	40	0-50	350	0-150	40	30-0-100	900		
0-100	700	0-300	75	0-60	400	0-300	75	30-0-150	1500		
0-200	1400			0-100	700			30-0-300	2400		
0-400	2800			0-125	850			30-0-600	4000		
0-600	4K			0-200	1400						
				0-300	2K						
				0-600	4K						
				0-900	6K						
				0-1 000	7K						
				0-1 500	10K						
				0-3 000	20K						
				0-6 000	40K						
				0-10 000	70K						

^AFor upper range values of 7000 kPa (1000 lb/in.²) and above.

S1.5.2.4 Mounting method, if other than specified herein.

S1.5.2.5 Type of pressure connection, if other than specified herein.

S1.5.2.6 Type of electrical connection, if other than specified herein.

S1.5.2.7 When the electrical connection mating plug is not to be provided.

S1.5.2.8 Quantity of transducers required.

S1.5.2.9 If deviation requests are required when departing from material guidance.

S1.5.2.10 When first-article tests are required.

S1.5.2.11 Special product marking requirements.

S1.5.2.12 Special packaging or package marking requirements.

S1.5.2.13 When ISO 9001 quality assurance system is not required.

S1.5.2.14 Special warranty requirements.

S1.5.3 First-Article Tests—When first-article testing is required, the purchaser should provide specific guidance to offerors whether the item(s) should be a preproduction sample, a first-article sample, a first production item, a sample selected from the first production items, or a standard production item from the manufacturer's current inventory. The number of items to be tested in accordance with S1.12.4 should be specified. The purchaser should include specific instructions in acquisition documents regarding arrangements for tests, approval of first-article test results and time period for approval, and disposition of first articles. Invitations for bids should provide that the purchaser reserves the right to waive the requirement for samples for first-article testing to those manufacturers offering a product that has been previously acquired or tested by the purchaser; and that manufacturers offering such products, who wish to rely on such production or test, must furnish evidence with the bid that prior purchaser approval is presently appropriate for the pending contract. The manufacture of items before purchaser approval should be specified as the responsibility of the manufacturer.

S1.6 Materials

S1.6.1 Sensing Elements—The materials for the sensing element and wetted parts shall be selected for long-term compatibility (see S1.8.1) with the process medium (see S1.4.3). Table S1.2 is provided for guidance as acceptable material and process medium compatibility. Dissimilar metals shall not be used in contact with each other unless suitably finished to prevent electrolytic corrosion. When departing from this guidance, the manufacturer shall provide evidence of material compatibility to the procuring activity, unless specified otherwise (see S1.5.1).

S1.7 Physical Properties

S1.7.1 Enclosure—The transducer body and pressure cavity shall be environmentally sealed unless otherwise specified. The transducer enclosure shall be Type 4 in accordance with NEMA Standard 250.

S1.7.2 Transducer Mounting—The transducer shall have a mounting plate as shown on Fig. S1.1. If required in a specific application and with prior approval of the purchaser, the transducer may be mounted by its pressure piping connection. For Type D transducers, the high-pressure port shall be used. If

TABLE S1.2 Material Versus Application

Sensing Element and Wetted Parts	Process Medium			
	Application Designation F	Application Designation S	Application Designation G	Application Designation X
CRES 304L, 316L, 321 & 347	X		X	
CRES 15-5 PH, 17-4 PH, and 17-7 PH	X			
Monel and K-Monel	X	X		X
Inconel 600 and 750	X	X		
Inconel 625 and 718	X	X		
Hastelloy C276	X	X	X	
Titanium CP and 6A1-4V	X	X		
CuNi 70/30	X	X		X
Ni Span	X			
Tantalum	X	X		
Carpenter A286			X	X

the transducer is mounted by its pressure connection, the mounting plate shall not be required (see S1.5.2). If the transducer is mounted by its pressure port connection and the mounting plate is provided, mounting holes shall not be required.

S1.7.3 External Configuration—The transducer shall have an external configuration within the boundaries established by Fig. S1.1.

S1.7.4 Electrical Connector—An electrical interface connector receptacle and mating plug shall be provided with each transducer unless otherwise specified. The electrical connector shall be a standard threaded coupling receptacle, AN type, MS3452W/14S-5P, or equivalent, for dc-power input, or AN type, MS3452W/14S-5PX, or equivalent, for ac-power input. The mating plug shall be a MS3456W/14S-5S, or equivalent, for dc-power input, or MS3456W/14S-5SX, or equivalent, for ac-power input.

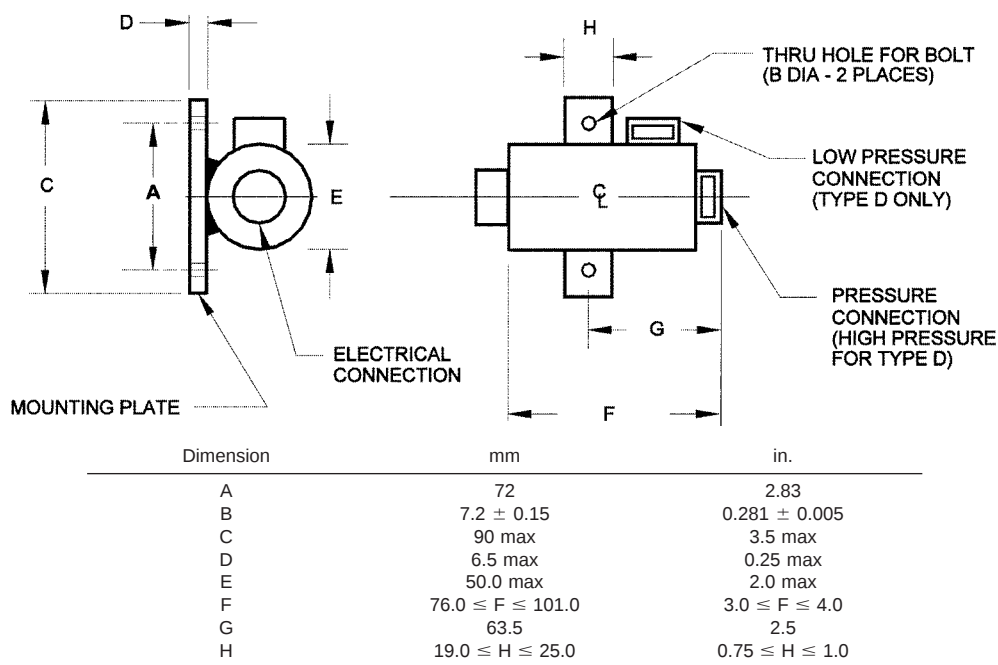
S1.7.4.1 dc-Power Input—Output 2—The receptacle shall be wired to provide the performance described herein. Receptacle Pin A shall be +28-Vdc power input, Pin B shall be –28-Vdc power input, and Pin C shall be case ground. Receptacle Pins A and B shall also serve as the 4- to 20-mA dc signal output.

S1.7.4.2 dc Power Input—Output 3, 4, 5, 6—The receptacle shall be wired to provide the performance described herein. Receptacle Pin A shall be +28-Vdc power input, Pin B shall be –28-Vdc power input, Pin C shall be case ground, Pin D shall be positive dc voltage signal output, and Pin E shall be negative dc voltage signal output.

S1.7.4.3 ac Power Input—Output 2—The receptacle shall be wired to provide the performance described herein. Receptacle Pins A and B shall be 115-Vac power input, Pin C shall be case ground, Pin D shall be +4- to 20-mA dc-signal output, and Pin E shall be –4- to 20-mA dc signal output.

S1.7.4.4 ac Power Input—Output 3, 4, 5, 6—The receptacle shall be wired to provide the performance described herein. Receptacle Pins A and B shall be 115-Vac power input, Pin C shall be case ground, Pin D shall be positive dc-voltage signal output, and Pin E shall be negative dc voltage signal output.

S1.7.5 Pressure Connections—Unless otherwise specified, transducer pressure-sensing connections for all services shall



NOTE 1—Transducer housing (body) cross section is shown as circular. Any alternate cross section not exceeding 50 mm (2 in.) in width and 50 mm (2 in.) in height is acceptable.

NOTE 2—Dimension tolerance is plus or minus 1.25 mm (0.05 in.), unless otherwise specified.

NOTE 3—The pressure connection(s) shall be generally located as shown.

FIG. S1.1 External Configuration

be M12 $\times$ 1.5 (7/16-20 UNF-2B) tube connection in accordance with ISO 6149-1. When pressure connection Type X is specified, as commonly used on submarine oxygen replenishment systems, the transducer sensing connections shall be a nickel-copper pipe nipple 1/4 nominal pipe size (nps) with 3.1-mm (0.12-in.) minimum wall thickness, 155 mm (6 in.) long, welded to the socket (see S1.5.2). For Type D transducers, the high-pressure connection shall be on the end and the low-pressure connection shall be on the side (see Fig. S1.1).

S1.7.6 Welding—For Application X, all pressure boundary joints shall be welded.

S1.7.7 Lubrication—The transducer shall operate without lubrication of moving parts after assembly.

S1.7.8 Damping—The use of a media for damping in transducers shall be cited on the equipment drawing.

S1.7.9 Weight—The weight of a transducer shall not exceed 510 g (18 oz).

S1.8 Performance Requirements

S1.8.1 Service Life—The transducer shall be constructed for a life of 40 000 h of operation and shall meet the requirements specified herein when operated in the naval shipboard environment.

S1.8.2 Input Power—The transducer shall be designed to operate using 115-V, 60-Hz, single-phase, ungrounded, ac power as defined in MIL-STD-1399, Section 300 or 28 $\pm$ 4.5-Vdc power. The transducer shall operate with power supply variations as specified in S1.11.2.8 and S1.11.2.11.

S1.8.3 Output—The electrical signal output of the transducer shall be dc, directly proportional to the pressure or differential pressure input. The output shall be a true current source or true voltage source.

S1.8.3.1 Current Output—When a 4- to 20-mA current output is specified (see S1.5.2), the requirements specified herein shall be met regardless of external load resistance variations over a range from 0 to 250 Ω . The 4-mA output shall correspond to the lower pressure or differential pressure range value, and the 20-mA output shall correspond to the upper pressure or differential pressure range value for the ranges specified in Table S1.1.

S1.8.3.2 Voltage Output—When a voltage output is specified (see S1.5.2), the requirements specified herein shall be met for external load resistance exceeding 100 000 Ω . The 0-V output shall correspond to the lower pressure or differential pressure range value, and the 5-V, 12-V, 3-mV, and 200- μ V output shall correspond to the upper pressure or differential pressure range value for the ranges specified in Table S1.1.

S1.8.4 Transducer Performance—Unless otherwise specified, performance tolerances are specified in percent of transducer output span.

S1.8.4.1 Static Error Band—The transducer static error band shall not exceed $\pm 0.5\%$.

S1.8.4.2 Output—The output shall conform to S1.8.3, and the transducer performance shall be within the static error band specified in S1.8.4.1.

S1.8.4.3 Warm-Up Time—The transducer output shall attain a value within $\pm 0.5\%$ of the steady-state output with no overshoot in excess of 0.5% . Output shall reach this band within 15 s after the transducer is energized and shall remain in this band.

S1.8.4.4 Enclosure—The transducer shall meet all test criteria in NEMA Standard 250 for Type 4X enclosures.

S1.8.4.5 Repeatability—Repeatability of the transducer output shall be within 0.5% .

S1.8.4.6 Sensitivity Factor—The sensitivity factor shall not be less than 0.75 nor more than 1.25.

S1.8.4.7 Ripple—The transducer root mean square (rms) output ripple shall not exceed 0.15% of full-scale dc output.

S1.8.4.8 Steady-State Supply Voltage and Frequency (ac) or Supply Voltage (dc)—The maximum difference between outputs at any voltage and frequency or voltage (for dc) condition and the normal (115-V, 60-Hz, or 28-Vdc) at the same input and test temperature (differential pressure shall be included for Type D) shall not exceed 0.5% .

S1.8.4.9 Common Mode Pressure (Type D Only)—During the common mode pressure test, transducer performance shall be within the range formed by extending the upper and lower static error band limits specified in S1.8.4.1 by a percentage equal to the following:

$$(1/10) \frac{(\text{system pressure rating})^{1/3}}{\text{differential pressure range}}$$

S1.8.4.10 Response—Transducer output shall conform to the following criteria, where all percentages are of transducer span:

(1) The transducer output shall be within $\pm 2\%$ of the maximum ramp pressure within 0.01 s of the time that pressure is attained.

(2) The transducer output shall exhibit no overshoot of maximum ramp pressure in excess of 2% .

(3) The transducer output shall indicate the actual pressure to within $\pm 1\%$ in 0.175 s or less after attainment of the maximum ramp pressure, and shall remain within this error band for the duration of the applied steady-state pressure.

S1.8.4.11 Transient Supply Voltage and Frequency (ac) or Supply Voltage (dc):

(1) **Voltage**—During the voltage transient test, the transducer output shall remain within $\pm 0.5\%$ of the pretransient output.

(2) **Frequency**—During the frequency transient test, the transducer output shall remain within $\pm 0.5\%$ of the steady-state output.

S1.8.4.12 Temperature—During the temperature test, the transducer performance shall be within the static error band specified in S1.8.4.1.

S1.8.4.13 Overpressure—The calibration conducted after the overpressure test shall have no values in excess of 1% deviation from the pre-overpressure test reference measurement.

S1.8.4.14 Line Pressure (Type D Only)—After the line pressure test, the transducer performance shall be within the static error band specified in S1.8.4.1.

S1.8.4.15 Pressure Cycling—The calibration conducted after completion of pressure cycling test shall have no values in excess of 1% deviation from pretest reference measurement.

S1.8.4.16 Insulation Resistance—The insulation resistance of the transducer shall be not less than $10\text{ M}\Omega$.

S1.8.4.17 Vibration—Monitored transducer output during all phases of vibration test shall show no variation from steady-state output in excess of 2% . There shall be no visible evidence of damage to the transducer as a result of the vibration test.

S1.8.4.18 Shock—The transducer shall operate during and after the shock test. After the shock test, the transducer output shall have no value in excess of 1% deviation from the preshock test reference measurement. There shall be no visual evidence of damage to the transducer as a result of the shock test.

S1.8.4.19 Burst Pressure—The transducer shall withstand the burst pressure specified in S1.11.2.19 without showing any evidence of leakage.

S1.8.4.20 Electromagnetic Interference (EMI)—The transducers shall meet the requirements of Table II of MIL-STD-461, except as modified as follows:

(1) CE101—The test signal shall be applied only to the ac power leads of the test sample.

(2) CE102—The test signal shall be applied only to the ac power leads of the test sample.

(3) CS114—Only Limit Curve #2 shall apply with the frequency range limited from 10 kHz to 30 MHz.

(4) RE101—Only the limit curve for 50 cm shall apply.

(5) RS103—The frequency range shall be limited from 10 kHz to 18 GHz with an electric field strength test level of 10 V/m .

S1.9 Workmanship, Finish, and Appearance

S1.9.1 Transducer Cleaning—The manufacturer shall ensure that pressure transducers shall be free of all loose scale, rust, grit, filings, and other foreign substances and free of mercury, oil, grease, or other organic materials. In addition, the following shall apply:

S1.9.1.1 Transducers for oxygen service, Application X (see S1.4.3), shall be clean gas calibrated, cleaned, and pressure connections capped.

S1.9.1.2 Transducers for all other applications shall be freshwater or clean gas calibrated, cleaned, and pressure connections capped.

S1.10 Number of Tests and Retests

S1.10.1 The number of test specimens to be subjected to first-article and conformance tests shall depend on the transducer design. If each range is covered by a separate and distinct design, a test specimen for each range shall require testing. In instances in which a singular design series may cover multiple ranges and types, only three test specimens need be tested provided the electrical and mechanical similarities are approved by the purchaser. In no case, however, shall less than three units, one unit each representing the low, medium, and high ranges, be tested, regardless of design similarity.

