AN AMERICAN NATIONAL STANDARD

# ASME B40.100a-2001

# ADDENDA

to

## ASME B40.100-1998
## PRESSURE GAUGES AND GAUGE ATTACHMENTS

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS
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# ASME B40.100a-2001

Following approval by the ASME B40 Committee and ASME, and after public review, ASME B40.1, ASME B40.2, and ASME B40.5 were approved by the American National Standards Institute (ANSI) on December 1, 2000; and ASME B40.6 was approved by ANSI on February 5, 2001.

Addenda to the 1998 edition of ASME B40.100 are issued in the form of replacement pages. Revisions, additions, and deletions are incorporated directly into the affected pages. It is advisable, however, that this page, the Addenda title and copyright pages, and all replaced pages be retained for reference.

## SUMMARY OF CHANGES

This is the first Addenda to be published to ASME B40.100-1998.

Replace or insert the pages listed. Changes given below are identified on the pages by a margin note, **(a)**, placed next to the affected area. The pages not listed are the reverse sides of the listed pages and contain no changes.

| *Page* | *Location* | *Change* |
|---|---|---|
| vii | Preface | Updated to reflect Addenda |
| ix, x | Roster | Updated to reflect Addenda |
| xi | Contents | Updated to reflect Addenda |
| 1 | ASME B40.1 Contents | Updated to reflect Addenda |
| 36.1–36.12 | ASME B40.1 | Nonmandatory Appendix C added |
| 36.13–36.37 | ASME B40.2 | Added |
| 36.39–36.60 | ASME B40.5 | Added |
| 36.61–36.70 | ASME B40.6 | Added |

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# PREFACE (a)

## ORGANIZATION OF THIS DOCUMENT

This Standard compiles the following standards.

| *Standard* | *Title* |
|---|---|
| ASME B40.1 | Gauges: Pressure Indicating Dial Type: Elastic Element |
| ASME B40.2 | Diaphragm Seals |
| ASME B40.5 | Snubbers |
| ASME B40.6 | Pressure Limiter Valves |
| ASME B40.7 | Gauges: Pressure Indicating Digital |

## ADDENDA SERVICE

This edition of ASME B40.100 includes an automatic addenda subscription service up to the publication of the next edition. The addenda subscription service will include the additional B40 documents not already included in the initial publication, and approved revisions to the existing parts.



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**G. G. Wang,** Illumina, Inc.
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# CONTENTS

(a)


Foreword ..... iii
Correspondence with B40 Committee ..... v
Preface ..... vii
Standards Committee Roster ..... ix

**ASME B40.1 Gauges: Pressure Indicating Dial Type: Elastic Element** ..... 1

**ASME B40.2 Diaphragm Seals** ..... 36.13

**ASME B40.5 Snubbers** ..... 36.39

**ASME B40.6 Pressure Limiter Valves** ..... 36.61

**ASME B40.7 Gauges: Pressure Digital Indicating** ..... 37




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# ASME B40.1 (a)


**1 Scope** ..... 3

**2 Pressure Gauges, General** ..... 3

**3 General Recommendations** ..... 15

**4 Safety** ..... 20

**5 Cleanliness** ..... 24

**6 Pressure Gauge Testing** ..... 25

**7 Ordering Parameters and Related Standards** ..... 26

**Figures**

1 Basic Pressure Terms ..... 4
2 Pressure Gauge Components (C Type Bourdon Illustrated) ..... 5
3 Elastic Elements ..... 6
4 Cases ..... 7
5 Example: Dial, Dual Scale ..... 8
6 Cases/Mounting ..... 10
7 Example: Scale Shown is Retarded from 10 to 30 ..... 11
8 Example: Scale Shown is Suppressed 0 to 50 ..... 11
9 Recommended Case and Mounting Dimensions ..... 17

**Tables**

1 Accuracy Grades ..... 4
2 Cleanliness Levels ..... 24

**Nonmandatory Appendices**

A Some Definitions and Suggested Test Procedures for Parameters Used to Measure New Gauge Performance ..... 29
B Gauges Used on Regulators ..... 33
C Supplemental Requirements ..... 36.1




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# NONMANDATORY APPENDIX C
# SUPPLEMENTAL REQUIREMENTS

(a)

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 (ASME B40.1) and this supplement, the requirements of this supplement shall take precedence for equipment acquired by this supplement. This document supercedes MIL-G-18997, Gauges, Pressure, Dial Indicating, for new ship construction.

## C1 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 ASME B40.1 apply, however some modified and/or additional requirements, which include withstanding shock and salt-water spray, are included.

## C2 GENERAL REQUIREMENTS

### C2.1 Gauge Sizes

Naval hardened gauges are limited to these five nominal sizes: 2 in., 2½ in., 3½ in., 4½ in., and 8½ in.

### C2.2 Ranges

The following gauge types are shown with their ranges and respective range designators.

**C2.2.1 Positive Pressure.** Table C1 shows the ranges and range designators for general purpose positive pressure gauges.

**C2.2.2 Negative Pressure.** Table C2 shows the ranges and range designators for negative (vacuum) pressure gauges.

**C2.2.3 Compound Pressure.** Table C3 shows the ranges and range designators for general purpose compound pressure gauges.

**C2.2.4 Refrigerant Pressure.** Table C4 shows the ranges and range designators for refrigerant pressure gauges.

**C2.2.4.1 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 refrigerant used with the pressure gauge shall be marked on the dial (see para. C2.3.3.2).

**TABLE C1 POSITIVE PRESSURE RANGE DESIGNATORS**

| Positive Pressure, lb/in.$^2$ | Range Designator |
|---|---|
| 0/15 | 15P |
| 0/30 | 30P |
| 0/60 | 60P |
| 0/100 | 1hP |
| 0/160 | 160P |
| 0/200 | 2hP |
| 0/300 | 3hP |
| 0/400 | 4hP |
| 0/600 | 6hP |
| 0/800 | 8hP |
| 0/1000 | 1kP |
| 0/1500 | 15hP |
| 0/2000 | 2kP |
| 0/3000 | 3kP |
| 0/5000 | 5kP |
| 0/8000 | 8kP |
| 0/10000 | 10kP |

GENERAL NOTES:
(a) Gauge pressure ranges from 0/15 to 0/1000 are applicable to both simplex and duplex indicators.
(b) Gauge pressure ranges from 0/1500 to 0/10000 are applicable to simplex only.

**TABLE C2 NEGATIVE PRESSURE RANGE DESIGNATORS**

| Negative Pressure, in. Hg Vacuum | Range Designator |
|---|---|
| 0/30 | V |

**C2.2.5 Suppressed.** Table C5 shows the range and range designator for suppressed pressure gauges.

**C2.2.6 Retard.** Table C6 shows the ranges and range designators for retard pressure gauges.



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**TABLE C3 COMPOUND PRESSURE RANGE DESIGNATORS**

| Compound Pressure | | |
|---|---|---|
| Vacuum in. Hg | Gauge Pressure, lb/in.$^2$ | Range Designator |
| 30 | 0/15 | 15C |
| 30 | 0/30 | 30C |
| 30 | 0/60 | 60C |
| 30 | 0/100 | 1hC |
| 30 | 0/150 | 150C |
| 30 | 0/200 | 2hC |
| 30 | 0/300 | 3hC |
| 30 | 0/400 | 4hC |
| 30 | 0/600 | 6hC |
| 30 | 0/800 | 8hC |

**TABLE C4 REFRIGERANT PRESSURE RANGE DESIGNATORS**

| Ranges | | | |
|---|---|---|---|
| Vacuum, in. Hg | Gauge Pressure, lb/in.$^2$ | Refrigerant Type | Range Designator |
| 30 | 0/30 | R-11 | A11 |
| 30 | 0/100 | R-11 | B11 |
| 30 | 0/150 | R-11 | C11 |
| 30 | 0/300 | R-11 | D11 |
| 30 | 0/100 | R-12 | E12 |
| 30 | 0/150 | R-12 | F12 |
| 30 | 0/300 | R-12 | G12 |
| 30 | 0/150 | R-22 | H22 |
| 30 | 0/300 | R-22 | J22 |
| 30 | 0/30 | R-114 | K14 |
| 30 | 0/100 | R-114 | L14 |
| 30 | 0/150 | R-134A | M34 |
| 30 | 0/300 | R-134A | N34 |

**TABLE C5 SUPPRESSED PRESSURE RANGE DESIGNATORS**

| Suppressed Pressure Range, lb/in.$^2$ | Range Designator |
|---|---|
| 1000/1500 | S |

**C2.2.7 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 C7 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.

**TABLE C6 RETARD PRESSURE RANGE DESIGNATORS**

| Retard | | | |
|---|---|---|---|
| Vacuum, in. Hg | Gauge Pressure, lb/in.$^2$ | Expanded Portion | Range Designator |
| . . . | 0/30 | 0/10 | R1 |
| 30 | 0/30 | 30 in. 0/5 lb/in.$^2$ | R2 |
| 30 | 0/150 | 30 in. 0/75 lb/in.$^2$ | R3 |

**TABLE C7 CAISSON PRESSURE RANGE DESIGNATORS**

| Caisson | Range Designator |
|---|---|
| 0/100 lb/in.$^2$ – 0/230 ft depth | 1hK |
| 0/200 lb/in.$^2$ – 0/450 ft depth | 2hK |
| 0/300 lb/in.$^2$ – 0/675 ft depth | 3hK |
| 0/380 lb/in.$^2$ – 0/850 ft depth | 380K |
| 0/380 lb/in.$^2$ – 0/900 ft depth | 4hK |

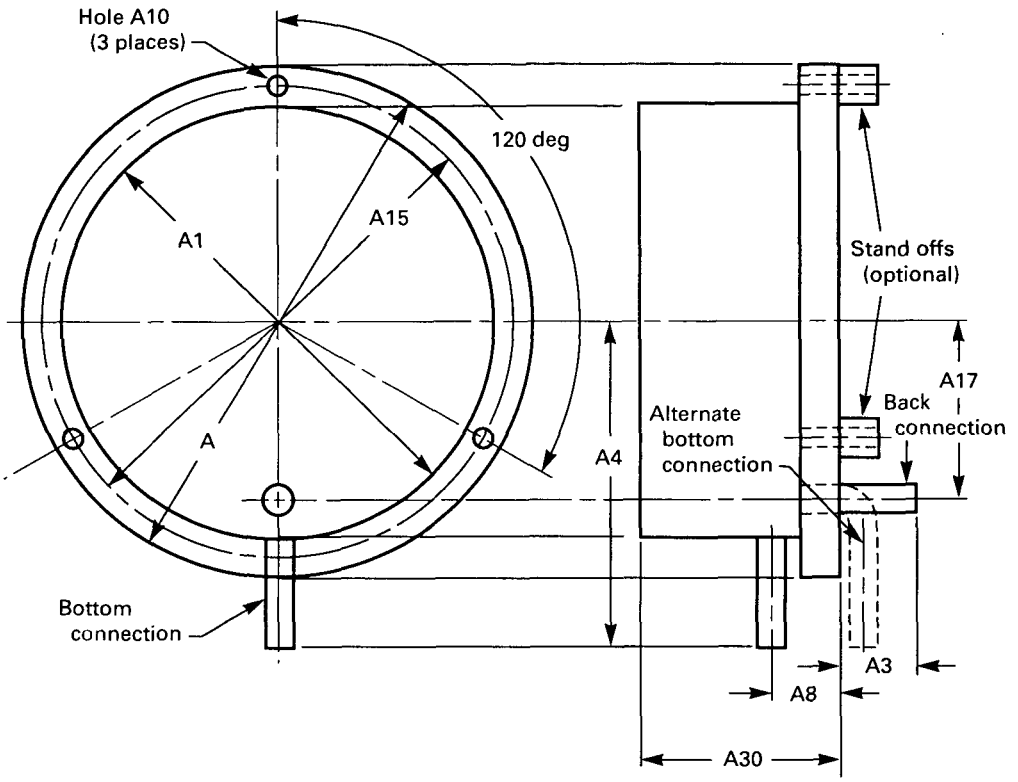
## C2.3 Construction

### C2.3.1 Case

**C2.3.1.1 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 per ASTM B 26, B 85, and B 209 shall be protected against corrosion. Case finish shall then include air dry primer and a gray enamel finish coat in accordance with FED-STD-595, color 26307. Corrosion resisting steel (CRES) shall be per ASTM A 167 Series 300 and ASTM A 473 Series 300 when used. Cases shall be interchangeable for



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| Size/DIM | A ± 0.1 | A1 + 0.000 − 0.1 | A3 ± 0.3 | A4 ± 0.3 | A8 ± 0.1 | A10 ± 0.01 | A15 ± 0.015 | A17 ± 0.050 | A30 |
|---|---|---|---|---|---|---|---|---|---|
| 3½ | 4.75 | 3.97 | 1.2 | 3.2 | 1.0 | 0.22 | 4.25 | 1.063 | 2.54 – 4.0 |
| 4½ | 5.80 | 5.00 | 1.2 | 3.8 | 1.0 | 0.22 | 5.375 | 1.625 | 2.54 – 4.0 |
| 8½ | 10.25 | 8.97 | 1.2 | 5.8 | 1.0 | 0.28 | 9.625 | 3.625 | 2.54 – 4.0 |

GENERAL NOTES:
(a) For flush mounting, standard panel hole diameters are:
$3\frac{1}{2} \longrightarrow 4\frac{15}{32}$
$4\frac{1}{2} \longrightarrow 5\frac{19}{32}$
$8\frac{1}{2} \longrightarrow 9\frac{29}{32}$
(b) Dimensions are in inches.

**FIG. C1 CASE DESIGN**

mounting purposes with the case shown in Fig. C1. Dimensions A3, A4, A8, A10, A15, and A17 shall be critical dimensions and shall be in accordance with Fig. C1.

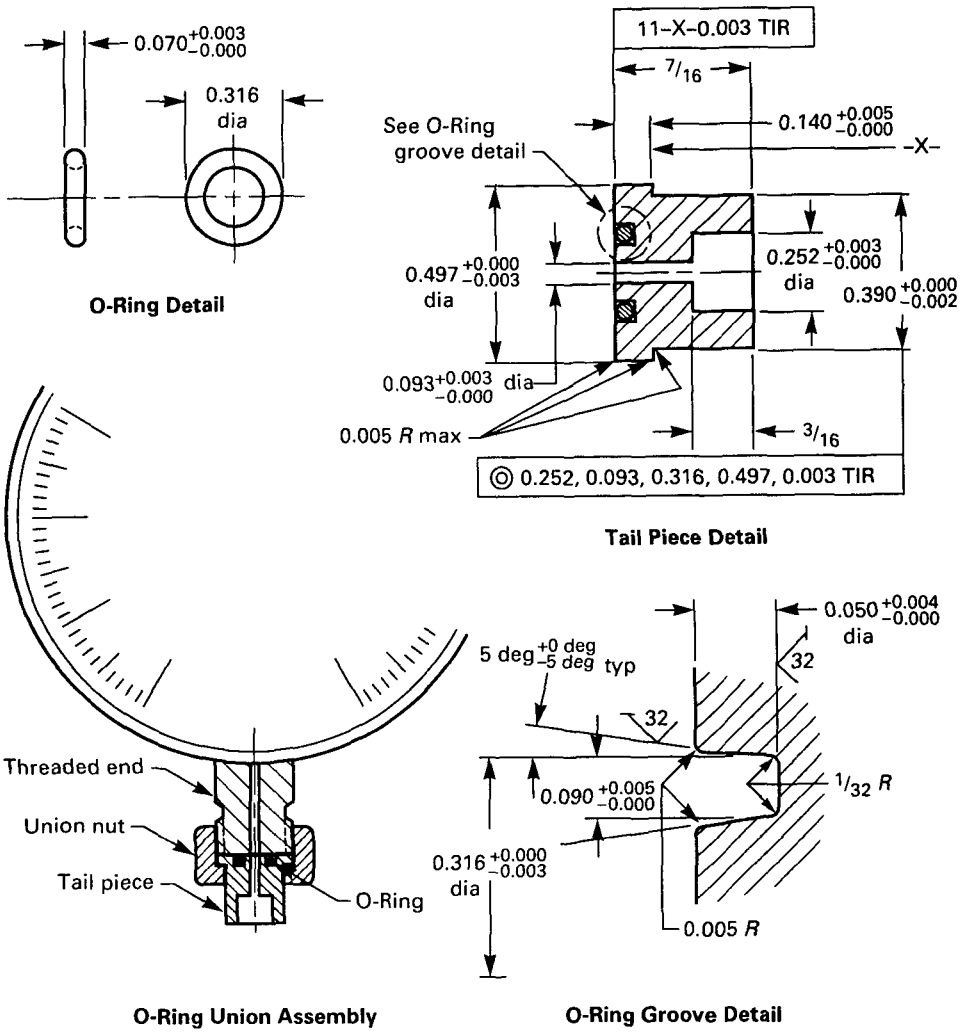
**C2.3.1.2 Mounting.** Flush mounting kits shall be provided with all pressure gauges. Material shall be CRES except steel may be used for the ring and clamping ring. The maximum outside diameter of the flush mounting rings shall overlap the panel hole by no more than 0.25 in.

### C2.3.2 Internal and Other Parts

**C2.3.2.1 Welding or Nicrobrazing.** Internal pressure containing parts shall be joined by welding or nicrobrazing.



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GENERAL NOTE: Dimensions are in inches.

**FIG. C2 O-RING UNION ASSEMBLY**

**C2.3.2.2 Materials.** Wetted parts shall be nickel-copper alloys. Wetted parts include any part that comes in contact with the measured fluid, e.g., Bourdon tube, stem, tail piece (see Fig. C2), etc. Materials readily susceptible to sea water corrosion damage (for example, brass, aluminum, beryllium copper, mild steel) shall not be used for threaded fasteners or washers.

**C2.3.2.3 O-Ring.** O-rings shall be fluorocarbon rubber in accordance with SAE-AMS 7259, hardness of 85 to 95 Durameter.

**C2.3.3 Dials.** Dials shall be designed to resist damage from corrosion.

**C2.3.3.1 Units.** The standard units for gauges shall be customary (English). Dual scale (customary and SI) may be used on all gauges except for Caisson (see para. C2.2.7) and Refrigeration (see para. C2.2.4), in order to permit transition to SI units. Refrigeration gauges that show both temperature and pressure readings shall use customary units for readability.

**C2.3.3.2 Markings.** Dial markings shall include:

(*a*) The manufacturer's name or trademark (or both);

(*b*) CAGE (Commercial and Government Entity) code;

(*c*) Part Identifying Number (PIN) (see para. C6.2.1);

(*d*) NSN (National Stock Number), if assigned;

(*e*) scale graduations, numerals, and units of graduations;

(*f*) refrigerant gauges shall include the type refrigerant and applicable temperature equivalent scale.



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**TABLE C8 PRESSURE CONNECTION REQUIREMENTS AND APPLICATIONS**

| Pressure Connection | Threads | Reference | Intended Use |
|---|---|---|---|
| O-ring union | $^{9}/_{16}$-UNF-3A | Figs. C2 and C3 | For all applications, except nuclear |
| Taper pipe thread (male) | $^{1}/_{4}$-18 NPT | ASME B1.20.1 | For use in stem-mounted pressure gauges with ranges 0/100 lb/in.$^2$ or below |
| Flareless (bite type) $^{1}/_{4}$ in., tubing, 6,000 psi | $^{7}/_{16}$-20 UNF-2A | SAE J 1926 | For nuclear applications |

**C2.3.4 Pointer.** Indicating pointers shall be a nonreflective black with white background dials or white when dials have black backgrounds. The index pointer shall be a nonreflective red and shall be set off-scale prior to delivery. Duplex indicator pointers shall be orange (left) and green (right).

**C2.3.5 Pressure Connection.** The pressure connection shall be in accordance with Table C8. The O-ring union connection (see Figs. C2 and C3) shall be supplied unless otherwise specified and shall include the threaded end, union nut, tail piece and O-ring.

**C2.3.5.1 Location.** Table C9 lists the four possible connection locations.

**C2.3.5.2 Type of Connection.** Threads shall be in accordance with Table C8. Tapered threads shall not be used except on 2 in. and 2½ in., dial sizes for ranges 0/100 lb/in.$^2$ or below.

**C2.3.6 Windows.** Windows shall be fabricated from scratch-resistant thermoplastic in accordance with ASTM D 788.

**C2.3.7 Maximum Stop.** Gauges shall incorporate a maximum stop (see para. 3.3.7.1).

## C3 CLEANLINESS AND PACKAGING

### C3.1 Wetted Parts Cleanliness

Naval hardened gauges shall meet Cleanliness Level IV (see Table 2) for all applications except for oxygen service (see para. C7.8). Naval pressure gauges (especially the wetted parts) shall be free of loose scale, rust, grit, filings, mercury, calibration liquids, oil, grease, solvents, and other organic materials.

### C3.2 Packaging

Unless special packaging is specified, gauges shall be bagged and boxed in accordance with ASTM D 3951.

## C4 VERIFICATION

### C4.1 Responsibility for Inspection

Unless otherwise specified in the contract or purchase order, the manufacturer is responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified in the contract or purchase order, the manufacturer may use his own or any other facilities suitable for the performance of the inspection requirements specified herein, unless disapproved by the purchaser. The purchaser reserves the right to perform any of the inspections set forth in the standard where such inspections are deemed necessary to ensure supplies and services conform to prescribed requirements.

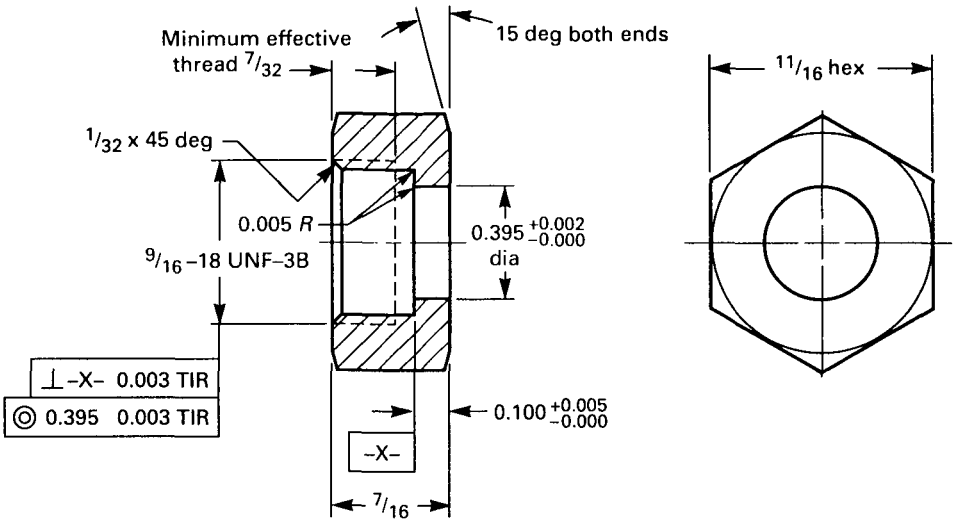
**C4.1.1 Responsibility for Compliance.** All items shall meet all requirements of section C5. The inspection set forth in this specification shall become a part of the manufacturer's overall inspection system or quality program. The absence of any inspection requirements in this specification shall not relieve the manufacturer of the responsibility of assuring that all products or supplies submitted to the purchaser for acceptance comply with all requirements of the contract. Sampling inspection, as part of the manufacturing operations, is an acceptable practice to ascertain conformance to requirements, however this does not authorize submission of known defective material, either indicated or actual, nor does it commit the purchaser to accept defective material.

### C4.2 Classification of Inspections

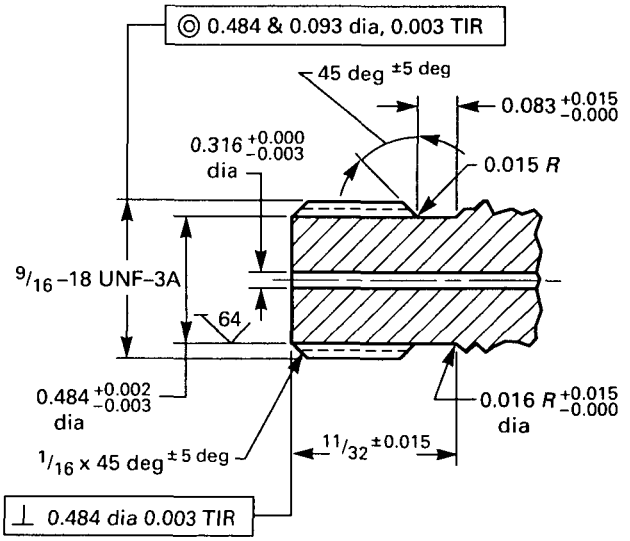
**C4.2.1 Qualification Inspection.** Qualification inspection shall be performed and passed prior to production. Qualification inspection shall be performed on samples which have been produced with equipment and procedures normally used in production and shall



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**Union Nut Detail**




**Threaded End Detail**

GENERAL NOTE: Dimensions are in inches.

**FIG. C3 O-RING UNION NUT/THREADED END DETAIL**



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**TABLE C9 GAUGE CONNECTION POSITIONS**

| Case | Bottom | Lower Back | Center Back | 5 O'clock Position |
|---|---|---|---|---|
| Flush/surface mounted | X | X | ... | X |
| Caisson | X | ... | ... | ... |
| Stem-mounted | X | ... | X | ... |

**TABLE C10 INSPECTION REQUIREMENTS**

| Inspection | Qualification | Conformance |
|---|---|---|
| Examination | X | X |
| Accuracy | X | X |
| Friction error | X | X |
| Repeatability | X | X |
| Inclination | X | ... |
| Temperature | X | ... |
| Salt spray | X | ... |
| Load test | X | ... |
| Pressure cycling | X | ... |
| Elastic element or joining means failure | X | ... |
| Vibration | X | ... |
| Shock | X | ... |
| Pressure rupture | X | ... |

consist of the examination and tests specified in Table C10.

**C4.2.1.1 Sample Size.** Two gauges of each design, size, range, and elastic element style shall be subjected to the qualification inspection.

**C4.2.2 Conformance Inspection.** Conformance inspection shall be performed at the place of manufacture. Each gauge shall be subjected to conformance inspection which consists of the examination and tests specified in Table C10.

**C4.2.3 Acceptance Criteria.** If any gauge sample fails to meet the conformance inspection requirements of Table C10, no gauges shall be accepted until the manufacturer has determined the cause of the defect and has taken the necessary action to correct or eliminate the defect from each gauge in the lot. The failed test shall be repeated to demonstrate that the corrective action will enable the gauges to conform to the requirements of this specification. In addition, the results of previous tests may be deemed invalid, unless the manufacturer can prove to the satisfaction of the purchaser that such test would not be adversely impacted by the corrective action.

**C4.2.3.1 Lot.** A lot consists of all gauges of the same part identification number which are manufactured at one time.

## C5 TEST PROCEDURES AND REQUIREMENTS

### C5.1 Examination

Gauges shall be examined to determine that the material, finish, workmanship, construction, assembly, dimensions and markings conform to this Standard.

### C5.2 Accuracy

Accuracy shall be tested in accordance with para. 6.2.4.1. Accuracy for 3½, 4½, and 8½ shall be in accordance with the requirements of Table 1, accuracy grade 1A. Accuracy for 2 and 2½ shall be in accordance with the requirements of Table 1, accuracy grade B.

### C5.3 Friction Error

Friction error shall be tested in accordance with para. 6.2.4.1. The friction error shall not exceed ½% of span for ranges above 0/60 lb/in.$^2$; for ranges 0/60 lb/in.$^2$ and below, the friction error shall not exceed 1% of span.

### C5.4 Repeatability

Repeatability shall be tested in accordance with para. 6.2.4.2. Repeatability requirements shall be within ±½% of span.

### C5.5 Inclination

Pressure gauges shall be pressurized so that the pointer is in a vertical position. The sample shall be positioned so that the dial faces the operator. The sample shall then be inclined 60 deg to the right, left, front, and back. The sample shall remain at each of these inclined positions for at least one minute. Maximum deviation of the indication shall be within half of the specified accuracy except for ranges 0/100 psi and below, which shall be within twice the specified accuracy.

### C5.6 Temperature

**C5.6.1 High Temperature Error.** High temperature error shall be tested in accordance with para. A2.2 except for the manufacturers recommended high



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temperature; high temperature shall be 145°F for all testing. At the conclusion of the test, accuracy shall be in accordance with Table 1, accuracy grade 1A.

**C5.6.2 Low Temperature Error.** Low temperature error shall be tested in accordance with para. A2.3 except for the manufacturer's recommended low temperature. Low temperature shall be 40°F for all testing. At the conclusion of the test, accuracy shall be in accordance with para. C5.2.

## C5.7 Shock

Pressure gauges shall be subjected to a shock test in accordance with MIL-S-901, grade A, class I, except for duplex pressure gauges which shall be grade B. All pressure gauges shall be subjected to nine blows. Flush and surface mounted pressure gauges shall be mounted on a 6D-1 adapter plate except the plate shall be ¼ in., in thickness to simulate the more rigid instrument boards installed in submarines. Stem mounted pressure gauges (i.e., 2 in. and 2½ in., dial size) shall be mounted on a 4C-2 adapter plate. The pressure gauge shall be mounted no less than 3 in., from the sides or rear of the adapter plate. For each classification of flush/surface mounted pressure gauge samples submitted, one pressure gauge sample shall be secured to the adapter plate in a flush mounted configuration and the other pressure gauge sample in a surface mounted configuration. Throughout this test, the pressure gauge(s) shall be pressurized to mid-span.

**C5.7.1 Requirements for Ranges 0/60 lb/in.$^2$ and Above.** The pressure gauge shall show no evidence of improper operation, failure, or damage. A shift in the pointer indication shall not exceed five times the specified accuracy. The red index shall not shift during the shock test. The accuracy, after a zero adjustment is made, shall meet the requirements of para. C5.2.

**C5.7.2 Requirements for Ranges 0/30 lb/in.$^2$ and Below.** The pressure gauge shall show no evidence of improper operation, failure, or damage. A shift in the pointer indication shall not exceed ±25% of span. The red index shall not shift during the shock test. The accuracy after a zero adjustment is made shall meet the requirements of para. C5.2.

## C5.8 Salt Spray

Pressure gauges shall be subjected to salt spray tests in accordance with ASTM B 117. The test(s) shall have a duration of 96 hr. The pressure connection shall be sealed to prevent penetration into the elastic element. The pressure gauge shall show no evidence of visible corrosion or other damage, or exhibit improper operation. Accuracy shall be in accordance with para. C5.2.

## C5.9 Load

The load test shall only be performed on stem mounted pressure gauges. The pressure gauge shall be threaded into a plate and securely held in place. A constant load of 150 lb shall be applied to the pressure gauge case as shown on Fig. C4 for 5 min. At the conclusion of the test, accuracy shall be in accordance with para. C5.2.

## C5.10 Vibration

Flush and surface mounted gauges shall be vibration tested in accordance with para. A2.5. Stem mounted gauges shall be tested in accordance with Table C11. The red index pointer shall not shift during the test. Total pointer oscillation shall not exceed ±5% of span (±10% of span for ranges 0/100 lb/in.$^2$ and below), peak to peak, at any test frequency. At the conclusion of the test, accuracy shall be in accordance with para. C5.2.

## C5.11 Pressure Cycling

Testing shall be in accordance with para. A2.8. Fatigue error shall not exceed three times the specified accuracy. No leakage is permitted.

**C5.11.1 Pressure Gauges.** A total of 260,000 cycles for pressure ranges 0/3,000 lb/in.$^2$ and below. A total of 50,000 cycles for pressure ranges 0/5,000 lb/in.$^2$ and above shall be conducted, with a cycle of 40 ± 4% to 60 ± 4% of span.

**C5.11.2 Vacuum Gauges.** The gauge shall be cycled by pulling a vacuum between 20 ± 4% to 80 ± 4% of span. A total of 260,000 cycles shall be conducted.

**C5.11.3 Compound Gauges.** Compound pressure gauges shall be tested on pressure portions.

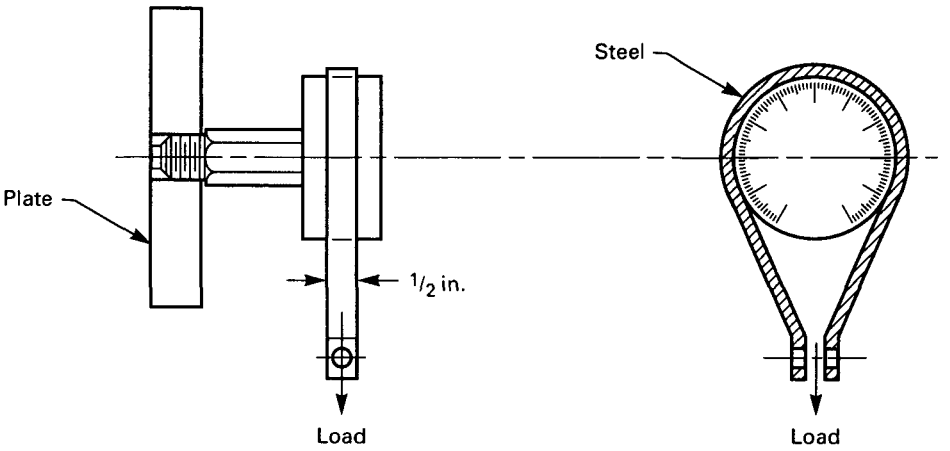
**C5.11.4 Retard Gauges.** The gauge shall be cycled from 20 ± 4% to 80 ± 4% of the expanded portion of the span. A total of 260,000 cycles shall be conducted.

## C5.12 Elastic Element or Joining Means Failure

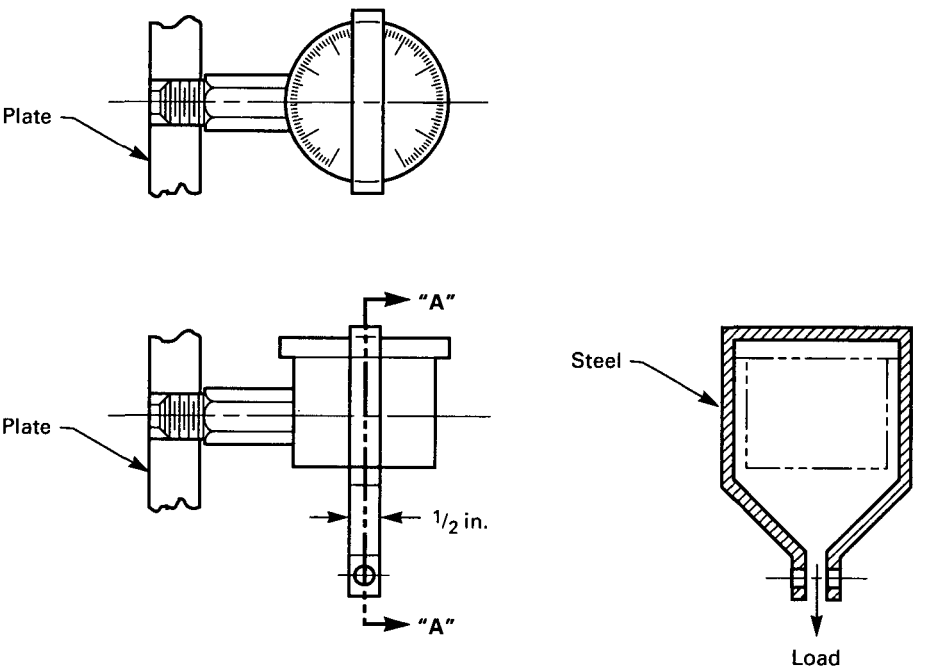
Nonsolid front gauges with ranges 0/60 lb/in.$^2$ and above shall be subjected to the internal explosion test as specified in UL 404 for each unique case design.



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**Back Connected Configuration**




**Section A–A**

**Bottom Connected Configuration**

**FIG. C4 LOAD TEST**



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**TABLE C11 STEM-MOUNTED GAUGE VIBRATION**

| Frequency Range (Hz) (inclusive) | Table Displacement (Inches, Peak To Peak) | |
|---|---|---|
| | Exploratory Test | Variable Frequency Test |
| 5 to 20 | 0.0200 ± 0.0040 | 0.060 ± 0.012 |
| 21 to 50 | 0.0100 ± 0.0020 | 0.040 ± 0.008 |
| 51 to 100 | 0.0050 ± 0.0010 | 0.020 ± 0.004 |
| 101 to 200 | 0.0010 ± 0.0002 | 0.004 ± 0.001 |

The pressure relief device shall successfully relieve the pressure from the case without causing a failure in either the case or the window.

