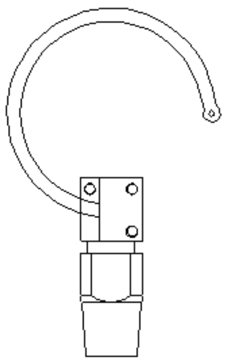
PRESSURE SOLUTIONS

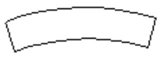
P103: Pressure Gauge Theory

There are basically 3 mechanisms which may be found in a mechanical pressure gauge. Almost all pressure gauges for industrial use above 50 kPa use a bourdon tube.

Bourdon Tub e:

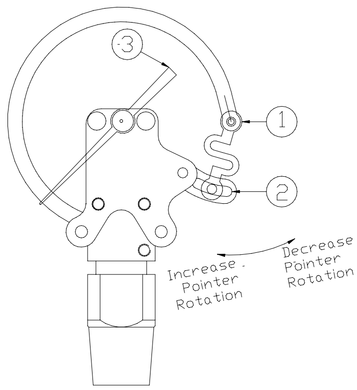
The bourdon tube is made from a section of tube, rolled into a circular shape, and fixed at one end. This may be a C-shape as shown, or may form a helix.





If we consider a small section, with pressure on the inside, we can see that the area on the outside is greater than the area on the inside. This results in a net resultant force which wants to straighten the tube. As long as we are working within the yield point of the material, the tube will act as a spring, and the tube will deflect until the spring force matches the unbalanced pressure resultant.

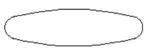
The mathematics are quite complex, but the end of the tube will describe a curve moving upward and outward.



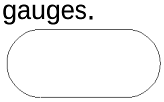
To make a pressure gauge, we need to convert this curvi-linear motion into a rotary motion. If we magnify this motion, we approximate to straight line motion, and obtain a more linear relationship between tube travel and pointer rotation. The movement consists of a quadrant, which has a C-shaped section of gear (not shown) at one end which meshes with a pinion on the pointer shaft. The other end is slotted as shown, and there is a pivot in the middle. Thus the movement of the end of the tube pulls the link which pulls the quadrant and causes it to rotate against the pointer shaft pinion, which causes the pointer to rotate.

In a properly designed bourdon tube pressure gauge, the accuracy will be within 1%. When great care is taken, as for test gauges, linear scales can be produced to at least 0,2% FS.

The cross-section of the bourdon tube does not matter from a theoretical point of view. In practice, we come across the following shapes:-



Elliptical cross sections are the most sensitive, giving the most movement for a given pressure. The small radius at the edges is a stress raiser and reduces the life of the tube. This cross-section is used for low pressures, typically 60 to 100 kPa on the Blanes 100mm gauges.



Flat oval cross sections are stronger, yet still fairly sensitive. This cross-section is used for medium pressures, typically 160 kPa up to as high as 25 MPa.

For high pressures, a circular cross section is used. This is the strongest shape, but not sensitive, so multiple turns are used in a helical arrangement to provide sufficient movement. This is the normal design for high pressure gauges, from 6 MPa upwards.

Schaffer Diaphragm:
This design is as old as the bourdon tube. It consists of a circular corrugated diaphragm which acts like a flat spring.

The outer diameter of the diaphragm is clamped. Pressure applied underneath will move the centre part upwards. This element is not very common today, because it is not as accurate as the bourdon tube, and more difficult to make, hence more expensive. It has some advantages, mainly that it can be used for low pressure measurement of liquids.

Capsule and Bellows:
The Schaffer diaphragm has a lower limitation typically 1 to 5 kPa. To measure lower pressures, down to about 250 Pa, we can increase the movement from a diaphragm by fastening two together, sealed at the outside with the pressure on the inside. Two diaphragms make up a capsule. If more are used, we make a bellows. The more diaphragms used, the greater the sensitivity. Capsules and bellows are usually used with gases only since the effect of liquid inside the element can cause significant errors.

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