S1.10.1.1 Low Range—Less than 700 kPa (less than 100 lb/in.^2).

S1.10.1.2 Medium Range— 700 kPa to less than 7 MPa (100 to less than 1000 lb/in.^2).

S1.10.1.3 High Range— 7 MPa and greater (1000 lb/in.^2 and greater).

S1.11 Test Methods

S1.11.1 *Test Conditions*—Except where the following factors are the variables, the tests specified in S1.11.2 shall be conducted with the equipment under the following operating environmental conditions:

S1.11.1.1 Ambient temperature shall be $23 \pm 2^\circ\text{C}$.

S1.11.1.2 Relative humidity shall be ambient.

S1.11.2 *Tests*—Except for the warm-up time test (see S1.11.2.3), the transducer and all associated test equipment shall be energized for a period of time sufficient to ensure complete warm-up.

S1.11.2.1 *Reference Measurement*—A reference measurement consisting of one-trial calibration with at least five equally spaced intervals over the entire transducer range both upscale and downscale shall be conducted when specified in the individual test.

S1.11.2.2 *Output*—A reference measurement shall be made in accordance with S1.11.2.1. Performance shall conform to the requirements of S1.8.4.2.

S1.11.2.3 *Warm-Up Time*—The test shall be conducted to determine the elapsed time between the application of line power to the transducer and the point at which the transducer output reaches the conditions specified in S1.8.4.3.

S1.11.2.3.1 *Test Conditions*—The transducer shall be subjected to the ambient temperature of the testing location, while deenergized, for not less than 2 h. Recording equipment and other auxiliary equipment shall be energized to ensure complete warm-up. An input pressure (differential pressure for Type D) of $80 \pm 5\%$ of the transducer span shall be applied to the transducer and maintained constant during this test. Performance shall conform to S1.8.4.

S1.11.2.4 *Enclosure*—The enclosure shall be subjected to the tests in NEMA Standard 250 for Type 4X enclosures. Performance shall conform to S1.8.4.4.

S1.11.2.5 *Static Error Band and Repeatability*—The transducer shall first be flexed over its full-pressure range by slowly increasing and decreasing the applied pressure for six continuous cycles. The calibration measurement shall be made at a minimum of five equally spaced intervals over the entire range (both upscale and downscale). Precaution shall be taken to avoid overshoot. This calibration procedure shall be applied three successive times to determine repeatability. Static error band of all calibrations shall meet the requirements of S1.8.4.1. Repeatability shall meet the requirements of S1.8.4.5.

S1.11.2.6 *Sensitivity Factor*—The sensitivity factor shall be determined as follows: Provide a pressure (differential pressure for Type D) to the transducer to a level of $80 \pm 5\%$ of span. Record the input pressure (differential pressure) and corresponding electrical output. Increase the pressure (differential pressure) by an amount not exceeding 1 % of span. Record both the new pressure (differential pressure) and corresponding new electrical output. Calculate the change in both applied pressure (differential pressure) and electrical output as a percentage of transducer span. Determine the ratio of electrical output percentage change to applied pressure (differential pressure) percent change. Repeat this procedure for a pressure (differential pressure) decrease not exceeding 1 % of span. Performance shall conform to the requirements of S1.8.4.6.

S1.11.2.7 *Ripple*—Transducer output root mean square ripple shall be determined at an input pressure (differential pressure for Type D) of $80 \pm 5\%$ of transducer span. Performance shall conform to the requirements of S1.8.4.7.

S1.11.2.8 *Steady-State Supply Voltage and Frequency (ac) or Supply Voltage (dc)*—The transducer shall be operated at normal, maximum, and minimum steady-state voltages (dc) and at all possible combinations of normal, maximum, and minimum voltages and frequencies (ac). The ambient temperature shall also vary, with the transducer operated for at least 15 min at each test temperature before the first reference measurement. The transducer shall be allowed at least 15 min to stabilize at each configuration at which point a reference measurement shall be taken (see S1.11.2.1). Reference measurements shall be performed at ambient temperatures of 0 ± 2 , 25 ± 2 , and $65 \pm 2^\circ\text{C}$. Test temperatures shall be accomplished by varying temperature in steps of 10°C each (30 min for each step) until the desired ambient temperature is reached. Performance shall conform to S1.8.4.8.

S1.11.2.9 *Common Mode Pressure (Transducer Type D Only)*—The rated pressure of the transducer shall be applied simultaneously to both pressure ports. The pressure at the low-pressure port shall then be decreased in pressure increments specified in S1.11.2.1 to the specified transducer range and then increased in similar increments to the transducer-rated pressure. Performance shall conform to S1.8.4.9.

S1.11.2.10 *Response*—A pressure (differential pressure for Type D) ramp consisting of a pressure (differential pressure for Type D) rise of at least 40 % of transducer span occurring at a rate of not less than 400 %/s shall be applied to the transducer. The maximum ramp pressure shall be maintained for at least 0.50 s and shall not vary by more than $\pm 2\%$ of the transducer span. Performance shall conform to S1.8.4.10.

S1.11.2.11 *Transient Supply Voltage and Frequency (ac) or Supply Voltage (dc)*—Tests shall be conducted with a pressure (differential pressure for Type D) input signal equal to $80 \pm 5\%$ of the transducer span. Performance shall conform to the requirements of S1.8.4.11.

(1) Transient Voltage:

(a) *Upper and Lower Limits of Steady-State Voltage*—With the transducer operating at the upper and lower limits of steady-state ac voltage, the ac-powered transducer shall have a transient voltage of no more than $\pm 16\%$, recovering to the steady-state band in 2 s, superimposed. With the transducer operating at the upper and lower limits of steady-state dc voltage, the dc-powered transducer shall have a transient voltage of no more than $\pm 2\text{ V}$, respectively, recovering to the steady-state band in 2 s, superimposed. Performance shall conform to the requirements of S1.8.4.11.

(2) Transient Frequency (for ac-Powered Transducers):

(a) *Upper Limit of Steady-State Frequency*—With the transducer operating at the upper limit of steady-state frequency, a transient frequency of +1.5 Hz recovering to the steady-state band in 2 s shall be superimposed. Performance shall conform to the requirements of S1.8.4.11.

(b) *Lower Limit of Steady-State Frequency*—With the transducer operating at the lower limit of steady-state frequency, a transient frequency of -1.5 Hz recovering to the steady-state

band in 2 s shall be superimposed. Performance shall conform to the requirements of S1.8.4.11.

S1.11.2.12 Temperature—The transducer shall operate normally (without alignment or adjustment) throughout the following temperature cycle. Tolerances in operating characteristics shall be as specified herein.

(1) Hold the test temperature at $0 \pm 2^\circ\text{C}$ for at least 24 h.

(2) Increase the test temperature in steps of 10° each, at 30 min for each step, until $+65 \pm 2^\circ\text{C}$ is reached and hold at that temperature for at least 4 h.

(3) Reduce the test temperature in steps of 10° each, at 30 min for each step, until $+25 \pm 2^\circ\text{C}$ is reached and hold at that temperature for at least 4 h. At each temperature plateau (0, 65, and 25°C), a reference measurement (see S1.11.2.1) shall be made. Performance shall conform to S1.8.4.12.

S1.11.2.13 Overpressure—Before the overpressure test, a reference measurement in accordance with S1.11.2.1 shall be made. The transducer shall successfully withstand pressure (differential pressure for Type D) equal to 200 % of its range with a maximum pressure of 85 MPa (12 000 lb/in.²) for a period of $\frac{1}{2}$ h. At the end of this period, transducers shall be immediately subjected to a pressure equal to 7 kPa (1 lb/in.²) or 10 % of range, whichever is less, below atmospheric for an additional period of $\frac{1}{2}$ h. Within 10 min after release of this pressure, a reference measurement (see S1.11.2.1) shall be made for comparison. Performance shall conform to S1.8.4.13. For Type D only, if the line pressure rating exceeds 200 % of the differential pressure range, the overpressure test shall be omitted and 0.5 % deviation shall be applied to the line pressure test (see S1.11.2.14).

S1.11.2.14 Line Pressure (for Type D Only)—The transducer shall successfully withstand the pressure rating, when applied to the high-pressure port with the low-pressure port vented to atmosphere for a period of 10 min. The preceding shall be repeated with the pressure applied to the low-pressure port of the transducer. After each test, a reference measurement in accordance with S1.11.2.1 shall be made. Performance shall conform to S1.8.4.14.

S1.11.2.15 Pressure Cycling—Before performing the pressure cycling test, a reference measurement shall be made (see S1.11.2.1). The test shall be conducted on a suitable system by applying a periodic pressure change of not more than 20 % to not less than 80 % of span for a total of 260 000 cycles. The rate of cycling shall be within the range from 0.25 to 2 Hz. The transducer shall be energized throughout the test. After completion of the pressure cycling test, a reference measurement shall be made for comparison (see S1.11.2.1). Performance shall conform to S1.8.4.15.

S1.11.2.16 Insulation Resistance—The insulation resistance of the transducer shall be determined by applying 50 Vdc between electrical input and output circuits and between these circuits and ground. The relative humidity shall be $50 \pm 10\%$. The insulation resistance measurement shall be made immediately after a 2-min period of uninterrupted test voltage application. However, if the indication of insulation resistance meets the specified limit (see S1.8.4.16) and is steady or increasing, the test may be terminated before the end of the 2-min period.

S1.11.2.17 Vibration—The transducer shall be tested in accordance with Type I vibration of MIL-STD-167-1 except that the upper frequency shall be 175 Hz. The amplitude of vibration shall be in accordance with Table S1.3 and for the variable frequency portion, the vibration level shall be maintained for 2 min at each integral value of frequency. If no resonance frequencies are observed, the 2-h endurance test shall be conducted at 175 Hz. During the vibration test, a fluid pressure of $80 \pm 5\%$ of the transducer span shall be applied to the transducer. Transducer output during the test shall be monitored. Performance shall conform to S1.8.4.17.

S1.11.2.18 Shock—The shock tests shall be conducted in accordance with Grade A, Class 1, Type C using bulkhead mounting Fixture 4-A of MIL-S-901. During the test, a fluid pressure (differential pressure for Type D) of $80 \pm 5\%$ of the transducer span shall be applied to the transducer. The transducer output during the test shall be monitored. Before and after the shock test, reference measurements shall be made for comparison. Performance shall conform to S1.8.4.18.

S1.11.2.19 Burst Pressure—The transducer shall be subjected to a liquid pressure equal to 300 % of the range with a maximum pressure of 105 MPa (15 000 lb/in.²) applied to the transducer (simultaneously to both sides for Type D) for a period of 10 min. The transducer shall conform to the requirements of S1.8.4.19. No performance test shall be required after the burst pressure test. A reference measurement (see S1.11.2.1) shall be recorded for information purposes.

S1.11.2.20 EMI Tests—The EMI tests shall be in accordance with the test methods specified in MIL-STD-461, with the modifications as specified in S1.8.4.20. Performance shall be as specified in S1.8.4.20.

S1.12 Inspection

S1.12.1 Classification of Inspections—The inspection requirements specified herein are classified as follows:

S1.12.1.1 First-article tests (see S1.12.2).

S1.12.1.2 Conformance tests (see S1.12.3).

S1.12.2 First-Article Tests—First-article tests shall be performed before production. First-article tests shall be performed on samples that have been produced with equipment and procedures normally used in production. First-article tests shall consist of the tests specified in Table S1.4. Failure of any pressure transducer to meet the requirements of this specification shall be cause for rejection.

S1.12.2.1 Order of First-Article Tests—With the exception of the electromagnetic interference emission and susceptibility

TABLE S1.3 Amplitude of Vibration

Frequency Range, Hz	Table Amplitude	
	Exploratory	Variable Frequency
SI Units, mm		
5 to 20	0.255 ± 0.050	0.765 ± 0.150
21 to 50	0.105 ± 0.025	0.510 ± 0.100
51 to 100	0.0380 ± 0.0075	0.255 ± 0.050
101 to 175	0.0130 ± 0.0025	0.0380 ± 0.0075
Inch-Pound Units, in.		
5 to 20	0.010 ± 0.002	0.030 ± 0.006
21 to 50	0.004 ± 0.001	0.020 ± 0.004
51 to 100	0.0015 ± 0.0003	0.010 ± 0.002
101 to 175	0.0005 ± 0.0001	0.0015 ± 0.0003

TABLE S1.4 First-Article Tests

Test	Test Method	Requirement
Output	S1.11.2.2	S1.8.4.2
Warm-up time	S1.11.2.3	S1.8.4.3
Enclosure	S1.11.2.4	S1.8.4.4
Static error band and repeatability	S1.11.2.5	S1.8.4.1 and S1.8.4.5
Sensitivity factor	S1.11.2.6	S1.8.4.6
Ripple	S1.11.2.7	S1.8.4.7
Supply voltage and frequency (steady-state)	S1.11.2.8	S1.8.4.8
Common mode pressure (transducer Type D only)	S1.11.2.9	S1.8.4.9
Response	S1.11.2.10	S1.8.4.10
Supply voltage and frequency (transient)	S1.11.2.11	S1.8.4.11
Temperature	S1.11.2.12	S1.8.4.12
Overpressure	S1.11.2.13	S1.8.4.13
Line pressure (transducer Type D only)	S1.11.2.14	S1.8.4.14
Pressure cycling	S1.11.2.15	S1.8.4.15
Insulation resistance	S1.11.2.16	S1.8.4.16
Vibration	S1.11.2.17	S1.8.4.17
Shock	S1.11.2.18	S1.8.4.18
Burst pressure	S1.11.2.19	S1.8.4.19
EMI	S1.11.2.20	S1.8.4.20

test which may be conducted on separate transducers, the test specimens (transducers) shall be subjected to the tests specified in Table S1.4 in the order listed. Deviation of the test order shall be approved by the purchaser.

S1.12.3 Conformance Tests—Each pressure transducer in each lot offered for delivery shall be subjected to the tests listed in Table S1.5 and shall be conducted in the order listed. Failure of any pressure transducer to meet the requirements of this specification shall be cause for rejection.

S1.12.4 General Examination—Each transducer shall be given a thorough examination to determine conformance to the requirements of this specification with respect to material, finish, workmanship, construction, assembly, dimensions, weight, and marking of identification. Examination shall be limited to the examinations that may be performed without disassembling the units. The manufacturer shall be responsible for ensuring that materials used are manufactured, examined, and tested in accordance with applicable approved industry standards.

S1.13 Certification

S1.13.1 The purchase order or contract should specify whether the purchaser shall be furnished certification that samples representing each lot have been either tested or inspected as directed in this specification and the requirements have been met. The purchase order or contract should specify when a report of the test results shall be furnished. Otherwise, the purchase order or contract should specify that all test data remain on file for three years at the manufacturer's facility for review by the purchaser upon request.

S1.14 Product Marking

TABLE S1.5 Conformance Tests

Test	Test Method	Requirement
General examination	S1.12.5	S1.6 and S1.7
Output	S1.11.2.2	S1.8.4.2
Static error band and repeatability	S1.11.2.5	S1.8.4.1 and S1.8.4.5
Sensitivity factor	S1.11.2.6	S1.8.4.6
Overpressure	S1.11.2.13	S1.8.4.13
Line pressure (transducer Type D only)	S1.11.2.14	S1.8.4.14
Insulation resistance	S1.11.2.16	S1.8.4.16

S1.14.1 Label Plates—A label plate with engraved or stamped markings shall be permanently affixed to the transducer. At a minimum, it shall contain the following:

S1.14.1.1 "PRESSURE TRANSDUCER" or "DIFFERENTIAL PRESSURE TRANSDUCER,"

S1.14.1.2 Manufacturer's name,

S1.14.1.3 National Stock Number (NSN), if available,

S1.14.1.4 Date of manufacture,

S1.14.1.5 Designation, and

S1.14.1.6 Pressure rating for Type D transducers.

