5.2 Accessories (Seals, Snubbers, Calibrators, Manifolds)


Types of Accessories:
A. Chemical seals
B. Snubbers, pulsation dampeners
C. Manifolds
D. Dead-weight testers, calibrators
E. Smart communicators, calibrators

Design Pressure (Seals):
Up to 2500 PSIG (17 MPa) with standard units; specials to 20,000 PSIG (138 MPa) and higher

Design Temperature (Seals):
Up to 600°F (316°C) with standard units; specials up to 1500°F (815°C)

Materials of Construction:
Standard seal lower housing can be Kynar, polypropylene, polyvinyl chloride, chlorinated polyvinyl chloride, glass- or carbon-filled Teflon, brass, carbon steel, 304 or 316 stainless steel, Carpenter 20, Hastelloy B or C, Inconel, Monel, nickel, titanium, or tantalum-plated. Diaphragms can be Buna-N, Kel-F, Teflon, Viton, 316 stainless steel, Hastelloy B or C, Inconel 600 Monel K500, Nickel 200, tantalum, titanium, Carpenter 20, silver, or gold-plated. Several manufacturers can provide other special materials.

Costs:
Snubber and pulsation dampener costs range from $10 to $300 depending on features and materials of construction. A few seals are available for less than $50. A seal similar to Figure 5.2d with carbon steel wetted parts is about $130; with wetted parts in stainless steel or Monel it is about $300, in Inconel or Carpenter 20 about $400, in nickel or titanium about $500, and in Hastelloy B or C about $750. A 3-in. (76-mm) flanged seal with a 6-in. (152-mm) extended diaphragm seal with a short capillary with stainless steel wetted parts is about $900 and with Hastelloy C wetted parts may be over $2000. Manufacturers may offer only 1 or 2 seal configurations, but many offer more than 50 choices among more than a dozen detail options, providing an extremely wide range of choices and costs. Shutoff valve manifolds range from $100 up depending on features and materials of construction. For dead-weight testers see Section 5.8. The cost of smart field communicators, which include recalibration capability, range from $800 to $4000.

Partial List of Suppliers:
3D Instruments LLC (D) (www.3dinst.com)
Ametek U.S. Gage M & G (A, B) (www.ametek.com)
Ametek/Rochester Instruments (E) (www.rochester.com)
Anderson Greenwood (B, C) (www.andersongreenwood.com)
DH Instruments Inc. (D, E) (www.dhinstruments.com)
Differential Pressure Plus, Inc. (B) (www.differentialpressure.com)
Dresser Measurements (A, E) (www.dresser.com)
Dwyer Instruments Inc. (A, B) (www.dwyer-inst.com)
FLW Inc. Ashcroft (A, C) (www.flw.com/ashcroft.htm)
H.O. Trierce Co. (A) (www.hotrierce.com)
Helicoid Div. of Bristol Babcock (A, B, C) (www.bristolbabcock.com)
Hex Valve Div. of Richards Industries (C) (www.hexvalve.com)
Hoke Inc. (C) (www.hoke.com)
Honeywell Inc. (A, B, E) (www.acs.honeywell.com)
Combined in this section are a variety of devices that might serve as accessories to pressure instruments. They range from simple snubbers and shutoff valves to a wide variety of chemical seal devices. These mechanical components serve to protect the pressure instruments from high or low temperatures, plugging, corrosion, and pulsation, or to provide the means for isolating the instrument for removal or maintenance. Other more sophisticated and more expensive accessories used in connection with pressure instrumentation are the various types of calibrators and electronic communication devices used in combination with the smart transmitters discussed in Section 5.1.

