ASME B40.100-2022
(Revision of ASME B40.100-2013)

Pressure Gauges and Gauge Attachments

AN AMERICAN NATIONAL STANDARD

The American Society of Mechanical Engineers

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The American Society of Mechanical Engineers
Two Park Avenue • New York, NY • 10016 USA

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CONTENTS

Tables

FOREWORD

ASME Standards Committee B40 is comprised of a group of volunteers representing pressure gauge users, manufacturers, governmental agencies, testing laboratories, and other standard-producing bodies. All are convinced that national standards such as this serve not only to provide product performance and configuration guidelines but also to inform and assist both those who specify and the users regarding the science of pressure gauge production, application, and use. The standards are vehicles by which the Committee as a body can transmit to users the benefits of their combined knowledge and experience as regards the proper and safe use of pressure gauges.

The use of this Standard is entirely voluntary and shall in no way preclude the manufacturer or use of products that do not conform. Neither ASME nor the B40 Committee assumes responsibility for the effects of observance or nonobservance of recommendations made herein.

The 2005 edition, which was approved on September 19, 2005, was issued to include Nonmandatory Appendix C on Supplemental Requirements to B40.100.

The 2013 revision, which was approved on June 18, 2013, was issued to clarify wording in the B40.1 body document as well as in Nonmandatory Appendix C, now designated as Mandatory Appendix III. Nonmandatory Appendix A was also rewritten to include new gauge performance criteria, and it was designated as Mandatory Appendix I. Nonmandatory Appendix B was designated as Mandatory Appendix II.

The 2022 revision was issued to consolidate the previously combined ASME B40 standards: ASME B40.1, ASME B40.2, ASME B40.5, and ASME B40.6, now designated as Sections 1 through 4, respectively. ASME B40.7 has been removed from this Standard and will be revised and incorporated into ASME B40.300. All appendices are now grouped at the end of this Standard. Definitions and references have been consolidated and moved to the beginning of the standard along with a comprehensive scope of the overall standard. Following approval by the ASME B40 Standards Committee, ASME B40.100-2022 was approved by the American National Standards Institute on June 6, 2022.

ASME B40 COMMITTEE
Specifications for Pressure and Vacuum Gauges

(The following is the roster of the Committee at the time of approval of this Standard.)

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CORRESPONDENCE WITH THE B40 COMMITTEE

General. ASME codes and standards are developed and maintained by committees with the intent to represent the consensus of concerned interests. Users of ASME codes and standards may correspond with the committees to propose revisions or cases, report errata, or request interpretations. Correspondence for this Standard should be sent to the staff secretary noted on the committee's web page, accessible at https://go.asme.org/B40committee.

Revisions and Errata. The committee processes revisions to this Standard on a periodic basis to incorporate changes that appear necessary or desirable as demonstrated by the experience gained from the application of the Standard. Approved revisions will be published in the next edition of the Standard.

In addition, the committee may post errata on the committee web page. Errata become effective on the date posted. Users can register on the committee web page to receive e-mail notifications of posted errata.

This Standard is always open for comment, and the committee welcomes proposals for revisions. Such proposals should be as specific as possible, citing the paragraph number(s), the proposed wording, and a detailed description of the reasons for the proposal, including any pertinent background information and supporting documentation.

Cases

(a) The most common applications for cases are

(1) to permit early implementation of a revision based on an urgent need

(2) to provide alternative requirements

(3) to allow users to gain experience with alternative or potential additional requirements prior to incorporation directly into the Standard

(4) to permit the use of a new material or process

(b) Users are cautioned that not all jurisdictions or owners automatically accept cases. Cases are not to be considered as approving, recommending, certifying, or endorsing any proprietary or specific design, or as limiting in any way the freedom of manufacturers, constructors, or owners to choose any method of design or any form of construction that conforms to the Standard.

(c) A proposed case shall be written as a question and reply in the same format as existing cases. The proposal shall also include the following information:

(1) a statement of need and background information

(2) the urgency of the case (e.g., the case concerns a project that is underway or imminent)

(3) the Standard and the paragraph, figure, or table number(s)

(4) the edition(s) of the Standard to which the proposed case applies

(d) A case is effective for use when the public review process has been completed and it is approved by the cognizant supervisory board. Approved cases are posted on the committee web page.

Interpretations. The committee does not issue interpretations for this Standard.

Committee Meetings. The B40 Standards Committee regularly holds meetings that are open to the public. Persons wishing to attend any meeting should contact the secretary of the committee. Information on future committee meetings can be found on the committee web page at https://go.asme.org/B40committee.

Section 1
Scope, References, Definitions

1-1 SCOPE

This Standard covers analog, dial-type gauges, which, using elastic elements, mechanically sense pressure and indicate it by means of a pointer moving over a graduated scale.

It also includes the following attachments installed between the pressure source and gauge(s): diaphragm seals, snubbers, and pressure limiting valves.

This Standard does not include gauges of special configuration designed for specific applications, edge reading, deadweight or piston gauges, other gauges not using an elastic element to sense pressure, diaphragm actuated pressure instruments that employ mechanical linkages to transmit the applied pressure, other attachments such as siphons, electric contacts, and gauge isolation valves or other separation devices designed to protect the pressure element assembly.

1-2 REFERENCES

Other standards and specifications relating to pressure gauges and their performance requirements follow. The edition bearing the latest date of issuance shall be used.

3-A 63-04, Sanitary Fittings
Publisher: 3-A Sanitary Standards, Inc., 6888 Elm Street, Suite 2D, McLean, VA 22101 (www.3-a.org)

ANSI Z26.1, Safety Glazing Materials for Glazing Motor Vehicles and Motor Vehicle Equipment Operating on Land Highways — Safety Standard
Publisher: SAE International, 400 Commonwealth Drive, Warrendale, PA 15096 (www.sae.org)

ASME B1.13M, Metric Screw Threads: M Profile
ASME B1.20.1, Pipe Threads, General Purpose (Inch)
ASME B1.20.3, Dryseal Pipe Threads (Inch)
ASME B16.5, Pipe Flanges and Flanged Fittings: NPS ½ Through NPS 24, Metric/Inch Standard
ASME B16.9, Factory-Made Wrought Buttwelding Fittings
ASME B16.11, Forged Fittings, Socket-Welding and Threaded
ASME B31.3, Process Piping
ASME BPE, Bioprocessing Equipment
ASME BPVC VIII-1, Rules for Construction of Pressure Vessels Division 1
ASME PTC 19.2, Pressure Measurement: Instruments and Apparatus Supplement
Publisher: The American Society of Mechanical Engineers (ASME), Two Park Avenue, New York, NY 10016-5990 (www.asme.org)

ASTM C1048, Standard Specification for Heat-Strengthened and Fully Tempered Flat Glass
ASTM C1422, Standard Specification for Chemically Strengthened Flat Glass
ASTM G93, Standard Guide for Cleanliness Levels and Cleaning Methods for Materials and Equipment Used in Oxygen-Enriched Environments
Publisher: American Society for Testing and Materials (ASTM International), 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959

CGA E-4, Standard for Gas Pressure Regulators
CGA G-4.1, Cleaning of Equipment for Oxygen Service
Publisher: Compressed Gas Association (CGA), 14501 George Carter Way, Suite 103, Chantilly, VA 20151 (www.cganet.com)

EN 837-1, Pressure Gauges Part 1: Bourdon Tube Pressure Gauge — Dimensions, Metrology, Requirements, and Testing
Publisher: European Committee for Standardization (CEN), Avenue Marnix 17, B-1000, Brussels, Belgium (www.cen.eu)

IEC 60529, Degrees of Protection Provided by Enclosure (IP Code)
Publisher: International Electrotechnical Commission (IEC), 3, rue de Varembé, Case Postale 131, CH-1211, Genèva 20, Switzerland/Suisse (www.iec.ch)

ISA RP2.1, Manometer Tables
Publisher: International Society of Automation (ISA), 67 T.W. Alexander Drive, P.O. Box 12277, Research Triangle Park, NC 27709 (www.isa.org)

ISO 15001, Anaesthetic and respiratory equipment — Compatibility with oxygen
Publisher: International Organization for Standardization (ISO), Central Secretariat, Chemin de Blandonnet 8, Case Postale 401, 1214 Vernier, Geneva, Switzerland (www.iso.org)

FED-STD-H28, Screw-Thread Standards for Federal Services. Defense Industrial Supply Center, 700 Robbins Avenue, Philadelphia, PA 19111-5096

NBS Monograph No. 8, Mercury Barometers and Manometers, National Bureau of Standards, Department of Commerce

NBS Monograph No. 65, Reduction of Data for Piston Gauge Pressure Measurement, National Bureau of Standards, Department of Commerce

Publisher: Federal specification available from: Superintendent of Documents, U.S. Government Publishing Office (GPO), 732 N. Capitol Street, NW, Washington, DC 20401 (www.gpo.gov)

NIST.gov, 2017, "Non-NIST International Organizations and Programs" from https://www.nist.gov/iaao/non-nist-international-organizations-and-programs

SAE J906, Automotive Safety Glazing Manual

Publisher: SAE International, 400 Commonwealth Drive, Warrendale, PA 15096 (www.sae.org)

UL 404, Standard for Gauges, Indicating Pressure, for Compressed Gas Service. Underwriters Laboratories Inc. (UL), 333 Pfingsten Road, Northbrook, IL 60062-2096 (www.ul.com)

Publisher: Underwriters Laboratories Inc. (UL), 333 Pfingsten Road, Northbrook, IL 60062-2096 (www.ul.com)

1-3 DEFINITIONS

The following definitions are provided to ensure understanding of select terms used in this Standard:

absolute pressure: see *pressure, absolute*.

absolute pressure gauge: see *gauge, absolute pressure*.

acceleration of gravity: the acceleration of a body in free fall under the influence of earth's gravity expressed as the rate of increase of velocity per unit of time and assigned the standard value of 980.665 centimeters per second per second — also called *g*.

accuracy: the conformity of a gauge indication to an accepted standard or true value. Accuracy is the difference (error) between the true value and the gauge indication expressed as a percent of the gauge span. It is the combined effects of method, observer, apparatus, and environment. Accuracy error includes hysteresis and repeatability errors, but not friction error (mechanical gauges only, see *friction error*). It is determined under specific conditions (see Table 2-2.4-1).

adjustment: the process of graduating the pressure scale or adjusting the mechanism to cause the gauge to indicate within specified accuracy limits.

ambient pressure: see *pressure, ambient*.

baffle wall: in a pressure gauge, the wall between the Bourdon tube and dial. The baffle wall should have a minimal number of openings. These openings shall be less than 5% of the area of the baffle wall.

bar: a metric pressure unit equal to approximately 14.50 psi.

bellows: a thin-walled, convoluted elastic pressure-sensing element (see Figure 1-3-1).

Bourdon tube: a tubular elastic pressure-sensing element. May have a "C," helical, spiral, or other form (see Figure 1-3-1).

brazing: a metal joining process wherein coalescence is produced by use of nonferrous filler metal having a melting point above 425°C (800°F) but lower than that of the base metals joined.

calibration: refers to either calibration adjustment or calibration verification, but not specifically to one or the other.

calibration adjustment: the adjustments made on a gauge so it indicates within the specified accuracy limits.

calibration verification: the checking of a gauge by comparison with a given standard to determine the indication error at specified points of the scale.

capsule: see *diaphragm capsule*.

case: the housing or container that supports, protects, and surrounds the internal pressure system and other components.

case, liquid filled: a case that is filled with a liquid such as glycerin or silicone fluid to at least 75% of its total internal volume. Liquid-filled cases may be either open front or solid front types. The purpose of this construction is to exclude ambient corrosives or protect the internal components from damage caused by severe vibration or pulsation.

case, open front with case pressure relief: a case with a pressure relief device or openings and no partition between the pressure element and the window [see Figure 1-3-2, illustration (a)]. An alternate construction is a plastic window especially designed to relieve internal case pressure.

case, open front without case pressure relief: a case having no partition between the pressure element and the window, and no pressure relief devices or openings [see Figure 1-3-2, illustration (a)].

case, pressure tight: a case capable of maintaining a pressure differential between the inside and the outside of the case.

case, sealed: a case that is sealed to exclude ambient corrosives.

case, solid front with pressure relief back: a case having a partition with minimum opening(s) between the pressure element and the window, and a pressure-relieving back.

Figure 1-3-1
Elastic Elements

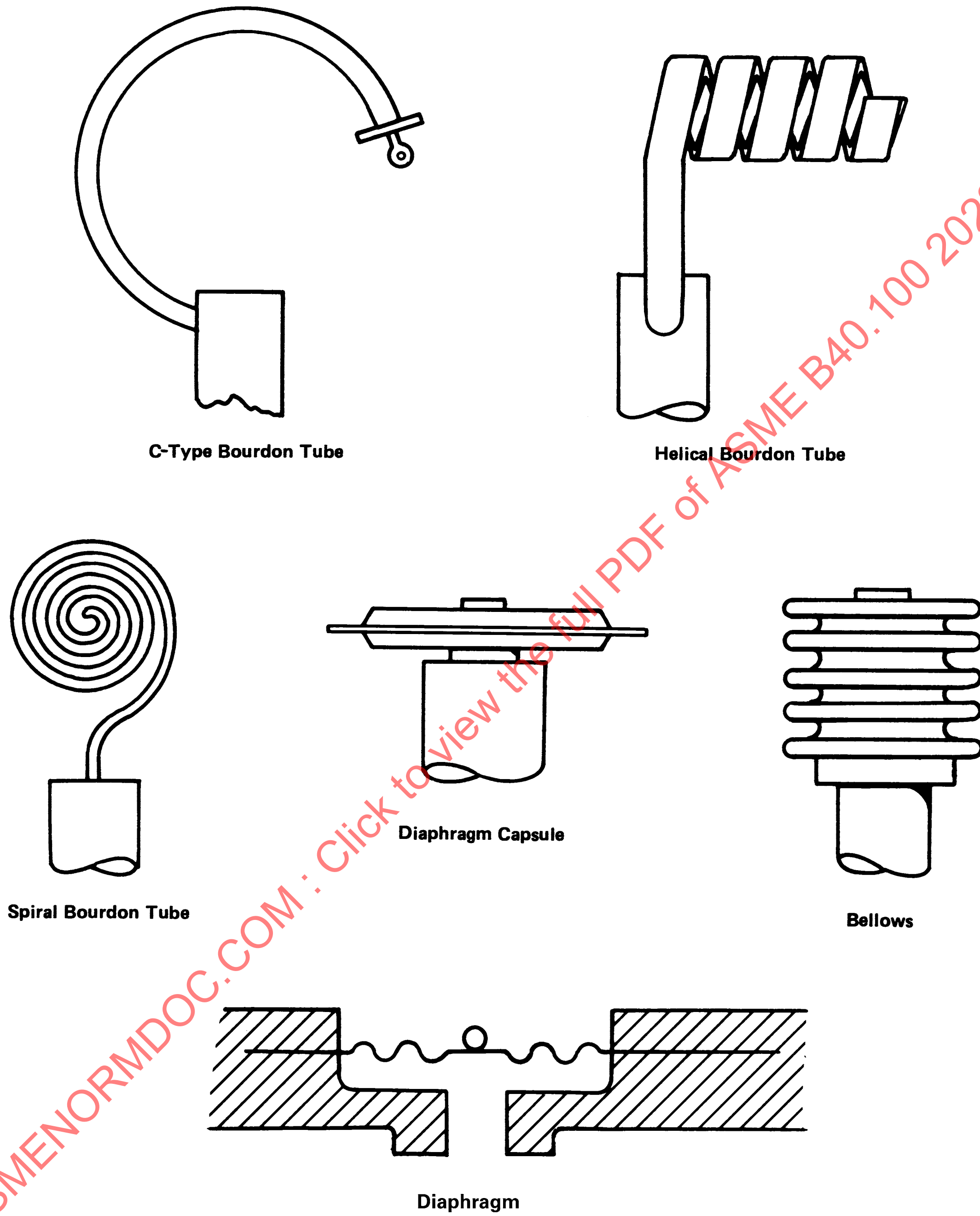
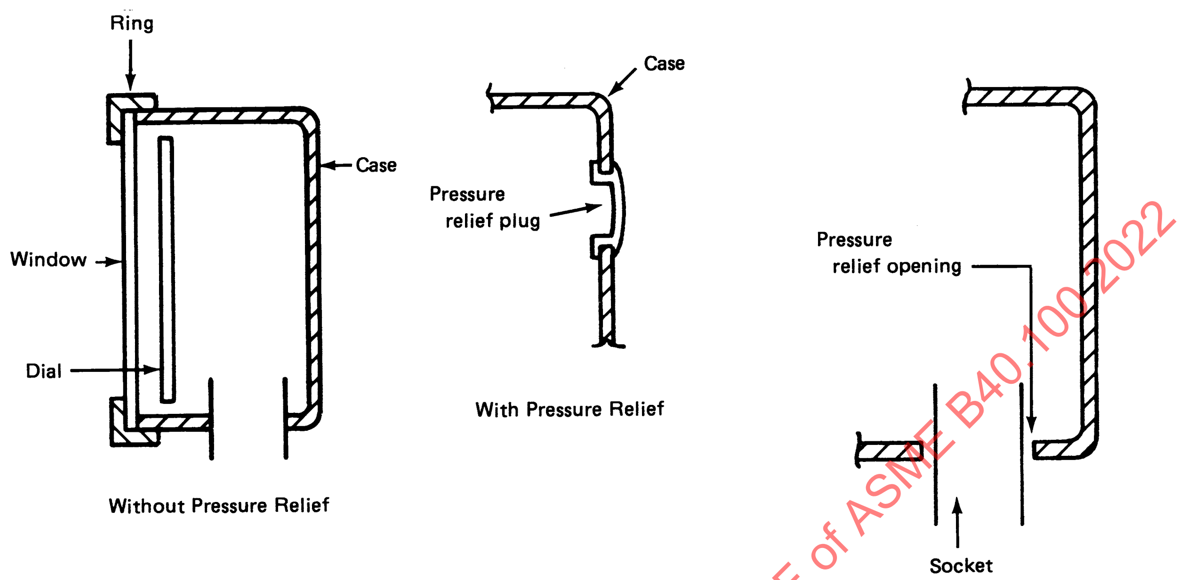
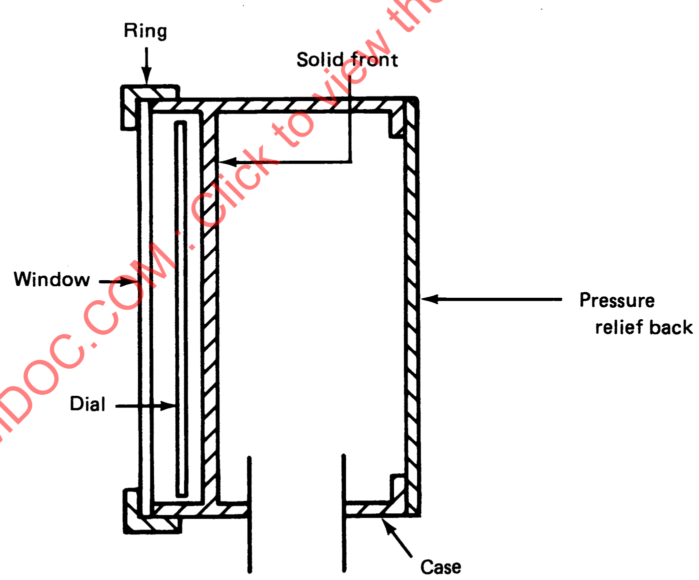


Figure 1-3-2
Cases



(a) Open Front



(b) Solid Front With Pressure Relief Back

The partition may be an integral part of the case [see Figure 1-3-2, illustration (b)].

coefficient of thermal expansion: volumetric change per unit of temperature change.

cold flow: a physical change in the shape of a part at room temperature due to applied forces.

compressibility: the property of a substance capable of being reduced in volume by application of pressure.

connection: see *mounting*.

correction: the quantity that is algebraically added to an indicated value to obtain the true value. The algebraic sign of the correction is opposite to the sign of the error.

dial: the gauge component that contains the scale artwork and nomenclature.

diaphragm: an elastic element in the form of a single flat or convoluted plate that deforms to provide displacement in response to a change in pressure differential across the plate (see Figure 1-3-1).

diaphragm capsule: an elastic element comprised of two convoluted diaphragm plates jointed to form a capsule or pressure container that expands and contracts in response to a change in pressure differential across the plates. Diaphragm capsule elements may have one or more capsules to provide appropriate displacement (see Figure 1-3-1).

diaphragm seal: a diaphragm seal is a mechanical separator using a diaphragm or bladder together with a fill fluid to transmit pressure from the medium to the pressure element assembly. Other terms used are chemical seal and gauge isolator. This device is intended to keep the medium out of the pressure element assembly. The purpose of this device is to prevent damage from corrosion or clogging, to maintain sanitary requirements of the medium, or to reduce the process temperature to which the pressure element assembly is exposed.

elastic element: the elastic component of the pressure element assembly that moves in response to pressure changes. It may be a Bourdon tube, bellows, diaphragm, or other type of member (see Figure 1-3-1).

end piece: see *tip*.

environment: see *environmental conditions*.

environmental conditions: the conditions external to the gauge, including weather, temperature, humidity, salt spray, vibration, corrosive atmosphere, and other similar conditions that could affect the performance of the gauge.

error: the difference between the indicated value and the true value of the variable being measured. A positive error denotes that the indicated value is greater than the true value (see also *correction*).

error, fatigue: the change of pressure indication that results from repeated applications of stress (pressure cycles). It is expressed as a percentage of span, number of cycles, and minimum and maximum values of pressure cycles.

explosive failure: elastic element failure caused by the release of explosive energy generated by a chemical reaction inside the element.

fatigue failure: elastic element failure resulting from repeated applications of stress.

fiber: any nonmetallic, flexible, threadlike contaminant with a length-to-diameter ratio of at least 10:1.

fill fluid:

(a) in a liquid-filled gauge, the case fill liquid used in a sealed pressure gauge

(b) in a diaphragm seal assembly, the liquid used to fill that portion of the pressure-sensing system between the diaphragm and the pressure-sensing element

flow through seal: see *in-line seal*.

fluctuation: a nonperiodic surge of pressure.

freeze point: the temperature at which a liquid and a solid may be in equilibrium.

friction error: applicable to mechanical gauges only, it represents the contribution to the accuracy error of the gauge resulting from the mechanical friction of the internal components of the gauge.

full scale pressure: see *pressure, full scale*.

gasket: a means used to seal joints exposed to the process medium or fill fluid.

gauge, absolute pressure: a gauge that indicates absolute pressure.

gauge, compound: a gauge that indicates both positive and negative gauge pressure.

gauge, differential: a gauge having two pressure connections and a pointer, which indicates the difference between two applied pressures.

gauge, duplex: a gauge having two pressure connections and two pointers, which indicate two applied pressures simultaneously.

head effect: a change of an instrument's indication or output when the elevation of the instrument is above or below the seal.

Hg: mercury.

in. H_2O*:* inches of water (ISA RP2.1); a unit of pressure measurement. 1 in. H_2O (20°C) is equal to 1 in. of water at 20°C (68°F) and 980.665 cm/sec^2 gravity (0.036063 psi).

hysteresis: a retardation of an effect when the forces acting upon a body are changed (as if from viscosity or internal friction).

hysteresis error: the difference between increasing pressure and decreasing pressure readings at any point on the scale obtained during a pressure cycle after friction errors have been eliminated by tapping (Figure 2-5.2.4.3-1).

in. Hg: inches of mercury. 1 in. Hg is equal to 1 in. of mercury at 32°F (0°C) (0.4911 psi).

in-line seal: a diaphragm seal installed directly in the process flow line.

internal stop: see *stop, internal*.

kg/cm^2: kilograms per square centimeter. 1 kg/cm^2 is equal to kilogram force per square centimeter.

kPa: kilopascal. 1 kPa is equal to 1,000 Pa.

lens: see *window*.

life, fatigue: the number of pressure cycles beyond which leakage of the pressure element assembly may occur. Accuracy may be degraded even if leakage has not occurred (see *error, fatigue*).

link: the component that connects the elastic element to the movement.

liquid column: a pressure-measuring device employing a column and reservoir of liquid (oil, water, mercury, or other liquid). Pressure is indicated by the height of the liquid column, measured at the meniscus.

liquid-filled case: a case that is filled with a liquid such as glycerin or silicone fluid to at least 75% of its total internal volume. Liquid-filled cases may be either open-front or solid-front types. The purpose of this construction is to exclude ambient corrosives or protect the internals from damage caused by severe vibration or pulsation.

liquid-filled gauge: a gauge in which the case is filled with a liquid.

liquid-level gauge: a gauge with a dial graduated in units of head heights, such as feet (meters) of water.

long-term stability (closed system): for diaphragm seals, the resistance to decomposition, physical disintegration, or other chemical change over a long period of time.

lower housing: the diaphragm seal component connected to the process line and wetted by the process fluid.

manometer: see ASME PTC 19.2.

medium: the process fluid (gas or liquid), also known as media.

NOTE: the terms "media" and "medium" are used in this Standard in place of the term "fluid" insofar as the process fluid may be a nonhomogeneous fluid (e.g., one that contains solid particulate) in certain applications and, therefore, isn't strictly a fluid. Therefore, the terms "media" and "medium" indicate a gas, liquid, or non-homogeneous process fluid.

mid-housing (cleanout ring): the diaphragm seal component located between the upper and lower housing.

mirror, dial: a dial with a reflector band adjacent to the scale for the purpose of reducing reading-parallax errors.

mounting: the means by which the gauge or diaphragm seal is installed or supported.

mounting, flush: a gauge provided with supporting means on the case so that it may be set through a hole in a panel. When installed, the dial is approximately flush with the panel (see Figure 1-3-3).

mounting, gauge: see *mounting*.

mounting, stem socket: a gauge supported by attachment at the stem (socket) pressure connection (see Figure 1-3-3).

mounting, surface (wall): a gauge whose case can be mounted to a wall or flat surface (see Figure 1-3-3).

NIST: National Institute of Standards and Technology

nomenclature, dial: may include, but is not restricted to, the following:

(a) materials of wetted parts
(b) restricted application notices such as USE NO OIL
(c) presence of special features such as an internal stop

normal operating conditions: the environmental conditions in which the stated accuracy applies.

NPT: American Standard taper pipe threads. Defined by ASME B1.20.1.

operating pressure: see *pressure, operating*.

overpressure: the application of a pressure beyond the full-scale pressure.

overpressure failure: elastic element failure caused by the application of internal pressure (positive or negative) in excess of the rated pressure of the element.

Pa: see *Pascal*.

particle: any solid contaminant other than fiber.

partition: see *baffle wall*.

Pascal: unit of pressure measurement. 1 Pa is equal to 1 N/m^2.

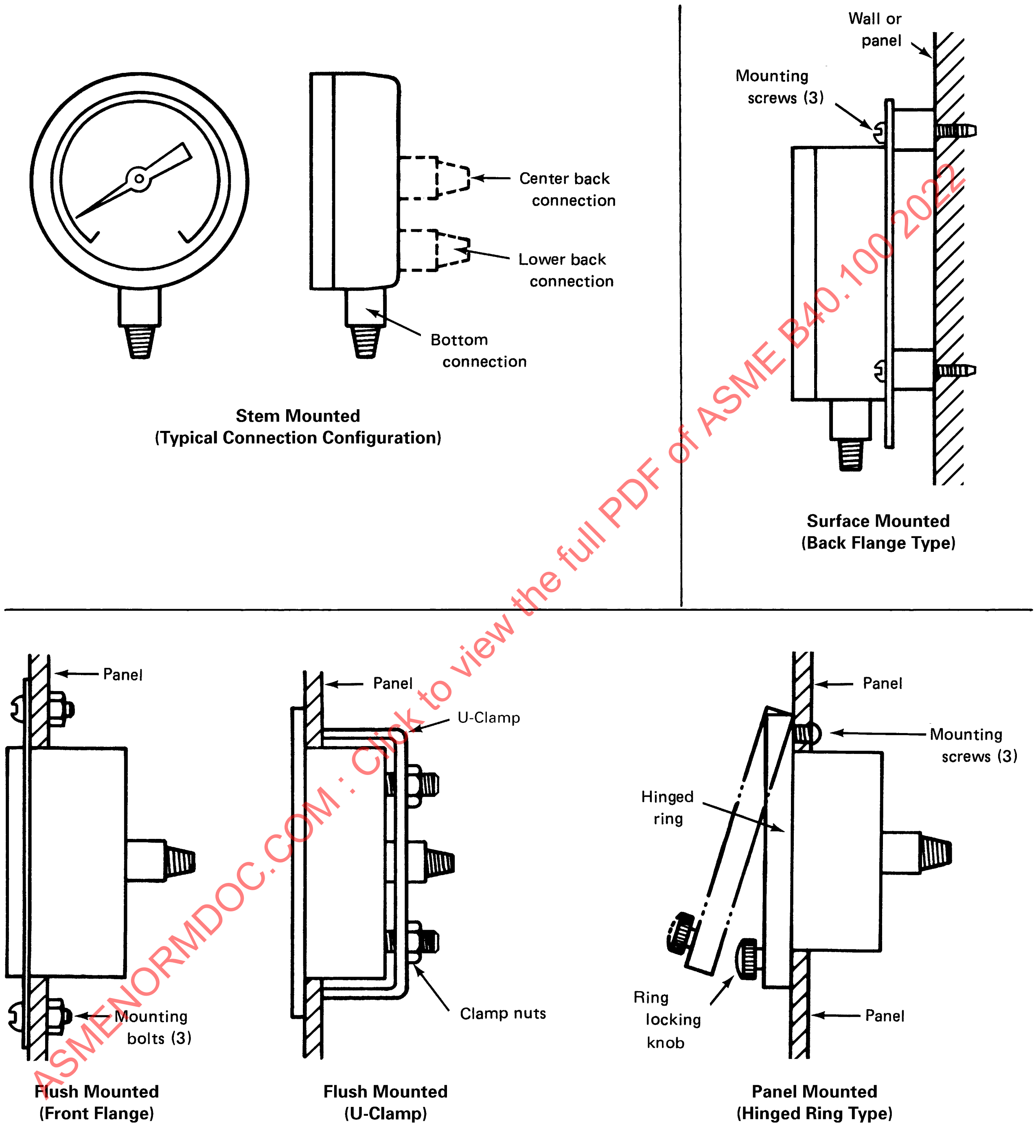
piston gauge: a device that indicates the presence of a predetermined pressure by means of weights loaded on an effective area such as a floating piston or a ball.

plug, pressure relief: a plug inserted in the gauge case wall that, in the event of an element leak, vents, minimizing case pressure buildup.

pointer: the component that, in conjunction with the dial, indicates pressure.

pointer adjustment: a means of causing a change in indication. The change is approximately equal over the entire scale. Some examples of this type of adjustment are adjustable pointers, rotatable dials, rotatable movements, and other similar items. This adjustment, if provided, is generally accessible to the gauge user.

Figure 1-3-3
Cases/Mounting



GENERAL NOTES:
(a) These diagrams are schematic and not intended to show design details.
(b) Surface and flush-mounted cases may also be stem mounted.

position error: the change of pressure indication that results when the gauge is placed in a position different from that in which it was calibrated.

positive pressure: see *pressure, positive*.

pressure, absolute: a pressure using zero absolute pressure as datum (see Figure 2-1-1).

pressure, ambient: the pressure surrounding the gauge, usually atmospheric (barometric) pressure (see Figure 2-1-1).

pressure, burst: see *pressure, rupture*.

pressure, closing: in a pressure limiter valve, the system pressure at which the sealing mechanism closes, isolating the pressure-sensing instrument from rising system pressure.

pressure, differential: the difference between two pressures (see Figure 2-1-1).

pressure, full scale: the highest numerically defined graduation on the unretarded portion of the scale.

pressure, gauge: a positive pressure (greater than ambient) or negative pressure (less than ambient) using ambient pressure as datum (see Figure 2-1-1).

pressure, maximum inlet: the maximum pressure that can be applied to the inlet port of a pressure limiter valve continually or repeatedly without degradation in the performance of the valve.

pressure, maximum working: maximum inlet pressure; see *pressure, maximum inlet*.

pressure, negative (vacuum): gauge pressure less than ambient pressure using ambient pressure as datum (see Figure 2-1-1).

pressure, operating: the pressure at which a gauge is normally operated.

pressure, over-range: for pressure limiter valves, the maximum pressure differential between inlet and outlet ports for a given closing pressure. This pressure may be continuously or repeatedly applied without degradation in performance. It may be expressed as a pressure or as a percentage of the closing pressure above the closing pressure.

pressure, positive: gauge pressure greater than ambient pressure (see Figure 2-1-1).

pressure, process: the pressure of the process medium at the pressure connection of the sockets.

pressure, proof: the maximum pressure a gauge can withstand without plastic deformation of the pressure element. Proof pressure may be a semidestructive test and should not be conducted repeatedly on the same gauge. It may be expressed as a pressure or as a percentage of full scale.

pressure, rated: full scale pressure unless otherwise specified.

pressure, reopening: for pressure limiter valves, the system pressure at which a closed sealing mechanism reopens, generally expressed as a percentage of closing pressure.

pressure, rupture: for pressure gauges and diaphragm seals, the maximum pressure above which the pressure element assembly may no longer hold pressure.

pressure, set: for pressure limiter valves, closing pressure; see *pressure, closing*.

pressure, system: the pressure of the process medium at the inlet pressure connection.

pressure, variable: pressure that increases or decreases, or both, at a rate greater than that allowed for steady pressure; may include high pressure, short duration impulses (pressure spikes).

pressure element: the assembly, including the elastic element, that converts a pressure change into motion. It may also include a stem, tip, restrictor, and other components (see Figure 2-1-2).

pressure gauge: a device that senses and indicates pressure using ambient pressure as datum.

pressure rating: the maximum operating pressure.

pressure relief plug: a plug inserted in the gauge case wall that, in the event of an element leak, vents, minimizing case pressure buildup.

pressure-sensing instrument: in a system with a pressure-limiting valve, the instrument being protected by the pressure limiter valve.

process connection: a method for attaching or installing a diaphragm seal to a process line, tank, vessel, etc.

psi: pounds per square inch; a unit of pressure measurement. 1 psi = 1 pound force per square inch gauge pressure.

psia: 1 psia = 1 pound force per square inch absolute pressure; see *psi*.

psid: 1 psid = 1 pound force per square inch differential pressure; see *psi*.

pulsation: a periodic surge of the pressure source.