S1.14.2 Transducers for use with Applications F and X (see S1.4.3) shall have "USE NO OIL FOR CALIBRATION" prominently marked on the body.

S1.14.3 For Type D transducers, the high- and low-pressure connections shall be clearly marked on the transducer body adjacent to the connections.

S1.14.4 The legend "DO NOT LUBRICATE" shall be prominently marked on the body.

S1.15 Packaging and Package Marking

S1.15.1 Packaging and package marking shall be in accordance with Section 15.

S1.16 Quality Assurance

S1.16.1 Quality System—A quality assurance system in accordance with ISO 9001 shall be maintained to control the quality of the product being supplied effectively, unless otherwise specified in the acquisition requirements (see S1.5.2).

S1.16.2 Warranty—Any special warranty requirements shall be specified in the acquisition requirements (see S1.5.2).

The following supplementary requirement, established for U.S. naval shipboard application, shall apply when specified in the contract or purchase order. When there is conflict between this specification and this supplementary requirement, this supplementary requirement shall take precedence. This document supersedes MIL-S-24796, *Sensors, Absolute Pressure, Fiber Optic (Naval Shipboard Use)*, for new ship construction.

S2. TRANSDUCERS, PRESSURE AND DIFFERENTIAL PRESSURE, FIBER-OPTIC

S2.1. Scope

S2.1.1 This supplement covers the requirements for fiber-optic pressure transducers designed to meet the requirements for use onboard naval ships.

S2.1.2 The values stated in SI units are to be regarded as the standard. Inch-pound units are provided for information only. Where information is to be specified, it shall be stated in SI units.

S2.2 Referenced Documents

S2.2.1 ASTM Standards:

D 542 Test Methods for Index of Refraction of Transparent Organic Plastics⁷

D 570 Test Method for Water Absorption of Plastics⁷

S2.2.2 EIA Standard:

TIA-422 Electrical Characteristics of Balanced Voltage Digital Interface Circuits⁸

⁷ *Annual Book of ASTM Standards*, Vol 08.01.

⁸ Available from Electronic Industries Association, 2500 Wilson Blvd., Arlington, VA 22201.

S2.2.3 ISO Standard:

6149-1 Connections for Fluid Power and General Use—Ports and Stud Ends with ISO 261 Threads and O-Ring Sealing—Part 1: Port with O-Ring Seal in Truncated Housing⁴

S2.2.4 NEMA Standard:

250 Enclosures for Electrical Equipment (1000 Volts Maximum)⁵

S2.2.5 Military Standards:

MIL-PRF-49291 Fiber, Optical (Metric), General Specification for⁶

MIL-S-901 Shock Tests, H.I. (High-Impact); Shipboard Machinery, Equipment and Systems, Requirements for⁶

MIL-STD-167-1 Mechanical Vibrations of Shipboard Equipment (Type I—Environmental and Type II—Internally Excited)⁶

MIL-STD-461 Electromagnetic Interference Characteristics of Subsystems and Equipment, Requirements for the Control of⁶

MIL-STD-1399, Section 300 Interface Standard for Shipboard Systems, Electric Power, Alternating Current⁶

MS3452 Connector, Receptacle, Electric, Box Mounting, Rear Release, Crimp Contact, AN Type⁶

MS3456 Connector, Plug, Electrical, Rear Release, Crimp Contact, AN Type⁶

S2.3 Terminology

S2.3.1 Terminology is consistent with that of Section 3 and the referenced documents.

S2.4 Classification

S2.4.1 *Designation*—For this specification, fiber-optic pressure transducer designations shall be assigned in accordance with S2.5.1 and listed in the following format:

Example: F25FXMS2-P-F-X-AC-A-N-1-P-100A

F25FXMS2	P	F	X	AC	A	N	1	P	100A
Specifica- tion	Type	Applica- tion	Press Rating, g	Power Supply	Output Conn	Press Conn	Opto- Elec- tronics Module	Mount- ing	Range

S2.4.2 S2.4.3 S2.4.4 S2.4.5 S2.4.6 S2.4.7 S2.4.8 S2.4.9 S2.4.10

S2.4.2 *Type*—The following designators have been established for the various types of fiber-optic transducers:

D—Pressure, differential

P—Pressure (gage, sealed, absolute)

V—Pressure, vacuum

C—Pressure, compound

S2.4.3 *Application*—The following application designations have been established for the media to be measured:

F—Freshwater, oil, condensate, steam, nitrogen, and other inert gases

S—Seawater

G—Flue gas and ammonia

X—Oxygen

S2.4.4 *Pressure Rating*—The pressure rating shall be indicated by the designator for its numerical value for Type D transducers (“X” for Type P, V, and C transducers) and shall be limited to the following:

Designator	Rating, kPaG	Inch-Pound Units, psig
1	100	15
2	1000	150

3	2000	300
4	4000	600
5	10 000	1500
6	20 000	3000
7	40 000	6000

S2.4.5 *Power Supply*—Transducers shall operate with either ac or dc input power, but not both. Designators shall be as follows:

S2.4.5.1 dc—Direct current supply.

S2.4.5.2 ac—Alternating current supply.

S2.4.6 *Output*—The prime output shall be an electrical dc signal. A supplemental output shall also be provided when specified. The signal output of the transducer shall be designated by the following designators:

A—4 to 20 mA

V—0 to 5 V

O—Optical (and current)

D—Digital (and current)

S2.4.7 *Pressure Connection*—Transducer pressure sensing connection shall be as follows:

N—M12 × 1.5 (7/16-20 UNF-2B) (see S7.5)

X—1/4 nps, 155-mm (6-in.) long pipe nipple (see S7.5)

Z—Other

S2.4.8 *Optoelectronics Module*—The optoelectronics module shall be designated as follows:

1—Bulkhead mounted

2—Console mounted

S2.4.9 *Transducer Mounting*—The transducer mounting method shall be designated as follows:

P—Pressure port connection

M—Mounting plate

S2.4.10 *Range*—The pressure range of the transducer shall be designated by two parts. The first part shall be the designator for the upper range value. The second part shall be the designator for the upper range unit of measure (see S2.4.8.1). The transducer pressure ranges shall be in accordance with Table S2.1.

S2.4.10.1 *Units*—The units shall be designated by the corresponding letter designator and are limited to the following:

Letter	SI Units	Inch-Pound Units
V	kPaV—kiloPascals, vacuum	Hg—inches of mercury vacuum
A	kPaA—kiloPascals, absolute	psia—pounds per square inch, absolute
D	kPaD—kiloPascals, differential	psid—pounds per square inch, differential
G	kPaG—kiloPascals, gage	psig—pounds per square inch, gage
S	kPaS—kiloPascals, sealed at 101.4 kPaA	psis—pounds per square inch, sealed at 14.7 psia
W	kPaW—kiloPascals, water column	WC—inches of water column
N	KpaWD—kiloPascals, water column, differential	WCD—inches of water column, differential

S2.5 Ordering Information

S2.5.1 The purchaser shall provide the manufacturer with all of the pertinent application data in accordance with S2.5.2. If special application operating conditions exist that are not in the acquisition requirements, they shall also be described.

S2.5.2 *Acquisition Requirements*—Acquisition documents shall specify the following:

S2.5.2.1 Title, number, and date of this specification.

TABLE S2.1 Range

Type D				Type P				Type C		Type V	
SI Units											
Differential Pressure Ranges, kPaD		Differential Pressure Water Column Ranges, kPaWD		Pressure Ranges, kPaG, kPaA, or kPaS ^A		Water Column Ranges, kPaW		Compound Ranges, kPaV/kPaG		Vacuum Range, kPaV	
Range	Designator	Range	Designator	Range	Designator	Range	Designator	Range	Designator	Range	Designator
0-100	100	0-2.5	2	0-100	100	0-2.5	2	100/150	150	0-100	100
0-200	200	0-15	15	0-200	200	0-15	15	100/300	300		
0-400	400	0-40	40	0-350	350	0-40	40	100/900	900		
0-700	700	0-75	75	0-400	400	0-75	75	100/1500	1500		
0-1400	1400			0-700	700			100/2400	2400		
0-2800	2800			0-850	850			100/4000	4000		
0-4000	4K			0-1 400	1400						
				0-2 000	2K						
				0-4 000	4K						
				0-6 000	6K						
				0-7 000	7K						
				0-10 000	10K						
				0-20 000	20K						
				0-40 000	40K						
				0-70 000	70K						
Inch-Pound Units											
Differential Pressure Ranges, psid		Differential Pressure Water Column Ranges, WCD		Pressure Ranges, psig, psia, or psis ^A		Water Column Ranges, WC		Compound Ranges, Hg-0-psig		Vacuum Range, Hg	
Range	Designator	Range	Designator	Range	Designator	Range	Designator	Range	Designator	Range	Designator
0-15	100	0-10	2	0-15	100	0-10	2	30-0-15	150	0-30	100
0-30	200	0-60	15	0-30	200	0-60	15	30-0-30	300		
0-60	400	0-150	40	0-50	350	0-150	40	30-0-100	900		
0-100	700	0-300	75	0-60	400	0-300	75	30-0-150	1500		
0-200	1400			0-100	700			30-0-300	2400		
0-400	2800			0-125	850			30-0-600	4000		
0-600	4K			0-200	1400						
				0-300	2K						
				0-600	4K						
				0-900	6K						
				0-1 000	7K						
				0-1 500	10K						
				0-3 000	20K						
				0-6 000	40K						
				0-10 000	70K						

^AFor upper range values of 7000 kPa (1000 lb/in.²) and above.

S2.5.2.2 Part designation required (see S2.4.1).

S2.5.2.3 National Stock Number (NSN), if available.

S2.5.2.4 Transducer mounting method, if other than specified herein (see S2.7.2).

S2.5.2.5 Optoelectronics module mounting method, if other than specified herein (see S2.7.2).

S2.5.2.6 Type of pressure connection, if other than specified herein (see S2.7.7).

S2.5.2.7 Type of electrical connection, if other than specified herein (see S2.7.6).

S2.5.2.8 When the electrical connection mating plug is not to be provided (see S2.7.6).

S2.5.2.9 Requirements when Type 2 optoelectronics module is specified (see S2.7.2.2).

S2.5.2.10 Fiber-optic cable length required (see S2.7.3).

S2.5.2.11 Output requirements when Type O output is specified (see S2.8.3.3) or output requirements and data format when Type D output is specified (see S2.8.3.4).

S2.5.2.12 Electrical connectors when Type D output is specified (see S2.7.6).

S2.5.2.13 When overload protection is required for the optoelectronics module (see S2.7.9).

S2.5.2.14 Quantity of transducers required.

S2.5.2.15 When first-article tests are required (see S2.12.3).

S2.5.2.16 Group B inspection sample size (see S2.12.3.2).

S2.5.2.17 Special product marking requirements (see S2.14).

S2.5.2.18 Special packaging or package marking requirements (see S2.15).

S2.5.2.19 When ISO 9001 quality assurance system is not required (see S2.16.1).

S2.5.2.20 Special warranty requirements (see S2.16.2).

S2.5.3 *First-Article Tests*—When first-article tests are required, the purchaser should provide specific guidance to offerors whether the item(s) should be a preproduction sample, a first-article sample, a first production item, a sample selected from the first production items, or a standard production item from the manufacturer's current inventory. The number of items to be tested in accordance with S2.12.4 should be specified. The purchaser should also include specific instructions in acquisition documents regarding arrangements for tests, approval of first-article test results and time period for approval, and disposition of first articles. Invitations for bids should provide that the purchaser reserves the right to waive the requirement for samples for first-article testing to those manufacturers offering a product that has been previously

acquired or tested by the purchaser, and that manufacturers offering such products, who wish to rely on such production or test, must furnish evidence with the bid that prior purchaser approval is presently appropriate for the pending contract. The manufacture of items before purchaser approval should be specified as the responsibility of the manufacturer.

S2.6 Materials

S2.6.1 Metals—Unless otherwise specified herein, all metals used in the construction of the transducer shall be corrosion resistant. Dissimilar metals shall not be used in contact with each other unless suitably finished to prevent electrolytic corrosion. The materials for the wetted parts shall be selected for long-term compatibility with the process medium.

S2.6.2 Flammable Materials—Materials used in the construction of the transducer shall in the end configuration be noncombustible or fire retardant in the most hazardous conditions of atmosphere, pressure, and temperature to be expected in the application. Fire retardance shall not be achieved by use of nonpermanent additives to the basic material.

S2.6.3 Fungus-Resistant Materials—Materials used in the construction of the transducer shall not support the growth of fungus.

S2.6.4 Solvents, Adhesives, and Cleaning Agents—When chemicals or cements are used in bonding of internal transducer components, no degradation shall result during in-service use.

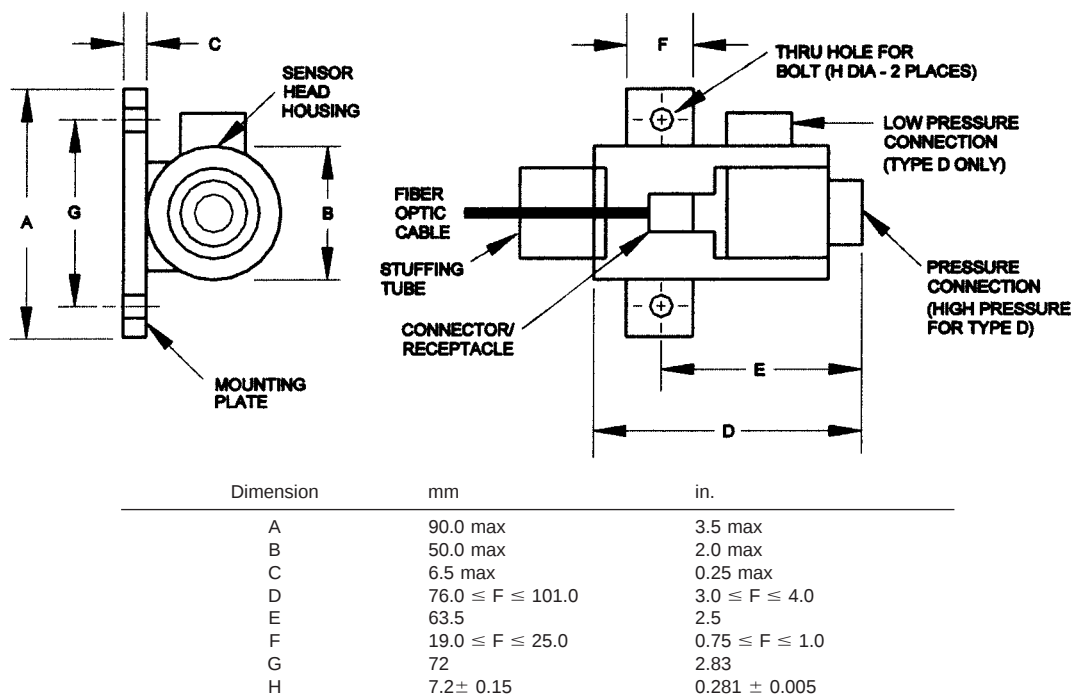
S2.6.5 Refractive Index Matching Gels, Fluids, or Compounds—Refractive index matching gels, fluids, or com-

pounds shall not produce toxic, corrosive, or explosive by-products. The material is subject to a toxicological data and formulations review and inspection, for safety of material, by the purchaser. The index matching material shall be either silicone or aliphatic hydrocarbon material and shall be clear and transparent. The index matching material shall have an index of refraction of 1.46 ± 0.01 as tested in accordance with Test Methods D 542, when exposed to operating temperature extremes between -28 and $+85^{\circ}\text{C}$. The index matching material shall not flow at elevated temperatures. The index matching material shall remain clear and transparent when tested for water absorption in accordance with Test Method D 570. The index matching material shall have a shelf life not less than 36 months at $25 \pm 5^{\circ}\text{C}$. The 36-month period commences on the date of adhesive manufacture.