### C5.13 Pressure Rupture

The rupture test shall be in accordance with para. A2.7. The maximum pressure applied shall be 12 times the span. The maximum pressure shall be maintained for at least 10 min. The gauge shall show no signs of leakage.

## C6 ORDERING PARAMETERS

### C6.1 Acquisition Requirements

When specifying a gauge for acquisition, the following shall be provided:

(a) Title, number and date of this supplement;
(b) Part Identifying Number (PIN);
(c) When qualification is required;
(d) Special dial marking, when required;
(e) National Stock Number (NSN), if available;
(f) Special dial color, when required.

### C6.2 Part Identifying Number (PIN) Parameters

Hardened pressure gauges are classified according to the following variables:

(a) Design;
(b) Dial size and case design;
(c) Elastic element style;
(d) Dial color;
(e) Pressure connection and connection location;
(f) Liquid fill case fluid and cleanliness;
(g) Dial range.

**C6.2.1 Part Identifying Number (PIN) Format.** The PIN to be used for items acquired to this supplement are created as shown in Table C12.

**C6.2.2 Design.** Pressure gauge design is designated by one of the following symbols:

| Pressure Gauge Design | Symbol |
|---|---|
| Simplex | S |
| Caisson | K |
| Oxygen | X |
| Duplex | D |

**C6.2.3 Dial Size and Case Design.** The dial size and case design is designated by one of the following symbols:

| Size | Case Design | Symbol |
|---|---|---|
| 2 | Stem mounted | 1 |
| 2½ | Stem mounted | 2 |
| 3½ | Flush/surface mounted | 3 |
| 4½ | Flush/surface mounted | 4 |
| 8½ | Flush/surface mounted | 8 |

**C6.2.4 Elastic Element.** The elastic element is designated as shown below.

| Elastic Element Style | Symbol |
|---|---|
| C-type Bourdon tube | C |
| Helical (also helical-spiral) Bourdon tube | D |
| C-type, or helical — manufacturer option | N |

**C6.2.5 Dial Color.** The color of the dial is designated by one of the following symbols:

| Dial Color | Symbol |
|---|---|
| Black background dial with white graduations and markings | B |
| White background dial with black graduations and markings | W |
| Special | S |

**C6.2.6 Pressure Connection and Connection Location.** The type of pressure connection and its location for connection is designated by two symbols as provided below. The first symbol designates the type of connection fitting. The second symbol designates the location of the pressure connection.



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**TABLE C12 PART IDENTIFYING NUMBER (PIN)**

| B40.1 C1 | C | 1 | C | W | RA | NG | 3P |
|---|---|---|---|---|---|---|---|
| Precedes classification (Appendix C to B40.1) | Design | Dial Size and Case Design | Elastic element style | Dial color | Pressure connection and Connection location | Liquid fill case fluid and Cleanliness | Dial range |

GENERAL NOTE: Example B40.1 C1-C1CWRANG3P.

| Pressure Connection | Symbol |
|---|---|
| O-ring union | R |
| ¼ NPT (male) | P |
| Welded nipple | W |
| Threaded vent (caisson only) | K |
| Flareless (bite type) $^{7}/_{16}$ -20 UNF-2A | C |

| Connection Location | Symbol |
|---|---|
| Back | A |
| Bottom | O |
| 5 o'clock | C |

**C6.2.7 Liquid Fill Case Fluid and Cleanliness.** Liquid fill applies to stem mounted gauges only. The option for the pressure gauge case containing a liquid fill and the cleanliness is designated by the two symbols as provided below. The first symbol designates whether a fill fluid is required. The second symbol designates the cleanliness.

| Liquid Fill (stem mount only) | Symbol |
|---|---|
| None | N |
| Glycerine | G |

| Cleanliness | Symbol |
|---|---|
| General | G |
| Oxygen | X |

**C6.2.8 Ranges.** The range is designated by a sequence of symbols (see para. C2.2). Special ranges are permissible. The range designator shall be constructed in accordance with the formats as shown in Tables C1 through C4.

## C7 OXYGEN PRESSURE GAUGES

### C7.1 Case

Stem mounted cases are not permitted. Joints shall be welded for all ranges.

**TABLE C13 OXYGEN SERVICE RANGES**

| Ranges, lb/in.$^2$ | Range Designator |
|---|---|
| 0/100 | 1hX |
| 0/3000 | 3kX |
| 0/5000 | 5kX |

### C7.2 Dial

Dial markings shall include the words "OXYGEN CLEAN – USE NO OIL" in red printing, when oxygen application designated.

### C7.3 Pressure Connection

Pressure connection shall be a Monel (per ASTM B 127, B 164, and B 564) pipe nipple, ¼ in., nominal pipe size (NPS) with 0.109 in., minimum wall thickness, 6 in., long, welded to the socket. Connection location shall be at the lower back or bottom of the case.

### C7.4 Ranges

Table C13 shows the ranges and range designators for oxygen gauges.

### C7.5 Internal Dimensions

Pressure gauges designated for oxygen service shall have a minimum internal dimensions throughout the pressure element assembly of not less than 0.025 in. to promote cleaning.

### C7.6 Liquid Filled Gauges

Liquid filled gauges shall not be used on oxygen systems, and shall have a warning label on the rear of the case which states:

**"WARNING DO NOT USE ON OXYGEN SYSTEMS — LIQUID FILLED."**



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### C7.7 Quality Control

Oxygen service gauges shall not be examined on a sampling basis. One hundred percent (100%) of all oxygen service gauges shall be examined for cleanliness, marking, and packaging.

### C7.8 Cleaning

Cleaning for oxygen service gauges shall be per MIL-STD-1330.

### C7.9 Qualification and Conformance Inspection

Qualification and conformance inspections shall be performed in accordance with para. C4.2.

## C8 REFERENCED DOCUMENTS

ANSI B1.20.1, Pipe Threads, General Purpose (Inch)
Publisher: American National Standards Institute (ANSI), 11 West 42nd Street, New York, NY 10036

ASTM A 167, Specification for Stainless and Heat-Resisting Chromium-Nickel Steel Plate Sheet, and Strip
ASTM A 473, Specification for Stainless and Heat-Resisting Steel Forgings
ASTM B 26, Specification for Aluminum-Alloy Sand Castings
ASTM B 85, Specification for Aluminum-Alloy Die Castings
ASTM B 117, Practice for Operating Salt Spray (Fog) Apparatus
ASTM B 127, Specification for Nickel-Copper Alloy (UNS N04400) Plate, Sheet, and Strip
ASTM B 164, Specification for Nickel-Copper Alloy Rod, Bar, and Wire
ASTM B 209, Specification for Aluminum and Aluminum-Alloy Sheet and Plate
ASTM B 564, Specification for Nickel Alloy Forgings
ASTM D 788, Classification System for Poly (Methyl Methacrylate) (PMMA) Molding and Extrusion Compounds
ASTM D 3951, Practice for Commercial Packaging
Publisher: American Society for Testing and Materials (ASTM), 100 Bar Harbor Drive, West Conshohocken, PA 19428

FED-STD-595, Standard Practice for Precision Cleaning and Testing of Shipboard Oxygen, Helium, Helium-Oxygen, Nitrogen, and Hydrogen System
MIL-S-901, Shock Tests, High Impact, Shipboard Machinery, Equipment and Systems Requirements
MIL-STD-1330, Standard Practice for Precision Cleaning and Testing of Shipboard Oxygen, Helium, Helium-Oxygen, Nitrogen and Hydrogen Systems
Publisher: Federal specifications available from: Superintendent of Documents, United States Government Printing Office, Washington, DC 20402

SAE AMS 7259, Rings, Sealings, Fluorocarbon (FKM) Rubber High-Temperature-Fluid Resistant Very-Low Compression Set 85 to 95
SAE J 1926, Connections for General Use and Fluid Power – Ports and Stud Ends with ISO 725 Threads and O-Ring Sealing — Part 1: Threaded Port with O-Ring Seal in Truncated Housing
Publisher: Society of Automotive Engineers (SAE), 400 Commonwealth Drive, Warrendale, PA 15096

UL 404, Underwriter's Laboratory Standard for Safety Gauges, Indicating Pressure, for Compressed Gas Service
Publisher: Underwriter's Laboratories (UL), 333 Pfingsten Road, Northbrook, IL 60062



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**1 Scope** ..... 36.15

**2 Diaphragm Seal** ..... 36.15

**Figures**

1 Upper Housing, Continuous Duty ..... 36.18
2 Upper Housing, Noncontinous Duty ..... 36.19
3 Upper Housing, Removable ..... 36.20
4A Upper Housing, Removable ..... 36.21
4B Upper Housing, Removable ..... 36.21
5 Upper Housing, Nonremovable ..... 36.22
6A Lower Housing ..... 36.22
6B Lower Housing With Reinforcing Ring ..... 36.23
7A Flanged Seal ..... 36.23
7B Flanged Seal ..... 36.24
8 Threaded Seal ..... 36.24
9A Flanged Seal ..... 36.25
9B Flanged Seal With Sleeve ..... 36.25
10 Butt Weld Seal ..... 36.26
11 Socket Weld Seal ..... 36.26
12A Welded Seal Saddle ..... 36.27
12B Welded Seal Saddle ..... 36.27
13A Welded Assembly ..... 36.28
13B Clamped Assembly ..... 36.28
14A Gauge Isolator ..... 36.29
14B Gauge Isolator ..... 36.29
15 Sealed Setting ..... 36.33
16A Fill Setting ..... 36.34
16B Fill Setting ..... 36.34



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# DIAPHRAGM SEALS (a)

## 1 SCOPE

This Standard is confined to mechanical separators utilizing diaphragms or bladders together with a fill fluid to transmit pressure from the medium to the pressure element assembly of pressure gauges or other pressure measuring instruments such as transducers, transmitters, and switches.

It does not include diaphragm actuated pressure instruments that employ mechanical linkages to transmit the applied pressure or other separation devices designed to protect the pressure element assembly.

## 2 DIAPHRAGM SEAL

### 2.1 Terminology and Definitions

*accuracy:* the conformity of an instrument's performance to an accepted standard or true value [see para. 2.10.4.2(a)].

*capsule:* an all welded diaphragm assembly that threads into the upper housing (see Fig. 3).

*chemical seal:* see *diaphragm seal.*

*coefficient of thermal expansion:* volumetric change per unit of volume per unit of temperature change [see paras. 2.5.2.5 and 2.5.1.1(a)].

*cold flow:* a physical change in the shape of a part at room temperature due to applied forces (see para. 2.4.3).

*compressibility:* the property of a substance capable of being reduced in volume by application of pressure [see paras. 2.5.2.10 and 2.5.1.1(f)].

*connection:* see *mounting.*

*connection, butt welded:* the lower housing is butt welded directly to the process line [see para. 2.3.10.3(c)].

*connection, fill/bleed:* a connection in the upper housing used for filling the seal or bleeding excess fill fluid (see para. 2.3.8).

*connection, flanged:* a process connection using a flange (see para. 2.3.10.2).

*connection, flanged pressure class:* common pipe flange pressure classes that conform to pressure/temperature ratings per ASME B16.5 (see para. 2.3.14).

*connection, flushing:* a connection which permits the user to purge the volume below the diaphragm without removing the entire seal from the process line (see para. 2.3.11).

*connection, instrument:* a pressure connection in the upper housing to which the pressure instrument is attached (see para. 2.3.9).

*connection, saddle:* the lower housing is fillet welded within a hole cut in the process line or may be secured by a saddle adapter welded onto the process line [see para. 2.3.10.3(e) and (f)].

*connection sleeve:* a type of in-line (flow through) connection [see para. 2.3.10.3(g)].

*connection, socket welded:* a lower housing socket welded directly to the process line [see para. 2.3.10.3(d)].

*connection, threaded:* the lower housing is connected to the process line using a threaded connection (see para. 2.3.10.1).

*continous duty:* see *upper housing, continous duty.*

*continous seal:* see *upper housing, continous seal.*

*diaphragm:* the flexible component that separates the medium from the fill fluid (see para. 2.3.1).

*diaphragm seal:* a diaphragm seal is a mechanical separator using a diaphragm or bladder together with a fill fluid to trasmit pressure from the medium to the pressure element assembly. Other term used are chemical seal and gage 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.

*fill fluid:* the liquid used to fill that portion of the pressure sensing system between the diaphragm and the pressure sensing element (see para. 2.5.1).



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*freeze point:* the temperature at which a liquid and a solid may be in equilibium [see para. 2.5.1.1(g)].

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

*gage isolator:* a seal consisting of an elastomeric bladder installled within the connection of a pressure instrument or in an adapter fitting (see para. 2.3.13).

*gasket:* a means used to seal joints exposed to the medium or fill fluid (see para. 2.3.5).

*head effect:* a change of an instrument's indication or output when the elevation of the instrument is above or below the seal (see para. 2.5.2.7).

*in-line:* a diaphragm seal installed directly in the process flow line (see para. 2.3.10.3).

*long term stability (closed system):* the resistance to decomposition, physical disintegration, or other chemical change over a long period of time [see paras. 2.5.2.4 and 2.5.1.1(j)].

*lower housing:* the component connected to the process line and wetted by the process fluid (see para. 2.3.3).

*medium:* the process fluid (gas or liquid).

*mid-housing (cleanout ring):* the component located between the upper and lower housing (see para. 2.3.4).

*pressure rating:* the maximum operating pressure (see para. 2.3.14).

*process connection:* a method for attaching or installing a diaphragm seal to a process line, tank, vessel, etc. (see para. 2.3.10).

*reinforcing rings:* rings which support clamping forces on nonmetallic lower housings (see para. 2.3.6).

*sanitary seal:* a quick disconnect type, where the upper and lower housings are held together by a unique clamp, permitting ease of dismantling and cleaning (see para. 2.3.12).

*service temperature range:* the high and low temperatures between which the fill fluid will remain serviceable [see para 2.5.1.1(b)].

*specific gravity:* the ratio of a fluid's density to the density of water at 4°C (39.2°F) [see paras. 2.5.2.7 and 2.5.1.1(c)].

*spontaneous ignition temperature:* the temperature at which ignition can occur resulting from the generation of heat which cannot be readily dissipated [see para. 2.5.1.1(i)].

*temperature, ambient:* the temperature of the atmosphere surrounding the instrument/seal assembly (see para. 2.5.2.5).

*temperature, process:* the temperature of the medium at the pressure connection of the lower housing (see para. 2.5.2.5).

*temperature, storage:* the extremes of temperature (high and low) that the instrument/seal will be exposed to when not pressurized (see para. 2.5.2.6).

*thermal decomposition point:* the temperature at which changes in the chemical or physical characteristics of a material are initiated [see para. 2.5.1.1(h)].

*upper housing:* the component which includes a connection for the pressure instrument (see para. 2.3.2).

*upper housing, continuous duty:* an upper housing which prevents damage to the diaphragm or leaking of the process fluid should the pressure instrument leak or be removed (see para. 2.3.2.1).

*upper housing, continuous seal:* an upper housing which prevents leaking of the process medium should the pressure instrument leak or be removed, however the diaphragm may be damaged (see para. 2.3.2.2).

*upper housing, noncontinuous duty:* an upper housing which does not prevent damage to the diaphragm or leaking of the process fluid should the pressure instrument leak or be removed (see para. 2.3.2.3).

*upper housing, nonremovable:* an upper housing which if removed from the bottom housing with the instrument installed will result in the loss of fill fluid (see para. 2.3.2.5).

*upper housing, removable:* an upper housing which may be removed from the bottom housing with the instrument installed without loss of fill fluid (see para. 2.3.2.4).

*vapor pressure:* the pressure of the vapor in equilibrium with the liquid [see paras. 2.5.1.1(e) and 2.5.2.9].

*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 [see paras. 2.5.2.8 and 2.5.1.1(d)].

*volumetric displacement:* the volume of fill fluid displaced by the movement of the diaphragm (see para. 2.6.1).

*volumentric spring rate:* the flexibility of the diaphragm (see para. 2.6.1).



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*wetted surface:* the portions of the diaphragm seal that are exposed to the medium.

## 2.2 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.

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 ¼ 18 NPT to 1½ 11.5 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 sufficiently viscous, or of the type that will solidify in the take off pipe or the lower housing of the diaphragm seal within the limits of the ambient and process temperatures.

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 ½ in. to 6 in. with ASME B16.5 flanges in pressure classes of 150, 300, 600, 1500, and 2500. Flanged seals may also be manufactured to other standards such as DIN.

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. This "in-line" type should be used when the process media is a slurry or a liquid which 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.

*(5) 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.

*(6) 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.

## 2.3 Construction

A diaphragm seal consists of several components, as described in paras. 2.3.1 through 2.3.15.

**2.3.1 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.

**2.3.2 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 ¼ 18 NPT and ½ 14 NPT female.

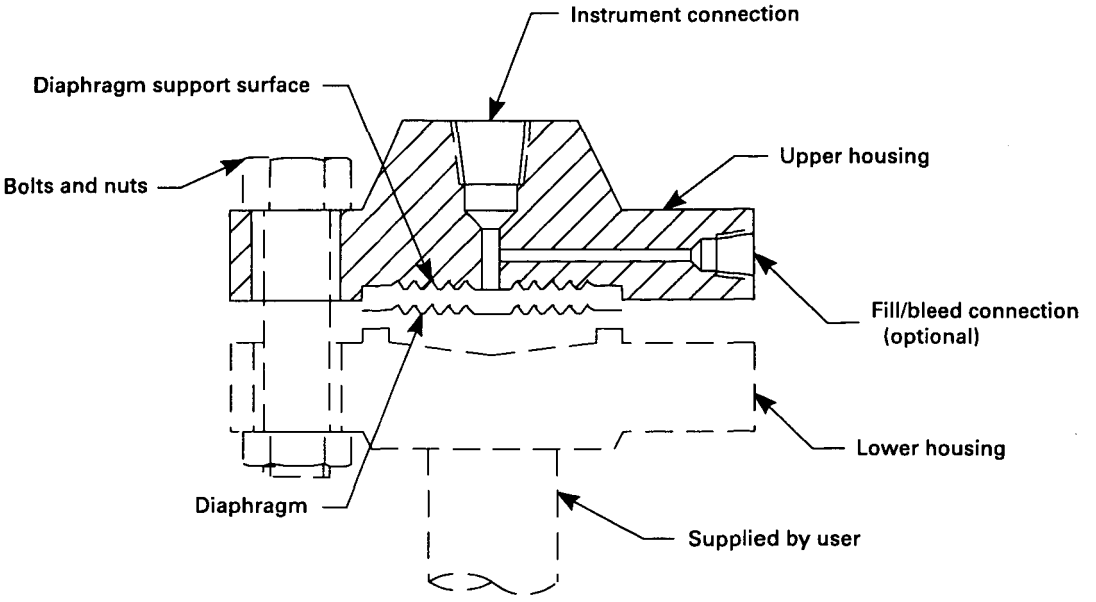
**2.3.2.1 Upper Housing, Continuous Duty.** Should the pressure instrument leak or be removed, the diaphragm will seat against a matching or other support surface in the upper housing, preventing damage to the diaphragm or leaking of the medium (see Fig. 1). See para. 2.10.4.2 (h).

**2.3.2.2 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. 2.10.4.2 (i)].

**2.3.2.3 Upper Housing, Noncontinuous Duty.** The upper housing does not contain a matching



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**FIG. 1 UPPER HOUSING, CONTINUOUS DUTY**

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 Fig. 2).

**2.3.2.4 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 clamped to the upper housing with a middle housing, welded, bonded, or otherwise attached to the upper housing. The diaphragm may be made in the form of a capsule threaded into the upper housing (see Figs. 3, 4A, and 4B).

**2.3.2.5 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 Fig. 5).

**2.3.3 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. 2.3.10 for process connections.

**2.3.4 Mid-Housing (Cleanout Ring).** The mid-housing (cleanout ring) is located between the upper and lower housing. This housing is utilized 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 utilized, a mid-housing may not be required (see Figs. 3 and 4A).

**2.3.5 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.

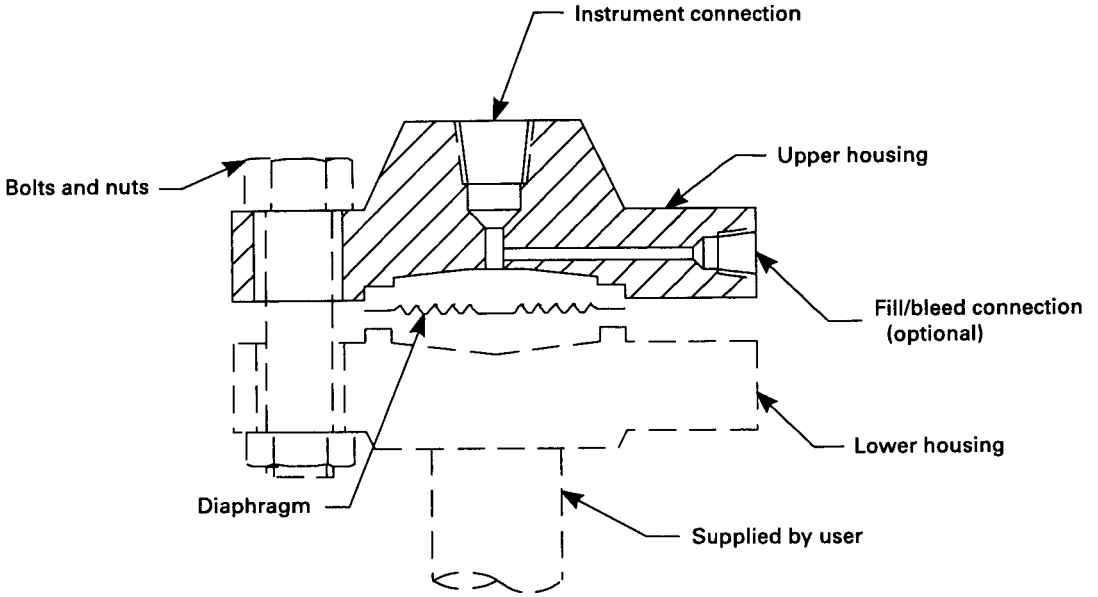
**2.3.6 Reinforcing Rings.** Some diaphragm seal designs use reinforcing rings to support clamping forces on nonmetallic lower housings. These rings are generally not in contact with the medium and are commonly made of steel. If the external atmosphere contains corrosive elements, other materials may be required (see Fig. 6B).

**2.3.7 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.



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**FIG. 2 UPPER HOUSING, NONCONTINUOUS DUTY**

*(b) Clamp.* A clamp assembly may fasten the upper housing to the lower housing.

*(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 Fig. 13A).

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

**2.3.8 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 Fig. 1).

**2.3.9 Instrument Connection.** The pressure instrument is attached directly to the diaphragm seal. Standard instrument connection ports are ¼ 18 NPT and ½ 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 (temperature, corrosive atmosphere, vibration, etc.);

*(b)* to locate the instrument in a more convenient location for readability or serviceability (see Fig. 1).

**2.3.9.1 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:

*(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.

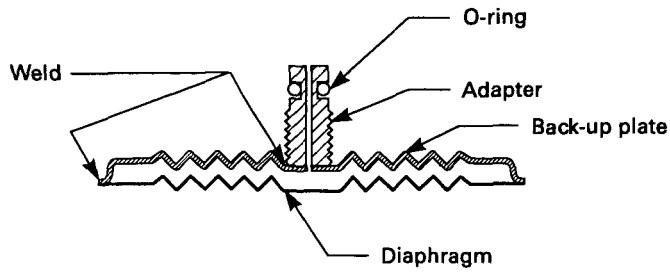
*(b)* The capillary material and size must be suitable for the maximum and minimum pressure and temperature of the medium and the maximum and minimum ambient temperatures.

*(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.

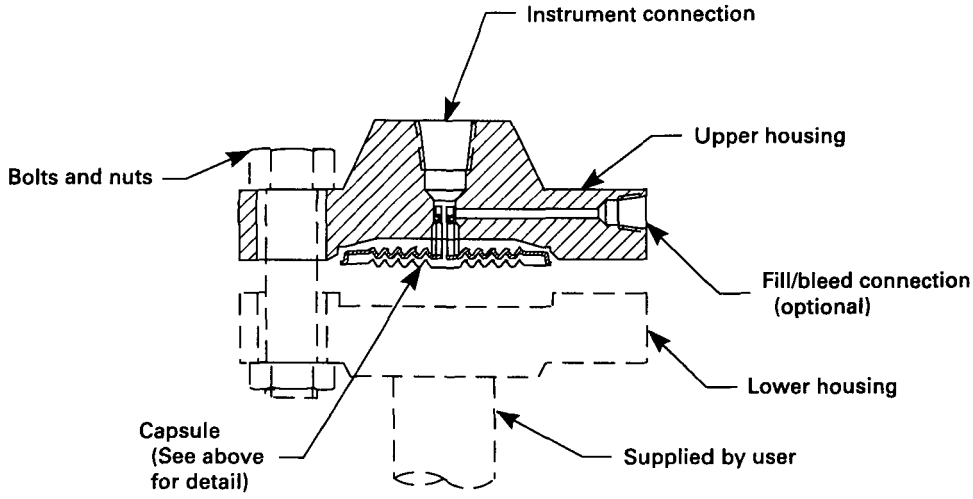
*(d)* As capillary length increases, time response and temperature errors will increase.



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**Capsule**




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**FIG. 3 UPPER HOUSING, REMOVABLE**

*(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.

**2.3.10 Process Connections (Lower Housing).** Common process connections are described in paras 2.3.10.1 through 2.3.10.3.

**2.3.10.1 Threaded.** The lower housing includes a threaded connection for attachment to the process line (see Figs. 6A and 6B). A threaded lower housing may be provided with wrench flats or spanner wrench holes to facilitate assembly.

**2.3.10.2 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, or forgings (see Fig. 7A). In the smaller sizes, the use of studs assembled to the lower housing may be necessary because of diaphragm design considerations (see Fig. 7B).

**2.3.10.3 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:

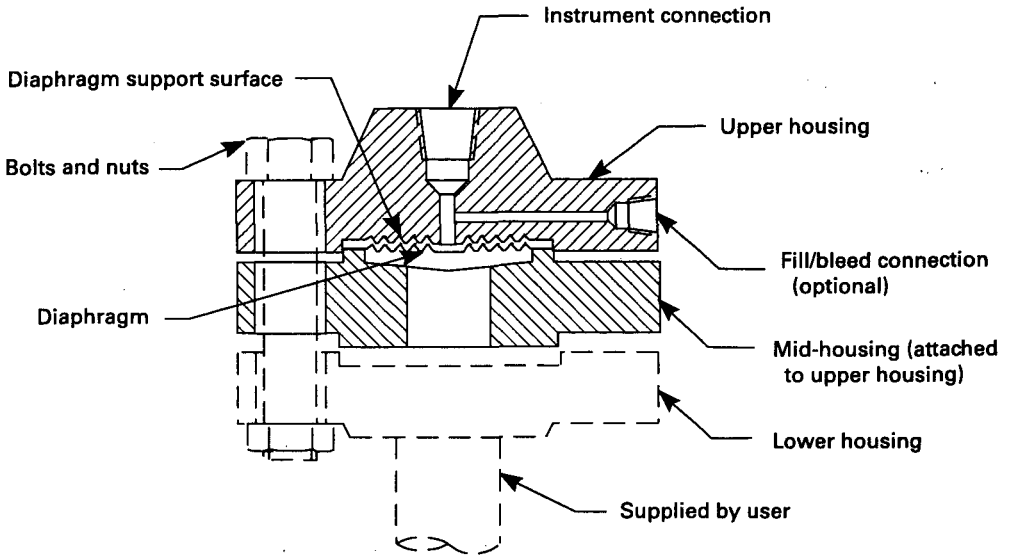
*(a)* Threaded (see Fig. 8);

*(b)* Flanged (see Figs. 9A and 9B);

*(c)* Butt Weld (see Fig. 10);

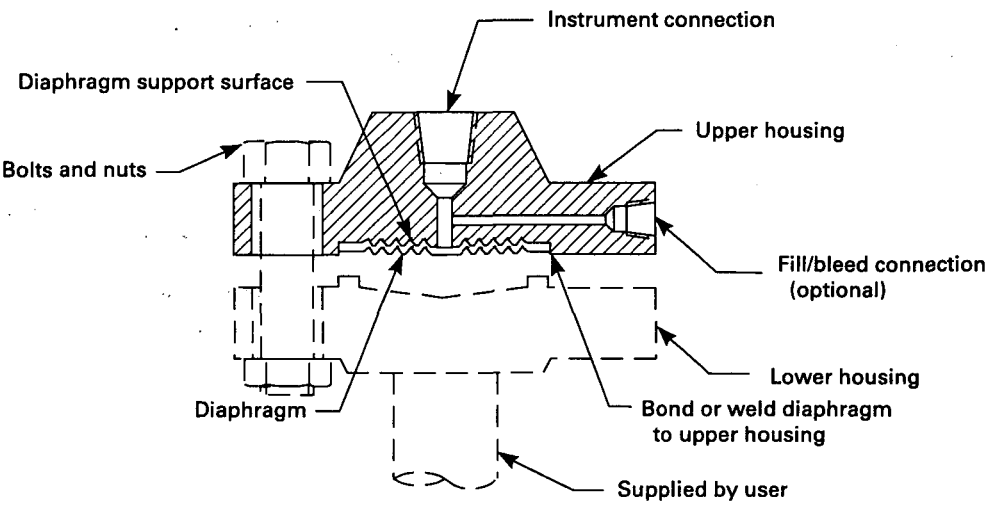


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**FIG. 4A UPPER HOUSING, REMOVABLE**




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**FIG. 4B UPPER HOUSING, REMOVABLE**

*(d)* Socket Weld (see Fig. 11);

*(e) Saddle.* Fillet welded within a hole cut in the process line (see Fig. 12A);

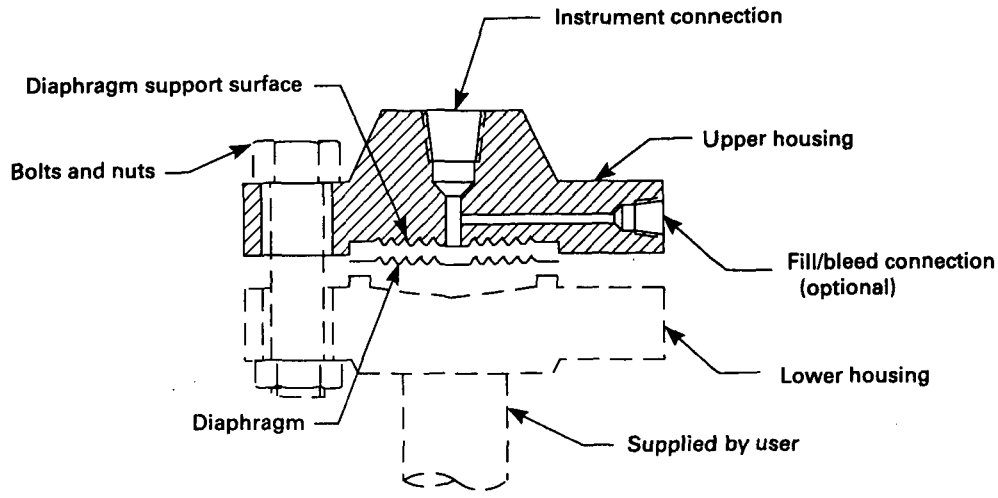
*(f) Saddle.* Fillet welded onto the process line (see Fig. 12B);

*(g)* Sleeve (see Fig. 9B).

**2.3.11 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 seal from the process line. This connection may be located in the mid-housing, if supplied (see Fig. 6A).

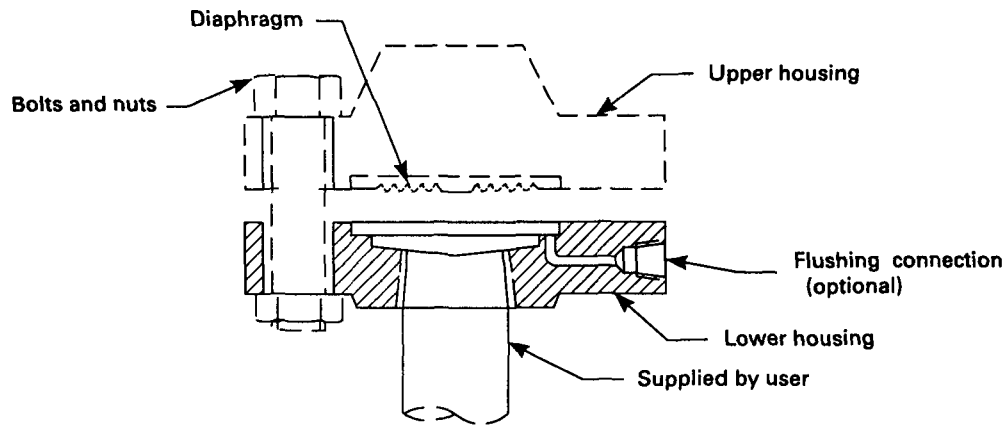


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**FIG. 5 UPPER HOUSING, NONREMOVABLE**




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**FIG. 6A LOWER HOUSING**

**2.3.12 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 Fig. 13B).

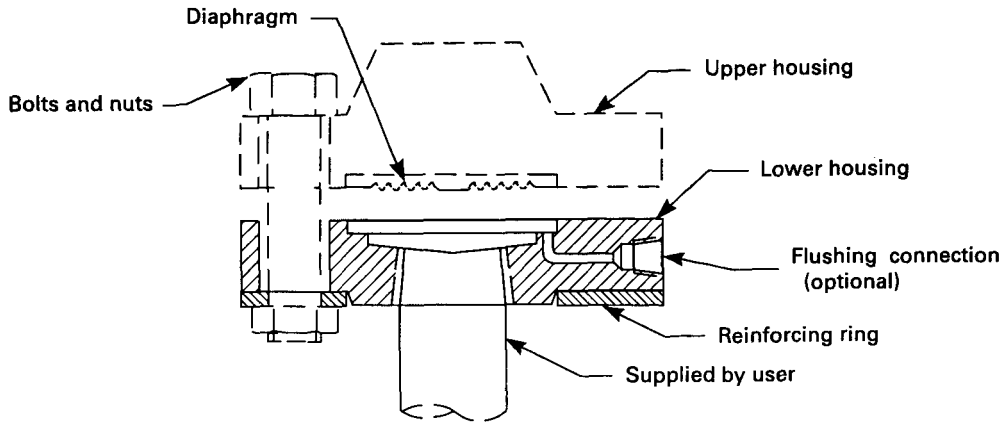
**2.3.13 Gage Isolators.** This type of seal consists of an elastomeric bladder installed within the connection of a pressure instrument or within an adapter fitting (see Figs. 14A and 14B).

**2.3.14 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/

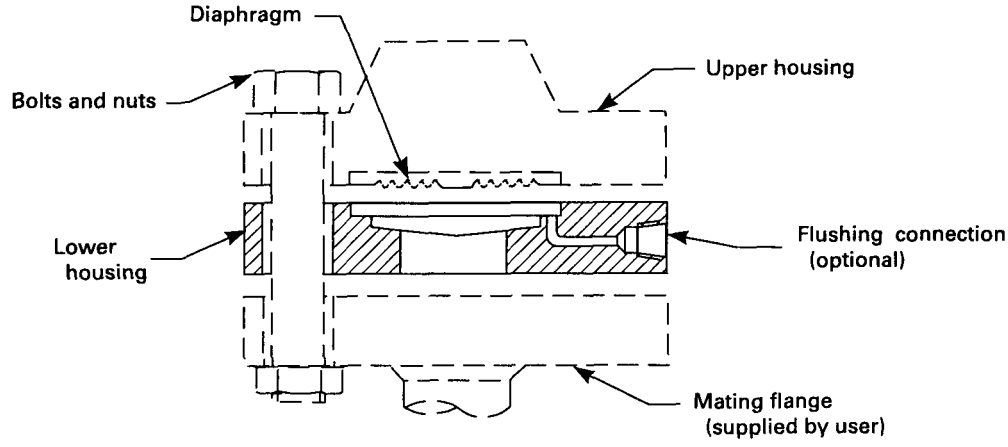


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**FIG. 6B LOWER HOUSING WITH REINFORCING RING**




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**FIG. 7A FLANGED SEAL**

temperature ratings of plastic components are generally lower than metal components.