**PULSATION DAMPENERS AND SIPHONS**

On steam service, it is desirable to prevent the live steam from entering the sensing element, which could cause temperature damage. Such prevention is accomplished by installing a coil pipe siphon between the gauge and the process connection (Figure 5.2a). Where sudden pressure shocks or rapidly fluctuating pressures are expected, snubbers or pulsation dampers are installed between the gauge and the process. Some of the snubber design variations are illustrated in Figure 5.2b. One design consists of a fitting with a corrosion-resistant porous metal filter disk. Such device delays the equilibrium reading on the indicator by about 10 seconds. Another snubber design depends for its dampening action on a small piston in the inlet fitting; the piston rises and falls with pressure impulses, absorbing shocks and surges. Still another snubber design uses the adjustable restriction created by a microvalve in the inlet fitting to damp pulsations. Where system dynamics are important to the measurement and/or to system safety, the time delay effects of damping must be considered when selecting safety trip settings. Pulsation dampeners should not be used with any instrument installed specifically to measure high frequency pulsations; this may be necessary when investigating the discharge characteristics of a reciprocating pump, or diagnosing cavitation symptoms of a centrifugal machine.
FREEZE PROTECTION

Where there is a possibility that the process fluid might freeze inside the pressure element, steam tracing can be provided or small electric heaters can be installed inside the cases of larger instruments. A heater can provide a temperature rise of about 80°F (27°C) and is available with gauges having dial diameters of 4.5 in. (112 mm) or larger. For smaller instruments, resistance-wire-type heat tracing can be wrapped around the transmitter. When this is done, a thermostat should be included to prevent the case from exceeding normal design temperatures. This is particularly important for electronic instruments. Some manufacturers can furnish hollow bolts in the transmitter housing with provisions for connecting them to a low-pressure steam supply. This can be useful in plants that are provided with steam-tracing systems for the process piping. The need for freeze protection is not limited to water services. Freeze protection is also provided for liquid metal systems (sodium, potassium, etc.) and for high-viscosity fluids such as bunker fuels and molasses. Instruments connected to such processes should always be protected from freezing of the process fluids.

CHEMICAL SEALS

Chemical seals or diaphragm protectors can be provided with most pressure sensors. These components serve the following functions:

1. They avoid freezing, gelling, or settling out of the process fluid in the sensing line due to temperature changes.
2. They prevent poisonous, noxious, radioactive, or corrosive process materials from entering the pressure sensor.
3. They prevent slurries or viscous polymers from entering, plugging the detector element.

In the following discussion, several chemical seal designs are described. All are filled with essentially noncompressible liquids that hydraulically transmit the process pressure to the protected pressure element.

Filling fluids are selected to provide low thermal expansion and low viscosity and to avoid danger of process contamination in case of diaphragm rupture. Table 5.2c lists some filling fluids, their applicable temperature ranges, and their thermal expansion coefficients. One of the popular filling fluids is a 70 to 30% mixture of glycerin and water used between 30 and 300°F (−1 to 149°C). For lower temperatures, ethyl alcohol, kerosene, toluene, or silicon oils are used in the −50 to 100°F (−46 to 38°C) range. Some silicone oils, fluorocarbons, and halocarbons can stretch the range to 500°F (260°C). For high temperatures sodium-potassium alloys are available for the range of 70 to 1500°F (25 to 816°C). The gasketing materials are plastics, elastomers, or Teflon up to 400°F (250°C), while on high temperature services metallic gaskets or special volumetric elements are used. All-welded designs are also available for installations where gaskets are inappropriate.

