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An American National Standard

Standard Specification for Transducers, Pressure and Differential, Pressure, Electrical and Fiber-Optic[1]

This standard is issued under the fixed designation F2070; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

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

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

1.3 The values stated in SI units are to be regarded as standard. The values given in parentheses are mathematical conversions to inch-pound units that are provided for information only and are not considered standard. Where information is to be specified, it shall be stated in SI units.

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

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D3951 Practice for Commercial Packaging

2.2 *ANSI/ISA Standards:*[3]

ANSI/ISA S37.1 Electrical Transducer Nomenclature and Terminology

2.3 *ISO Standards:*[4]

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

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.

3.2 *Definitions:*

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

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

3.2.3 *ambient conditions, n*—conditions such as pressure and temperature of the medium surrounding the case of the transducer. **ANSI/ISA S37.1**

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

3.2.5 *calibration, n*—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**

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

3.2.7 *differential pressure, n*—the difference in pressure between two points of measurement. **ANSI/ISA S37.1**

3.2.8 *environmental conditions, n*—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**

3.2.9 *error, n*—the algebraic difference between the indicated value and the true value of the measurand. **ANSI/ISA S37.1**

[1] This specification is under the jurisdiction of ASTM Committee F25 on Ships and Marine Technology and is the direct responsibility of Subcommittee F25.10 on Electrical.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

[4] Available from International Organization for Standardization (ISO), ISO Central Secretariat, BIBC II, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland, http://www.iso.org.

3.2.10 *fiber-optic pressure transducer, n*—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.

3.2.11 *hysteresis, n*—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**

3.2.12 *insulation resistance, n*—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.

3.2.13 *line pressure, n*—the pressure relative to which a differential pressure transducer measures pressure. **ANSI/ISA S37.1**

3.2.14 *operating environmental conditions, n*— environmental conditions during exposure to which a transducer must perform in some specified manner. **ANSI/ISA S37.1**

3.2.15 *optical, adj*—involving the use of light-sensitive devices to acquire information.

3.2.16 *optical fiber, n*—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.

3.2.17 *optoelectronics module, n*—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.

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

3.2.19 *overpressure, n*—the maximum magnitude of measurand that can be applied to a transducer without causing a change in performance beyond the specified tolerance.

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

3.2.21 *pressure rating, n*—the maximum allowable applied pressure of a differential pressure transducer.

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

3.2.23 *range, n*—measurand values, over which a transducer is intended to measure, specified by their upper and lower limits. **ANSI/ISA S37.1**

3.2.24 *repeatability, n*—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**

3.2.25 *response, n*—the measured output of a transducer to a specified change in measurand.

3.2.26 *ripple, n*—the peak-to-peak ac component of the dc output.

3.2.27 *sensing element, n*—that part of the transducer that responds directly to the measurand. **ANSI/ISA S37.1**

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

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

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

3.2.31 *static error band, n*—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.

3.2.32 *transducer, n*—device that provides a usable output in response to a specified measurand. **ANSI/ISA S37.1**

3.2.33 *wetted parts, n*—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 pigtails 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 D3951.

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 (Specification F2070) 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 standard. The values given in parentheses are mathematical conversions to inch-pound units that are provided for information only and are not considered standard. Where information is to be specified, it shall be stated in SI units.

S1.2 Referenced Documents

S1.2.1 *ISO Standards:*[4]

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 Housing

S1.2.2 *NEMA Standards:*[5]

250 Enclosures for Electrical Equipment (1000 Volts Maximum)

S1.2.3 *Military Standards:*[6]

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

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

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

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

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

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

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:

[5] Available from National Electrical Manufacturers Association (NEMA), 1300 N. 17th St., Suite 900, Arlington, VA 22209, http://www.nema.org.

[6] Available from DLA Document Services, Building 4/D, 700 Robbins Ave., Philadelphia, PA 19111-5094, http://quicksearch.dla.mil.

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

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

4—0-12 V

5—0-3 mV

6—0-200 µV

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

N—M12 × 1.5 (7⁄16-20 UNF-2B) (see S1.7.5)

X—¼ 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.

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

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						

[A] For upper range values of 7000 kPa (1000 lb/in.^{2}) and above.

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).

TABLE S1.2 Material Versus Application

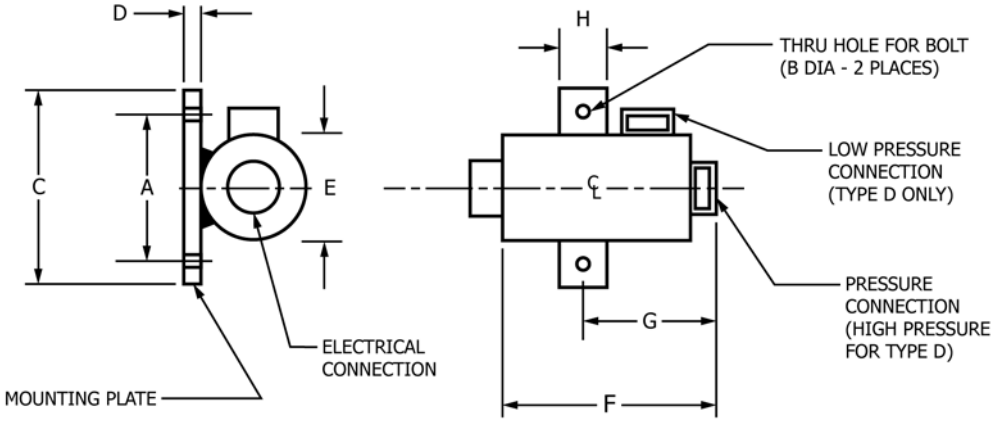
Sensing Element and Wetted Parts	Process Medium			
	Application Designation F	Application Designation S	Application Designation G	Application Designation X
CRES 304L, 316L, 321 & 347	X		X	
CRES 15-5 PH, 17-4 PH, and 17-7 PH	X			
Monel and K-Monel	X	X		X
Inconel 600 and 750	X	X		
Inconel 625 and 718	X	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

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 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.



Dimension	mm	in.
A	72	2.83
B	7.2 ± 0.15	0.281 ± 0.005
C	90 max	3.5 max
D	6.5 max	0.25 max
E	50.0 max	2.0 max
F	76.0 ≤ F ≤ 101.0	3.0 ≤ F ≤ 4.0
G	63.5	2.5
H	19.0 ≤ H ≤ 25.0	0.75 ≤ H ≤ 1.0

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

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 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 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 ± 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-μV 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 ±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 ±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:

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

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 ±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 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 ±0.5 % of the pretransient output.

(2) Frequency—During the frequency transient test, the transducer output shall remain within ±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 MΩ.

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 °C ± 2 °C.

S1.11.1.2 Relative humidity shall be ambient.

S1.11.2 *Tests*—Except for the warm-up time test (see S.1.11.2.3), 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 % ± 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 % ± 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 % ± 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 °C ± 2 °C, 25 °C ± 2 °C, and 65 °C ± 2 °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 ±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 % ± 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 ±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 ±2 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 °C ± 2 °C for at least 24 h.

(2) Increase the test temperature in steps of 10° each, at 30 min for each step, until +65 °C ± 2 °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 °C ± 2 °C is reached and hold at that temperature for at least 4 h. At each temperature plateau (0 °C, 65 °C, 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 ½ 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 ½ h. Within 10 min after release of this pressure, a reference measurement (see S.1.11.2.1) 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 S.1.11.2.14).

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 S.1.11.2.1). 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 Hz 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 S.1.11.2.1). 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 % ± 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

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