S2.7 Physical Properties

S2.7.1 Sensor Head Configuration—The sensor head shall be constructed in accordance with configuration limits in Fig. S2.1. When required for repair or maintenance, replacement of sensor head components shall be accomplished with the sensor head body remaining fixed in place at mounting plate and pressure connection points.

S2.7.1.1 Sensor Head Mounting—The sensor head shall be mounted using mounting holes in locations shown in Fig. S2.1. If required in a specific application and with prior approval of the purchaser, the sensor head may be mounted by its pressure piping connection (see S2.5.2). For Type D transducers, the high-pressure port shall be used. If the sensor head is mounted



NOTE 1—Sensor head housing (body) cross section is shown as circular. Any alternate cross section not exceeding 50 mm (2 in.) in width and 50 mm (2 in.) in height is acceptable.

NOTE 2—Dimension tolerance is plus or minus 1.25 mm (0.05 in.), unless otherwise specified.

NOTE 3—The pressure connection(s) shall be generally located as shown.

FIG. S2.1 Sensor Head External Configuration

by its pressure connection, mounting holes shall not be required. It is recommended that the sensor head be installed such that sufficient clearance is provided for repair and maintenance of the unit.

S2.7.2 Optoelectronics Module—The optoelectronics module shall contain the optical and signal conditioner devices necessary to convert the sensor head output to the specified transducer output signal. Access to the interior of the optoelectronics module shall be possible to replace the connectorized cable. The module shall be bulkhead mounted or console mounted as specified in acquisition requirements (see S2.5.2).

S2.7.2.1 Bulkhead Mounted (Type 1)—The optoelectronics module shall be housed in a NEMA Standard 250 Type 4 enclosure.

S2.7.2.2 Console Mounted (Type 2)—The optoelectronics module shall be packaged in a console-mounted circuit card as specified in acquisition requirements (see S2.5.2).

S2.7.2.3 Fiber-Optic Cable—A fiber-optic cable shall be used to connect the sensor head to the optoelectronics module. There shall be no less than two times the number of fibers needed for operation of the transducer in the cable. Penetration of the fiber-optic cable into both the sensor head and the optoelectronics module shall be watertight. The required length of cable shall be as specified in acquisition requirements (see S2.5.2).

S2.7.4 Optical Fiber—All optical fiber used in the construction of the transducer shall be in accordance with MIL-PRF-49291.

S2.7.5 Fiber-Optic Connectors, Receptacles, and Bulkhead Adapters—All fiber-optic connectors, receptacles, and bulkhead adapters shall be in accordance with MIL-C-83522 and MIL-C-83522/16, 17, and 18, respectively, or equivalent. Connectors shall be assembled at both ends of the fiber-optic cable between the sensor head and the optoelectronics module. The connectors and receptacles shall be mounted inside the sensor head and optoelectronics module.

S2.7.6 Electrical Connector—An electrical interface connector receptacle and mating plug shall be provided with each optoelectronics module of the transducer unless otherwise specified. The electrical connector shall be a standard threaded coupling receptacle, AN type, MS3452W/14S-5P, or equivalent, for dc-power input, or AN type, MS3452W/14S-5PX, or equivalent, for ac-power input. The mating plug shall be a MS3456W/14S-5S, or equivalent, for dc-power input, or MS3456W/14S-5SX, or equivalent, for ac-power input. Electrical connectors for digital output shall be as specified (see S2.5.2).

S2.7.6.1 dc-Power Input—Current Output—The receptacle shall be wired to provide the performance described herein. Receptacle Pin A shall be +28-Vdc power input, Pin B shall be –28-Vdc power input, and Pin C shall be case ground. Receptacle Pins A and B shall also serve as the 4-20-mA dc signal output.

S2.7.6.2 dc-Power Input—Voltage Output—The receptacle shall be wired to provide the performance described herein. Receptacle Pin A shall be +28-Vdc power input, Pin B shall be

–28-Vdc power input, Pin C shall be case ground, Pin D shall be +0-5-Vdc signal output, and Pin E shall be –0-5-Vdc signal output.

S2.7.6.3 ac-Power Input—Current Output—The receptacle shall be wired to provide the performance described herein. Receptacle Pins A and B shall be 115-Vac power input, Pin C shall be case ground, Pin D shall be +4-20-mA dc signal output, and Pin E shall be –4-20-mA dc signal output.

S2.7.6.4 ac-Power Input—Voltage Output—The receptacle shall be wired to provide the performance described herein. Receptacle Pins A and B shall be 115-Vac power input, Pin C shall be case ground, Pin D shall be +0-5-Vdc signal output, and Pin E shall be –0-5-Vdc signal output.

S2.7.7 Pressure Connections—Unless otherwise specified, transducer pressure-sensing connections for all services shall be M12 × 1.5 (7/16-20 UNF-2B) tube connection in accordance with ISO 6149-1. When pressure connection Type X is specified, as commonly used on submarine oxygen replenishment systems, the transducer sensing connections shall be a nickel-copper pipe nipple ¼ nominal pipe size (nps) with 3.1-mm (0.12-in.) minimum wall thickness, 155 mm (6 in.) long, welded to the socket (see S2.5.2). For Type D transducers, the high-pressure connection shall be on the end and the low-pressure connection shall be on the side (see Fig. S2.1).

S2.7.8 Adjustments—Tamper-proof adjustments for zero and span may be provided on the optoelectronics module for calibration purposes. The number of adjustments shall be kept to a minimum consistent with the operation and maintenance requirements. Electrical disconnection shall not be required to accomplish these adjustments.

S2.7.9 Electrical Overload Protection and Isolation—The optoelectronics module shall be provided with overload protection when not adequately protected by the ship's power circuits (see S2.5.2). A means of isolating the optoelectronics module from ship power shall be provided on the unit.

S2.7.10 Calibration Media—Oil shall not be used as the calibration media.

S2.7.11 Welding—For Application X, all pressure boundary joints shall be welded.

S2.7.12 Lubrication—The transducer shall not require lubrication.

S2.7.13 Damping—The use of oil for damping is prohibited.

S2.7.14 Weight—The weight of the sensor head shall not exceed 510 g (18 oz). The weight of the optoelectronics module shall not exceed 4.5 kg (10 lb).

S2.8 Performance Requirements

S2.8.1 Service Life—The transducer shall be constructed for a service life of no less than 40 000 h and shall meet the requirements specified herein when operated in the naval shipboard environment.

S2.8.2 Input Power—The transducer shall be designed to operate using 115-V, 60-Hz, single-phase, ungrounded, ac power as defined in MIL-STD-1399, Section 300 or 28 ± 4.5-V dc power. The transducer shall operate with power supply variations as specified in S2.11.2.7 and S2.11.2.8.

S2.8.3 Output—The prime transducer output shall be an electrical dc signal that is directly proportional to the input

pressure and shall be a true current or voltage source. If an optical or digital output is required, it shall be a supplemental output.

S2.8.3.1 Current Output—When a 4- to 20-mA current output is specified (see S2.5.2), the requirements specified herein shall be met regardless of external load resistance variations over a range from 0 to 250 Ω . The output shall be directly proportional to the input pressure. The 4-mA output shall correspond to the lower pressure range value and the 20-mA output shall correspond to the upper pressure range value for the ranges specified in Table S2.1.

S2.8.3.2 Voltage Output—When a 0- to 5-V output is specified (see S2.5.2), the requirements specified herein shall be met for external load resistance exceeding 100 000 Ω . The output shall be directly proportional to the input pressure. The 0-V output shall correspond to the lower pressure range value, and the 5-V output shall correspond to the upper pressure range value for the ranges specified in Table S2.1.

S2.8.3.3 Optical Output—When an optical output is specified (see S2.5.2), the optical output requirements shall be as specified in the ordering data (see S2.5.2).

S2.8.3.4 Digital Output—When an electrical digital output is specified (see S2.5.2), the digital output requirements shall be as specified in the ordering data (see S2.5.2). The electrical characteristics shall be in accordance with EIA Standard TIA-422 for balanced voltage digital interface circuitry, or as specified (see S2.5.2). The data format shall be as specified (see S2.5.2).

S2.8.4 Transducer Performance—Unless otherwise specified, performance tolerances are specified in percent of transducer output span.

S2.8.4.1 Static Error Band—The transducer static error band shall not exceed $\pm 1\%$.

S2.8.4.2 Repeatability—Repeatability of the transducer output shall be within 0.5 %.

S2.8.4.3 Sensitivity Factor—The sensitivity factor shall not be less than 0.75 nor more than 1.25.

S2.8.4.4 Response—The transducer output shall conform to the following criteria, where all percentages are of transducer span:

(1) The transducer output shall be within $\pm 2\%$ of the maximum ramp pressure within 0.01 s of the time that pressure is attained.

(2) The transducer output shall exhibit no overshoot of maximum ramp pressure in excess of 2 %.

(3) The transducer output shall indicate the actual pressure to within $\pm 1\%$ in 0.2 s or less after attainment of maximum ramp pressure, and shall remain within this error band for the duration of applied steady-state pressure.

S2.8.4.5 Warm-Up Time—The transducer output shall attain a value within $\pm 1\%$ of the steady-state output with no overshoot in excess of 1 %. Output shall reach this band within 1 min after the transducer is energized and shall remain in this band.

S2.8.4.6 Ripple—The transducer rms output ripple shall not be greater than 0.5 %.

S2.8.4.7 Steady-State Supply Voltage and Frequency (ac) or Supply Voltage (dc)—The maximum difference between out-

puts at any voltage and frequency or voltage (for dc) condition and the normal (115-V, 60-Hz, or 28-V dc) at the same input and test temperature (differential shall be included for Type D) shall not exceed 1 %.

S2.8.4.8 Transient Supply Voltage and Frequency (ac) or Supply Voltage (dc):

S2.8.4.8.1 Voltage—During the voltage transient test, the transducer output shall remain within $\pm 0.5\%$ of the pre-transient output.

S2.8.4.8.2 Frequency—During the frequency transient test, the transducer output shall remain within $\pm 0.5\%$ of the pre-transient output.

S2.8.4.9 Power interruption—During the power interruption test, the transducer performance shall conform to S2.8.4.1.

S2.8.4.10 Common Mode Pressure (Type D Only)—During the common mode pressure test, transducer performance shall be within the range formed by extending the upper and lower static error band limits specified in S2.8.4.1 by a percentage equal to:

$$(1/10) \frac{(\text{system pressure rating})^{1/3}}{\text{differential pressure range}}$$

S2.8.4.11 Temperature—During the temperature test, the transducer performance shall be within the static error band specified in S2.8.4.1.

S2.8.4.12 Enclosure—The sensor head and optoelectronics module shall meet all test criteria in NEMA Standard 250 for Type 4X enclosures.

S2.8.4.13 Overpressure—Calibration conducted after overpressure test shall have no values in excess of 1 % deviation from the pre-overpressure test reference measurement.

S2.8.4.14 Line Pressure (Type D Only)—After the line pressure test, transducer performance shall be within the static error band specified in S2.8.4.1.

S2.8.4.15 Pressure Cycling—Calibration conducted after completion of pressure cycling test shall have no values in excess of 1 % deviation from pretest reference measurement.

S2.8.4.16 Vibration—Monitored transducer output during all phases of the vibration test shall show no variation from steady-state output in excess of 2 %. There shall be no visible evidence of damage to the transducer as a result of the vibration test.

S2.8.4.17 Shock—The transducer shall operate during and after the shock test. After the shock test, the transducer output shall have no value in excess of 1 % deviation from the pre-shock test reference measurement. There shall be no visual evidence of damage to the transducer as a result of the shock test.

S2.8.4.18 Burst Pressure—The transducer shall withstand the burst pressure specified in S2.11.2.19 without showing any evidence of leakage.

S2.8.4.19 Short-Circuit (Output Type A Only)—After the short-circuit test, the transducer shall exhibit no damage and shall conform to S2.8.4.1.

S2.8.4.20 Line Voltage Reversal (dc Power Supply Only)—The transducer shall conform to S2.8.4.1 after the line voltage reversal test.

S2.8.4.21 Insulation Resistance—The insulation resistance of the transducer shall be not less than 10 M Ω .

S2.8.4.22 Electromagnetic Interference (EMI) Emission and Susceptibility—The transducers shall meet the requirements of Table II of MIL-STD-461, except as modified as follows:

- (1) CE101—The test signal shall be applied only to the ac-power leads of the test sample.
- (2) CE102—The test signal shall be applied only to the ac-power leads of the test sample.
- (3) CS114—Only Limit Curve #2 shall apply with the frequency range limited from 10 kHz to 30 MHz.
- (4) RE101—Only the limit curve for 50 cm shall apply.
- (5) RS103—The frequency range shall be limited from 10 kHz to 18 GHz with an electric field strength test level of 10 V/m.

S2.9 Workmanship, Finish, and Appearance

S2.9.1 Transducer Cleaning—The manufacturer shall ensure that pressure transducers shall be free of all loose scale, rust, grit, filings, and other foreign substances and free of mercury, oil, grease, or other organic materials. In addition, the following shall apply:

S2.9.1.1 Transducers for oxygen service, Application X (see S2.4.3), shall be clean gas calibrated, cleaned, and pressure connections capped.

S2.9.1.2 Transducers for all other applications shall be freshwater or clean gas calibrated, cleaned, and pressure connections capped.

S2.9.2 Surface Finish—Surfaces of castings, forgings, molded parts, stampings, and machined and welded parts shall be free of defects such as cracks, pores, undercuts, voids, and gaps. External surfaces shall be smooth and edges shall be either rounded or beveled. There shall be no burn through, warpage, or dimensional change as a result of heat from welding. There shall be no damage to adjacent parts resulting from welding.

S2.10 Number of Tests and Retests

S2.10.1 Test Specimen—see 10.1.

S2.11 Test Methods

S2.11.1 Test Conditions—Except where the following factors are the variables, the tests specified in S2.11.2 shall be conducted with the equipment under the following operating environmental conditions:

S2.11.1.1 Ambient temperature shall be $23 \pm 2^\circ\text{C}$.

S2.11.1.2 Relative humidity shall be ambient.

S2.11.2 Tests—Except for the warm-up time test (see S2.11.2.5), the transducer and all associated test equipment shall be energized for a period of time sufficient to ensure complete warm-up.

S2.11.2.1 Reference Measurement—A reference measurement consisting of a one-trial calibration with at least five equally spaced intervals over the entire transducer range both upscale and downscale shall be conducted when specified in the individual test. No adjustments to the transducer are permitted during the reference measurement.

S2.11.2.2 Static Error Band and Repeatability—The transducer shall first be flexed over its full-pressure range by slowly increasing and decreasing the applied pressure for six continuous cycles. The calibration measurement shall be made at a minimum of five equally spaced intervals over the entire range (both upscale and downscale). Precaution shall be taken to

avoid overshoot. This calibration procedure shall be applied three successive times to determine repeatability. Static error band of all calibration shall meet the requirements of S2.8.4.1. Repeatability shall meet the requirements of S2.8.4.2.

S2.11.2.3 Sensitivity Factor—The sensitivity factor shall be determined as follows: Provide an input pressure (differential pressure for Type D) to the transducer of $80 \pm 5\%$ of span. Record the input pressure (differential pressure) and corresponding electrical output. Increase the pressure (differential pressure) by an amount not exceeding 1% of span. Record both the new pressure (differential pressure) and corresponding new electrical output. Calculate the change in both applied pressure (differential pressure) and electrical output as a percentage of transducer span. Determine the ratio of electrical output percentage change to applied pressure (differential pressure) percentage change. Repeat this procedure for a pressure (differential pressure) decrease not exceeding 1% of span. Performance shall conform to the requirements of S2.8.4.3.

S2.11.2.4 Response—A pressure (differential pressure for Type D) ramp consisting of a pressure (differential pressure for Type D) rise of at least 40% of span occurring in not greater than 0.1 s shall be applied to the transducer. The maximum ramp pressure shall be maintained for at least 0.5 s and shall not vary by more than $\pm 2\%$ of the transducer span. Performance shall conform to the requirements of S2.8.4.4.