<table>
<thead>
<tr>
<th>Filling Fluid</th>
<th>Temperature Range</th>
<th>Expansion Coefficient (SG/°F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Toluene</td>
<td>−40 to 200°F −40 to 93°C</td>
<td>0.00063</td>
</tr>
<tr>
<td>Dow Corning silicone (DC-200)</td>
<td>−30 to 300°F −34 to 148°C</td>
<td>0.00075</td>
</tr>
<tr>
<td>Kerosene</td>
<td>−30 to 350°F −34 to 177°C</td>
<td>0.00051</td>
</tr>
<tr>
<td>Hooker (FS-5)</td>
<td>−20 to 300°F −29 to 148°C</td>
<td>0.00049</td>
</tr>
<tr>
<td>Mercury*</td>
<td>−30 to 700°F −34 to 371°C</td>
<td>—</td>
</tr>
<tr>
<td>Dibutyl phthalate</td>
<td>20 to 300°F −7 to 148°C</td>
<td>0.0008</td>
</tr>
<tr>
<td>22% sodium–78% potassium</td>
<td>20 to 1400°F −7 to 760°C</td>
<td>—</td>
</tr>
<tr>
<td>70% glycerin–30% water</td>
<td>30 to 300°F −1 to 148°C</td>
<td>0.00051</td>
</tr>
<tr>
<td>Instrument oil</td>
<td>35 to 300°F 2 to 148°C</td>
<td>0.00035</td>
</tr>
<tr>
<td>Light turbine oil</td>
<td>40 to 300°F 4 to 148°C</td>
<td>0.00048</td>
</tr>
<tr>
<td>Dow Corning silicone (DC-550)</td>
<td>40 to 500°F 4 to 260°C</td>
<td>0.00042</td>
</tr>
<tr>
<td>Dow Corning silicone (DC-703)</td>
<td>40 to 600°F 4 to 316°C</td>
<td>0.00055</td>
</tr>
<tr>
<td>96.5% glycerin</td>
<td>70 to 450°F 21 to 232°C</td>
<td>0.00039</td>
</tr>
<tr>
<td>56% sodium–44% potassium</td>
<td>70 to 1500°F 21 to 815°C</td>
<td>—</td>
</tr>
</tbody>
</table>

* No longer used due to environmental/biological hazard. If found in an old installation, it should be removed only by, or under the direction of, a certified health physicist.
Even with the proper selection of filling fluids, the temperature effects will not be completely eliminated. Some expansion coefficients based on specific gravity are listed in Table 5.2c. Resulting temperature effects may typically be about 3 PSI/100°F (21 kPa/38°C). Temperature effects are caused by direct expansion of the fill fluid against the elasticity of the diaphragm, and by variations in the weight of fluid if there is an elevation or suppression between the sensing point and the instrument. Therefore, it is desirable to calibrate critical units at operating temperature to eliminate errors.

The common fill fluids listed in Table 5.2c are not expected to decompose at the highest process temperature listed, and their viscosities are expected to remain low enough to operate the process elements efficiently at the lowest process temperatures. Note that the sodium–potassium (NaK) mixtures freeze not far below room temperature. The eutectic (78% Na–22% K) freezes at 0°F (−12.3°C); other mixtures between 40 and 90% K freeze at increasing temperatures up to room temperature. Since they shrink upon freezing, it is not likely that any damage will occur, but the instrument will suddenly stop working and may become a safety hazard or cause a product deviation due to this loss of function.

**Limitations**

Other limitations of chemical seal protectors involve the spans and the vacuum applications. The working pressure ranges with metal diaphragm seal protection should have an upper range value greater than 50 PSI (350 kPa), because otherwise the spring rate of the diaphragm will introduce excessive errors. Displacement of the attached instrument over the expected measurement span is also important to selection of a seal; the seal’s diaphragm must not bottom out, even partially, as the pressure increases and fluid is displaced into the instrument. This is becoming less of a problem since modern electronic transmitters typically have displacements of less than 0.1 in.³ (1.6 cm³).

The use of diaphragm seals on vacuum service can be troublesome, but careful selection of fill fluid combined with high vacuum filling will usually allow satisfactory operation on low to medium vacuum services. If pressures go below the fill fluid’s vapor pressure or if dissolved vapors come out of solution, gas bubbles will be present and the filling fluid will no longer be incompressible. The higher the operating temperature (at any point along the capillary), the more severe this limitation becomes since temperature effects on vapor pressure are exponential. Therefore, it is suggested that devices other than liquid-filled chemical seals be used on high vacuum service. On low to medium vacuum services, Silicone 704 is recommended as the filling fluid, since its vapor pressure is less than 1.00 × 10⁻⁶ mmHg at near room temperature.