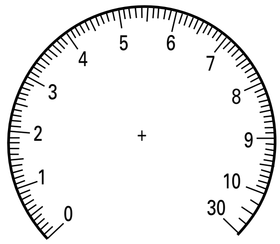
range: the high and low limits of the scale (including retarded portions) expressed in the sequences and units in which they occur. For example: 0/100 kPa, 200/500 psi, 30 in. Hg vac/30 psi.

range spring: in a pressure-limiting valve, the spring against which the pressure-sensing element works. Changing the load on the range spring changes the closing pressure.

rate of pressure change: pressure change per time interval.

readability: the uncertainty inherent in the observer's ability to determine the indicated pressure value. Factors that may affect readability include distance between observer and scale, and illumination. For

Figure 1-3-4
Example of a Retard Gauge



GENERAL NOTE: Scale shown is retarded from 10 to 30.

mechanical gauges, additional factors include length of scale, graduation configuration and spacing, pointer design and width, parallax, stability of pointer, pointer and scale colors, and the liquid level line in liquid-filled gauges.

receiver gauge: a gauge designed to indicate the output signal from a pneumatic transmitter. It is calibrated in terms of the transmitter output. The dial may be graduated in units of pressure, temperature, flow, or other measurements corresponding to the transmitter input.

refrigerant gauge: a gauge with a dial graduated in units of pressure and equivalent saturation temperature for refrigerants other than ammonia.

reinforcing rings: in a diaphragm seal: rings that support clamping forces on nonmetallic lower housings.

repeatability: the maximum difference between any two or more consecutive indications for the same applied pressure under the same operating conditions, approaching from the same direction, after lightly tapping the gauge. It is usually expressed as a percentage of span.

repeatability of closing pressure: for pressure-limiter valves, the maximum difference between several consecutive closing pressures for the same applied rate of pressure change under the same operating conditions. It is usually expressed as a percentage of closing pressure.

resonance: the condition in which an object or system is subjected to an oscillating force with a frequency near its own natural frequency. For purposes of this Standard, the frequency with the highest amplitude, as discovered through a frequency scan, is considered the primary resonant frequency; however, additional (lesser) resonant frequencies may also exist and should be considered by the manufacturer.

response time: the time required for a change in system pressure to be indicated by the instrument.

restrictor: the device that restricts fluid flow between the pressure source and the pressure element. It is used to reduce the effect of pressure fluctuations or to control flow from a pressure element that has failed in service, or both. It may be integrally mounted or separate from the gauge.

retard gauge: a gauge having a scale that is compressed at one or both ends. One example of the many different types in common use is shown in Figure 1-3-4.

ring: the component that secures the window to the case. Ring configurations will vary for design and aesthetic reasons.

ring, bayonet: see *ring, cam*.

ring, cam: a ring similar to a threaded ring except that the threads are replaced by a cam arrangement.

ring, friction: a ring retained by means of an interference or friction fit between it and the case.

ring, hinged: a ring retained by a hinge-type device and a single retaining screw.

ring, slip: a ring similar to the friction ring except that it has a clearance fit with the case and is secured by screws.

ring, snap: a ring that snaps into a groove on the case.

ring, threaded: a ring having threads that match threads on the case.

sanitary seal: a quick disconnect type of diaphragm seal, where the upper and lower housings are held together by a unique clamp, permitting ease of dismantling and cleaning.

scale: markings on the dial, consisting of graduations, related numerals, and units of measure.

sealed case: a case that is sealed to exclude ambient corrosives.

service temperature range: the high and low temperatures between which the fill fluid will remain serviceable.

set point: for pressure limiter valves, closing pressure; see *pressure, closing*.

shock (impact) resistance: the maximum deceleration a gauge can withstand without damage or evidence of a change in accuracy of more than a specified value. It is expressed in g's (acceleration of gravity), time duration (10% to 90% of the leading edge of the shock pulse), and number of impacts.

significant surface: see *surface, wetted*.

silver brazing: brazing using a nonferrous filler metal containing silver.

single gauge: a gauge having one pressure connection and one pointer, which indicates one applied pressure.

siphon: an attachment device intended to provide, in effect, a heat exchanger where vapors can condense. Siphons are most often used when measuring steam pressure.

size, gauge: the nominal diameter of the gauge, which can be expressed as the approximate inside or outside of diameter of the case size depending on the type of gauge (see Figure 2-2.3.1.5-1).

slip ring: see *ring, slip*.

snap ring: see *ring, snap*.

snubber: a surge-dampening device that is designed to minimize the effect of pressure spikes and surges on instruments while allowing changes in system pressure and low frequency pulsations to be transmitted to the instrument.

socket: the main supporting component of the pressure element assembly to which the elastic element is attached. It may include the pressure connection and mounting for the movement and case.

soft soldering: see *soldering*.

soldering (soft soldering): a metal-joining process wherein coalescence is produced by heating to a suitable temperature and by using a nonferrous alloy fusible at temperatures below 425°C (800°F) and having a melting point below that of the base metals being joined.

solid front: in a pressure gauge, the partition between the pressure element and the window (see *baffle wall*).

span: the algebraic difference between the limits of the unretarded portion of the scale.

span adjustment: a means of causing a change in the angle of pointer rotation for a given change in pressure. This adjustment is not generally accessible to the gauge user.

span, compound gauge: see *span*.

span, suppressed scale: see *span*.

specific gravity: the ratio of a fluid's density to the density of water at 4°C (39.2°F).

specific service gauge: gauge designed for a specific service, such as indicating the pressure of explosive, corrosive, or viscous media.

spike: a short duration, high amplitude sudden rise or drop in system pressure.

spontaneous explosive failure: see *explosive failure*.

spontaneous ignition temperature: the temperature at which ignition can occur resulting from the generation of heat that cannot be readily dissipated.

standard: see *standard, calibration*.

standard, calibration: a pressure instrument used to determine the accuracy of a gauge (see ASME PTC 19.2).

standard, transfer: see ASME PTC 19.2.

standard, working: see ASME PTC 19.2.

steady pressure: pressure that increases or decreases, or both, at a rate less than or equal to that allowed for steady pressure.

stem (socket): see *socket*.

stop: the component that limits the motion of the pointer (see *stop, internal*, and *stop pin*).

stop, internal: a stop designed to restrain the pressure element motion by acting directly on it or on the movement mechanism.

stop pin: the component on the dial that limits the angular rotation of the pointer.

suppressed scale gauge: a gauge having a scale that starts at some value appreciably above zero. One example of the many different types in common use is shown in Figure 1-3-5.

surface (wall) mounted: a gauge whose case can be mounted to a wall or flat surface (see Figure 1-3-3).

surface, wetted: any surface that directly contacts the pressure media.

surge: a sudden rise or drop in system pressure.

take-up: the portion of the scale between the position where the pointer is stopped and its true zero pressure position.

temperature, ambient: the temperature of the atmosphere surrounding the gauge.

temperature, process: the temperature of the medium at the pressure connection of the gauge or gauge accessory.

temperature, storage: the extremes of temperature (high and low) that the instrument or accessory will be exposed to when not pressurized.

temperature error: the change of pressure indication that results when the gauge components are at a temperature different from the temperature at which they were calibrated.

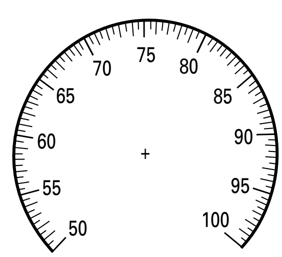
test gauge: a gauge used to check the accuracy of other gauges or pressure-actuated devices. The test gauge has an accuracy significantly better than the device being tested.

thermal decomposition point: the temperature at which changes in the chemical or physical characteristics of a material are initiated.

threaded ring: see *ring, threaded*.

threaded window: see *window, threaded*.

Figure 1-3-5
Example of a Suppressed Scale Gauge



GENERAL NOTE: Scale shown is suppressed from 0 to 50.

tip: the motion or force transmitting component at the free end of an elastic element.

Torr: a unit of pressure measurement, typically used in situations where vacuum will be measured. 1 Torr is equal to 1.0 mm Hg absolute pressure.

traceability: documentation of the existence of a calibration chain between an instrument and a primary standard.

transfer standard: see *standard, transfer*.

vacuum: see *pressure, negative*.

upper housing: the diaphragm seal component that includes a connection for the pressure instrument.

upper housing, continuous duty: an upper housing that prevents damage to the diaphragm or leaking of the process fluid should the pressure instrument leak or be removed.

upper housing, continuous seal: an upper housing that prevents leaking of the process medium should the pressure instrument leak or be removed; however, the diaphragm may be damaged.

upper housing, non-continuous duty: an upper housing that does not prevent damage to the diaphragm or leaking of the process fluid should the pressure instrument leak or be removed.

upper housing, non-removable: an upper housing that if removed from the bottom housing with the instrument installed will result in the loss of fill fluid.

upper housing, removable: an upper housing that may be removed from the bottom housing with the instrument installed without loss of fill fluid.

vacuum gauge: a gauge that indicates negative gauge pressure (vacuum).

variable pressure: see *pressure, variable*.

vapor pressure: the pressure of the vapor in equilibrium with the liquid.

vibration resistance: the maximum sinusoidal acceleration a gauge can withstand without damage or evidence of a change in accuracy of more than a specified value. It is expressed in g's, or amplitude over a frequency range and time period.

viscosity: the resistance that a gaseous or liquid system offers to flow when it is subjected to a shear stress. Also, known as *flow resistance*.

volumetric displacement: the volume of fill fluid displaced by the movement of a diaphragm.

volumetric spring rate: the flexibility of a diaphragm.

welding: a metal-joining process wherein coalescence is produced by heating to suitable temperatures to melt the base metals together, with or without the addition of filler metal. If filler metal is used, it shall have a melting point and composition approximately the same as the base metal.

wetted parts: components of the device that directly contact the process medium.

wetted surface: the portions of the wetted parts that are exposed to the medium.

window: a transparent component that closes the front of the case (see Figure 2-1-2).

window, heat-treated glass: a window of specially heat treated (tempered) glass, which, when broken, will form into small, granular pieces, usually with no jagged edges.

window, laminated glass: a window with two or more sheets of glass held together by an intervening layer(s) of clear plastic. When it is cracked or broken, the pieces of glass tend to adhere to the plastic.

window, plain glass: a window of commercial single or double strength plate or sheet glass.

window, plastic: a window of transparent plastic.

window, threaded: window, generally made of plastic, with integral threads that match threads on the case. No separate ring is required.

Section 2
Gauges: Pressure-Indicating Dial Type — Elastic Element

2-1 PRESSURE GAUGES, GENERAL

Figures 2-1-1 and 2-1-2 illustrate basic pressure terms and typical pressure gauge components.

2-2 GENERAL RECOMMENDATIONS

2-2.1 Gauge Sizes

2-2.2 Typical Ranges.

Many ranges in addition to the ones listed herein are available.

(a) Positive Gauge Pressure. See Table 2-2.2-1 for a list of positive pressure ranges.

(b) Negative Gauge Pressure. The following is a list of negative gauge pressure:

in. Hg/psi	kPa	bar
30/0	−100/0	−1/0

(c) Compound Pressure. See Table 2-2.2-2 for a list of compound pressure ranges.

(d) Receiver. See below for receiver pressure range.

psi	kPa	bar
3/15	20/100	0.2/1.0

2-2.3 Construction

2-2.3.1 Cases (See Figure 1-3-2)

2-2.3.1.1 General. Cases may be fabricated from various materials using various manufacturing processes. They may have solid fronts or open fronts, and may or may not employ various case pressure relief means. Specific applications may require design variations with respect to case construction. There should be mutual agreement between user, supplier, or manufacturer, or some combination, regarding the applications and the design variations.

2-2.3.1.2 Cases With Pressure Relief Means. Use of a pressure relief device is recommended. For gauges incorporating a pressure relief device, the device shall function at a pressure not greater than half the burst pressure of the window.

2-2.3.1.3 Front With Pressure Relief Back. In the event of failure of the elastic element within its rated pressure range, the solid front (partition between the pressure element and the window) and the pressure relief back shall be designed to reduce the possibility of window failure and projection of parts outward through the front of the gauge and shall function at a pressure not greater than 25 psi (1.5 bar). The user should consult with the supplier regarding the degree of protection required (see subsection 2-3).

Normal mounting of the gauge shall not prevent proper functioning of the pressure relief means.

2-2.3.1.4 Open Front With Pressure Relief. In the event of a slow leak of media through the elastic element, the case pressure relief shall be sufficient to vent the case pressure increase before window failure occurs. If case pressure increases rapidly, however, the case pressure relief device may not prevent parts from being expelled.

Normal mounting of the gauge shall not prevent proper function of the case pressure relief means.

2-2.3.1.5 Mounting. Mounting holes or studs are used for flush and surface-mounted gauges. They shall be sized and located as shown in Figure 2-2.3.1.5-1.

Figure 2-1-1
Basic Pressure Terms

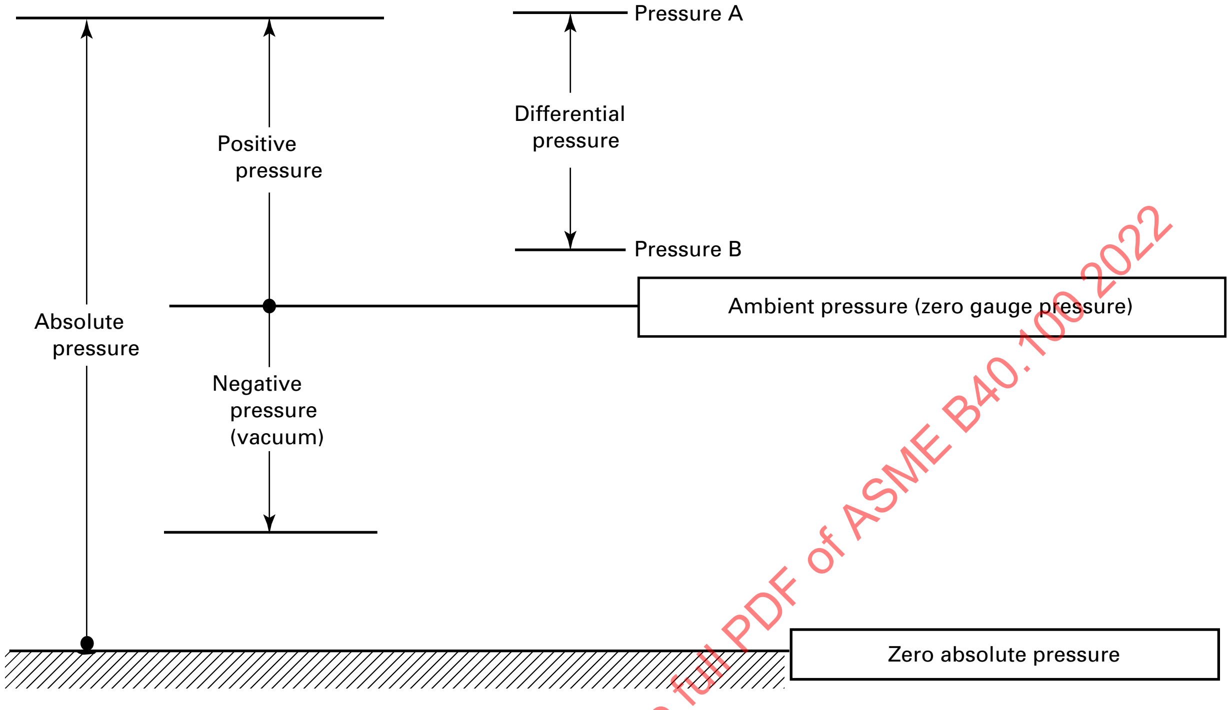


Figure 2-1-2
Typical Pressure Gauge Components (C-Type Bourdon Tube Illustrated)

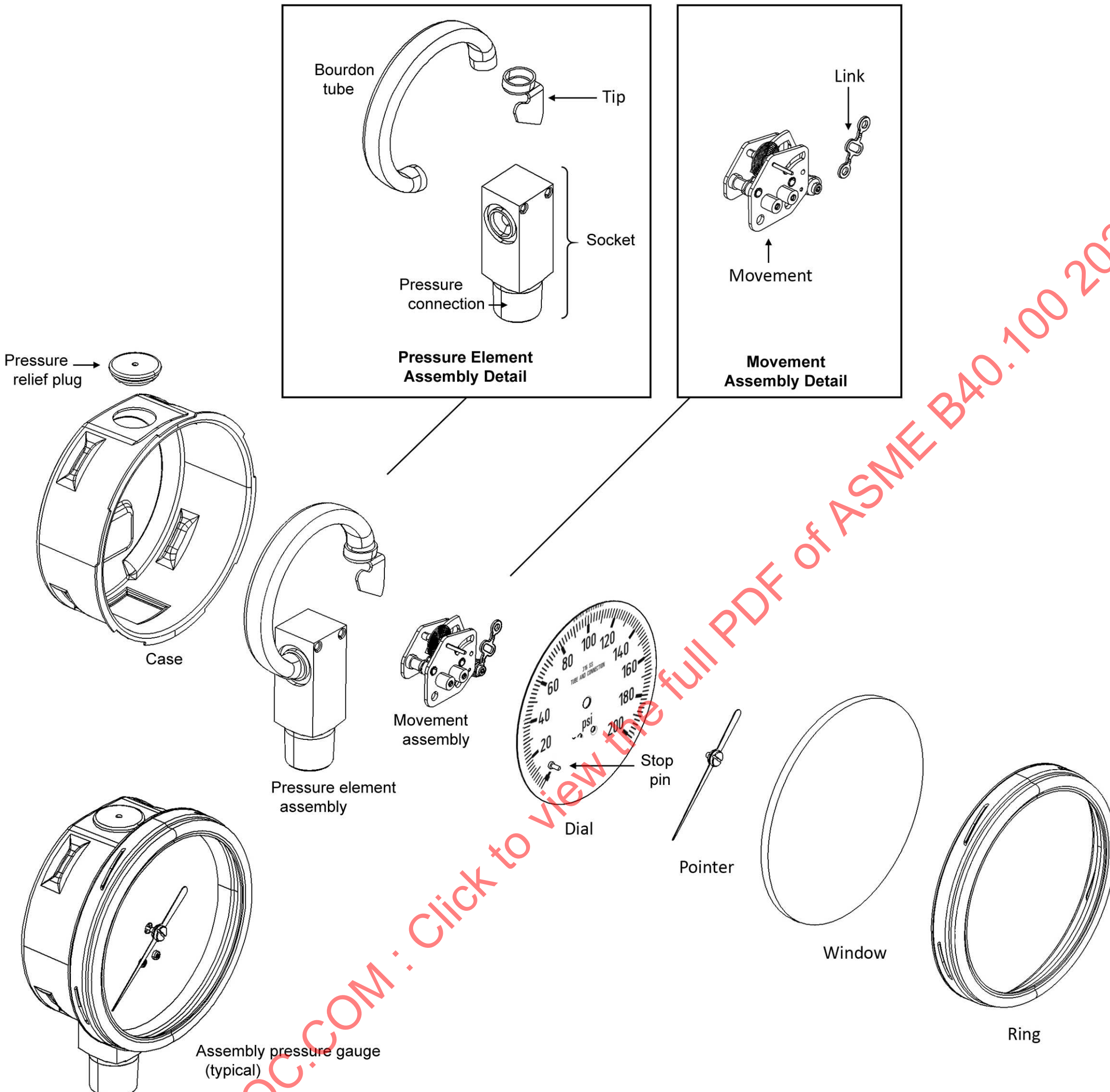


Table 2-2.2-1
Positive Pressure Ranges

in. H_2O			psi		
0/10			0/3	0/300	0/6,000
0/15			0/5	0/600	0/10,000
0/30			0/10	0/800	0/15,000
0/60			0/15	0/1,000	0/20,000
0/100			0/30	0/1,500	0/30,000
0/200			0/60	0/2,000	0/40,000
0/300			0/100	0/3,000	0/60,000
			0/160	0/4,000	0/80,000
			0/200	0/5,000	0/100,000
kPa					
0/1	0/10	0/100	0/1 000	0/10 000	0/100 000
0/1.6	0/16	0/160	0/1 600	0/16 000	1/160 000
0/2.5	0/25	0/250	0/2 500	0/25 000	0/250 000
0/4	0/40	0/400	0/4 000	0/40 000	0/400 000
0/6	0/60	0/600	0/6 000	0/60 000	0/600 000
bar					
0/0.01	0/0.10	0/1.0	0/10	0/100	0/1,000
0/0.016	0/0.16	0/1.6	0/16	0/160	0/1,600
0/0.025	0/0.25	0/2.5	0/25	0/250	0/2,500
0/0.04	0/0.40	0/4.0	0/40	0/400	0/4,000
0/0.06	0/0.60	0/6.0	0/60	0/600	0/6,000

Table 2-2.2-2
Compound Pressure Ranges

in. Hg/psi	kPa	Bar
30 in. Hg vac/15 psi	−100/150	−1/1.5
30 in. Hg vac/30 psi	−100/300	−1/3
30 in. Hg vac/60 psi	−100/500	−1/5
30 in. Hg vac/100 psi	−100/900	−1/9
30 in. Hg vac/150 psi	−100/1 500	−1/15
30 in. Hg vac/300 psi	−100/2 400	−1/24

2-2.3.2 Dials

2-2.3.2.1 Common Units

(a) Over the years, different classifications of units of measure have been used. Many of the older units, although not presently officially recognized by standard-setting bodies, are still in widespread use and are therefore included in this Standard for the purpose of definition. The three basic classifications are as follows:

(1) SI [Système international (d'unités)]. These units are recognized by the CIPM (Comité International des Poids et Mesures).

(2) MKSA (meter, kilogram-force, second, ampere). The former metric units, which are being replaced by the SI units.

(3) Customary (inch, pound-force, second, ampere). Customary units are used primarily in English-speaking countries and are being replaced in most countries by SI units.

(b) For conversion factors, see para. 2-6.2.

(c) For definitions of the various units, see Table 2-2.3.2.1-1.

2-2.3.2.2 Dial Information. Dials shall indicate the units in which the scale is graduated.

Dual scale dials are useful where gauges are employed on equipment that may be used internationally, or where users plan to convert from one unit of measure to another over a period of time.

Each scale on a dial with multiple scales shall indicate the units in which it is graduated. One of the scales should be one of the typical ranges (see para. 2-2.2).

Receiver gauge dials shall indicate the input pressure range of the gauge.

Dials with a scale graduated in non-pressure units, or a scale range different from the range of the pressure element assembly, shall clearly indicate the maximum pressure that may be applied to the gauge without loss of calibration.

The use of multipliers, such as ×100, × 1 000, and ×100 kPa, is discouraged because of potential misapplication or misinterpretation.

All of the above scales indicate gauge pressure unless otherwise specified, except when psia, psid, or Torr are displayed. For all other scales, absolute or differential pressures are indicated by adding the words ABSOLUTE or DIFFERENTIAL. Uppercase or lowercase letters are acceptable. When space does not permit, the abbreviation ABS, DIFF, or AP may be used.

Dial markings may include manufacturer's or customer's trademark, or both, and any other information deemed appropriate for safety of specific service requirements (see para. 2-3.2.8).

Numerals shall be sufficient in number to enable the operator to accurately and quickly identify any pressure on the scale. They shall not obscure or crowd graduations or important markings.

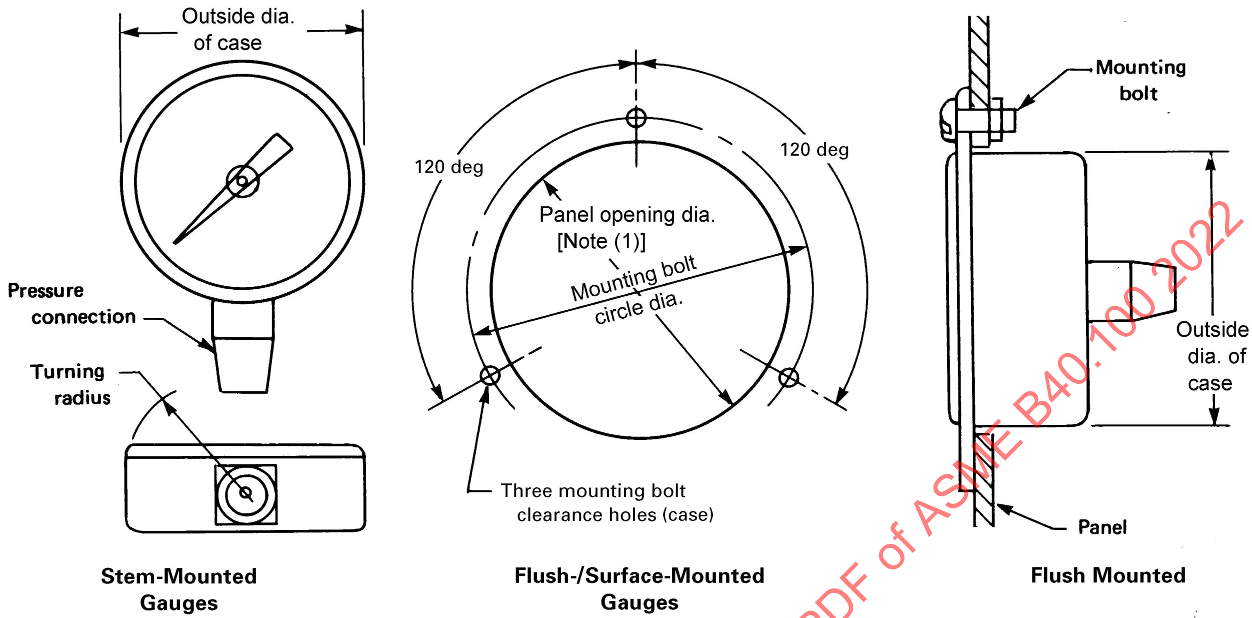
Numerals shall not extend beyond the calibrated portion of the scale.

Negative (vacuum) values shall be indicated by preceding the appropriate numerals with a minus (−) or clearly marking the dial with the words VAC or VACUUM. Uppercase or lowercase letters are acceptable. Both signs and words should not appear on the same scale.

The absence of a sign before a numeral indicates a positive value except when accompanied by the words VAC or VACUUM.

2-2.3.2.3 Scale Arcs. The recommended graduated scale arc is 270 deg. Special applications and ranges may require scale arcs greater or less than 270 deg.

Figure 2-2.3.1.5-1
Recommended Case and Mounting Dimensions



Flush/Surface Mounting Dimensions

Gauge Size	Mounting Bolt Circle Diameter, in. (mm)	Mounting Bolt Hole Diameter, in. (mm)	Panel Opening Diameter, in. (mm)	Case Max. Outside Diameter, in. (mm) [Note (1)]
1½	1.91 (48.5)	0.13 (3.4)	1.65 (41.9)	1.59 (40.4)
2	2.56 (65.0)	0.16 (4.5)	2.19 (55.6)	2.13 (54.1)
2½	3.13 (79.5)	0.16 (4.5)	2.81 (71.4)	2.75 (69.9)
3½	4.25 (108)	0.22 (5.6)	3.81 (96.8)	3.75 (95.3)
4½	5.38 (137)	0.22 (5.6)	4.94 (125)	4.88 (124)
6	7.00 (178)	0.28 (7.1)	6.50 (165)	6.44 (164)
8½	9.63 (245)	0.28 (7.1)	9.00 (229)	8.94 (227)
12	13.50 (343)	0.28 (7.1)	12.62 (321)	12.56 (319)
16	17.00 (432)	0.28 (7.1)	16.50 (419)	16.44 (418)

The sizes listed above are equal to the approximate inside diameter of the case, in inches, at the dial. The EN case sizes listed below define size as the outside diameter of the case. Because of this difference, gauges made to the inch-based sizes may not be interchangeable with those made to the EN sizes, even though the nominal sizes may be very close. For instance, the outside diameter of a size 2½ gauge may be as large as 70 mm, 7 mm larger than that of an EN 63-mm gauge.

EN 837.1 Case Sizes

Gauge Size	Mounting Bolt Circle Diameter, mm (in.)	Case Outside Diameter, mm (in.) [Note (2)]
40	51 (2.01)	40 (1.57)
50	60 (2.36)	50 (1.97)
63	75 (2.95)	63 (2.48)
80	95 (3.74)	80 (3.15)
100	118 (4.65)	100 (3.94)
150	168 (6.61)	150 (5.91)
160	178 (7.01)	160 (6.30)
250	276 (10.87)	250 (9.84)

GENERAL NOTE: Contact supplier for actual mounting dimensions (panel openings, bolt circle diameter, etc.).

Figure 2-2.3.1.5-1
Recommended Case and Mounting Dimensions (Cont'd)

NOTES:
(1) Flush-mounted cases only.
(2) The reader should reference ISO 3/ANSI Z17.1-1973 for additional details.

Table 2-2.3.2.1-1
Definitions of Pressure Various Units

SI Abbreviation	Unit	Definition
bar	bar	1 bar = 100 kPa (The bar is a unit outside the SI, which is nevertheless recognized by CIPM.)
kPa	kilopascal	1 kPa = 1 000 Pa
mbar	millibar	1 mbar = bar/1 000 = 100 Pa
MPa	megapascal	1 MPa = 1 000 000 Pa
N/m^2	newton per square meter	1 N/m^2 = 1 Pa
Pa	Pascal	1 Pa = 1 N/m^2
MKSA Abbreviation	**Unit**	**Definition**
kg/cm^2	kilograms per square centimeter	1 kg/cm^2 = 1 kilogram force per square centimeter
m H_2O	meters of water	1 m H_2O = 1 meter of water at 68°F (20°C)
mmHg	millimeters of mercury	1 mm Hg = 1 millimeter of mercury at 32°F (0°C)
torr	torr	1 torr = 1.0 mm Hg absolute pressure
Customary Abbreviation	**Unit**	**Definition**
ft H_2O	feet of fresh water	1 ft H_2O = 1 foot of water at 68°F (20°C) (0.4328 psi)
ft seawater	feet of seawater	1 ft seawater = 0.4444 psi (0.9877 ft H_2O)
in. Hg	inches of mercury	1 in. Hg = 1 inch of mercury at 32°F (0°C) (0.4911 psi)
in. H_20 (20°C)	inches of water (Ref. ISA RP2.1)	1 in. H_2O (20°C) = 1 inch of water at 20°C (68°F) and 980.665 cm/sec^2 gravity (0.036063 psi)
in. H_20 (60°F)	inches of water (Ref. AGA Report #3)	1 in. H_2O (60°F) = 1 inch of water at 60°F (15.6°C) and 980.665 cm/sec^2 gravity (0.036092 psi)
in. H_2O (4°C)	inches of water	1 in. H_2O (4°C) = 1 inch of water at 4°C and 980.665 cm/sec^2 gravity (0.036127 psi)
$oz/in.^2$	ounces per square inch	1 $oz/in.^2$ = 1 ounce force per square inch
psi	pounds per square inch	1 psi = 1 pound force per square inch gauge pressure
psia	pounds per square inch absolute	1 psia = 1 pound force per square inch absolute pressure
psid	pounds per square inch differential	1 psid = 1 pound force per square inch differential pressure

2-2.3.2.4 Graduation Lines. Graduation lines shall be radial to the center of rotation of the pointer and shall project beyond the arc described by the end of the pointer (mirror and multiple scale dials excepted). Major and intermediate graduation lines shall be emphasized. Graduations shall not extend beyond the calibrated portion of the scale.

Where possible, scale, numeral, and graduation increments should follow the format: 1×10^n, 2×10^n, or 5×10^n, where n is a whole positive or negative number or zero.

It is desirable that the smallest graduation increment should not exceed twice the error permitted (accuracy) in the middle half of the scale.

2-2.3.2.5 Graduation Near Zero. On dials for Grades 4A and 3A gauges, there shall be no take-up. The number and the spacing of the minor graduations near zero, shall be the same, commencing at true zero, as in the rest of the scale. On dials for all other grades, takeup may be incorporated. However, if it is incorporated, it shall be readily apparent at what pressure the graduations start. A zero graduation or numeral, or both, shall not be permitted at the stopped pointer position on gauges using a stop pin or internal stops that prevent free pointer motion to the actual zero pressure position.

2-2.3.3 Pointer

(a) Length (All Grades). The tip of the pointer shall cover 10% to 90% of the minor graduation. The pointer may overlap the graduations.

(b) Tip Width (Grades 4A and 3A). The width of the pointer tip shall not be greater than the width of the minor graduation lines.

(c) Pointer Rotation. The pointer shall rotate clockwise for increasing positive pressure and counterclockwise for increasing negative pressure.

(d) Pointer Adjustment. Pointer adjustment can only be used to match the indication to a reference pressure at one point on the scale and should not be depended upon to recalibrate the gauge. Such an adjustment could cause a significant error at pressures above or below the setting point.

2-2.3.4 Pressure Connection

2-2.3.4.1 Location of Connection.

(a) Stem mounted — bottom or back
(b) Surface mounted — bottom or back
(c) Flush mounted — back

2-2.3.4.2 Type of Connection. Taper pipe connections for pressures less than or equal to 20,000 psi (160,000 kPa) are usually $\frac{1}{8}$ NPT, $\frac{1}{4}$ NPT, or $\frac{1}{2}$ NPT American Standard external or internal taper pipe threads per ASME B1.20.1, as required. Above this pressure, $\frac{1}{4}$ in. high-pressure tubing connections, or equal, may be used. Other appropriately sized connections, employing sealing means other than tapered threads, are acceptable.

In applications of stem-mounted gauges, especially with liquid-filled cases and where vibration is severe, consideration should be given to the possibility of failure of the stem or associated piping caused by the vibrating mass of the gauge. A larger connection (e.g., $\frac{1}{2}$ NPT instead of $\frac{1}{4}$ NPT) or a stronger stem material (e.g., stainless steel instead of brass), or both, should be considered.

2-2.3.5 Rings. Removable rings, size 4$\frac{1}{2}$ and larger, generally have window retaining devices.

2-2.3.6 Internal Stop. An internal stop is a device that restrains the motion of the pressure element or the mechanism to reduce the probability of damage to the pressure element or disengagement of the movement mechanism caused by application of pressure below the minimum scale value or above the maximum scale value. It will also reduce the possibility of disengagement of the movement mechanism caused by the inertial effect of sudden pressure changes.

2-2.3.6.1 Maximum Stop. A maximum stop shall prevent pointer motion beyond a point approximately midway between the last and the first dial graduation and shall prevent the pointer from rotating beyond one full revolution of the dial. Pointer motion shall not be restrained at less than 105% of full scale pressure.

2-2.3.6.2 Minimum Stop. A minimum stop shall prevent pointer motion below a point 5% lower than the first scale graduation and a point approximately midway between the last and the first dial graduation. When incorporated, the requirements of para. 2-2.3.2.5 shall apply.

2-2.3.7 Windows

2-2.3.7.1 Laminated Glass. Laminated glass shall comply with ANSI/SAE Z26.1. Laminated glass offers some protection in all applications. It reduces the possibility of glass particles scattering if the pressure element ruptures and window failure results.

2-2.3.7.2 Tempered Glass. Tempered glass shall comply with ASTM C1048 (heat treated) or ASTM C1422 (chemically treated). Tempered glass is generally 2 to 5 times stronger than annealed (plain) glass.

2-2.3.7.3 Plastic. Impact and abrasive environmental conditions, especially temperature and corrosive atmosphere, must be carefully considered to determine the type of plastic best suited for the application.

2-2.3.7.4 Plain Glass. This window material is commonly used due to its abrasion, chemical, and wear resistance properties. Careful consideration of its use should be given for hazardous applications.

2-2.4 Accuracy

Pressure gauge accuracy is graded as shown in Table 2-2.4-1 (see subsection 2-5 for testing procedures).

2-2.4.1 General Discussion

2-2.4.1.1 Elastic elements are made of many materials to meet various requirements of corrosion resistance and performance. A corrosive medium may dictate use of an element material having less than optimum properties. The accuracy classification of such a gauge depends to a large extent on these properties.

2-2.4.1.2 Using a pressure gauge in an environment or with media that cause the temperature of the elastic element to be different from that at which it was calibrated will increase the indication error. This is caused by temperature effects on the elastic element, movement, and link.