S2.11.2.5 Warm-Up Time—The test shall be conducted to determine the elapsed time between the application of the line power to the transducer and the point at which the transducer output reaches the conditions specified in S2.8.4.5.

(1) Test Conditions—The transducer shall be subjected to the ambient temperature of the testing location, while de-energized, for not less than 2 h . Recording equipment and other auxiliary equipment shall be energized to ensure complete warm-up. An input pressure of $80 \pm 5\%$ of span shall be applied to the transducer and maintained constant during this test. Performance shall conform to the requirements of S2.8.4.

S2.11.2.6 Ripple—Transducer output rms ripple shall be determined at an output pressure (differential pressure for Type D) of $80 \pm 5\%$ of transducer span. Performance shall conform to the requirements of S2.8.4.6.

S2.11.2.7 Steady-State Supply Voltage and Frequency (ac) or Supply Voltage (dc)—The transducer shall be operated at normal, maximum, and minimum steady-state voltages (dc) and at all possible combinations of normal, maximum, and minimum voltages and frequencies (ac). The ambient temperature shall also vary, with the transducer operated for at least 1 h at each test temperature before the first reference measurement (see S2.11.2.1). Reference measurements shall be performed at ambient temperatures of $0 \pm 2^\circ\text{C}$, $25 \pm 2^\circ\text{C}$, and $65 \pm 2^\circ\text{C}$. Test temperatures shall be accomplished by varying temperature in steps of 10°C each (30 min for each step) until the desired ambient temperature is reached. Performance shall conform to the requirements of S2.8.4.7.

S2.11.2.8 Transient Supply Voltage and Frequency (ac) or Supply Voltage (dc)—Tests shall be conducted with a pressure (differential pressure for Type D) input signal equal to $80 \pm 5\%$ of the transducer span. The transducer output shall be

monitored throughout the test. Performance shall conform to the requirements of S2.8.4.8.

S2.11.2.8.1 Transient Voltage:

(1) *Upper and Lower Limits of Steady-State Voltage*—With the transducer operating at the upper and lower limits of steady-state ac voltage, the ac-powered transducer shall have a transient voltage of $\pm 16\%$, recovering to the steady-state band in 2 s, superimposed. With the transducer operating at the upper and lower limits of steady-state dc voltage, the dc-powered transducer shall have a transient voltage of ± 2 V, respectively, recovering to the steady-state band in 2 s, superimposed. Performance shall conform to the requirements of S2.8.4.8.

S2.11.2.8.2 Transient Frequency (for ac-Powered Transducers):

(1) *Upper Limit of Steady-State Frequency*—With the transducer operating at the upper limit of steady-state frequency, a transient frequency of +1.5 Hz recovering to the steady-state band in 2 s shall be superimposed. Performance shall conform to the requirements of S2.8.4.8.

(2) *Lower Limit of Steady-State Frequency*—With the transducer operating at the lower limit of steady-state frequency, a transient frequency of –1.5 Hz recovering to the steady-state band in 2 s shall be superimposed. Performance shall conform to the requirements of S2.8.4.8.

S2.11.2.9 Power Interruption—An input pressure (differential pressure for Type D) of $80 \pm 5\%$ of span shall be applied to the transducer and maintained constant during the test. With the transducer operating within the steady-state tolerances of voltage and frequency, the external power supply shall be interrupted for an interval of 3 to 4 s. The power supply shall then be reestablished to within steady-state tolerances. The transducer shall be operated at steady-state power for 1 min. The power supply shall then be interrupted for an interval of 30 s. This cycle shall be repeated three times. Performance shall conform to the requirements of S2.8.4.9.

S2.11.2.10 Common Mode Pressure (Transducer Type D Only)—The rated pressure of the transducer shall be applied simultaneously to both pressure ports. The pressure at the low-pressure port shall then be decreased in pressure increments specified in S2.11.2.1 to the specified transducer range and then increased in similar increments to the transducer-rated pressure. Performance shall conform to the requirements of S2.8.4.10.

S2.11.2.11 Temperature—The transducer shall operate normally (without alignment or adjustment) throughout the following temperature cycle. Tolerances in operating characteristics shall be as specified herein. Performance shall conform to the requirements of S2.8.4.11.

(1) Hold the test temperature at $0 \pm 2^\circ\text{C}$ for at least 24 h. During the last hour of operation, a reference measurement shall be made (see S2.11.2.1).

(2) Increase the test temperature in steps of 10° each, at 30 min for each step, until $+65 \pm 2^\circ\text{C}$ is reached and hold at that temperature for at least 24 h. During the last hour of operation, a reference measurement shall be made (see S2.11.2.1).

(3) Reduce the test temperature in steps of 10° each, at 30 min for each step, until $+25 \pm 2^\circ\text{C}$ is reached and hold at that

temperature for at least 24 h. During the last hour of operation, a reference measurement shall be made (see S2.11.2.1).

S2.11.2.12 Enclosure—The sensor head and optoelectronics module (Type 1 only) shall be subjected to the tests in NEMA Standard 250 for Type 4X enclosures. Performance shall conform to the requirements of S2.8.4.12.

S2.11.2.13 Overpressure—Before the overpressure test, a reference measurement in accordance with S2.11.2.1 shall be made. The transducer shall be subjected to a pressure equal to 200 % of the upper limit of its range for a period of 30 min. Within 10 min after release of this pressure, a reference measurement (see S2.11.2.1) shall be made for comparison. Performance shall conform to the requirements of S2.8.4.13.

S2.11.2.14 Line Pressure (for Type D Only)—The transducer shall successfully withstand the pressure rating, when applied to the high-pressure port with the low-pressure port vented to atmosphere, for a period of 10 min. The preceding shall be repeated with the pressure applied to the low-pressure port of the transducer. After each test, a reference measurement in accordance with S2.11.2.1 shall be made. Performance shall conform to S2.8.4.14.

S2.11.2.15 Pressure Cycling—Before performing the pressure cycling test, a reference measurement shall be made (see S2.11.2.1). The test shall be conducted by applying a periodic pressure change of not more than 20 % of span to not less than 80 % of span for a total of 260 000 cycles. The rate of cycling shall be within the range from 0.25 to 2 Hz. The transducer shall be energized throughout the test. After completion of the pressure cycling test, a reference measurement shall be made for comparison (see S2.11.2.1). Performance shall conform to the requirements of S2.8.4.15.

S2.11.2.16 Vibration—A reference measurement (see S2.11.2.1) shall be made before the vibration test. The transducer shall be tested in accordance with Type I (environmental) vibration of MIL-STD-167-1 except that the upper frequency shall be 175 Hz; the amplitude of vibration shall be in accordance with Table S2.2; and for the variable frequency portion, the vibration level shall be maintained for two minutes at each integral value of frequency. If no resonances are observed, the 2-h endurance test shall be conducted at 175 Hz. During the vibration test, a fluid pressure of $80 \pm 5\%$ of the transducer span shall be applied to the transducer. Transducer output during the test shall be monitored. Performance shall conform to the requirements of S2.8.4.16.

TABLE S2.2 Amplitudes of Vibration

Frequency Range, Hz	Table Amplitude	
	Exploratory	Variable Frequency
SI Units, mm		
5 to 20	0.255 ± 0.050	0.765 ± 0.150
21 to 50	0.105 ± 0.025	0.510 ± 0.100
51 to 100	0.0380 ± 0.0075	0.255 ± 0.050
101 to 175	0.0130 ± 0.0025	0.0380 ± 0.0075
Inch-Pound Units, in.		
5 to 20	0.010 ± 0.002	0.030 ± 0.006
21 to 50	0.004 ± 0.001	0.020 ± 0.004
51 to 100	0.0015 ± 0.0003	0.010 ± 0.002
101 to 175	0.0005 ± 0.0001	0.0015 ± 0.0003

S2.11.2.17 *Shock*—The shock tests shall be conducted in accordance with Grade A, Class 1, Type C using bulkhead mounting fixture 4-A of MIL-S-901. During the test, a fluid pressure of $80 \pm 5\%$ of the transducer span shall be applied to the transducer. The transducer output during the test shall be monitored. Before and after the shock test, reference measurements shall be made for comparison. Performance shall conform to the requirements of S2.8.4.18.

S2.11.2.18 *Burst Pressure*—The transducer shall be subjected to a liquid pressure equal to 300 % of the upper limit of its range applied to the transducer for a period of 10 min. The transducer shall conform to the requirements of S2.8.4.18. No performance test shall be required after the burst pressure test. A reference measurement (see S2.11.2.1) shall be recorded for information purposes.

S2.11.2.19 *Short-Circuit (Output Type A Only)*—An input pressure (differential pressure for Type D) of $80 \pm 5\%$ of span shall be applied to the transducer and maintained constant during the test. The transducer shall be de-energized. The electrical output pins of the optoelectronics module shall be connected together with no load resistance. The transducer shall be energized for 5 min. Immediately following the 5-min period, the output pins shall be unshorted. The transducer shall conform to the requirements of S2.8.4.19.

S2.11.2.20 *Line Voltage Reversal (dc Power Supply Only)*—An input pressure (differential pressure for Type D) of $80 \pm 5\%$ of span shall be applied to the transducer and maintained constant during the test. The positive 28-Vdc signal shall be applied to Connector Pin B. The dc reference signal shall be applied to Connector Pin A. The transducer shall be energized for a period of 10 min and then disconnected. The power shall then be correctly applied (Pin A positive, Pin B negative). A reference measurement shall be made (see S2.11.2.1). The transducer shall conform to the requirements of S2.8.4.20.

S2.11.2.21 *Insulation Resistance*—The insulation resistance of the transducer shall be determined by applying 50 Vdc between electrical input and output circuits and between these circuits and ground. The relative humidity shall be $50 \pm 10\%$. The insulation resistance measurement shall be made immediately after a 2-min period of uninterrupted test voltage application. However, if the indication of insulation resistance meets the specified limit (see S2.8.4.21) and is steady or increasing, the test may be terminated before the end of the 2-min period.

S2.11.2.22 *EMI Emission and Susceptibility*—The EMI tests shall be in accordance with the test methods specified in MIL-STD-461, with the modifications as specified in S2.8.4.22. Performance shall conform to the requirements of S2.8.4.22.

S2.12 Inspection

S2.12.1 *Classification of Inspections*—The inspection requirements specified herein are classified as follows:

S2.12.1.1 First-article tests (see S2.12.2).

S2.12.1.2 Conformance tests (see S2.12.3).

S2.12.2 *First-Article Tests*—First-article tests shall be performed before production. First-article tests shall be performed on samples that have been produced with equipment and

procedures normally used in production. First-article tests shall consist of the examination and tests specified in Table S2.3. Failure of any pressure transducer to meet the requirements of this specification shall be cause for rejection.

S2.12.2.1 *First-Article Tests Sample Size*—Two transducers of each lot shall be subjected to first-article testing, Table S2.3. One sample shall be subjected to the tests of Group I and one sample shall be subjected to the tests of Group II of Table S2.3. The fiber-optic connecting cable shall not be less than 100 ft.

S2.12.2.2 *Order of First-Article Tests*—The sample transducers shall be subjected to the tests specified in Table S2.3 in the order listed except that the steady-state supply voltage and frequency inspection may be performed concurrently with the temperature inspection. Any deviation in the test order shall first be approved by the purchaser.

S2.12.3 *Conformance Tests*—Each lot of transducers offered for delivery shall be subjected to the tests of Table S2.4.

S2.12.3.1 *Group A Tests*—All transducers offered for delivery shall be subjected to Group A tests as listed in Table S2.4. Failure of any transducer to meet the requirements of this specification shall be cause for rejection.

S2.12.3.2 *Group B Tests*—Group B tests shall be as listed in Table S2.4. The number of samples subjected to Group B tests shall be in accordance with Table S2.5. Failure of any transducer to meet the requirements of this specification shall be cause for rejection.

S2.12.4 *General Examination*—Each transducer shall be given a thorough examination to determine conformance to the requirements of this specification with respect to material, finish, workmanship, construction, assembly, dimensions, weight, and marking of identification. Examination shall be limited to the examinations that may be performed without disassembling the units. Examination shall include a check of

TABLE S2.3 First-Article Tests

Test	Test Method	Requirement
Group I		
Static error band and repeatability	S2.11.2.2	S2.8.4.1 and S2.8.4.2
Sensitivity factor	S2.11.2.3	S2.8.4.3
Response	S2.11.2.4	S2.8.4.4
Warm-up time	S2.11.2.5	S2.8.4.5
Ripple	S2.11.2.6	S2.8.4.6
Supply voltage and frequency (steady-state)	S2.11.2.7	S2.8.4.7
Supply voltage and frequency (transient)	S2.11.2.8	S2.8.4.8
Power interruption	S2.11.2.9	S2.8.4.9
Common mode pressure (transducer Type D only)	S2.11.2.10	S2.8.4.10
Temperature	S2.11.2.11	S2.8.4.11
Enclosure	S2.11.2.12	S2.8.4.12
Overpressure	S2.11.2.13	S2.8.4.13
Line pressure (transducer Type D only)	S2.11.2.14	S2.8.4.14
Pressure cycling	S2.11.2.15	S2.8.4.15
Vibration	S2.11.2.16	S2.8.4.16
Shock	S2.11.2.17	S2.8.4.17
Burst pressure	S2.11.2.18	S2.8.4.18
Group II		
Static error band and repeatability	S2.11.2.2	S2.8.4.1 and S2.8.4.2
Short-circuit (output Type A only)	S2.11.2.19	S2.8.4.19
Line voltage reversal (dc power supply only)	S2.11.2.20	S2.8.4.20
Insulation resistance	S2.11.2.21	S2.8.4.21
EMI emission and susceptibility	S2.11.2.22	S2.8.4.22

**TABLE S2.4 Conformance Tests**

Test	Test Method	Requirement
Group A		
General examination	S2.12.5	S2.6 and S2.7
Static error band and repeatability	S2.11.2.2	S2.8.4.1 and S2.8.4.2
Sensitivity factor	S2.11.2.3	S2.8.4.3
Group B		
Insulation resistance	S2.11.2.21	S2.8.4.21
Temperature	S2.11.2.11	S2.8.4.11
Enclosure	S2.11.2.12	S2.8.4.12
Line pressure (Type D only)	S2.11.2.14	S2.8.4.14
Overpressure	S2.11.2.13	S2.8.4.13

TABLE S2.5 Group B Tests Sample Size

Lot or Batch Size	Sample Size
2 to 8	2
9 to 15	3
16 to 25	5
26 to 50	8
51 to 90	13
91 to 150	20
151 to 280	32
281 to 500	50
501 to 1200	80
1201 to 4200	125
4201+	3 per 100

all adjustments, if applicable. The manufacturer shall be responsible for ensuring that materials used are manufactured, examined, and tested in accordance with applicable approved industry standards.

S2.13 Certification

S2.13.1 The purchase order or contract should specify whether the purchaser shall be furnished certification that samples representing each lot have been either tested or inspected as directed in this specification and the requirements have been met. The purchase order or contract should specify when a report of the test results shall be furnished. Otherwise, the purchase order or contract should specify that all test data remain on file for three years at the manufacturer's facility for review by the purchaser upon request.

S2.14 Product Marking

S2.14.1 *Label Plates*—A label plate with engraved or stamped markings shall be permanently affixed to the sensor head and to the optoelectronics module.

S2.14.1.1 *Sensor Head*—At a minimum, the following information shall be provided on the label plate:

- (1) "SENSOR HEAD,"
- (2) Manufacturer's name,
- (3) Manufacturer's serial number,
- (4) Manufacturer's part number and drawing number,
- (5) Designation,
- (6) National Stock Number (NSN), if available, and
- (7) Date of manufacture.