The measuring instrument can be direct-connected to the seal, or it can be connected by capillary tubing. In general, it is desirable to limit the tubing length to 25 ft (7.5 m) and to route the capillary through an area where the ambient temperature around the capillary and the instrument case is relatively steady and in the range of 50 to 110°F (10 to 43°C). Heat tracing can be added if the fill fluid can freeze or become unacceptably viscous at normally expected ambient temperatures. Some manufacturers will provide up to 50 ft (15 m) of capillary for special orders.

**Standard Seals**

Figure 5.2d illustrates the main components of a representative chemical seal: the upper and lower body and the diaphragm. The upper housing is in contact with the filling fluid only; therefore, if the environment is not corrosive, standard construction materials are acceptable. Once the seal is attached to the pressure instrument, either directly or through a capillary, the filling screw is used to fill the total system under vacuum.

Factory-filled seals furnished with the pressure instrument provide the most reliable sealed system, and can be provided by most suppliers if the length of the sensing capillary can be specified. However, field filling is also fairly common and can be accomplished reliably as long as a high vacuum source is available to evacuate the sensing line prior to and during filling, and as long as the fill fluids can be easily handled. It is important that the filling screw be reliably closed off without introduction of air. In some cases, the filling screw is further sealed by welding, or is replaced by a capillary which can be crimped and seal welded. One should not attempt to fill a system by simply pressure purging the fill fluid from one end to the other because even a tiny bubble can cause serious error.

The diaphragm seal assembly shown is a composite of several representative designs. Some seal manufacturers use a single diaphragm element welded to the upper housing. Others use a capsule consisting of a thin lower diaphragm bonded to a sturdy corrugated backup plate, and the whole assembly is screwed into the top housing. It is important that the diaphragm be as slack as possible, within the confines of necessary durability, so that it moves freely and hydraulically transmits the pressure without adding any differential. If the diaphragm is an elastomer, the outer edge of the diaphragm itself may be used as the sealing gasket.
Leakage is the most frequent source of seal failure. When it occurs, the diaphragm is pressed against the corrugated backup plate, which prevents diaphragm distortion and seals in the process pressure. (The instrument, however, ceases to operate.) Many designs incorporate a metal or elastomer valve and seat to stop any further flow into the capillary. The rupture pressure rating of conventional seals is 2500 PSIG (17 MPa). The diaphragm capsule is in contact with the process fluid, and therefore it is available in corrosion-resistant metallic construction or with a lining of Kel-F, Teflon, or a similar material.

The top section and the diaphragm capsule can often be removed while remaining connected to the associated instrument without disconnecting the bottom housing from the process. This feature allows the lower housing to be permanently welded to the process and enables the operator to clean the assembly without refilling or recalibrating the unit. Where elastomer seals are used on the diaphragm, a retainer ring is provided to allow this operation. The bottom housing, which is in contact with the process media as well as the atmospheric environment, is available in many corrosion-resistant metals or plastic materials. A flushing connection can be provided on the lower housing to flush the pressure chamber below the diaphragm. This allows for continuous or intermittent purge to remove the material buildup that may have accumulated below the diaphragm or in the connecting piping.

Selection of the bolting materials may be the primary determining factor in establishing pressure rating. If necessary to replace bolting, be sure to use bolts of the original strength class. Changing from high-strength carbon steel bolts to ordinary stainless steel bolts may reduce the pressure rating by 50%. Some designs do not use bolts, incorporating a pipe union type of joint, or a totally welded system.

Process Connections Every type of process connection, including sanitary spud or tri-clamp, can be accommodated for the process side of the seal. Figure 5.2e shows off-line seal design with screwed or flanged process connections. These units are utilized where the seal is needed to provide protection against corrosion or freezing. Due to the dead-ended cavity between the process line and the seal, these designs are not suitable to protect against plugging.

