Tech Sheet #I 307

Selection Guide for Mechanical Pressure Gauges

SCOPE

The purpose of this document is to provide the user and/or specifier with general guidelines and considerations that will help simplify the selection process of mechanical pressure gauges (including vacuum gauges).

BACKGROUND

Mechanical pressure gauges are one of the most commonly applied field instruments for direct pressure measurement. While they have been in use for over 100 years, many technological advances have been made and continue to be made in their capabilities.

In the fast paced, highly competitive world of manufacturing, it's often easy to overlook the real reason pressure gauges are used. However, it's exactly that functionality that is so important in the selection process. Total operating expense, safety and operational efficiency can all be improved by the proper selection and use of the best pressure gauge for the intended application.

PRINCIPLES OF OPERATION

Before delving into the specifics of the proper selection process it may be beneficial to review the basics of operation.

Pressure and vacuum gauges are all dependent upon an elastic metal chamber (or sensor, most commonly referred to as a bourdon tube) that moves in a linear fashion in response to pressure increases or decreases and then transfers that motion to a movement which converts it to rotary motion, which in turn actuates the pointer.

Some of the more common measuring systems include:

The C-Type Bourdon Tube; the original and most commonly used shape received its name because it is shaped like the letter C.

The Coiled-Safety Bourdon Tube is typically round tubing that is spiral wound around a central axis. This typically provides greater surface area to more evenly spread out the stresses of mid to higher pressure ranges.

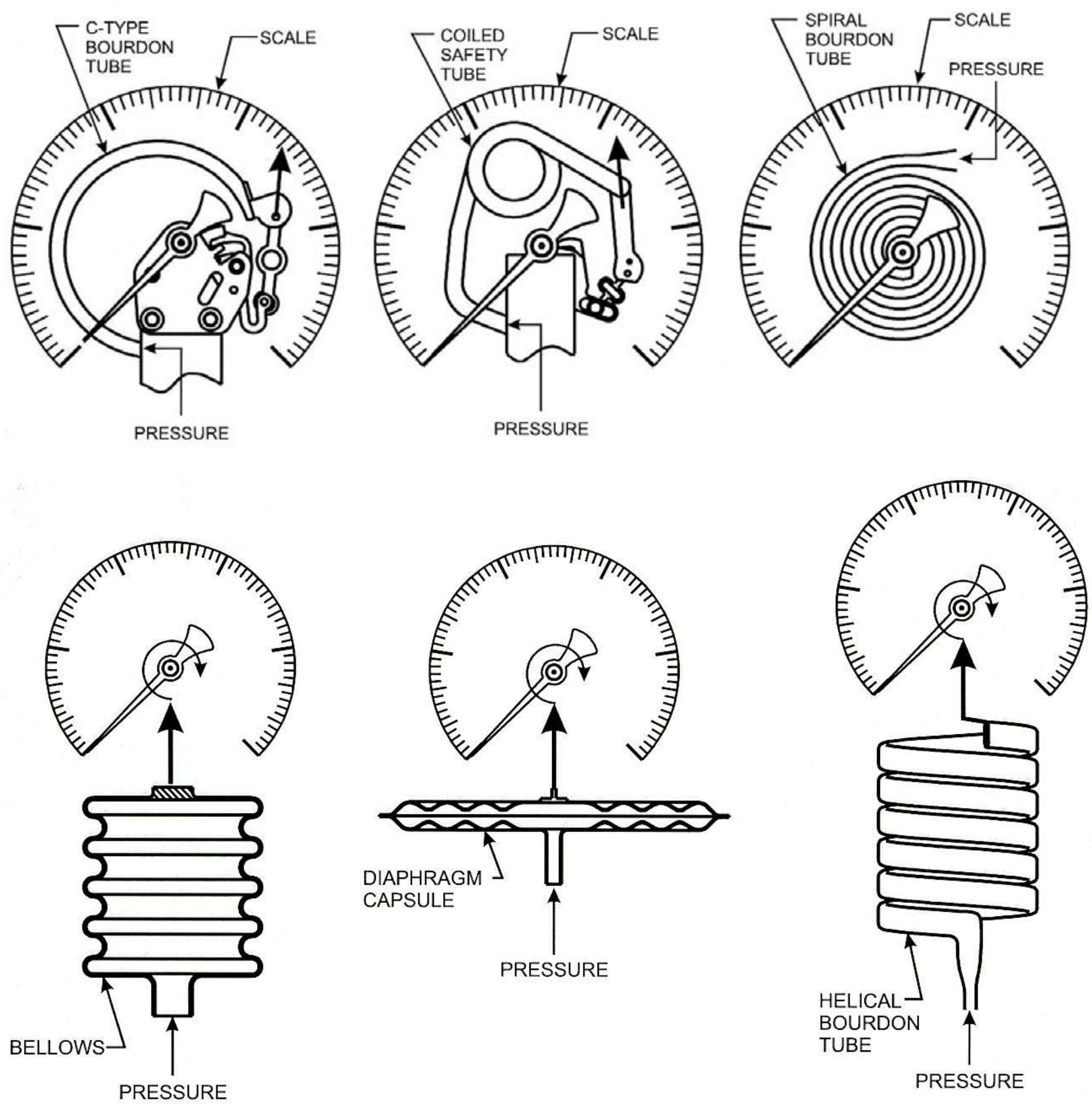
The Diaphragm Capsule is essentially two separate convoluted diaphragms attached to each other. These are typically used in applications of 0-10 psi and lower because of the greater sensitivity of this design.