S2.14.1.2 *Optoelectronics Module*—At a minimum, the following information shall be provided on the label plate:

- (1) "OPTOELECTRONICS MODULE,"
- (2) Manufacturer's name,
- (3) Manufacturer's serial number,
- (4) Manufacturer's part number,

(5) Electrical and optical (if any) output (see S2.8.3),

(6) National Stock Number (NSN), if available, and

(7) Date of manufacture.

S2.14.2 *Labeling*—Labels shall be permanently and prominently marked.

S2.14.2.1 The legend "USE NO OIL FOR CALIBRATION" shall be marked on the sensor head housing.

S2.14.2.2 The legend "DO NOT LUBRICATE" shall be marked on the sensor head housing.

S2.14.2.3 A visible label, consisting of yellow lettering on a black background, shall be affixed to the outside of the optoelectronics module cover and shall contain the following:

NOTICE

UNTERMINATED OPTICAL CONNECTIONS MAY

EMIT LASER RADIATION

DO NOT VIEW BEAM WITH OPTICAL INSTRUMENTS

AND AVOID DIRECT EXPOSURE TO THE BEAM

S2.14.2.4 A visible label, consisting of yellow lettering on a black background, shall be affixed to the sensor head and the inside of the optoelectronics module and shall contain the following:

WARNING

INVISIBLE LASER RADIATION

AVOID EXPOSURE TO THE BEAM

S2.15 Packaging and Package Marking

S2.15.1 Packaging and package marking shall be in accordance with Section 15.

S2.16 Quality Assurance

S2.16.1 *Quality System*—A quality assurance system in accordance with ISO 9001 shall be maintained to effectively control the quality of the product being supplied, unless otherwise specified in the acquisition requirements (see S2.5.2).

S2.16.2 *Warranty*—Any special warranty requirements shall be specified in the acquisition requirements (see S2.5.2).

The following supplementary requirement, established for naval shipboard application, shall apply when specified in the contract or purchase order. When there is conflict between this specification and this supplementary requirement, this supplementary requirement shall take precedence.

S3. TRANSDUCERS, SMART PRESSURE AND DIFFERENTIAL PRESSURE (ELECTRICAL)

S3.1 Scope

S3.1.1 This supplementary requirement covers the requirements for smart pressure and differential pressure transducers designed to meet the requirements for use onboard naval ships.

S3.1.2 The values stated in SI units are to be regarded as the standard. Inch-pound units are provided for information only. Where information is to be specified, it shall be stated in SI units.

S3.2 Referenced Documents

S3.2.1 ISO Standard:

6149-1 Connections for Fluid Power and General Use—Ports and Stud Ends with ISO 261 Threads and O-Ring Sealing—Part 1: Ports with O-Ring Seal in Truncated Housing⁴

S3.2.2 NEMA Standard:

250 Enclosures for Electrical Equipment (1000 Volts Maximum)⁵

S3.2.3 Military Standards:

MIL-S-901 Shock Tests, H.I. (High-Impact); Shipboard Machinery, Equipment and Systems, Requirements for⁶

MIL-STD-167-1 Mechanical Vibrations of Shipboard Equipment (Type I—Environmental and Type II—Internally Excited)⁶

MIL-STD-461 Electromagnetic Interference Characteristics of Subsystems and Equipment, Requirements for the Control of⁶

S3.3 Terminology

S3.3.1 Terminology is consistent with that of Section 3 and the referenced documents.

S3.4 Classification

S3.4.1 *Designation*—For this specification, pressure transducer designations shall be assigned in accordance with S3.5.1 and listed in the following format:

Example: F25XMS3-D-F-DC-2-10KD					
F25XMS3	D	F	DC	2	10KD
Specification	Type	Application	Power Supply	Output	Range
	S3.4.2	S3.4.3	S3.4.4	S3.4.5	S3.4.6

S3.4.2 *Types*—The following designators have been established for the various types of transducers:

D—Pressure, differential

P—Pressure (gage, absolute and sealed)

V—Pressure, vacuum

C—Pressure, compound

S3.4.3 *Application*—The following application designations have been established for the corresponding process media:

F—Freshwater, oil, condensate, steam, nitrogen and other inert gases

S—Seawater

G—Flue gas and ammonia

S3.4.4 *Power Supply*—Transducers shall operate with dc input power. The designator shall be as follows:

DC—Direct current supply

S3.4.5 *Output*—The default dc electrical signal output of the transducer shall be designated by the following designators:

2—4 to 20 mA

3—1 to 5 V

4—0.8 to 3.2 V

S3.4.6 *Range*—The pressure range of the transducer shall be designated by two parts. The first part shall be the designator

for the upper range value. The second part shall be the designator for the upper range unit of measure (see S3.4.6.1). The transducer pressure ranges shall be in accordance with Table S3.1.

S3.4.6.1 *Units*—The units shall be designated by the corresponding letter designator and are limited to the following:

Letter	SI Units	Inch-Pound Units
V	KPaV—kiloPascals, vacuum	Hg—inches of mercury vacuum
A	KPaA—kiloPascals, absolute	psia—pounds per square inch, absolute
D	KPaD—kiloPascals, differential	psid—pounds per square inch, differential
G	kPaG—kiloPascals, gage	psig—pounds per square inch, gage
S	kPaS—kiloPascals, sealed at 101.4 kPaA	psis—pounds per square inch, sealed at 14.7 psia
W	kPaW—kiloPascals, water column	WC—inches of water column
N	kPaWD—kiloPascals, water column, differential	WCD—inches of water column, Differential

S3.5 Ordering Information

S3.5.1 The purchaser shall provide the manufacturer with all of the pertinent application data in accordance with S3.5.2. If special application operating conditions exist that are not in the acquisition requirements, they shall also be described.

S3.5.2 *Acquisition Requirements*—Acquisition documents shall specify the following:

S3.5.2.1 Title, number, and date of this specification.

S3.5.2.2 Part designation required (see S3.4.1).

S3.5.2.3 National Stock Number (NSN), if available.

S3.5.2.4 Mounting method, if other than specified herein (see S3.7.2).

S3.5.2.5 Type of pressure connection, if other than specified herein (see S3.7.5).

S3.5.2.6 Type of electrical connection, if other than specified herein (see S3.7.4).

S3.5.2.7 Quantity of transducers required.

S3.5.2.8 Quantity of handheld communicators required (see S3.7.8).

S3.5.2.9 If deviation requests are not required when departing from material guidance (see S3.6).

S3.5.2.10 When the first article inspection is required (see S3.12.3).

S3.5.2.11 Special product marking requirements (see S3.13).

S3.5.2.12 Special packaging or package marking requirements (see S3.14).

TABLE S3.1 Range

Type D				Type P				Type C		Type V	
				SI Units							
Differential Pressure Ranges, kPaD		Differential Pressure Water Column Ranges, kPaWD		Pressure Ranges, kPaG, kPaA, or kPaS ⁴		Water Column Ranges, kPaW		Compound Ranges, kPaV/kPaG		Vacuum Range, kPaV	
Range	Designator	Range	Designator	Range	Designator	Range	Designator	Range	Designator	Range	Designator
0-10 000	10K	0-7000	7K	0-10 000	10K	0-7000	7K	100/4000	4K	0-100	100
				0-70 000	70K						
Inch-Pound Units											
Differential Pressure Ranges, psid		Differential Pressure Water Column Ranges, WCD		Pressure Ranges, psig, psia, or psis ⁴		Water Column Ranges, WC		Compound Ranges, Hg-0-psig		Vacuum Range, Hg	
Range	Designator	Range	Designator	Range	Designator	Range	Designator	Range	Designator	Range	Designator
0-1 500	10K	0-1 000	7K	0-1 500	10K	0-1 000	7K	30-0-600	4K	0-30	100
				0-10 000	70K						

⁴For upper range values of 7000 kPa (1000 lb/in.²) and above.

S3.5.2.13 When ISO 9001 quality assurance system is not required (see S3.16.1).

S3.5.2.14 Special warranty requirements (see S3.16.2).

S3.5.3 *First-Article Tests*—When first-article testing is required, the purchaser should provide specific guidance to offerors whether the item(s) should be a preproduction sample, a first-article sample, a first production item, a sample selected from the first production items, or a standard production item from the manufacturer's current inventory. The number of items to be tested in accordance with S3.12.3 should be specified. The purchaser should also include specific instructions in acquisition documents regarding arrangements for tests, approval of first-article test results and time period for approval, and disposition of first articles. Invitations for bids should provide that the purchaser reserves the right to waive the requirement for samples for first-article testing to those manufacturers offering a product which has been previously acquired or tested by the purchaser; and that manufacturers offering such products, who wish to rely on such production or test, must furnish evidence with the bid that prior purchaser approval is presently appropriate for the pending contract. The manufacture of items before purchaser approval should be specified as the responsibility of the manufacturer.

S3.6 Materials

S3.6.1 *Metals*—Unless otherwise specified herein, all metals used in the construction of the transducer shall be corrosion-resistant or treated to provide corrosion resistance. Dissimilar metals shall not be used in contact with each other unless suitably finished to prevent electrolytic corrosion. The materials for the sensing element and wetted parts shall be selected for long-term compatibility (see S3.8.1) with the process medium (see S3.4.3).

S3.6.2 *Flammable Materials*—Materials used in the construction of the transducer shall in the end configuration be noncombustible or fire retardant in the most hazardous conditions of atmosphere, pressure, and temperature to be expected in the application. Fire retardance shall not be achieved by use of nonpermanent additives to the material.

S3.6.3 *Fungus-Resistant Materials*—Materials used in the construction of the sensor shall not support the growth of fungus.

S3.6.4 *Solvents, Adhesives, and Cleaning Agents*—When chemicals or cements are used in bonding of internal transducer components, no degradation shall result during in-service use.

S3.7 Physical Properties

S3.7.1 *Enclosure*—The transducer body and pressure cavity shall be environmentally sealed unless otherwise specified. The transducer enclosure shall be Type 4X in accordance with NEMA Standard 250.

S3.7.2 *Transducer Mounting*—The transducer shall be mounted on an integral coplanar flange/bracket, as shown in Fig. S3.1, for interface with the process medium. For Types P, V, and C transducers, the equalizing valve control handles shall be removed and equalizing valve ports shall be blanked.

S3.7.3 *External Configuration*—The transducer shall have an external configuration within the boundaries established by Figs. S3.1 and S3.2.

S3.7.4 *Electrical Connection*—A terminal block shall be provided in the transducer for connection of electrical conductors for power supply input, dc electrical signal output, and transducer case ground.

S3.7.5 *Pressure Connections*—The pressure connections that interface with shipboard systems shall be M12 $\times$ 1.5 (7/16-20 UNF-2B) tube connection in accordance with ISO 6149-1. The traditional flange (see Fig. S3.2) provides these connections for differential pressure units and the flat adapter (see Fig. S3.3) provides these connections for pressure units. Differential units shall mount on the traditional flange and pressure units shall interface with the flat adapter.

S3.7.6 *Digital Meter*—The transducer shall have a direct reading digital meter to display pressure in pressure engineering units and in percent of analog range values. The meter shall display diagnostic messages for local troubleshooting. The meter shall be capable of being rotated 90° clockwise or counterclockwise within the transducer housing for meter reading flexibility.

S3.7.7 *Communications Protocol*—The transducer shall be microprocessor-based. The transducer shall be capable of digital communications with field devices using the frequency shift keying Highway Addressable Remote Transducer (HART) protocol supported by the HART Communication Foundation. Using the HART protocol, the transducer shall be capable of providing analog signal output (see 3.8.3) and digital communications over the same pair of wires.

S3.7.8 *Handheld Communicator*—A handheld communicator shall be provided when specified (see S3.5.2). The handheld communicator shall enable communication by an operator with the transducer using the HART protocol. The handheld communicator shall be capable of communicating with the transducer for configuration, test, and detailed setup of the transducer (see 3.8.5.2).

S3.7.9 *Lubrication*—The transducer shall operate without lubrication of moving parts after assembly.

S3.7.10 *Damping*—The use of a media for damping in transducers shall be cited on the equipment drawing.

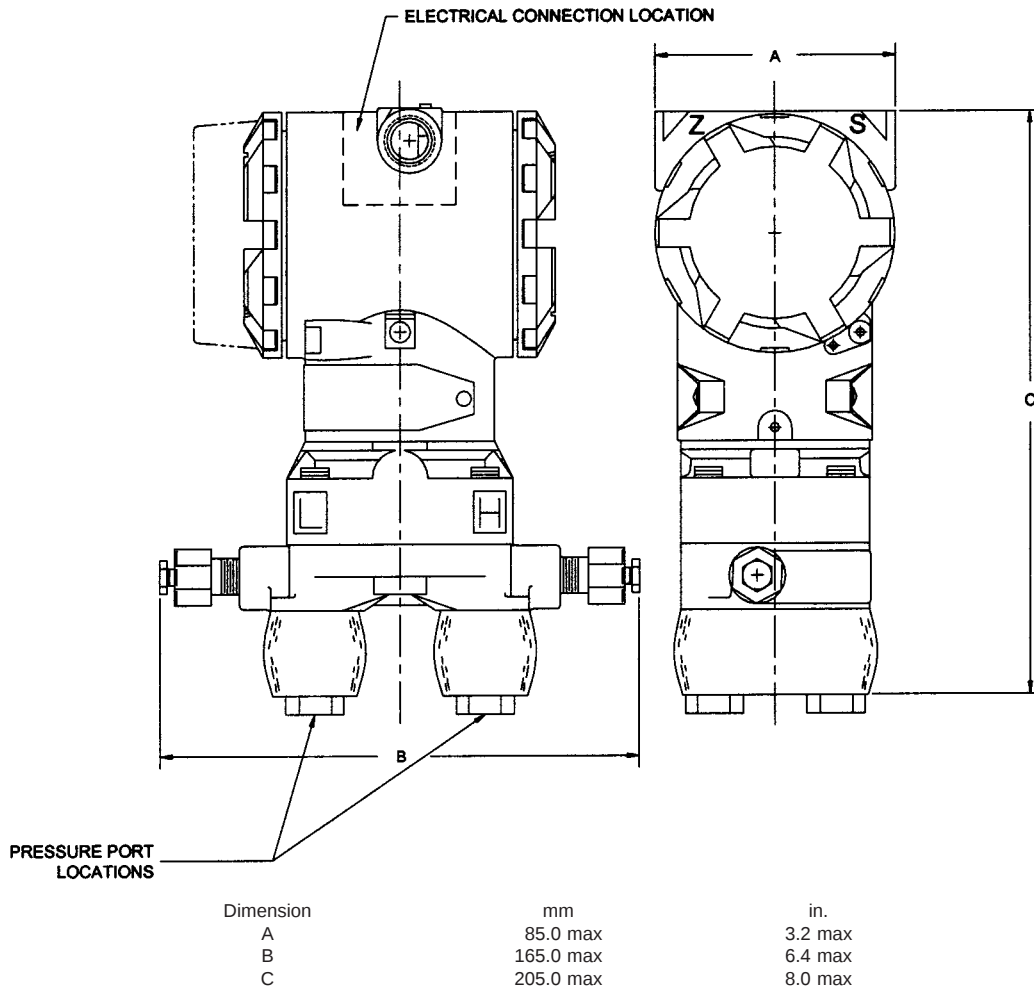
S3.7.12 *Weight*—The weight of a transducer shall not exceed 2.7 kg (6 lb). The weight of a traditional flange/bracket shall not exceed 2.7 kg.

S3.8 Performance Requirements

S3.8.1 *Service Life*—The transducer shall be constructed for a life of 25 years of operation and shall meet the requirements specified herein when operated in the naval shipboard environment.

S3.8.2 *Input Power*—The transducer shall be designed to operate using 28 ± 4.5 Vdc power. The transducer shall operate with power supply variations as specified in S3.11.2.10 and S3.11.2.13.

S3.8.3 *Output*—The electrical signal output of the transducer shall be dc, directly proportional to the pressure or differential pressure input. The output shall be a true current source or true voltage source. The output type shall be selectable via a handheld communicator (see S3.7.8) or other device using the HART protocol. Selectable output types shall be 4 to 20 mA, 1 to 5 V, and 0.8 to 3.2 V.