**2.3.15 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.

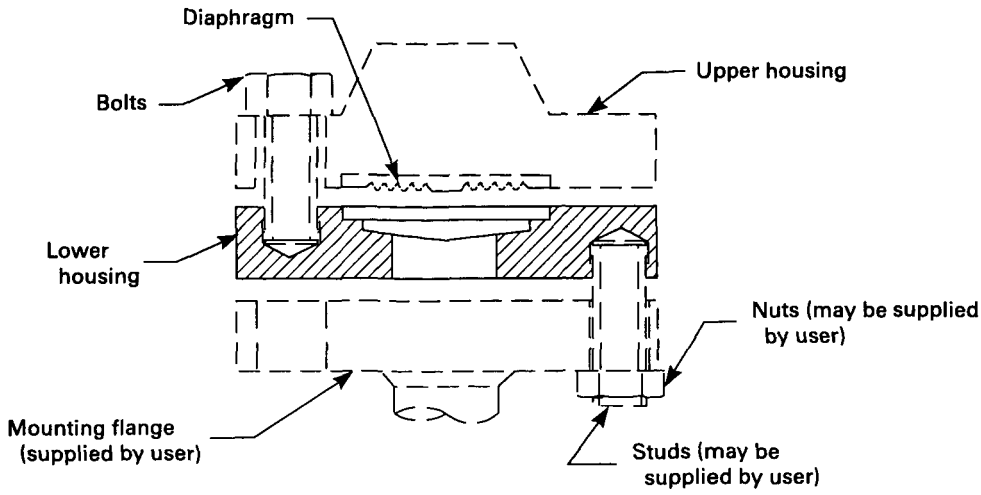
## 2.4 Material Selection

**2.4.1** The materials used in fabrication of the diaphragm seal will depend upon the chemical and physical properties of the medium.

**2.4.2** 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, pipe lines, 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,

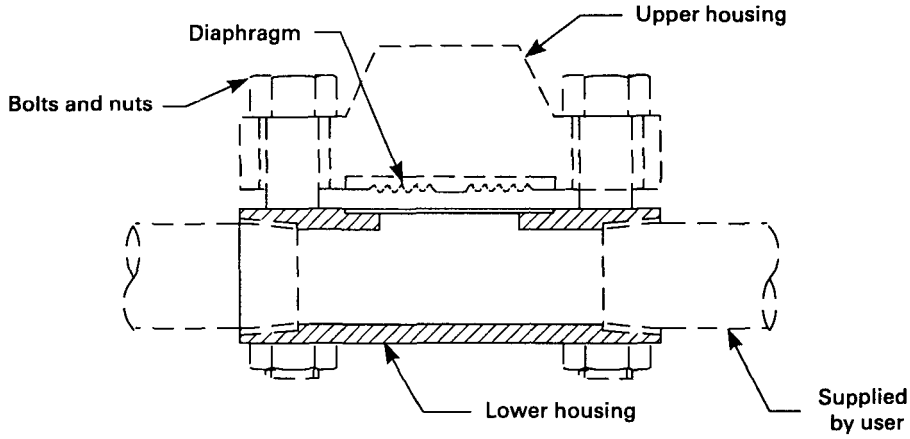


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**FIG. 7B FLANGED SEAL**




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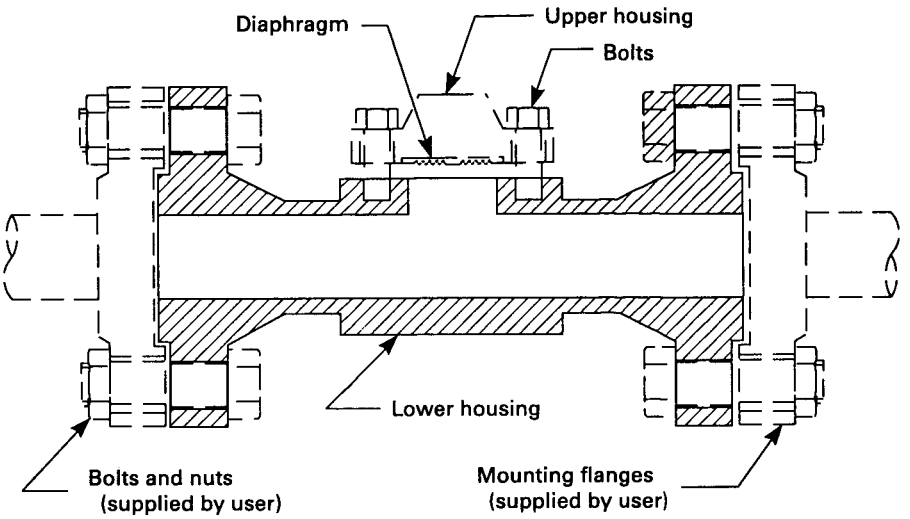
**FIG. 8 THREADED SEAL**

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.

**2.4.3** 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 over-tightening the process

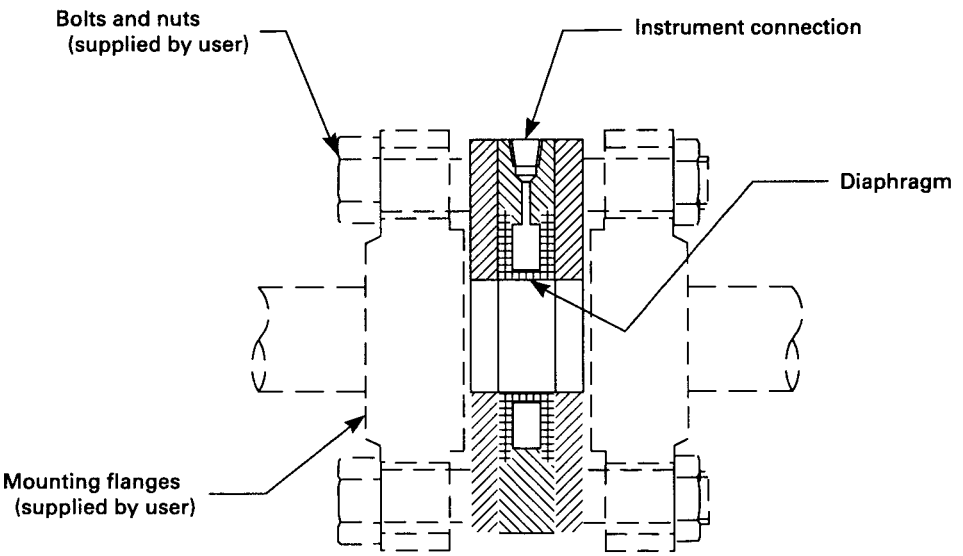


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**FIG. 9A FLANGED SEAL**




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**FIG. 9B FLANGED SEAL WITH SLEEVE**

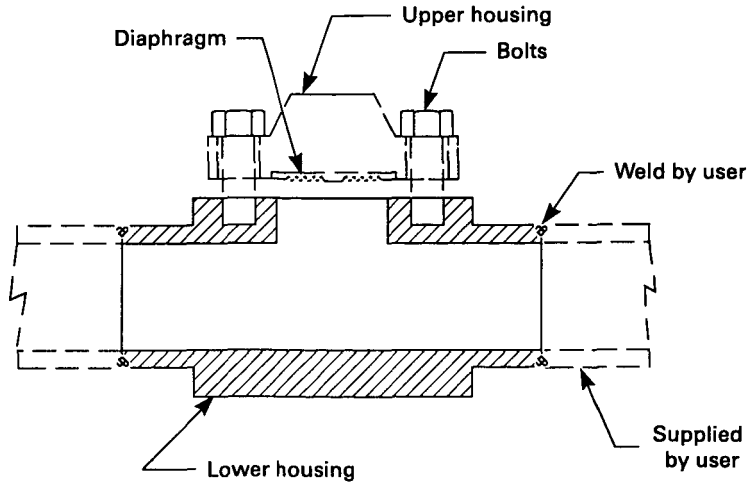
connection which could cause failure of the housing after a period of time.

**2.4.4** 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.

**2.4.5** 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. 2.5.2.2).

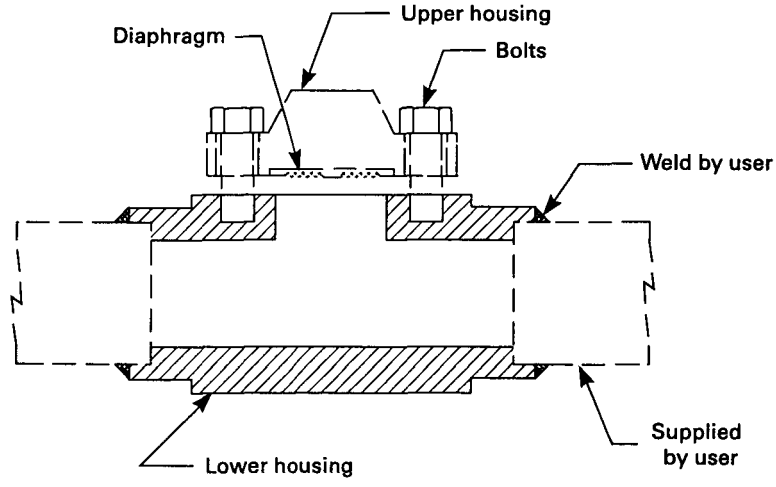


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**FIG. 10 BUTT WELD SEAL**




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**FIG. 11 SOCKET WELD SEAL**

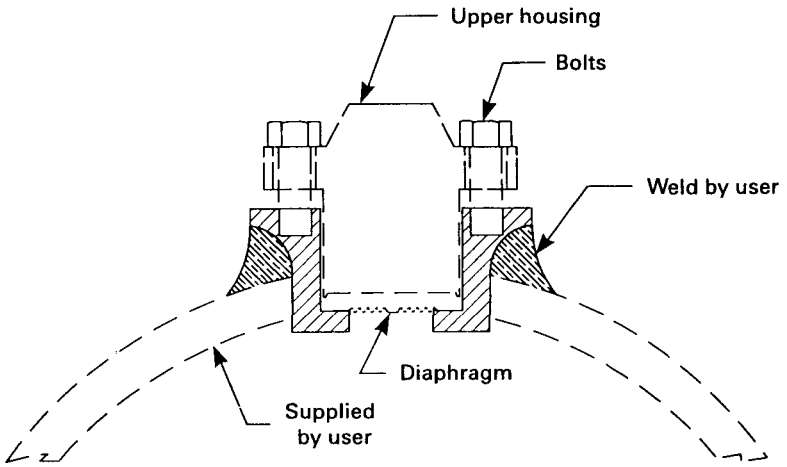
**2.4.6** If the medium contains a hard solid, and the diaphragm seal is the flanged or flow through type, the possibility of erosion of the thin diaphragm should be considered. Caution must be taken to select the proper diaphragm material.

**2.4.7** 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 which allow corrosion. The permeability of the coating to the chemicals in the media must also be considered.

**2.4.8** 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.

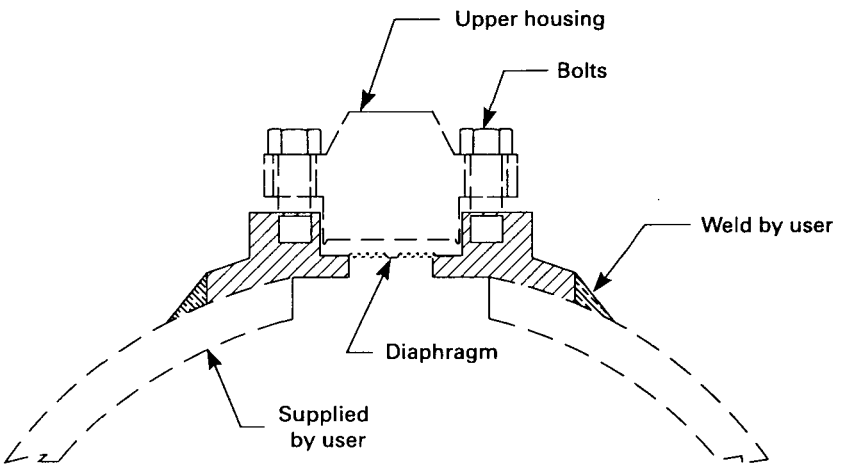


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**FIG. 12A WELDED SEAL SADDLE**

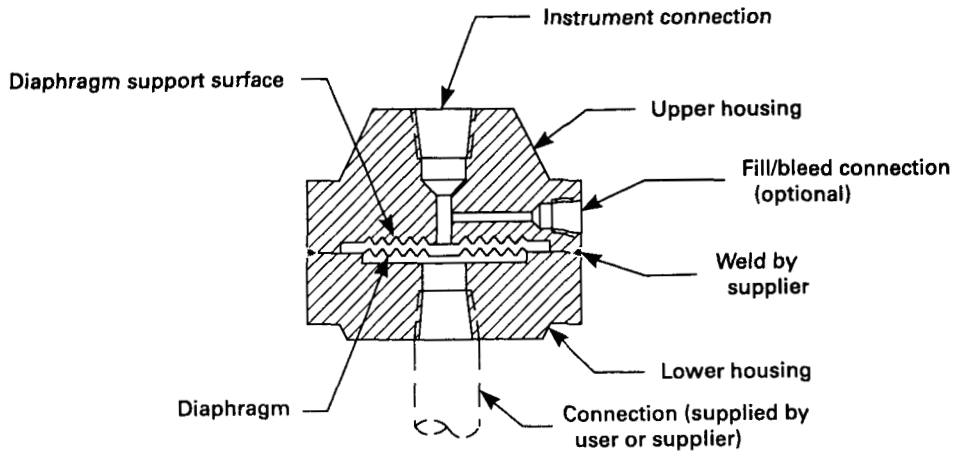



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**FIG. 12B WELDED SEAL SADDLE**

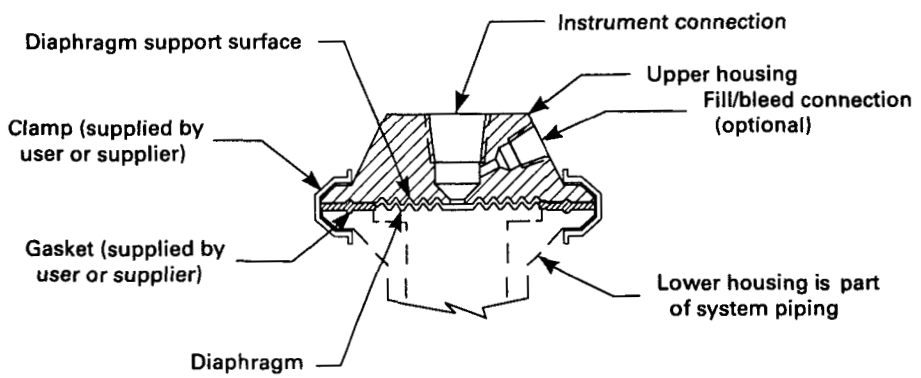


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**FIG. 13A WELDED ASSEMBLY**




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**FIG. 13B CLAMPED ASSEMBLY**

**2.4.9** Fasteners which 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.

**2.4.10** Gaskets used to seal the joints between the diaphragm, middle, and bottom housing must be resistant to the medium.

## 2.5 Fill Fluids and Selection

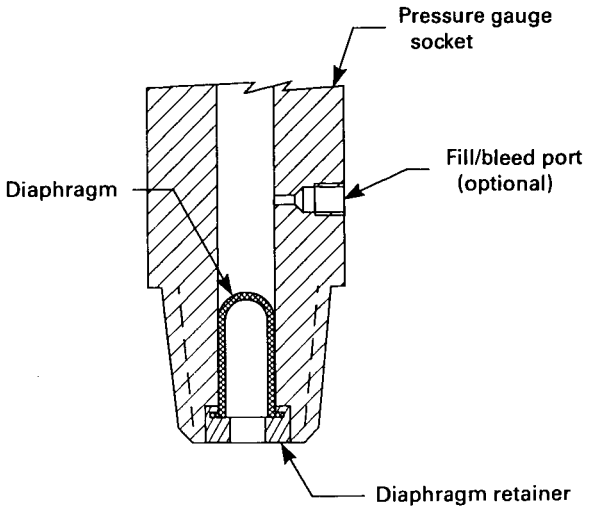
**2.5.1 Fill Fluid.** The liquid used to fill that portion of the pressure sensing system between the diaphragm and the pressure sensing element, acting as the hydraulic medium for transmission of pressure.

### 2.5.1.1 Physical Properties

*(a)* Coefficient of Thermal Expansion;
*(b)* Service Temperature Range;
*(c)* Specific Gravity;
*(d)* Viscosity;

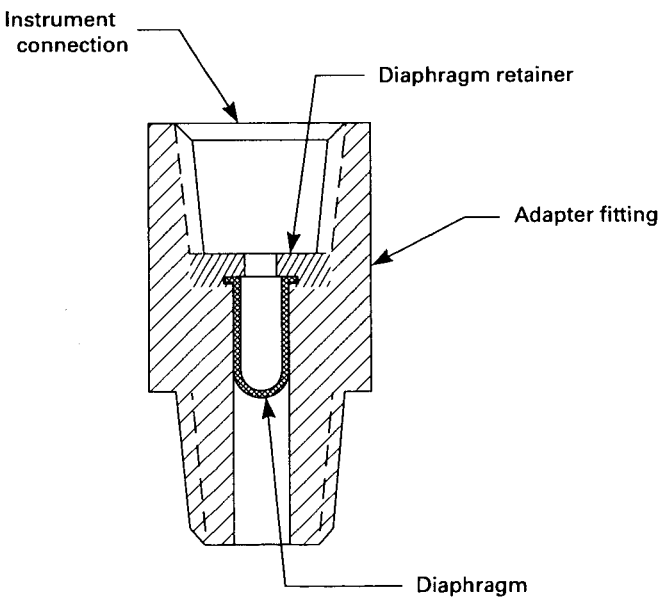


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**FIG. 14A GAUGE ISOLATOR**




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**FIG. 14B GAUGE ISOLATOR**



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(e) Vapor Pressure;
(f) Compressibility;
(g) Freeze Point;
(h) Thermal Decomposition Point;
(i) Spontaneous Ignition Temperature;
(j) Long Term Stability (Closed System).

**2.5.2 Fluid Selection.** The following attributes of a fluid shall be considered:

**2.5.2.1 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.

**2.5.2.2 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 or corrosive contaminating 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 (see para. 2.8).

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

**2.5.2.4 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, solidification, etc.

**2.5.2.5 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 mid-summer to mid-winter. Exposed components may be insulated, heated, or cooled to reduce the effects of ambient temperature variations.

**2.5.2.6 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.

**2.5.2.7 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.

**2.5.2.8 Viscosity.** The fluid viscosity or resistance to flow has an effect upon 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.

**2.5.2.9 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.

**2.5.2.10 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.

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

## 2.6 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.

**2.6.1 Degradation of Accuracy.** The volumetric displacement and volumetric spring rate of the diaphragm must be adequate to actuate the sensing mecha-



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nism 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 also the desired accuracy.

**2.6.2 Process Pressure.** The maximum and minimum medium pressure that will be applied to the diaphragm seal.

**2.6.3 Temperature**

*(a)* Process Temperature (see para. 2.5.2.5);
*(b)* Ambient Temperature (see para. 2.5.2.5);
*(c)* Storage Temperature (see para. 2.5.2.6).

**2.6.4 Mounting**

**2.6.4.1 Mounting Style.** See para. 2.2.

*(a)* Attached to the outside of a pipe or vessel;
*(b)* In-line.

**2.6.4.2 Mounting Method.** See para. 2.2.

*(a)* Threaded;
*(b)* Flanged;
*(c)* Welded;
*(d)* Saddle;
*(e)* Clamped (Sanitary).

**2.6.4.3 Process Connection** See para. 2.3.10.

*(a)* Thread (e.g., ½ 14 NPT);
*(b)* Flange size and rating and face configuration (e.g., ASME B16.5, 1½ in. Class 150 RF);
*(c)* Weld size and configuration (e.g., 1 in. socket weld);
*(d)* Saddle, pipe size (e.g., 3 in.);
*(e)* Clamp, size and type.

**2.6.5 Materials** See para. 2.4.

**2.6.5.1 Parts in Contact With the Medium**

*(a)* Diaphragm;
*(b)* Lower housing;
*(c)* Mid housing;
*(d)* Gaskets;
*(e)* Weld;
*(f)* Flushing connection plug.

**2.6.5.2 Parts Not in Contact With Medium**

*(a)* Upper housing;
*(b)* Bolts and nuts;
*(d)* Reinforcing rings;
*(e)* Seal within the filled system;
*(f)* Fill/bleed screw.

**2.6.6 Instrument Connection.** See para. 2.3.9.

*(a)* Size (e.g., ½ 14 NPT female);
*(b)* Direct or remote.

**2.6.7 Fill Fluid.** See para. 2.5.

**2.6.8 Other Features.** See para. 2.3.

*(a)* Continuous/noncontinuous;
*(b)* Removable/nonremovable;
*(c)* Flushing connection (see para. 2.3.11);
*(d)* Locking device (see para. 2.3.15).

## 2.7 Reuse of Diaphragm Seals

It is not recommended that diaphragm seals be moved from one application to another for the reasons stated in paras. 2.7.1 through 2.7.4.

**2.7.1 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 Compressed Gas Association, Inc., STD. CGA 4.1, "Cleaning Equipment for Oxygen Service.") Diaphragm seals should be disassembled and cleaned with appropriate solvents prior to any reuse on different applications.

**2.7.2 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.

**2.7.3 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.

**2.7.4 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 (see para. 2.5.2).



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## 2.8 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 Section 2.4). Improper selection could result in failure and possible injury or property damage.

**2.8.1** 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 heavier 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.

**2.8.2** The maximum allowable pressure must not be exceeded. Flanged seals are generally limited to the maximum rating of the flange itself. Plastic lower housing will not withstand the same pressures as metal equivalents. Maximum allowable pressures for all materials decrease as temperatures increase.

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

**2.8.4** 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 fluorinated or chlorinated fluids, or both, may be more suitable for such applications.

**2.8.5** 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 utilized on parts which 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, 3A Sanitary Standards, or other applicable standards.

**2.8.6** 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.

**2.8.7** 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.

## 2.9 Filling Diaphragm Seals

**2.9.1 Objective of the Filling Operation.** The objective 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, over-filling the limited volume within the sealed system, causing inaccurate pressure measurements and frequently distorting metal diaphragms.

### 2.9.2 Filling Stations

*(a)* The fill station shown on Fig. 15 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 on Figs. 16A and 16B 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 on Fig. 16A, the vacuum is applied to the sealed system and the fluid is degassed. When valves are positioned as shown on Fig. 16B, the fill fluid enters the sealed system.

**2.9.3 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.

**2.9.3.1 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



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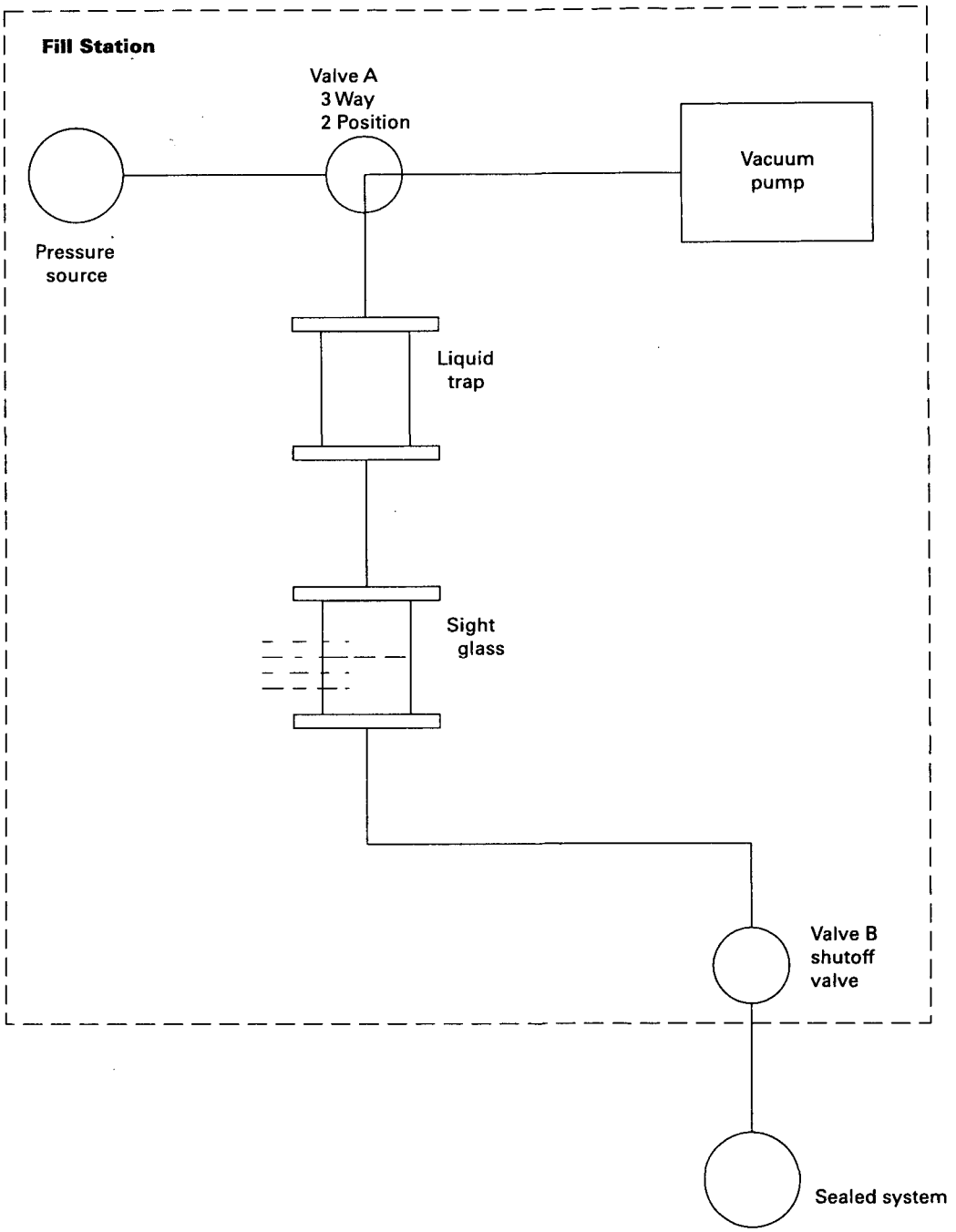



**FIG. 15 SEALED SETTING**



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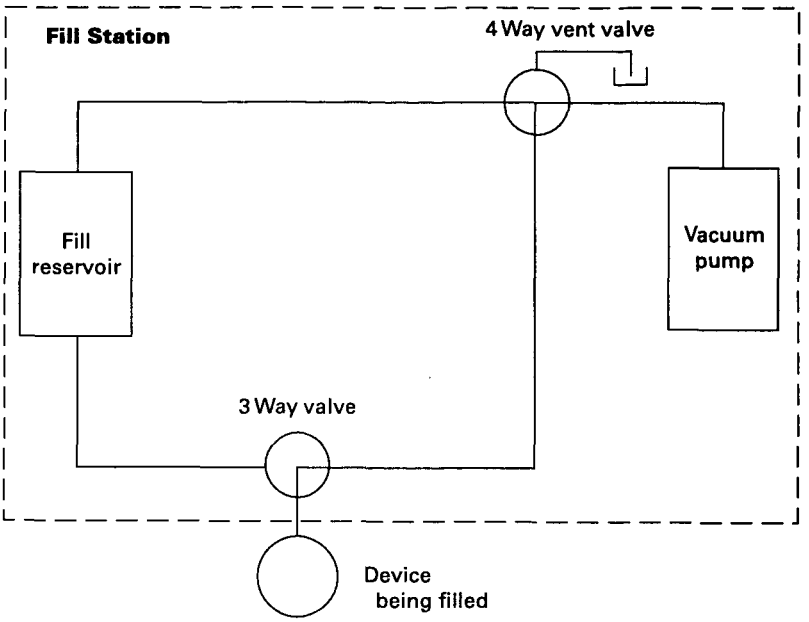



FIG. 16A FILL SETTING

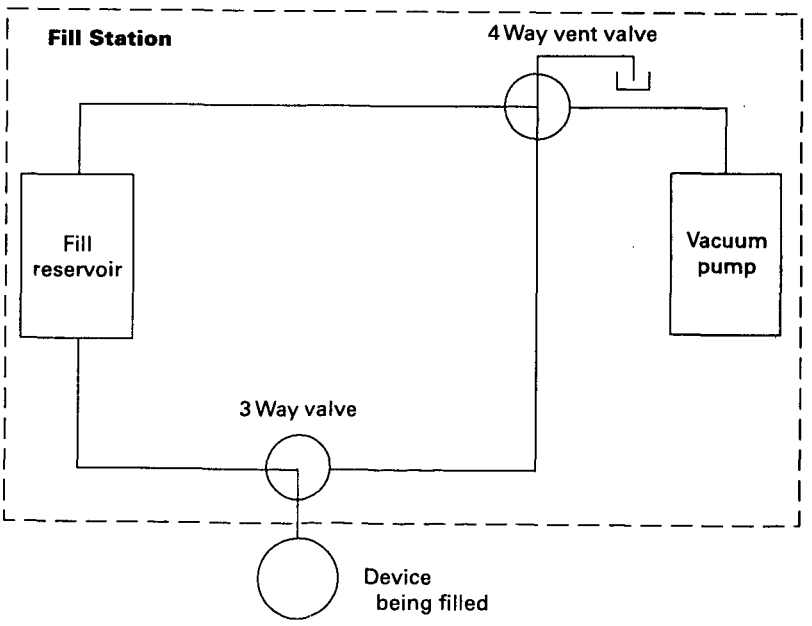



FIG. 16B FILL SETTING



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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: if the diaphragm is not flat, excessive nonlinearity and/or temperature error may result. If the diaphragm is convex toward the process side (over-filled), gently press the diaphragm upward until it is flat and then tighten the fill/bleed screw. 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. 2.9.3.2 and 2.9.3.3.

#### 2.9.3.2 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 Seal to a Filled Instrument.* After filling both the seal [para. 2.9.3.2(a)] and the instrument [para. 2.9.3.2(b)], 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. 2.9.3.1.

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.

#### 2.9.3.3 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. 2.9.3.1.

If filled before assembly, first the seal and instrument should be filled as per paras. 2.9.3.2(a) and 2.9.3.2(b) and then the capillary 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 seal in the same manner as the seal and instrument assembly described in para. 2.9.3.2(c).

### 2.10 Testing

**2.10.1 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 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 match more closely the application. A functional test in the intended application is generally the best evaluation method.

**2.10.2 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 Section 2.9. 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.

#### 2.10.3 Calibration Standards

##### 2.10.3.1 General Discussion

*(a)* Information regarding manometers and piston gages 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 National Institute of Standards and Technology, NIST, (formerly National Bureau of Standards) Manometry Manual, and NIST Piston Gage Manual.

*(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.



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(c) For information regarding indicating dial gauges used as working standards, see ASME B40.1.

**2.10.3.2 Recommended Standards.** Standards shall have nominal errors no greater than ¼ 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 gages, or other standards which contain oil or other hydrocarbon fluids, shall not be used to test diaphragm seal/instrument assemblies cleaned for oxygen service.**

### 2.10.4 Test Procedures

**2.10.4.1 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 73.4°F (23°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 gage, appropriate compensation shall be made for liquid head effects.

**2.10.4.2 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 ASME B40.1. 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 ASME B40.1. 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 ASME B40.1. 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 para 2.10.4.2(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 para. 2.10.4.2(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.* The diaphragm seal/instrument assembly shall be tested in accordance with para 2.10.4.2(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 para. 2.10.4.2(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 para. 2.10.4.2(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 hr. 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 hr. This 48 hr cycle shall be repeated for a total of 2 complete cycles. The assembly shall then be allowed to stabilize at room temperature and then checked for accuracy in acccordance with para. 2.10.4.2(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 utilizing 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 para.



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2.10.4.2(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 down scale accelerations or high amplitude impulses (pressure spikes). The assembly shall be tested for accuracy in accordance with the test specified in para. 2.10.4.2(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. 2.3.2.1.

*(1)* The diaphragm seal/instrument assembly shall be filled in accordance with the procedures described in para. 2.9. The instrument may be recalibrated and the assembly shall be tested in accordance with para. 2.10.4.2(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. 2.9. The instrument may be recalibrated and the assembly shall be tested for accuracy in accordance with para. 2.10.4.2(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. 2.3.2.2.

The diaphragm seal/instrument assembly shall be filled in accordance with para. 2.9. 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 determine 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. 2.9. It shall then be subjected to repeated applications of pressure (hydraulic perferred) equal to approximately 20% to 80% of the range of the instrument, at a rate of 0.5 Hz. The rate of presssure change should approximate a sine wave, to avoid upscale or down scale 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.



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**1 Scope** ..... 36.41

**2 Purpose** ..... 36.41

**3 General** ..... 36.41

**4 Safety** ..... 36.44

**5 Testing** ..... 36.45

**Figures**

1 Fixed Orifice ..... 36.42
2 Valve ..... 36.42
3 Porous Metal ..... 36.43
4 Felt Plug — Fluid-Filled ..... 36.43
5 Piston ..... 36.44
6 Test Set-Up ..... 36.47
7 Typical Input Surge ..... 36.48
8 Desirable Snubber Output ..... 36.49

**Nonmandatory Appendix**

A Supplemental Requirements ..... 36.51



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# SNUBBERS (a)

## 1 SCOPE

This Standard is confined to devices that are installed between the pressure source and the pressure sensing element and are used to minimize the effect of pressure surges on positive and negative pressure sensing instruments.

## 2 PURPOSE

These devices commonly known as snubbers, pulsation dampeners, pressure equalizers, gauge protectors, gauge savers, etc., are used to improve the output or readability of the instrument, and to reduce the effect of pressure surges on the instrument. They also limit the external discharge of the pressure medium, in the event a discontinuity should occur on the instrument side of the snubber.

## 3 GENERAL

### 3.1 Terminology Defined

Terms relevant to this Standard and its application are as follows:

*amplitude:* the maximum departure of the pressure from the average pressure.

*fluctuation:* a nonperiodic surge.

*pulsation:* a periodic surge.

*rate of pressure change:* pressure change per time interval.

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

*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.

*spike:* a short duration, high amplitude surge.

*surge:* a sudden rise or drop in system pressure.

### 3.2 Connections

**3.2.1 Type of Connection.** Tapered pipe connections for pressure up through 20,000 psi or 160,000 kPa are usually $\frac{1}{8}$ in., 27 NPT, ¼ in., 18 NPT, or ½ in., 14 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., ½ in., 14 NPT instead of ¼ in., 18 NPT) and/or a stronger material (e.g., stainless steel instead of brass) should be considered.

### 3.3 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 insure compatibility with the process medium, temperature, and pressure.

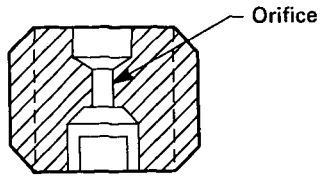
### 3.4 Types of Snubbers

**3.4.1 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 Fig. 1.

**3.4.2 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 closeoff the valve completely. See Fig. 2.

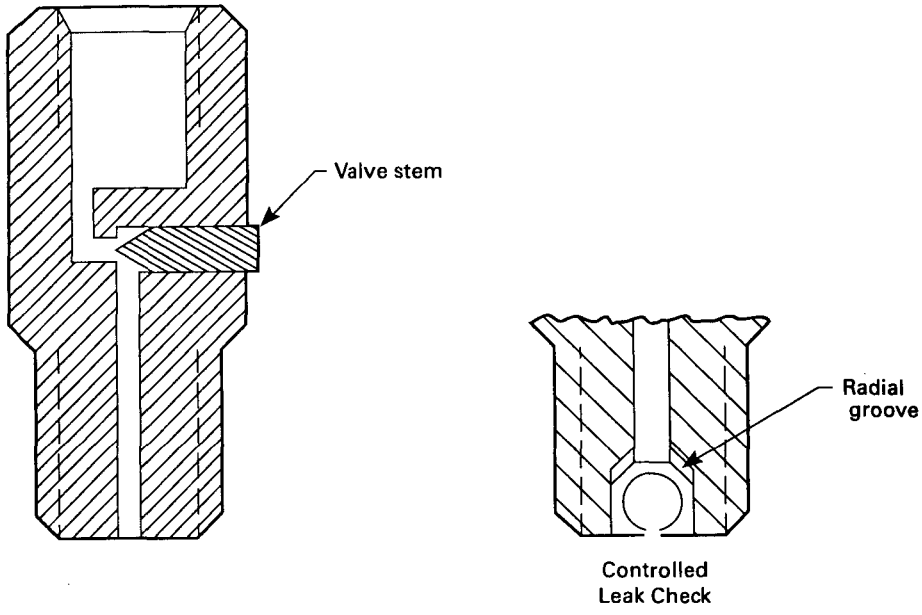


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**FIG. 1 FIXED ORIFICE**




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**FIG. 2 VALVE**

**3.4.3 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 Fig. 3.

**3.4.4 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 Fig. 4.

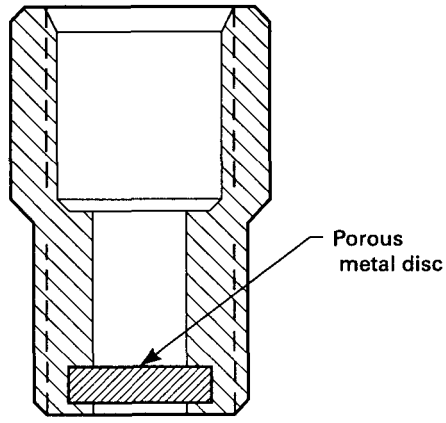
**3.4.5 Piston.** This device consists of a movable piston in a hole. The clearance between the piston and the hole determines the amount of dampening. It is usually furnished with multiple pistons or a cylinder with multiple holes. The amount of snubbing can be changed by changing pistons or holes. Piston type snubbers tend to be self-cleaning because of the action of the piston. See Fig. 5.

