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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 F 2070; 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 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 Packaging[2]

2.2 *ANSI/ISA Standards:*

ANSI/ISA S37.1 Electrical Transducer Nomenclature and Terminology[3]

2.3 *ISO Standard:*

ISO 9001 Quality System—Model for Quality Assurance in Design/Development, Production, Installation, and Servicing[4]

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.

[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] *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, Geneve, 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 measurand 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 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.