Figure 5.2f illustrates the in-line or flow-through designs in which the dead-ended cavities have been minimized. These units can be considered for both plugging and corrosive services, but their removal for maintenance necessitates the draining of the process pipe. Because the displacement in these seals is small, they are compatible with only small displacement-sensing elements, such as Bourdon tubes, force balance diaphragms, spiral and helical elements, or small-diameter bellows. For instruments with larger than 0.75 in. (19 mm) diameter bellows, the capacity of the standard seal is not sufficient to match the displacement of the pressure element, and large-capacity seals are needed. Such a design using a rolling diaphragm is illustrated in Figure 5.2g.

Self-Cleaning Seals

When plugging or material buildup is a very serious consideration, even the in-line seals shown in Figure 5.2f will not give satisfactory performance, and it is necessary to eliminate all cavities completely. This is achieved with the full-stream seal shown in Figure 5.2h. The three main components
of this seal are the flexible cylinder, the cast iron housing, and the end flanges. The space between the flexible sleeve and the housing is filled with the sensing fluid. The sleeve is available in neoprene, gum rubber, butyl, hypalon, ethylene propylene terpolymer, or Teflon, and the end flanges can be of stainless steel or other metals compatible with the process. This design eliminates all cavities and is applicable to low and medium pressure applications up to 200 PSIG (1.4 MPa).

These self-cleaning seals are also available in the wafer design, which can be inserted between 1 to 48 in. (25 mm to 1.22 m) flanges and can take up to 20,000 PSIG (138 MPa) pressure in the smaller sizes. For smaller pipelines, threaded units made out of steel, stainless steel, aluminum, or polyvinyl chloride can be obtained down to 0.5 in. (13 mm) connection size.

**Volumetric Seal Elements**

Figure 5.2i shows a number of volumetric seal designs, all of them consisting of a flexible member, a housing, and filling liquid to transmit the process pressure to the pressure instrument through a capillary tubing. Each of these devices serves to minimize or eliminate cavities. In the diaphragm units, there is a definite relationship between the process pressure to be detected and the required diaphragm area. Extended or wafer elements with greater than 2 in. (50 mm) diameter diaphragm surface areas can handle pressure spans from 0–50 to 0–1000 PSIG (0–350 kPa to 0–6.9 MPa).

The small button diaphragm designs will work with a minimum span of a few hundred pounds per square inch and can handle ranges up to 10,000 PSIG (69 MPa) or greater. The bellows design is more sensitive than the same diameter button diaphragm and can handle spans from 75 to 1,000 PSIG (0.5 to 6.9 MPa). This element, having flexibility in both directions, is more applicable to compound pressure applications than the other elements. The tube seal element is applicable to spans between 1,000 and 5,000 PSI (6.9 and 35 MPa).

The earlier discussion of chemical seal fill fluids, temperature effects, and spans also applies to volumetric elements. The construction materials for these units are more limited than those for standard seals. Stainless steel is the standard material for wetted parts, but more corrosion-resistant materials are also available. Liquid-filled, extended diaphragm seals can be obtained with extension lengths and diameters as needed to bring the diaphragm surface flush with the inside of the pipe or tank on which the seal is installed.

There may be applications where the requirements for low-pressure span, vacuum service, or process temperature considerations would make the liquid-filled seals undesirable but in which dead-ended cavities cannot be tolerated. If so, the extended diaphragm differential pressure cells discussed in Section 5.6 or the extended diaphragm pressure repeaters covered in Section 5.12 can be considered.

**FIG. 5.2i**

Volumetric seal elements.
Valve manifolds serve to simplify periodic calibration of pressure instruments. They can also allow the calibration, and even instrument replacement, during continued operation. This is particularly important for processes that rarely shut down, such as in power plants. Because the process fluids may be toxic, corrosive, radioactive, or otherwise noxious to personnel or the environment, it is necessary to protect against the release of these fluids during calibration.