### 3.5 Selection

**3.5.1 System Parameters.** The following system parameters should be considered by the user for each application of a snubber. The effect of these parameters

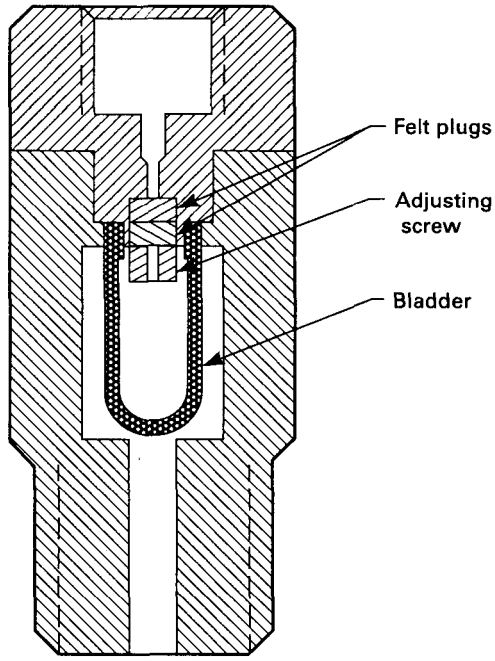


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**FIG. 3 POROUS METAL**




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**FIG. 4 FELT PLUG — FLUID-FILLED**

may vary depending on the instrument used. The supplier should be consulted for assistance, if required.

**3.5.1.1 Viscosity.** More dampening is required for media of low viscosity.

**3.5.1.2 Pressure.** The higher the pressure the greated the amount of dampening that is 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.

**3.5.1.3 Rate of Pressure Change.** The higher the maximum rate of pressure change, the greater the amount damping that is required.

**3.5.1.4 Amplitude of Pressure Change.** The higher the amplitude of pressure change, the greater amount of dampening is required.

**3.5.1.5 Volumetric Displacement of the Instrument.** Generally less dampening is required with higher instrument volumetric displacement.

**3.5.1.6 System Pressure.** The snubber must be capable of withstanding the system pressure.

**3.5.1.7 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.

**3.5.1.8 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 insure compatibility with the process medium, temperature, and pressure.

**3.5.2 Consultation.** Due to the extensive number of variables associated with the selection of snubber types, styles, operating prarmeters, etc., detailed selection criteria is beyond the scope of this Standard. The user should consult the supplier for recommendation.

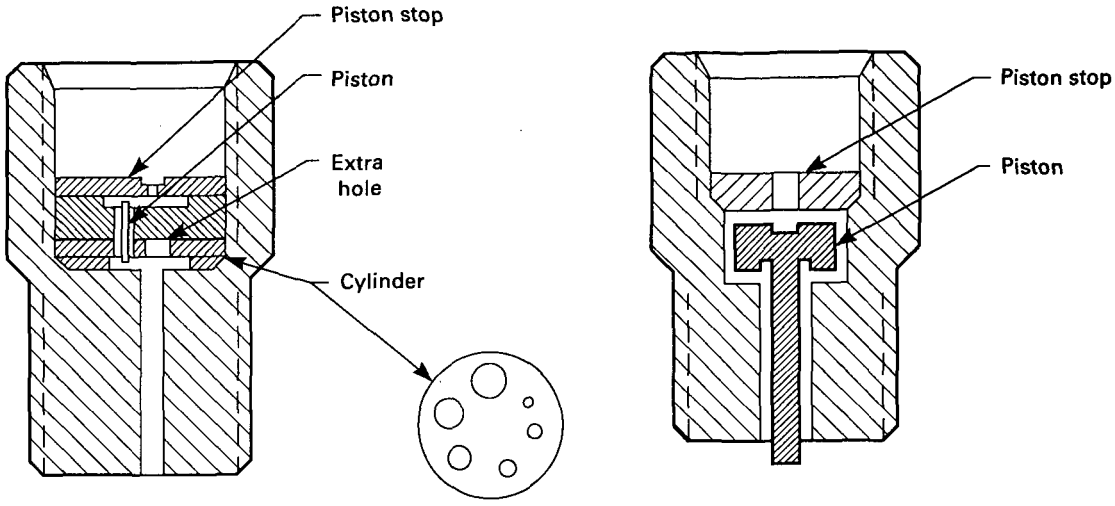
### 3.6 Performance

**3.6.1 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.

**3.6.2 General.** When the working parts are properly selected in accordance with para. 3.5, 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



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GENERAL NOTE: Not intended to show design detail.

**FIG. 5 PISTON**

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.

**3.6.3 Mechanical Vibration.** Most snubbers will not be effective in reducing the effects of mechanical vibration.

**3.6.4 Existing Systems.** The installation of a new properly selected snubber in a system, containing a worn instrument may not provide the desired result.

**3.6.5 Response Time.** There are two response times that are of interest (paras. 3.6.5.1 and 3.6.5.2).

**3.6.5.1 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 eleminating all gas between the snubber and the pressure sensing element. The response time may be reduced by reducing the amount of dampening.

**3.6.5.2 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.

**3.6.6 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.

**3.6.7 Location.** The snubber should be located as close as possible to the instrument.

**3.6.8 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 SAFETY

### 4.1 Scope

This Section of the standard 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.



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## 4.2 General Discussion

**4.2.1 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.

**4.2.2 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)* non-steady 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.

**4.2.3 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.

**4.2.4 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.

### 4.2.5 Caution to Users

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

**4.2.5.2 Reuse.** It is recommended that a snubber not be moved from one application to another. Should it be 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.

# 5 TESTING

## 5.1 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 match more closely the application. A functional test in the intended application is generally the best evaluation method.



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### 5.2 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.

### 5.3 Comparison Testing

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

### 5.4 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.

### 5.5 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 SECTION 4 BEFORE CONDUCTING ANY TESTING.**

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

**5.5.2 Test Set-Up.** See Fig. 6 for a test set-up that has been successfully used. It generates surges approximately twice the input pressure. A typical input surge is shown in Fig. 7.

**5.5.3 Desirable Snubber Output.** The dampened output should resemble Fig. 8. Generally the maximum rate of pressure rise would be from 5,000 to 15,000 psi/sec; 30,000 psi/sec would be maximum for effective protection of the instrument without any pressure overshoot.

### 5.6 Equipmennt

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.

**5.6.1 Solenoids.** The solenoids must be fast acting.

**5.6.2 Twelve Foot Coil.** The twelve foot 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.

**5.6.3 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.

**5.6.4 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 effect the test results.

**5.6.5 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.

### 5.7 Test Procedure

*(a)* The system should be filled with the pressure medium, and all air bled from the system with particular attention being paid to the space between the pressure pick-up and the snubber. Filling at low pressure helps eliminate foam and air bubbles.

*(b)* Open needle valves, 1, 2, 3, and 4.

*(c)* Close needle valve 3.

*(d)* Pressurize the accumulator to the test pressure.

*(e)* Actuate the solenoid valves to apply pressure to the system and start the oscilloscope trace.

*(f)* When the results have been observed and/or recorded, actuate the solenoid valves to drop the system pressure.

*(g)* To repeat start at para. 5.7(d).



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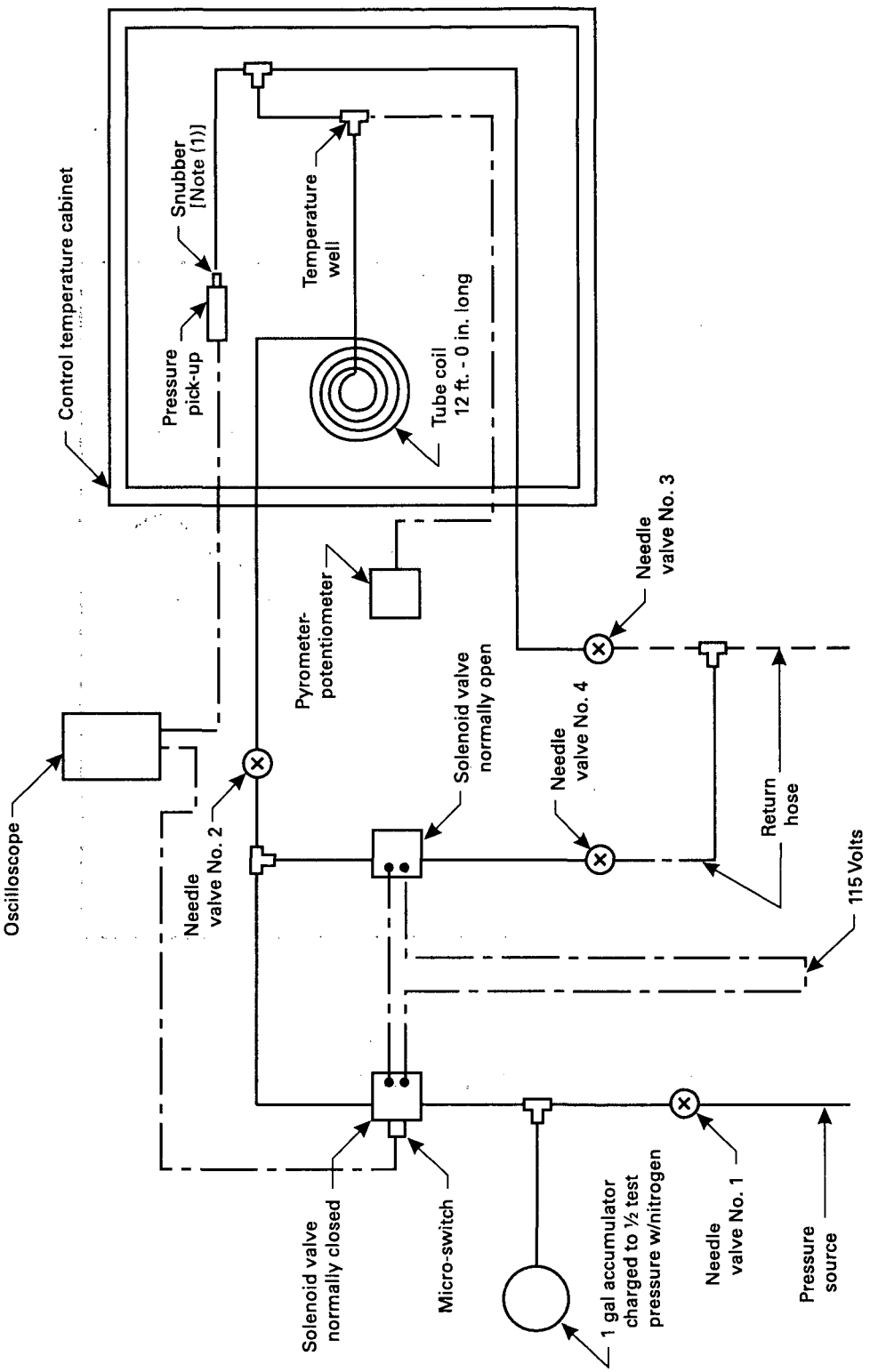


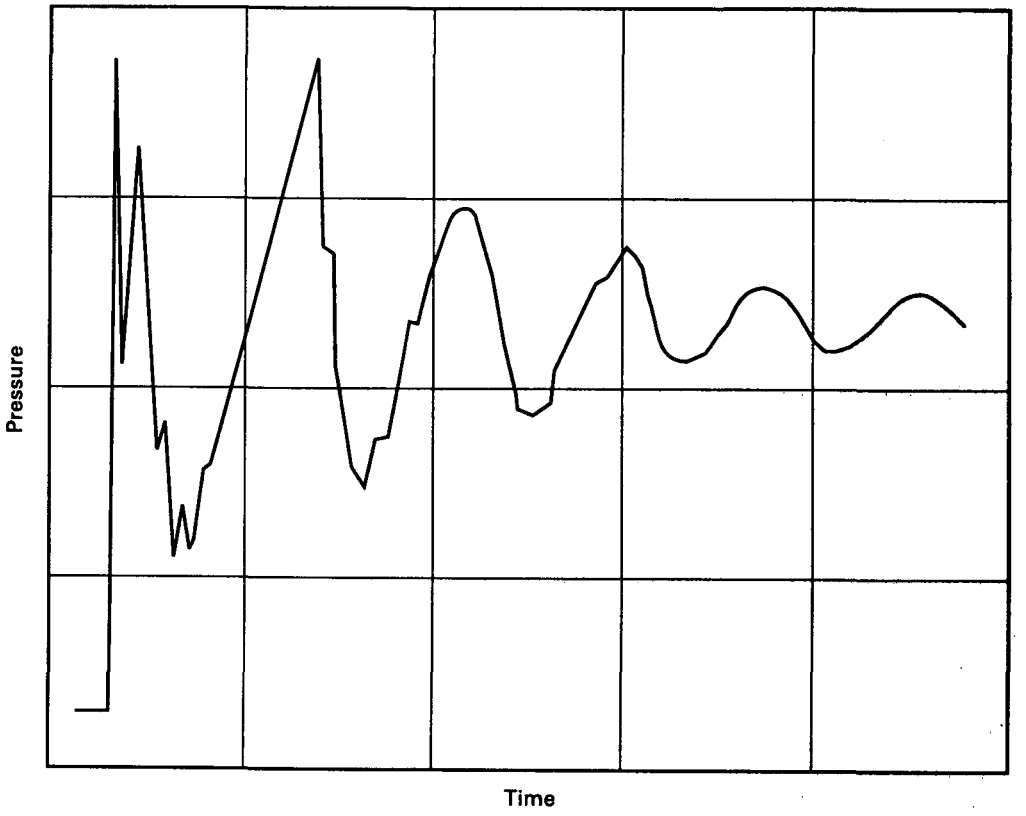

FIG. 6 TEST SET-UP

GENERAL NOTE: See para. 5.5.2.

NOTE:
(1) Device under test.



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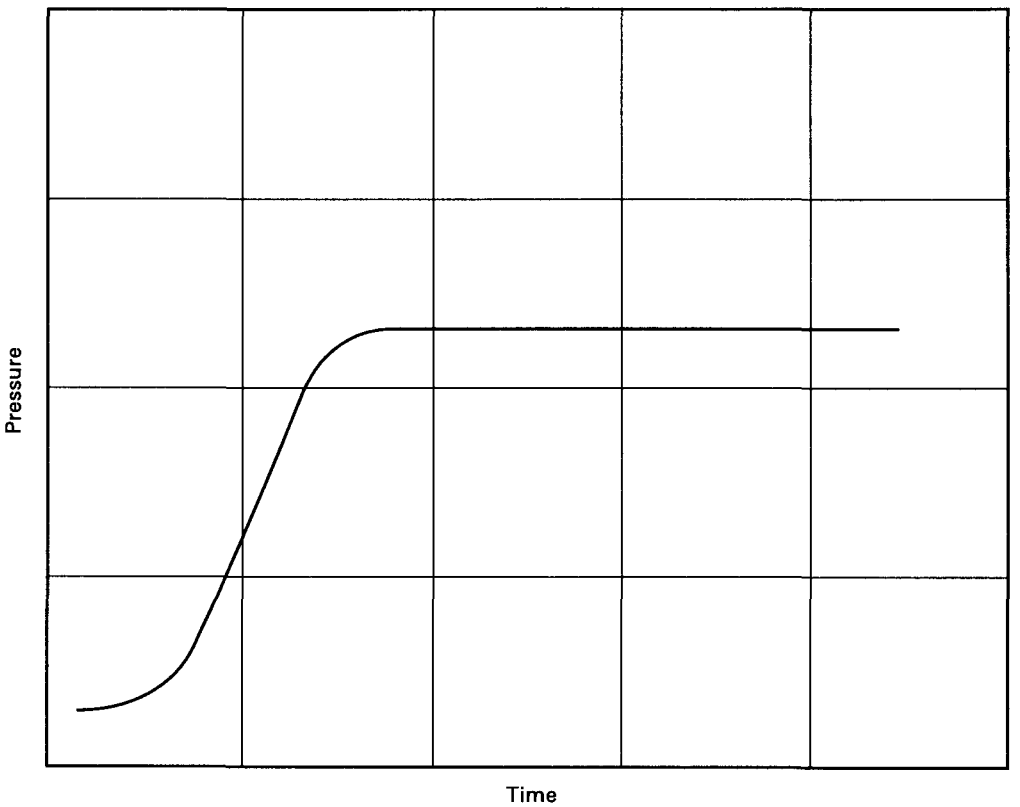



GENERAL NOTE: See para. 5.5.2.

**FIG. 7 TYPICAL INPUT SURGE**



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GENERAL NOTE: See para. 5.5.3.

**FIG. 8 DESIRABLE SNUBBER OUTPUT**



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# NONMANDATORY APPENDIX A SUPPLEMENTAL REQUIREMENTS (a)

The following supplementary requirements established for naval shipboard applications shall apply when specified in the contract or purchase order. When there is conflict between the standard (ASME B40.5) and this supplement, the requirements of this supplement shall take precedence for equipment acquired by this supplement. This document supersedes MIL-S-2940, Snubbers, Fluid Pressure, Instrument Protection, for new ship construction.

## A1 SCOPE

This specification supplement covers shock resistant, environmentally hardened devices that are installed between the pressure source and the pressure sensing element and are used to minimize the effect of pressure surges on positive and negative pressure sensing instruments.

## A2 GENERAL

### A2.1 Connections

Materials used for connections shall be compatible with the specified snubber body composition.

**A2.1.1 General Pressure Applications.** Snubbers used in pressure applications shall be as follows:

**A2.1.1.1 O-ring Union Connection.** Snubbers used for O-ring union pressure gauge applications shall have a connection in accordance with Figs. A1 and A2. When the O-ring union is specified, each snubber shall be furnished with a union nut, tailpiece, and O-ring as shown on Figs. A1 and A2.

**A2.1.1.2 Flareless (Bite Type) Connection.** Snubbers used for flareless (bite type) pressure gauge applications shall have $^{7}/_{16}$ in. 20 UNF-2A external threads on the inlet connection and $^{7}/_{16}$ in. 20 UNF-2B internal threads on the outlet connection in accordance with SAE J 1926, 6,000 psi for ¼ in., tubing.

**A2.1.1.3 Pressure Transducer Connection.** Snubbers used for pressure transducer applications shall have a $^{7}/_{16}$ in. 20 UNF flareless tube connection [¼ in., outside diameter (OD)] on the inlet connection. The outlet connection shall be $^{7}/_{16}$ in. 20 UNF-2A external thread to mate with the SAE J 1926 internal connection port of the pressure transducer. An O-ring shall be supplied on the outlet connection.

**A2.1.1.4 Other Connections.** Snubbers not used in any of the above applications shall have connections specified in the contract or ordering data.

### A2.2 Materials

Materials for snubbers and guidance for proven materials are specified in A2.2.2.1 through A2.2.2.6. Material for wetted parts shall be selected for long term compatibility with the service fluid (see A4.2.2) and shall be equal to or superior in corrosion resistance to that used in the body except that corrosion resistant steel is prohibited for Type 4 (sea water) snubbers or for oxygen applications.

**A2.2.1 Recycled, Recovered, or Environmentally Preferable Materials.** Recycled, recovered, or environmentally preferable materials should be used to the maximum extent possible provided that the material meets or exceeds the operational and maintenance requirements and promotes economically advantageous life cycle costs.

**A2.2.2 Snubber Body.** The materials for construction of the bodies of snubbers may be selected from compositions A, B, and C. Snubber body material shall be of composition X if other than A, B, or C.

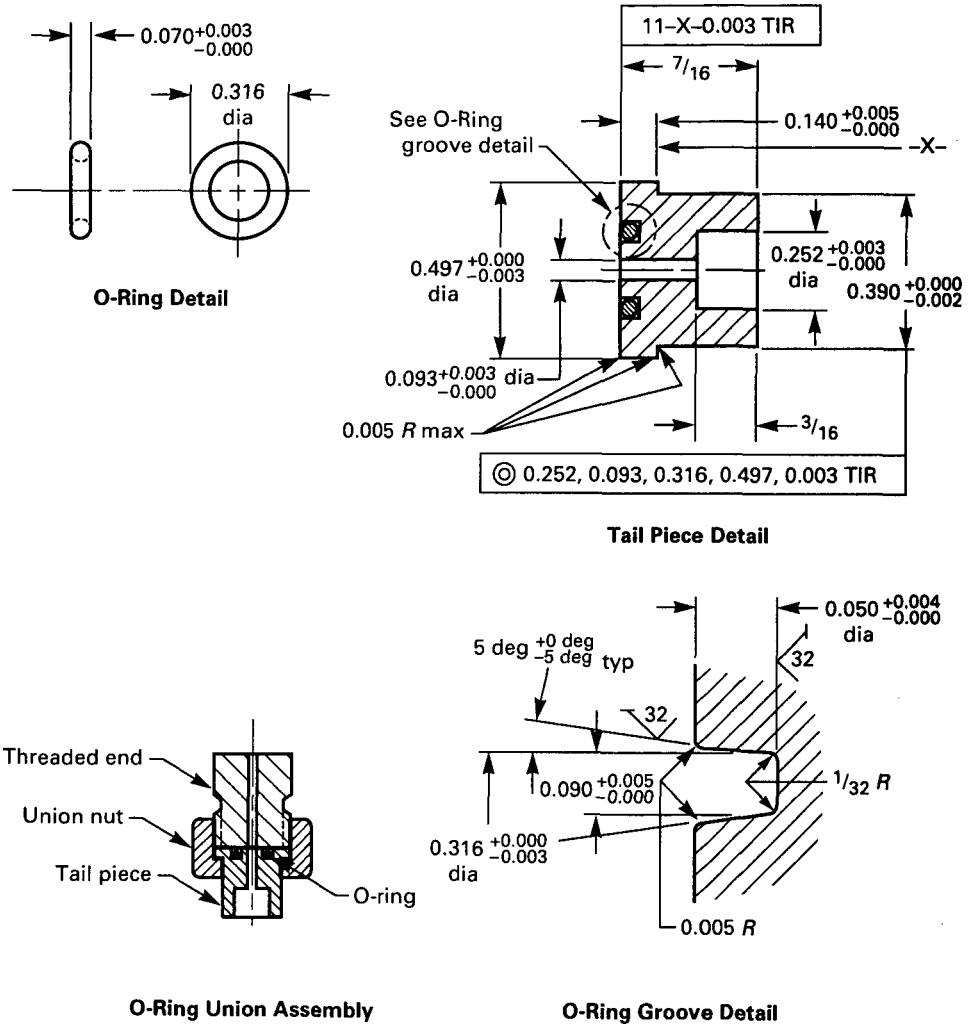
**A2.2.2.1 Composition A.** The material for composition "A" shall be copper-nickel alloy in accordance with ASTM B 122 and ASTM B 151 and may be used for Types 1 through 4.

**A2.2.2.2 Composition B.** The material for composition "B" shall be nickel-copper alloy in accordance with ASTM B 127, ASTM B 164, and ASTM B 564, and may be used for Types 1 through 4.

**A2.2.2.3 Composition C.** The material for composition "C" shall be corrosion resistant steel (CRES), Classes 304L (UNS S30403), 316L (UNS S31603), 321 (UNS S32100), or 347 (UNS S34700) and may be



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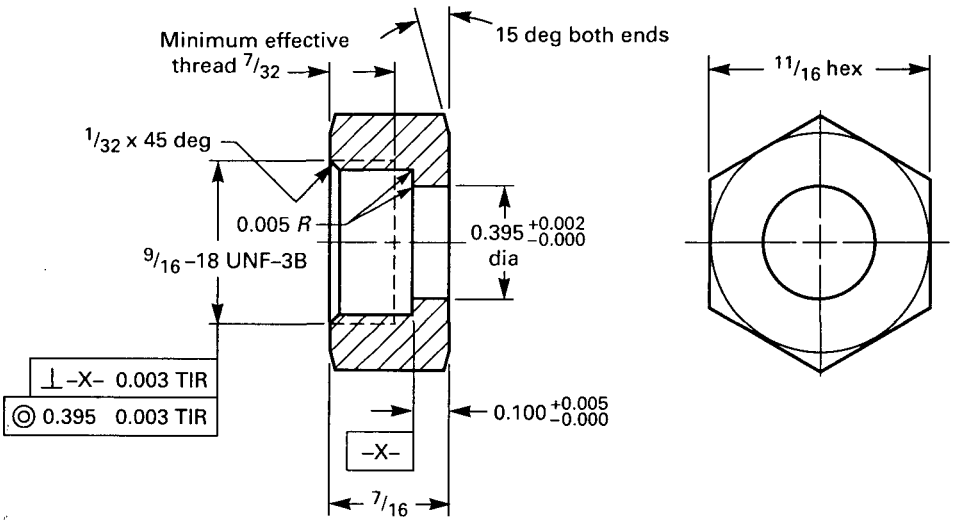



GENERAL NOTE: Dimensions are in inches.

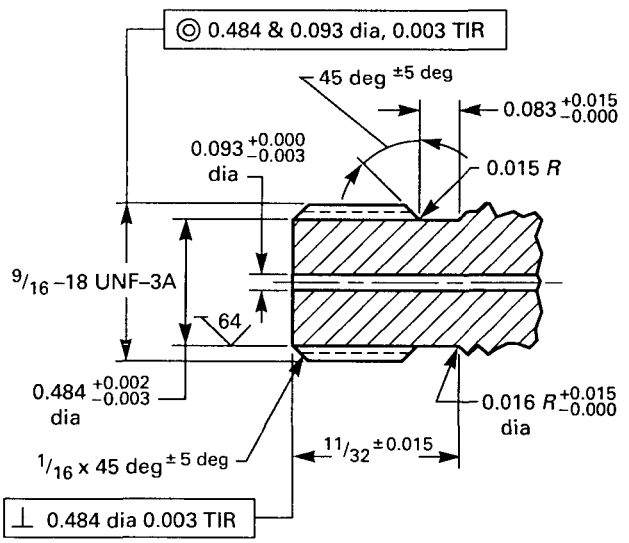
**FIG. A1 O-RING UNION CONNECTION**



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**Union Nut Detail**




**Threaded End Detail**

GENERAL NOTE: Dimensions are in inches.

**FIG. A2 O-RING UNION NUT/THREADED END DETAIL**



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used for Types 1 through 3, except oxygen applications. Where the end connections do not require welding, Classes 304 (UNS S30400) or 316 (UNS S31600) are also acceptable.

**A2.2.2.4 Composition X.** The material for composition "X" is any material, metallic or nonmetallic, used for the snubber body not covered under compositions A through C. Material shall be compatible with the service fluid. For composition "X", material identification shall be included in the snubber marking (see para. A2.2.4).

**A2.2.2.5 Nonmetallic Materials.** Nonmetals shall be moisture and flame resistant, shall not support fungus growth, and shall not be adversely affected by the ambient environments specified in the configuration and performance requirements of this specification. Nonmetals shall not chemically react, degrade, or outgas when subjected to the following: air, distilled water, sea water, salt, petroleum and silicone based oils, oil solvents, prolonged (greater than one month) periods of exposure to ambient temperatures, prolonged periods of exposure to elevated temperatures (up to 350°F), and exposure to prolonged cycling periods from ambient to elevated temperatures. Any material, which provides a nutrient medium for fungus and insects, shall not be used.

**A2.2.2.5.1 O-Ring.** O-rings shall be fluorocarbon rubber with SAE AMS 7259, hardness of 85 to 95.

**A2.2.2.6 Porous Metal.** Snubbers with a porous metal composition (internal parts and configuration) are prohibited for gas (Type 3) or for sea water (Type 4) service. When used for oil or water (Types 1 and 2) service, snubbers with porous metal compositions shall only be employed in systems with particulate contaminants less than 25 microns in size.

**A2.2.3 Snubber Body Size.** The length of the assembled snubber body shall not exceed 4 in. The body shall have hexagonal cross-sections of sufficient widths to allow the use of a wrench for installing and removing. The distance across the flats shall not exceed 1.25 in. The maximum diameter of the snubber body shall not exceed 2.0 in.

**A2.2.4 Marking.** Each snubber shall be metal stamped with the following:

*(a)* The maximum working pressure, followed by the abbreviation "psi" (ex. 6,000 psi);

*(b)* Part Identifying Number (see A4.2);

*(c)* Manufacturer's stamp or trademark;

*(d)* material type (if composition "X" is used).

**A2.2.4.1 Flow Direction.** The direction of flow through the snubber shall be indicated by an arrow with the word "sensor" at the point of the arrow. The arrow shall be raised from the surface (0.010 in., min) or marked into the surface in a permanent manner and to the extent that it can be easily identified by human touch. The word "sensor" shall be metal stamped or otherwise permanently marked.

**A2.2.4.2 Warning Label.** Type 3 snubbers shall have a warning label included on its primary pack marked "oxygen" or "dry nitrogen" service, as applicable for the system use when cleaned for these applications.

### A2.3 Cleaning and Packaging

Surfaces of castings, forgings, molded parts, stampings, machined, and welded parts shall be free of defects such as cracks, porosity, undercuts, voids, and gaps as well as sand, dirt, fins, sharp edges, scale, flux, and other harmful or extraneous materials. External surfaces shall be smooth and edges shall be either rounded or beveled. There shall be no warpage or dimensional change due to heat from welding operations. There shall be no damage to adjacent parts resulting from welding. Unless special cleaning, drying, unit protection and intermediate packaging are specified, the snubber shall be cleaned, dried, and bagged with boxing in accordance with ASTM D 3951.

## A3 VERIFICATION

### A3.1 Responsibility for Inspection

Unless otherwise specified in the contract or purchase order, the manufacturer is responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified in the contract or purchase order, the manufacturer may use his own or any other facilities suitable for the performance of the inspection requirements specified herein, unless disapproved by the buyer. The buyer reserves the right to perform any of the inspections set forth in the standard where such inspections are deemed necessary to assure supplies and services conform to prescribed requirements.

**A3.1.1 Responsibility for Compliance.** All items shall meet the requirements of Sections A2 and A3. The inspection set forth in this specification shall become a part of the manufacturer's overall inspection system or quality program. The absence of any inspec-



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**TABLE A1 QUALIFICATION AND CONFORMANCE INSPECTIONS**

| Inspection | Qualification Inspection | Conformance Inspection |
|---|---|---|
| Examination | X | X |
| Steady state transmission | X | ... |
| Dampening | X | X |
| Temperature | X | ... |
| Vibration | X | ... |
| Shock | X | ... |
| Pressure integrity | X | ... |

tion requirements in this specification shall not relieve the manufacturer of the responsibility of assuring that all products or supplies submitted to the government for acceptance comply with all requirements of the contract. Sampling inspection, as part of the manufacturing operations, is an acceptable practice to ascertain conformance to requirements, however this does not authorize submission of known defective material, either indicated or actual, nor does it commit the buyer to accept defective material.

## A3.2 Classification of Inspections

**A3.2.1 Qualification Inspection.** Qualification inspection shall consist of examination and tests specified in Table A1 and shall be performed and passed prior to production. Qualification inspection shall be performed on samples which have been produced with equipment and procedures normally used in production.

**A3.2.1.1 Sample Size.** Two snubber samples of each type, class, and composition shall be subjected to the qualification inspection.

**A3.2.2 Conformance Inspection.** Conformance inspection shall be performed at the place of manufacture. Conformance inspection shall consist of the examination and tests specified in Table A1 and shall be performed on samples selected from each lot.

**A3.2.2.1 Lot.** A lot shall consist of all snubbers of the same type, class, composition, and end connection manufactured at one time.

**A3.2.2.2 Sampling.** Sample selection shall be in accordance with ANSI/ASQC Z1.4, inspection level I, acceptable quality level (AQL); 1½% nonconformities apply.

**A3.2.2.3 Nonconformity.** The AQL for each nonconformity is as shown in Table A2.

**A3.2.3 Acceptance Criteria.** If any snubber sample fails to meet the inspection requirements of Table A1, no snubbers shall be accepted until the manufacturer has determined the cause of the defect and has taken the necessary action to correct or eliminate the defect from each snubber in the lot. The failed test shall be repeated to demonstrate that the corrective action will enable the snubbers to conform to the requirements of this specification. In addition, the results of previous tests may be deemed invalid, unless the manufacturer can prove to the satisfaction of the buyer that such test would not be adversely impacted by the corrective action.

## A3.3 Test Conditions

Test conditions shall be as specified in the applicable examinations and test procedures.

## A3.4 General Examination

The snubbers shall be subjected to a thorough examination to ascertain that the material, finish, workmanship, construction, assembly, dimensions, and marking are in conformance with the requirements of this specification. Examinations shall be limited to disassembling the snubbers to the extent that the performance, durability, or appearance would not be affected.

## A3.5 Test Procedures and Requirements

Tests shall be conducted as described below. For the dampening test, a storage oscilloscope, oscillographic recorder, or other data acquisition system with a frequency response sufficient to resolve full scale deflections in 10 milliseconds or less shall be utilized. Input signal resolution shall be 2% or less of full scale. Signals from both the test and monitoring transducers shall be recorded simultaneously (see A3.5.2). With the exception of the dampening test, which requires the use of pressure transducers, all other tests may be monitored with either a pressure transducer or a pressure gauge of suitable range which shall have accuracies of 1% of span or better and shall have an overpressure rating of at least 125% of upper range value. To maintain sufficient accuracy, the maximum upper range limit for any pressure transducer or pressure gauge shall not exceed twice the maximum pressure expected in any test. In addition, controls of the storage oscilloscope, oscillographic recorder, or other data acquisition



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**TABLE A2 AQL FOR NONCONFORMITIES**

| Categories | Nonconformities | AQL |
|---|---|---|
| **Critical** | | |
| 1 | Evidence that snubbers for oxygen service are not cleaned, improperly marked, or improperly packaged. | 0 |
| 2 | Snubber does not meet the pressure integrity. | 0 |
| **Major** | | |
| 101 | Evidence of unauthorized material. | 0 |
| 102 | Inspection systems are not provided, dimensional tolerances not maintained, mounting dimensions not interchangeable, pressure connection wrong design, or dimensions erroneous. | 0 |
| 103 | Snubber does not meet steady state transmission or dampening. | 0 |
| 104 | Markings not provided or erroneous; part number not provided. | 0 |
| **Minor** | | |
| 202 | Evidence that snubber for nonoxygen service are not cleaned. | 1½ |
| 203 | Finish non-conforming, scratched, chipped; burrs not removed. | 4 |
| 204 | Cleaning, drying, preservation, packaging, or packing. | 4 |

system should be set that recorded signals are at least 50% of full scale. Except for the dampening tests which require a specific fill fluid, the others may employ fresh water as the fill fluid. If fresh water is used as the fill fluid for the temperature test, provision should be made to employ a suitable additive to prevent freezing. As applicable, the snubber should be thoroughly cleaned prior to conducting the dampening test. The fill fluids for the dampening tests shall be as follows:

*(a) Type 1.* 2190-TEP oil or equivalent;

*(b) Types 2 and 4.* Fresh water;

*(c) Type 3.* Air or nitrogen.

Unless otherwise indicated, the pressure transducer or pressure gauge shall be connected to the output side of the snubber with only an adapter fitting between them. Except where temperature is a variable, the test in this specification shall be conducted at an ambient temperature of 75 ± 10°F.

**A3.5.1 Steady State Transmission.** A reference measurement shall be made employing either a pressure transducer, or pressure gauge, both with and without a snubber. The reference measurement shall be made both upscale and down scale at the test pressures for the applicable class (see para. A4.2.3) as shown in Table A3. The difference in indicated output with and without the snubber under test shall be within the accuracy limits of the pressure instrumentation employed.