2-2.4.1.3 Temperature change affects the stiffness of the elastic element. The change in stiffness of a material with change in temperature is the thermoelastic coefficient (TEC) of the material. Stiffness change is produced

Table 2-2.4-1
Accuracy Grades/Classes and Recommended Number of Test Points

Accuracy Grade	Permissible Error (± of Span; Excluding Friction) Lower ¼ of Scale	Middle ½ of Scale	Upper ¼ of Scale	Maximum Friction (Percent of Span)	Minimum Recommended Gauge Size (in.) (270 deg Dial Arc)	Minimum Recommended Number of Test Points [Note (1)]
4A	0.1%	0.1%	0.1%	[Note (2)]	8½	10
3A	0.25%	0.25%	0.25%	0.25%	6	5
2A	0.5%	0.5%	0.5%	0.5%	4	5
1A	1.0%	1.0%	1.0%	1.0%	2½	5
A	2.0%	1.0%	2.0%	1.0%	1½	5
B	3.0%	2.0%	3.0%	2.0%	1½	3
C	4.0%	3.0%	4.0%	3.0%	1½	3
D	5.0%	5.0%	5.0%	3.0%	1½	3

EN 837-1

Class	Permissible Error (± of Span; Excluding Friction) Lower ¼ of Scale	Middle ½ of Scale	Upper ¼ of Scale	Maximum Friction (Percent of Span)	Minimum Recommended Gauge Size (mm) (270 deg Dial Arc)	Minimum Recommended Number of Test Points for EN 837-1
0.1	0.10%	0.10%	0.10%	0.10%	250	10
0.25	0.25%	0.25%	0.25%	0.25%	150	10
0.6	0.60%	0.60%	0.60%	0.60%	100	10
1	1.00%	1.00%	1.00%	1.00%	63	5
1.6	1.60%	1.60%	1.60%	1.60%	40	3
2.5	2.50%	2.50%	2.50%	2.50%	40	3
4	4.00%	4.00%	4.00%	4.00%	40	3

GENERAL NOTE: Light tapping of the gauge is permissible at each pressure reading

NOTES:
(1) The test points shall be distributed over the dial range and shall include points within 10% of the ends of the dial range.
(2) Grade 4A gauges must remain within specified tolerance before and after being lightly tapped.

by a combination of changes in the elastic modulus (Young's Modulus) due to thermal effects and a change in linear dimensions due to linear expansion and contraction.

Using a pressure gauge in an environment or with media that cause the temperature of the elastic element to be different from that at which it was calibrated will increase the indication error.

For common materials of construction (e.g., stainless steel, bronze), the error caused by temperature will be approximately the percentage values given by the following equation:

$$\text{error (change in span)} = \pm\, 0.04 \times (t_2 - t_1) \times \frac{\%}{^\circ\text{C}} \quad \textbf{(1)}$$

where

t_1 = the temperature at calibration, °C
t_2 = the current temperature of the gauge in service, °C

For example, a change of 1% at full scale pressure occurs for each 25°C change in temperature. This error is approximately proportional to the applied pressure and because it is a percentage, becomes more apparent as pressure approaches full span.

Special alloys such as NiSpan C (Alloy 902) are also used for elastic elements where heat treatment could control the TEC and reduce the temperature error.

This error is approximately proportional to the applied pressure and therefore cannot be corrected by resetting the pointer.

For a given temperature condition, correction can be made by calculating the approximate error at each applied pressure value and adding it to or subtracting it from the indicated value. If the temperature condition is stable and a more accurate indication is required, recalibration may be appropriate.

2-2.4.1.4 Gauges represented as being compensated for service at various temperatures generally have components of special materials and design to compensate not only for the temperature effects on the elastic element stiffness, but also to compensate for similar effects on the gauge mechanism. The accuracy classification of a temperature-compensated gauge is established by the magnitude of the largest error encountered when the gauge is tested over its entire rated service temperature range.

2-2.4.1.5 Gauges with sealed cases, liquid filled or not, will exhibit additional error as a result of exposure to ambient or media temperature different from that at which the case was sealed unless compensation is provided. This error is caused by internal case pressure changes and depends on fill media, extent of fill, and other factors.

The error is constant over the entire scale, and if the temperature is stable, within limits, it can be corrected by resetting the pointer.

An increase in temperature generally causes an increase in internal case pressure with a resulting decrease in indicated pressure. The opposite occurs for a decrease in temperature.

For a given temperature change, the percentage of error noted on the gauge is a function of the range (or span) of the gauge. If, for example, the temperature increases causing the internal case pressure to increase by 3 psi, then on a 0/30 psi gauge, this will cause a −10% error, whereas on a 0/100 psi gauge, the error will be −3%. For higher ranges, the percentage of error becomes proportionately less.

2-2.4.1.6 The accuracy of a retard gauge shall be expressed as a percentage of the expanded portion of the scale. The accuracy for the compressed portion of the scale may be substantially different.

2-2.4.1.7 The accuracy of a gauge with suppressed scale shall be expressed as a percentage of span.

2-2.4.1.8 The accuracy of a compound gauge shall be expressed as a percentage of span.

2-2.4.1.9 Accuracy is affected by readability. For this reason, more accurate gauges are generally made in larger sizes (see Table 2-2.4-1).

2-2.4.1.10 Mounting a pressure gauge in a position other than that at which it was calibrated can affect its accuracy. Normal calibrating position is upright and vertical. For applications requiring mounting in other than this position, consult the supplier.

2-2.4.1.11 Some absolute pressure gauges are pressure gauges with the pointer set to indicate 14.7 psia with the elastic element unpressurized. These gauges indicate in terms of absolute pressure, but will be in error by the difference between the ambient pressure and 14.7 psia. Other absolute pressure gauges indicate the correct absolute pressure value, even though the ambient pressure may vary.

2-2.4.1.12 Pressure gauges can be rendered inaccurate during shipment despite care taken in packaging. To ensure conformance to the standard grade to which the pressure gauge was manufactured, it should be checked before use in the orientation in which it was calibrated.

2-2.5 Installation

Before installing a pressure gauge, consideration should be given to environmental conditions such as temperature, humidity, vibration, pulsation, and shock and the possible need for protective attachments, maintenance, and/or special installation requirements. Refer to subsection 2-3.

The gauge connection must be compatible with the mating connection, and appropriate assembly techniques must be used.

Installation of the gauge should be accomplished by tightening the pressure connection using the wrench flats if provided. Failure to do so may result in loss of accuracy, excessive friction, or mechanical damage to the pressure element or case.

2-3 SAFETY

This section of the Standard presents certain information to guide users, suppliers, and manufacturers to minimize the hazards that could result from misuse or misapplication of pressure gauges with elastic elements. The user should become familiar with all sections of this Standard, as all aspects of safety cannot be covered in this section. Consult the manufacturer or supplier for advice whenever there is uncertainty about the safe application of a pressure gauge.

2-3.1 General Discussion

2-3.1.1 Adequate safety results from intelligent planning and careful selection and installation of gauges into a pressure system. The user should inform the supplier of all conditions pertinent to the application and environment so that the supplier can recommend the most suitable gauge for the application.

2-3.1.2 The history of safety with respect to the use of pressure gauges has been excellent. Injuries to personnel and damages to property have been minimal. In most instances, the cause of failure has been misuse or misapplication.

2-3.1.3 The pressure-sensing element in most gauges is subjected to high internal stresses, and applications exist where the possibility of catastrophic failure is present. Pressure regulators, diaphragm (chemical) seals, pulsation dampers or snubbers, siphons, and other similar items, are available for use in these potentially hazardous systems. The hazard potential increases at higher operating pressure.

2-3.1.4 The following systems are considered potentially hazardous and must be carefully evaluated:

(a) compressed gas systems

(b) oxygen systems
(c) systems containing hydrogen or free hydrogen atoms
(d) corrosive fluid systems (gas and liquid)
(e) pressure systems containing any explosive or flammable mixture or medium
(f) steam systems
(g) nonsteady pressure systems
(h) systems where high overpressure could be accidentally applied
(i) systems wherein interchangeability of gauges could result in hazardous internal contamination or where lower pressure gauges could be installed in higher pressure systems
(j) systems containing radioactive or toxic fluids (liquids or gases)
(k) systems installed in a hazardous environment

2-3.1.5 When gauges are to be used in contact with media having known or uncertain corrosive effects or known to be radioactive, random or unique destructive phenomena can occur. In such cases the user should always furnish the supplier or manufacturer with information relative to the application and solicit his advice prior to installation of the gauge.

2-3.1.6 Fire and explosions within a pressure system can cause pressure element failure with very violent effects, even to the point of completely disintegrating or melting the pressure gauge. Violent effects are also produced when failure occurs due to
(a) hydrogen embrittlement
(b) contamination of a compressed gas
(c) formation of acetylides
(d) weakening of soft solder joints by steam or other heat sources
(e) weakening of soft soldered or silver-brazed joints caused by heat sources such as fires
(f) corrosion
(g) fatigue
(h) mechanical shock
(i) excessive vibration

Failure in a compressed gas system can be expected to produce violent effects.

2-3.1.7 Modes of Pressure Gauge Failure. The following represents some of the more common, possible failure modes for pressure gauges; however, it is not a comprehensive list.

2-3.1.7.1 Fatigue Failure. Fatigue failure caused by pressure-induced stress generally occurs from the inside to the outside along a highly stressed edge radius of a Bourdon tube, appearing as a small crack that propagates along the edge radius. Such failures are usually more critical with compressed gas media than with liquid media.

Fatigue cracks usually release the medium slowly so case pressure buildup can be averted by providing pressure relief openings in the gauge case. However, in high pressure elastic elements where the yield strength approaches the ultimate strength of the element material, fatigue failure may resemble explosive failure.

A snubber (restrictor) placed in the gauge pressure inlet will reduce pressure surges and fluid flow from the ruptured elastic element (see Mandatory Appendix I, para. I-2.4).

2-3.1.7.2 Overpressure Failure. Overpressure failure is caused by the application of internal pressure greater than the rated limits of the elastic element and can occur when a low-pressure gauge is installed in a high-pressure port or system. The effects of overpressure failure, usually more critical in compressed gas systems than in liquid-filled systems, are unpredictable and may cause parts to be propelled in any direction. Cases with pressure relief openings will not always retain expelled parts. Placing a snubber (restrictor) in the pressure gauge inlet will not reduce the immediate effect of failure, but will help control flow of escaping fluid following rupture and reduce the potential of secondary effects.

It is generally accepted that solid front cases with pressure relief back will reduce the possibility of parts being projected forward in the event of failure.

The window alone will not provide adequate protection against internal case pressure buildup, and can be the most hazardous component.

Short duration pressure impulses (pressure spikes) may occur in hydraulic or pneumatic systems, especially when valves open or close. The magnitude of the spikes may be many times the normal operating pressure, and may not be indicated by the gauge. The result could be immediate failure, or a large upscale error. A snubber (restrictor) may reduce the magnitude of the pressure transmitted to the elastic element.

Use of a pressure limiter valve can isolate the pressure gauge from pressures greater than the rated limits of the elastic element, protecting the gauge from overpressure failure. A pressure limiter valve is a device that is designed to close on rising pressure, limiting the pressure at the outlet of the device. The closing pressure is adjustable and should be set to close above the full scale range of the pressure gauge and below the rated limit of the elastic element. Complete information regarding pressure limiter valves is contained in Section 4.

2-3.1.7.3 Corrosion Failure. Corrosion failure occurs when the elastic element has been weakened through attack by corrosive chemicals present in either the media inside or the environment outside it. Failure may occur as pinhole leakage through the element walls or early fatigue failure due to stress cracking brought about by chemical deterioration or embrittlement of the material. A diaphragm (chemical) seal should be considered for use with pressure media that may have a corrosive effect on the elastic element.

The addition of a seal may reduce accuracy or sensitivity or both. For further detail see Section 3.

2-3.1.7.4 Explosive Failure. Explosive failure is caused by the release of explosive energy generated by a chemical reaction such as can result when adiabatic compression of oxygen occurs in the presence of hydrocarbons. It is generally accepted that there is no known means of predicting the magnitude or effects of this type of failure. For this mode of failure, a solid wall or portion between the elastic element and the window will not necessarily prevent parts being projected forward.

2-3.1.7.5 Vibration Failure. The most common mode of vibration failure is wear of mechanical components because of high cyclic loading caused by vibration. This is characterized by gradual loss of accuracy, and, ultimately failure of the pointer to indicate any pressure change.

2-3.1.7.6 Vibration-Induced Fatigue Failure. In addition to its effect on the gauge movement and linkage, (see para. 2-3.1.7.5), vibration may in some instances result in high loading of various parts of the pressure element assembly. This loading could cause cracks in the element itself, or in the joints. Case pressure buildup may be slow, but it is possible that a large hole may suddenly develop, with a high rate of case pressure rise, which could result in a failure similar to an explosive failure.

2-3.1.7.7 Plugging. Apparent failure may be encountered due to plugging (clogging) of internal pressure passages or throttling devices by the pressure media. A diaphragm seal should be considered for use with pressure media that may cause plugging or clogging.

2-3.1.7.8 Pressure Connection. See recommendations in para. 2-2.3.4. Very high operating pressures may lead to leakage or failure of pipe thread pressure connections (e.g. NPT, BSP). Pipe threads will yield at high pressures creating a leak path resulting in loss of fluid containment. Using smaller diameter connections or high-pressure autoclave style connections will reduce the operating stresses, mitigating this mode of failure at high pressure.

2-3.2 Safety Recommendations

2-3.2.1 Operating Pressure. The pressure gauge selected should have a full-scale pressure such that the operating pressure occurs in the middle half (25% to 75%) of the scale. The full-scale pressure of the gauge selected should be approximately 2 times the intended operating pressure.

If it is necessary for the operating pressure to exceed 75% of full scale, the supplier should be contacted for recommendations.

This does not apply to test retarded or suppressed scale gauges.

NOTE: Gauges that are obviously not working or indicating erroneously should be immediately valved off or removed from service to prevent further damage.

2-3.2.2 Use of Gauges Near Zero Pressure. The use of gauges near zero pressure is not recommended because the accuracy tolerance of the gauge may be a large percentage of the applied pressure. If, for example, a 0/100 psi Grade A gauge is used to measure 4 psi, the accuracy of measurement will be ±2 psi, or 50% of the applied pressure.

For this reason, gauges should not be used for the purpose of indicating the residual pressure in a tank, autoclave, or other similar device that has been seemingly exhausted. Depending on the accuracy and the range of the gauge, hazardous pressure may remain in the tank even though the gauge is indicating zero pressure.

The operator may develop a false sense of security when the gauge indicates zero or near-zero pressure even though there may be substantial pressure in the system. A venting device must be used to completely reduce the pressure to zero before unlocking covers, removing fittings, or performing other similar activities.

2-3.2.3 Compatibility With Medium

2-3.2.3.1 Wetted Parts. The elastic element is generally a thin-walled member, which of necessity operates under high stress conditions and must, therefore, be carefully selected for compatibility with the medium being measured. None of the common element materials is impervious to every type of chemical attack. The potential for corrosive attack is established by many factors, including the concentration, temperature, and contamination of the medium. The user should inform the gauge supplier of the installation conditions so that the appropriate element materials can be selected.

2-3.2.3.2 Calibration Test Fluid. The calibration fluid must be compatible with the medium. Test fluids containing hydrocarbons should not be used when the medium is oxygen or other oxidants.

2-3.2.3.3 Capability of a Pressure Element. In addition to the factors discussed above, the capability of a pressure element is influenced by the design, materials, and fabrication of the joints between its parts.

Common methods of joining are soft soldering, silver brazing, and welding. Joints can be affected by temperature, stress, and corrosive media. Where application questions arise, these factors should be considered and discussed by the user and supplier.

2-3.2.5 Special Applications. Some special applications require that the pressure element assembly have a high degree of leakage integrity. Users should contact the supplier to ensure that the allowable leakage rate is not exceeded.

2-3.2.6 Cases

2-3.2.6.1 Cases, Solid Front. It is generally accepted that a solid front case per para. 2-2.3.1 will reduce the possibility of parts being projected forward in the event of elastic element assembly failure. An exception is explosive failure of the elastic element assembly.

2-3.2.6.2 Cases, Liquid-Filled. It has been general practice to use glycerin or silicone filling fluids. These fluids must be avoided where strong oxidizing agents including, but not limited to, oxygen, chlorine, nitric acid, and hydrogen peroxide are involved. In the presence of oxidizing agents, potential hazard can result from chemical reaction, ignition, or explosion. Completely fluorinated or chlorinated fluids, or both, may be more suitable for such applications.

The user shall furnish detailed information relative to the application of gauges having liquid-filled cases and solicit the advice of the gauge supplier prior to installation.

In a compressed gas application, consideration should also be given to the instantaneous hydraulic effect that may be created by one of the modes of failure outlined in para. 2-3.1.7. The hydraulic effect due to pressure element failure could cause the window to be projected forward even when a case having a solid front is employed.

2-3.2.7 Snubber. Placing a snubber or a restrictor between the pressure connection and the elastic element will not reduce the immediate effect of failure, but will help reduce flow of escaping fluid following rupture and reduce the potential of secondary effects. For further details, see Section 4.

2-3.2.8 Specific Service Conditions. Specific applications for pressure gauges exist where hazards are known. In many instances, requirements for design, construction, and use of gauges for these applications are specified by state or federal agencies or Underwriters Laboratories, Inc. Some of these specific service gauges are listed in paras. 2-3.2.8.1 through 2-3.2.8.4. The list is not intended to include all types, and the user should always advise the supplier of all application details.

2-3.2.8.1 Acetylene Gauge. A gauge designed to indicate acetylene pressure (and other gases having similar properties). The gauge may bear the inscription ACETYLENE on the dial. For material recommendations see CGA E-4.

2-3.2.8.2 Ammonia Gauge. A gauge designed to indicate ammonia pressure and to withstand the corrosive effects of ammonia. The gauge may bear the inscription AMMONIA or NH3 on the dial. It should also include the equivalent saturation temperature scale markings on the dial. Materials such as copper, brass, and silver brazing alloys should not be used.

2-3.2.8.3 Chemical Gauge. A gauge designed to indicate the pressure of corrosive or high viscosity fluids, or both. The primary material(s) in contact with the medium may be identified on the dial. It may be equipped with a diaphragm (chemical) seal, pulsation damper, or pressure relief device, or a combination. These devices help to minimize potential damage to personnel and property in the event of gauge failure. They may, however, also reduce accuracy or sensitivity, or both.

2-3.2.8.4 Oxygen Gauge. A gauge designed to indicate oxygen pressure. Cleanliness shall comply with Level IV (see subsection 2-4) or an established oxygen cleaning standard such as CGA G4.1, ASTM G93, and ISO 150001. The dial shall be clearly marked with a universal symbol and/or USE NO OIL in red color. An alternative standard could be used as agreed upon between the manufacturer and customer.

2-3.2.9 Reuse of Pressure Gauges. It is not recommended that pressure gauges be moved from one application to another for the following reasons:

(a) Chemical Compatibility. The consequences of incompatibility can range from contamination to explosive failure. For example, moving an oil service gauge to oxygen services can result in explosive failure.

(b) Partial Fatigue. The first installation may involve pressure pulsation that has expended most of the gauge life, resulting in early fatigue in the second installation.

(c) Corrosion. Corrosion of the pressure element assembly in the first installation may be sufficient to cause early failure in the second installation.

2-4 CLEANLINESS

2-4.1 General

This section provides standardized reference for gauge users in specifying cleanliness requirements and guidance to manufacturers in meeting these requirements.

If gauge cleanliness is important for the application, such as for use on equipment involving food processing, life support, or oxidizing fluids, the user should specify the appropriate level of cleanliness listed in Table 2-4.2-1.

If the cleanliness requirements of the intended application are not covered in Table 2-4.2-1, the user should so advise the manufacturer.

2-4.2 Cleanliness Levels

Cleanliness is determined by the size and quantity of maximum permissible solid contaminants on wetted surfaces or by the quantity of contaminant (hydrocarbons) discernible in the fluids used to flush or clean

Table 2-4.2-1
Cleanliness Levels

Cleanliness Level	General Cleanliness Requirements	Particles		Fibers		Maximum Hydrocarbon mg/m [Note (2)]
		Size, µm	Maximum Quantity [Note (1)]	Size, µm	Maximum Quantity [Note (1)]	
I	Normal cleanliness attained through high standard shop practices	No limit	No limit	No limit	No limit	No limit
IV [Note (2)]	Gauge shall be free of visually [Note (3)] (unaided eye) detectable moisture and foreign matter (chips, slivers, weld slag or splatter, shop soil, greases, oils, or other contaminants) that could be mechanically detrimental to proper function of gauge)	Less than 100 100–500 Over 500	No limit 25 0	Less than 700 700–1000 Over 1000	No limit 10 0	220 [Note (4)]

NOTES:
(1) Quantity = number by count per solvent flush.
(2) Other oxygen cleaning standard, (e.g., CGA G4.1, ASTM G93, ISO 150001) are capable of meeting the intent of Cleanliness Level IV. Products cleaned to one of these standards may be used in oxygen applications, subject to manufacturer/customer agreement.
(3) Excluding particle, fiber, and hydrocarbon detection procedures.
(4) Changed from 50 ppm (B40.100-2013) to align with other widely-accepted standard in the industry.

such surfaces, or by both. Common cleanliness levels are defined in Table 2-4.2-1.

2-4.3 Inspection for Cleanliness

Hydrocarbon contamination may be determined by quantitative methods such as infrared spectrophotometry or qualitative methods such as black light (ultraviolet) radiation of the long wave type [approximately 3,600 angstrom units (360 nm)], where the solvent used to flush the pressure element assembly is evaluated.

When black light radiation methods are employed, the manufacturer should ascertain that the solvent used will dissolve all hydrocarbons that could be present and that all hydrocarbons are detectable and fluoresce under black light.

The dimensions of particles and fibers are usually determined by microscopic examination of filter paper through which the flushing solvent has been passed.

2-4.4 Packaging

Gauges shall be packaged in such a manner that specified cleanliness requirements are maintained.

The user shall take proper precautions so that cleanliness levels for socket and pressure element are maintained after the gauge is removed from its package for installation.

2-5 PRESSURE GAUGE TESTING

2-5.1 Calibration Standards

2-5.1.1 General Discussion

2-5.1.1.1 Standards shall have nominal errors not greater than $\frac{1}{4}$ of those permitted for the gauge being tested. For example, when testing a 200 psi Grade 1A (1%) gauge, the standard must have errors not more than $\frac{1}{4}$ of 1%, or 0.5 psi. The range of the standard must not be less than that of the gauge under test but may be higher, as long as the errors do not exceed 0.5 psi. A 200 psi Grade 3A gauge, with errors of 0.25% of 200 (0.5 psi), or a 500 psi Grade 4A gauge, with errors of 0.1% of 500 (0.5 psi) or a 1,000 psi digital gauge with errors of 0.05% of 1,000 (0.5 psi) may be used.

Standards for pressure, weight, density, and linear dimensions used in manufacturing and calibrating the test instruments shall conform to equivalent measuring standards that have been calibrated at NIST and shall have a documented path to NIST or comparable international organization (see subsection 1-2 for more information on references).

Complete information regarding manometers and piston gauges is contained in ASME PTC 19.2. To compute their errors, geographical location and elevation must be determined and gravity corrections applied, as outlined in NIST manometery and piston gauge monographs.

2-5.1.1.2 Gauges used as standards shall be tested for accuracy regularly. The frequency of such testing will depend on their demonstrated ability to retain accuracy after a period of time and after repeated use. The date of the last test may be noted on the front of the gauge.

2-5.1.1.3 Piston gauges or other standards that contain oil or other hydrocarbon fluids shall not be used to test oxygen gauges or other gauges cleaned to Level IV. See para. 2-3.2.3.2 and Table 2-4.2-1.

2-5.1.1.4 If a liquid medium is used, correction for the difference in liquid head between the standard and the gauge being tested may be necessary, especially in the case of low-pressure gauges.

2-5.1.1.5 A liquid medium shall not be used to test gauges where the weight of liquid in the pressure element will introduce significant errors. This effect is greater on low-pressure gauges.

2-5.1.1.6 If an air piston gauge is used, no liquid is permitted in the gauge under test, or in the lines between the gauge and the piston gauge.

2-5.1.2 Recommended Standards. A wide variety of mechanical and electronic standards may be used to test gauges. Some of these are

(a) piston gauge (hydraulic or air)
(b) manometer
(c) test gauge
(d) pressure transducer or transmitter

Selection of a standard is determined by the accuracy and pressure range of the gauge being tested, suitability of the medium, convenience of use, and availability.

2-5.2 Verification Test Procedures

The following procedures are suggested when testing a pressure gauge to determine its compliance with the accuracy grades defined in para. 2-2.4. Statistical methods or alternate test procedures, or both, may be used when agreed to by the supplier and the user.

2-5.2.1 Reference Temperature (All Grades). A temperature of 20°C ± 1°C (approximately 68°F ± 2°F) shall be the reference standard. Temperature-compensated gauges shall be tested at several ambient temperatures within the compensated range.

2-5.2.2 Reference Barometric Pressure. A barometric pressure 101.32 kPa (29.92 in. Hg) shall be the reference standard. Only absolute pressure gauges with the pointer set to indicate 14.7 psia will be affected by changes in barometric pressure (see para. 2-2.4.1.11).

2-5.2.3 Calibration Standards. See para. 2-5.1.

2-5.2.4 Procedures

2-5.2.4.1 Accuracy. Usage, range, and accuracy of the gauge should be considered when choosing a test medium.

(a) Grades 3A and 4A. Before conducting the accuracy test, subject the gauge to a pressure equal to the maximum indicated pressure (or vacuum). Conduct the accuracy test within 10 minutes.

(b) All Grades/Classes. Accuracy shall be assessed using one of the following two methods:

(1) Direct Reading. Known pressure shall be applied at each test point on increasing pressure (or vacuum) and record the pressure indication of the gauge under test.

(2) Reverse Reading. Pressurize to a selected pressure indication on the gauge under test and record the pressure indication of the standard used.

At each test point (see Table 2-2.4-1 for the minimum number of recommended test points) the gauge under test shall be read, lightly tapped, and then read again. The difference of the readings is friction error. The same sequence shall be repeated on decreasing pressure (or vacuum). The entire set of upscale and downscale readings shall then be repeated.

The error can be determined from the data obtained in the two pressure cycles and is equal to the maximum error at each test point, in either direction, after tapping. When expressed as a percentage of span, the error shall not exceed the limits for the applicable grade of accuracy.

2-5.2.4.2 Repeatability. Repeatability can be determined from the data obtained in para. 2-5.2.4.1. It is the difference between any two readings taken after tapping, at the same pressure, approached from the same direction, and in the two pressure cycles, expressed in percentage of span. More than two pressure cycles may be desirable.

Repeatability does not include hysteresis or friction error.

2-5.2.4.3 Hysteresis. Hysteresis can be determined from the data obtained in the two pressure cycles (see para. 2-5.2.4.1). It is the difference at each test point between increasing pressure and decreasing pressure readings taken after tapping, at the same test point, approached from both increasing and decreasing pressure directions; in a single pressure cycle, expressed in percentage of span (see Figure 2-5.2.4.3-1).

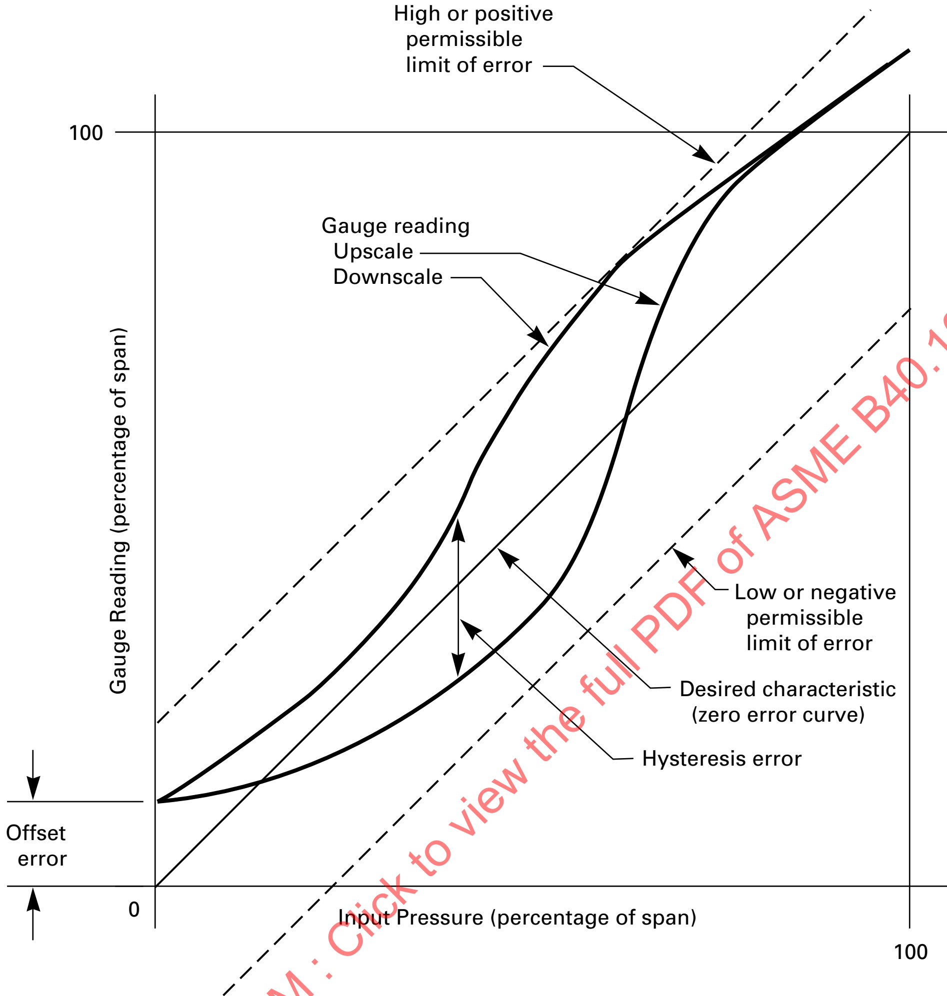
The hysteresis value is lower if the pressure excursion is less than full scale. Hysteresis does not include friction error. Hysteresis error shall not exceed the absolute value of the limits of permissible error at a reference temperature of 20°C (68°F). The amount of hysteresis errors should not move the readings outside the permissible error limits for accuracy (see Figure 2-5.2.4.3-1).

2-6 ORDERING PARAMETERS AND RELATED STANDARDS

2-6.1 Order Checklist

The following includes some factors to consider and questions to answer when ordering pressure gauges.

Figure 2-5.2.4.3-1
Hysteresis and Offset Error



2-6.1.1 Assistance Not Required. If the user does not require assistance with selection and recommendation for service involved, specify

(a) supplier's catalog number, size, range, and connection location and size

(b) variations or accessories, or both, if required

2-6.1.2 Moderate Assistance Required. If the user requires moderate assistance, specify

(a) range (include units of measure) (see para. 2-2.2)

(b) accuracy (see para. 2-2.4)

(c) size (see para. 2-2.1 and Figure 2-2.3.1.5-1)

(d) method of joining the pressure-containing components

(e) connection type, location, and size

(f) mounting (stem, surface, or flush) (see Figure 1-3-3)

(g) supplier's catalog number

(h) variations or accessories, or both

2-6.1.3 Detailed Assistance Required. If the user requires detailed assistance, specify items listed in para. 2-6.1.2 plus the applicable portions of the following:

(a) medium, name and state (gas or liquid), concentration, temperature

(b) material of process equipment

(c) pressure pulsation range and frequency

(d) sudden pressure increase or decrease (spike or surge)

(e) case and ring materials

(f) window material

(g) environmental conditions such as

(1) vibration frequency and amplitude

(2) temperature

(3) indoor and outdoor use

(4) corrosive atmosphere

(5) dust

(6) weather resistance

(7) humidity

(8) mechanical shock

2-6.2 Conversion Factors (Customary Units to SI Units)

The Customary measuring units are listed below with their corresponding SI units and conversion factors. Multiplying the Customary units by the conversion factor will yield the correct value in SI units (see Table 2-6.2-1).

Table 2-6.2-1
Conversion Factors

Customary Unit X	Conversion Factor [Note (1)]	= SI Unit
atmosphere (standard)	1.01325 E+05	Pa (pascal)
bar [Note (2)]	1.00000 E+05	Pa
in. (inch)	2.54000 E−02	m (meter)
ft (foot)	3.04800 E−01	m
in. H_2O (4°C)	2.49081 E+02	Pa
in. H_2O (20°C)	2.48640 E+02	Pa
in. H_2O (60°F)	2.48850 E+02	Pa
ft H_2O (20°C)	2.98370 E+03	Pa
in.^{2} (square inches)	6.45160 E−04	m^2 (square meters)
ft^2 (square feet)	9.29030 E−02	m^2
psi (pound force per	6.89476 E+03	Pa
square inch)	6.89476 E−02	bar [Note (2)]
oz/in.^{2} (ounce per square inch)	4.30922 E+02	Pa
in. Hg (mercury) (0°C)	3.38638 E+03	Pa
micron	1.00000 E−06	m
°F (degree Fahrenheit)	(°F − 32)/1.8	°C (degree Celsius)

NOTES:

(1) Conversion factors are expressed as a number between 1.0 and 10.0 with five decimal places. This number is followed by the letter E (for exponent), a plus or minus symbol, and two digits indicating the power of 10 by which the number must be multiplied to correctly place the decimal point. The plus or minus indicates the direction the decimal must be moved: plus to the right, minus to the left. See following examples:

2.54000 E−02 means 2.54000×10^{-2} and equals 0.025400
1.01325 E+05 means 1.01325×10^{5} and equals 101,325

(2) The bar is a unit outside the SI system that is nevertheless recognized by the Comité International des Poids et Mesures (CIPM).

Section 3
Diaphragm Seals

3-1 DIAPHRAGM SEALS, GENERAL

3-1.1 Mounting of Diaphragm Seals.

The physical or "flow properties" of the medium such as listed below may determine the method of attaching or installing the diaphragm seal:

(a) the physical characteristics, i.e., a gas or liquid
(b) the percentage of solids
(c) the melting and freezing point
(d) the effect of changes in process or ambient temperatures on the viscosity
(e) the maximum and minimum temperatures
(f) the maximum and minimum process pressure
(g) the need to provide the capability to clean the process piping

3-1.1.1 Threaded Connection. The most common method for attaching or installing a diaphragm seal to a process line, tank, or vessel is with a threaded connection. Common connections are from $^1/_4$ NPT to $1^1/_2$ NPT per ASME B1.20.1. With this method of connection, process media should be either liquid, vapor, or gas, or a combination of these, but free from solids. A small percentage of solids could plug or clog the process takeoff pipe or build up in the isolator cavity on the process side of the diaphragm.

Process media should not be excessively viscous, or of the type that will solidify in the takeoff pipe or the lower housing of the diaphragm seal within the limits of the ambient and process temperatures.

3-1.1.2 Flanged Connection. A second method of attaching diaphragm seals is by a flanged connection. The integral flange of the isolator is bolted to a companion flange in the process piping or to flange openings, as hand holes, on tanks and vessels. Common pipe sizes are from $^1/_2$ in. to 6 in. with ASME B16.5 flanges in pressure classes of 150, 300, 600, 1500, and 2500; however, this list is not all-inclusive. Refer to ASME 16.5 for more information. Flanged seals may also be manufactured to other standards such as DIN.