NOTE 1—Dimension tolerance is ± 1.25 mm (0.05 in.), unless otherwise specified.

NOTE 2—The pressure port(s) shall be generally located as shown. Differential pressure transducer ports shall be located to match traditional flange/bracket configuration.

FIG. S3.1 Transducer External Configuration Boundary Limits

S3.8.3.1 Current Output—When a 4- to 20-mA current output is selected, the requirements specified herein shall be met regardless of external load resistance variations over a range from 0 to 250 Ω . The 4-mA output shall correspond to the lower pressure or differential pressure range value and the 20-mA output shall correspond to the upper pressure or differential pressure range value for the transducer span programmed into the transducer (see S3.8.3.3).

S3.8.3.2 Voltage Output—When a voltage output is selected, the requirements specified herein shall be met for external load resistance exceeding 100 000 Ω . The 1- or 0.8-V output (output Type 3 or 4, respectively) shall correspond to the lower pressure or differential pressure range value for the transducer span programmed into the transducer (see S3.8.3.3). The 5- or 3.2-V output (output Type 3 or 4, respectively) shall correspond to the upper pressure or differential pressure range value for the transducer span programmed into the transducer (see S3.8.3.3).

S3.8.3.3 Floating (Live) Zero—The transducer shall be capable of assigning the low output value (4 mA, 1 V, or 0.8 V)

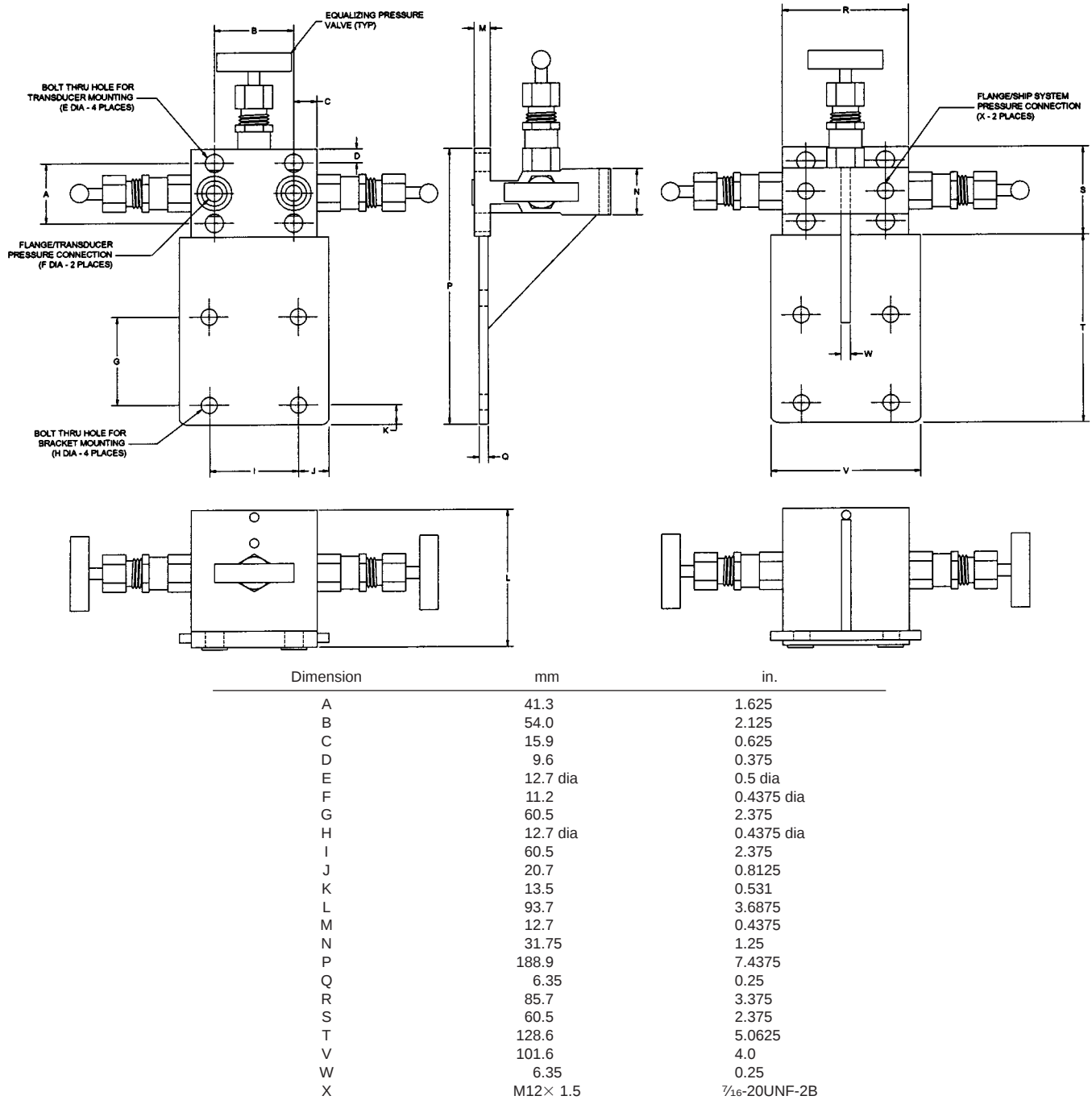
to any pressure value within the programmed transducer span. The transducer shall be capable of assigning the high output value (20 mA, 5 V, or 3.2 V) to any pressure value within the programmed transducer span that is higher than the low output pressure value.

S3.8.4 Pressure Ports (Transducer Type D Only)—The transducer shall be capable of operation with either pressure port as the high-pressure port and the other as the low-pressure port. Selection of high- and low-pressure ports shall be programmable from a remote device using the HART protocol.

S3.8.5 Transducer Performance—Unless otherwise specified, performance tolerances are specified in percent of transducer output span for each settable span.

S3.8.5.1 Rangeability—Rangeability of the transducer shall be 100 to 1. Span values shall be settable anywhere within the range limits. Minimum span shall be no more than 1 % of the upper range value.

S3.8.5.2 Communications—The transducer shall be capable of communication with field devices using the HART protocol (see S3.7.8). The transducer shall be programmed such that



NOTE 1—Dimension tolerance is ± 1.25 mm (0.05 in.), unless otherwise specified.

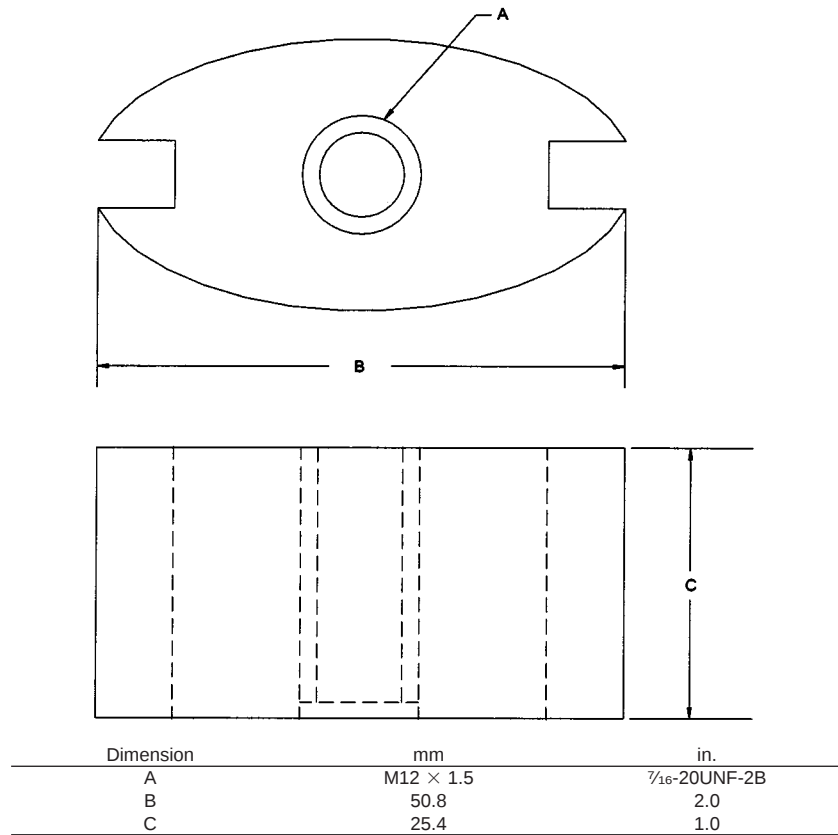
FIG. S3.2 Traditional Flange/Bracket Configuration

field device operators can perform configuration, test, and detailed setup of the transducer.

S3.8.5.2.1 Configuration—In the configuration mode, field device operators shall be capable of the adjustment of transducer operational parameters including, but not limited to, linear or square root output, damping, engineering unit selection, and assigning high and low pressure ports (differential transducers). The field device operator shall be capable of entering informational data for identification and physical

description of the transducer. Informational data shall include tag, descriptor, and message fields for the transducer, date, flange type, flange material, drain/vent material, O-ring material, and remote seal information.

S3.8.5.2.2 Test—In the test mode, field device operators shall be capable of interrogation of the transducer when a problem has been detected. The field device operator shall be capable of being directed to give specific outputs for loop testing.



NOTE 1—Dimension tolerance is ± 1.25 mm (0.05 in.), unless otherwise specified.

FIG. S3.3 Flat Adapter

S3.8.5.2.3 Detailed Setup—The detailed setup mode is used during initial setup of the transducer and for maintenance of the digital electronics. Detailed setup shall include the setting of transducer zero and span values anywhere within available range limits, analog output selection, and transducer calibration. The field device operator shall be capable of selecting security features to prevent accidental or deliberate adjustment of analog output setpoints.

S3.8.5.3 Static Error Band—The transducer static error band shall not exceed ± 0.25 %.

S3.8.5.4 Output—The output shall conform to S3.8.3 and the transducer performance shall be within the static error band specified in S3.8.5.3.

S3.8.5.5 Warm-Up Time—The transducer output shall attain a value within ± 0.5 % of the steady-state output with no overshoot in excess of 0.5 %. Output shall reach this band within 2 s after the transducer is energized and shall remain in this band.

S3.8.5.6 Enclosure—The transducer shall meet all test criteria in NEMA Standard 250 for Type 4X enclosures.

S3.8.5.7 Repeatability—Repeatability of transducer output shall be within 0.5 %.

S3.8.5.8 Sensitivity Factor—The sensitivity factor shall not be less than 0.75 nor more than 1.25.

S3.8.5.9 Stability and Temperature—The transducer shall remain within the static error band specified in S3.8.5.3 throughout the stability and temperature test.

S3.8.5.10 Ripple—Transducer rms output ripple shall not exceed 0.15 % of full-scale dc output.

S3.8.5.11 Steady-State Supply Voltage—Maximum difference between outputs at any voltage condition and the normal (28-Vdc) at the same input and test temperature (differential pressure shall be included for Type D) shall not exceed 0.5 %.

S3.8.5.12 Pressure Rating and Common Mode Pressure (Transducer Type D Only)—Type D transducers shall have a pressure rating of 21 MPa (3000 lb/in.²). During the common mode pressure test, transducer performance shall be within the range formed by extending the upper and lower static error band limits specified in S3.8.5.3 by a percentage equal to:

$$(1/10) \frac{(\text{System pressure rating})^{1/3}}{\text{Differential pressure range}}$$

S3.8.5.13 Response—Transducer output shall conform to the following criteria, where all percentages are of transducer span:

(1) The transducer output shall be within ± 2 % of the maximum ramp pressure within 0.01 s of the time that pressure is attained.

(2) The transducer output shall exhibit no overshoot of maximum ramp pressure in excess of 2 %.

(3) The transducer output shall indicate the actual pressure to within ± 1 % in 0.175 s or less after attainment of maximum ramp pressure, and shall remain within this error band for the duration of applied steady-state pressure.

S3.8.5.14 Transient Supply Voltage—During the voltage transient test, the transducer output shall remain within $\pm 0.5\%$ of the pretransient output.

S3.8.5.15 Power Interruption—During the power interruption test, transducer performance shall conform to S3.8.5.3.

S3.8.5.16 Overpressure—Calibration conducted after overpressure test shall have no values in excess of 1 % deviation from the pre-overpressure test reference measurement.

S3.8.5.17 Line Pressure (Transducer Type D Only)—After the line pressure test, transducer performance shall be within the static error band specified in S3.8.5.3.

S3.8.5.18 Pressure Cycling—Calibration conducted after completion of pressure cycling test shall have no values in excess of 1 % deviation from pretest reference measurement.

S3.8.5.19 Insulation Resistance—The insulation resistance of the transducer shall be not less than 10 M Ω .

S3.8.5.20 Vibration—Monitored transducer output during all phases of vibration test shall show no variation from steady-state output in excess of 2 %. There shall be no visible evidence of damage to the transducer as a result of the vibration test.

S3.8.5.21 Shock—The transducer shall operate during and after the shock test. After the shock test, the transducer output shall have no value in excess of 1 % deviation from the pre-shock test reference measurement. There shall be no visual evidence of damage to the transducer as a result of the shock test.

S3.8.5.22 Burst Pressure—The transducer shall withstand the burst pressure specified in S3.11.2.21 without showing any evidence of leakage.

S3.8.5.23 Short-Circuit Test—After the short-circuit test, the transducer shall exhibit no damage and shall conform to S3.8.5.3.

S3.8.5.24 Line Voltage Reversal Test—The transducer shall conform to S3.8.5.3 after the line voltage reversal test.

S3.8.5.25 Electromagnetic Interference (EMI)—The transducers shall meet the requirements of Table II of MIL-STD-461, except as modified as follows:

(1) CE101—The test signal shall be applied only to the ac power leads of the test sample.

(2) CE102—The test signal shall be applied only to the ac power leads of the test sample.

(3) CS114—Only Limit Curve #2 shall apply with the frequency range limited from 10 kHz to 30 MHz.

(4) RE101—Only the limit curve for 50 cm shall apply.

(5) RS103—The frequency range shall be limited from 10 kHz to 18 GHz with an electric field strength test level of 10 V/m.

S3.9 Workmanship, Finish, and Appearance

S3.9.1 Transducer Cleaning—The manufacturer shall ensure that pressure transducers shall be free of all loose scale, rust, grit, filings and other foreign substances and free of mercury, oil, grease, or other organic materials. Transducers for all applications shall be freshwater or clean gas calibrated, cleaned, and pressure connections capped.

S3.10 Number of Tests and Retests

S3.10.1 Test Specimen—(see 10.1).

S3.11 Test Methods

S3.11.1 Test Conditions—Except where the following factors are the variables, the tests specified in S3.11.2 shall be conducted with the equipment under the following operating environmental conditions:

S3.11.1.1 Ambient temperature shall be $23 \pm 2^\circ\text{C}$.

S3.11.1.2 Relative humidity shall be ambient.

S3.11.1.3 Range Setting—The transducer has a rangeability from 100 to 1 (S3.8.5.1). All tests, excluding static error band and repeatability (S3.11.2.6), shall be conducted with the transducer set at approximately the mid range. Static error band and repeatability shall be accomplished at 3 ranges (low, medium, and high) within the capability of the transducer under test.

S3.11.2 Tests—Except for the warm-up time test (see S3.11.2.4), the transducer and all associated test equipment shall be energized for a period of time sufficient to ensure complete warm-up.

S3.11.2.1 Reference Measurement—A reference measurement consisting of a one-trial calibration with at least five equally spaced intervals over the entire transducer range both upscale and downscale shall be conducted when specified in the individual test.

S3.11.2.2 Communications—The test shall be conducted with a handheld communicator using the HART protocol. Configuration, test, and detailed setup of the transducer shall be performed. In the test mode, transducer problems shall be simulated to verify test mode functions. Performance shall conform to S3.8.3, S3.8.4, S3.8.5.1, and S3.8.5.2. All handheld communicator functions shall be verified.