**A3.5.2 Dampening.** The dampening test shall be conducted utilizing an apparatus similar to that shown on Fig. A3. A step change shall be made from atmospheric pressure to 200 ± 10 psi for Class L snubbers and from atmospheric pressure to 1,500 ± 100 psi for Class H snubbers. The pressure step change shall be accomplished in 100 milliseconds or less as measured with the monitoring pressure transducer. Both the test and monitoring pressure transducers shall have frequency response characteristics sufficient to respond to and produce an electrical signal output in response to a full scale pressure change occurring in 10 milliseconds or less. The pressure as indicated by the test pressure transducer shall satisfy the following criteria:

*(a)* Indicate a pressure of 25% or less of the final steady state pressure at a time equal to that at which the monitoring pressure transducer initially reaches its step pressure level.

*(b)* Reach at least 90% of its final steady state pressure in not more than 2.5 sec after initiation of the pressure step as indicated by the monitoring transducer.

**A3.5.2.1 Procedure.** The following procedure, applicable to Fig. A3, may be used to perform the dampening test:

*(a)* Ensure that V2 and V4 are closed and that V3 is open.

*(b)* Utilizing V3, introduce the fill fluid, as applicable in the monitoring and test transducer legs. Loosen the fittings at T1 and T2 to ensure a complete fill. Tighten all



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**TABLE A3 STEADY STATE TRANSMISSION PRESSURES**

| Snubber Class (see A4.2.3) | Operating Range Upper Limit, psi | Test Pressures, psi |
|---|---|---|
| L | 10/1000 | 10, 250, 500, 750, 1000 |
| H | 1001/6000 | 1200, 2400, 3600, 4800, 6000 |

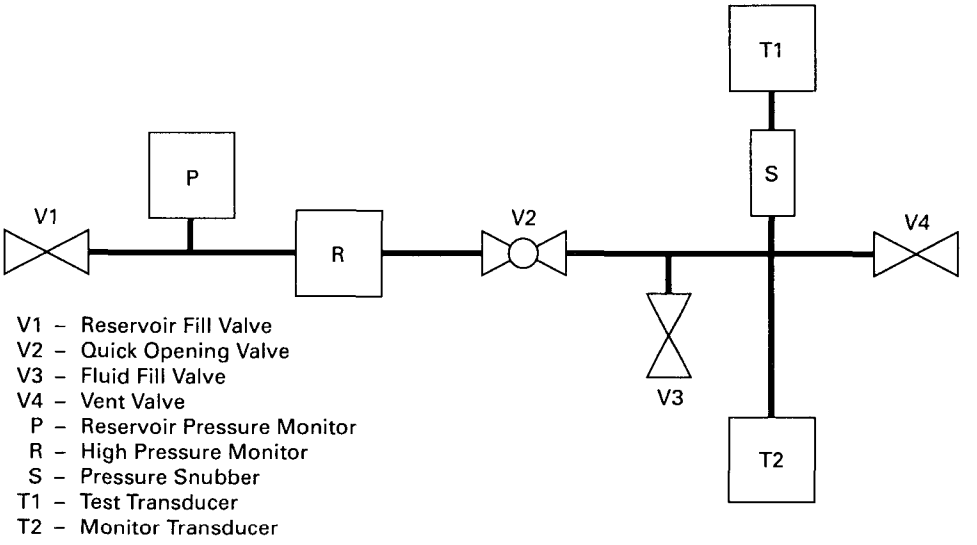



**FIG. A3 SUGGESTED DAMPENING TEST SET UP**

transducer fittings and close V3 after the fill procedure is complete.

*(c)* Utilizing V1, pressurize the high pressure reservoir with nitrogen to a value sufficient to ensure that the pressure step change in the transducer legs will satisfy the criteria of A3.5.2. Close V1.

*(d)* Energize the transducers and applicable monitoring equipment, and actuate V2.

*(e)* After steady state has been achieved, close V2 and relieve the test pressure by opening V4.

*(f)* As applicable, thoroughly clean the entire dampening apparatus to remove residual traces of the fill fluid.

### A3.5.3 Temperature

**A3.5.3.1 High Temperature.** Place the snubber in an environmental chamber and pressurize the snubber to 250 ± 10 psi for a Class L snubber and 1,500 ± 50 psi for a Class H snubber. Increase the chamber temperature from ambient to 150 ± 5°F in not less than 1 hr. Adjust the pressure as necessary to maintain the required pressure. Maintain the pressure and temperature conditions for a minimum of 4 hr. Reduce the chamber to ambient temperature in not less than 1 hr. Remove the snubber from the chamber. Allow it to remain at ambient temperature for at least 1 hr. The snubber shall show no evidence of leakage or damage and shall meet the dampening requirement of para. A3.5.2 after the high temperature test.

**A3.5.3.2 Low Temperature.** Place the snubber in an environmental chamber and pressurize the snubber to 250 ± 10 psi for a Class L snubber and 1500 ± 50 psi for a Class H snubber. Decrease the chamber temperature from ambient to 40 ± 5°F in not less than 1 hr. Adjust the pressure as necessary to maintain the required pressure. Maintain the pressure and temperature conditions for a minimum of 4 hr. Increase the chamber to ambient temperature in not less than 1 hr. Remove the snubber from the chamber and allow it to remain at ambient temperature for at least 1 hr. The snubber shall show no evidence of leakage or damage and shall meet the dampening requirement of A3.5.2 after the low temperature test.

**A3.5.3.3 Temperature Cycling.** Place the snubber in an environmental chamber. The snubber



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**TABLE A4 TEMPERATURE CYCLE**

| Step | Temperature Condition | Duration |
|---|---|---|
| 1 | Increase temperature [Note (1)] from 75 ± 5°F to 150 ± 5°F | 1 hr |
| 2 | Constant temperature of 150 ± 50°F | 22 hr [Note (3)] |
| 3 | Decrease temperature to − 10 ± 5°F | 2 hr |
| 4 | Constant temperature of − 10 ± 5°F | 22 hr [Note (3)] |
| 5 | Increasing temperature to 75 ± 5°F [Note (2)] | 1 hr |

NOTES:
(1) Ambient temperature for the first cycle.
(2) Ambient temperature for the last cycle.
(3) Minimum duration.

**TABLE A5 VIBRATORY DISPLACEMENT CRITERIA**

| Frequency Range (Hz) (inclusive) | Table Displacement (Inches, Peak To Peak) | |
|---|---|---|
| | Exploratory Test | Variable Frequency Test |
| 5 to 20 | 0.020 ± 0.004 | 0.060 ± 0.012 |
| 21 to 50 | 0.010 ± 0.002 | 0.040 ± 0.008 |
| 51 to 100 | 0.003 ± 0.0006 | 0.020 ± 0.004 |
| 101 to 175 | 0.001 ± 0.0002 | 0.003 ± 0.0006 |

shall remain unpressurized during the temperature cycling. The test shall consist of 4 complete cycles (steps 1 through 4), as shown in Table A4. After completion of the fourth cycle, the snubber shall be removed from the chamber and allowed to stabilize at ambient conditions for at least 1 hr. The snubber shall show no evidence of leakage or damage and shall meet the dampening requirement of para. A3.5.2 after the temperature cycling test.

**A3.5.4 Vibration.** The snubber shall be tested in accordance with Type I (environmental) vibration of MIL-STD-167-1 except that the upper frequency shall be 175 Hz; the amplitude of vibration shall be in accordance with Table A5; and for the variable frequency portion, the vibration level shall be maintained for 2 min at every integral value of frequency. If no resonances are observed, the 2 hr endurance test shall be conducted at 175 Hz. If a particular snubber is determined to be axisymmetric, then the vibration test need only be conducted along the two mutually perpendicular axes. The snubber shall be pressurized to 250 ± 10 psi for a Class L snubber and 1,500 ± 50 psi for a Class H snubber and monitored throughout the test. After this test, the snubber shall show no indication of leakage or damage and shall meet the dampening requirement of para. A3.5.2.

**A3.5.4.1 Fixture.** The snubber shall be connected to the outlet side of an instrument cutoff valve. The valve and snubber assembly shall be mounted to a vertical panel of the vibration fixture. A flexible hose shall be used to connect the pressure source to the inlet side of the instrument cutoff valve. A flexible hose shall be used to connect a pressure monitor (gauge or transducer) to the test connection port located in the stem of the instrument cutoff valve. Flexible pressure hoses shall be of sufficient length so as not to interfere with the vibration fixture and shall have appropriate pressure ratings. After filling and pressurizing the system, the snubber and pressure monitor shall be isolated from the pressure source by means of the instrument cutoff valve. Test fixturing shall replicate typical shipboard installation.

**A3.5.5 Shock.** A lightweight shock test shall be conducted in accordance with MIL-S-901 for Grade A, Class 1, Type A equipment. A total of nine blows shall be applied, three blows applied parallel to each axis of the snubber. The snubber shall be pressurized to 250 ± 10 psi for a Class L snubber and 1,500 ± 50 psi for a Class H snubber and monitored throughout the test. The snubber shall show no indication of leakage or damage and shall meet the dampening requirements of para. A3.5.2.



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**A3.5.5.1 Fixture.** The snubber shall be connected to the outlet side of an instrument cutoff valve. The valve and snubber assembly shall be mounted to a vertical panel of a type 6D-1 adapter plate. A flexible hose shall be used to connect the pressure source to the inlet side of the instrument cutoff valve. A flexible hose shall be used to connect a pressure monitor (gauge or transducer) to the test connection port located in the stem of the instrument cutoff valve. Flexible pressure hoses shall be of sufficient length so as to not interfere with the shock fixture and shall have appropriate pressure ratings. After filling and pressurizing the system, the snubber and pressure monitor shall be isolated from the pressure source by means of the instrument cutoff valve. Test fixturing shall replicate typical shipboard installation.

**A3.5.6 Pressure Integrity.** Pressurize the Class L snubber to 1,500 psi and the class H snubber to 9000 psi. Isolate the pressurized snubber from the pressure source and monitor the snubber pressure with the appropriate range pressure transducer or pressure gauge. Maintain the pressure for a period of 1 hr. After this test, the snubber shall show no evidence of leakage or damage and shall meet the dampening requirements of para. A3.5.2.

## A4 ORDERING PARAMETERS

### A4.1 Acquisition Requirements

Acquisition documents should specify the following:

*(a)* Title, number and date of this specification;
*(b)* Part Identifying Number (PIN);
*(c)* When qualification is required;
*(d)* Special marking.

### A4.2 Part Identifying Number (PIN) Parameters

*(a)* Type;
*(b)* Class;
*(c)* Composition;
*(d)* End connection;
*(e)* Cleanliness.

**A4.2.1 Part Identifying Number (PIN) Format.** The PINs to be used for items acquired to this supplement shall be created as follows:

Example: B40.5A1-1LCPG

| B40.5A1 | 1 | L | C | P | G |
|---|---|---|---|---|---|
| Precedes classification | Type | Class | Composition | End connection | Cleanlines |

**A4.2.2 Types.** The type of service in which the snubber will be used shall be designated by one of the following numbers and shall be selected based on the expected fluid and fluid temperature (viscosity) at the snubber location.

| Type | Service |
|---|---|
| 1 | Oil, hydraulic fluid above 20 centistokes at operating temperature. Oil above 225 saybolt universal seconds at operating temperatures |
| 2 | Fresh water, steam, gasoline, light oils below 20 centistokes at operating temperature |
| 3 | Gases |
| 4 | Sea water |

**A4.2.3 Class.** The range of operating pressures is designated by a single character.

| Class | Operating Range Limit, Psi |
|---|---|
| L | 10 to 1000 |
| H | 1001 to 6000 |

**A4.2.4 Composition.** The material composition of the snubber is designated by one letter.

| Composition | Material |
|---|---|
| A | Copper nickel alloy (see A2.2.2.1) |
| B | Nickel-copper alloy (see A2.2.2.2) |
| C | Corrosion resisting steel (see A2.2.2.3) |
| X | Other (see A2.2.2.4) |

**A4.2.5 End Connection.** The configuration for the snubber's end connection is designated by a single character.

| End Connection | Application |
|---|---|
| P | Pressure gauge O-ring union (see A2.1.1.1) |
| F | Pressure gauge flareless (Bite type (see A2.1.1.2) |
| T | Pressure transducer (see A2.1.1.3) |
| S | Other. The end connections must be specified in the contract or ordering data. |

**A4.2.6 Cleanliness.** The level of cleanliness of the snubber is designated by a single character. Cleaning for oxygen applications shall be in accordance with MIL-STD-1330. Cleaning for general applications shall be in accordance with Cleanliness Level IV, Table 2 of ASME B40.1.



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| Cleanliness | Application |
|---|---|
| G | General |
| X | Oxygen and dry nitrogen |

## A5 REFERENCES

ANSI/ASQC Z1.4, Sampling Procedures and Tables for Inspection by Attributes

Publisher: American National Standards Institute (ANSI), 11 West 42nd Street, New York, NY 10036

ASTM B 122, Standard Specification for Copper-Nickel-Tin Alloy, Copper-Nickel-Zinc Alloy (Nickel Silver), and Copper-Nickel Alloy Plate, Sheet, Strip, and Rolled Bar

ASTM B 127, Standard Specification for Nickel-Copper Alloy (UNS N04400) Plate, Sheet, and Strip

ASTM B 151, Standard Specification for Copper-Nickel-Zinc Alloy (Nickel Silver) and Copper-Nickel Rod and Bar

ASTM B 164, Standard Specification for Nickel-Copper Alloy Rod, Bar, and Wire

ASTM B 564, Aluminum and Aluminum-Nickel Alloy Forgings

ASTM D 3951, Standard Practice for Commercial Packaging

Publisher: American Society for Testing and Materials (ASTM), 100 Bar Harbor Drive, West Conshohocken, PA 19428

MIL-S-901, Shock Tests, High Impact, Shipboard Machinery, Equipment and Systems Requirements

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

MIL-STD-1330, Standard Practice for Precision Cleaning and Testing of Shipboard Oxygen, Helium, Helium-Oxygen, Nitrogen and Hydrogen Systems

Publisher: Federal specifications available from: Superintendent of Documents, United States Government Printing Office, Washington, DC 20402

SAE AMS 7259, Rings, Sealings, Fluorocarbon (FKM) Rubber High-Temperature-Fluid Resistant Very-Low Compression Set 85 to 95

SAE J 1926, Connections for General Use and Fluid Power – Ports and Stud Ends with ISO 725 Threads and O-Ring Sealing — Part 1: Threaded Port with O-Ring Seal in Truncated Housing

Publisher: Society of Automotive Engineers (SAE), 400 Commonwealth Drive, Warrendale, PA 15096



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**1 Scope** ..... 36.63

**2 Pressure Limiter Valves, General** ..... 36.63

**3 Construction** ..... 36.64

**4 Selection of Pressure Limiter Valves** ..... 36.64

**5 Installation** ..... 36.66

**6 Safety** ..... 36.68

**7 Testing** ..... 36.69

**Figures**

1 Piston Type ..... 36.65
2 Diaphragm Type ..... 36.66
3 Relief Valve Type ..... 36.67
4 Bellows Type ..... 36.67




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# PRESSURE LIMITER VALVES (a)

## 1 SCOPE

This Standard is confined to devices that protect pressure-sensing instruments from pressure sources in the event of system pressure rising above the adjusted closing pressure of the device. These devices are not pressure regulators. Pressure limiter valves are designed only to prevent the passage of excessive pressure to downstream pressure-sensing instruments. Hereafter, pressure limiter valves may be referred to as "devices."

## 2 PRESSURE LIMITER VALVES, GENERAL

### 2.1 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.

### 2.2 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.

### 2.3 Pressure Limiter Valve Terminology

*closing range:* the minimum and maximum values of closing pressure.

*element, pressure-sensing:* the element that, in conjunction with a range spring, converts a pressure change into motion.

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

*medium:* the process fluid (gas or liquid).

*pressure, burst:* the maximum pressure, above which a device may no longer hold pressure.

*pressure, closing:* the system pressure at which the sealing mechanism closes, isolating the pressure-sensing instrument from rising system pressure.

*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, over-range:* 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, proof:* the pressure a device can withstand without degradation in performance. Repeated application of proof pressure may be destructive.

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

*pressure, rupture:* the pressure differential between inlet and outlet ports at which the device may no longer limit pressure.



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*pressure-sensing instrument:* instrument being protected by the pressure limiter valve.

*pressure, set:* closing pressure; see pressure, closing.

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

*pulsation:* a periodic surge.

*range spring:* 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.

*repeatability of closing pressure:* the maximum difference between a number of 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.

*set point:* closing pressure; see pressure, closing.

*spike:* a short duration, high amplitude surge.

*surge:* a sudden rise or drop in system pressure.

*temperature, ambient:* the temperature of the atmosphere surrounding the pressure limiter valve.

*temperature, process:* the temperature of the process medium at the inlet pressure connection of the pressure limiter valve.

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

## 3 CONSTRUCTION

### 3.1 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 Fig. 1.)

### 3.2 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 Fig. 2.)

### 3.3 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 Fig. 3.)

### 3.4 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 Fig. 4.)

## 4 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.

### 4.1 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



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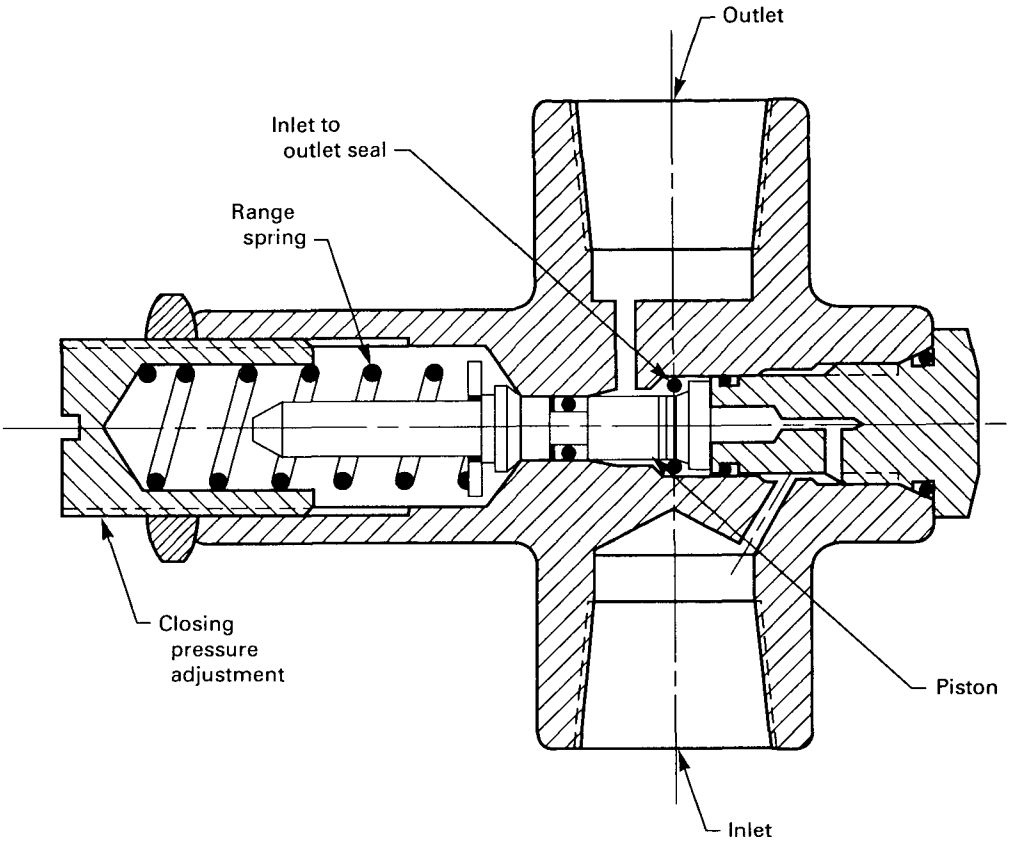



**FIG. 1 PISTON TYPE**

pressure. Some devices have over-range pressure expressed as a percentage of the closing pressure above the closing pressure, which may limit the over-range pressure.

### 4.2 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.

### 4.3 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.

### 4.4 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, environment, etc. (see para. 6.2.5). The effects of structural or mechanical loading must also be considered.

### 4.5 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. 4.7.)

### 4.6 Repeatability of Closing Pressure

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

### 4.7 Rate of Pressure Change

Where wide excursions in rates of pressure change occur in the system, devices with minimal variation of



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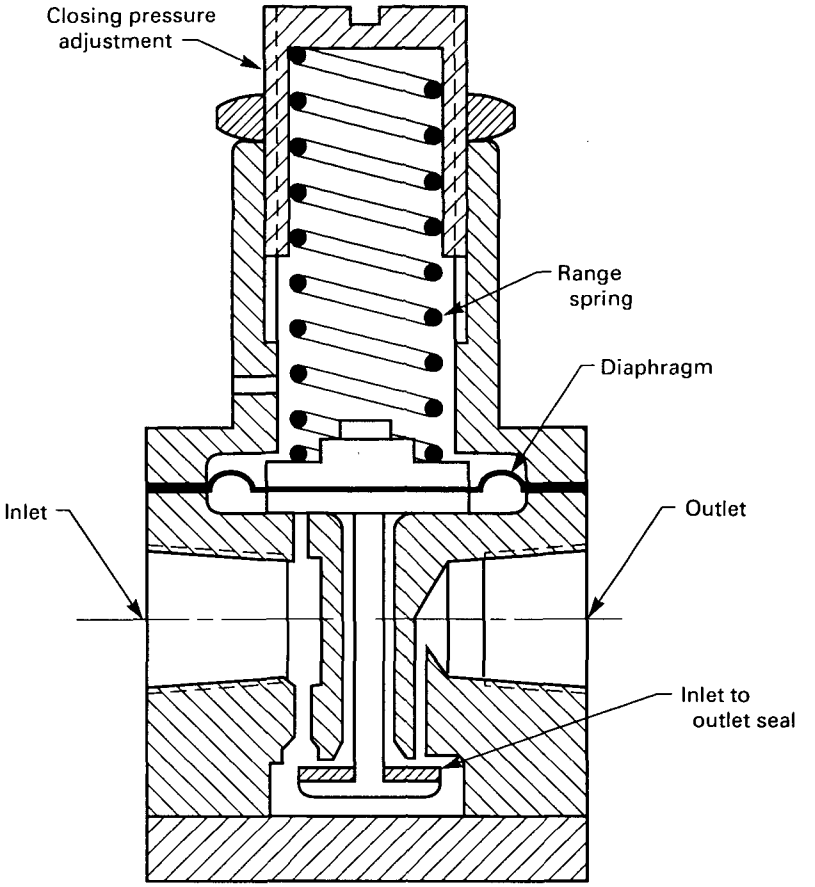



**FIG. 2 DIAPHRAGM TYPE**

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. 4.5.)

### 4.8 External Venting

Some pressure limiter valves may vent into the atmosphere (see para. 3.3). Hazardous process media should be diverted to a suitable container.

### 4.9 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 INSTALLATION

### 5.1 Connections

The most common connections are $\frac{1}{8}$ in., 27 NPT, $\frac{1}{4}$ in., 18 NPT, or $\frac{1}{2}$ in., 14 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.

### 5.2 *Methods of Installation*

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



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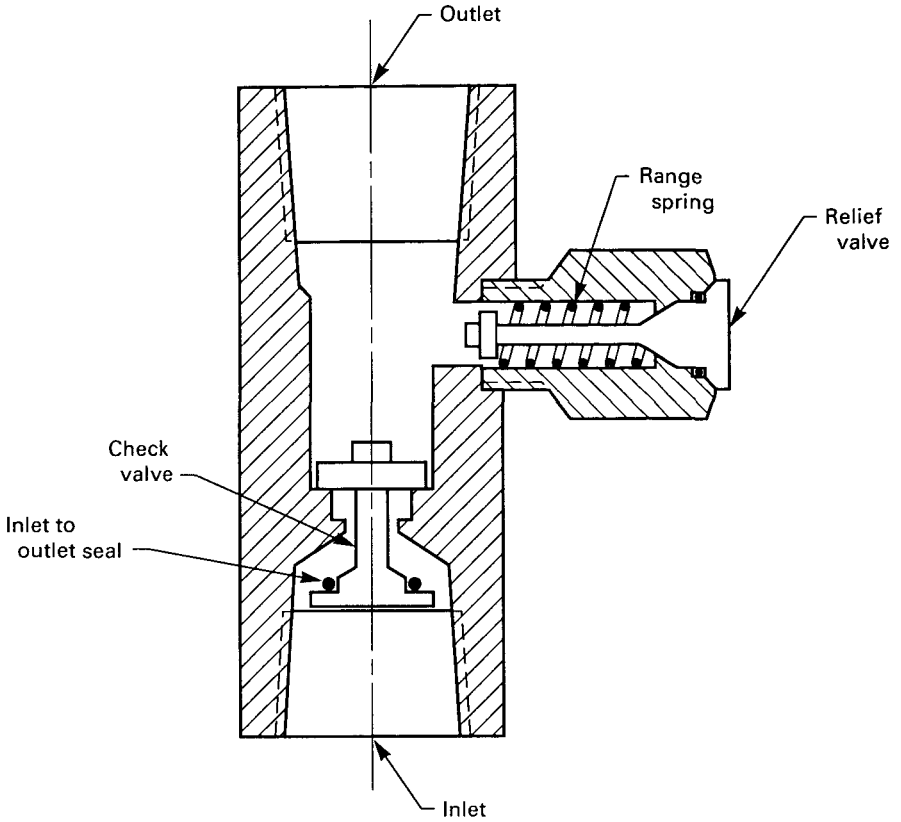



**FIG. 3 RELIEF VALVE TYPE**

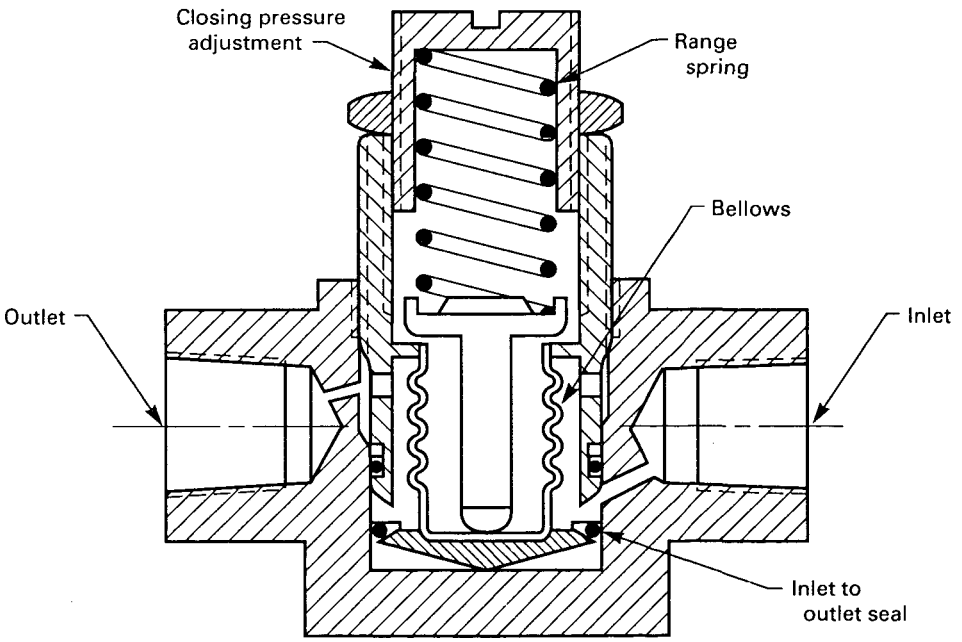



**FIG. 4 BELLOWS TYPE**



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### 5.3 Setting Pressure Limiter Valves

**5.3.1 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.

**5.3.2 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. 4.5.)

**5.3.3 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. 6.2.5.3.) The devices should be set with the process medium or a medium of similar viscosity.

**5.3.4 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.

## 6 SAFETY

### 6.1 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.

### 6.2 General Discussion

**6.2.1 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.

**6.2.2 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.

**6.2.3 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.

**6.2.4 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.

#### 6.2.5 Modes of Failure

**6.2.5.1 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.



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**6.2.5.2 Over-Pressure Failure.** Over-pressure 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 over-pressure failure, usually more critical in compressed gas systems than in liquid-filled systems, are unpredictable.

**6.2.5.3 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.

**6.2.5.4 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.

## 6.3 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.

**6.3.1 Chemical Incompatibility.** The consequences of incompatibility can range from contamination to explosive failure.

**6.3.2 Corrosion/Chemical Attack.** Corrosion and/or chemical attack of the device in the first installation may be sufficient to cause early failure in the second installation.

# 7 TESTING

## 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, (i.e., 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.

## 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 is less than with pneumatic media. Read Section 6 of this Standard before conducting any testing.

## 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.

### 7.3.1 Nondestructive Tests

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

**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.

**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



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for several pressure cycles to determine the variation of the closing pressure as the rate of pressure change varies.

**7.3.1.4 Over-Range Pressure Test.** For a given closing pressure, apply the rated over-range pressure (hydraulic preferred, see para. 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.

**7.3.1.5 Proof Pressure Test.** Apply rated proof pressure (hydraulic preferred, see para. 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.

### 7.3.2 Destructive Tests

**7.3.2.1 Burst Pressure Test.** Apply pressure (hydraulic preferred, see para. 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.

**7.3.2.2 Rupture Pressure Test.** Apply pressure (hydraulic preferred, see para. 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.

**7.3.2.3 Fatigue.** Desired pressure limiter valve performance (see para. 7.3.1) should be tested. The device should then be subjected to repeated pressure cycles (hydraulic preferred, see para. 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 to 0.6 Hz (18 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 hr 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.



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ASME B40.100-1998

# PRESSURE GAUGES AND GAUGE ATTACHMENTS

Incorporating ASME B40.1-1998 and ASME B40.7-1998

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# FOREWORD

ASME Standards Committee B40 is comprised of a balanced cross section of pressure gauge users, manufacturers, and interested members representing governmental agencies, testing laboratories, and other standards-producing bodies. All are convinced that national standards such as this one serve not only to provide product performance and configuration guidelines, but also to inform and update the specifier and user 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.

This Standard is advisory only. Its use is entirely a voluntary matter and shall in no way preclude the manufacture 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.

This Standard was approved by the B40 Standards Committee and approved as an American National Standard by the American National Standards Institute on December 22, 1998.



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*Proposing Revisions.* Revisions are made periodically to the Standard 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 periodically.

The Committee welcomes proposals for revisions to this Standard. 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 documentation.

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# PREFACE

## ORGANIZATION OF THIS DOCUMENT

This Standard compiles the following standards.

| *Standard* | *Title* |
|---|---|
| ASME B40.1 | Gauges: Pressure Indicating Dial Type: Elastic Element |
| ASME B40.2 | To be added in addenda |
| ASME B40.5 | To be added in addenda |
| ASME B40.6 | To be added in addenda |
| ASME B40.7 | Gauges: Pressure Indicating Digital |

## ADDENDA SERVICE

This edition of ASME B40.100 includes an automatic addenda subscription service up to the publication of the next edition. The addenda subscription service will include the additional B40 documents not already included in the initial publication, and approved revisions to the existing parts.



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# Specifications for Pressure and Vacuum Gauges

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**D. B. Pearl,** Continental Precision Instruments, Inc.
**J. H. Qadri, Ph.D.,** Consultant
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# CONTENTS

Foreword ..... iii
Correspondence with B40 Committee ..... v
Preface ..... vii
Standards Committee Roster ..... ix

**ASME B40.1-1998 Gauges: Pressure Indicating Dial Type: Elastic Element** ..... 1

**ASME B40.7-1998 Gauges: Pressure Digital Indicating** ..... 37



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# ASME B40.1


**1 Scope** ..... 3

**2 Pressure Gauges, General** ..... 3

**3 General Recommendations** ..... 15

**4 Safety** ..... 20

**5 Cleanliness** ..... 24

**6 Pressure Gauge Testing** ..... 25

**7 Ordering Parameters and Related Standards** ..... 26

**Figures**

1 Basic Pressure Terms ..... 4
2 Pressure Gauge Components (C Type Bourdon Illustrated) ..... 5
3 Elastic Elements ..... 6
4 Cases ..... 7
5 Example: Dial, Dual Scale ..... 8
6 Cases/Mounting ..... 10
7 Example: Scale Shown is Retarded from 10 to 30 ..... 11
8 Example: Scale Shown is Suppressed 0 to 50 ..... 11
9 Recommended Case and Mounting Dimensions ..... 17

**Tables**

1 Accuracy Grades ..... 4
2 Cleanliness Levels ..... 24

**Nonmandatory Appendices**

A Some Definitions and Suggested Test Procedures for Parameters Used to Measure New Gauge Performance ..... 29
B Gauges Used on Regulators ..... 33




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# GAUGES: PRESSURE INDICATING DIAL TYPE: ELASTIC ELEMENT

## 1 SCOPE

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

It does not include gauges of special configuration designed for specific applications, edge reading, dead-weight or piston gages, or any other gauges not utilizing an elastic element to sense pressure.

## 2 PRESSURE GAUGES, GENERAL

### 2.1 Pressure Terms

See Fig. 1.

### 2.2 Pressure Gauge Components

See Fig. 2.

### 2.3 Pressure Gauge Terminology

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

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

*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. It is determined under specific conditions. See Table 1.

*accuracy, reference:* the accuracy of a gauge under reference conditions [normal position at 23°C ±1°C (approximately 73°F ±2°F) and 29.92 in. Hg (101.32 E+03 Pa) barometric pressure].

*adjustment, pointer indication:* 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 (see para. 3.3.4).

*adjustment, span:* 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.

*ambient pressure:* see *pressure, ambient.*

*bar:* a metric pressure unit equal to approximately 14.50 psi (see para. 7.2)

*bellows:* a thin walled, convoluted elastic pressure sensing element (see Fig. 3).

*bezel:* see *ring.*

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

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

*calibration:* the process of graduating the pressure scale or adjusting the mechanism to cause the gauge to indicate within 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.

*case:* the housing or container that supports, protects, and surrounds the internals.

*case, liquid filled:* a case that is filled with a liquid such as glycerin or silicone fluid to a 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.

*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 Fig. 4a). An alternate construction is a plastic window especially designed to relieve internal case pressure.