3-1.1.3 In-Line Connection. A third method is to install the diaphragm seal directly in the process flow line. These are referred to as "in-line" or "flow-through" types. This diaphragm seal is so designed that the diaphragm is essentially flush with the flow stream and thus continually washed by the process media. The "inline" type should be used when the process media is a slurry or a liquid that contains a solid component, is viscous, or has a melting or freezing point at normal ambient temperatures. This method is frequently used where process lines are externally heated. The process connections are as follows:

(a) Threaded. Pressure lines are connected using a threaded connection; generally, NPT.
(b) Flanged. Process connections are connected to pressure flanges.
(c) Butt Welded. The diaphragm seal is butt welded directly to the process line.
(d) Socket Welded. The diaphragm seal is socket welded directly to the process line.
(e) Saddle. The diaphragm seal is fillet welded within a hole cut into the process pipe or may be secured by a saddle adapter welded onto the process pipe.
(f) Clamped (Sanitary). Sanitary application, such as food processing require diaphragm seals to be easily cleaned after use. Quick removable clamps may be used to connect the diaphragm seal to the process connection (lower housing). Industry standards cover specific details of these applications.

3-1.2 Construction

A diaphragm seal consists of several components, as described in paras. 3-1.2.1 through 3-1.2.15.

3-1.2.1 Diaphragm. The diaphragm is the most critical component in the assembly. It separates the medium from the fill fluid. It is designed to flex in a direction essentially perpendicular to its surface. Diaphragms are generally convoluted, because sensitivity over a wide range of pressure is greater than that of a flat diaphragm of the same diameter.

3-1.2.2 Upper Housing. The upper housing includes a connection for the pressure instrument. Since this component is not in contact with the process fluid, it is commonly made of steel. However, if the external atmosphere contains corrosive elements, other materials may be required. Standard instrument connections are $^1/_4$ NPT and $^1/_2$ NPT female.

3-1.2.2.1 Upper Housing, Continuous Duty. Should the pressure instrument leak or be removed, the diaphragm will seat against a matching or other support surface in the upper housing, preventing damage to the diaphragm or leaking of the medium [see Figure 3-1.2.2.1-1 and para. 3-1.9.4.2(h)].

3-1.2.2.2 Upper Housing, Continuous Seal. Should the pressure instrument leak, or be removed accidentally, the diaphragm will seat against a support surface in the upper housing to prevent leakage of the medium. The diaphragm may be damaged [see para. 3-1.9.4.2(i)].

3-1.2.2.3 Upper Housing, Noncontinuous Duty. The upper housing does not contain a matching or other support surface to support the diaphragm. Leakage of the pressure instrument or removal may result in damage to the diaphragm and loss of the medium (see Figure 3-1.2.2.3-1).

3-1.2.2.4 Upper Housing, Removable. The pressure instrument and top housing assembly may be removed from the bottom housing as a unit, without loss of fill fluid (this should be done only when there is no pressure in the process line. The diaphragm may be made in the form of a capsule threaded into the upper housing or the diaphragm may be clamped to the upper housing with a middle housing, welded, bonded, or otherwise attached to the upper housing (see Figures 3-1.2.2.4-1 and 3-1.2.2.4-2).

3-1.2.2.5 Upper Housing, Nonremovable. When the diaphragm is clamped to the upper housing by the lower housing, removal of the pressure instrument and upper housing assembly from the lower housing will result in loss of the fill fluid (see Figure 3-1.2.2.5-1).

3-1.2.2.6 Upper Housing, Flush Flanged. Flanged seals include a mounting flange that assists when aligning the diaphragm with the process connection. The 2 in. to 5 in. versions of this seal may be used with the diaphragm surface flush with the process or with a flushing ring. The diaphragm is an integral part of a standard flange and installed to be flush with the flange sealing face [see Figure 3-1.2.2.6-1, illustration (a)].

3-1.2.2.7 Upper Housing, Flush Flanged Seal (Sandwiched) With Backup Flange. These seals provide a basic 2 in. to 5 in. process connection. Available with or without a flushing ring, this seal has a flush or recessed diaphragm surface. The capillary connection is on the side of the seal, enabling use in areas where space is limited or restricted on the outside of the vessel. Because the flange is not a permanent part of this seal, it provides more user flexibility where flanges with different pressure ratings are required. The diaphragm housing corresponds to the size of the sealing face of a standard flange. Upon installation, the diaphragm seal is sandwiched between the process flange and a standard blind flange [see Figure 3-1.2.2.6-1, illustration (b)].

3-1.2.2.8 Upper Housing, Inserted Flange. The upper housing with its welded diaphragm is separated from the retainer flange (see Figure 3-1.2.2.8-1).

3-1.2.2.9 Upper Housing, Flanged Seal With Extended Diaphragm. Extended flanged seals in 2 in. to 5 in. versions are common and provide a choice of extension length. Typical extension lengths are 2 in., 4 in., 6 in., and 8 in. These seals mount on pipe flanges and extend through insulation to the tank wall (see Figure 3-1.2.2.9-1).

3-1.2.3 Lower Housing. The lower housing connects to the process line, and is wetted by the medium. For this reason, the material must be compatible with the medium. See para. 3-1.2.10 for process connections.

3-1.2.4 Mid-Housing (Cleanout Ring). The mid-housing (cleanout ring) is located between the upper and lower housing. This housing is used on diaphragm seals with replaceable diaphragms. Removal of the connection between the mid-housing and the lower housing permits access to the process side of the diaphragm without loss of the seal between the upper housing and the diaphragm. This housing is exposed to the medium and the material must be compatible with the medium. If a diaphragm capsule is used, a mid-housing may not be required [see Figures 3-1.2.2.4-1 and 3-1.2.2.4-2, illustration (a)].

3-1.2.5 Gasket. A gasket or O-ring may be used to seal joints exposed to the medium. The material must be compatible with the medium. A coating on the diaphragm or housing may function as the gasket.

3-1.2.6 Reinforcing Rings. Some diaphragm seal designs use reinforcing rings to support clamping forces on nonmetallic lower housings. These rings are generally not in contact with the medium and are commonly made of steel. If the external atmosphere contains corrosive elements, other materials may be required [see Figure 3-1.2.6-1, illustration (b)].

3-1.2.7 Fastening Methods. Several methods may be employed to fasten the upper, mid, and lower housing together.

(a) Bolts and Nuts. A series of bolts and nuts are used to fasten the upper housing to either the mid or lower housing. The housing may be tapped to replace the nut.

(b) Clamp. A clamp assembly may fasten the upper housing to the lower housing [see Figure 3-1.2.7-1, illustration (a)].

(c) Welded. The upper and lower housings may be joined by a weld. Weld filler material is generally identical to the material of the lower housing [see Figure 3-1.2.7-1, illustration (b)].

The fastening method is generally not in contact with the medium.

Figure 3-1.2.2.1-1
Upper Housing, Continuous Duty

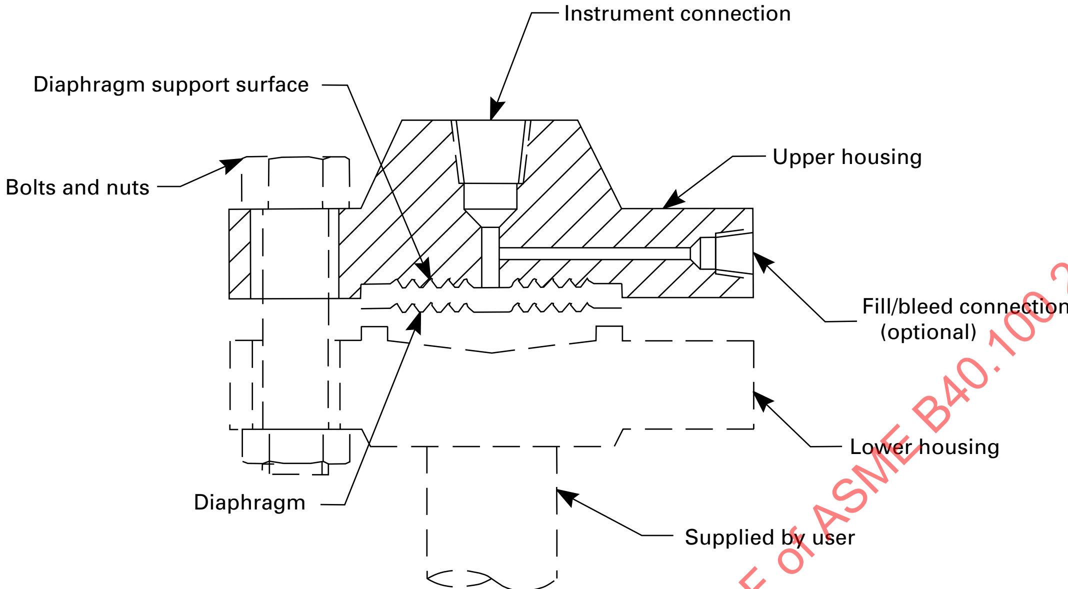


Figure 3-1.2.2.3-1
Upper Housing, Noncontinuous Duty

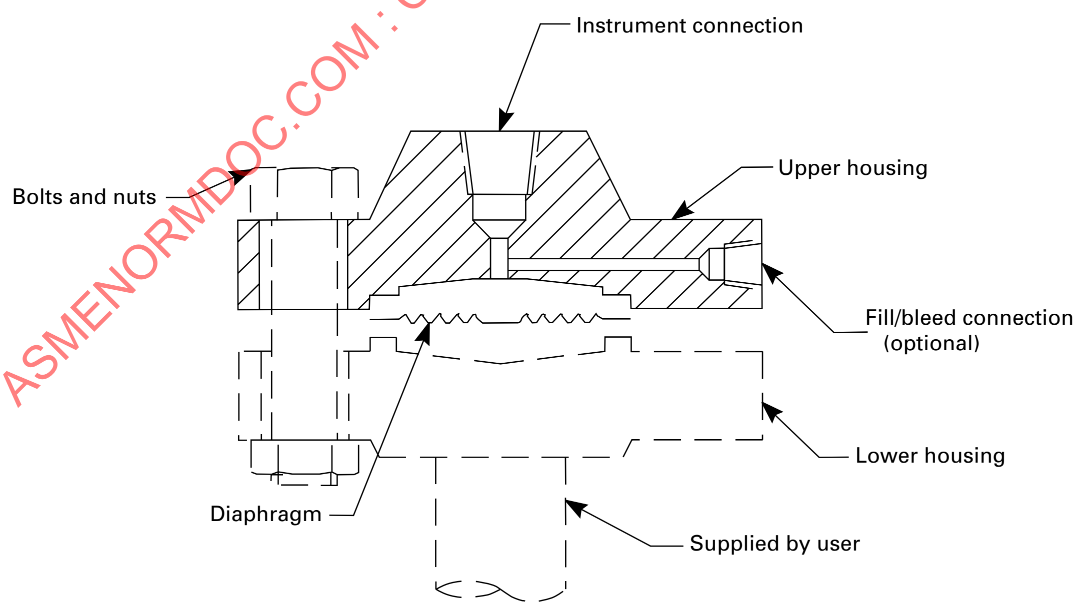
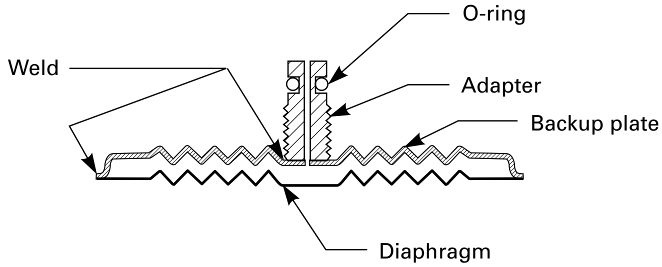


Figure 3-1.2.2.4-1
Upper Housing, Removable (With Capsule Assembly)



Capsule

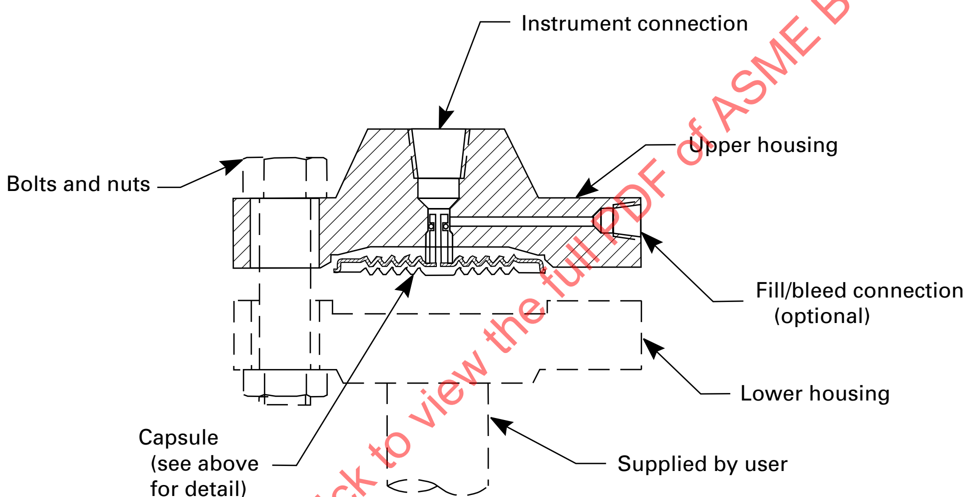
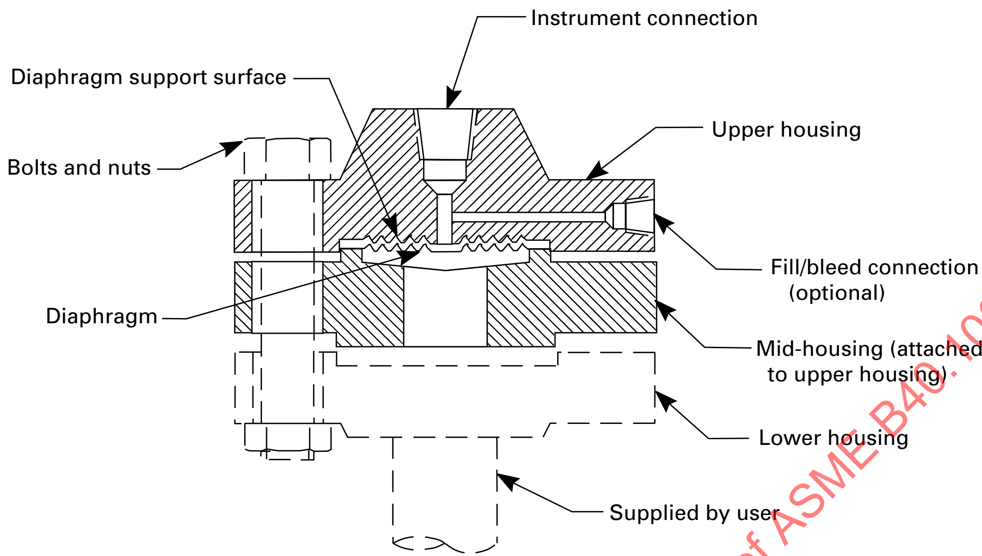
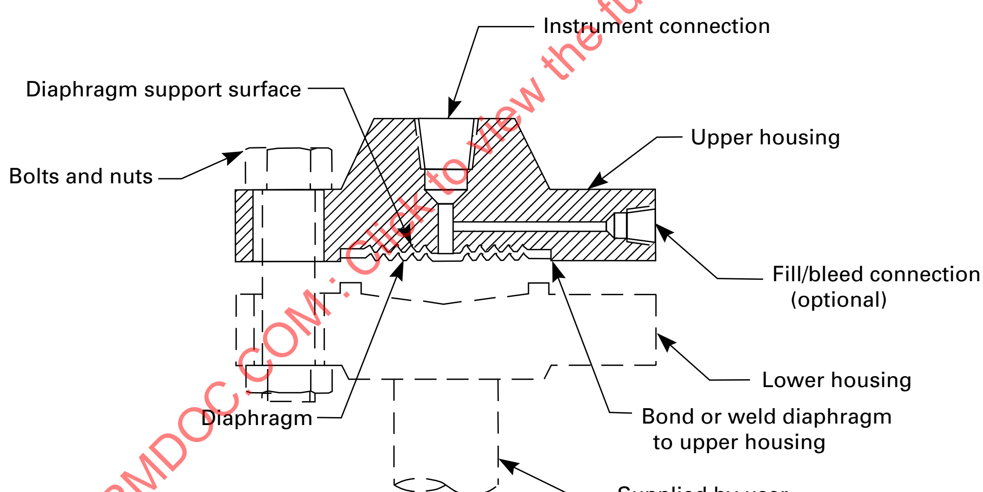


Figure 3-1.2.2.4-2
Upper Housing, Removable



(a)



(b)

Figure 3-1.2.2.5-1
Upper Housing, Nonremovable

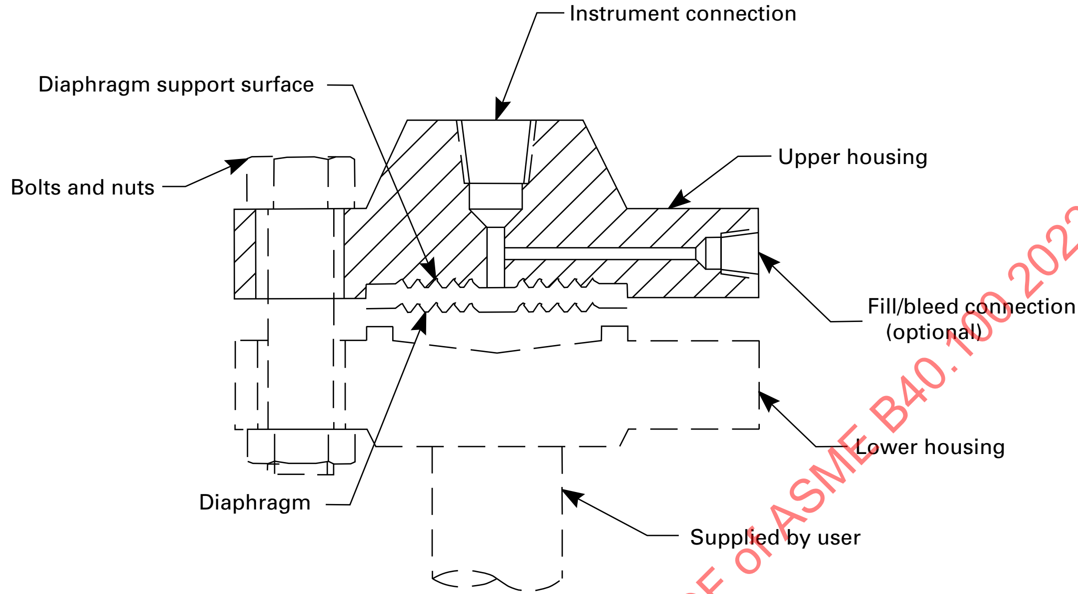
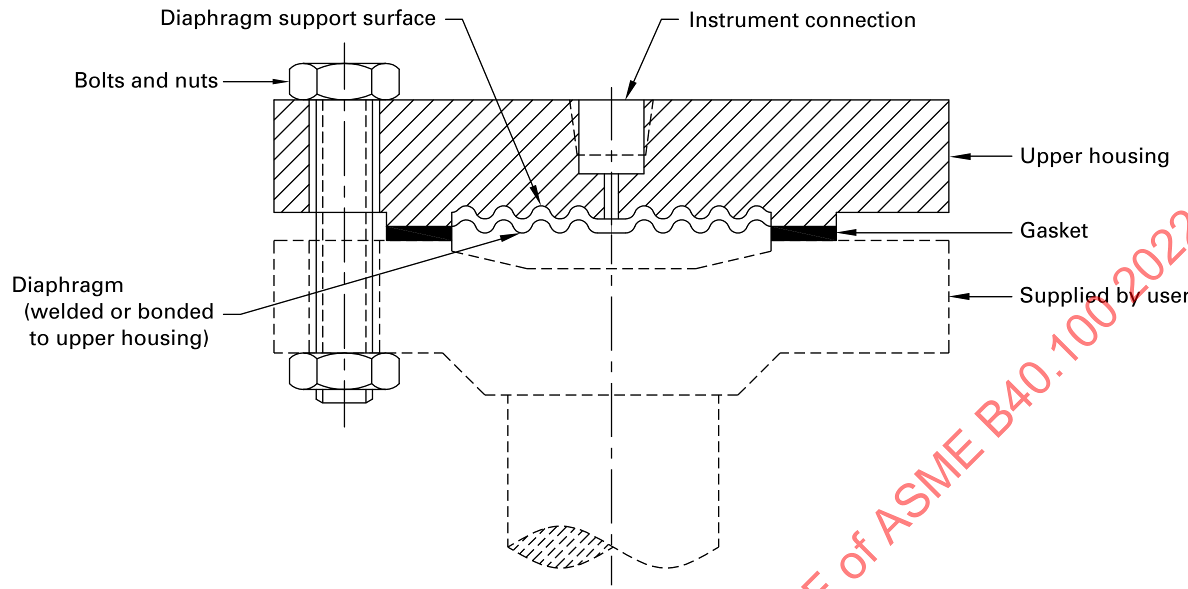
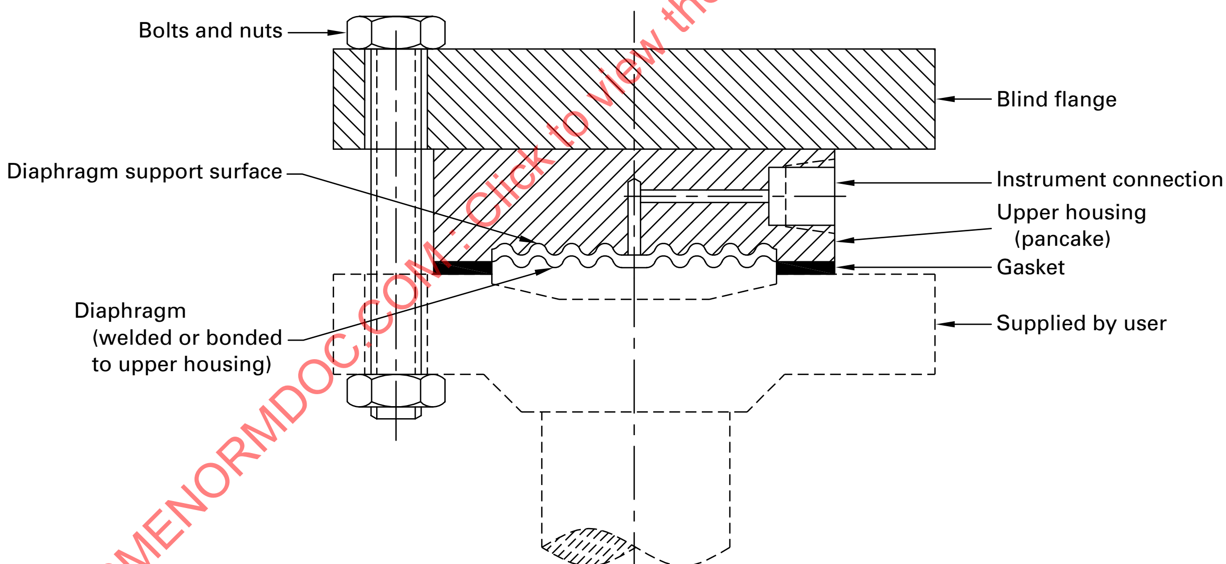


Figure 3-1.2.2.6-1
Upper Housing, Flush Flanged



(a)



(b)

Figure 3-1.2.2.8-1
Upper Housing, Inserted Flange

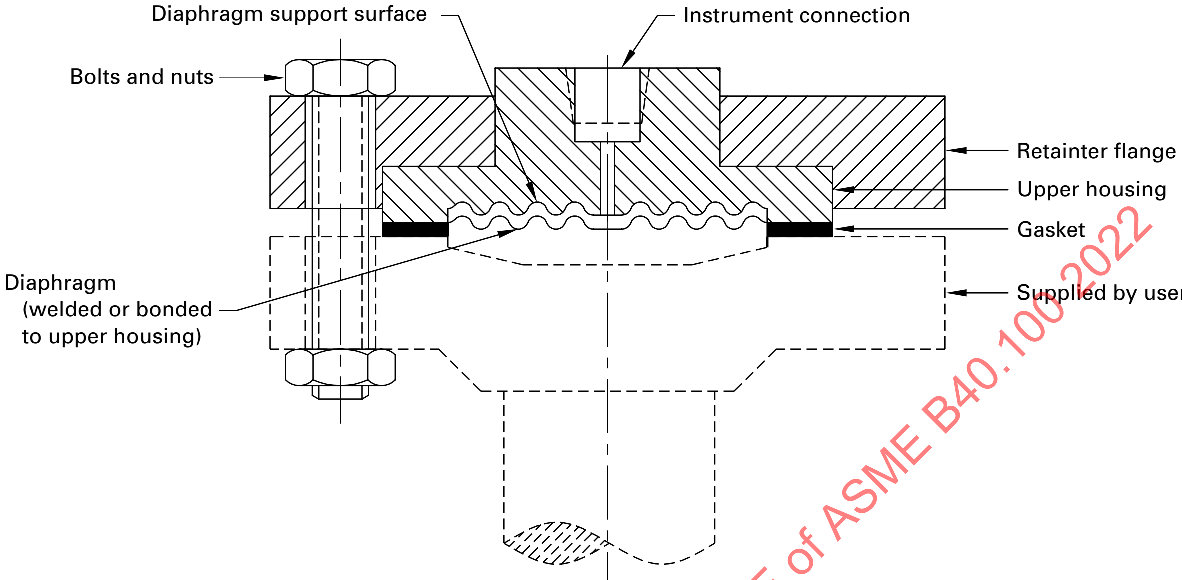


Figure 3-1.2.2.9-1
Upper Housing, Flanged Seal

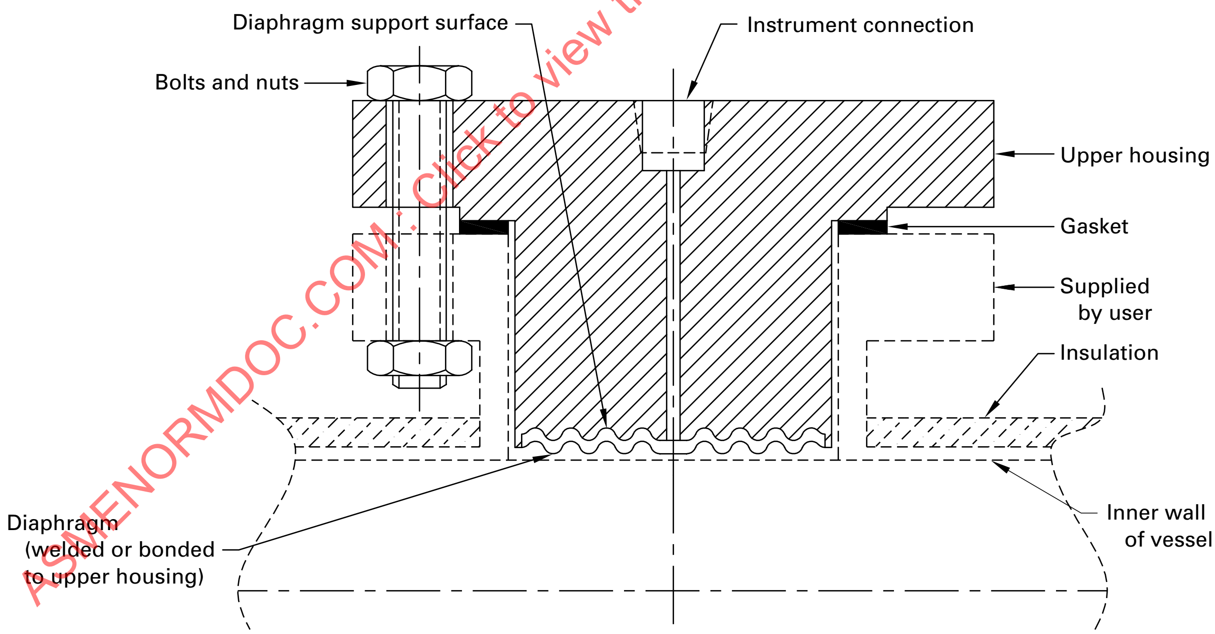
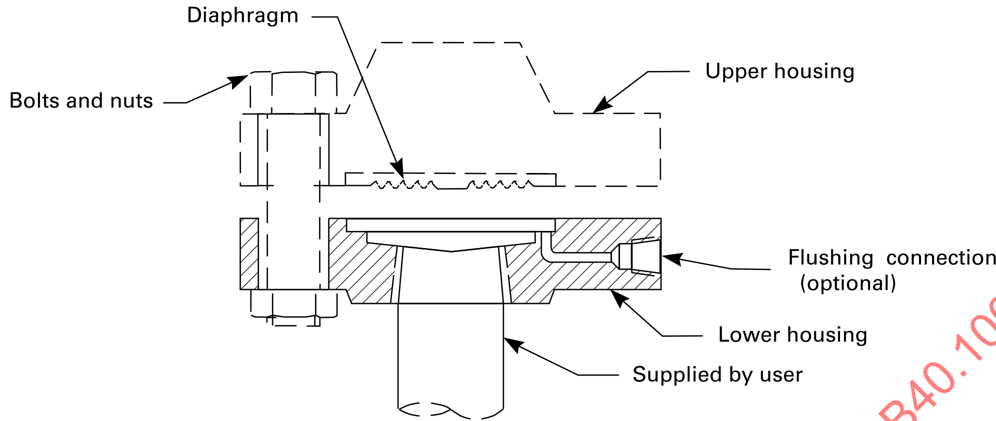
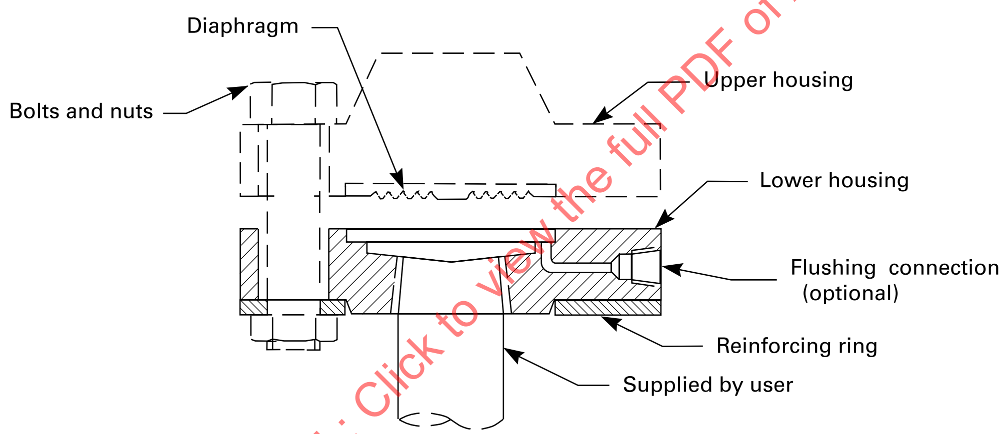


Figure 3-1.2.6-1
Lower Housing



(a) Without Reinforcing Ring



(b) With Reinforcing Ring

3-1.2.8 Fill/Bleed Connection (Optional Feature). A fill/bleed port is a connection machined integral with the upper housing, accessing the filled volume. A fill adapter may be inserted into the fill/bleed port allowing filling of the diaphragm seal/instrument assembly after assembly. After filling, the bleed screw is inserted into the fill/bleed port for sealing purposes and may be used to permit bleeding excess fill fluid (see Figure 3-1.2.2.1-1).

3-1.2.9 Instrument Connection. The pressure instrument is attached directly to the diaphragm seal. Standard instrument connection ports are 1/4 NPT and 1/2 NPT female, although other connections may be used as required.

It may be desirable, however, to install the instrument remote from the seal, for one or more of the following reasons:

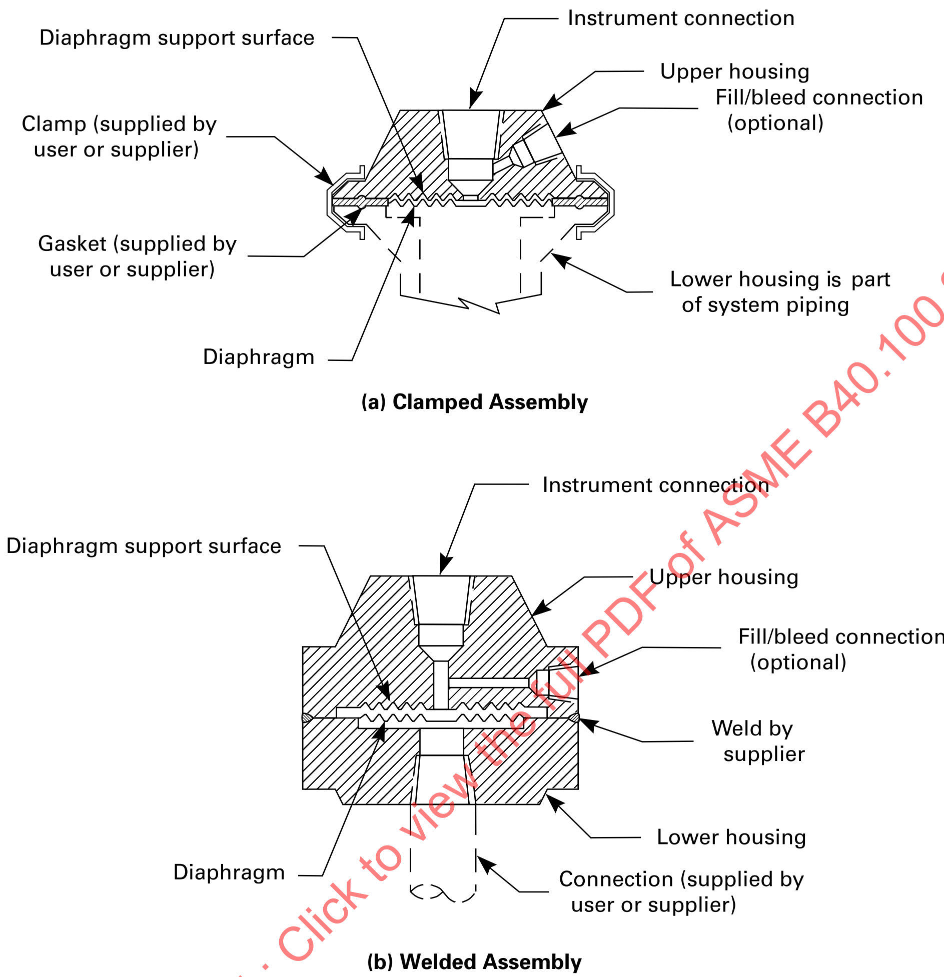
(a) to remove the instrument from an adverse environment (e.g., temperature, corrosive atmosphere, and vibration)

(b) to locate the instrument in a more convenient location for readability or serviceability

3-1.2.9.1 Remote Instrument Attachment. If remote attachment is necessary, a length of capillary with suitable end fittings may be installed between the instrument and the seal. This capillary may be enclosed in a protective armor.