A three-valve manifold, such as that shown by the solid lines in Figure 5.2j, may be used to serve this purpose. Valve P is used to isolate the process, D is the drain valve which discharges the process fluid from the instrument to a safe containment, and T can be used to flush any trapped fluid to the drain and to apply the calibration or test pressure. When applied to each side of a differential pressure instrument, as shown by \(P_H\), \(D_H\), \(T_H\), and the dashed lines, a bypass valve, B, is usually added. This can result in a seven-valve manifold. Proper operation of the valves (shut the high side process valve \(P_H\) then open the bypass B) allows verification of the instrument zero at actual operating pressure.

For pressure instruments with dual connections (the unused connection plugged), the valves T and \(T_H\) (or D and \(D_H\)) may be connected as individual valves in place of the plug in the otherwise unused connections. This permits flow-through purging of noxious fluids from the instrument. For a relatively low pressure system containing benign fluids, test valves and/or drain valves are often eliminated in favor of a simple straight-thread cap that can be safely loosened to relieve a drop or two residual fluid pressure and serve as the calibration connection. In the extreme, this results in a single valve and test tee. However, the most common choices of manufactured manifolds are the two-, three-, and five-valve arrangements.

With all the valves and connections preassembled into a manufactured manifold, space and field assembly time are saved and the chances for leaks are reduced. Manifolds are available to bolt directly to standard instruments in place of their normal flanged adapters and may be provided preassembled to the instrument.

Calibrations and Communicators

The dead-weight-type pressure testers and calibrators are described in Section 5.8. Portable, hand-held electronic pressure calibrators are also available. These units are provided with National Institute of Standards and Technology (NIST) traceable pressure readouts with inaccuracies of 0.1% of reading or better. For lower pressures (from a few inches of
water to 200 PSIG, or 14 bars), these calibrators can be provided with a small hand pump to provide a pressure source for calibration. Some models can store several sets of configuration data and the calibration procedures for each. Calibration data can be captured and stored for later trending or uploading to a personal computer (PC) or network server. One of the many capabilities of these calibrators is instant conversion between various systems of units.

The smart transmitters (see Section 5.1) can also be provided with digital indication and with memory for trending or record keeping. When integrated into a network or into a distributed control system, (DCS), PC-, or programmable logic controller-operated system, the calibration steps and the use of stored specifications can all be automated. The calibrator/communicator units range from the palm-sized through the suitcase-sized up to the rollaround packages. Most provide storage of multiple device protocol libraries so that communication is possible with almost any manufacturer’s transmitter. Some of the protocols in use, and their year of introduction, include ARCNet (1975), WorldFIP (1988), Highway Addressable Remote Transducer (HART) (1989), Foundation Fieldbus H1, (1995), and Profinet (2001).

Smart, microprocessor-based transmitters can be provided with communicators that are integral to, or separate from, the electronic calibration unit. These communication units allow the operator to modify zeroes or spans, change units, or verify the current values. If a PID algorithm is included in the smart transmitter, the communicator can be used to modify its setpoint or tuning values. Where transmitters are networked into a DCS system, it is not necessary to go to the transmitter to communicate with it. In such installations the individual transmitter can be accessed from the control room or engineer’s desk through the data highway.

Establishment of an industry-wide communication protocol for digital control systems (similar to the 3 to 15 PSIG [0.2 to 1.0 bar] or the 4–20 mA DC signal ranges that have been developed and accepted worldwide for analog control) still eludes consensus. Nevertheless, sufficient digital bridges and adapters are available so that a completely digital instrumentation system is likely to be possible in any particular plant or system. Also, there are now at least two wireless local area network communication standards—“Bluetooth” and IEEE-802.11b—that may be useful and appropriate for some installations.

Bibliography

“Improved Online Calibration” InTech, December 7, 2001