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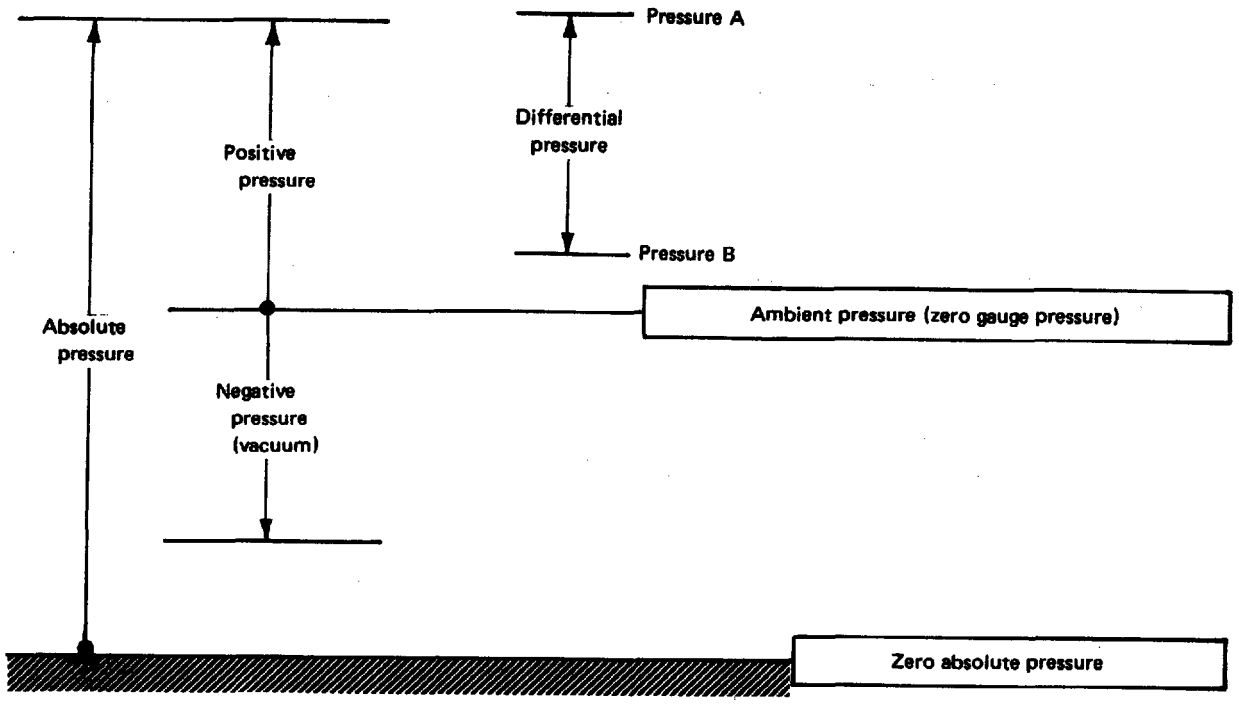



**FIG. 1 BASIC PRESSURE TERMS**

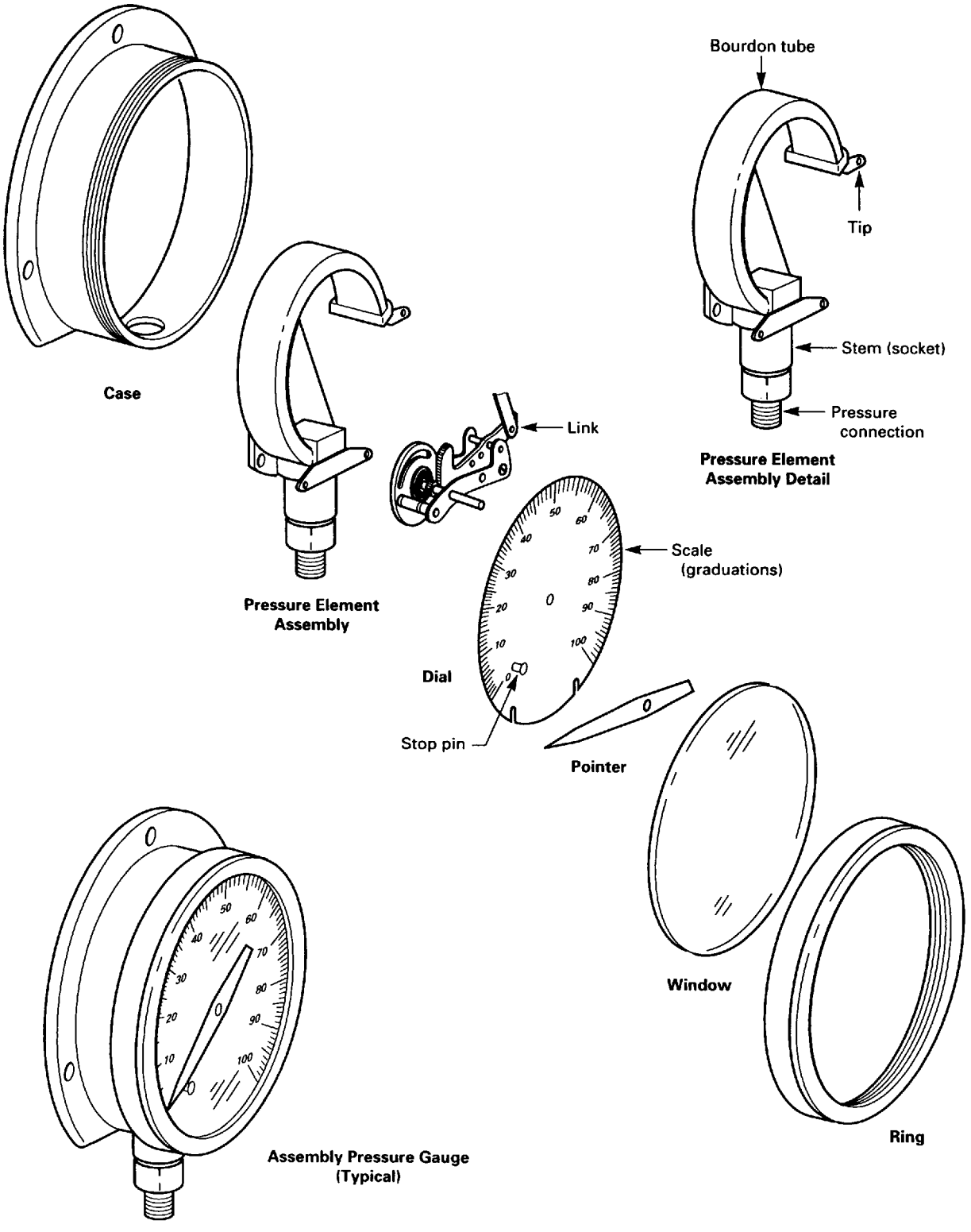
**TABLE 1 ACCURACY GRADES**

| Accuracy Grade | Permissible Error (+/– Percent of Span) (Excluding Friction) | | | Maximum Friction (Percent of Span) | Minimum Recommended Gauge Size (270 deg Dial Arc) |
|---|---|---|---|---|---|
| | Lower ¼ of Scale | Middle ½ of Scale | Upper ¼ of Scale | | |
| 4A | ← | 0.1 | → | [Note (1)] | 8½ |
| 3A | ← | 0.25 | → | 0.25 | 4½ |
| 2A | ← | 0.5 | → | 0.5 | 2½ |
| 1A | ← | 1.0 | → | 1.0 | 1½ |
| A | 2.0 | 1.0 | 2.0 | 1.0 | 1½ |
| B | 3.0 | 2.0 | 3.0 | 2.0 | 1½ |
| C | 4.0 | 3.0 | 4.0 | 3.0 | 1½ |
| D | 5.0 | 5.0 | 5.0 | 3.0 | 1½ |

NOTE:
(1) Grade 4A gauges must remain within specified tolerance before and after being lightly tapped.



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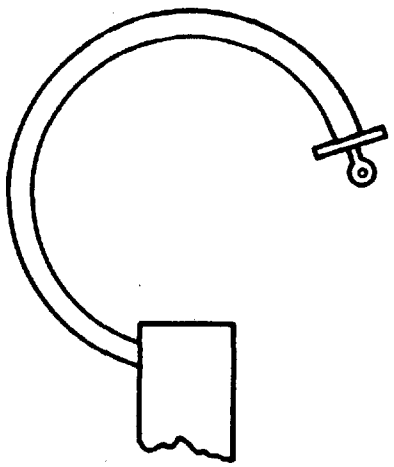



GENERAL NOTE: The above diagrams are schematic and not intended to show design details.

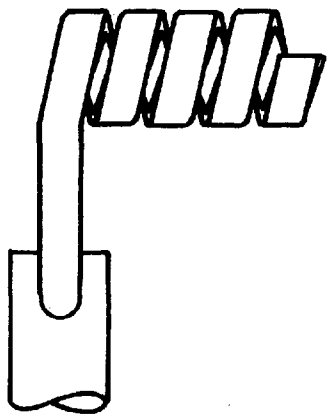
**FIG. 2 PRESSURE GAUGE COMPONENTS (C TYPE BOURDON ILLUSTRATED)**



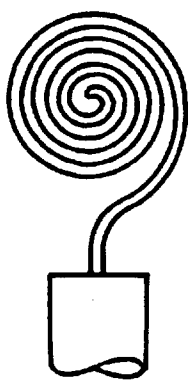
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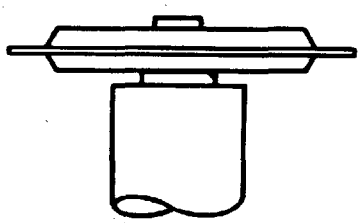
C-Type Bourdon Tube



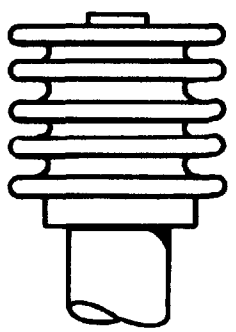
Helical Bourdon Tube



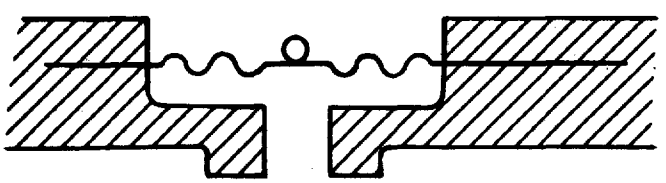
Spiral Bourdon Tube



Diaphragm Capsule



Bellows



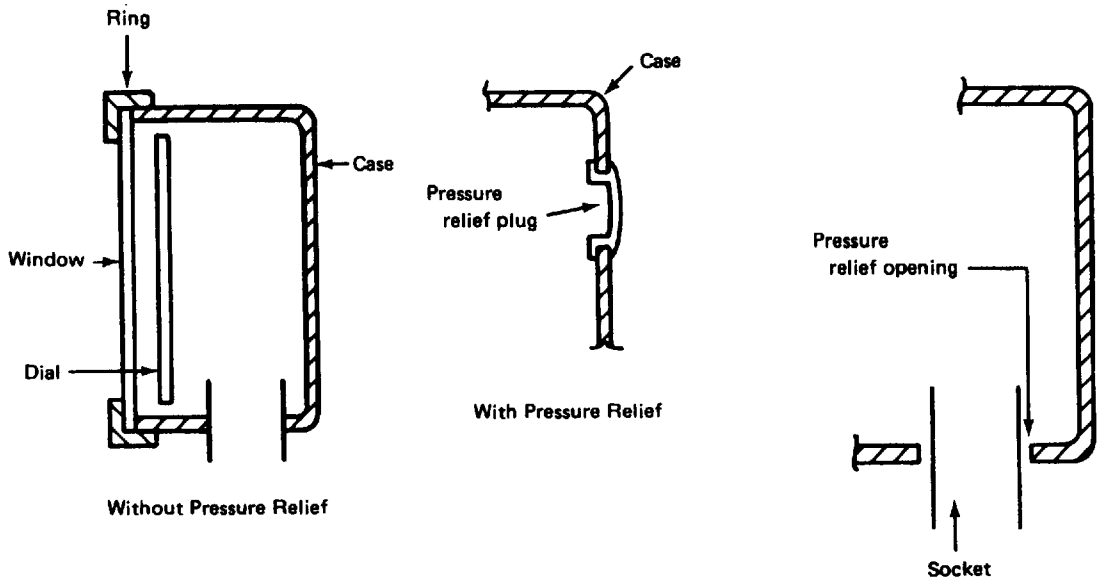
Diaphragm

GENERAL NOTES:
(a) The above diagrams are schematic and not intended to show design detail.
(b) The above diagrams are various types of elastic elements used in pressure gauges.

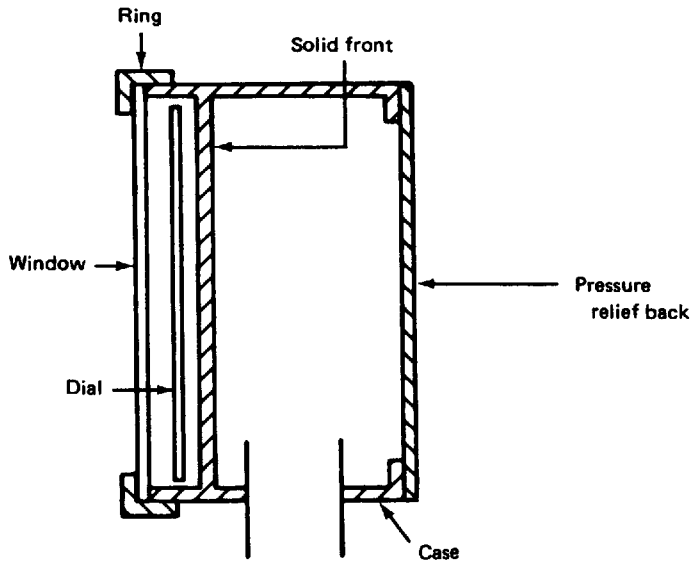
**FIG. 3 ELASTIC ELEMENTS**



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(a) Open Front




(b) Solid Front With Pressure Relief Back

FIG. 4 CASES



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*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 Fig. 4a).

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

*case ring:* see *ring.*

*case, sealed:* a case which is sealed to exclude ambient corrosives.

*case, size:* see *size, gauge.*

*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. The partition may be an integral part of the case (see Fig. 4b).

*column, liquid:* see *liquid column.*

*compound gauge:* see *gauge, compound.*

*conditions, environmental:* 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.

*conditions, extreme operating:* the limits of the environmental conditions within which the instrument may be operated. Under these conditions, the stated accuracy does not necessarily apply.

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

*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.

*corrosion failure:* see *failure, corrosion.*

*creep:* a progressive change in indication with constant applied pressure, under the same environmental conditions. It is usually expressed as a percentage of span per unit of time.

*crystal:* see *window.*

*dead weight tester:* a pressure testing device by which very accurate known pressures can be generated by means of a pressure source and a piston gage.

*dial:* the component that contains the scale and nomenclature.

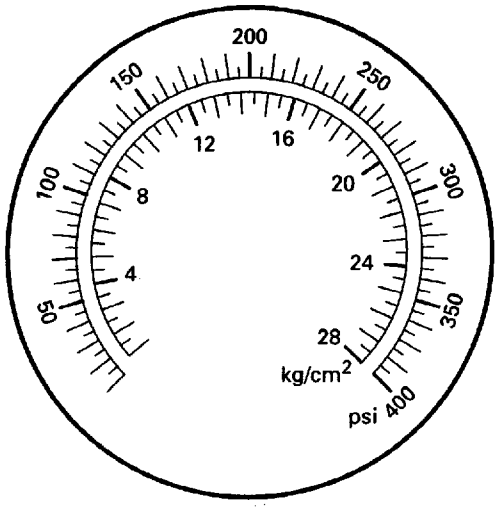



**FIG. 5 EXAMPLE: DIAL, DUAL SCALE**

*dial, dual scale:* a dial indicating pressure in terms of two different units of measure, on concentric arcs, such as kPa and psi. One example of the many different types in common use is illustrated in Fig. 5.

*dial graduations:* the individual division marks of the scale that indicate pressure magnitude.

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

*dial nomenclature:* see *nomenclature, dial.*

*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 Fig. 3).

*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 Fig. 3).

*differential gauge:* see *gauge, differential.*

*differential pressure:* see *pressure, differential.*

*duplex gauge:* see *gauge, duplex.*

*elastic element:* see *element, elastic.*

*element, elastic:* the elastic component of the pressure element assembly that moves in response to pressure



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changes. It may be a Bourdon tube, bellows, diaphragm, or other type of member (see Fig. 3).

*element assembly, pressure:* 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 Fig. 2).

*environmental conditions:* see *conditions, environmental.*

*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.

*error, friction:* the difference between indicated readings before and after the gauge has been lightly tapped.

*error, hysteresis:* 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 (see para. 6.2.4.3 and Fig. A1).

*error, offset:* the error exhibited when the elastic element is unpressurized. It is expressed as a percentage of span (see Fig. A1).

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

*error, span:* the error exhibited when the input is at maximum scale pressure minus the error exhibited when the input is at minimum scale pressure. It is expressed as a percentage of span.

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

*explosive failure:* see *failure, explosive.*

*extreme operating conditions:* see *conditions, extreme operating*

*failure, corrosion:* elastic element failure resulting from corrosive chemical attack on the element walls (see para. 4.2.7.3).

*failure, explosive:* elastic element failure caused by the release of explosive energy generated by a chemical reaction inside the element (see para. 4.2.7.4).

*failure, fatigue:* elastic element failure resulting from repeated applications of stress (see para. 4.2.7.1).

*failure, overpressure:* elastic element failure caused by the application of internal pressure (positive or negative) in excess of the rated pressure of the element (see para. 4.2.7.2).

*failure, overtemperature:* failure as a result of continuous exposure to high ambient temperature.

*failure, thermal shock:* failure as a result of repeated, rapid exposure to ambient temperature extremes.

*fatigue failure:* see *failure, fatigue.*

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

*flush mounted:* see *gauge, flush mounted.*

*friction error:* see *error, friction.*

*friction ring:* see *ring, friction.*

*ft $H_2O$:* see para. 3.3.2.1.

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

*gage, piston:* 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 (see para. 6.1.1.2).

*gauge, absolute pressure:* a gauge that indicates absolute pressure (see para. 3.4.1.12).

*gauge, acetylene:* see para. 4.3.8.2.

*gauge, ammonia:* see para. 4.3.8.3.

*gauge, chemical:* see para. 4.3.8.4.

*gauge, compound:* a gauge that indicates both positive and negative gauge pressure (see para. 3.4.1.8).

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

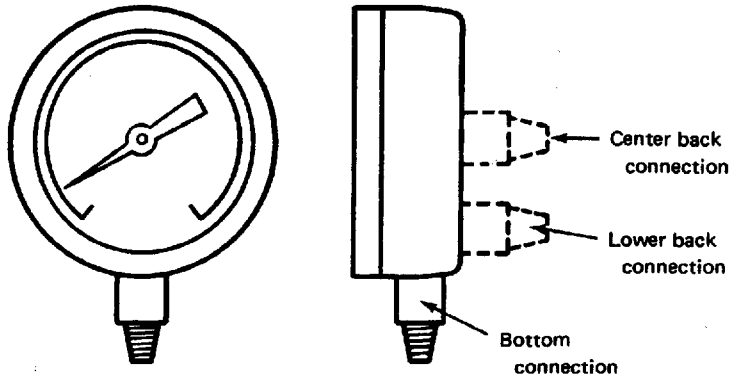
*gauge, duplex:* a gauge having two pressure connections and two pointers, which indicate two applied pressures simultaneously.

*gauge, flush mounted:* 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 Fig. 6).

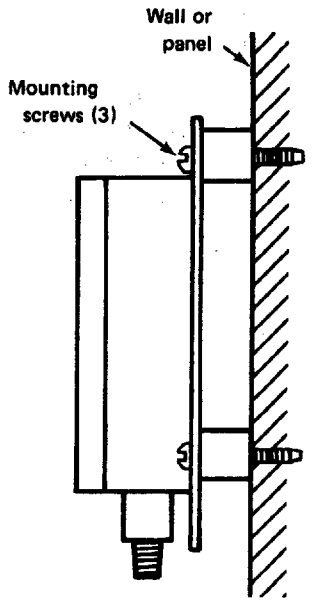


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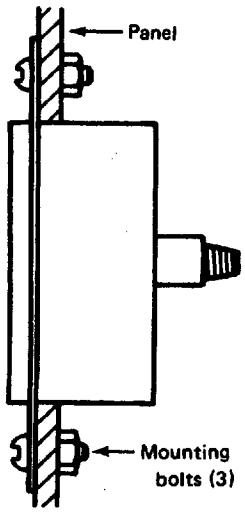
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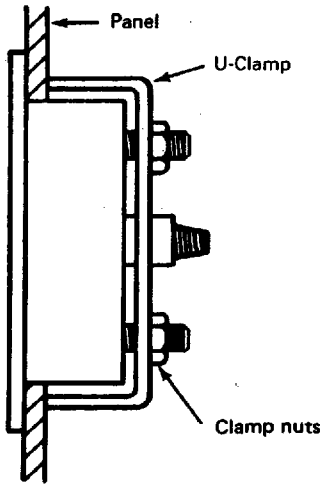

**Stem Mounted**
**(Typical Connection Configuration)**



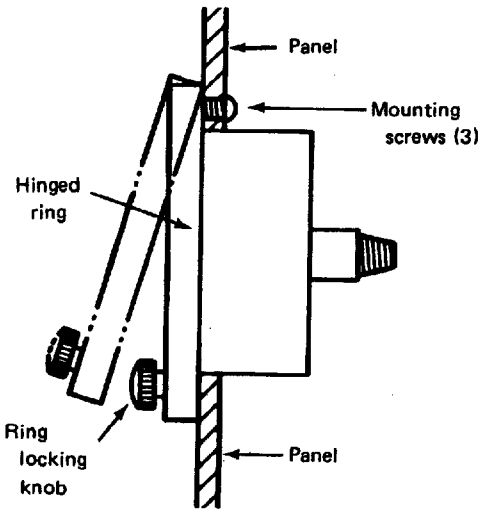

**Surface Mounted**
**(Back Flange Type)**




**Flush Mounted**
**(Front Flange)**




**Flush Mounted**
**(U-Clamp)**




**Panel Mounted**
**(Hinged Ring Type)**

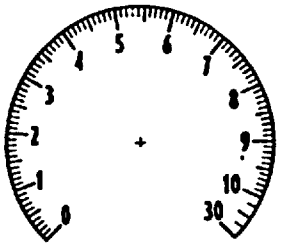
GENERAL NOTES
(a) These diagrams are schematic and not intended to show design details.
(b) Surface and flush mounted cases may also be stem mounted.

**FIG. 6 CASES/MOUNTING**



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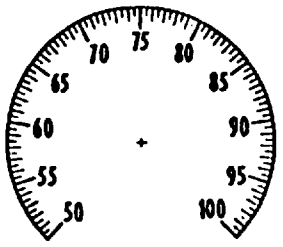
**Example:**




**Scale shown is retarded from 10 to 30**

**FIG. 7 EXAMPLE: SCALE SHOWN IS RETARDED FROM 10 TO 30**

**Example:**




**Scale shown is suppressed 0 to 50**

**FIG. 8 EXAMPLE: SCALE SHOWN IS SUPPRESSED 0 TO 50**

*gauge, hydraulic:* a gauge designed to indicate the pressure developed in hydraulic systems. It may be equipped with a protective means to prevent damage to the internals in the event of a sudden pressure release.

*gauge, liquid filled:* a gauge in which the case is filled with a liquid (see *case, liquid filled*).

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

*gauge, oxygen:* see para. 4.3.8.5.

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

*gauge, receiver:* 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.

*gauge, refrigerant:* a gauge with a dial graduated in units of pressure and equivalent saturation temperature for refrigerant(s) other than ammonia.

*gauge, retard:* a gauge having a scale that is compressed at one or both ends (see para. 3.4.1.6). One example of the many different types in common use is shown in Fig. 7.

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

*gauge, specific service:* a gauge designed for a specific service, such as indicating the pressure of explosive, corrosive, or viscous media (see para. 4.3.8).

*gauge, stem (socket) mounted:* a gauge supported by attachment at the stem (socket) pressure connection (see Fig. 6).

*gauge, suppressed scale:* a gauge having a scale that starts at some value appreciably above zero (see para. 3.4.1.7). One example of the many different types in common use is shown in Fig 8.

*gauge, surface (wall) mounted:* a gauge whose case can be mounted to a wall or flat surface (See Fig. 6).

*gauge, temperature compensated:* a gauge that is compensated to reduce errors caused by operation at ambient temperatures other than that at which it was calibrated.

*gauge, test:* 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.

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

*graduations, dial:* see *dial, graduations.*

*grommet:* see *plug, pressure relief.*

*$H_2O$:* water.

*Hg:* mercury.

*hydraulic gauge:* see *gauge, hydraulic.*

*hysteresis error:* see *error, hysteresis.*

*in. $H_2O$:* see para. 3.3.2.1.

*in. Hg:* see para. 3.3.2.1.

*internal stop:* see *stop, internal.*

*kg/cm2:* see para. 3.3.2.1.



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*kPa:* see para. 3.3.2.1.

*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 indicated by the height of the liquid column, measured at the meniscus.

*liquid filled case:* see *case, liquid filled.*

*liquid filled gauge:* see *gauge, liquid filled.*

*liquid level gauge:* see *gauge, liquid level.*

*manometer:* see ASME PTC 19.2, *Pressure Measurement.*

*medium:* the process fluid (gas or liquid).

*mirror, dial:* see *dial, mirror.*

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

*mounting, flush:* see *gauge, flush mounted.*

*mounting, gauge:* see *mounting.*

*mounting, stem socket:* see *gauge, stem (socket) mounted.*

*mounting, surface (wall):* see *gauge, surface (wall) mounted.*

*movement:* the gauge component that converts pressure element motion to rotary pointer motion.

*NBS:* National Bureau of Standards (see *NIST*).

*negative pressure (vacuum):* see *pressure, negative.*

*NIST:* National Institute of Standards and Technology (formerly NBS).

*nomenclature, dial:* may include, but is not restricted to, the following: materials of wetted parts, restricted application notices such as USE NO OIL, and presence of special features such as an internal stop.

*normal operating conditions:* see *conditions, normal operating.*

*NPT:* American Standard taper pipe threads. Defined by ASME B1.20.1, *Pipe Threads (Except Dryseal).*

*operating pressure:* see *pressure, operating.*

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

*overpressure failure:* see *failure, overpressure*

*Pa:* see para. 3.3.2.1.

*particle:* any solid contaminant other than fiber.

*pascal:* see para. 3.3.2.1.

*piston gage:* see *gage, piston.*

*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:* see *adjustment, pointer.*

*position error:* see *error, position.*

*positive pressure:* see *pressure, positive.*

*pressure, absolute:* a pressure using zero absolute pressure as datum (see Fig. 1).

*pressure, ambient:* the pressure surrounding the gauge, usually atmospheric (barometric) pressure (see Fig. 1).

*pressure, burst:* see *pressure, rupture.*

*pressure, differential:* the difference between two pressures (see Fig. 1).

*pressure element:* see *element assembly, pressure.*

*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 Fig. 1).

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

*pressure, negative (vacuum):* gauge pressure less than ambient pressure using ambient pressure as datum (see Fig. 1).

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

*pressure, positive:* gauge pressure greater than ambient pressure (see Fig. 1).

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



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*pressure, proof:* the maximum pressure a gauge can withstand without evidence of change in accuracy. 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 relief plug:* see *plug, pressure relief.*

*pressure, rupture:* the maximum pressure above which the pressure element assembly may no longer hold pressure.

*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).

*psi:* see para. 3.3.2.1.

*psia:* see para. 3.3.2.1.

*psid:* see para. 3.3.2.1.

*psig:* psi (see para. 3.3.2.1).

*pulsation:* a periodic surge.

*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.

*readability:* the uncertainty inherent in the observer's ability to determine the indicated pressure value. Factors that may affect readability include length of scale, graduation configuration and spacing, pointer design and width, parallax, distance between observer and scale, illumination, stability of pointer, pointer and scale colors, and the liquid level line in liquid filled gauges.

*receiver gauge:* see *gauge, receiver.*

*refrigerant gauge:* see *gauge, refrigerant.*

*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.

*resonance:* resonance of a system-forced oscillation exists when any change, however small, in the frequency of excitation causes a decrease in the response of the system. (A resonance may occur in an internal part of the gauge, with no outward manifestation.)

*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:* see *gauge, retard.*

*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 the 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.

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

*sealed case:* see *case, sealed.*

*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, 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:* see *gauge, single.*

*size, gauge:* the nominal size of a gauge.

*slip ring:* see *ring, slip.*

*snap ring:* see *ring, snap.*



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*snubber:* a device that is used to reduce the effect of pressure fluctuations and surges, or to reduce flow from a pressure element that has failed in service, or both. See ASME B40.5

*socket:* see *stem.*

*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 800°F (425°C) and having a melting point below that of the base metals being joined.

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

The span of a 0/100 kPa gauge is 100 kPa.

The span of a suppressed scale gauge is the difference between the maximum and minimum scale pressures. For example, the span of 200/500 psi gauge is 300 psi.

The span of a *compound gauge* is the algebraic difference between the limits of the vacuum and pressure scales when both are expressed in the same units. For example: the span of 30 in. Hg vac (approximately (15 psi) to 30 psi pressure scale is 45 psi.

*span adjustment:* see *adjustment, span.*

*span, compound gauge:* see *span.*

*span, suppressed scale:* see *span.*

*specific service gauge:* see *gauge, specific service.*

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

*spontaneous explosive failure:* see *failure, explosive.*

*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:* see *pressure, steady.*

*stem (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.

*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 (see para. 3.3.7).

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

*suppressed scale gauge:* see *gauge, suppressed scale.*

*surface (wall) mounted:* see *gauge, surface (wall) mounted.*

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

*surge:* a sudden rise or drop in system pressure.

*takeup:* 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 coefficient:* see *coefficient, temperature.*

*temperature error:* see *error, temperature.*

*temperature, process:* the temperature of the process medium at the pressure connection of the socket.

*temperature, storage:* the extremes of temperature (high and low) that the gauge may be exposed to when it is not pressurized.

*test gauge:* see *gauge, test.*

*threaded ring:* see *ring, threaded.*

*threaded window:* see *window, threaded.*

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

*torr:* see para. 3.3.2.1.

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

*transfer standard:* see *standard, transfer.*

*vacuum gauge:* see *gauge, vacuum.*

*vacuum:* see *pressure, negative.*

*variable pressure:* see *pressure, variable.*

*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.



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*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.

*window:* a transparent component that closes the front of the case (see Fig. 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.

## 3 GENERAL RECOMMENDATIONS

### 3.1 Gauge Sizes

| Size | Approximate Inside Diameter of Case at Face of Dial (mm) |
|---|---|
| 1½ | 40 |
| 2 | 50 |
| 2½ | 65 |
| 3½ | 90 |
| 4½ | 115 |
| 6 | 150 |
| 8½ | 215 |
| 12 | 305 |
| 16 | 405 |

### 3.2 Typical Ranges

NOTE: Other ranges are in common use and accepted.

#### 3.2.1 Positive Gauge Pressure

| 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 | 0/1 100 | 0/1 000 | 0/10 000 | 0/100 000 |
| 0/1.6 | 0/16 | 0/160 | 0/1 600 | 0/16 000 | 0/160 000 |
| 0/2.5 | 0/25 | 0/250 | 0/2 500 | 0/25 000 | 0/250 000 |
| 0/4 | 0/40 | 0/1400 | 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 |

#### 3.2.2 Negative Gauge Pressure

| in. Hg Vacuum | kPa | bar |
|---|---|---|
| 30/0 | −100/0 | −1/0 |

#### 3.2.3 Compound Pressure

| 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 | −100/1500 | −1/15 |
| 30 in. Hg vac/300 psi | −100/2400 | −1/24 |

#### 3.2.4 Receiver

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

### 3.3 Construction

**3.3.1 Cases.** See Fig. 4.

**3.3.1.1 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.



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**3.3.1.2 Cases With Pressure Relief Means.** For gauges used to measure gas pressures of 400 psi (2800 kPa) and higher and liquid pressures of 1000 psi (7000 kPa) and higher, cases with pressure relief means are recommended.

**3.3.1.3 Solid 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. The user should consult with the supplier regarding the degree of protection required (see Section 4).

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

**3.3.1.4 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.

**3.3.1.5 Mounting.** Mounting holes or studs are used for flush and surface mounted gauges. They shall be sized and located as shown in Fig. 9.

### 3.3.2 Dials

#### 3.3.2.1 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 (Le Système International d'Unitès* these units are recognized by the CIPM (Comitè International des Poids et Measures).

*(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)* Definitions of the various units are as follows.

| 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 = 1000 Pa |
| mbar | millibar | 1 mbar = bar/1000 = 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 $N/m^2$ |

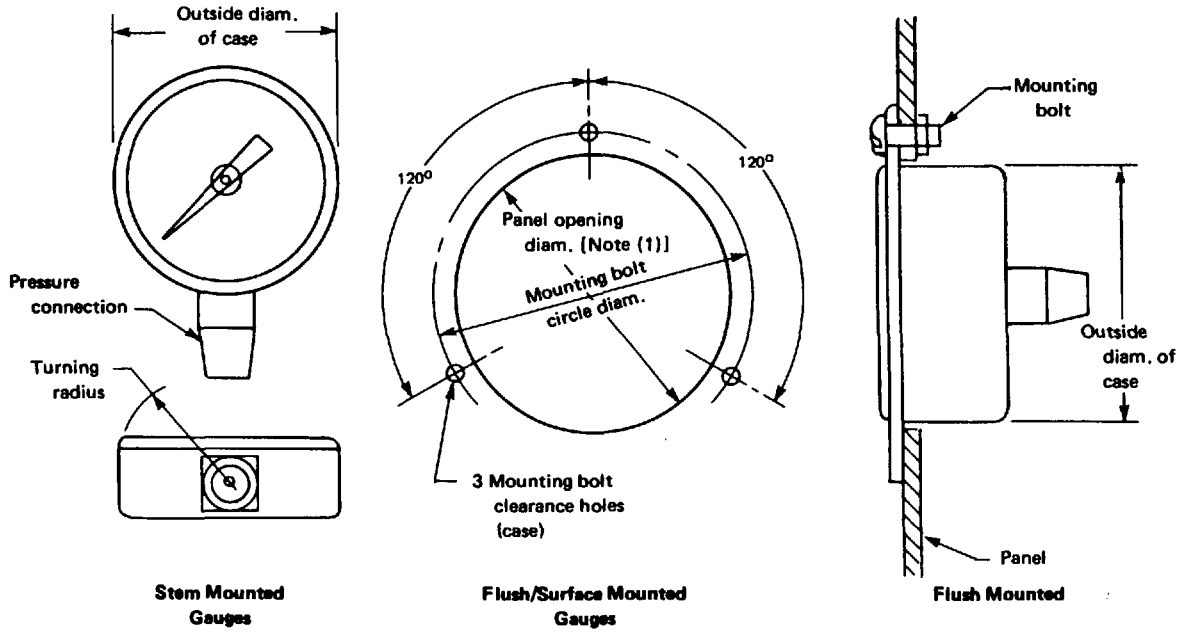
| MKSA Abbreviation | Unit | Definition |
|---|---|---|
| $kg/cm^2$ | kilograms per square centimeter | 1 $kg/cm^2$ = 1 kilogram force per square centimeter |
| m $H_2O$ | meters of water | 1 m $H_2O$ = 1 meter of water at 68°F (20°C) |
| mmHg | millimeters of mercury | 1 mm Hg = 1 millimeter of mercury 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 sea water | feet of sea water | 1 ft sea water = 0.4453 water 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. $H_2O$ (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 gravity (0.036063 psi) |
| in. $H_2O$ (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. 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 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 |



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**Flush/Surface Mounting Dimensions**

| Gauge Size | Mounting Bolt Circle Diameter | | Mounting Bolt Hole Diameter | | Panel Opening Diameter | | Case Max. [Note (1)] | |
|---|---|---|---|---|---|---|---|---|
| | in. | mm | in. | mm | in. | mm | in. | mm |
| 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 DIN 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 DIN 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 a DIN 63 mm gauge.

**DIN CASE SIZES**

| Gauge Size | Mounting Bolt Circle Diameter | | Case Outside Diameter | |
|---|---|---|---|---|
| | mm | in. | mm | in. |
| 50 | 60 | 2.36 | 50 | 1.97 |
| 63 | 75 | 2.95 | 63 | 2.48 |
| 80 | 95 | 3.74 | 80 | 3.15 |
| 100 | 100 | 4.57 | 100 | 3.94 |
| 160 | 160 | 7.01 | 160 | 6.30 |

NOTE:
(1) Flush mounted cases only.

**FIG. 9 RECOMMENDED CASE AND MOUNTING DIMENSIONS**



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**3.3.2.2 Units.** 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 scale shall indicate the units in which it is graduated. One of the scales should be one of the typical ranges (see para. 3.2).

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

Dials with a scale graduated in nonpressure 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, ×1000, and ×100 kPa, is discouraged because of potential misapplication or misinterpretation.

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

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. Upper- 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.

The pointer shall rotate clockwise for increasing positive pressure and counterclockwise for increasing negative pressure.

**3.3.2.3 Scale Graduations.** The recommended graduated scale is 270 degrees. Special applications and ranges may require scale arcs greater or less than 270 degrees.

**3.3.2.4 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: $1 \times 10^n$, $2 \times 10^n$, or $5 \times 10^n$, where $n$ is a whole positive or negative number or zero.

The smallest graduation increment should not exceed twice the error permitted (accuracy) in the middle half of the scale.

**3.3.2.5 Graduation Near Zero.** On dials for Grades 4A and 3A gauges, there shall be no takeup. The number and the spacing of the minor graduations near zero, shall be the same, commencing at the true zero, as in the rest of the scale. On dials for all other grades, take up 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.

**3.3.2.6 Markings.** 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. 4.3.8).

**3.3.2.7 Numerals.** 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.

### 3.3.3 Pointers

**3.3.3.1 Length (All Grades).** The tip of the pointer shall pass within one minor graduation line width of the inner end of the minor graduations.

The pointer may overlap the graduations.

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

**3.3.4 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.

### 3.3.5 Pressure Connection

**3.3.5.1 Location of Connection**

*(a) Stem mounted* — bottom or back

*(b) Surface mounted* — bottom or back

*(c) Flush mounted* — back



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**3.3.5.2 Type of Connection.** Taper pipe connections for pressures up through 20,000 psi or 160,000 kPa are usually 1/8–27 NPT, 1/4–18 NPT, or 1/2–14 NPT American Standard external or internal taper pipe threads per ASME B1.20.1 as required. Above this pressure, 1/4 inch 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., 1/2 NPT instead of 1/4 NPT) or a stronger stem material (e.g., stainless steel instead of brass), or both, should be considered.