The following factors must be considered when remote mounting is required:

Figure 3-1.2.7-1
Fastening Methods



(a) The bore of the capillary must be kept to a minimum in order to reduce the effect of ambient temperature changes upon the accuracy of the instrument. If the bore is too small, however, the response time of the assembly may become unacceptably long and filling will be more difficult. A bore of approximately $^1/_{16}$ in. (2 mm) is suggested for most applications.

(b) The capillary material and size must be suitable for the maximum and minimum pressure and temperature of the medium and the maximum and minimum ambient temperatures.

(c) The elevation of the instrument above or below the seal will introduce a head effect on its reading or output, and will be more significant at low operating pressures.

(d) As capillary length increases, time response and temperature errors will increase.

(e) Length, size, material, and stiffness of the capillary must be such that it can be suitably installed.

(f) Capillary material, and joints between capillary and end fittings, must be compatible with expected ambient conditions, especially ambient temperatures and corrosiveness.

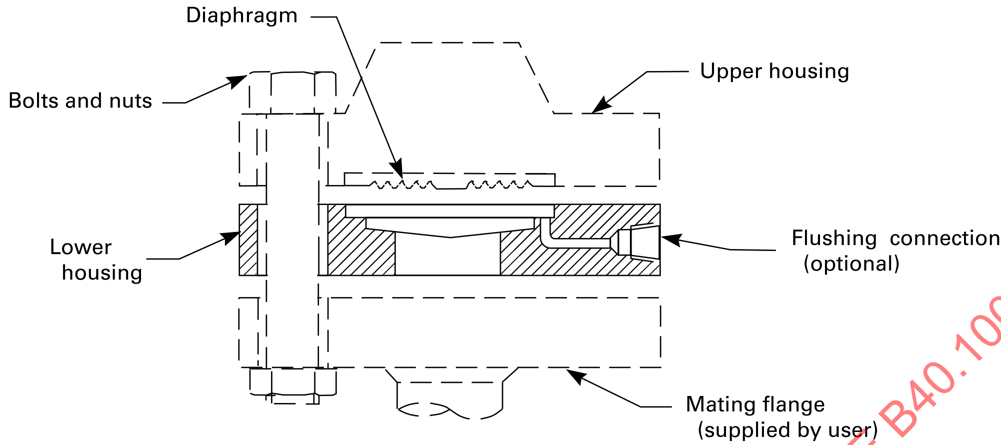
(g) All joints between the seal and the instrument must be leak-tight.

3-1.2.10 Process Connections (Lower Housing). Common process connections are described in paras. 3-1.2.10.1 through 3-1.2.10.5.

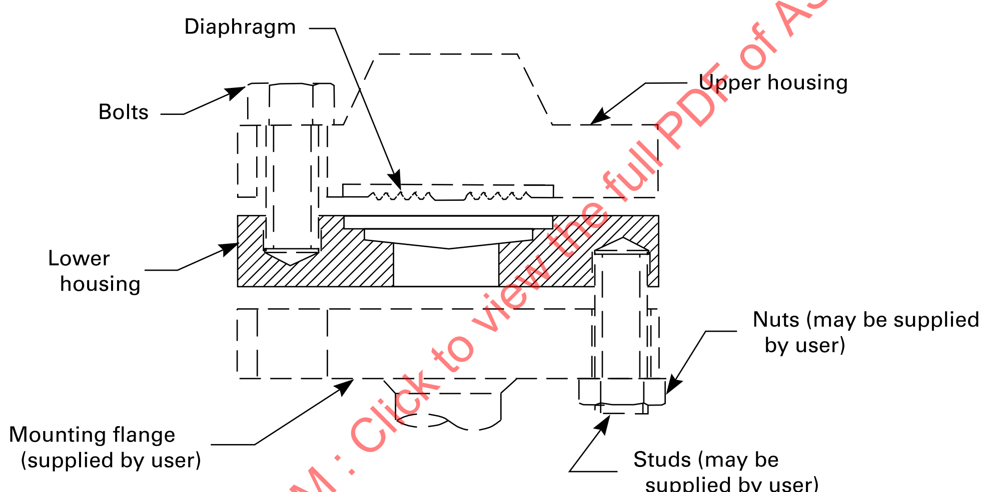
3-1.2.10.1 Threaded. The lower housing includes a threaded connection for attachment to the process line (see Figure 3-1.2.6-1). A threaded lower housing may be provided with wrench flats or spanner wrench holes to facilitate assembly.

3-1.2.10.2 Flanged. The lower housing is designed to mate and seal with a companion ASME B16.5 flange in various sizes and pressure ratings. Flanged diaphragm seal parts may be manufactured of bar stock, castings,

Figure 3-1.2.10.2-1
Flanged Seal



(a)



(b)

or forgings [see Figure 3-1.2.10.2-1, illustration (a)]. In the smaller sizes, the use of studs assembled to the lower housing may be necessary because of diaphragm design considerations [see Figure 3-1.2.10.2-1, illustration (b)].

3-1.2.10.3 In-Line (Flow-Through). In this type, the diaphragm surface is paralleled to the process flow, resulting in minimum restriction of the flow, and less tendency to build up deposits in the seal because the flow tends to wash the diaphragm continually. Connections are as follow:

(a) threaded (see Figure 3-1.2.10.3-1)
(b) flanged (see Figure 3-1.2.10.3-2)
(c) butt weld (see Figure 3-1.2.10.3-3)
(d) socket weld (see Figure 3-1.2.10.3-4)
(e) Saddle

(1) fillet welded within a hole cut in the process line [see Figure 3-1.2.10.3-5, illustration (a)]

(2) fillet welded onto the process line [see Figure 3-1.2.10.3-5, illustration (b)]

(f) sleeve [see Figure 3-1.2.10.3-2, illustration (b)].

3-1.2.10.4 Standard Saddle: Typical Design Approaches. There are two typical styles of saddles used in practice today. For purposes of this standard, the first style group is termed "traditional", which historically has been most common in the U.S. market, while the second is termed "unified upper housing saddle", which historically has been the common approach for European designs. See Figure 3-1.2.10.3-5 for details regarding the designs referenced below.

Figure 3-1.2.10.3-1
Threaded Seal

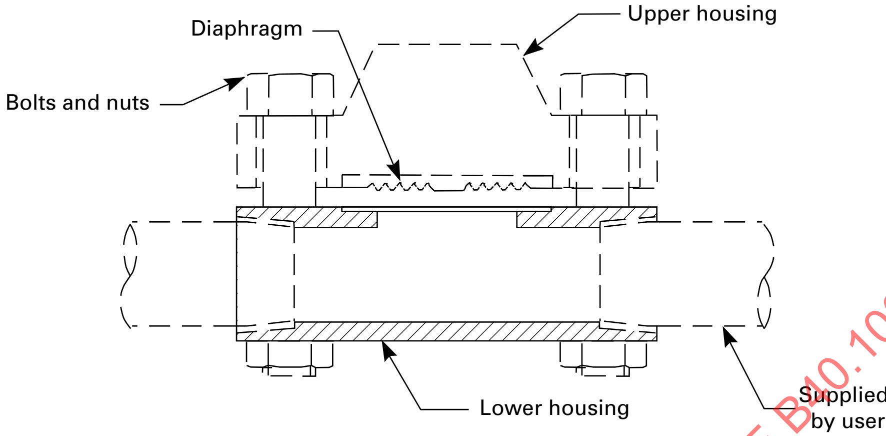
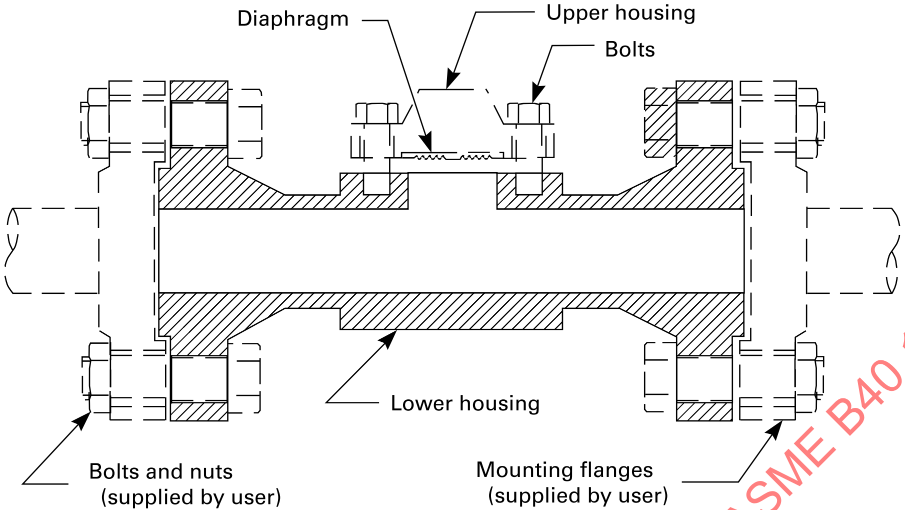
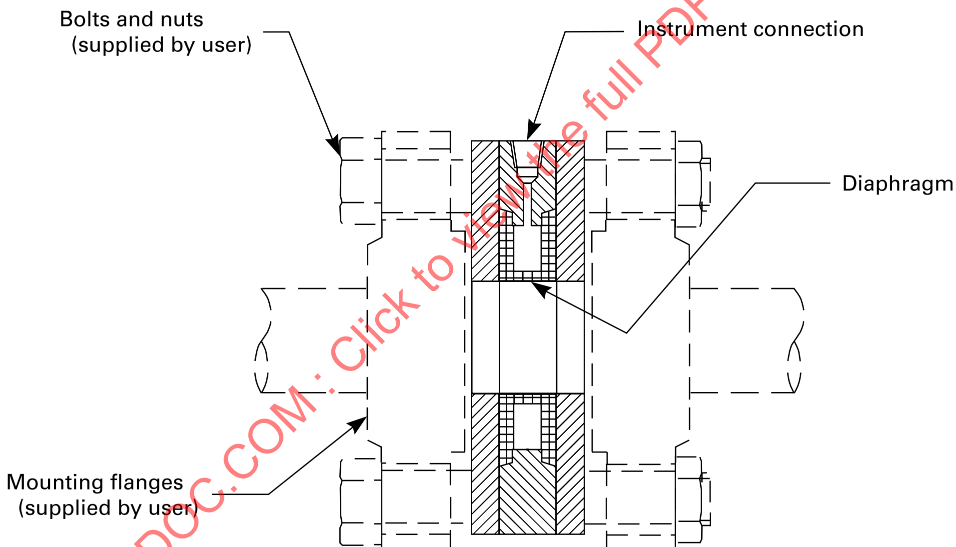


Figure 3-1.2.10.3-2
Flanged Seal With Sleeve



(a)



(b) With Sleeve

Figure 3-1.2.10.3-3
Butt Weld Seal

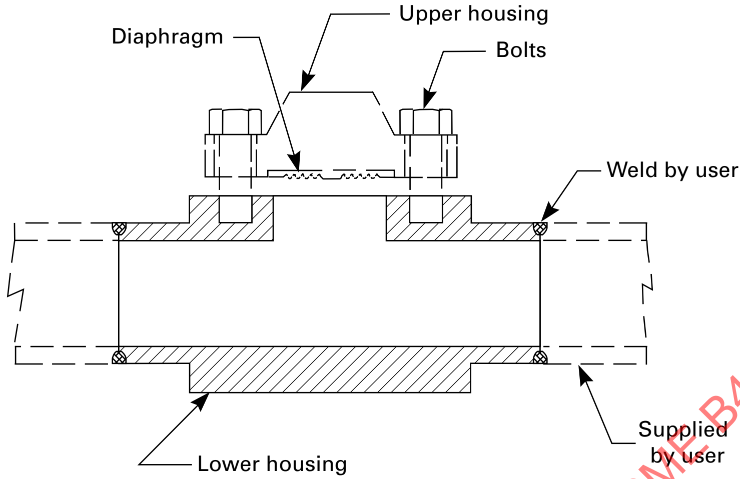


Figure 3-1.2.10.3-4
Socket Weld Seal

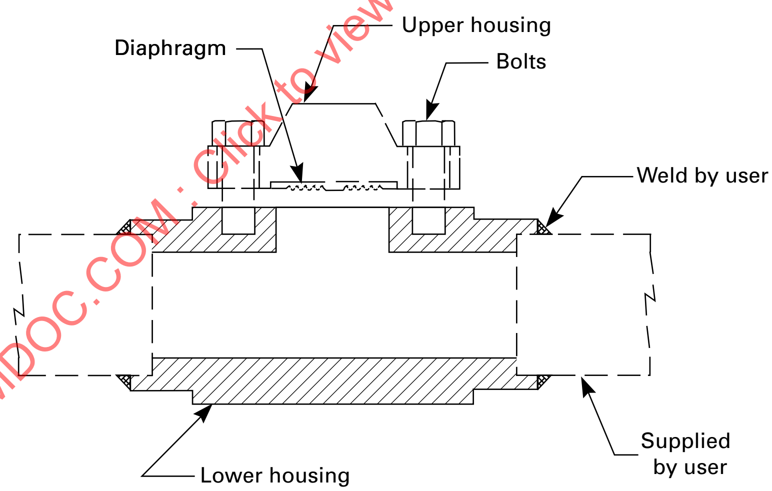
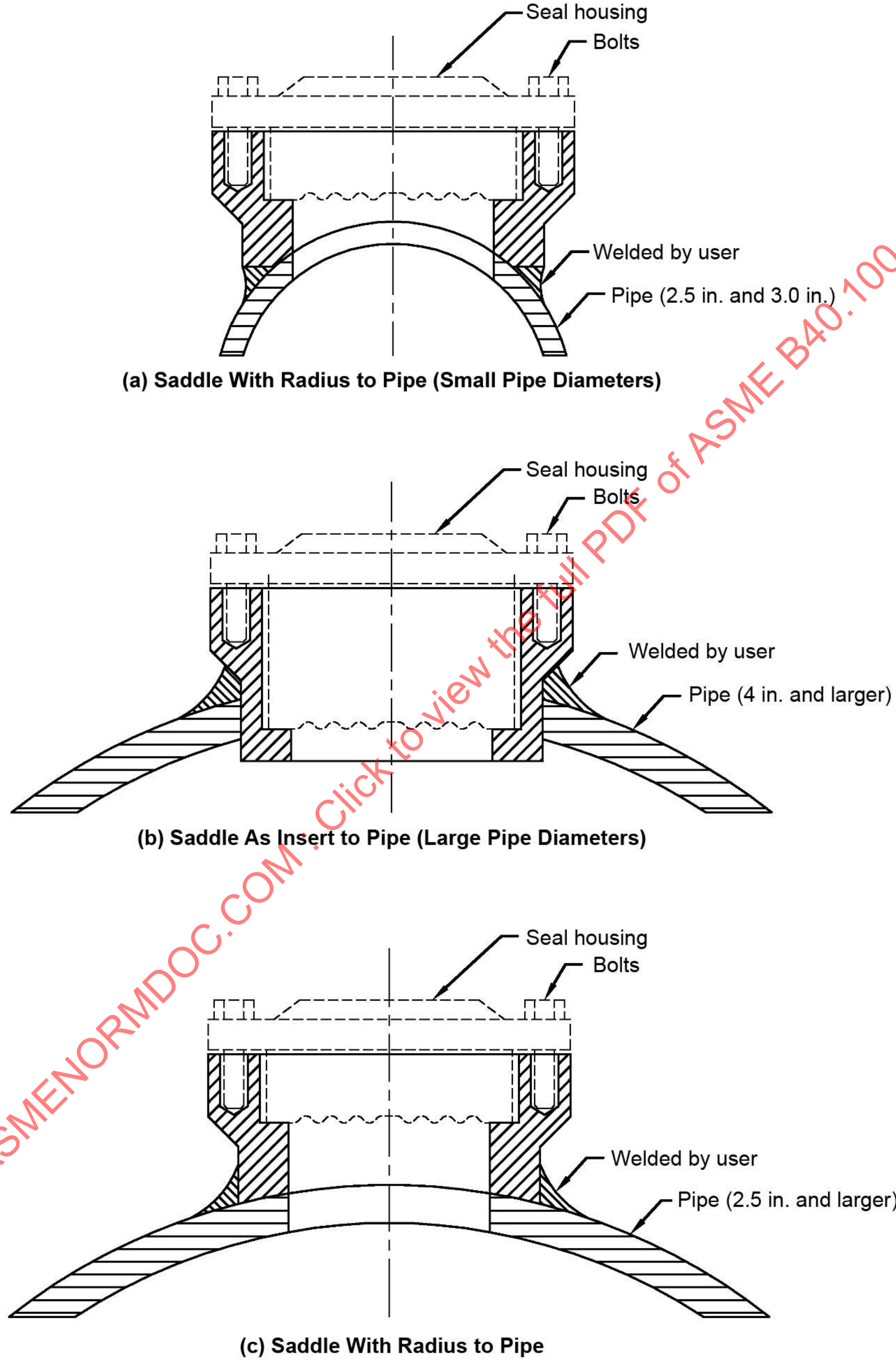


Figure 3-1.2.10.3-5
Welded Seal Saddle



(a) Traditional. Use Design (a) for pipes 2.5 in. and 3 in. where the saddle base has radius equal to the pipe size. Use Design (b) for pipes 4 in. and larger where the saddle base is of an insertion-type design. Notes regarding these designs are as follows:

(1) insert lengths differ

(2) bolt hole patterns are the same

(3) hardware is the same (bolts, gasket, etc.)

(4) maximum working pressure of 1,500 psi (100 bar)[1]

(5) best practices/welding procedure are determined per manufacturer

(b) Unified Upper Housing Saddle. Use Design (c) for pipes for 2.5 in. and larger. Notes regarding this design:

(1) radius is determined by pipe size; up to 24 in.

(2) insert length is the same

(3) bolt hole pattern is the same

(4) hardware is the same (bolts, gasket etc.)

(5) maximum working pressure of 1,500 psi (100 bar)[1]

(6) best practices/welding procedure are determined per manufacturer

3-1.2.10.5 In-Line Seal (Crevice Free). This seal is suitable for rapidly flowing process fluids. The seal forms an integral part of the pipe to allow undisturbed flow of the process. The housing diameter corresponds to the size of the sealing face of a standard flange or standard clamp connection. The seal is comprised of a cylindrical jacket section (tube) in which the round diaphragm is welded (see Figure 3-1.2.10.5-1).

3-1.2.11 Flushing Connection (Optional Feature). Threaded and flanged lower housings may be provided with a flushing connection, permitting the user to purge the area below the diaphragm without removing the diaphragm seal from the process line. This connection may be located in the mid-housing, if supplied [see Figure 3-1.2.6-1, illustration (a)].

3-1.2.11.1 Flushing Ring. Flushing rings are commonly provided with one or two ¼ NPT or ½ NPT connection(s). The ring facilitates purging of the process cavity. The ring is mounted between the diaphragm seal and the process flange (see Figure 3-1.2.11.1-1).

3-1.2.13 Sanitary Seals. Sanitary seals are quick disconnect types, where the upper and lower housings are held together by a unique clamp, permitting ease of dismantling and cleaning [see Figure 3-1.2.7-1, illustration (a)].

3-1.2.14 Gauge Isolators. This type of seal consists of an elastomeric bladder installed within the connection of a pressure instrument or within an adapter fitting (see Figure 3-1.2.14-1).

3-1.2.15 Pressure Ratings. Pressure ratings decrease (possibly significantly) as process or ambient temperatures increase. Suppliers provide pressure/temperature ratings for various materials and configurations of diaphragm seals.

Most metal threaded lower housing connections have a rating of 2,500 psi at 100°F (37.8°C). Ratings of flanged seals are usually determined by the ASME B16.5 flange pressure and temperature ratings. Pressure/ temperature ratings of plastic components are generally lower than metal components.

3-1.2.16 Locking Device (Optional Feature). A device that minimizes the possibility of an instrument turning after installation on the diaphragm seal. The locking device bolts to the top housing and holds the instrument's wrench flat in a stationary position.

3-1.3 Material Selection

3-1.3.1 The materials used in fabrication of the diaphragm seal will depend upon the chemical and physical properties of the medium.

3-1.3.2 The majority of failures of diaphragm seals are due to the improper selection of materials for diaphragms and other surfaces exposed to the medium. In the selection of materials of construction for any medium resistance to corrosion is usually the determining factor. As a general rule, the same material used in process construction, pipelines, tanks, etc., should be used for the surfaces exposed to the medium. Because of the thin cross section, special attention must be given to the selection of material for the diaphragm. Sometimes a material more corrosion resistant than the heavier bottom housing or associated piping should be considered. The physical characteristics of the medium, such as temperature and pressure, should also be considered. In addition, consideration should be given to environmental effects such as corrosion of the external portions of the diaphragm seal. Laboratory corrosion tests duplicating process and/or ambient conditions may be required. The user should obtain expert advice from a qualified source for selection of materials. The materials of construction in contact with the medium should be identified on the diaphragm seal.

3-1.3.3 Plastics such as PVC, Teflon®, etc., are used for lower and middle housings in diaphragm seals. However, there are temperature and pressure limitations to all plastics which must be strictly adhered to, or the application will fail. Because of their low tensile strength and cold flow characteristics, plastics are usually not recommended for threaded process connections. If threaded plastic bottom housings are required, care must be taken to avoid overtightening the process connection, which could cause failure of the housing after a period of time.

[1] Pressure ranges exceeding 1,500 psi must be checked for viability.

Figure 3-1.2.10.5-1
In-Line Seal (Crevice Free)

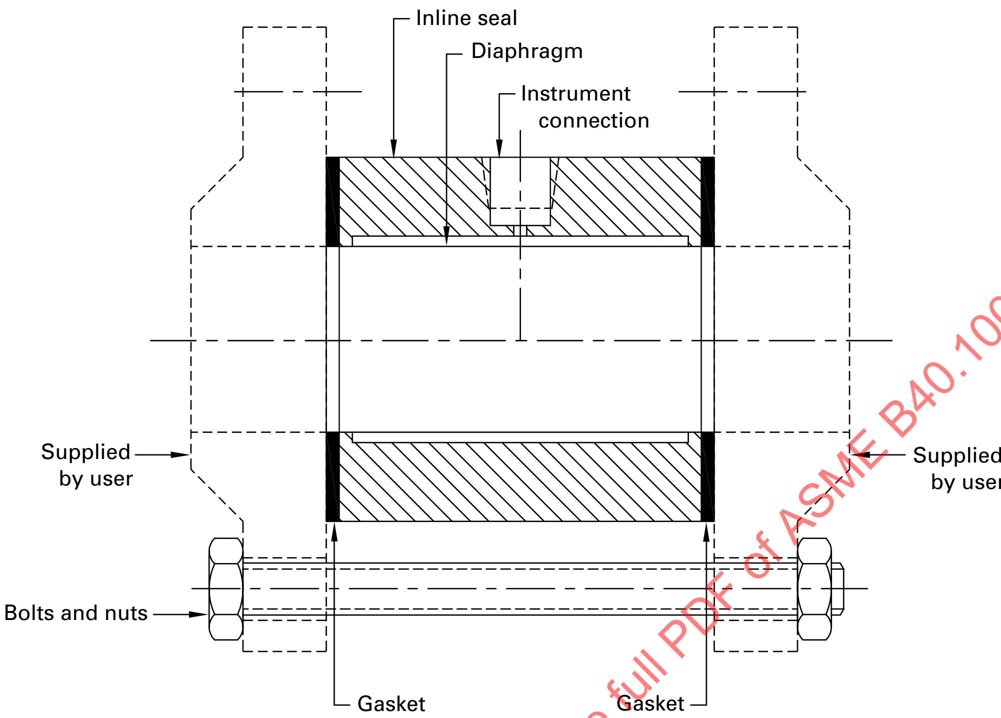


Figure 3-1.2.11.1-1
Flushing Ring

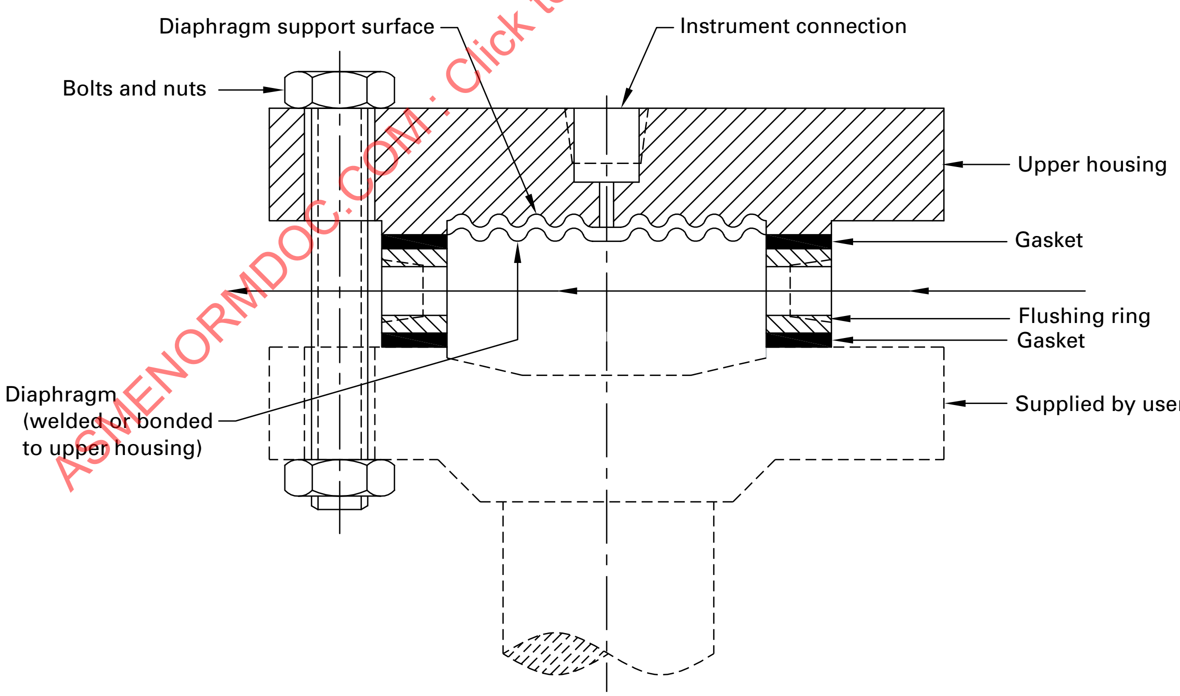
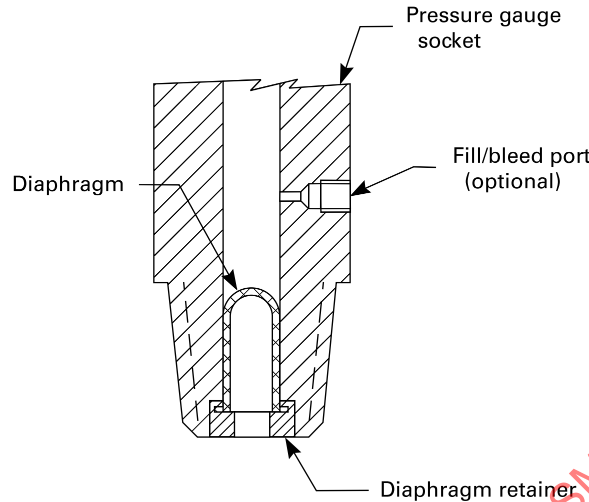
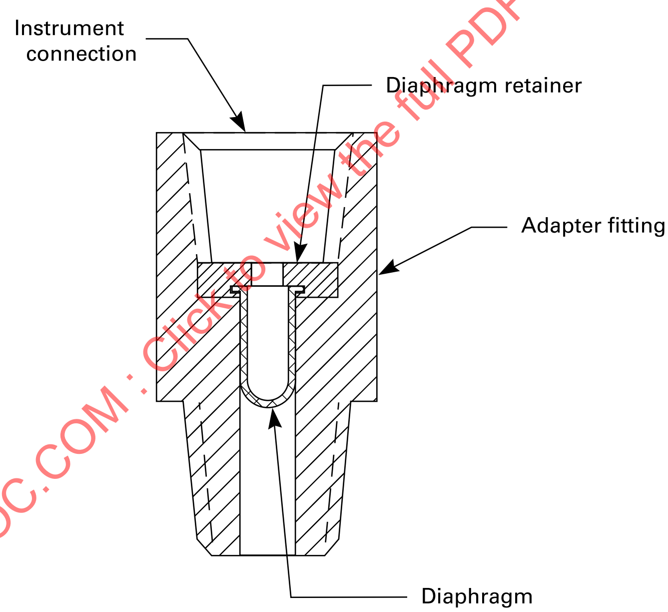


Figure 3-1.2.14-1
Gauge Isolator



(a)



(b)

3-1.3.4 When using a flange-connected type, caution must be used in attaching to the companion flange. As all these materials are slightly compressible, bolts must be tightened evenly. Over-tightening may result in distortion of the plastic parts and possible failure.

3-1.3.5 Diaphragm materials such as Teflon®, other plastics, or elastomers are sometimes used. Because of the thin sections, these materials may be porous. Consideration must be given to potentially hazardous interaction between the medium and the fluid used to fill the diaphragm seal and pressure instrument (see para. 3-1.4.2.2).

3-1.3.6 If the medium contains a hard solid, and the diaphragm seal is the flanged or flow-through type, the possibility of erosion of the thin diaphragm should be considered. Caution must be taken to select the proper diaphragm material.

3-1.3.7 A coating on a diaphragm should not be relied on for corrosion resistance unless specifically recommended by the supplier. Coatings may have been applied for other purposes and may have voids that allow corrosion. The permeability of the coating to the chemicals in the media must also be considered.

3-1.3.8 Lower or middle housings may be coated or plated to improve corrosion resistance. Caution must be taken on threaded housings as the coating or plating on the housings may be damaged during installation.

3-1.3.9 Fasteners that are usually highly stressed must be selected with consideration to strength, ambient temperature, and environmental effects. Stainless steel fasteners have improved corrosion resistance over carbon steel but may have lower strength. Some fastener materials may begin to lose strength at temperatures as low as 100°F (37.8°C). Combined effect of stress and corrosive ambient environments should be considered.

3-1.3.10 Gaskets used to seal the joints between the diaphragm, middle, and bottom housing must be resistant to the medium.

3-1.4 Fill Fluids and Selection

5-1.4.1 Fill Fluid Physical Properties. Fill fluid is the liquid used to fill that portion of the pressure-sensing system between the diaphragm and the pressure-sensing element, acting as the hydraulic medium for transmission of pressure.

The following are physical properties of fill fluid:

(a) coefficient of thermal expansion
(b) service temperature range
(c) specific gravity
(d) viscosity
(e) vapor pressure
(f) compressibility
(g) freeze point
(h) thermal decomposition point
(i) spontaneous ignition temperature
(j) long-term stability (closed system)

3-1.4.2 Fluid Selection. The attributes of a fluid, specified in paras. 3-1.4.2.1 through 3-1.4.2.11, shall be considered.

3-1.4.2.1 Toxicity. Consideration must be made of the possibility of health hazards associated with the handling of fill fluids. If the fill fluid is to be used in an application to measure pressure in a food, beverage, or pharmaceutical process, the user should determine the nature of the risk involved, if small quantities of the fill fluid enter the process stream, by means of a leak.

3-1.4.2.2 Medium and External Environmental Compatibility. A fill fluid should not react adversely with the medium or environment if a leak should occur. Reaction with the environment could include toxic and/or corrosive contamination and/or ignition. Reaction with the medium could include toxic contamination or loss of purity, which may damage the process or render the medium unusable.

3-1.4.2.3 Instrument Compatibility. The fill fluid must be compatible with all materials it contacts such as O-rings, gaskets, diaphragms, pressure elements, and housings.

3-1.4.2.4 Long Term Stability. Fill fluid shall be suitable for continuous operation at specified application service temperatures, pressures, and other service conditions. Incorrect selection with respect to service temperature range could result in fill fluid freezing, gel formation, polymerization, or solidification.

3-1.4.2.5 Effect of Temperature. The addition of a liquid-filled diaphragm seal to an instrument may create a detectable error in the pressure reading. Sealed systems contain fixed volumes of liquid. Temperature induced expansion and/or contraction of the fill fluid may increase or decrease the pressure reading. These effects will be greater for lower pressure instruments.

(a) Consideration should be given to the consequences of difference between assembly point (shop) ambient temperature and process service and ambient temperatures. When optimum accuracy is required, the filled seal and instrument system should be calibrated at the process service and ambient temperature.

(b) Consideration should also be given to the consequences of potential high or low ambient temperatures to which all or a portion of the seal/instrument assembly may be exposed, for example, sun shining on exposed capillary line, temperature changes from noon to midnight or midsummer to midwinter. Exposed components may be insulated, heated, or cooled to reduce the effects of ambient temperature variations.

3-1.4.2.6 Storage Temperature. Consideration shall be given to prevent damage to the seal/instrument assembly caused by high and/or low ambient temperature while the assembly is in transit or storage.

3-1.4.2.7 Effect of Liquid Head. The specific gravity of the fluid may have a distorting effect because of the static head pressure. This static head pressure will be a function of the fluid specific gravity and the elevation difference between the diaphragm and the sensing element of the instrument.

3-1.4.2.8 Viscosity. The fluid viscosity or resistance to flow effects the speed or response of the pressure instrument to a pressure change at the diaphragm. This effect will be greater on a system in which the instrument is connected to a diaphragm seal by a length of capillary.

3-1.4.2.9 Vapor Pressure. The fill fluid vapor pressure must be compatible with the following:
(a) evacuation and fill procedures
(b) ambient temperatures
(c) transport and storage temperatures
(d) medium pressure and temperature

3-1.4.2.10 Compressibility. Compressibility of the fill fluid must be considered in higher pressure applications because of the finite displacement capability of the diaphragm. Movement of the diaphragm is required to produce both the volume of compression of the fill fluid and the displacement required for the pressure-sensing element to function.

3-1.4.2.11 Other Considerations. The fill fluid should not support bacteriological growth or react with the materials of the diaphragm seal or the instrument.

3-1.5 Selection of a Diaphragm Seal

The following attributes of an application should be considered by the user for each application of a diaphragm seal. This listing is intended as an outline only with paragraph references to detailed descriptions. The supplier should be consulted for assistance if required.

3-1.5.1 Degradation of Accuracy. The volumetric displacement and volumetric spring rate of the diaphragm must be adequate to actuate the sensing mechanism of the instrument. The addition of the seal will, however, affect the accuracy of the instrument. Because the diaphragm has a finite spring rate, it will require some pressure to displace the fluid necessary to operate the pressure element.

This effect will be greater on instruments with elements requiring more fluid displacement, with diaphragms having higher volumetric spring rates, and on lower pressure range instruments.

The need to recalibrate the instrument with the seal attached will depend on the range and the desired accuracy.

3-1.5.2 Process Pressure. Process pressure is the maximum and minimum medium pressure that will be applied to the diaphragm seal.

3-1.5.3 Temperature. The following are types of temperature:
(a) process temperature (see para. 3-1.4.2.5)
(b) ambient temperature (see para. 3-1.4.2.5)
(c) storage temperature (see para. 3-1.4.2.6)

3-1.5.4 Mounting

3-1.5.4.1 Mounting Style. See para. 3-1.1 and the following:
(a) attached to the outside of a pipe or vessel
(b) in-line

3-1.5.4.2 Mounting Method. See para. 3-1.1 and the following:
(a) threaded
(b) flanged
(c) welded
(d) saddle
(e) clamped (sanitary)

3-1.5.4.3 Process Connection. Consider maximum working pressure and temperature before selecting a process connection. For general information, refer to ASME BPVC, Section VIII, Division 1 (ASME BPVC-VIII-1). Additionally, see para. 3-1.2.10 and the following:

(a) thread (e.g., $^1\!/_2$ NPT). [See also ASME B1.20.1 (inch) and ASME B1.13M (metric)]

(b) flange size and rating and face configuration (e.g., ASME B16.5, 1$^1\!/_2$ in. Class 150 RF).