The Bellows Capsule is a series of diaphragm capsules sharing a common pressure chamber and is used in similar applications to the diaphragm capsule.

The Helical Bourdon Tube is wound in an elongated helix with the pointer attached directly to the tube itself, thus eliminating the need for a separate movement. This design is also referred to as “direct drive”.

The Spiral Bourdon Tube is a spiral wound, low profile variation of the helical tube. It is a direct drive measurement system and is typically utilized in high volume, low cost applications where compact size is important requirements but higher accuracy and readability are not critical.

All of the above sensing elements have their place as they all present strengths and weakness’ dependent upon the specific application and use. Each manufacturer uses its best practices and knowledge in the design of its measuring elements and pressure gauges. It is not the purpose of this document to discuss those designs in detail; it is our intent only to assist the user in making better informed decisions.



SELECTION CRITERIA

By following a step by step process, the end user and/or specifier will be able to select the pressure gauge and accessories that will lead to the best service life, safety, reliability and value for the application.

Installing a pressure gauge without proper consideration of the application requirements is ill-advised and could possibly result in personal injury or death as well as loss of plant operation functions.

1. Process
   a. Medium Type of medium; this will determine the material used for the bourdon tube and socket of the gauge (typically copper alloy or 316 SS). The material must obviously be compatible with the medium being measured.
   b. Is the medium gaseous or fluid; is it viscous or does it contain solids. This will determine the functionality of the process port and whether an isolator or diaphragm seal may be necessary.
   c. What is the temperature of the medium and the ambient temperature? This may also influence the tube material and attachment method (copper alloy or 316 SS, soldered, brazed or welded?) It may also dictate use of a steam siphon or remote mounting of the gauge with a capillary and/or diaphragm seal to a cooler area to stay within the published temperature limitations of the gauge.

2. Application Dynamics
   a. Cycle rate
   b. Pulsation
   c. Physical shock
   d. Vibration
   e. Static Measurement

   On static pressure applications it is generally acceptable to use a standard dry (non-filled) pressure gauge, however, whenever shock, vibration pulsation or high cycle rates are present, a liquid filled gauge is normally recommended.

   When using liquid filled gauges it is important to be sure that the fluid fill is compatible with the medium being measured.

3. Accuracy
   Accuracy considerations take into account the measurement goal. Is it's intended use general monitoring, is it for general measurement that affects control functions or is it for precision measurement or testing. It's also important to note that accuracy is always expressed as a percentage of full scale (or span) and not as a percentage of indicated reading.

   Accuracy is also affected by both ambient and medium temperatures. Most manufacturers can provide temperature compensation formulas for applications that vary from standard reference calibration temperatures (typically 70°F/20°C).

   Additional consideration must be given to lower pressure and vacuum sealed case gauges, such as a liquid filled gauges due to the affect of barometric pressure changes and temperature changes on the internal case pressure which may affect accuracy. It is a generally accepted practice to provide a venting mechanism on these gauges.

It is important to be realistic about the accuracy criteria as it affects many other selection points. The most accurate gauge offered by a manufacture may not necessarily be the best for your application; as an example; a ¼% Test Gauge will likely fail in its first hour of use on a high cycle, dynamic application and a 2.5% industrial gauge may not provide the accuracy or resolution on a critical test application.

Please refer to the manufacturer's guidelines and specifications for more detail.

4. Pressure Range
   Considerations here are either static or dynamic pressure measurement.
   a. Static Pressure; in most static applications the upper pressure range of the application should not exceed 90% of gauge range.
   b. Dynamic Pressure; in all dynamic applications the full scale of the gauge must be higher than the highest possible pressure spike or surge. It is generally accepted that the user should select a range approximately twice the normal operating range being measured. It is also a common practice to incorporate an orifice restrictor in the gauge connection or to use a separate pressure snubber to help protect the measuring system from the worst affects of pressure spikes or surges often found in dynamic applications.

      Another consideration is the engineering unit of the measurement. It is always recommended that the user consult with the manufacturer for more specific guidelines in the pressure range selection process and the various available measuring scale variations.

5. Size & Mounting
   a. Readability and accuracy determine size. How far away must the gauge be read at and what is the level of accuracy of that reading?
   b. Connection Size and Location are both important considerations. Direct mounting of the gauge to the measured pressure is preferred over reducers or adapters as there are fewer leak paths. Additional considerations include the connection location. Most manufacturers offer bottom, back and side connection options to allow the gauge face to be in the convenient location for readability. Other possibilities may include various options for panel mounting.

6. Safety
   Because pressure gauges, by their very nature, are sealed pressure vessels inside of another enclosure consideration must be given to the affects of a catastrophic (or bourdon tube) failure.