**3.3.6 Rings.** Removable rings, size 4 1/2 and larger, generally have window retaining devices.

**3.3.7 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.

**3.3.7.1 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 striking an obstruction. Pointer motion shall not be restrained at less than 105% of full scale pressure.

**3.3.7.2 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, requirements of para. 3.3.2.5 shall apply.

### 3.3.8 Windows

**3.3.8.1 Laminated Glass.** Laminated glass shall comply with ANSI 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.

**3.3.8.2 Heat Treated Glass.** Heat treated glass shall comply with ANSI Z26.1. Heat treated glass has greater resistance to mechanical damage than plain glass.

**3.3.8.3 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.

**3.3.8.4 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.

## 3.4 Accuracy

Pressure gauge accuracy is graded as shown in Table 1 (see Section 6 for testing procedures).

### 3.4.1 General Discussion

**3.4.1.1** 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.

**3.4.1.2** 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.

**3.4.1.3** 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 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. Except when special element materials are employed, such as NI-SPAN-C® (International Nickel Company, Inc.) Alloy 902 (an alloy that can be heat treated to control TEC), the error caused by temperature change will be approximately 1% at full scale pressure for each 50°F (28°C) change in temperature. 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



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is stable and a more accurate indication is required, recalibration may be appropriate.

**3.4.1.4** 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.

**3.4.1.5** 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.

**3.4.1.6** 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.

**3.4.1.7** The accuracy of a gauge with suppressed scale shall be expressed as a percentage of span.

**3.4.1.8** The accuracy of a compound gauge shall be expressed as a percentage of span.

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

**3.4.1.10** 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.

**3.4.1.11** 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.

**3.4.1.12** 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.

### 3.5 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 and/or special installation requirements. Refer to Section 4, Safety.

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

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.

## 4 SAFETY

### 4.1 Scope

This section of the Standard presents certain information to guide users, suppliers, and manufacturers toward minimizing 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.

### 4.2 General Discussion

**4.2.1** Adequate safety results from intelligent planning and careful selection and installation of gauges into a pressure system. The user should inform the



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supplier of all conditions pertinent to the application and environment so that the supplier can recommend the most suitable gauge for the application.

**4.2.2** 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.

**4.2.3** 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, syphons, and other similar items, are available for use in these potentially hazardous systems. The hazard potential increases at higher operating pressure.

**4.2.4** 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

**4.2.5** 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.

**4.2.6** 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, and;

*(i)* excessive vibration.

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

### 4.2.7 Modes of Pressure Gauge Failure

**4.2.7.1 Fatigue Failure.** Fatigue failure caused by pressure induced stress generally occurs from the inside to the outside along a highly stressed edge radius, 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 partially open elastic element.

**4.2.7.2 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.



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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 ASME B40.6.

**4.2.7.3 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 ASME B40.2.

**4.2.7.4 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.

**4.2.7.5 Vibration Failure.** The most common mode of vibration failure is movement parts wear because of high cyclic loading caused by vibration, resulting in gradual loss of accuracy, and, ultimately failure of the pointer to indicate any pressure change.

**4.2.7.6 Vibration-Induced Fatigue Failure.** In addition to its effect on the gauge movement and linkage, (see para. 4.2.7.5), 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 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.

**4.2.8 Pressure Connection.** See recommendations in para. 3.3.5.

### 4.3 Safety Recommendations

**4.3.1 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 two times the intended operating pressure.

Should it be necessary for the operating pressure to exceed 75% of full scale, contact the supplier for recommendations.

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

**4.3.2 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 which 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.

### 4.3.3 Compatibility With Medium

**4.3.3.1 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.



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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.

**4.3.3.2 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.

**4.3.4** 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.

**4.3.5** Some special applications require that the pressure element assembly have a high degree of leakage integrity. Users should contact the supplier to assure that the allowable leakage rate is not exceeded.

### 4.3.6 Cases

**4.3.6.1 Cases, Solid Front.** It is generally accepted that a solid front case per para. 3.3.1 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.

**4.3.6.2 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. 4.2.7. 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.

**4.3.7 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.

### 4.3.8 Specific Service Conditions

**4.3.8.1** 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 below. The list is not intended to include all types, and the user should always advise the supplier of all application details.

**4.3.8.2 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.

**4.3.8.3 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.

**4.3.8.4 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.

**4.3.8.5 Oxygen Gauge.** A gauge designed to indicate oxygen pressure. Cleanliness shall comply with Level IV (see Section 5). The dial shall be clearly marked with a universal symbol and/or USE NO OIL in red color (see para. 6.1.1.4).

## 4.4 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 explo-



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**TABLE 2 CLEANLINESS LEVELS**

| Cleanliness Level [Note (1)] | General Cleanliness Requirements Applicable to All Levels | Allowable Size and Quantity | | | | Hydrocarbon ppm [Note (3)], Maximum |
|---|---|---|---|---|---|---|
| | | Particles | | Fibers | | |
| | | Size (Micrometers) | Maximum Quantity [Note (2)] | Size (Micrometers) | Maximum Quantity [Note (2)] | |
| I | Normal cleanliness attained through high standard shop practices | No limit | No limit | No limit | No limit | No limit |
| IV | Gauge shall be free of visually [Note (4)] (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<br>100/500<br>Over 500 | No limit<br>25<br>0 | Less than 700<br>700/1000<br>Over 1000 | No limit<br>10<br>0 | 50 |

NOTES:
(1) Levels II and III intentionally omitted.
(2) Quantity = number by count per solvent flush.
(3) Ppm per solvent flush (approximately the volume contained by the wetted surface).
(4) Excluding particle, fiber, and hydrocarbon detection procedures.

sive 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.

## 5 CLEANLINESS

### 5.1 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.

If the cleanliness requirements of the intended application are not covered in this Table, the user should so advise the manufacturer.

### 5.2 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 such surfaces, or by both. Common cleanliness levels are defined in Table 2.

### 5.3 Inspection for Cleanliness

Hydrocarbon concentration may be determined by methods such as infrared spectrophotometry or black light (ultraviolet) radiation of the long wave type [approximately 3600 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.

### 5.4 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.



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## 6 PRESSURE GAUGE TESTING

### 6.1 Calibration Standards

#### 6.1.1 General Discussion

**6.1.1.1** Standards shall have nominal errors no greater than 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 no more than $\frac{1}{4}$ of 1%, or 0.5 psi. The range of the standard must be no 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 1000 psi digital gauge with errors of 0.05% of 1000 (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.

**6.1.1.2** Complete information regarding manometers and piston gages 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 gage monographs.

**6.1.1.3** 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.

**6.1.1.4** Piston gages or other standards which contain oil or other hydrocarbon fluids shall not be used to test oxygen gauges or other gauges cleaned to Level IV. See Table 2 and para. 4.3.3.2.

**6.1.1.5** 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.

**6.1.1.6** 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.

**6.1.1.7** If an air piston gage is used, no liquid is permitted in the gauge under test, or in the lines between the gauge and the piston gage.

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

*(a)* piston gage (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.

### 6.2 Verification Test Procedures

The following procedures are suggested when testing a pressure gauge to determine its compliance with the accuracy grades defined in para 3.4. Statistical methods or alternate test procedures, or both, may be used when agreed to by the supplier and the user.

**6.2.1 Reference Temperature (All Grades).** A temperature of 23°C ±1°C (approximately 73°F ±2°F) shall be the reference standard. Temperature compensated gauges shall be tested at several ambient temperatures within the compensated range.

**6.2.2 Reference Barometric Pressure.** A barometric pressure 29.92 in. Hg. (1.0132 E+05 Pa) 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. 3.4.1.11.

**6.2.3 Calibration Standards.** See para. 6.1.

#### 6.2.4 Procedures

##### 6.2.4.1 Accuracy

*(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.* Known pressure shall be applied at each test point on increasing pressure (or vacuum). At each test point the gauge 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.

| Accuracy Grade | Minimum Recommended Number of Test Points (Note) |
|---|---|
| 4A | 10 |
| 3A, 2A, 1A, A | 5 |
| B, C, D | 3 |



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NOTE: The test points shall be distributed over the dial range and shall include points within 10% of the ends of the dial range.

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 in Table 1 for the applicable grade of accuracy.

**6.2.4.2 Repeatability.** Repeatability can be determined from the data obtained in para. 6.2.4.1. 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.

**6.2.4.3 Hysteresis.** Hysteresis can be determined from the data obtained in the two pressure cycles. See para. 6.2.4.1. 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 Fig. A1.

The hysteresis value is lower if the pressure excursion is less than full scale. Hysteresis does not include friction error.

## 7 ORDERING PARAMETERS AND RELATED STANDARDS

### 7.1 Order Checklist

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

**7.1.1 Assistance Not Required.** If 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; and

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

**7.1.2. Moderate Assistance Required.** If user requires moderate assistance, specify

*(a)* range (specify units of measure) (see para. 3.2);

*(b)* accuracy (see para. 3.4);

*(c)* size (para. 3.1 and Fig. 6);

*(d)* material;

*(e)* method of joining the pressure containing components;

*(f)* connection type, location, and size;

*(g)* mounting (stem, surface, or flush) (see Figs. 5 and 6);

*(h)* supplier's catalog number, and;

*(i)* variations or accessories, or both.

**7.1.3 Detailed Assistance Required.** If user requires detailed assistance, specify items listed in para. 7.1.2 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

### 7.2 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.



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| 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 square inch) | 6.89476 E+03 | Pa |
| | 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.

EXAMPLES:

(a) 2.54000 E–02 means 2.54000 x $10^{-2}$ and equals 0.025400

(b) 1.01325 E+05 means 1.01325 x $10^{5}$ and equals 101,325

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

### 7.3 Related Standards

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

ANSI Z26.1, Safety Code for Glazing Materials for Glazing Motor Vehicles Operating on Land Highways

Publisher: American National Standards Institute (ANSI), 11 West 42nd Street, New York, NY 10036

ASME B1.20.1, Pipe Threads, General Purpose (Inch) (Except Dryseal)

ASME B1.20.3, Dryseal Pipe Threads

ASME PTC 19.2, Performance Test Code, Pressure Measurement

ASME B40.2, Diaphragm Seals

ASME B40.5, Snubbers

ASME B40.6, Pressure Limiter Valves

Publisher: American Society of Mechanical Engineers (ASME International), Three Park Avenue, New York, NY 10016

ISA RP2.1, Manometer Tables

Publisher: Instrument Society of America (ISA), 67 Alexander Drive, P.O. Box 12277, Research Triangle Park, NC 27709

FED-STD-H28, Screw-Thread Standards for Federal Services

MIL-G-6019, Gage, Pressure, Dial Indicating, Oxygen, Low Pressure

MIL-G-6035, Gage, Pressure, Dial Indicating, Oxygen, High Pressure

MIL-G-17489, Gage, (Pressure) (Air) Boiler

MIL-G-18997, Gage, Pressure, Dial Indicating

Publisher: Federal specifications available from: Superintendent of Documents, United States Government Printing Office, Washington, DC 20402

NBS Monograph No. 8, Mercury Manometers

NBS Monograph No. 65, Reduction pf Data for Piston Gauge Pressure Measurement (NBS Technical Note on Error Assessment)

SAE J906, Automotive Safety Glazing Manual

Publisher: Society of Automotive Engineers (SAE), 400 Commonwealth Drive, Warrendale, PA 15096

UL 299, Fire Extinguishers, Dry Chemical

UL 393 (ANSI B156.1), Indicating Pressure Gauges for Fire Protection Service

UL 404, Gauges, Indicating Pressure, for Compressed Gas Service

UL 626, Fire Extinguishers, Halogenated Agent

Publisher: Underwriters Laboratories (UL), 333 Pfingsten Road, Northbrook, IL 60062

CGA E-4 Standard for Gas Pressure Regulators

Publisher: Compressed Gas Association (CGA), 1235 Jefferson Davis Highway, Arlington, VA 22202

ISO 5171, Pressure Gauges Used In Welding, Cutting and Related Processes

Publisher: International Organization for Standardization (ISO), 1 rue de Varembe, Case Postale 56, CH-1121, Geneve 20, Switzerland/Suisse

The above listing may not be complete.



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# NONMANDATORY APPENDIX A
# SOME DEFINITIONS AND SUGGESTED TEST PROCEDURES USED TO MEASURE NEW GAUGE PERFORMANCE

## A1 SCOPE

This Appendix is intended to provide an outline of the parameters used when evaluating new gauge performance 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 gauges will encounter conditions more severe or less severe than those specified, the test may be modified to match more closely the application. A functional test in the intended application is generally the best evaluation method. (See Fig. A1.)

## A2 EVALUATION PROCEDURES

**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 SECTION 4 BEFORE CONDUCTING ANY TESTING.**

### A2.1 Error, Position

The gauge shall be mounted in its normal calibrating position (see para. 3.4.3.10) and checked for accuracy in accordance with para. 6.2.4.1. The gauge shall then be placed in its intended operating position(s) and again checked for accuracy in accordance with para. 6.2.4.1. The difference between the two sets of readings is the position error.

### A2.2 High Temperature Error

The gauge shall be tested for accuracy in accordance with para. 6.2.4.1. The gauge shall then be placed in a temperature test chamber at the manufacturer's rated maximum operating temperature and allowed to stabilize for a period of not less than 4 hr. The gauge shall then be checked for accuracy at this temperature, in accordance with para. 6.2.4.1. The difference in readings at each test point between room temperature and the maximum operating temperature is the high temperature error.

### A2.3 Low Temperature Error

The gauge shall be tested for accuracy in accordance with para. 6.2.4.1. The gauge shall then be placed in a temperature test chamber at the manufacturer's rated minimum operating temperature and allowed to stabilize for a period of not less than 4 hr. The gauge shall then be checked for accuracy at this temperature, in accordance with para. 6.2.4.1. The difference in readings at each test point between room temperature and the minimum operating temperature is the low temperature error.

### A2.4 Storage Temperature

The gauge shall be tested for accuracy in accordance with para. 6.2.4.1. The gauge shall then be placed in a temperature test chamber at the manufacturer's high limit of storage temperature for a period of 24 hr. The gauge shall then be placed in a temperature test chamber at the manufacturer's low limit of storage temperature for a period of 24 hr. This 48 hr 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. 6.2.4.1. The difference between the two accuracy tests is the effect of storage temperature expressed as a percentage of span.

### A2.5 Vibration

**A2.5.1 Vibration Tests.** The gauge shall be tested for accuracy in accordance with para. 6.2.4.1 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



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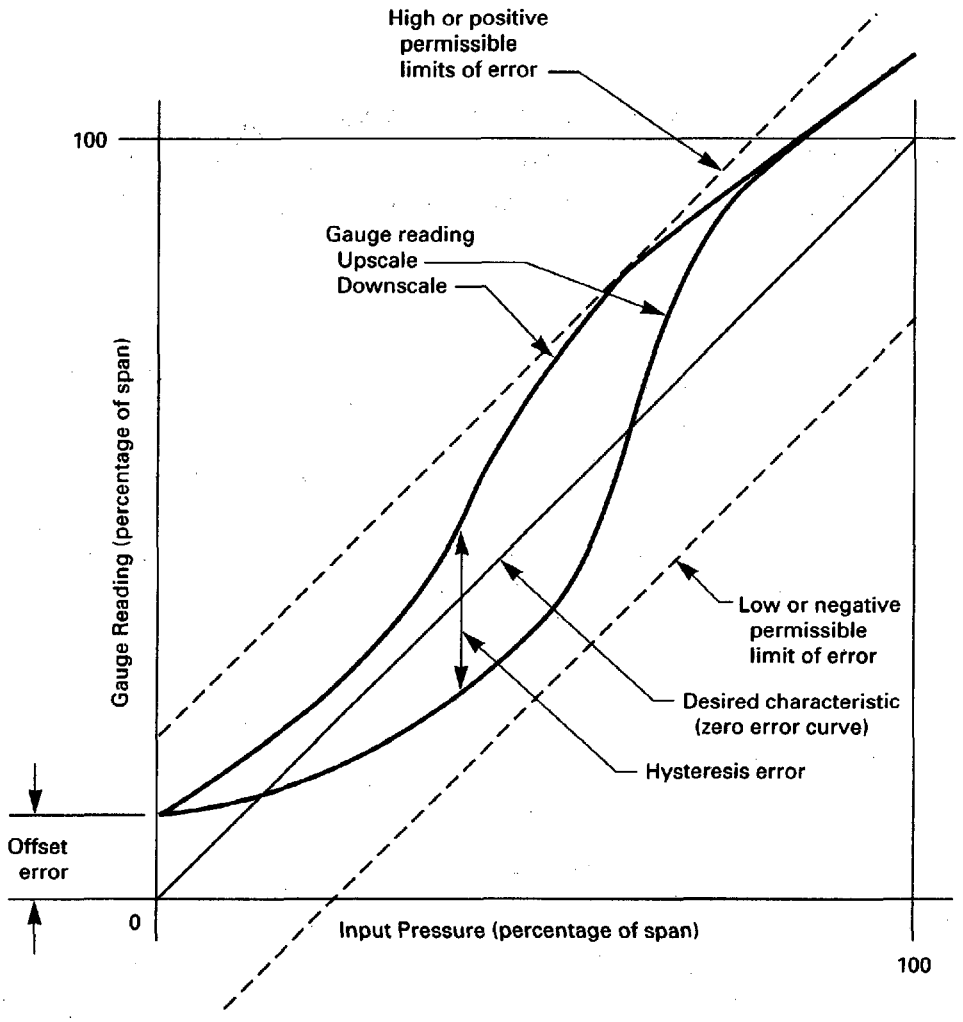



**FIG. A1 HYSTERESIS AND OFFSET ERROR**

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 conditions 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.

**A2.5.2 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 A1. The change in frequency shall be made in discrete frequency intervals of approximately 1 Hz and maintained at each frequency for about 15 sec.

**TABLE A1 VIBRATION TEST AMPLITUDES**

| Frequency Hz | Amplitude in. | Amplitude mm |
|---|---|---|
| 5 to 15 | 0.060 ± 0.012 | 1.5 ± 0.3 |
| 15 to 25 | 0.040 ± 0.008 | 1.0 ± 0.2 |
| 26 to 33 | 0.020 ± 0.004 | 0.5 ± 0.1 |
| 34 to 40 | 0.010 ± 0.002 | 0.25 ± 0.05 |
| 41 to 60 | 0.005 ± 0.001 | 0.013 ± 0.025 |

The frequencies and locations at which resonances occur shall be noted.

**A2.5.3 Endurance Test.** The gauge shall be tested for a period of 2 hr in each of three mutually perpendicular axes (6 hr total) at the resonant frequency. If more than one resonant frequency exists, the test shall be conducted at the highest resonant frequency. If no



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resonance is observed, the test shall be in accordance with Table A1. Test for accuracy in accordance with para. 6.2.4.1. The difference between the two accuracy tests is the effect of vibration expressed as a percent of span.

### A2.6 Pressure, Proof

NOTE: This test is applicable only to new gauges and is not intended for gauges that have been fatigue tested or otherwise had their useful life reduced.

The gauge shall be tested for accuracy in accordance with para. 6.2.4.1. Apply proof pressure to the gauge under test and maintain for 1 min. Release pressure and allow gauge to stabilize. Test for accuracy in accordance with para. 6.2.4.1. The difference between the two accuracy tests is the effect of proof pressure expressed as a percentage of span.

NOTE: Proof pressure may be a semidestructive test and should not be conducted repeatedly on the same gauge.

### A2.7 Pressure, Rupture

NOTE: This test is applicable only to new gauges and is not intended for gauges that have had their useful life reduced.

**CAUTION: Select a reference gauge with a full scale pressure rating above the rupture pressure of the gauge under test to avoid damaging the reference gauge.**

Apply pressure (hydraulic preferred) to the gauge under test, increasing at a rate not to exceed 20% of full scale per second of the gauge being tested. The pressure at which the pressure element assembly will no longer hold pressure is the rupture pressure.

### A2.8 Fatigue

The gauge shall be tested for accuracy in accordance with para. 6.2.4.1. The gauge shall then 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 to 0.6 Hz (18 to 36 cpm). 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 gauge shall be tested periodically for accuracy in accordance with the test specified in para. 6.2.4.1 not less than 1 hr after stopping the pressure cycling. The difference between the first set of readings at each test point and the latest set of readings at each test point is fatigue error at this point.

The gauge shall also be tested periodically for leakage of the pressure element assembly at full scale pressure. The fatigue life is the number of cycles to leakage.

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

### A2.9 Liquid Filled Gauges — Seal Integrity and Stability

NOTE: 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 hr.

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

*(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.

### A2.10 Case — Slow Leak Test

NOTE: Applies only to sealed cases, without venting.

*(a)* Open Bourdon tube to allow gas to flow freely from the socket. Open socket hole to $\frac{1}{8}$ in. diameter.

*(b)* For a liquid filled gauge — refill the case.

*(c)* With the gauge at 65°F/85°F, apply gas pressure to the socket, and slowly increase to allow case pressure to equal applied pressure at approximately 1 psi/sec. Record pressure required to activate relief mechanism.

*(d)* Case must relieve applied pressure without ejecting parts, other than the pressure relief device.

NOTE: Testing at higher or lower temperature may change results drastically. If gauge is to be used at other temperatures, test should be repeated at those temperatures. Supplier's temperature limit may not be exceeded.



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# NONMANDATORY APPENDIX B
# GAUGES USED ON REGULATORS

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.

## B1 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.

## B2 RECOMMENDATIONS

### B2.1 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.

### B2.2 General Contents

**B2.2.1 Basic Terms.** Basic terms and definitions are outlined in Section 2.

**B2.2.2 General Requirements.** General requirements are provided in Section 3. Gauges used on regulators are usually size $1\frac{1}{2}$, 2, and $2\frac{1}{2}$, mounted by the stem (socket), and have open front cases with pressure relief. They shall be grade B accuracy or better.

**B2.2.3 Safety Considerations.** Safety considerations are discussed in Section 4.

**B2.2.4 Cleanliness Levels.** Cleanliness levels are detailed in Section 5. Gauges used on oxygen regulators shall have cleanliness equivalent to Level IV.

**B2.2.5 Testing Standards and Procedures.** Pressure gauge testing standards and procedures are discussed in Section 6. Additional information is outlined in Appendix A.

**B2.2.6 Helpful Information.** Section 7 contains helpful information relative to ordering gauges, related standards, and conversion factors.

### B2.3 Gauges Used on Regulators

The following references to specific paragraphs of this Standard apply to gauges used on regulators. Appropriate additional considerations are discussed.

**B2.3.1 Sizes.** See para. 3.1. The nominal gauge sizes are $1\frac{1}{2}$, 2, and $2\frac{1}{2}$ for regulator applications.

**B2.3.2 Ranges.** See para. 3.2. Common ranges for gauges used on regulators are listed in Table B1 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 B1 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.

**B2.3.3 Cases.** See paras. 3.3.1 and 4.3.8. The cases commonly used for regulator gauge applications are open front with pressure relief. Figure 6 and paras. 3.3.1.1 and 3.3.1.4 outline case construction.

**B2.3.4 Dials.** See para. 3.3.2.



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**TABLE B1 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 | 1000 | 4,000 |
| 0/5,000 | 100 | 1,000 | 0/35,000 | 1000 | 5,000 |
| 0/6,000 | 200 | 1,000 | 0/40,000 | 1000 | 10,000 |
| 0/7,500 | 200 | 1,000 | 0/50,000 | 1000 | 10,000 |
| 0/10,000 | 200 | 2,000 | 0/70,000 | 2000 | 10,000 |

**B2.3.4.1** Recommended units of measure for gauges used on regulators are kPa and psi (psig) presented together (dual scale).

**B2.3.4.2** Paras. 3.3.2.3, 3.3.2.4, and 3.3.2.5 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.

**B2.3.4.3** Dials used on regulator gauges having ranges greater than 1000 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.

**B2.3.5 Pointer Length.** See para. 3.3.3.

**B2.3.6 Pressure Connection.** See para. 3.3.5. Gauges used on regulators are stem mounted and have 1/8-27 NPT or 1/4-18 NPT taper pipe threads, per ANSI B1.20.1.

**B2.3.7 Windows.** See para. 3.3.8. Plastic windows are most commonly used on regulator gauges.

**B2.3.8 Accuracy.** See para. 3.4. Gauges shall have an accuracy of Grade B or better (see Table 1). Applicable paragraphs in this section include: 3.4.1, 3.4.1.1, 3.4.1.2, 3.4.1.6, 3.4.1.9, 3.4.1.10, and 3.4.1.12.

**B2.3.9 Safety.** See Section 4. Personnel specifying and installing pressure gauges used on oxy-fuel gas regulators should become familiar with the material presented in this section.

**B2.3.10 Cleanliness.** See Section 5. Gauges used on oxygen regulators shall comply with cleanliness Level IV or better.

**B2.3.11 Acetylene.** See para. 4.3.8.2

**B2.3.12 Pressure Gauge Testing.** See Section 6. The pressure medium used for testing shall maintain the required cleanliness level of the gauge under calibration or calibration verification. The dead-ended pressure element assembly of regulator gauges cannot be reliably



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cleaned once contaminated. Gauges contaminated with hydrocarbon pressure media shall not be used on oxygen regulators.

## B3 INSTALLATION

### B3.1 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.

### B3.2 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.

### B3.3 Installation Precautions

**DO maintain the pressure element assembly and connection cleanliness level required for the intended application.**
**DO refer to the manufacturer's instruction manual for the correct pressure ranges to be used.**
**DO use the wrench flats provided on the gauge connection and the proper size wrench to secure the gauge to the regulator.**
**DO use only the thread sealant recommended by the regulator manufacturer for the specific application.**
**DO NOT install a low pressure gauge into the high pressure port on a regulator.**
**DO NOT use the gauge case for wrenching.**
**DO NOT interchange gauges from one gas application to another.**
**DO NOT exchange gauges from one regulator to another.**
**DO NOT conduct calibration verification using air from shop air lines, oil, or a contaminated pressure source.**
**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.**

### B3.4 Operation Precautions

Gauges can fail during operation and the energy contained in compressed gases can produce violent effects should the pressure element assembly rupture.

**DO always apply cylinder pressure slowly. Heat due to adiabatic compression can cause ignition.**
**DO use safety glasses or provide eye protection.**
**DO stand with the cylinder between yourself and the regulator (cylinder valve outlet facing away) when opening the cylinder valve.**
**DO read CGA Safety Bulletin SB-8, Use of Oxy-Fuel Gas Welding and Cutting Apparatus.**
**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.**
**DO NOT operate regulators without eye protection.**

## B4 Referenced Documents

The edition bearing the latest date of issuance shall be used.

ASME B1.20.1, Pipe Threads, General Purpose, (Inch) (Except Dryseal)

Publisher: The American Society of Mechanical Engineers, Three Park Avenue, New York, NY 10016

CGA E-4 Regulator Pressure Gauges
CGA TB8 Use of Oxy-Fuel Gas Welding and Cutting Apparatus, Technical Bulletin

Publisher: Compressed Gas Association, Inc., 1235 Jefferson Davis Highway, Arlington, VA 22202

NIOSH Publication No. 78-138, Safety and Health in Arc Welding and Gas Welding and Cutting
29 CFR, Part 1910, Subpart Q, National Institute for Occupational Safety and Health. (NIOSH), Safety and Health in Arc Welding and Gas Welding and Cutting

Publisher: Department of Health, Education and Welfare, Public Health Service, National Institute of Occupational Safety and Health, Robert A. Taft Laboratories, 4676 Columbia Parkway, Cincinnati, OH 45226

UL 404, Gauges, Indicating Pressure, for Compressed Gas Service

Publisher: Underwriters Laboratories, Inc., 333 Pfingsten Road, Northbrook, IL 60062



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# ASME B40.7

**1 Scope** ..... 39

**2 Terminology and Definitions** ..... 39

**3 General Recommendations** ..... 44

**4 Safety Recommendations** ..... 49

**5 Cleanliness** ..... 51

**6 Test Procedures** ..... 51

**7 Reference Documents** ..... 54

**Figures**

1 Basic Pressure Terms ..... 41
2 Accuracy ..... 46
3 Hysteresis and Offset Error ..... 48

**Tables**

1 Cleanliness Levels ..... 52
2 Vibration Test Amplitudes ..... 54



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# GAUGES: PRESSURE DIGITAL INDICATING

## 1 SCOPE

This Standard is confined to digital gauges with integral pressure transducers, which respond to pressure and indicate numerically.

It does not include panel meters with remote mounted transducers, non-indicating pressure transmitters, or pressure switches.

## 2 TERMINOLOGY AND DEFINITIONS

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

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

*accuracy:* the conformity of an instrument's indication to an accepted standard or true value. Accuracy is the difference (error) between the true value (T) and indicated value (I) expressed as either a percent of reading or of span.

$$\% \text{ Accuracy based on reading} = \frac{I - T}{T} \times 100$$

$$\% \text{ Accuracy based on span} = \frac{I - T}{S} \times 100$$

where

$I$ = indicated value (indication)
$T$ = true value (pressure standard)
$S$ = span value

Accuracy includes the combined effects of method, observer, apparatus, and environment. Accuracy error includes hysteresis, linearity, and repeatability error. It is determined under specific conditions (see paras. 3.7.1 and 3.8.3).

*accuracy, reference:* the accuracy of a gauge under reference conditions [normal position at 23°C ±1°C (approximately 73°F ±2°F and 29.92 in. Hg (30.32 E+5 Pa) barometric pressure].

*adjustment, span:* an adjustment increasing or decreasing the total span or algebraic difference between the lower and upper limits of the gauge. Adjustments can be accomplished by electronic or mechanical means. Microprocessor-based gauges may automatically perform this function.

*adjustment, zero:* a means of causing a change in indication at a given point, usually zero (0) This adjustment, if provided, is generally accessible to the user (see para. 3.7.3.8). Microprocessor-based gauges may automatically perform this function.

*ambient pressure:* see *pressure, ambient.*

*bar:* a metric pressure unit equivalent to approximately 14.50 psi.

*calibration:* the process of adjustment to cause the gauge to indicate within specified accuracy limits.

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

*case:* the housing or container that supports, protects, and surrounds the internals.

*case, sealed:* a case which is sealed to exclude ambient corrosives.

*compound gauge:* see *gauge, compound.*

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

*conditions, extreme operating:* the limits of the environmental conditions within which the instrument may be operated.

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

*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.

*corrosion failure:* see *failure, corrosion.*

*crystal:* see *window.*



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*dead weight tester:* a pressure testing device by which very accurate known pressures can be generated by means of a pressure source and a piston gage.

*drift:* a progressive change in indication with constant applied pressure, under the same environmental conditions. It is usually expressed as a percentage of span or reading per unit of time (see para. 3.7.3.6).

*electromagnetic interference (EMI):* see *interference, electromagnetic.*

*element, elastic:* the elastic component of the pressure element assembly that moves in response to pressure changes.

*environmental conditions:* see *conditions, environmental.*

*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.

*error, hysteresis:* the difference between increasing pressure and decreasing pressure readings at any point within the range (see Fig. 1).

*error, offset:* the error exhibited when the gauge is unpressurized. It is expressed as a percentage of span.

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

*error, span:* the error exhibited when the input is at maximum range pressure minus the error exhibited when the input is at minimum range pressure. It is expressed as a percentage of span.

*error, temperature:* the change of pressure indication that results when the gauge components are at a temperature different from their temperature at calibration.

*extreme operating conditions:* see *conditions, extreme operating.*

*failure, corrosion:* element failure resulting from corrosive chemical attack inside the element (see para. 4.2.7.3).

*failure, fatigue:* element failure resulting from repeated applications of stress (see para. 4.2.7.1).

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

*failure, overtemperature:* failure as a result of continuous exposure to high ambient temperature.

*fatigue failure:* see *failure, fatigue.*

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

*fiber optics:* see *optical fiber.*

*flush mounted:* see *gauge, flush mounted.*

*ft. $H_2O$:* see para. 3.2.1.

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

*gage, piston:* 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.

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

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

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

*gauge, flush mounted:* a gauge provided with supporting means on the case so that it may be set through a hole in a panel. When installed the face is approximately flush with the panel.

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

*gauge, pressure:* a device that senses and indicates pressure using ambient pressure as a datum (zero).

*gauge, stem (socket) mounted:* a gauge supported by attachment at the stem (socket) pressure connection.

*gauge, surface (wall) mounted:* a gauge whose case can be mounted to a wall or flat surface.

*gauge, test:* 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.

*gauge, vacuum:* a gauge that indicates negative gauge pressure.

*grommet:* see *plug, pressure relief.*

*$H_2O$:* water.



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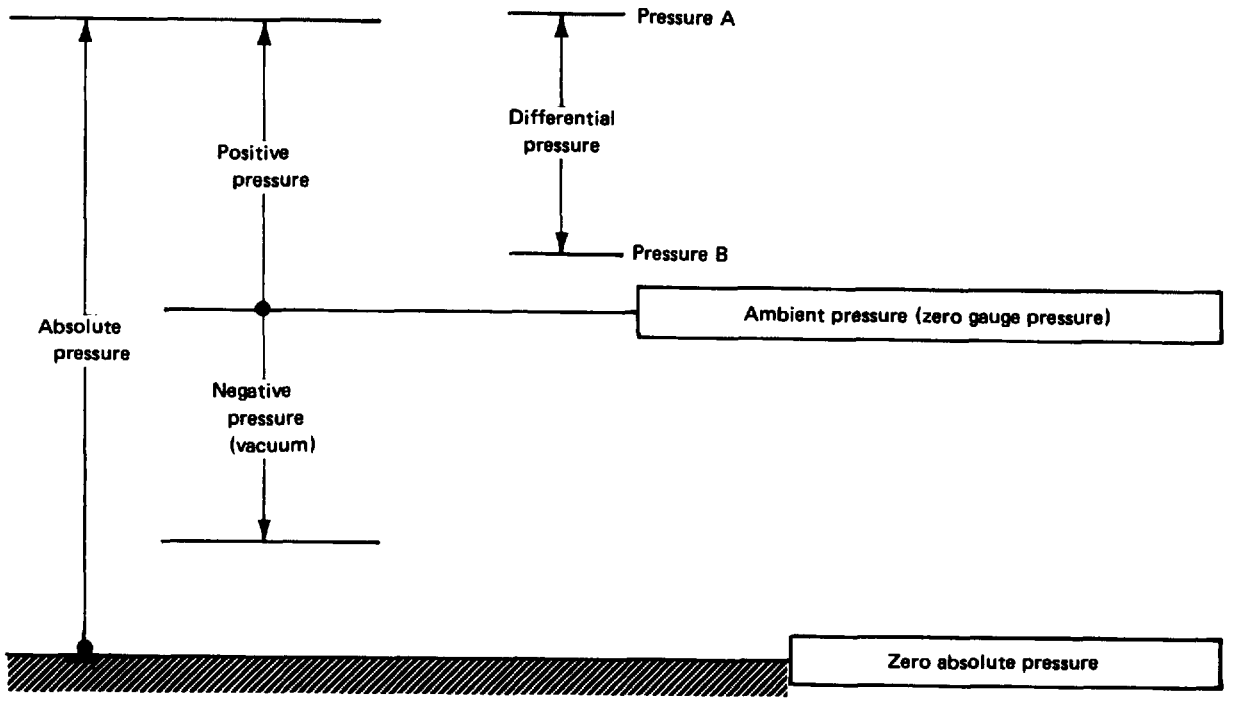



**FIG. 1 BASIC PRESSURE TERMS**

*Hg:* mercury.

*hysteresis error:* see *error, hysteresis.*

*in. $H_2O$:* see para. 3.2.1.

*in. Hg:* see para. 3.2.1.

*interference, electromagnetic (EMI):* external interference generated from electrical devices such as transformers, radio and TV transmitters which interrupts or interferes with other sensitive electronic equipment.

*interference, radiofrequency (RFI):* external interference generated from radio transmission in the Megahertz frequency range which interrupts or interferes with other sensitive electronic equipment.

*$kg/cm^2$:* see para. 3.2.1.

*kPa:* see para. 3.2.1.

*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*).

*linearity, best fit straight line (BFSL):* see *linearity, independent.*

*linearity, independent:* see para. 3.7.3.1.1.

*linearity, terminal-based:* see para. 3.7.3.1.2.

*linearity, zero-based:* see para. 3.7.3.1.3.

*liquid level gauge:* see *gauge, liquid level*

*manometer:* see ASME PTC 19.2.