(c) weld size and configuration (e.g., 1-in. socket weld)

(d) saddle, pipe size (e.g., 3 in.), welding per ASME B31.3, Process Piping

(e) clamp, size, and type

(f) sanitary applications, refer to ASME BPE-2016, Bioprocessing Equipment

(g) adapter (e.g. welding for lower housings); refer to ASME B31.3, ASME B16.11, and ASME B16.9

NOTE: For others, such as BSP, DIN, EN, reference locale-specific standards.

3-1.5.5 Materials. See para. 3-1.3.

3-1.5.5.1 Parts in Contact With the Medium. The following parts are in contact with the medium:
(a) diaphragm
(b) lower housing
(c) mid housing
(d) gaskets
(e) weld
(f) flushing connection plug

3-1.5.5.2 Parts Not in Contact With Medium. The following parts are not in contact with the medium:
(a) upper housing
(b) bolts and nuts
(c) reinforcing rings
(d) seal within the filled system
(e) fill/bleed screw

3-1.5.6 Instrument Connection. See para. 3-1.2.9. Also, see the following:
(a) size (e.g., $^1\!/_2$ NPT female)
(b) direct or remote

3-1.5.7 Fill Fluid. See para. 3-1.4.

3-1.5.8 Other Features. Also, see the following:
(a) continuous/noncontinuous
(b) removable/nonremovable
(c) flushing connection (see para. 3-1.2.11)
(d) locking device (see para. 3-1.2.16)

3-1.6 Reuse of Diaphragm Seals

It is not recommended that diaphragm seals be moved from one application to another for the reasons stated in paras. 3-1.6.1 through 3-1.6.4.

3-1.6.1 Chemical Compatibility. The consequence of re-use without cleaning can range from contamination to explosive failure. For example, moving an oil service diaphragm seal to oxygen service without cleaning for oxygen service can result in explosive failure (see CGA G-4.1) Diaphragm seals should be disassembled and cleaned with appropriate solvents prior to any reuse on different applications.

3-1.6.2 Partial Fatigue. The first installation may involve pressure pulsations that have expended most of the diaphragm fatigue life, resulting in early fatigue in the second installation.

3-1.6.3 Corrosion. Corrosion of the diaphragm, lower- and mid-housings, gaskets, and other parts wetted by the medium in the first installation may be sufficient to cause early failure in the second installation.

3-1.6.4 Other Considerations. If reusing a diaphragm seal is required, all guidelines covered in this Standard, relative to applications of diaphragm seals, should be followed in the same manner as when a new diaphragm seal is selected.

3-1.7 Safety

All diaphragm seal components, including fasteners, must be selected considering all process and ambient operating conditions, including corrosion, temperature, and pressure, to prevent misapplication (see para. 3-1.3). Improper selection could result in failure and possible injury or property damage.

3-1.7.1 Because of its thin cross section, special attention must be given to diaphragm material selection. Sometimes a material more corrosion resistant than that of the thicker-bottom housing or associated piping should be considered. Operating temperatures must not exceed the limit for the materials selected, including that of the fill fluids.

3-1.7.2 The maximum allowable pressure must not be exceeded. Flanged seals are generally limited to the maximum rating of the flange itself. Polymeric lower housings will not withstand the same pressures as metal equivalents. Maximum allowable pressures for all materials decrease as temperatures increase.

3-1.7.3 Fasteners used to secure the structural components of the diaphragm seal shall only be replaced with fasteners specified by the supplier.

3-1.7.4 The fill fluid must be capable of withstanding the operating temperature. Glycerin or silicone fill fluids are not suitable for all applications. These fluids must be avoided where strong oxidizing agents are involved including, but not limited to, oxygen, chlorine, nitric acid, and hydrogen peroxide. In the presence of oxidizing agents, potential hazard will result from chemical reaction, ignition, or explosion. Completely halogenated fluids may be more suitable for such applications.

3-1.7.5 Specific applications of diaphragm seals may require specific types of handling and cleaning of parts during manufacture. Oil and/or hydrocarbon compounds should not be used on parts that will contact oxygen. Seals to be used on pharmaceutical or food processing application should be manufactured and/or cleaned in accordance with U.S. Food and Drug Administration, 3-A Sanitary Standards, or other applicable standards.

3-1.7.6 The entire filled portion of the system must be leak-tight. It is not recommended that the user tamper with the pressure instrument and diaphragm seal assembly. Any loss of fill fluid will result in significant errors or complete failure to transmit pressure to the instrument. In addition, the exposure of the fill fluid to the medium and surrounding area could cause a hazardous condition.

3-1.7.7 Care should be taken when welding is used to connect the lower housing to the process line to avoid damage from overheating. Consult the supplier for installation instructions.

3-1.8 Filling Diaphragm Seals

3-1.8.1 Objective of the Filling Operation. The objective of the filling operation is to fill the sealed system consisting of the diaphragm seal top assembly, connections, and the instrument with the fill fluid. Air bubbles cause some loss of accuracy but are particularly troublesome when operating either at high temperature or vacuum. Under these conditions the air expands, overfilling the limited volume within the sealed system, causing inaccurate pressure measurements and frequently distorting metal diaphragms.

3-1.8.2 Filling Stations

(a) The fill station shown in Figure 3-1.8.2-1 consists of a vacuum pump, a sight glass, a liquid trap, and a regulated source of pressure. In operation, the system to be filled is attached to the fill station. When the vacuum is applied, the air is drawn from the sealed system and is visible as bubbles in the sight glass. When the vacuum is withdrawn, the fill fluid fills the sealed system. The fill fluid is automatically degassed during the fill operation.

(b) The fill station shown in Figure 3-1.8.2-2 consists of a vacuum pump, a fill reservoir, and two valves. Fill fluid is placed in the reservoir. When the valves are positioned as shown in Figure 3-1.8.2-2, illustration (a), the vacuum is applied to the sealed system and the fluid is degassed. When valves are positioned as shown in Figure 3-1.8.2-2, illustration (b), the fill fluid enters the sealed system.

3-1.8.3 Filling Procedures. The procedures described within this section are generalized for use as guidelines. The diaphragm seal supplier should be consulted for assistance with specific procedures. Applying vacuum to low pressure instruments may damage the instrument. Consult the instrument supplier for specific procedures.

3-1.8.3.1 Filling Diaphragm Seal and Instrument After Assembly. The seal should be attached to the instrument and all joints leak tested. The fill/bleed port should be connected to the manifold in the filling system. Vacuum is then applied to the assembly until all air is removed. Vacuum is then released and the fill fluid permitted to enter the interior of the assembly. After filling, before tightening the fill/bleed screw, the flatness of the diaphragm should be checked as follows:

(a) If the diaphragm is not flat, excessive nonlinearity and/or temperature error may result.

(b) If the diaphragm is convex toward the process side (overfilled), gently press the diaphragm upward until it is flat and then tighten the fill/bleed screw.

(c) If the diaphragm is concave, additional fill fluid should be added.

Special procedures may be required to fill diaphragm seals with elastomeric or Teflon® diaphragms because the diaphragm may be excessively distorted by the application of vacuum. The seal and instrument may also be filled per paras. 3-1.8.3.2 and 3-1.8.3.3.

3-1.8.3.2 Filling Diaphragm Seal and Instrument Before Assembly

(a) Filling a Diaphragm Seal. A diaphragm seal without a fill/bleed screw can be filled using an oil can. The diaphragm should be flexed gently using a finger or pencil eraser on the process side to remove the air bubbles. Diaphragm seals with Teflon® or elastomeric diaphragms may also be filled by pouring the fill fluid into the seal. These diaphragms are soft and may sag when the liquid is poured. This sag may be prevented by attaching a low-pressure source to the process side of the seal to support the diaphragm. The supplier should be consulted for advice on the pressure required for diaphragm support.

(b) Filling an Instrument. An instrument may be filled by attaching it to a manifold and applying vacuum to the connection until all air is removed. The vacuum is then released and the fill fluid permitted to enter the interior of the instrument.

(c) Assembling a Filled Diaphragm Seal to a Filled Instrument. After filling both, the connection of the instrument should be quickly inserted into the instrument connection on the seal and tightened. The fill/bleed screw (if supplied) should be left open so that excess fluid can be allowed to escape. The diaphragm flatness should be checked in the same manner as described in para. 3-1.8.3.1. If the seal does not contain a fill/bleed screw, the connection between the instrument and seal must be left slightly loosened until the diaphragm flatness has been achieved, and then the connection may be carefully tightened.

3-1.8.3.3 Filling a Seal With Capillary Between the Seal and the Pressure Instrument. These assemblies can be filled as a unit using the procedures described in para. 3-1.8.3.1.

If filled before assembly, first the seal and instrument should be filled as per paras. 3-1.8.3.2(a) and 3-1.8.3.2(b) and then the capillary should be filled either by pressurizing the fill fluid into one end and allowing flow until no bubbles appear at the other end, or by applying vacuum to one end of the capillary and immersing the other end into a container of fill fluid, continuing the process until all air is removed.

The filled capillary is then assembled to the instrument and sealed in the same manner as the seal and instrument assembly described in para. 3-1.8.3.2(c).

5-1.8.3.4 Diaphragm Seal Filling for Special Requirements[2]

(a) Vacuum Service. In the case where an assembly for a vacuum application is required; use completed assemblies only. Where possible, use metal-to-metal or welded connections. Filling requires special attention to:

(1) fill fluid selection
(2) evacuation time
(3) final filling time

[2] Please consult with your seal and/or instrument supplier for more subject matter expertise regarding filling and assembly.

Figure 3-1.8.2-1
Sealed Setting

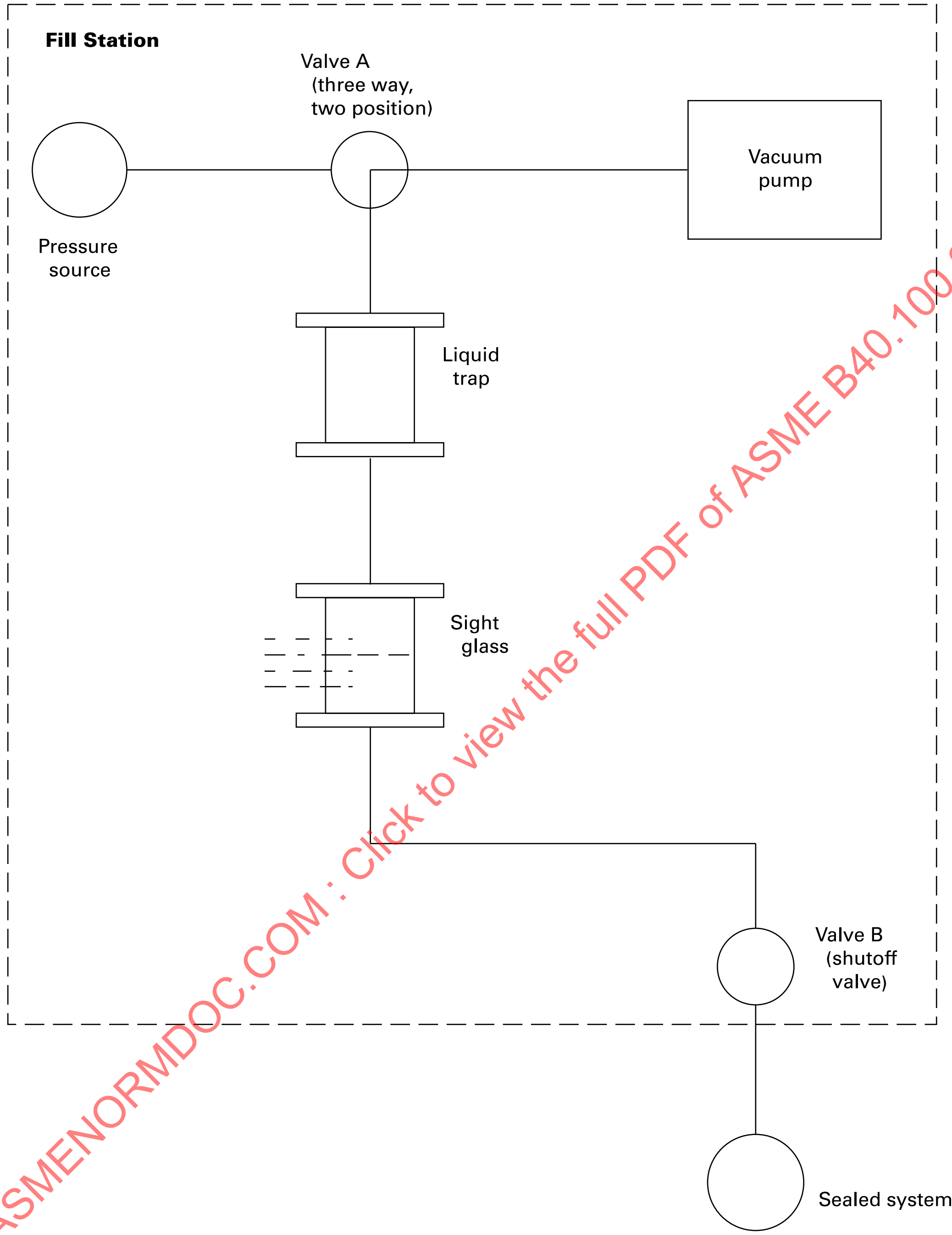
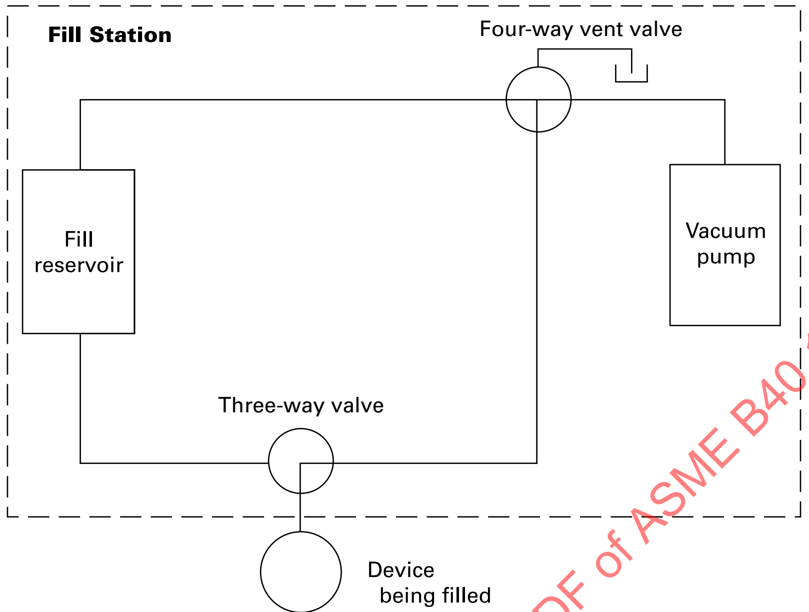
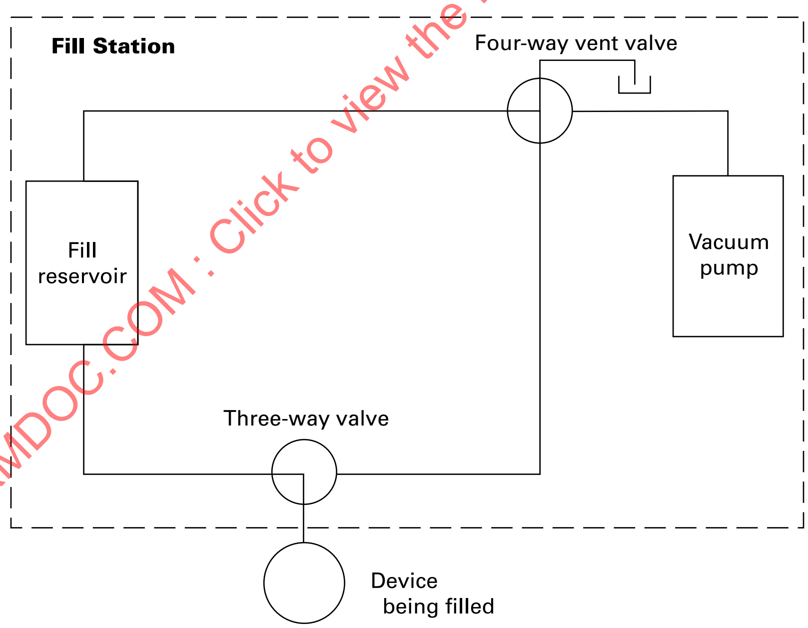


Figure 3-1.8.2-2
Fill Setting



(a)



(b)

Fluid vapor pressure should also be taken into consideration. Instruments rated for vacuum-suitable environments should be used for all vacuum applications. Due to the risk of penetration/rupture plastic material should not be used in high vacuum applications.

For both high and low temperature applications use metal-to-metal or welded connections.

(b) High Temperature. As a consequence of thermal expansion, slight underfill may be required.

(c) Low Temperature. As a consequence of thermal contraction, slight overfill may be required.

3-1.9 Testing

3-1.9.1 Scope. This section is intended to provide an outline of the parameters used when evaluating the performance of diaphragm seal/instrument assemblies and to suggest evaluation outlines. These test methods may or may not satisfy the requirements of the intended application. When it is known that the diaphragm seal/instrument assembly will encounter conditions more or less severe than those specified, the test may be modified to more closely match the application. A functional test in the intended application is generally the best evaluation method.

3-1.9.2 General. All tests described within this section shall be conducted with a diaphragm seal instrument that is filled in accordance with the procedures described in para. 3-1.8. After assembly and filling, the instrument shall be recalibrated to its specified accuracy prior to conducting any accuracy testing of the diaphragm seal/instrument assembly. The accuracy and other test parameters of the diaphragm seal/instrument assembly may exceed the specified parameters of the instrument used within the assembly. Acceptable performance specifications shall be agreed to by the supplier and user.

3-1.9.3 Calibration Standards

3-1.9.3.1 General Discussion

(a) Information regarding manometers and piston gauges is contained in ASME PTC 19.2. In computing the accuracy of these instruments, their geographical location must be accurately ascertained and corrections applied as outlined in NBS Monograph No. 8 and NBS Monograph No. 65.

(b) Working standards shall be tested before and after a period of use. The frequency of recalibration will depend on their ability to retain their accuracy during use.

(c) For information regarding indicating dial gauges used as working standards, see subsection 2-5.

3-1.9.3.2 Recommended Standards. Standards shall have nominal errors no greater than $\frac{1}{4}$ of those permitted for the seal/instrument assembly being tested. If a liquid medium is used, correction for the difference in liquid head between the standard and the instrument being tested may be necessary.

CAUTION: Piston gauges, or other standards that contain oil or other hydrocarbon fluids, shall not be used to test diaphragm seal/instrument assemblies cleaned for oxygen service.

3-1.9.4 Test Procedures

3-1.9.4.1 General. The following procedures are suggested when testing a diaphragm seal/instrument assembly. Statistical methods, alternate procedures, or both, may be used when agreed to by the supplier and user.

(a) Reference Temperature. A temperature of 68°F (20°C) shall be the reference standard for testing all diaphragm seal/instrument assemblies. Temperature compensated pressure instruments shall be tested at several ambient temperatures within the range specified by the supplier.

(b) Liquid Head. When using a liquid-filled dead weight piston gauge, appropriate compensation shall be made for liquid head effects.

3-1.9.4.2 Procedures. It is suggested that all testing be conducted on the assembly of a diaphragm seal and the attached pressure instrument. Statistical methods or alternate test procedures, or both, may be used when agreed to by the supplier and the user.

(a) Accuracy. The accuracy of the diaphragm seal/instrument assembly shall be tested using the procedures for the instrument alone. Procedures for accuracy testing elastic element pressure gauges are described in para. 2-5.2.4. Appropriate procedures should be applied to other types of pressure instruments.

(b) Repeatability. The repeatability of the diaphragm seal/instrument assembly shall be tested using the procedures for the instrument alone. Procedures for repeatability testing elastic element pressure gauges are described in para. 2-5.2.4.2. Appropriate procedures should be applied to other types of pressure instruments.

(c) Hysteresis. The hysteresis of the diaphragm seal/instrument assembly shall be tested using the procedures for the instrument alone. Procedures for hysteresis testing of elastic element pressure gauges are described in para. 2-5.2.4.3. Appropriate procedures should be applied to other types of pressure instruments.

(d) High Temperature Error. The diaphragm seal/instrument assembly shall be tested in accordance with (a). The assembly shall be placed in a temperature test chamber at a temperature not to exceed the supplier's maximum operating temperature and allowed to stabilize for a period of not less than 4 hr. The assembly shall then be checked for accuracy at this temperature, in accordance with (a). The difference in test readings at each test point between room temperature and the maximum operating temperature is the high temperature error.

(e) Low Temperature Error. The diaphragm seal/instrument assembly shall be tested in accordance with (a). The assembly shall be placed in a temperature test chamber at a temperature no lower than the supplier's low limit and allowed to stabilize for a period of not less than 4 hr. The assembly shall then be checked for accuracy at this temperature, in accordance with (a). The difference in test readings at each test point between room temperature and the minimum operating temperature is the low temperature error.

(f) Storage Temperature. The diaphragm seal/instrument assembly shall be tested for accuracy in accordance with (a). The assembly shall then be placed in a temperature test chamber at a temperature no higher than the supplier's high limit of storage temperature for a period of 24 h. The assembly shall then be placed in a temperature test chamber at a temperature no lower than the supplier's low limit of storage temperature for a period of 24 h. This 48-h cycle shall be repeated for a total of two complete cycles. The assembly shall then be allowed to stabilize at room temperature and then checked for accuracy in accordance with (a). The difference between the two accuracy tests is the effect of storage temperature expressed as a percent of span.

(g) Pressure Cycling. The pressure cycling test shall be conducted with a diaphragm seal/instrument assembly as agreed to by the supplier and user. It is recommended that this test be performed using the instrument that has the largest actuating displacement (usually the lowest pressure) for the application which the test is being performed.

(1) Since the diaphragm is basically an isolator with nearly equal pressure on both sides, pressure stresses are very low. Working stresses, therefore, are mostly deflection related. Testing on a low pressure/large displacement seal/instrument assembly, therefore, would result in the highest diaphragm stresses.

(2) The diaphragm seal/instrument assembly shall be tested for accuracy in accordance with (a). The assembly shall then be subjected to repeated applications of a pressure (hydraulic preferred) that produces an indication of 20% to 80% of the range of the assembly at a rate of 0.5 Hz. The application and release of the pressure shall be as smooth as practicable, so as not to subject the instrument mechanism to excessive upscale or downscale accelerations or high amplitude impulses (pressure spikes). The assembly shall be tested for accuracy in accordance with the test specified in (a) not less than 1 hr after stopping the pressure cycling. The difference between the first set of readings at each test point and the last set of readings at each test point is the fatigue error at this point.

(3) The assembly shall also be examined periodically during the test for leakage of the diaphragm. The fatigue life is the number of cycles to leakage. If the instrument fails, the instrument shall be replaced and the test continued.

(h) Continuous Duty. This test is intended to be performed only on diaphragm seals that are specified for "Continuous Duty" performance per para. 3-1.2.2.1.

(1) The diaphragm seal/instrument assembly shall be filled in accordance with the procedures described in para. 3-1.8. The instrument may be recalibrated and the assembly shall be tested in accordance with (a). The instrument shall then be removed from the diaphragm seal and the instrument connection of the seal left open. The rated maximum operating pressure shall be applied to the process connection of the diaphragm seal for a period of 15 min. The diaphragm seal shall not show any evidence of leakage.

(2) After the test pressure is released, the instrument shall be reassembled to the diaphragm seal, the assembly refilled using the procedures described in para. 3-1.8 The instrument may be recalibrated and the assembly shall be tested for accuracy in accordance with (a). The assembly shall be within the accuracy limits observed prior to the test.

(i) Continuous Seal. This test is intended to be performed only on diaphragm seals that are specified for "Continuous Seal" performance per para. 3-1.2.2.2. The diaphragm seal/instrument assembly shall be filled in accordance with para. 3-1.8. The instrument shall then be removed from the diaphragm seal and the instrument connection of the seal left open. The rated maximum operating pressure shall be applied to the pressure connection of the diaphragm seal, with no instrument attached, for 15 min. The diaphragm seal shall not show any evidence of leakage.

(j) Fatigue. This test determines the fatigue life of the diaphragm. It shall be conducted on a diaphragm seal/instrument assembly, using the instrument with the largest actuating displacement (usually the lowest pressure range) for the intended application of the seal. Since the pressure is almost equal on both sides of the diaphragm, the highest stresses will be imposed when the diaphragm is displaced to its maximum.

(1) The diaphragm seal/instrument assembly shall be filled in accordance with para. 3-1.8. It shall then be subjected to repeated applications of pressure (hydraulic preferred) equal to approximately 20% to 80% of the range of the instrument, at a rate of 0.5 Hz. The rate of pressure change should approximate a sine wave, to avoid upscale or downscale impulses (spikes).

(2) The assembly shall be examined periodically for diaphragm leakage. The fatigue life is the number of cycles before leakage. If the instrument fails, it shall be replaced and the test continued.

Section 4
Snubbers

4-1 PURPOSE

Devices commonly known as snubbers, pulsation dampeners, pressure equalizers, gauge protectors, or gauge savers, are used to improve the output or readability of the instrument, and to reduce the effect of pressure surges on the instrument.

4-2 GENERAL

4-2.1 Connections

4-2.1.1 Type of Connection. Tapered pipe connections for pressure up through 20,000 psi or 160 000 kPa are usually $^1/_8$ NPT, $^1/_4$ NPT, or $^1/_2$ NPT American Standard external or internal tapered pipe threads per ANSI B1.20.1, as required. Above this pressure, high-pressure tubing connections, or equal, should be used. Other appropriately sized connections, that employ sealing means other than tapered threads are acceptable.

In applications of pipe-mounted instruments, where vibration is extremely severe, consideration should be given to the possibility of failure of the snubber or associated piping, caused by the vibrating mass. A larger connection (e.g., $^1/_2$ NPT instead of $^1/_4$ NPT) and/or a stronger material (e.g., stainless steel instead of brass) should be considered.

4-2.2 Materials

The internal materials must be compatible with the process and the external materials must be compatible with the environment. The effect of the structural or mechanical loading must also be considered. If elastomeric or nonmetallic materials are present, they should be selected to ensure compatibility with the process medium, temperature, and pressure.

4-2.3 Types of Snubbers

4-2.3.1 Fixed Orifice. This device contains one or more orifices, and is available in different sizes and configurations. The orifice may be in the form of a capillary. The fixed orifice is not adjustable and may become plugged in media with suspended solids. It can reduce moderate surges in clean systems (see Figure 4-2.3.1-1).

4-2.3.2 Needle Valve. This device consists of an externally adjustable valve. Closing the valve increases the dampening action. Some valves include long tapered plugs, filters, and/or controlled leak checks.

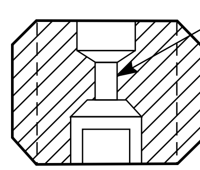
CAUTION: It may be possible to close off the valve completely (see Figure 4-2.3.2-1).

4-2.3.3 Porous Metal. This nonadjustable device consists of a porous metal element, available in several porosities, installed within a fitting. It has an increased range of dampening and a reduced tendency to plugging with suspended solids as compared to fixed orifices (see Figure 4-2.3.3-1).

4-2.3.4 Felt Plug — Fluid Filled. This device consists of a bladder or diaphragm enclosing a fluid-filled chamber with felt plugs inserted between the chamber and the instrument. The pressure-sensing element of the instrument must be fluid filled. The felt plugs can be compressed to provide the required dampening and the fluid-filled bladder minimizes plugging by media solids (see Figure 4-2.3.4-1).

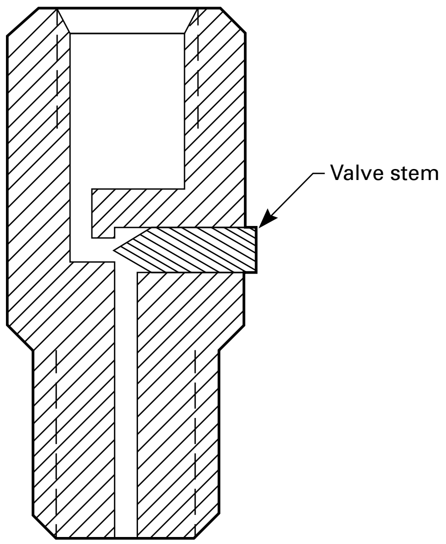
4-2.3.5 Piston. This device consists of a movable piston in a hole. The clearance between the piston and the hole determines the amount of dampening. It is usually furnished with multiple pistons or a cylinder with multiple holes. The amount of snubbing can be changed by changing pistons or holes. Piston-type snubbers tend to be self-cleaning because of the action of the piston (see Figure 4-2.3.5-1).

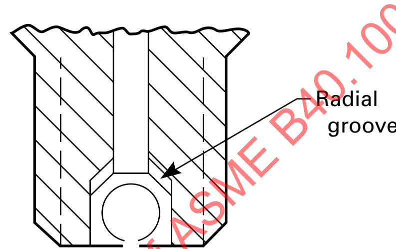
Figure 4-2.3.1-1
Fixed Orifice



GENERAL NOTE: Not intended to show design detail.

Figure 4-2.3.2-1
Needle Valve





Controlled
Leak Check

Figure 4-2.3.3-1
Porous Metal

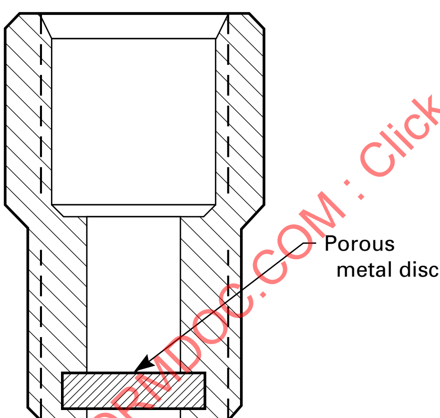


Figure 4-2.3.4-1
Felt Plug — Fluid Filled

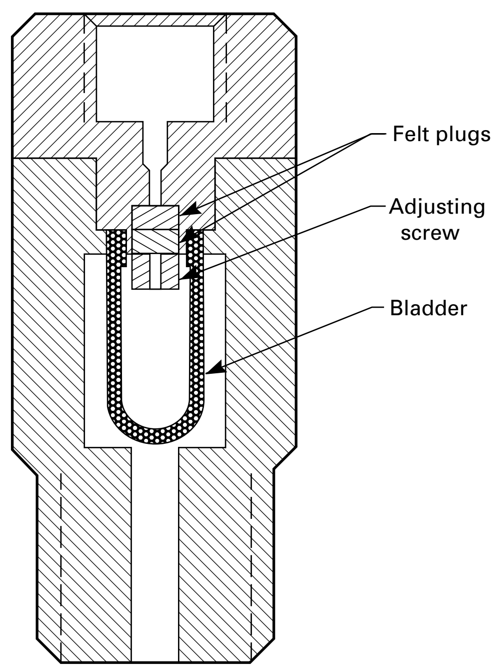
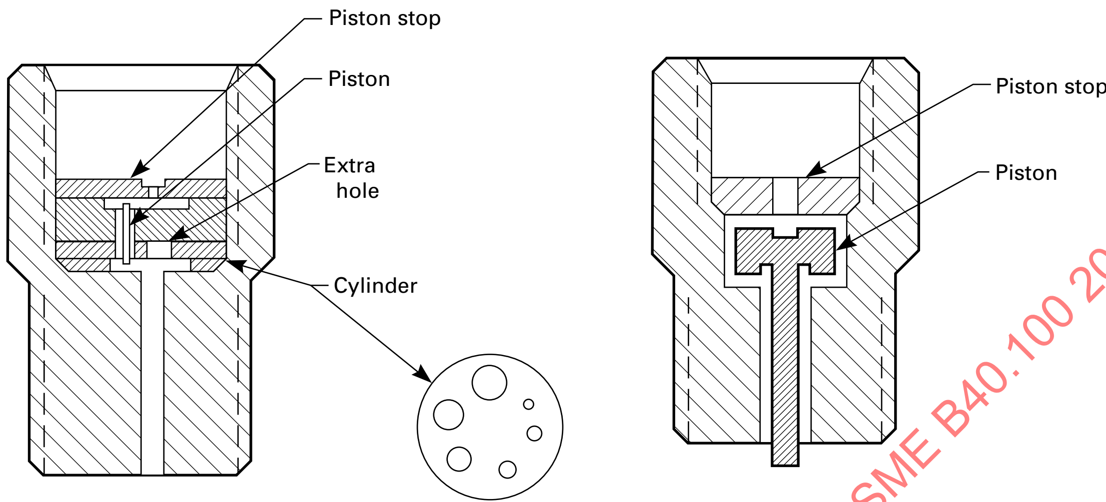


Figure 4-2.3.5-1
Piston



4-2.4 Selection

4-2.4.1 System Parameters. The following system parameters should be considered by the user for each application of a snubber. The effect of these parameters may vary depending on the instrument used. The supplier should be consulted for assistance, if required.

4-2.4.1.1 Viscosity. More dampening is required for media of low viscosity.

4-2.4.1.2 Pressure. The higher the pressure the greater the amount of dampening required. Below approximately 10 psi the performance becomes less predictable. At lower pressure generally less dampening is required, and some experimentation may be required to obtain the desired amount of dampening.

4-2.4.1.3 Rate of Pressure Change. The higher the maximum rate of pressure change, the greater the amount of dampening required.

4-2.4.1.4 Amplitude of Pressure Change. The higher the amplitude of pressure change, the greater the amount of dampening required.

4-2.4.1.5 Volumetric Displacement of the Instrument. Generally, less dampening is required with higher instrument volumetric displacement.

4-2.4.1.6 System Pressure. The snubber must be capable of withstanding the system pressure.

4-2.4.1.7 Suspended Solids. Some pressure media may contain solids. A snubber may be partially or completely plugged depending on its design. In these cases, it would be advisable to protect the instrument and the snubber with a diaphragm seal or similar device, unless this feature is provided in the snubber.

4-2.4.1.8 Materials of Construction. The internal material must be compatible with the process and the external materials must be compatible with the environment. The effect of the structural or mechanical loading must also be considered. If elastomeric or nonmetallic materials are present, they should be selected to ensure compatibility with the process medium, temperature, and pressure.

4-2.4.2 Consultation. Due to the extensive number of variables associated with the selection of snubber types, styles, and operating parameters, detailed selection criteria are beyond the scope of this Standard. The user should consult the supplier for recommendation.

4-2.5 Performance

4-2.5.1 General. When the working parts are properly selected in accordance with para. 4-2.4, as well as compatibility with the pressure medium, and when the instrument and the snubber are filled completely with the pressure medium, the instrument should respond to changes in system pressure within an acceptable time span without overshoot. When the system is at operating pressure, gradual fluctuation of the instrument output due to changes in pressure is permissible. The effect of pressure spikes on the instrument should be minimized.