   In a worst case scenario of a catastrophic failure, the inside of the gauge case will rapidly fill with the pressurized medium. To relieve this pressure build-up, the gauge should incorporate some type of pressure relief mechanism that allows the pressure to escape in a direction other than the face of the gauge.

Examples of "relief mechanisms" may include:

a. Blow-out plug. This may be located on the top, side or rear of the gauge case.
b. Solid Front or Safety Case. In this design the measuring system is separated from the face of the gauge by a solid protection plate between the dial and the bourdon tube. The entire back plate of the gauge then serves as a blow-out device to vent the pressure out the rear of the gauge.
c. Open Case design. In this most simplistic form, a gap or opening is typically provided between the gauge socket and the gauge case. This is common on standard utility gauges found in many non-critical applications.

7. Specialized Gauge & Application Considerations
   There are a number of specialized applications which call for specialized or application specific gauges. Some of these application specific gauges include, but are not limited to:

a. Boiler Gauges; which typically pairs the lower cost of a standard duty gauge with the higher temperature brazing or solder to withstand the higher temperatures of boiler applications.
b. Refrigeration Gauges: which are specifically designed, color-coded and scaled for freon refrigeration applications.
c. Water Discharge Gauges; which typically incorporate a standard hose bib connection and in some cases a separate relief mechanism.
d. Welding and/or Compressed Gas Gauges: which often incorporate a non-magnetic case, higher volume blow-out capabilities and are specifically cleaned to insure that no oils, solvents or hydrocarbons are present that may react violently with oxidizing gases.
e. Precision Test Gauges; that incorporate specific materials to maximize the accuracy and repeatability of the gauge along with mirrored scales and knife edge pointers to eliminate hysteresis and improve readability.
f. Ultra High Pressure Gauges; typically designed for measuring ranges of 0-20,000 psi through 0-100,000 psi. These gauges typically are constructed of special alloys that will tolerate the higher stresses of the elevated pressure requirements. They also incorporate special high pressure connections designed specifically for the applications. And, they usually incorporate increased blow-out and safety features due to the often dangerously high pressures encountered.
g. Retard Gauges; are gauges that expand the lower end of the scale reading and retard the upper end of the scale reading. They're typically used where pressure spikes may be encountered during start up of a system but normal operating pressures are considerably lower. There most common application is in the refrigeration industry.
h. Differential Gauges; are gauges that have both a high side and low side pressure input and indicate the difference between these two input pressures. They're often used in applications where pressure drop is critical, in flow measurement applications and in tank blanketing applications to determine accurate tank content levels.
i. Duplex Gauges; incorporate two inputs but enable the user to read both inputs on the same dial scale. Their primary use is in applications where multiple systems must be balanced.
j. Contact Gauges; also referred to as Switch Gauges employ the local indication of a standard pressure gauge and perform a switch function as well.

k. Sanitary Gauges; are designed to meet the cleanliness requirements of the food, beverage and pharmaceutical industries. They are typically attached to a flush-face isolator or diaphragm seal and have smooth finishes and fittings which resist contaminant build-up. They also lend themselves to high temperature cleaning and sanitation methods used on regular basis within their industry.

8. Optional Attachments
This document has referred to various attachments that are application specific. And while not complete, some of the more common attachments include:
a. Diaphragm Seals; which isolate the measured medium from the Gauge.
b. Capillary lines: which facilitate mounting the gauge away from the direct pressure source.
c. Orifice restrictors; are inserted into the gauge connection to serve as chokes or restrictors which help slow down the affects of pressure surges and spikes.
d. Pressure Snubbers; are separate attachments intended to slow down the affect of pressure surges and spikes.
e. Isolation, Shut-off or Gauge Valves; are simply valves installed between the gauge and the pressure source to facilitate changing or calibrating the gauge without shutting down the process. These are always recommended.
f. Maximum Indicating Pointers; indicate the highest recorded pressure attained until manually reset. These are an excellent diagnostic tool.
g. Set Pointers; are generally used to manually indicate the normal working pressure of a process or system.

9. Reference Documents
A number of Standards Documents exist that may cover specific applications. The two common "Standards" that directly relate to Pressure Gauges are listed below and are available through FCI or ASME. Additional Specialty Gauge Standards are typically available through that industry's Standards organization such as UL or 3A as examples.

a. ASME B.40 Pressure Gauges and Gauge Attachments
b. EN 837 Bourdon Tube Pressure Gauges, Dimensions, metrology, requirements and testing.

Additional FCI Instrument Selection Guides and related information that the user may find beneficial are available through the Fluid Controls Institute.

Please refer to the FCI website listed on this document to obtain FCI Standards, FCI Selection Guides and ASME Standards.

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INSTRUMENT SECTION MEMBERS and WEBSITES

AMETEK, U. S. GAUGE DIVISION

BURKERT FLUID CONTROL SYSTEMS

MID-WEST INSTRUMENT

MOELLER INSTRUMENT CO., INC.

NOSHOK, INC.

ORANGE RESEARCH

THUEMLING INSTRUMENT GROUP, INC.

TREND INSTRUMENTS INC.

WEISS INSTRUMENTS, INC.