S3.11.2.3 Output—Three reference measurements shall be made in accordance with S3.11.2.1. Each reference measurement shall use a different set of low- and high-output values (see S3.8.3.3). Performance shall conform to the requirements of S3.8.5.4.

S3.11.2.4 Warm-Up Time—The test shall be conducted to determine the elapsed time between the application of line power to the transducer and the point at which the transducer output reaches the conditions specified in S3.8.5.5.

S3.11.2.4.1 Test Conditions—The transducer shall be subjected to the ambient temperature of the testing location, while deenergized, for not less than 2 h. Recording equipment and other auxiliary equipment shall be energized to ensure complete warm-up. An input pressure (differential pressure for Type D) of $80 \pm 5\%$ of the transducer upper range limit shall be applied to the transducer and maintained constant during this test. Performance shall conform to S3.8.5.

S3.11.2.5 Enclosure—The enclosure shall be subjected to the tests in NEMA Standard 250 for Type 4X enclosures. Performance shall conform to S3.8.5.6.

S3.11.2.6 Static Error Band and Repeatability—The transducer shall first be flexed over its full pressure range by slowly increasing and decreasing the applied pressure for six continuous cycles. The calibration measurement shall be made at a minimum of five equally spaced intervals over the entire range (both upscale and downscale). Precaution shall be taken to avoid overshoot. This calibration procedure shall be applied three successive times to determine repeatability. Static error

band of all calibrations shall meet the requirements of S3.8.5.3. Repeatability shall meet the requirements of S3.8.5.7.

S3.11.2.7 Sensitivity Factor—The sensitivity factor shall be determined as follows: Provide a pressure (differential pressure for transducer Type D) to the transducer of $80 \pm 5\%$ of transducer upper range limit. Record the input pressure (differential pressure) and corresponding electrical output. Increase the pressure (differential pressure) by an amount not exceeding 1 % of upper range limit. Record both the new pressure (differential pressure) and corresponding new electrical output. Calculate the change in both applied pressure (differential pressure) and electrical output as a percentage of transducer range. Determine the ratio of electrical output percentage change to applied pressure (differential pressure) percent change. Repeat this procedure for a pressure (differential pressure) decrease not exceeding 1 % of upper range limit. Performance shall conform to the requirements of S3.8.5.8.

S3.11.2.8 Stability and Temperature—The transducer shall be operated at an input pressure (differential pressure for transducer Type D) of $80 \pm 5\%$ of transducer upper range limit for a period of ten days. Starting ambient temperature shall be $25 \pm 2^\circ\text{C}$. At the end of three days, the ambient temperature shall be changed to $0 \pm 2^\circ\text{C}$. At the end of five days, the ambient temperature shall be changed to $65 \pm 2^\circ\text{C}$. At the end of seven days, the ambient temperature shall be returned to $25 \pm 2^\circ\text{C}$. Performance shall conform to the requirements of S3.8.5.9.

S3.11.2.9 Ripple—Transducer output rms ripple shall be determined at an input pressure (differential pressure for transducer Type D) of $80 \pm 5\%$ of transducer upper range limit. Performance shall conform to the requirements of S3.8.5.10.

S3.11.2.10 Steady-State Supply Voltage—The transducer shall be operated at normal, maximum, and minimum steady-state voltages (dc). Performance shall conform to S3.8.5.11.

S3.11.2.11 Common Mode Pressure (Transducer Type D Only)—The rated pressure of the transducer shall be applied simultaneously to both pressure ports. The pressure at the assigned low-pressure port shall then be decreased in pressure increments specified in S3.11.2.1 to the specified transducer range and then increased in similar increments to the transducer-rated pressure. Performance shall conform to S3.8.4 and S3.8.5.12. The test shall be conducted once with each pressure port as the assigned low-pressure port.

S3.11.2.12 Response—A pressure (differential pressure for Type D) ramp consisting of a pressure (differential pressure for Type D) rise of at least 40 % of transducer upper range limit occurring at a rate of not less than 400 % per second shall be applied to the transducer. The maximum ramp pressure shall be maintained for at least 0.50 s and shall not vary by more than $\pm 2\%$ of the transducer upper range limit. Performance shall conform to S3.8.5.13.

S3.11.2.13 Transient Supply Voltage—Tests shall be conducted with a pressure (differential pressure for transducer Type D) input signal equal to $80 \pm 5\%$ of the transducer upper range limit. With the transducer operating at the upper and lower limits of steady-state dc voltage, the dc-powered transducer shall have a transient voltage of no more than $\pm 2\text{ V}$,

respectively, recovering to the steady-state band in 2 s, superimposed. Performance shall conform to the requirements of S3.8.5.14.

S3.11.2.14 Power Interruption—An input pressure (differential pressure for transducer Type D) of $80 \pm 5\%$ of transducer upper range limit shall be applied to the transducer and maintained constant during the test. With the transducer operating within the steady-state voltage tolerances, the external power supply shall be interrupted for an interval of 3 to 4 s. The power supply shall then be reestablished to within steady-state tolerances. The transducer shall be operated at steady-state power for 1 min. The power supply shall then be interrupted for an interval of 30 s. This cycle shall be repeated three times. Performance shall conform to the requirements of S3.8.5.15.

S3.11.2.15 Overpressure—Before the overpressure test, a reference measurement in accordance with S3.11.2.1 shall be made. The transducer shall successfully withstand pressure (differential pressure for transducer Type D) equal to 200 % of its upper range limit with a maximum pressure of 85 MPa (12 000 lb/in.²) for a period of $\frac{1}{2}$ h. At the end of this period, transducers shall be immediately subjected to a pressure equal to 7 kPa (1 lb/in.²) or 10 % of upper range limit, whichever is less, below atmospheric for an additional period of $\frac{1}{2}$ h. Within 10 min after release of this pressure, a reference measurement (see S3.11.2.1) shall be made for comparison. Performance shall conform to S3.8.5.16. For Type D only, if the line pressure rating exceeds 200 % of the maximum differential pressure range, the overpressure test shall be omitted and 0.5 % deviation shall be applied to the line pressure test (see S3.11.2.16).

S3.11.2.16 Line Pressure (for Transducer Type D Only)—The transducer shall successfully withstand the pressure rating, when applied to one pressure port with the other pressure port vented to the atmosphere for a period of 10 min. The preceding shall be repeated with the pressure applied to the opposite pressure port of the transducer. After each test, a reference measurement in accordance with S3.11.2.1 shall be made. Performance shall conform to S3.8.5.17.

S3.11.2.17 Pressure Cycling—Before performing the pressure cycling test, a reference measurement shall be made (see S3.11.2.1). The test shall be conducted on a suitable system by applying a periodic pressure change of not more than 20 % to not less than 80 % of upper range limit for a total of 260 000 cycles. The rate of cycling shall be within the range from 0.25 to 2 Hz. The transducer shall be energized throughout the test. After completion of the pressure cycling test, a reference measurement shall be made for comparison (see S3.11.2.1). Performance shall conform to S3.8.5.18.

S3.11.2.18 Insulation Resistance—The insulation resistance of the transducer shall be determined by applying 50 Vdc between electrical input and output circuits and between these circuits and ground. The relative humidity shall be $50 \pm 10\%$. The insulation resistance measurement shall be made immediately after a 2-min period of uninterrupted test voltage application. However, if the indication of insulation resistance

meets the specified limit (see S3.8.5.19) and is steady or increasing, the test may be terminated before the end of the two minute period.

S3.11.2.19 Vibration—The transducer shall be tested in accordance with Type I (environmental) vibration of MIL-STD-167-1. The following exceptions apply: the upper frequency shall be 175 Hz, the amplitude of vibration shall be in accordance with Table S3.2 for the variable frequency portion, and the vibration level shall be maintained for 2 min at each integral value of frequency. If no resonance frequencies are observed, the 2-h endurance test shall be conducted at 175 Hz. During the vibration test, a fluid pressure of $80 \pm 5\%$ of the transducer upper range limit shall be applied to the transducer. Transducer output during the test shall be monitored. Performance shall conform to S3.8.5.20.

S3.11.2.20 Shock—The shock tests shall be conducted in accordance with Grade A, Class 1, Type C using bulkhead mounting fixture 4-A of MIL-S-901. During the test, a fluid pressure (differential pressure for transducer Type D) of $80 \pm 5\%$ of the transducer upper range limit shall be applied to the transducer. The transducer output during the test shall be monitored. Before and after the shock test, reference measurements shall be made for comparison. Performance shall conform to S3.8.5.21.

S3.11.2.21 Burst Pressure—The transducer shall be subjected to a liquid pressure equal to 300 % of the upper range limit with a maximum pressure of 105 MPa (15 000 lb/in.²) applied to the transducer (simultaneously to both sides for transducer Type D) for a period of 10 min. The transducer shall conform to the requirements of S3.8.5.22. No performance test shall be required after the burst pressure test. A reference measurement (see S3.11.2.1) shall be recorded for information purposes.

S3.11.2.22 Short Circuit—An input pressure (differential pressure for transducer Type D) of $80 \pm 5\%$ of transducer upper range limit shall be applied to the transducer and maintained constant during the test. The transducer shall be de-energized. The electrical output terminals of the transducer shall be connected together with no load resistance. The transducer shall be energized for 5 min. Immediately following the 5-min period, the output terminals shall be unshorted. The transducer shall conform to the requirements of S3.8.5.23.

S3.11.2.23 Line Voltage Reversal—An input pressure (differential pressure for transducer Type D) of $80 \pm 5\%$ of

transducer upper range limit shall be applied to the transducer and maintained constant during the test. The +28-Vdc conductor from the power supply shall be connected to the negative terminal on the transducer terminal board. The –28-Vdc conductor from the power supply shall be connected to the positive terminal on the transducer terminal board. The transducer shall be energized for a period of 10 min and then disconnected. The power shall then be correctly connected (positive conductor to positive terminal and negative conductor to negative terminal). A reference measurement shall be made (see S3.12.2.1). The transducer shall conform to the requirements of S3.8.5.24.

S3.11.2.24 EMI Tests—The EMI tests shall be in accordance with the test methods specified in MIL-STD-461, with the modifications as specified in S3.8.5.25. Performance shall be as specified in S3.8.5.25.

S3.12 Inspection

S3.12.1 Classification of Inspections—The inspection requirements specified herein are classified as follows:

S3.12.1.1 First-article tests (see S3.12.3).

S3.12.1.2 Conformance tests (see S3.12.4).

S3.12.2 First-Article Tests—First-article tests shall be performed before production. First-article tests shall be performed on samples that have been produced with equipment and procedures normally used in production. First-article tests shall consist of the tests specified in Table S3.3. Failure of any pressure transducer to meet the requirements of this specification shall be cause for rejection.

S3.12.2.1 Order of First-Article Tests—With the exception of the electromagnetic interference emission and susceptibility test which may be conducted on separate transducers, the test specimens (transducers) shall be subjected to the tests specified in Table S3.3 in the order listed. Any deviation in the test order shall first be approved by the purchaser.

S3.12.3 Conformance Tests—Each pressure transducer in each lot offered for delivery shall be subjected to the tests listed

TABLE S3.2 Amplitudes of Vibration

Frequency Range, Hz	Table Amplitude	
	Exploratory	Variable Frequency
SI Units, mm		
5 to 20	0.255 ± 0.050	0.765 ± 0.150
21 to 50	0.105 ± 0.025	0.510 ± 0.100
51 to 100	0.0380 ± 0.0075	0.255 ± 0.050
101 to 175	0.0130 ± 0.0025	0.0380 ± 0.0075
Inch-Pound Units, in.		
5 to 20	0.010 ± 0.002	0.030 ± 0.006
21 to 50	0.004 ± 0.001	0.020 ± 0.004
51 to 100	0.0015 ± 0.0003	0.010 ± 0.002
101 to 175	0.0005 ± 0.0001	0.0015 ± 0.0003

TABLE S3.3 First-Article Tests

Test	Test Method	Requirement
Communications	S3.11.2.2	S3.8.5.1 and S3.8.5.2
Output	S3.11.2.3	S3.8.5.4
Warm-up time	S3.11.2.4	S3.8.5.5
Enclosure	S3.11.2.5	S3.8.5.6
Static error band and repeatability	S3.11.2.6	S3.8.5.3 and S3.8.5.7
Sensitivity factor	S3.11.2.7	S3.8.5.8
Stability and temperature	S3.11.2.8	S3.8.5.9
Ripple	S3.11.2.9	S3.8.5.10
Supply voltage (steady-state)	S3.11.2.10	S3.8.5.11
Common mode pressure (transducer Type D only)	S3.11.2.11	S3.8.5.12
Response	S3.11.2.12	S3.8.5.13
Supply voltage (transient)	S3.11.2.13	S3.8.5.14
Power interruption	S3.11.2.14	S3.8.5.15
Overpressure	S3.11.2.15	S3.8.5.16
Line pressure (transducer Type D only)	S3.11.2.16	S3.8.5.17
Pressure cycling	S3.11.2.17	S3.8.5.18
Insulation resistance	S3.11.2.18	S3.8.5.19
Vibration	S3.11.2.19	S3.8.5.20
Shock	S3.11.2.20	S3.8.5.21
Burst pressure	S3.11.2.21	S3.8.5.22
Short-circuit	S3.11.2.22	S3.8.5.23
Line voltage reversal	S3.11.2.23	S3.8.5.24
EMI	S3.11.2.24	S3.8.5.25

in Table S3.4 and shall be conducted in the order listed. Failure of any pressure transducer to meet the requirements of this specification shall be cause for rejection.

S3.12.4 General Examination—Each transducer shall be given a thorough examination to determine conformance to the requirements of this specification with respect to material, finish, workmanship, construction, assembly, dimensions, weight, and marking of identification. Examination shall be limited to the examinations that may be performed without disassembling the units. The manufacturer shall be responsible for ensuring that materials used are manufactured, examined, and tested in accordance with applicable approved industry standards.

S3.13 Certification

S3.13.1 The purchase order or contract should specify whether the purchaser shall be furnished certification that samples representing each lot have been either tested or inspected as directed in this specification and the requirements have been met. The purchase order or contract should specify when a report of the test results shall be furnished. Otherwise,

TABLE S3.4 Conformance Tests

Test	Test Method	Requirement
General examination	S3.12.5	S3.6 and S3.7
Output	S3.11.2.3	S3.8.5.4
Static error band and repeatability	S3.11.2.6	S3.8.5.3 and S3.8.5.7
Sensitivity factor	S3.11.2.7	S3.8.5.8
Insulation resistance	S3.11.2.18	S3.8.5.19

the purchase order or contract should specify that all test data remain on file for three years at the manufacturer's facility for review by the purchaser upon request.

S3.14 Product Marking

S3.14.1 Label Plates—A label plate with engraved or stamped markings shall be permanently affixed to the transducer. At a minimum, it shall contain the following:

S3.14.1.1 "PRESSURE TRANSDUCER" or "DIFFERENTIAL PRESSURE TRANSDUCER,"

S3.14.1.2 Manufacturer's name,

S3.14.1.3 National Stock Number (NSN), if available,

S3.14.1.4 Date of manufacture,

S3.14.1.5 Designation, and

S3.14.1.6 Pressure rating for Type D transducers.

S3.14.2 Transducers for use with Application F shall have "USE NO OIL FOR CALIBRATION" prominently marked on the body.

S3.14.3 The legend "DO NOT LUBRICATE" shall be prominently marked on the body.

S3.15 Packaging and Package Marking

S3.14.1 Packaging and package marking shall be in accordance with Section 15.

S3.16 Quality Assurance

S3.16.1 Quality System—A quality assurance system in accordance with ISO 9001 shall be maintained to control the quality of the product being supplied effectively, unless otherwise specified in the acquisition requirements (see S3.5.2).

S3.16.2 Warranty—Any special warranty requirements shall be specified in the acquisition requirements (see S3.5.2).

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