4-2.5.2 Pressure Transmission Characteristics. In systems that have surges, the snubber will minimize the effect of the peak pressures on the instrument. If high frequency pulsations are present, the instrument output will tend to be an average reading.

4-2.5.3 Mechanical Vibration. Most snubbers will not be effective in reducing the effects of mechanical vibration.

4-2.5.4 Existing Systems. The installation of a new properly selected snubber in a system that contains a worn instrument may not provide the desired result.

4-2.5.5 Response Time. There are two response times that are of interest.

4-2.5.5.1 Response Time at Operating Pressure. On a properly selected and installed unit, a change in system pressure should be indicated within an acceptable time span. This time is shortened by reducing the volume between the snubber and the pressure-sensing element and on liquid-filled systems by eliminating all gas between the snubber and the pressure-sensing element. The response time may be reduced by reducing the amount of dampening.

4-2.5.5.2 Response Time on Start-Up. When a system is initially pressurized, the pressure will register slowly for the initial and final portion of the pressure rise, but will be rapid for the central portion. To decrease the overall response time, minimize the fluid volume from the snubber to the pressure-sensing element. In liquid-filled systems remove all gas from the snubber to the pressure-sensing element or reduce the amount of dampening.

4-2.5.6 Temperature Effect on Response Time. A lower temperature that results in a more viscous pressure medium will increase the response time. This will be most noticeable on start-up.

4-2.5.7 Location. The snubber should be located as close as possible to the instrument.

4-2.5.8 Entrapped Gas. Entrapped gas in a liquid filled system will result in a slow response on initial pressurization, will cause the instrument to be slow to reach zero when pressure is removed, and will affect instrument accuracy to some extent.

4-3 SAFETY

4-3.1 Scope

Subsection 4-3 presents certain information to guide users, suppliers, and manufacturers toward minimizing the hazards that could result from misuse or misapplication of pressure snubbers. The user should become familiar with all sections of this Standard as all aspects of safety cannot be covered in this section. Consult the supplier for advice whenever there is uncertainty about the application.

4-3.2 General Discussion

4-3.2.1 Planning. Adequate safety results from intelligent planning, careful selection, and proper installation. The user should inform the supplier of all conditions pertinent to the application and environment so that the supplier can make the most suitable recommendation for the application.

4-3.2.2 Hazardous Systems and/or Conditions. Systems such as, but not limited to the following, are considered potentially hazardous and must be carefully evaluated:

(a) compressed gas systems
(b) oxygen systems
(c) systems containing hydrogen or free hydrogen atoms
(d) corrosive fluid systems (gas and liquid)
(e) pressure systems containing any explosive or flammable mixture or medium
(f) steam systems
(g) nonsteady pressure systems
(h) systems where high overpressure could be accidentally applied
(i) systems wherein interchangeability of snubber could result in hazardous internal contamination or where lower pressure snubbers could be installed in higher pressure systems
(j) systems containing radioactive or toxic fluids (liquid or gases)
(k) systems installed in a hazardous environment

4-3.2.3 Unique Media. When snubbers are to be used in contact with media having known or uncertain corrosive effects or known to be radioactive, random or unique destructive phenomena can occur. In such cases the user should always furnish the supplier with information relative to the application and solicit his advice prior to installation of the snubber.

4-3.2.4 Violent Effects. Fire and explosions within a pressure system can cause failure with very violent effects. Failure in a compressed gas system can be expected to produce violent effects. Violent effects may also be produced by other failure causes including, but not limited to the following:

(a) hydrogen embrittlement
(b) contamination of a compressed gas
(c) formation of acetylides
(d) weakening of soft soldered joints by steam or other heat sources
(e) weakening of soft-soldered or silver-brazed joints caused by heat sources such as fires
(f) corrosions
(g) fatigue
(h) mechanical shock
(i) excessive vibration

4-3.2.5 Caution to Users

4-3.2.5.1 Contamination. Oil from instrument adjustment or other sources should not come in contact with the internal part of the snubber that is intended for air, gas, or water service. If it does, unacceptable delays in the transmission of pressure may occur, resulting in accidental system overpressure or failure.

4-3.2.5.2 Reuse. It is recommended that a snubber is not moved from one application to another. If it is necessary, the following should be considered:

(a) *Chemical Compatibility.* The consequences of incompatibility can range from contamination to explosive failure. For example, moving an oil service device to oxygen or other oxidants can result in explosive failure.

(b) *Viscosity Compatibility.* The viscosity of the pressure medium must be within the range of the snubber being moved.

(c) *Pressure Compatibility.* The operating pressure of the new installation must not exceed the rating of the snubber being reused.

(d) *Other Considerations.* When reusing a snubber, all guidelines covered in this Standard relative to applications should be followed in the same manner as when a new snubber is selected.

4-4 TESTING

4-4.1 General

These tests are intended to provide an outline of the parameters used when evaluating new snubber performance and to suggest evaluation outlines. These tests may or may not satisfy the requirements of the intended application. When it is known that the snubber will encounter conditions more severe or less severe than those specified, the test may be modified to more closely match the application. A functional test in the intended application is generally the best evaluation method.

4-4.2 Surge Generation

To test the effectiveness of a snubber, a means of generating surges and a means of measuring pressure on the instrument side of the snubber are required.

4-4.3 Comparison Testing

If comparison tests are wanted, then the ability to repeat the surge and measure it with and without the snubber is necessary.

4-4.4 Test Fluid

The test fluid can be the fluid on which the snubber will operate or, if the test is for general effectiveness of the snubber, the fluid can be that which is used in existing test equipment. If the choice of fluids is optional, choose a low viscosity liquid such as water or a thin hydraulic fluid.

4-4.5 Test

WARNING: Failures during pressure testing are unpredictable and may cause parts to be propelled in any direction. All pressure testing should be conducted by qualified personnel using appropriate safety equipment such as safety glasses, shields, or enclosures, or a combination, to prevent personal injury and property damage. Read subsection 4-3 before conducting any testing.

4-4.5.1 Temperature Effect. If tests are to be compared to one another, the test temperatures should be the same. It may be worth noting that after a prolonged shutdown at cold temperatures, the first pressurization will be considerably slower than subsequent pressurization. This phenomenon can be overlooked if the system is pressurized for calibration immediately before the test.

4-4.5.2 Test Setup. See Figure 4-4.5.2-1 for a test setup that has been successfully used. This setup generates surges approximately twice the input pressure. A typical input surge is shown in Figure 4-4.5.2-2.

4-4.5.3 Desirable Snubber Output. The dampened output should resemble Figure 4-4.5.3-1. Generally, the maximum rate of pressure rise would be from 5,000 psi/sec to 15,000 psi/sec; 30,000 psi/sec would be the maximum for effective protection of the instrument without any pressure overshoot.

4-4.6 Equipment

Equipment can be added or changed to suit the test objectives. Electronic transducers and recording equipment reduce observation errors and give permanent test data. Simultaneous records of the input and output are an improvement. An environmental test chamber is necessary if high and/or low temperature tests are required.

4-4.6.1 Solenoids. The solenoids must be fast acting.

4-4.6.2 Twelve-Foot Coil. The 12-ft coil of tubing is to simulate system piping. It has very little effect on the rate of pressure rise, but it does reduce the frequency of the surges that follow the initial surge.

4-4.6.3 Transducer Location. It may be desirable to move the transducer out of the test chamber for tests at temperatures beyond the limits of the transducer. A second transducer could be added so surges could be measured with and without the snubber at the same time.

4-4.6.4 Needle Valves. The needle valves are in the system for convenience in setting up, but care must be taken because a partially closed valve could affect the test results.

4-4.6.5 Temperature Measurement. The method of temperature measurement is not important, but it is advisable to measure the fluid temperature, as well as the ambient temperature, to be certain that all elements of the system are at the same temperature.

4-4.7 Test Procedure

Step 1. Fill the system with the pressure medium. Filling at low pressure helps eliminate foam and air bubbles.

Step 2. Bleed all air from the system, paying particular attention to the space between the pressure pickup and the snubber.

Step 3. Open needle valves 1 through 4.

Step 4. Close needle valve 3.

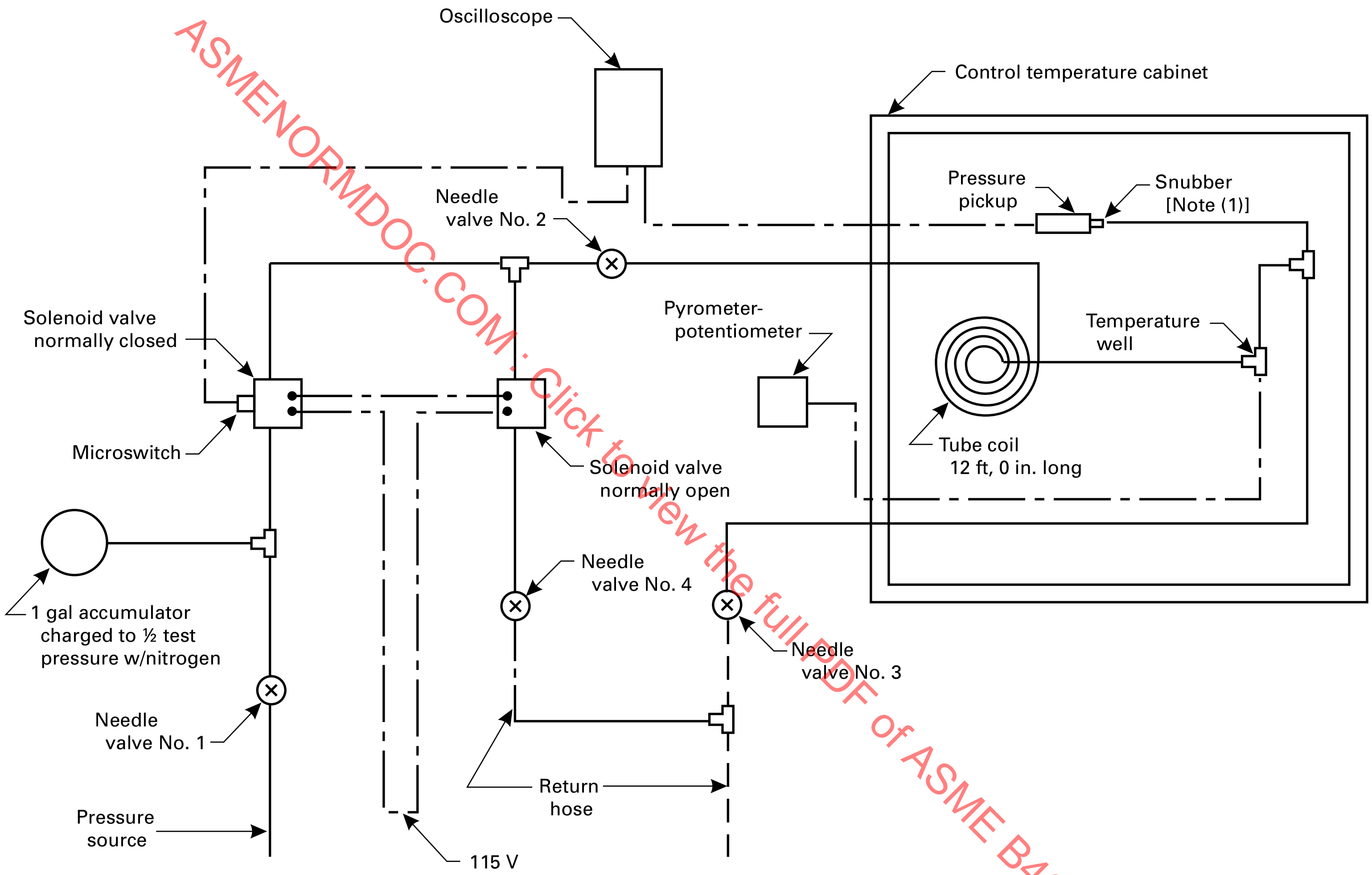
Step 5. Pressurize the accumulator to the test pressure.

Step 6. Actuate the solenoid valves to apply pressure to the system and start the oscilloscope trace.

Step 7. After observing and recording the results, actuate the solenoid valves to drop the system pressure.

To repeat the procedure, start at Step 5.

Figure 4-4.5.2-1
Test Setup



NOTE: (1) Devise under test.

Figure 4-4.5.2-2
Typical Input Surge

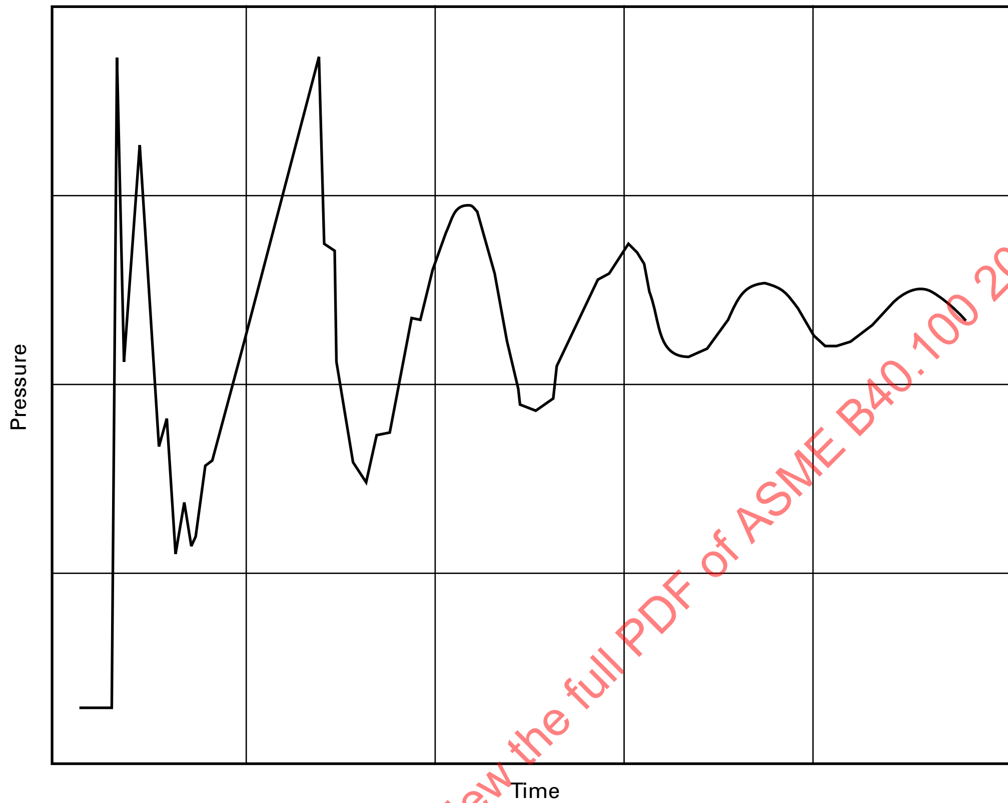
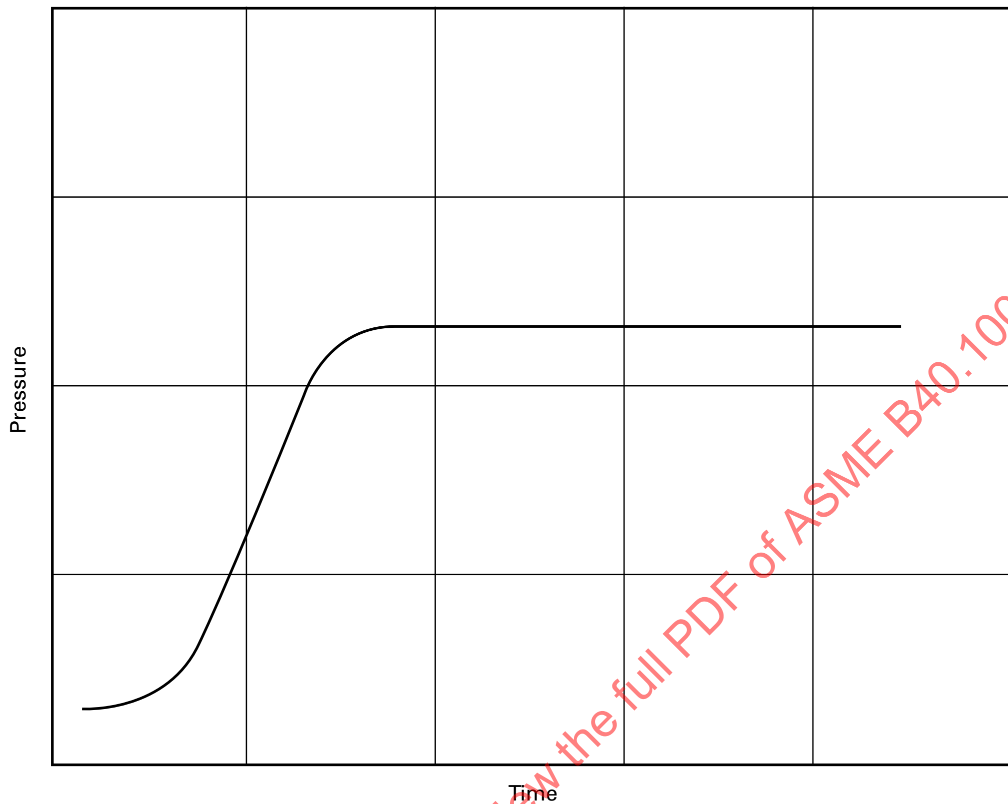


Figure 4-4.5.3-1
Desirable Snubber Output



Section 5
Pressure Limiter Valves

5-1 GENERAL

5-1.1 Purpose

Pressure limiter valves are used to protect pressure-sensing instruments against damage, loss of accuracy, and/or rupture in the event of excessive system pressure.

5-1.2 Principle of Operation

Generally, these devices consist of the following components:

(a) body with inlet and outlet ports, designed to contain maximum system design pressure

(b) pressure-sensing element

(c) range spring

(d) mechanism for sealing or isolating the outlet port from the inlet port

The pressure-sensing element has system pressure working against an adjustable range spring. The range spring holds the sealing mechanism in the open position, allowing system pressure into the instrument. Increasing load on the adjustable range spring increases closing pressure and decreasing the load lowers closing pressure. As system pressure overcomes the force of the range spring, the pressure-sensing element moves, causing the sealing mechanism to close. With the sealing mechanism closed, the outlet side is isolated from increasing system pressure and the instrument is protected. As system pressure drops to the reopening pressure of the pressure limiter valve, the sealing mechanism opens and allows transmission of system pressure back into the instrument.

5-2 CONSTRUCTION

5-2.1 Piston Type

The pressure-sensing element is a piston assembly. The piston assembly works against an adjustable range spring. The piston assembly contains a sealing mechanism to isolate system pressure from the instrument and operates within a bore with a seal designed to isolate system pressure from the range spring (see Figure 5-2.1-1).

5-2.2 Diaphragm Type

The pressure-sensing element is a diaphragm assembly. This assembly works against an adjustable range spring. The diaphragm assembly contains a sealing mechanism to isolate system pressure from the instrument and acts as a seal to isolate system pressure from the range spring (see Figure 5-2.2-1).

5-2.3 Relief Valve Type

The pressure-sensing element is an adjustable relief valve on the instrument side of a check valve. The relief valve operates against a range spring. When system pressure forces the relief valve open, the check valve closes. The check valve contains a sealing mechanism to isolate system pressure from the instrument. The relief valve vents externally, and the flow may be diverted. This type should not be used with diaphragm seals (see Figure 5-2.3-1).

5-2.4 Bellows Type

The pressure-sensing element is a bellows assembly. This assembly works against an adjustable range spring. The bellows assembly contains a sealing mechanism to isolate system pressure from the instrument and acts as a seal to isolate system pressure from the range spring (see Figure 5-2.4-1).

5-3 SELECTION OF PRESSURE LIMITER VALVES

The following is a partial list of criteria that should be considered by the user in the application and selection of a pressure limiter valve. Proper selection will help provide reliable performance with minimal maintenance. This is only a guideline; it is the user's responsibility to properly select a valve or properly and adequately describe the application so the correct device can be specified. The supplier should be consulted as required.

5-3.1 System Pressure

The pressure limiter valve must have an over-range pressure equal to or above the maximum system pressure, which may be considerably higher than the closing pressure. Some devices have over-range pressure expressed as a percentage of the closing pressure.

Figure 5-2.1-1
Piston Type

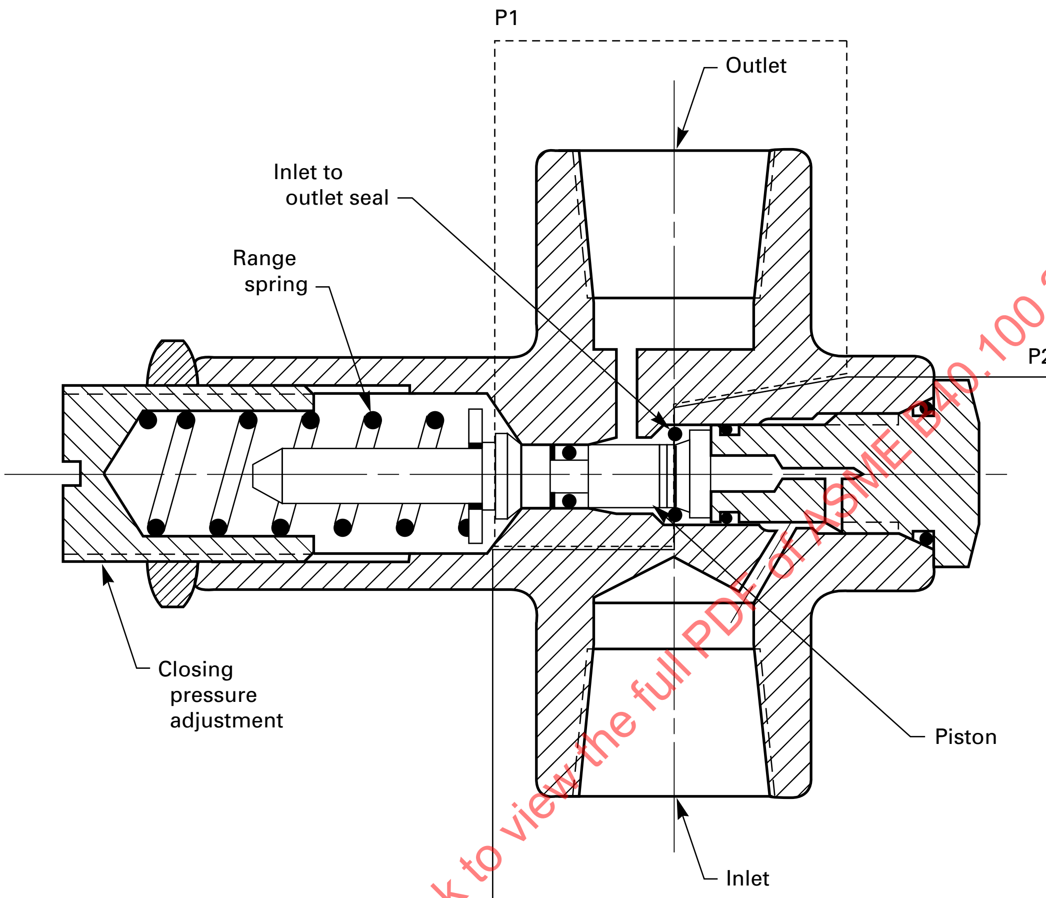


Figure 5-2.2-1
Diaphragm Type

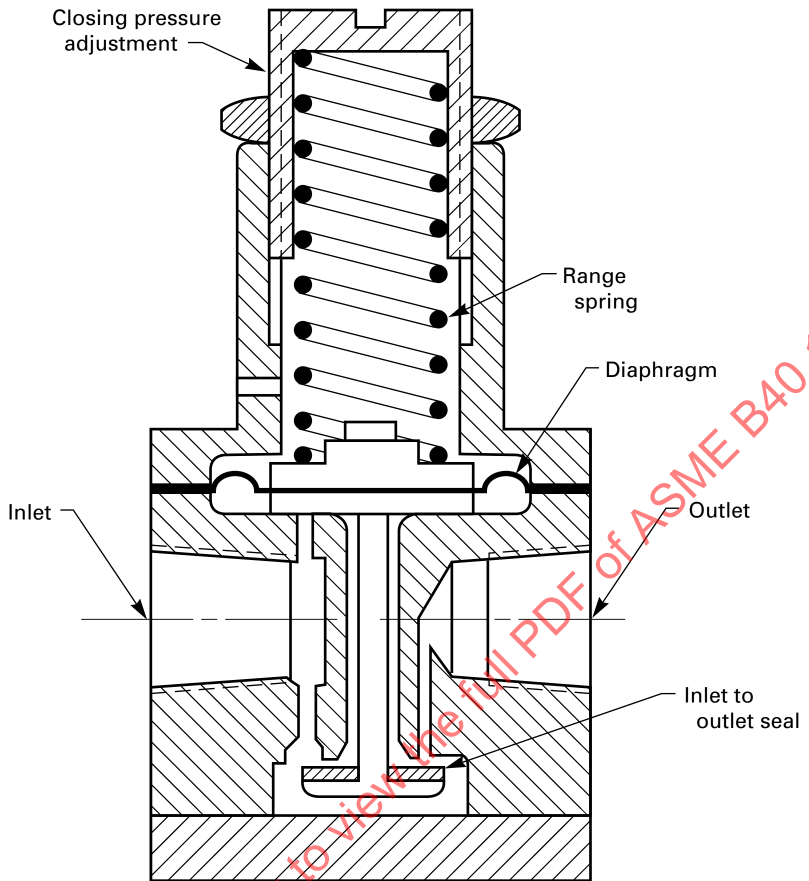


Figure 5-2.3-1
Relief Valve Type

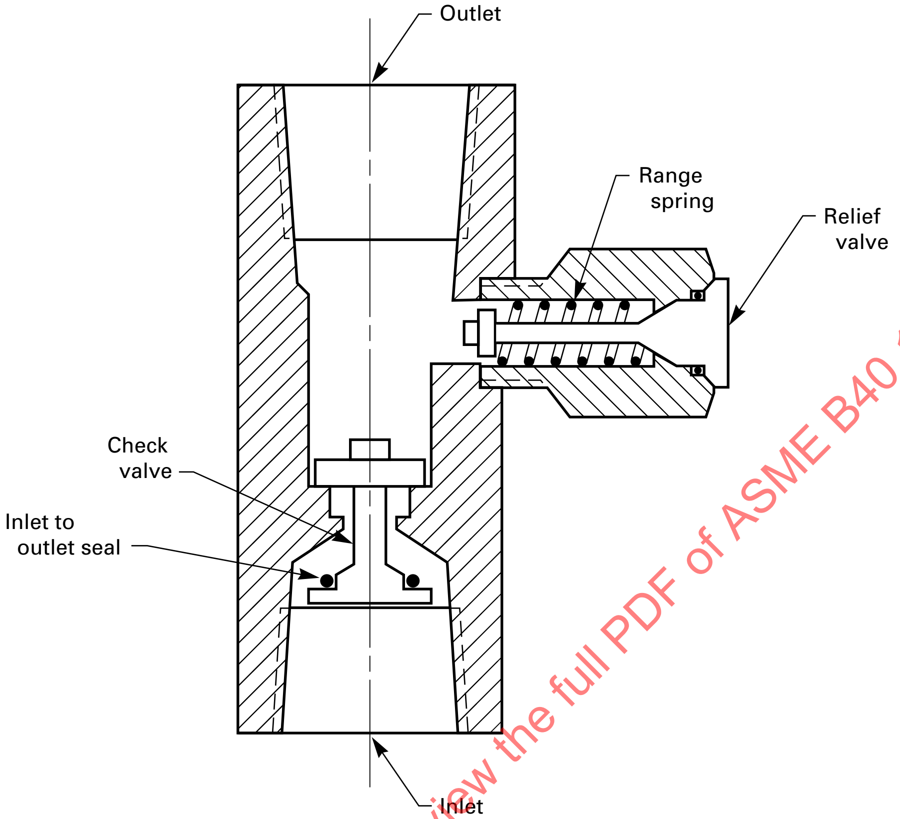
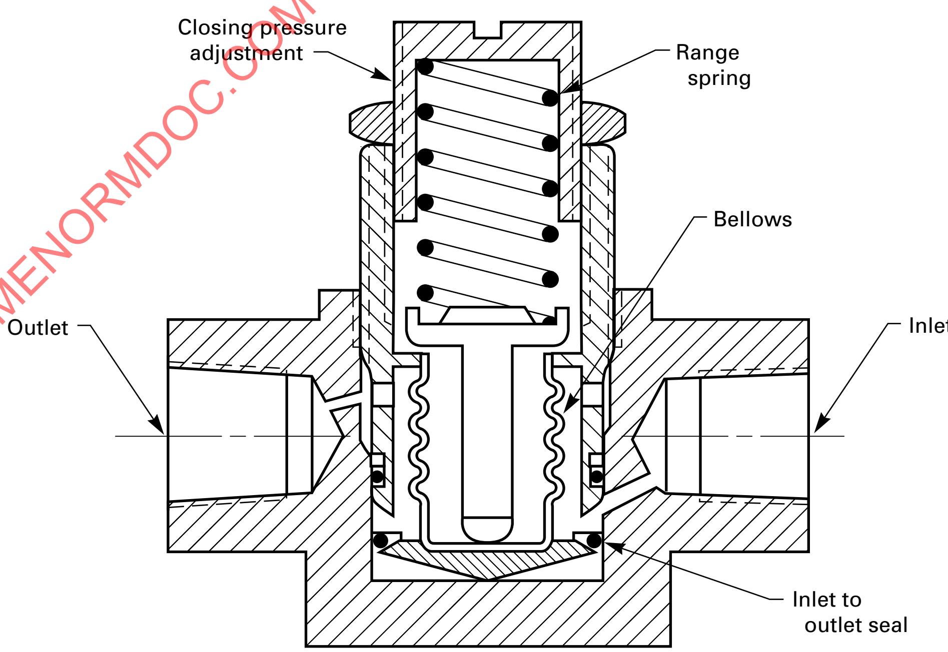


Figure 5-2.4-1
Bellows Type



5-3.2 Closing Range

The desired closing pressure must be within the closing range of the pressure limiter valve. The closing pressure must be below the proof pressure of the pressure-sensing instrument. Usually the closing pressure is set slightly above the full scale of the instrument being protected to allow indication of over-range. Typically, the diaphragm type can be set to the lowest closing pressure, followed by the bellows type, relief valve type, and piston type.

5-3.3 Reopening Pressure

The reopening pressure is always less than the closing pressure. Considerable variations in percentage between closing and reopening pressures may exist for different closing pressures within a given design.

5-3.4 Materials of Construction

Care should be given to the selection of metallic, nonmetallic, and elastomeric materials to ensure compatibility with process medium, process temperature and pressure, and environment. The effects of structural or mechanical loading must also be considered.

5-3.5 Pulsation/Surge Dampening

Some pressure limiter valves include fixed or adjustable pulsation and/or surge dampening features to minimize the effect of spikes (see para. 5-3.7).

5-3.6 Repeatability of Closing Pressure

Repeatability of closing pressure may be critical in some applications and should be considered.

5-3.7 Rate of Pressure Change

Where wide excursions in rates of pressure change occur in the system, devices with minimal variation of closing pressure — with respect to varying rates of pressure change — should be considered. Some devices may not close rapidly enough to protect pressure-sensing instruments against spikes. Addition of a snubber may be desirable (see para. 5-3.5).

5-3.8 External Venting

Some pressure limiter valves may vent into the atmosphere (see para. 5-2.3). Hazardous process media should be diverted to a suitable container.

5-3.9 Suspended Solids

Depending on design, a pressure limiter valve may be partially or completely plugged by solids in the medium. In these cases, it would be advisable to protect the instrument and pressure limiter valve with a filter, diaphragm seal, or similar accessory.

Care should be used in the application of a diaphragm seal. When a diaphragm seal is used, it must have sufficient volumetric displacement to operate the instrument and the pressure limiter valve. Pressure limiter valves that vent externally should not be used with diaphragm seals.

5-4 INSTALLATION

5-4.1 Connections

The most common connections are $\frac{1}{8}$ NPT, $\frac{1}{4}$ NPT, or $\frac{1}{2}$ NPT American Standard external or internal taper pipe threads per the latest edition of ASME B1.20.1. Other appropriately sized connections employing sealing means other than tapered threads are acceptable.

5-4.2 Methods of Installation

Most pressure limiter valves can be installed in any position in either gas or liquid processes. Follow the supplier's installation requirements.

5-4.3 Setting Pressure Limiter Valves

5-4.3.1 Supplier-Recommended Procedures. Supplier procedures must be followed when setting pressure limiter valves. Failure to follow recommended procedures may result in damage to the pressure limiter valve, an inaccurate closing pressure, and/or damage to the instrument.

5-4.3.2 Rate of Pressure Change. Closing pressures of pressure limiter valves may vary with the rate of pressure changes. The valves should be set with a rate of pressure change similar to that which they will experience in actual field applications (see para. 5-3.5).

5-4.3.3 Medium. If the setting medium is different from the process medium, it should be compatible with the process medium and all wetted parts (see para. 5-5.2.5.3). The devices should be set with the process medium or a medium of similar viscosity.

5-4.3.4 Supplier Preset Valves. Supplier preset devices should have the closing pressures carefully checked. The setting media and rates of pressure change used by the supplier may differ from field applications.

5-5 SAFETY

5-5.1 Scope

This section of the standard presents information to guide users and suppliers toward minimizing the hazards that could result from misuse or misapplication of pressure limiter valves. The user should become familiar with all sections of this Standard as all aspects of safety cannot be covered in this section. Consult the supplier for advice whenever there is uncertainty about the application.

5-5.2 General Discussion

5-5.2.1 Planning. Adequate safety results from intelligent planning, careful selection, and proper installation. The user should inform the supplier of all conditions pertinent to the application and environment so that the supplier can make the most suitable recommendation for the application.

5-5.2.2 Hazardous Systems and/or Conditions. Systems such as, but not limited to, the following are considered potentially hazardous and must be carefully evaluated:

(a) compressed gas systems
(b) oxygen systems (limiter valves not recommended)
(c) systems containing hydrogen or free hydrogen atoms
(d) corrosive fluid systems (gas and liquid)
(e) pressure systems containing any explosive or flammable mixture or medium
(f) steam systems
(g) nonsteady pressure systems
(h) systems wherein interchangeability of pressure limiter valves could result in hazardous internal contamination, or where lower working pressure devices could be installed in higher pressure systems
(i) systems containing radioactive or toxic fluids (liquids or gases)
(j) systems installed in a hazardous environment

5-5.2.3 Unique Media. When pressure limiter valves are to be used in contact with media having known or uncertain corrosive effects or known to be radioactive, random or unique destructive phenomena can occur. In such cases, the user should always furnish the supplier with information relative to the application and solicit his advice prior to installation of the device.

5-5.2.4 Violent Effects. Fire and explosions within a pressure system can cause failure with very violent effects. Failure in a compressed gas system can be expected to produce violent effects. Violent effects may also be caused by other failures including, but not limited to, the following:

(a) hydrogen embrittlement
(b) contamination of a compressed gas
(c) formation of acetylides
(d) weakening of soft-soldered joints by steam or other heat sources
(e) weakening of soft-soldered or silver-brazed joints caused by heat sources such as fires
(f) corrosion
(g) fatigue
(h) mechanical shock
(i) excessive vibration

Failure in a compressed gas system can be expected to produce violent effects.

