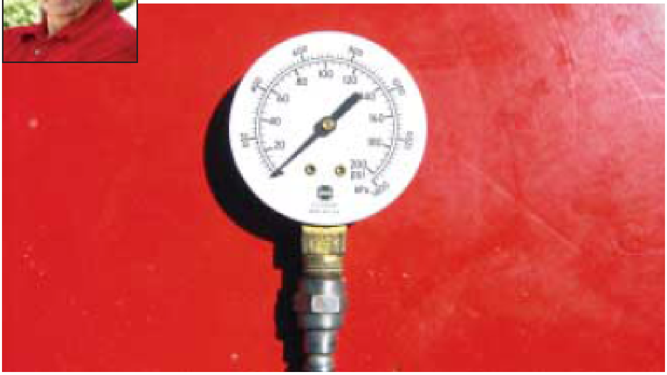
Mechanic's Corner with Eddie Konrad



Under Pressure

Many techniques have been developed for pressure and vacuum measurement. The instruments used to measure pressure are called pressure or vacuum gauges.

A manometer is a pressure-measuring instrument, usually limited to measuring near-to-atmospheric pressures. The term manometer is often used to refer specifically to liquid column hydrostatic instruments.

A vacuum gauge is used to measure the pressure in a vacuum, which is further divided into two subcategories: low and high vacuum (and sometimes ultra-high vacuum).

Although pressure is an absolute quantity, everyday pressure measurements (*i.e.* tire pressure) are usually made relative to ambient air pressure. In other cases, measurements are made relative to a vacuum or to some other ad hoc reference.

Tire pressure is a gauge pressure by convention, while atmospheric, deep vacuum and altimeter pressures must be absolute. Differential pressures are commonly used in industrial process systems. Differential pressure gauges have two inlet ports, each connected to one of the volumes whose pressure is being monitored. In effect, such a gauge performs the mathematical operation of subtraction through mechanical means, obviating the need for an operator or control system to watch two separate gauges and determine the difference in readings.

Atmospheric pressure is typically about 100 kPa (kilopascals) at sea level, but is variable with altitude and weather. If the absolute pressure of a fluid stays constant, the gauge pressure of the same fluid will vary as atmospheric pressure changes. For example, when a car drives up a mountain, its tire pressure rises.

The unit for pressure is the Pascal (Pa), equal to one Newton per square metre (N/m^2 or kg m-1s-2). This special name for the unit was added in 1971; before that, pressure was expressed in units such as N/m^2. When indicated, the zero reference is stated in parenthesis following the unit—for example, 101 kPa (abs). Pounds per square inch (psi) is still in widespread use in the U.S. and Canada, notably for cars. A letter is often appended to the psi unit to indicate the measurement's zero reference—for example, psia for absolute, psig for gauge or psid for differential.

Since pressure was once commonly measured by its ability to displace a column of liquid in a manometer, pressures are often expressed as a depth of a particular fluid (*i.e.* inches of water). The most common choices are water and mercury (Hg). Water is nontoxic and readily available, while mercury's density allows for a shorter column (and thus a smaller manometer).

Although no longer favoured by measurement experts, these manometric units are still encountered in many fields. Blood pressure is measured in millimetres of mercury in most of the world and measurement of lung pressures in centimetres of water is still common. Natural gas pipeline pressures are measured in inches of water, expressed as WC (water column). Scuba divers often use a manometric rule of thumb: the pressure exerted by a depth of 10 metres is approximately equal to one atmosphere. In vacuum systems, the units torr micrometer of mercury (micron), and inch of mercury (inHg) are most commonly used. Torr and micron indicate an absolute pressure, while inHg usually indicates a gauge pressure.

Atmospheric pressures are stated using kPa or atmospheres (atm), except in American meteorology where the hectopascal (hPa) and millibar (mbar) are preferred.

While static gauge pressure is of primary importance to determining net loads on pipe walls, dynamic pressure is used to measure flow rates and airspeed. Dynamic pressure can be measured by taking the differential pressure between instruments parallel and perpendicular to the flow. Pitot-static tubes, for example, perform this measurement on airplanes to determine airspeed.

Hydrostatic gauges (such as the mercury column manometer) compare pressure to the hydrostatic force-per-unit area at the base of a column of fluid. Hydrostatic gauge measurements are independent of the type of gas being measured, and can be designed to have a very linear calibration. They have poor dynamic response.

Piston-type gauges counterbalance the pressure of a fluid with a solid weight or a spring (*i.e.* dead-weight testers used for calibration and tire-pressure gauges.)

Aneroid gauges are based on a metallic pressure-sensing element that flexes elastically under the effect of a pressure difference across the element. Defined as "without fluid," the term aneroid originally distinguished these gauges from the hydrostatic gauges described above. However, aneroid gauges can be used to measure the pressure of a liquid as well as a gas, and they are not the only type of gauge that can operate without fluid. For this reason, in modern language, they are often called mechanical gauges. Aneroid gauges are not dependent on the type of gas being measured, unlike thermal and ionization gauges, and are less likely to contaminate the system than hydrostatic gauges. The pressure sensing element may be a Bourdon tube, a diaphragm, a capsule or a set of bellows, which will change shape in response to the pressure of the region in question. A linkage connected to a needle may read the deflection of the pressure-sensing element, or it may be read by a secondary transducer.

In 1849, Eugene Bourdon patented the Bourdon tube pressure gauge. The pressure-sensing element is a closed, coiled tube connected to the chamber or pipe in which pressure is to be sensed. As the gauge pressure increases, the tube uncoils, while reduced gauge pressure causes the tube to coil more tightly. This motion is transferred through a linkage to a gear train connected to an indicating needle. The needle is presented in front of a card face inscribed with the pressure indications associated with particular needle deflections. In a barometer, the Bourdon tube is sealed at both ends and the absolute pressure of the ambient atmosphere is sensed. Differential Bourdon gauges use two Bourdon tubes and a mechanical linkage that compares the readings.

Mechanical specs of a gauge

Stationary parts

- **Receiver block:** This joins the inlet pipe to the fixed end of the Bourdon tube and secures the chassis plate. The two holes hold screws securing the case.
- **Chassis plate:** The face card is attached to this. It contains bearing holes for the axles.
- **Secondary chassis plate:** This supports the outer ends of the axles.
- **Posts:** To join and space the two chassis plates.

Moving parts

- **Stationary end of Bourdon tube:** This communicates with the inlet pipe through the receiver block.
- **Moving end of Bourdon tube:** This end is sealed.
- Pivot and pivot pin.
- Link joining pivot pin to lever, with pins to allow joint rotation.
- **Lever:** This is an extension of the sector gear.
- Sector gear axle pin.
- Sector gear.
- **Indicator needle axle:** This has a spur gear that engages the sector gear and extends through the face to drive the indicator needle. Due to the short distance between the lever arm link boss and the pivot pin, and the difference between the effective radius of the sector gear and that of the spur gear, any motion of the Bourdon tube is greatly amplified. Small motion of the tube results in large motion of the indicator needle.
- **Hair spring:** This pre-loads the gear train to eliminate gear lash and hysteresis.