*medium:* the process fluid (gas or liquid).

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

*mounting, flush:* see *gauge, flush mounted.*

*mounting, gauge:* see *mounting.*

*mounting, stem socket:* see *gauge, stem (socket) mounted.*

*mounting, surface (wall):* see *gauge, surface (wall) mounted.*

*NBS:* National Bureau of Standards (see *NIST*).

*negative pressure (vacuum):* see *pressure, negative.*



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*NIST:* National Institute of Standards and Technology (formerly *NBS*).

*nomenclature:* may include, but not limited to, the following: material of wetted parts, range, and units of measure.

*normal operating conditions:* see *conditions, normal operating.*

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

*optical fiber:* a transparent fiber used to transmit optical signals.

*operating pressure:* see *pressure, operating*

*overpressure:* the application of a pressure beyond the full range pressure.

*overpressure failure:* see *failure, overpressure.*

*Pa:* see para. 3.2.1.

*particle:* any solid contaminant other than fiber.

*Pascal:* see para. 3.2.1.

*piston gage:* see *gage, piston.*

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

*position error:* see *error, position.*

*positive pressure:* see *pressure, positive.*

*pressure, absolute:* a pressure using zero absolute pressure as datum (see Fig. 1).

*pressure, ambient:* the pressure surrounding the gauge, usually atmospheric (barometric) pressure (see Fig. 1).

*pressure, burst:* see *pressure, rupture.*

*pressure, differential:* the difference between two pressures (see Fig. 1).

*pressure element:* see *element, elastic.*

*pressure, full range:* lowest to the highest calibrated indicated pressure reading.

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

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

*pressure, negative (vacuum):* gauge pressure less than ambient pressure using ambient pressure as datum (see Fig. 1).

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

*pressure, positive:* gauge pressure greater than ambient pressure (see Fig. 1).

*pressure, process:* the pressure of the process medium at the pressure connection of the socket.

*pressure, proof:* the maximum pressure a gauge can withstand without evidence of change in accuracy. 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 range pressure.

*pressure relief plug:* see *plug, pressure relief.*

*pressure, rupture:* the maximum pressure above which the pressure element assembly may no longer hold pressure.

*pressure transducer:* see *transducer, pressure.*

*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).

*psi:* see para. 3.2.1.

*psia:* see para. 3.2.1.

*psid:* see para. 3.2.1.

*psig:* see para. 3.2.1.

*radio frequency interference (RFI):* see *interference, radio frequency.*

*range:* the high and low limits of the gauge expressed in sequences and units in which they occur. For example: 0/100 kPa, 0/500 psi, -10 /10 in. $H_2O$.

*readability:* the uncertainty inherent in the observer's ability to determine the indicated pressure value. Contributing factors include distance between observer and indication, illumination, and constant fluctuation between two digits in the display.

*repeatability:* see para. 3.7.3.3.

*resolution, display:* see para. 3.7.3.4.



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*resonance:* the phenomenon when a system oscillates with the largest amplitude and energy due to the frequency of the driving force being close to the system's natural frequency. (A resonance may occur in an internal part of the gauge, with no outward manifestation.)

*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.

*sealed case:* see *case, sealed.*

*significant digits:* the digits from the first nonzero digit on the left to either (a) the last digit (zero or nonzero) on the right if there is a decimal point, or (b) the last nonzero digit of the number if there is no decimal point.

For example:

| | |
|---|---|
| 123 000 000 | has three significant digits |
| 2300. | has four significant digits |
| 0.000028 | has two significant digits |
| 0.03500 | has four significant digits |
| 0.04 | has one significant digit |

*significant surface:* see *surface, wetted.*

*snubber:* a device that is used to reduce the effect of pressure fluctuations and surges, or to reduce flow from a pressure element that has failed in service, or both.

*span:* the algebraic difference between the limits of the range. The span of a 0/100 kPa gauge is 100 kPa. The span of a compound gauge is the difference between the limits of the vacuum and pressure ranges when both are expressed in the same units. The span of a -15 psi to 30 psi gauge is 45 psi.

*span adjustment:* see *adjustment, span*

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

*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.

*stem:* the main supporting component of the pressure transducer which includes the pressure connection.

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

*tare:* a deduction from the gross pressure made to allow for a preexisting pressure.

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

*temperature error:* see *error, temperature.*

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

*temperature, storage:* the extremes of temperature (high and low) that the gauge may be exposed to when it is not pressurized.

*test gauge:* see *gauge, test.*

*time, warmup:* see para. 3.7.3.7.

*torr:* see para. 3.2.1.

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

*transfer standard:* see *standard, transfer.*

*transducer, pressure:* the pressure sensing device, inclusive of elastic element, that responds to pressure and produces an electrical signal.

*vacuum gauge:* see *gauge, vacuum.*

*vacuum:* see *pressure, negative.*

*variable pressure:* see *pressure, variable.*

*vibration resistance:* the maximum vibration a gauge can withstand without physical damage which will impair the gauge function or accuracy beyond acceptable limits. Requirements are expressed as sinusoidal displacements at given frequencies for a specified period of time. i.e, 0.060 ±0.012 inches double amplitude displacement at 5 to 15 Hz. for 15 seconds per 1 Hz increments.

*warmup time:* see *time, warmup.*

*welding:* a metal joining process wherein coalescence is produced by heating to suitable temperatures to melt together the base metals 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 gauge that directly contact the process medium.

*window:* a transparent component that closes the front of the case.

*zero adjustment:* see *adjustment, zero.*



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# 3 GENERAL RECOMMENDATIONS

## 3.1 Case Types & Sizes

Round Flush/Surface Mounting Dimensions
(Sizes shown are identical to B40.1 dimensions)

| Case Size | Mounting Bolt Circle Diameter | | Case Bolt Hole Diameter | |
|---|---|---|---|---|
| | in. | mm | in. | mm |
| 1½ | 1.81 | 48.5 | 0.13 | 3.4 |
| 2 | 2.56 | 65.0 | 0.16 | 4.5 |
| 2½ | 3.13 | 79.5 | 0.16 | 4.5 |
| 3½ | 4.25 | 108 | 0.22 | 5.6 |
| 4½ | 5.38 | 137 | 0.22 | 5.6 |
| 6 | 7.00 | 178 | 0.28 | 7.1 |
| 8½ | 9.63 | 245 | 0.28 | 7.1 |

| Case Size | Panel Opening Diameter | | Outside Diameter of Case, Maximum | |
|---|---|---|---|---|
| | in. | mm | in. | mm |
| 1½ | 1.65 | 41.9 | 1.59 | 40.4 |
| 2 | 2.19 | 55.6 | 2.13 | 54.1 |
| 2½ | 2.81 | 74.1 | 2.75 | 69.9 |
| 3½ | 3.81 | 96.8 | 3.75 | 95.3 |
| 4½ | 4.94 | 125 | 4.88 | 124 |
| 6 | 6.50 | 165 | 6.44 | 164 |
| 8½ | 9.00 | 229 | 8.94 | 227 |

NOTE: The case sizes listed above are equal to the approximate inside diameter of the case in inches. The round DIN 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 DIN 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, over 10% larger than that of a 63 mm gauge.

Round Flush/Surface Mounting Dimensions (DIN Equivalent)

| Case Size | Mounting Bolt Circle Diameter | | Case Bolt Hole Diameter | |
|---|---|---|---|---|
| | in. | mm | in. | mm |
| 40 | 2.01 | 51 | 0.14 | 3.6 |
| 50 | 2.36 | 60 | 0.14 | 3.6 |
| 63 | 2.95 | 75 | 0.14 | 3.6 |
| 80 | 3.74 | 95 | 0.19 | 4.8 |
| 100 | 4.57 | 116 | 0.19 | 4.8 |
| 160 | 7.01 | 178 | 0.23 | 5.8 |
| 250 | 10.63 | 270 | 0.23 | 5.8 |

| Case Size | Panel Opening Diameter | | Outside Diameter of Case, Maximum | |
|---|---|---|---|---|
| | in. | mm | in. | mm |
| 40 | 1.73 | 44 | 1.57 | 40 |
| 50 | 2.13 | 54 | 1.97 | 50 |
| 63 | 2.64 | 67 | 2.48 | 63 |
| 80 | 3.31 | 84 | 3.15 | 80 |
| 100 | 4.09 | 104 | 3.94 | 100 |
| 160 | 6.46 | 164 | 6.30 | 160 |
| 250 | 10 | 254 | 9.84 | 250 |

Rectangular Case Dimensions (DIN Equivalent)

| Case Size | Height | | Width | |
|---|---|---|---|---|
| | in. | mm | in. | mm |
| 1/16 | 1.89 | 48 | 1.89 | 48 |
| 1/8 | 1.89 | 48 | 3.78 | 96 |
| ... | 2.83 | 72 | 5.67 | 144 |
| 1/4 | 3.78 | 96 | 3.78 | 96 |
| ... | 3.78 | 96 | 7.56 | 192 |

## 3.2 Units and Ranges

**3.2.1 Common Units.** 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.

*(a) SI (Le Système International d'Unitès):* these units are recognized by the CIPM (Comitè International des Poids et Measures).

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

*(c) 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.

Definitions of the various units are as follows:

| 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 = 1000 Pa |
| mbar | millibar | 1 mbar = bar/1000 = 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) |
| mm Hg | 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 |



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| Customary Abbreviation | Unit | Definition |
|---|---|---|
| ft $H_2O$ | feet of fresh water | 1 ft fresh water = 0.43276 psi |
| ft sea water | feet of sea water | 1 ft sea water = 0.4453 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. $H_2O$ (20°C) | inches of water (Ref. ISA RP2.1) | 1 in. H2O (20°C) = 1 inch of water at 20°C (68°F) and 980.665 cm/sec gravity (0.036063 psi) |
| in $H_2O$ (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 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 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 |

### 3.2.2 Typical Ranges

| in. $H_2O$ | psi | |
|---|---|---|
| 0/10 | 0/10 | 0/600 |
| 0/30 | 0/30 | 0/1,000 |
| 0/60 | 0/60 | 0/2,000 |
| 0/100 | 0/100 | 0/3,000 |
| 0/200 | 0/200 | 0/6,000 |
| 0/300 | 0/300 | 0/10,000 |

NOTE: Other ranges including SI, MKSA, negative pressure (vacuum) and compound are in common use and are accepted.

**3.2.3 Full Scale Range.** The full scale range, inclusive of units and visible without the aid of power, shall be indicated on the front of the gauge.

## 3.3 Display Types

**3.3.1 Liquid Crystal (LCD).** Dependent on ambient lighting for readability. May be backlit for nighttime or low light conditions. Consumes low power for battery applications. Additional units of measure and alpha messages can be displayed.

**3.3.2 Light Emitting Diode (LED).** Available in a variety of colors, notably red, orange, yellow, green and blue. Readable in most ambient lighting conditions except bright sunlight.

**3.3.3 Vacuum Fluorescent.** Usually amber or green in color. These can be extremely bright and can be seen in direct sunlight. Usually consume more power than other display types.

## 3.4 Transducer Types

**3.4.1 Resistive (Strain Gauge/ Piezoresistive).** Operates on the principle of resistance change of a conductor or semiconductor when subjected to mechanical stress.

**3.4.2 Optical.** Light is transmitted to a measuring photodiode, reflected, interrupted, or attenuated by an object such as a vane that moves as the pressure varies.

**3.4.3 Capacitive.** Operates on the principle of changing the distance or area of conductive parallel plates as pressure varies.

**3.4.4 Inductive.** Variable Reluctance or LVDT (linear variable differential transformer) operates on the principle of changing impedance of a coil by a moving ferromagnetic core as pressure varies.

**3.4.5 Resonant Frequency.** A mechanical resonator detects pressure induced stress by means of changes in the oscillating frequency. A single beam resonator or a double-ended tuning fork resonator force sensor may be employed.

**3.4.6 Hall Effect.** An electromotive force developed as a result of a magnetic field interacting with a steady-state current.

NOTE: Other transducer types may be available.

## 3.5 Input Power

Common types of input power:
*(a)* VDC line
*(b)* VAC line
*(c)* battery (internal VDC)
*(d)* solar

## 3.6 Pressure Connection.

Taper pipe connections are most common, usually 1/8-27 NPT, 1/4-18 NPT, or 1/2-14 NPT American Standard external or internal per ASME B1.20.1. See para. 3.9.



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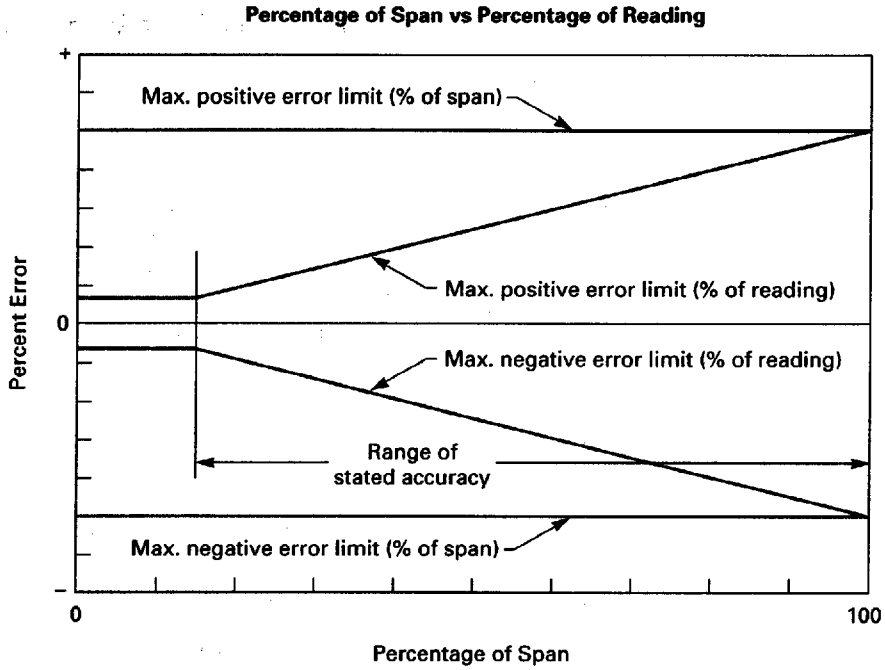



**FIG. 2 ACCURACY**

### 3.7 Accuracy

**3.7.1 General.** There are two ways to express the measurement accuracy of a digital pressure gauge. They are allowable indication error in percent of span and/or in percent of reading. It should be noted that for gauge ranges starting at zero, the percent of span equals percent of full scale. See Fig. 2.

For example:

*(a)* If a digital gauge has a span of 100 psi and an accuracy of 0.1% of *span*:

*(1)* Allowable indication error at 100 psi is 0.1% × 100 = 0.1 psi

*(2)* Allowable indication error at 10 psi is also 0.1% × 100 = 0.1 psi

*(b)* If a digital gauge has a span of 100 psi and an accuracy of 0.1% of *reading*:

*(1)* Allowable indication error at 100 psi is 0.1%× 100 = 0.1 psi

*(2)* Allowable indication error at 10 psi is 0.1% × 10 = 0.01 psi

When a percent of reading error is applied to a digital gauge, it shall be accompanied by the values of the range within which the accuracy statement applies. The values of the range are required because the allowable error approaches zero as the pressure approaches zero. See Fig. 2.

**3.7.2 Format.** Accuracy should be stated with a maximum of two significant digits followed by %S (percent of span) or %R (percent of reading). The most significant digit may be any whole number. The least significant digit when two digits are used must be a five.

| acceptable | not acceptable |
|---|---|
| 0.025% | 0.024% |
| 0.04% | 0.041% |
| 1.5% | 1.55% |

**3.7.3 Factors Which May Affect Accuracy.** The most common factors which contribute to the total accuracy are listed below. All of the error factors must be considered when comparing the accuracy statements of digital gauges. Manufacturers shall state which factors are included in the accuracy statement in order to allow the user to evaluate digital gauges. See Section 6 for recommended test procedures.

**3.7.3.1 Linearity.** The maximum deviation of a calibration curve (average of upscale and downscale readings) from a straight line.

**3.7.3.1.1 Linearity, Independent.** The maximum deviation of a calibration curve (average upscale and downscale readings) from a straight line so positioned as to minimize the maximum deviation.



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**3.7.3.1.2 Linearity, Terminal-Based.** The maximum deviation of a calibration curve (average upscale and downscale readings) from a straight line coinciding with the calibration curve at the upper and lower range values.

**3.7.3.1.3 Linearity, Zero-Based.** The maximum deviation of a calibration curve (average upscale and downscale readings) from a straight line so positioned as to coincide with the calibration curve at the lower range value and to minimize the maximum deviation.

**3.7.3.2 Hysteresis.** The difference at each test point between increasing pressure and decreasing pressure readings, at the same test point, approached from both increasing and decreasing pressure directions, in a single pressure cycle, expressed in the same format as accuracy. See Fig. 3.

**3.7.3.3 Repeatability.** The maximum difference between any two or more consecutive indications, under the same operating conditions, for the same applied pressure approached from the same direction, expressed in the same format as accuracy.

**3.7.3.4 Display Resolution.** The smallest incremental change of the input that can be indicated by the display. This value shall be less than the allowable error. A higher resolution does not necessarily reflect better accuracy.

**3.7.3.5 Temperature.** Errors may occur when a gauge is exposed to an ambient temperature which differs from the calibration temperature. The value of this error should be stated as a % of span/°C or /°F or as a % of reading/°C or /°F. The effect of temperature on zero and span may be expressed separately.

**3.7.3.5.1 Ambient Temperature Compensation.** If temperature compensation is employed, the effective temperature range of compensation must be specified.

**3.7.3.6 Drift (Long Term Stability).** Errors may occur over time. This error should be stated as a % of span or % of reading per specified period of time.

**3.7.3.7 Warmup Time.** The time required to achieve rated accuracy after power is applied.

**3.7.3.8 Zero Adjustment.** Two basic zero adjust methods are used which can affect accuracy:

*(a)* The entire span of the instrument is shifted either up or down in a direct relationship (without affecting span) allowing the user to reset the zero point. Care should be taken if this method is available because an incorrect zero setting may cause indications to be incorrect throughout the entire range.

*(b)* The instrument is "forced" to indicate zero as soon as the input pressure drops below some predetermined value. Commonly called "auto zero," this feature is usually incorporated within the instruments firmware and is therefore not adjustable by the user. Pressures near zero may be skewed or not indicated.

**3.7.3.9 Other Factors.** Position, vibration, acceleration, etc.

## 3.8 Selection and Options

**3.8.1 Selection.** The following is a list of criteria a user should check before selecting a pressure gauge:

*(a)* pressure range and unit(s) of measure
*(b)* accuracy
*(c)* display resolution
*(d)* case size and material
*(e)* transducer type
*(f)* readability: display type and size
*(g)* process connection thread size and type
*(h)* temperature compensation
*(i)* materials of wetted parts and joints
*(j)* environmental conditions
*(k)* power requirements and electrical connection type
*(l)* mounting
*(m)* noise: RFI, EMI, fluorescent lighting, etc.
*(n)* safety considerations: generation of sparks in hazardous areas, etc.

**3.8.2 Options.** The following is a partial list of options a user should consider before final selection:

*(a)* alarm(s)
*(b)* relay output(s)
*(c)* current and voltage analog output(s)
*(d)* peak and hold: instrument will display and retain the highest and/or lowest pressure
*(e)* press to read: a feature used to conserve battery life by suppressing the display and other power draining functions until a button is pressed
*(f)* communications:
*(1)* RS-232C
*(2)* IEEE 488
*(3)* HART
*(4)* ISA SP-50
*(5)* Other
*(g)* low power indicator
*(h)* auto ranging
*(i)* pressure unit selection



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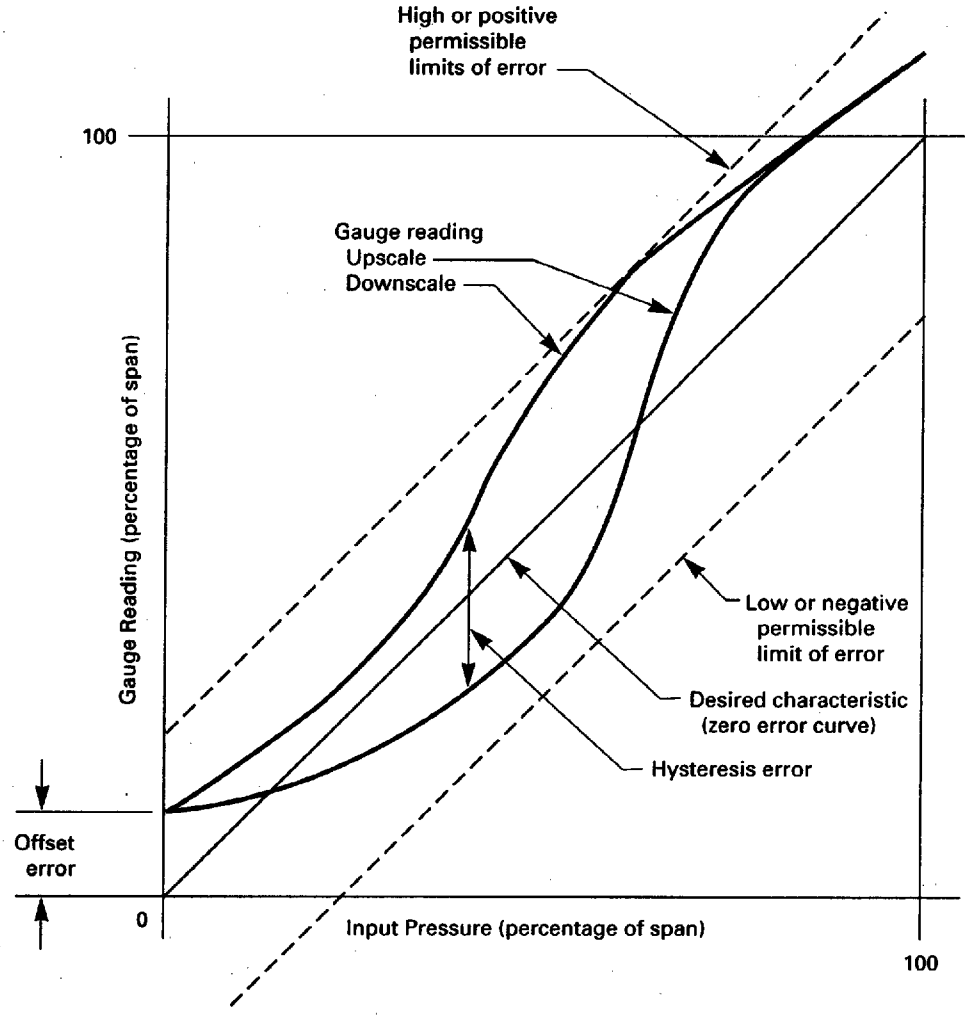



**FIG. 3 HYSTERESIS AND OFFSET ERROR**

*(j)* battery backup

**3.8.3 Grade.** Accuracy is graded as shown below (see para. 3.7.1):

| Grade | Permissible Error | |
|---|---|---|
| 5A | ±0.05% | of span |
| 4A | ±0.1% | of span |
| 3A | ±0.25% | of span |
| 2A | ±0.5% | of span |
| A | ±1.0% | of span |
| B | ±2.0% | of span |
| 5AR | ±0.05% | of reading |
| 4AR | ±0.1% | of reading |
| 3AR | ±0.25% | of reading |
| 2AR | ±0.5% | of reading |
| AR | ±1.0% | of reading |
| BR | ±2.0% | of reading |

## 3.9 Installation

Before using a pressure gauge, consideration should be given to environmental conditions such as temperature (ambient and process), humidity, vibration, pulsation, shock and the possible need for protective attachments and/or special installation requirements. Refer to Safety (see Section 4).

The pressure connection must be compatible with the mating connection, and appropriate assembly techniques must be utilized. For example, improper tightening could create a stress or strain in the transducer element, causing a shift in the gauge reading, damage to the case, or other internal components. Installation of the gauge should be accomplished by tightening the pressure connection using wrench flats if provided. Consult supplier for proper procedures.



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# 4 SAFETY RECOMMENDATIONS

## 4.1 Scope

This section of the Standard presents information to guide users, suppliers, and manufacturers toward minimizing the hazards that could result from misuse or misapplication of pressure gauges. 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.

## 4.2 General Discussion

**4.2.1 Planning.** 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.

**4.2.2 Safety.** The history of safety with respect to the use of pressure gauges has been excellent. Injury to personnel and damages to property have been minimal. In most instances, the cause of failure has been misuse or misapplication.

**4.2.3 Elastic Element (Transducer).** 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, syphons, and other similar items, are available for use in these potentially hazardous systems. The hazard potential increases at higher operating pressure.

**4.2.4 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 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

**4.2.5 Unique Media.** 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.

**4.2.6 Violent Effects.** Fire and explosions within a pressure system can cause failures. Failure in a compressed gas system can 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 of wetted parts by steam or other heat sources

*(e)* weakening of soft soldered or silver brazed joints of wetted parts caused by heat sources such as fires

*(f)* corrosion

*(g)* fatigue

*(h)* mechanical shock

*(i)* excessive vibration

### 4.2.7 Modes of Pressure Gauge Failure

**4.2.7.1 Fatigue Failure.** Fatigue failure caused by pressure induced stress generally occurs from the inside to the outside along a highly stressed edge radius. Such failures are usually more critical with compressed gas media than with liquid media.

**4.2.7.2 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 transducer 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.

Placing a snubber or restrictor in the pressure inlet may not reduce the immediate effect of failure, but will help control flow of escaping fluid following rupture and reduce the potential of secondary effects.



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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 instrument. The result could be immediate failure, or a large upscale error. A snubber or restrictor may reduce the magnitude of the pressure spikes transmitted to the transducer.

The 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 rated pressure and below the proof pressure of the elastic element. Complete information regarding pressure limiter valves is contained in ASME B40.6-1994, *Pressure Limiter Valves.*

**4.2.7.3 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.

NOTE: The addition of a diaphragm seal may degrade accuracy or sensitivity or both. See ASME B40.2 for complete information.

**4.2.7.4 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. Generally there is no known means of predicting the magnitude or effects of this type of failure.

**4.2.7.5 Vibration Failure.** The most common mode of vibration failure is that where components and/or connectors dislodge from their sockets. Instruments that are subject to high or constant vibration should be periodically checked for these failure modes.

**4.2.7.6 Vibration-Induced Fatigue Failure.** In addition to its effect on the instrument's electronics (see para. 4.2.7.5) 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 joints. Transducer enclosure 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.

**4.2.7.7 General Electronics Failure.** Although rare, electronic components do fail. The most common causes are excessive heat, excessive humidity and line transients.

**4.2.8 Pressure Connection.** See recommendations in para. 3.6.

### 4.3 Safety Recommendations

**4.3.1 Operating Pressure.** The pressure gauge selected should have a full range pressure such that the operating pressure occurs in the middle half (25% to 75%) of the range. The full range pressure of the gauge selected should be approximately two times the intended operating pressure. Should it be necessary for the operating pressure to exceed 75% of full range, contact the supplier for recommendations.

**4.3.2 Use of Gauges Near Zero Pressure.** The use of gauges near zero pressure is not recommended because the accuracy tolerance may be a large percentage of the applied pressure. If, for example, a 0/100 psi Grade B 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 pressure in a tank, autoclave, or other similar device, which has been seemingly exhausted. Depending on the accuracy and 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.

**4.3.3 Compatibility with the Medium.** The wetted parts must be carefully selected for compatibility with the medium. None of the common materials is impervious to every type of chemical attack.

**4.3.4 Use of Gauge in Hazardous Environment.** The electric or electronic parts in a digital pressure gauge may be capable of producing energy levels sufficient to release incendiary energy. This can be an ignition source for explosion when fuels and



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oxidizers are present. The user should select a gauge which is suitable for use in the specific hazardous environment.

**4.3.5 Electromagnetic Interference.** An electronic device may emit or be susceptible to electromagnetic interference (EMI). The emissions from one device may cause another device to malfunction. Electromagnetic compatibility, including emission susceptibility, and electrostatic discharge should be considered if digital pressure gauges are to be used in close proximity to other electronic devices.

**4.3.6 Power Requirements.** Power requirements must be complied with to avoid instrument damage and/or personal injury.

**4.3.7 Loss of Power.** When a digital gauge loses power the display will go blank. Extreme caution should be used when disconnecting the process connection because pressure may still be present.

### 4.4 Reuse of Pressure Gauges

**4.4.1 Consideration for Reuse.** 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 service 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.

**4.4.2 Other Considerations.** When reusing a gauge, all guidelines covered in this Standard relative to application of gauges should be followed in the same manner as when a new gauge is selected.

## 5 CLEANLINESS

### 5.1 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 for food processing, life support, or oxidizing fluids, the user should specify the appropriate level in Table 1.

If the cleanliness requirements of the intended application are not covered in this table, the user should so advise the supplier.

### 5.2 Cleanliness Levels

Cleanliness is determined by the size and quantity of maximum permissible solid contaminants on wetted surfaces or by the quantity of contaminants (hydrocarbons) discernible in the fluids used to flush or clean such surfaces, or by both. Common cleanliness levels are defined in Table 1.

### 5.3 Inspection for Cleanliness

Hydrocarbon concentration may be determined by methods such as infrared spectrophotometry or black-light (ultraviolet) radiation of the long wave type [approximately 3600 angstrom units (360 nm)], where the solvent used to flush the wetted parts 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 detectably fluorescent under black light. It may be necessary for the gauge manufacturer to add fluorescent additives to certain suspected contaminants to make their detection possible.

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

### 5.4 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 wetted parts are maintained after the gauge is removed from its package for installation.

## 6 TEST PROCEDURES

### 6.1 Scope

This section is intended to provide an outline of the parameters used when evaluating new gauge performance 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 gauges will encounter conditions more severe or less severe than those specified, the test may be modified to match more closely the application. A functional



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**TABLE 1 CLEANLINESS LEVELS**

| Cleanliness Level [Note (1)] | General Cleanliness Requirements Applicable to All Levels | Allowable Size and Quantity | | | | |
|---|---|---|---|---|---|---|
| | | Particles | | Fibers | | Hydrocarbon ppm [Note (3)], Maximum |
| | | Size (Micrometers) | Maximum Quantity [Note (2)] | Size (Micrometers) | Maximum Quantity [Note (2)] | |
| I | Normal cleanliness attained through high standard shop practices | No limit | No limit | No limit | No limit | No limit |
| IV | Gauge shall be free of visually [Note (4)] (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<br>100/500<br>Over 500 | No limit<br>25<br>0 | Less than 700<br>700/1000<br>Over 1000 | No limit<br>10<br>0 | 50 |

NOTES:
(1) Levels II and III intentionally omitted.
(2) Quantity = number by count per solvent flush.
(3) ppm per solvent flush (approximately the volume contained within the wetted parts).
(4) Excluding particle, fiber, and hydrocarbon detection procedures.

test in the intended application is generally the best evaluation method.

**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 Section 4 before conducting any testing.**

**6.1.1 Calibration Standards.** Standards shall have nominal errors no greater than 1/4 of those permitted for the gauge being tested. For example, when testing a 0/100 psi, Grade A (±1%) gauge, (permissible error of ±1 psi), you may use a 0/100 psi, Grade 3A (±0.25%), (permissible error of ±0.25 psi), or a 0/200 psi, Grade 4A (±0.1%), (permissible error of ±0.2 psi).

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.

**6.1.2 Manometers and Piston Gages.** Complete information regarding manometers and piston gages 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 Manometry and Piston Gage Manuals.

**6.1.3 Gauges as Standards.** 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.

**6.1.4 Reference Temperature.** A temperature of 23°C ±1°C (approximately 73°F ±2°F) shall be the reference standard. Temperature compensated gauges shall be tested at several ambient temperatures within the compensated range.

**6.1.5 Reference Barometric Pressure.** A barometric pressure of 29.92 in. Hg (30.32 E+5 Pa) shall be the reference standard.

### 6.2 Accuracy

**6.2.1 Purpose.** This test determines the accuracy of the gauge under test in compliance with para. 3.7.

**6.2.2 Procedure.** Known pressure shall be applied at each test point on increasing pressure (or vacuum) from one end to the other end of the scale. At each test point the gauge shall be read. The same sequence shall be repeated on decreasing pressure (or vacuum). The entire set of upscale and downscale readings shall then be repeated.



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| Accuracy Grade | Recommended Number of Test Points (Note) |
|---|---|
| 5A, 5AR | 15 |
| 4A, 4AR | 10 |
| 3A, 3AR, 2A, 2AR, A, AR | 5 |
| B, BR | 3 |

NOTE: The test points shall be distributed over the range and shall include points within 10% of the ends of the range.

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.

### 6.3 Repeatability

**6.3.1 Purpose.** This test determines the ability of the gauge to produce the same results when the accuracy test procedure is repeated.

**6.3.2 Procedure.** Repeatability can be determined from the data obtained in para. 6.2.2. It is the difference between any two readings taken 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 error.

### 6.4 Hysteresis

**6.4.1 Purpose.** This test determines the level of hysteresis resulting from a full range pressure excursion.

**6.4.2 Hysteresis.** Hysteresis can be determined from the data obtained in para. 6.2.2. It is the difference at each test point between increasing pressure and decreasing pressure readings taken 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 3).

The hysteresis value is lower if the pressure excursion is less than full scale.

### 6.5 Ambient Temperature Error

**6.5.1 Purpose.** This test determines the effect of short term exposure to suppliers' recommended minimum and maximum ambient operating temperatures.

**6.5.2 Procedure.** The gauge should be powered "on" throughout this test. Perform the accuracy test in accordance with para. 6.2.2 at the reference temperature (see para. 6.1.4). The gauge shall then be exposed to the supplier's rated minimum or maximum ambient operating temperature and allowed to stabilize for a period of not less than 4 hr. The gauge shall then be tested for accuracy, in accordance with para. 6.2.2, at this temperature. The difference in readings at each test point between the reference temperature and the minimum or maximum temperature is the ambient operating temperature error.

### 6.6 Storage Temperature

**6.6.1 Purpose.** This test determines the effects of long term exposure to temperature extremes on gauge operation.

**6.6.2 Procedure.** The gauge should be powered "off" throughout this test except when testing for accuracy. Perform the accuracy test in accordance with para. 6.2.2 at the reference temperature (see para. 6.1.4). The gauge shall then be exposed to the supplier's rated low limit of storage temperature. After a period of 24 hours the temperature shall be raised to the supplier's rated high limit of storage temperature for another 24-hour period. This 48-hour cycle shall be repeated two times. The gauge shall then be allowed to stabilize at the reference temperature and then tested for accuracy in accordance with para. 6.2.2. The difference between the two accuracy tests is the effect of the storage temperatures expressed as a percentage of span.

### 6.7 Vibration

**6.7.1 Purpose.** This test determines the effect of 6 hours of exposure to a specific vibration test pattern as described below.

**6.7.2 Procedure.** The gauge shall be tested for accuracy in accordance with para. 6.2.2 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 conditions 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.



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**TABLE 2 VIBRATION TEST AMPLITUDES**

| | Peak to Peak Vibration | |
|---|---|---|
| Frequency Range Hz | Amplitude in. | Amplitude mm |
| 5 to 15 | 0.060 ± 0.012 | 1.5 ± 0.3 |
| 16 to 25 | 0.040 ± 0.008 | 1.0 ± 0.2 |
| 26 to 33 | 0.020 ± 0.004 | 0.5 ± 0.1 |
| 34 to 40 | 0.010 ± 0.002 | 0.25 ± 0.05 |
| 41 to 60 | 0.005 ± 0.001 | 0.13 ± 0.025 |

**6.7.3 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 2. The change in frequency shall be made in discrete frequency intervals of approximately 1 Hz and maintained at each frequency for about 15 sec. The frequencies and locations at which resonances occur shall be noted.

**6.7.4 Endurance Test.** The gauge shall be tested for a period of 2 hr in each of three mutually perpendicular axes (6 hr total) at the resonant frequency. 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 conducted at 0.005 ±0.001 inches double amplitude displacement at 60 Hz. Test for accuracy in accordance with para. 6.2.2. The difference between the two accuracy tests is the effect of vibration expressed as a percentage of span.

## 7 REFERENCE DOCUMENTS

ASME B1.20.1, Pipe Threads, General Purpose (Inch)

ASME PTC 19.2, Instruments and Apparatus: Part 2, Pressure Measurement

ASME B40.1, Gauges: Pressure Indicating Dial Type: Elastic Element

ASME B40.2, Diaphragm Seals

ASME B40.5, Snubbers

ASME B40.6, Pressure Limiter Valves

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