5-5.2.5 Modes of Failure

5-5.2.5.1 Fatigue Failure. Fatigue failure of metallic parts caused by pressure-induced stress generally occurs from the inside to the outside along a highly stressed area. Such failures are usually more critical with compressed gas media than with liquid media.

5-5.2.5.2 Overpressure Failure. Overpressure failure is caused by the application of internal pressure greater than the rated limits of the pressure limiter valve and can occur when a lower pressure rated device is installed in a high-pressure port or system. The effects of overpressure failure, usually more critical in compressed gas systems than in liquid-filled systems, are unpredictable.

5-5.2.5.3 Chemical Failures

(a) *Metals.* Corrosion failure occurs when the metallic parts have been attacked either by the electrolytic action of dissimilar metals or by chemicals present in either the process medium or the environment. This may result in leakage, malfunction, or structural failure.
(b) *Nonmetals.* Failure occurs when the nonmetallic or elastomeric parts swell, harden, crack, dissolve, or fail through attack by chemicals present in the process medium or the environment. Failure may occur as leakage, improper or no shutoff, blockage of pressure transmission to the instrument, or structural failure.

5-5.2.5.4 Explosive Failure. Explosive failure is caused by the release of explosive energy generated by a chemical reaction. It is generally accepted that there are no known means of predicting the magnitude or effects of this type of failure.

5-6 REUSE OF PRESSURE LIMITER VALVES

It is not recommended that pressure limiter valves be moved from one application to another. Should it be necessary, all guidelines covered in this Standard relative to applications should be followed in the same manner as when a new device is selected. In addition, the following should be considered.

5-6.1 Chemical Incompatibility

The consequences of incompatibility can range from contamination to explosive failure.

5-6.2 Corrosion/Chemical Attack

Corrosion and/or chemical attack of the device in the first installation may be enough to cause early failure in the second installation.

5-7 TESTING

5-7.1 General

A functional test in the field application is the best testing method. If field testing is impractical, a test procedure close to field conditions (e.g., process media, rate of pressure change, temperature, and pressure cycles) should be designed. Always follow the supplier's recommended procedures for installation and adjustment during any product testing. If comparison tests are performed, it is imperative that each pressure limiter valve be tested with the same media, pressures, temperatures, and rates of pressure change.

5-7.2 Warning

Failures during pressure testing are unpredictable and may cause parts to be propelled in any direction. All pressure testing should be conducted by qualified personnel using appropriate safety equipment, such as safety glasses, shields, enclosures, or a combination thereof, to prevent personal injury and property damage. Hydraulic media is preferred for testing, particularly destructive testing, because the potential of hazardous failure with hydraulic media is less than with pneumatic media. Read subsection 5-5 before conducting any testing.

5-7.3 Evaluation Procedures

A pressure source (hydraulic or pneumatic) should be properly connected to the inlet port of the pressure limiter valve. A pressure-indicating instrument of suitable range should be properly connected to the outlet port of the pressure limiter valve. The pressure limiter valve should be adjusted per the supplier's recommended procedures. Apply increasing pressure to the inlet port to the maximum expected system pressure and record the closing pressure from the pressure-indicating instrument. Vent or release the pressure at the inlet port and record the reopening pressure. This pressure cycle should then be repeated without adjusting the pressure limiter valve.

5-7.3.1 Nondestructive Tests

5-7.3.1.1 Repeatability of Closing Pressure. Repeatability can be determined from the data obtained in two or more pressure cycles.

5-7.3.1.2 Reopening Pressure. Reopening pressure is determined by averaging the data obtained in two or more pressure cycles. The reopening pressure percentage below closing pressure may change as the closing pressure is changed.

The pressure limiter valve should be adjusted and the pressure cycle repeated to determine any changes in reopening pressure percentage versus closing pressure.

5-7.3.1.3 Closing Pressure Versus Rate of Pressure Change. The closing pressure may change as the rate of pressure change varies. Without readjusting the valve, the rate of pressure change should be altered for several pressure cycles to determine the variation of the closing pressure as the rate of pressure change varies.

5-7.3.1.4 Over-Range Pressure Test. For a given closing pressure, apply the rated over-range pressure (hydraulic preferred, see para. 5-7.2) to the pressure limiter valve inlet and maintain for 1 min. Release pressure and retest the valve to verify no degradation in performance has occurred. More than one cycle may be desired.

5-7.3.1.5 Proof Pressure Test. Apply rated proof pressure (hydraulic preferred, see para. 5-7.2) to the device and maintain for 1 min. Release pressure and retest the valve's performance.

NOTE: This test should not be conducted repeatedly on the same pressure limiter valve.

5-7.3.2 Destructive Tests

5-7.3.2.1 Burst Pressure Test. Apply pressure (hydraulic preferred, see para. 5-7.2) to the inlet and outlet ports of the pressure limiter valve. The pressure at which the assembly will no longer hold pressure is the burst pressure.

5-7.3.2.2 Rupture Pressure Test. Apply pressure (hydraulic preferred, see para. 5-7.2) to the inlet port of the pressure limiter valve, closing the sealing mechanism. The pressure at which the device fails to limit pressure from the inlet port to the outlet port is the rupture pressure.

5-7.3.2.3 Fatigue. Verify the closing and opening pressure of the pressure limiting valve (see para. 5-7.3.1). The device should then be subjected to repeated pressure cycles (hydraulic preferred, see para. 5-7.2). The maximum pressure should be 25% above the closing pressure, and the minimum pressure should be 25% below the reopening pressure at a rate of 0.3 Hz to 0.6 Hz (18 cpm to 36 cpm).

In order to prevent subjecting the device to pressure spikes, the application and release of pressure shall be as smooth as practical. The closing pressure of the valve should be 50% of the range of the instrument in the outlet port.

After the desired number of pressure cycles, retest the device not less than 1 h after stopping the pressure cycling. The fatigue life is the number of cycles completed before the pressure limiter valve fails to perform its intended function.

NOTE: These tests are applicable only to new pressure limiter valves. A new valve should be used for each test. Tested devices should not be put into service.

5-7.4 Production Testing

5-7.4.1 Definition of Pressure Zones. The pressure limiter consists of two pressure zones with the "inlet to outlet seal" being the boundary. The first pressure zone (P1) is from the inlet port to the "inlet to outlet seal." The second pressure zone (P2) is from the "inlet to outlet seal" to the outlet port (see Figure 5-2.1-1).

(a) The pressure in pressure zone (P1) can be the maximum system design pressure.

(b) The pressure in pressure zone (P2) can be the maximum closing pressure.

5-7.4.2 Shell/Seat Test of Pressure Zone P1. Each pressure limiter valve shall be given a shell/seat test of the pressure zone P1 at a gauge pressure no less than 1.5 times the 38°C (100°F) process pressure rating, rounded off to the next higher full pressure increment.

The typical test shall be made with water, which may contain a corrosion inhibitor, with kerosene, or with other suitable fluid, provided such fluid has viscosity not greater than that of water. The test fluid temperature shall not exceed 50°C (125°F).

The test time required for inspection after the pressure limiter is fully prepared and is under shell test pressure, shall be not less than 15 s.

Visually detectable leakage through the pressure boundary is not acceptable. The pressure boundary includes, along with the body, all gasketed joints.

NOTES:

(1) As the test pressure is higher than the closing pressure, the pressure limiter valve will close during this test and only the pressure zone P1 and the 'inlet to outlet seal' (seat) is tested.

(2) The range spring and the closing pressure adjustment do not have to be assembled for this test.

5-7.4.3 Shell Test of Pressure Zone P2. Each pressure limiter valve shall be given a shell test of the pressure zone P2 at a gauge pressure no less than 1.5 times the 38°C (100°F) maximum adjustable closing pressure, rounded off to the next higher full pressure increment.

The typical test shall be made with water, which may contain a corrosion inhibitor, with kerosene, or with other suitable fluid, provided such fluid has viscosity not greater than that of water. The test fluid temperature shall not exceed 50°C (125°F).

The test time required for inspection after the pressure limiter is fully prepared and is under shell test pressure, shall be not less than 15 s.

Visually detectable leakage through the pressure boundary is not acceptable. The pressure boundary includes, along with the body, all gasketed joints.

NOTES:

(1) As the test pressure is higher than the closing pressure, the sealing mechanism needs to be blocked in the half open position during this test, so that the test pressure can be applied to the pressure zone P2 without closing the valve.

(2) The range spring and the closing pressure adjustment do not have to be assembled for this test.

5-7.4.4 Set pressure. Before shipment, the closing pressure should be set to approximately the mid of the adjusting range. Regarding the setting to a required closing pressure, refer to para. 5-4.3.

MANDATORY APPENDIX I
TEST PROCEDURES USED TO MEASURE NEW GAUGE PERFORMANCE

I-1 SCOPE

This Appendix relates to the performance and test requirements of pressure gauges using C, spiral and helical-shaped Bourdon tubes. It covers pressure, compound, and vacuum gauges for industrial use up to 1 600 bar (23,000 psi); grades 3A, 2A, 1A, A and B, both dry and liquid filled; and all case sizes. It excludes

(a) gauges used on regulators as defined in Mandatory Appendix II

(b) gauges for Naval applications as defined in Mandatory Appendix III

(c) gauges employing diaphragm or bellows elastic elements

(d) duplex gauges, differential pressure gauges

(e) gauges with electrical contacts

Consult the manufacturer when it is known that the pressure gauges will encounter conditions more severe than those specified in this Appendix.

I-2 EVALUATION PROCEDURES

CAUTION: Failures during pressure testing are unpredictable and may cause parts to be propelled in any direction. All pressure testing should be conducted by qualified personnel using appropriate safety equipment, such as safety glasses, shields, enclosures, or a combination to prevent personal injury and property damage. Read subsection 2-3 before conducting any testing.

I-2.1 Accuracy

See para. 2-5.1 for a description of the test procedures.

I-2.2 Temperature-Related Errors

(For reference only, see para. 2-2.4.1.3 for more information.)

I-2.2.1 High Temperature Error. The gauge shall be tested for accuracy in accordance with para. 2-5.2.4.1. The gauge shall then be placed in a temperature test chamber at an elevated temperature [e.g., 60°C (140°F)] and allowed to stabilize for a period of not less than 4 h. The gauge shall then be checked for accuracy at this temperature, in accordance with para. 2-5.2.4.1. The difference in readings at each test point between room temperature and this temperature is the high temperature error.

NOTE: High temperature errors on liquid-filled gauges may be higher than those on dry gauges.

I-2.2.2 Low Temperature Error. The gauge shall be tested for accuracy in accordance with para. 2-5.2.4.1. The gauge shall then be placed in a temperature test chamber at a lower temperature [e.g., −20°C (−4°F)] and allowed to stabilize for a period of not less than 4 h. The gauge shall then be checked for accuracy at this temperature, in accordance with para. 2-5.2.4.1. The difference in readings at each test point between room temperature and this temperature is the low temperature error.

NOTE: Low temperature errors on liquid-filled gauges may be higher than those on dry gauges.

I-2.2.3 Storage Temperature Test. The gauge shall be tested for accuracy in accordance with para. 2-5.2.4.1. The gauge shall then be placed in a temperature test chamber and held at 70°C (158°F) for a period of 24 h. The gauge shall be allowed to cool to room temperature. The gauge shall then be placed in a temperature test chamber and held at −40°C (−40°F)] for a period of 24 h. This 48-h cycle shall be repeated four times for a total of five complete cycles. The gauge shall then be allowed to stabilize at room temperature and then be checked for accuracy, in accordance with para. 2-5.2.4.1. The readings shall be within the accuracy tolerance for the grade of the gauge. The gauge shall not exhibit any visible (by naked eye) change in appearance. The dial and pointer shall not crack, blister, or change color. If gauge cases are liquid filled, there shall be no evidence of the fill liquid leakage.

I-2.3 Pressure Testing

The following tests shall be conducted sequentially on the same gauge:

(a) Initial Reference Measurement. The gauge shall be tested for accuracy in accordance with para. 2-5.2.4.1.

(b) Rated Pressure Test. The gauge shall be pressurized to its full scale pressure for a minimum of 12 h. The leak rate shall not exceed 5×10^{-3} mbar × L/s (5×10^{-3} atm cc/s) at standard temperature using best practices.

Table I-2.3-1
Proof Pressure Testing Specifications

Pressure Range of Gauge, bar (psi)	Pressure in Percent of Span, %
0 to 100 (0 to 1,500)	125
>100 to 400 (>1,500 to 6,000)	115
>400 to 1 600 (>6,000 to 23,000 psi)	110

(c) Proof Pressure Testing. The gauge shall be overpressurized for 15 min to the values shown in Table I-2.3-1.

I-2.4 Fatigue Test (Cycling Pressure)

I-2.4.1 General. After the pressure testing described in I-2.3, the gauge shall be subjected to repeated applications of a pressure (hydraulic preferred) that produces an indication from 20% to 80% of the range of the gauge at a rate of 0.3 Hz to 0.6 Hz. The application and release of the pressure shall be as smooth as practicable, so as not to subject the gauge mechanism to excessive upscale or downscale accelerations or high amplitude impulses (pressure spikes). The number of cycles required for this test is shown on Table I-2.4.1-1.

NOTE: Pressure limits different from 20% to 80% of the range of the gauge can have a significant effect on the fatigue error and life.

I-2.4.2 Final Reference Measurement. Upon completion of the rated pressure test, proof pressure test, and fatigue test, the gauge shall be tested for accuracy in accordance with para. 2-5.2.4.1. The readings shall not exceed 1.2 times the accuracy tolerance for the grade of the gauge.

I-2.5 Rupture Pressure Test (Burst Test)

Apply pressure (hydraulic preferred) to the gauge under test, increasing the pressure at a maximum rate of 50% of the full scale per second until the Bourdon tube ruptures. The minimum rupture pressure shall be 2.5 times the ranges up to and including 300 bar (5,000 psi). For pressure ranges above 300 bar (5,000 psi), consult the manufacturer.

Table I-2.4.1-1
Fatigue Testing Cycle Requirements

Pressure Range Gauge, bar (psi)	Number of Cycles Required
0 to 25 (0 to 350)	300,000
25 to 600 (350 to 9,000)	100,000
600 to 1 600 (9,000 to 23,000)	20,000

I-2.6 Effect of Mechanical Shock

The gauge shall be tested for accuracy in accordance with para. 2-5.2.4.1. Gauges shall be tested in accordance with IEC 60068-2-27: 1987. Severity shall be 15 g or equivalent of 150 m/s^2 half sinewave with duration of 6 months. Three shock loads shall be applied in each of two directions of three orthogonal axes. The gauges shall be pressurized at 50% of span during the shock loads. The gauge shall be tested for accuracy in accordance with para. 2-5.2.4.1 after the shock loads. The changes in readings shall remain within the accuracy tolerance for the grade of the gauge.

I-2.7 Effect of Mechanical Vibration

The vibration test is required for gauges of accuracy grades 2A, 1A, A, and B.

The gauge shall be tested for accuracy in accordance with para. 2-5.2.4.1 before starting the vibration tests. Each of the tests specified below shall be conducted separately in each of three mutually perpendicular axes. All tests in one axis shall be completed before proceeding to tests in another axis. The gauge under test shall be secured to the vibration table in the same manner that it will be secured in service. In the case of surface or flush mounting, the panel shall be sufficiently rigid to ensure that its motion will be essentially the same as the motion of the platform of the vibration machine. Input condition should be monitored adjacent to the gauge mounting. A pressure of 50% ± 5% of full scale shall be applied to the gauge under test during vibration. This pressure may be applied by pressurizing the gauge and sealing the pressure port.

I-2.7.1 Exploratory Vibration Tests. To determine the presence of resonances, the gauge under test shall be vibrated at frequencies from 5 Hz to 60 Hz at a peak-to-peak amplitude not to exceed that shown in Table I-2.7.1-1. The change in frequency shall be made in discrete frequency intervals of approximately 1 Hz and maintained at each frequency for about 15 s. The frequencies and locations at which resonances occur shall be noted.

Table I-2.7.1-1
Vibration Test Amplitudes

Frequency, Hz	Amplitude, mm	Amplitude, in.
5 to 15	1.5 ± 0.3	0.060 ± 0.012
16 to 25	1.0 ± 0.2	0.012 ± 0.008
26 to 33	0.5 ± 0.1	0.020 ± 0.004
34 to 40	0.25 ± 0.05	0.010 ± 0.002
41 to 60	0.13 ± 0.025	0.005 ± 0.001
61 to 120	0.025 ± 0.005	0.001 ± 0.0002

I-2.7.2 Endurance Test. The gauge shall be tested for a period of 2 h in each of three mutually perpendicular axes (6 h total) at the resonant frequency determined in para. I-2.6. If more than one resonant frequency exists, the test shall be conducted at the highest resonant frequency. If no resonance is observed, the test shall be in accordance with Table I-2.7.1-1.

Test for accuracy in accordance with para. 2-5.2.4.1 before and after the endurance test. The readings shall not exceed 1.5 times the accuracy tolerance for the grade of the gauge.

I-2.8 Enclosure Tests

I-2.8.1 Pressure Relief — Solid Front Case, Slow Pressure Increase. Solid front gauges should protect the user from failure of the pressure system and the resulting release of pressurized media by deflecting the pressure release away from the front of the gauge.

The baffle wall between the Bourdon tube and dial should have a minimal number of openings. These openings should be less than 5% of the area of the baffle wall.

The existence of blowout devices should be verified by inspection of the gauge.

The functionality of the pressure relief devices should be tested by

(a) slowly pressurizing the case with air of the gauge, with the Bourdon tube removed

(b) sealing all areas of the case with low strength sealant, with the exception of the pressure relief areas

(c) slowly increasing a measured pressure until the pressure relief portion activates

(d) recording pressure at which the back blows out (for information only)

The window of the gauge should not fail during this test, nor should any components of the gauge be expelled from the front of the gauge.

I-2.8.2 Pressure Relief — Solid Front Case, Rapid Pressure Release. This test shall be conducted on a gauge from which the Bourdon tube has been removed as well as any fixed orifice devices. The pressure gauge shall be connected to a 1,500 psi air or nitrogen pressure source having sufficient volume to accommodate the internal volume of the gauge. Connection shall be made using a short length of $\frac{1}{4}$ in. (6 mm) minimum I.D. pipe or tubing of suitable wall thickness to withstand the required pressure. The pipe or tubing between the gauge and receiver shall include a union fitted with a frangible blowout disc. Sudden rupture of the elastic element in the pressure case shall be simulated by gradually raising the pressure in the receiver with nitrogen or air until the frangible disc ruptures. A quick opening valve may be substituted for the frangible blowout disc if the valve can be fully opened from the closed position in less than 25 ms. Upon release of pressure to the inside of the case, the gauge shall satisfy the following requirements: The pressure relief device (i.e. pressure relief plug, blowout disc, or pressure relief back) shall successfully open or relieve pressure within 500 ms from the case without expelling parts forward.

I-2.8.3 Pressure Relief — Open Front, Slow Pressure Increase. The functionality of pressure relief devices should be tested by removing the Bourdon tube and slowly pressurizing the case with air until the pressure relief device activates. The pressure shall be recorded. The pressure relief device (pressure relief plug, blowout disc, or pressure relief back) shall activate, successfully relieving pressure without causing a failure in the case or ejecting the window.

I-2.8.4 Liquid-Filled Gauges — Seal Integrity and Stability. This test must be conducted on each fill fluid.

(a) Mount gauge normally in accordance with the supplier's instruction.

(b) Heat filled gauge to the supplier's recommended maximum temperature, and hold for a minimum of 2 h.

(c) Reduce temperature to the supplier's recommended minimum temperature and hold for a minimum of 2 h.

(d) Repeat the above cycle 20 times.

(e) No leakage of the fill fluid is permitted.

(f) The dial must remain readable. No discoloration of the fill fluid, which degrades readability of the dial, is permitted.

NOTE: If some slight discoloration is observed, additional exposure to the maximum temperature may be desirable, to determine whether further darkening of the fluid, to the point where readability is affected, will occur.

I-2.8.5 Water and Particle Intrusion. The recommended minimum protection ratings shall be in accordance with IEC 60529.

(a) IP 31 for indoor use

(b) IP 44 for outdoor use

I-3 SELECTION OF GAUGES FOR TESTING

The following guidelines are provided for the purposes of demonstration of acceptance to the requirements of this Appendix.

(a) Gauge Types. Table I-3-1 shall be used to determine the types of gauges to be selected for the tests in this Appendix.

(b) Minimum Number of Gauges to be Tested. For the tests specified in Table I-3-1, unless otherwise specified, a minimum of four pieces shall be selected for each applicable Group specified in Table I-3-2. Selection shall include each applicable accuracy grade.

The selection within each group shall include the lowest and highest ranges manufactured.

Table I-3-1
Types and Number of Gauges to Be Tested

Test	Paragraph	Dry	Liquid-Filled	Minimum Number of Gauges
Accuracy	I-2.1	X	X	See para. I-3(b)
Temperature Related Errors (for reference only)	I-2.2	X	X	See para. I-3(b)
Storage Temperature	I-2.2.3	X		See para. I-3(b)
Pressure Tests	I-2.3	X		See para. I-3(b)
Fatigue	I-2.4	X		See para. I-3(b)
Rupture (Burst)	I-2.5	X		See para. I-3(b)
Mechanical Shock	I-2.6	X	X	See para. I-3(b)
Mechanical Vibration (Grades 2A, 1A, A, and B)	1-2.7	X	X	See para. I-3(b)
Enclosure Tests				4
Pressure Relief Solid Front (slow increase)	I-2.8.1	X		4
Pressure Relief Solid Front (rapid increase)	I-2.8.2	X		4
Pressure Relief Open Front	I-2.8.3	X		4
Liquid Fill Seal Integrity	I-2.8.4		X	4
Water and Particle Intrusion	I-2.8.5		X	4

Table I-3-2
Selection of Gauges for Testing

Group	Pressure Range, psi
A	−15 to 45
B	30 to 400
C	300 to 10,000
D	9,000 to 23,400

I-4 REFERENCED DOCUMENTS

IEC 60068-2-27: 1987, Basic Environmental Testing Procedures Part 2: Tests — Test Ea and Guidance: Shock.

IEC 60529, Degrees of Protection Provided by Enclosures (IP Code)

Publisher: International Electrotechnical Commission (IEC), 3, rue de Varembé, Case Postale 131, CH-1211, Genèva 20, Switzerland/Suisse (www.iec.ch)

MANDATORY APPENDIX II
GAUGES USED ON REGULATORS

II-1 GENERAL

This Appendix is intended to emphasize and supplement the recommendations contained in this Standard and to guide personnel specifying and installing gauges used on regulators for oxy-fuel gas welding, cutting, and allied processes. It should not be assumed that every test or safety procedure or method, precaution, equipment, or device is contained in this Appendix, or that abnormal or unusual circumstances may not warrant suggesting further requirements or additional procedures.

II-2 SCOPE

This Appendix is intended to emphasize those parts of this Standard that are applicable to gauges commonly used on regulators for oxy-fuel gas welding, cutting, and allied processes and to provide specific considerations for gauge dial printing (marking) and gauge installation.

II-3 RECOMMENDATIONS

II-3.1 General References

Gauges used on regulators for oxy-fuel gas welding, cutting, and allied processes are to be governed by the recommendations of this Standard.

To facilitate the use of this Standard, references have been made to specific sections and paragraphs.

II-3.2 General Contents

(a) Basic Terms. Basic terms and definitions are outlined in Section 3.

(b) General Requirements. General requirements are provided in subsection 2-2. Gauges used on regulators are usually size 1½ in., 2 in., and 2½ in., mounted by the stem (socket), and have open front cases with pressure relief. They shall be grade B accuracy or better.

(c) Safety Considerations. Safety considerations are discussed in subsection 2-3.

(d) Cleanliness Levels. Cleanliness levels are detailed in subsection 2-4. Gauges used on oxygen regulators shall have cleanliness equivalent to Level IV.

(e) Testing Standards and Procedures. Pressure gauge testing standards and procedures are discussed in subsection 2-5. Additional information is outlined in Mandatory Appendix I.

(f) Helpful Information. Subsection 2-6 contains helpful information relative to ordering gauges, related standards, and conversion factors.

II-3.3 Gauges Used on Regulators

The following references to specific paragraphs of this Standard apply to gauges used on regulators. Appropriate additional considerations are discussed.

(a) Sizes. See para. 2-2.1. The nominal gauge sizes are 1½ in., 2 in., and 2½ in. for regulator applications.

(b) Ranges. See para. 2-2.2. Common ranges for gauges used on regulators are listed in Table II-3.3-1 by customary units and the corresponding SI units (rounded to a maximum of two significant figures).

It is recommended that no larger graduations than those shown in Table II-3.3-1 be printed (marked) on the gauge dial. The spacing and displaying of the numerals marked on the gauge dial may vary for aesthetic reasons, provided that at least three numerals are displayed.

(c) Cases. See paras. 2-2.3.1 and 2-3.2.6. The cases commonly used for regulator gauge applications are open front with pressure relief. Figure 1-3-3 and paras. 2-2.3.1.1 and 2-2.3.1.4 outline case construction.

(d) Dials. See para. 2-2.3.2.

(1) Recommended units of measure for gauges used on regulators are kPa and psi (psig) presented together (dual scale).

(2) Paragraphs 2-2.3.2.3 through 2-2.3.2.5 are applicable. Scale graduations on gauges installed on the output side of acetylene regulators are usually restricted to 15 psi, with the scale red-lined above 15 psi.

(3) Dials used on regulator gauges having ranges greater than 1,000 psi usually contain a UL listing mark. The UL listing mark indicates that the gauge design complies with Underwriters Laboratories Safety Standard UL 404 and gauges bearing the listing mark are subject to UL follow-up procedures.

(e) Pointer Length. See para. 2-2.3.3(a).

(f) Pressure Connection. See para. 2-2.3.4. Gauges used on regulators are stem mounted and have ⅛ NPT or ¼ NPT taper pipe threads, per ANSI B1.20.1.

Table II-3.3-1
Ranges

Customary Units, psi			Si Units, kPa		
Range	Smallest Graduation	Numerals	Range	Smallest Graduation	Numerals
0/15	0.5	3.0	0/100	2.0	20
0/30	1.0	5.0	0/200	5.0	50
0/50	1.0	10	0/350	10	50
0/60	2.0	10	0/400	10	100
0/100	2.0	20	0/700	20	100
0/150	5.0	30	0/1 000	20	200
0/160	5.0	20	0/1 100	20	200
0/200	5.0	40	0/1 400	50	200
0/300	10	50	0/2 000	50	500
0/400	10	50	0/2 800	100	400
0/500	10	100	0/3 500	100	500
0/600	20	100	0/4 000	100	1 000
0/1,000	20	200	0/7 000	200	1 000
0/1,500	50	300	0/10 000	200	2 000
0/2,000	50	400	0/14 000	500	2 000
0/3,000	100	500	0/20 000	500	5 000
0/4,000	100	500	0/28 000	1 000	4 000
0/5,000	100	1,000	0/35 000	1 000	5 000
0/6,000	200	1,000	0/40 000	1 000	10 000
0/7,500	200	1,000	0/50 000	1 000	10 000
0/10,000	200	2,000	0/70 000	2 000	10 000

(g) Windows. See para. 2-2.3.7. Plastic windows are most commonly used on regulator gauges.

(h) Accuracy. See para. 2-2.4. Gauges shall have an accuracy of Grade B or better (see Table 2-2.4-1). Applicable paragraphs in this section include 2-2.4.1.1, 2-2.4.1.2, 2-2.4.1.6, 2-2.4.1.9, 2-2.4.1.10, and 2-2.4.1.12.

(i) Safety. See subsection 2-3. Personnel specifying and installing pressure gauges used on oxy-fuel gas regulators should become familiar with the material presented in this section.

(j) Cleanliness. See subsection 2-4. Gauges used on oxygen regulators shall comply with cleanliness Level IV or better.

(k) Acetylene. See para. 2-3.2.8.1.

(l) Pressure Gauge Testing. See subsection 2-5. The pressure medium used for testing shall maintain the required cleanliness level of the gauge under calibration adjustment or calibration verification. The dead-ended pressure element assembly of regulator gauges cannot be reliably cleaned once contaminated. Gauges contaminated with hydrocarbon pressure media shall not be used on oxygen regulators.

II-4 INSTALLATION

II-4.1 References

This section is limited to the installation of gauges on regulators, as used for oxy-fuel gas welding, cutting, and allied processes. The installation and operation of regulators may be found in manufacturer's instruction manuals or handbooks, in the Occupational Safety and Health Standards for Industry (29 CFR, Part 1910), Subpart Q, and in the National Institute for Occupational Safety and Health (NIOSH), Safety and Health in Arc Welding and Gas Welding and Cutting.

II-4.2 General Precautions

Oxygen and hydrocarbons (oil and grease are common hydrocarbons) under certain conditions can react violently, resulting in explosions, fire, and damage and injury to personnel and property. Never allow oil or grease to come into contact with any external or internal part of the threaded fitting or internal portion of the pressure element assembly of oxygen gauges. Even a minute amount of hydrocarbon can be hazardous in the presence of oxygen.

Regulator gauges should be installed or replaced only by skilled personnel who have been properly instructed.

II-4.3 Installation Precautions

(a) DO maintain the pressure element assembly and connection cleanliness level required for the intended application.

(b) DO refer to the manufacturer's instruction manual for the correct pressure ranges to be used.

(c) DO use the wrench flats provided on the gauge connection and the proper size wrench to secure the gauge to the regulator.

(d) DO use only the thread sealant recommended by the regulator manufacturer for the specific application.

(e) DO NOT install a low-pressure gauge into the high-pressure port on a regulator.

(f) DO NOT use the gauge case for wrenching.

(g) DO NOT interchange gauges from one gas application to another.

(h) DO NOT exchange gauges from one regulator to another.

(i) DO NOT conduct calibration using air from shop air lines, oil, or a contaminated pressure source.

(j) DO NOT remove the restrictor installed in the gauge connection. The restrictor limits gas flow and aids in limiting temperature rise due to adiabatic compression.

II-4.4 Operation Precautions

Gauges can fail during operation and the energy contained in compressed gases can produce violent effects should the pressure element assembly rupture.

(a) DO always apply cylinder pressure slowly. Heat due to adiabatic compression can cause ignition.

(b) DO use safety glasses or provide eye protection.

(c) DO stand with the cylinder between yourself and the regulator (cylinder valve outlet facing away) when opening the cylinder valve.

(d) DO read CGA Safety Bulletin SB-8, Use of Oxy-Fuel Gas Welding and Cutting Apparatus.

(e) DO NOT stand in front of or behind the pressure gauges when applying cylinder pressure to the regulator. This will reduce the possibility of injury from flying parts should the pressure element assembly rupture.

(f) DO NOT operate regulators without eye protection.

II-5 Referenced Documents

The edition bearing the latest date of issuance shall be used.

ASME B1.20.1, Pipe Threads, General Purpose, (Inch)
Publisher: The American Society of Mechanical Engineers (ASME), Two Park Avenue, New York, NY 10016-5990 (www.asme.org)

CGA E-4, Standard for Gas Pressure Regulators
CGA SB8, Use of Oxy-Fuel Gas Welding and Cutting Apparatus, Technical Bulletin
Publisher: Compressed Gas Association, Inc. (CGA), 14501 George Carter Way, Suite 103, Chantilly, VA 20151 (www.cganet.com)

29 CFR, Part 1910, Subpart Q, Occupational Safety and Health Administration (OSHA), Welding, Cutting and Brazing
Publisher: United States Department of Labor, 200 Constitution Ave NW, Washington, DC 20210 (www.osha.gov)

UL 404, Gauges, Indicating Pressure, for Compressed Gas Service
Publisher: Underwriters Laboratories, Inc. (UL), 333 Pfingsten Road, Northbrook, IL 60062-2096 (www.ul.com)

MANDATORY APPENDIX III
SUPPLEMENTAL REQUIREMENTS — NAVAL APPLICATIONS

III-1 INTRODUCTION

The following supplementary requirements established for naval shipboard application shall apply when specified in the contract or purchase order. When there is conflict between the Standard (see Section 4) and this Appendix, the requirements of this Appendix shall take precedence for equipment acquired by this supplement. This document supersedes MIL-G-18997E, for new ship construction.

III-2 SCOPE

This addendum describes requirements for Naval hardened pressure gauges for use in the demanding environment of marine applications. Many of the basic requirements of Section 2 apply; however some modified and/or additional requirements, which include withstanding shock and salt-water spray, are included.

III-3 GENERAL REQUIREMENTS

III-3.1 Gauge Sizes

Naval hardened gauges are limited to these five nominal sizes: 2 in., 2½ in., 3½ in., 4½ in., and 8½ in.

III-3.2 Gauge Ranges

The following gauge types are shown with their ranges and respective range designators:

(a) *Positive Pressure.* Table III-3.2-1 shows the ranges and range designators for general purpose positive pressure gauges.

(b) *Negative Pressure.* The range and range designator for negative (vacuum) pressure gauges are shown below.

Negative Pressure, in. Hg Vacuum	Range Designator
0/30	V

(c) *Compound Pressure.* Table III-3.2-2 shows the ranges and range designators for general purpose compound pressure gauges.

(d) *Refrigerant Pressure*

(1) *General.* Table III-3.2-3 shows the ranges and range designators for refrigerant pressure gauges.

(2) *Gauge Scale.* A separate temperature degrees Fahrenheit (°F) equivalent scale in red printing, in addition to the pressure scale in lb/in.^{2}, shall be included. The type of refrigerant used with the pressure gauge shall be marked on the dial (see para. III-2.3.3.2).

(e) *Suppressed.* The range and range designator for suppressed pressure gauges are shown below.

Suppressed Pressure Range, lb/in.^{2}	Range Designator
1,000/1,500	S

(f) *Retard.* Table III-3.2-4 shows the ranges and range designators for retard pressure gauges.

(g) *Caisson Pressure.* Caisson gauges are intended for use in submarine escape trunks and decompression chambers. They shall have a dual scale with the inner scale graduated in meters or feet of seawater and the outer scale in lb./in.^{2} The gauge case shall be open to the ambient pressure through a vent in the bottom of the case. The vent shall be threaded to accept a ¼ in. NPT male fitting. Table III-3.2-5 shows the ranges and range designators for caisson pressure gauges. Feet shall indicate feet (depth) of seawater. One foot of seawater shall equal 0.4453 psi.

III-3.3 Construction

III-3.3.1 Case

III-3.3.1.1 Design. Pressure gauge cases shall be safety solid front. However, a nonsolid front is permitted for gauges with elastic element Style D (helical and helical-spiral Bourdon tube). Cases for hardened gauges must withstand the demands of a saltwater environment and meet shock requirements. Cast iron, mild steel or plastic (with the exception of the window) shall not be used. When used, aluminum shall be protected against corrosion per ASTM B26, ASTM B85, and ASTM B209. Case finish shall then include air dry primer and a gray enamel finish coat in accordance with AMS-STD-595, color 26307. Corrosion resisting steel (CRES) shall be 300 series stainless steel per ASTM A240, ASTM A276, or ASTM A473 when used. Cases shall be interchangeable for mounting purposes with the case shown in Figure III-3.3.1.1-1. Dimensions A3, A4, A8, A10, A15, and A17 shall be critical dimensions and shall be in accordance with Figure III-3.3.1.1-1.