2CV OIL BREATHER

By Graeme Dennes

Revision 5

Background:

The Citroen 2CV engine is a horizontal flat twin-cylinder engine in the "boxer" configuration, i.e. where the two pistons are at top dead centre together and at bottom dead centre together. Because of this, as the pistons move inwards (towards the crankshaft), a positive pressure is formed in the crankcase because of the effective decrease in crankcase volume, while as the pistons move outwards (away from the crankshaft), a negative pressure (vacuum) is formed in the crankcase because of the effective increase in crankcase volume.

This results in a cyclical sequence of positive pressure pulses followed by negative pressure pulses within the crankcase over each revolution of the crankshaft. The ± crankcase pressure cycles are characteristic of the twin-cylinder boxer engine. (The four-cylinder boxer design does not suffer the ± pressure changes because it can be arranged so that when the two pistons of one pair are at top dead centre, the two pistons of the other pair are at bottom dead centre, resulting in net zero crankcase volume change as the crankshaft rotates, so net zero crankcase pressure change.)

And the problem is…?

Photo 1. 2CV Oil Breather

A key issue for engine designers is that *positive* pressure must never exist in the crankcase because it will cause the engine oil to be pushed out of every available crankcase orifice such as the crankshaft seals. Therefore, for an engine design to be practical, steps must be taken to ensure the crankcase always maintains a negative pressure (vacuum).

How did Citroen address this issue for the 2CV boxer engine which produces the ± pressure cycles in the crankcase? And the solution is…? It is addressed in a very simple and reliable manner with a crankcase ventilation system managed by the oil breather. The oil breather, shown in Photo 1 on the left courtesy of Der Franzose, is the small metal cylindrical device fitted at the top front of the engine, just to the rear of the oil cooler. It is best known as the engine's oil filling point via its sealed, hinged, latched cap at the top. The oil breather contains two rubber valves which have their inlet linked to the crankcase through the base and their outlet linked to the air filter housing via the rubber tube fitted to the upper metal spigot.

Consider the engine's pistons are moving towards the crankshaft (i.e. away from the heads). The resulting decrease in crankcase volume will create a positive pressure inside the crankcase which causes the rubber valves in the oil breather to be pushed open.

This allows the positive crankcase pressure to be immediately discharged into the air filter housing via a rubber tube. By this means, the crankcase experiences only a smidgen of positive pressure on the positive pressure cycle, of a level which is just enough to open the valves.

Now consider the pistons are moving away from the crankshaft (i.e. towards the heads). The resulting increase in crankcase volume will create a negative pressure (vacuum) inside the crankcase. This negative pressure "pulls" on the rubber valves in the oil breather, causing them to be held closed, effectively trapping the negative pressure inside the crankcase.

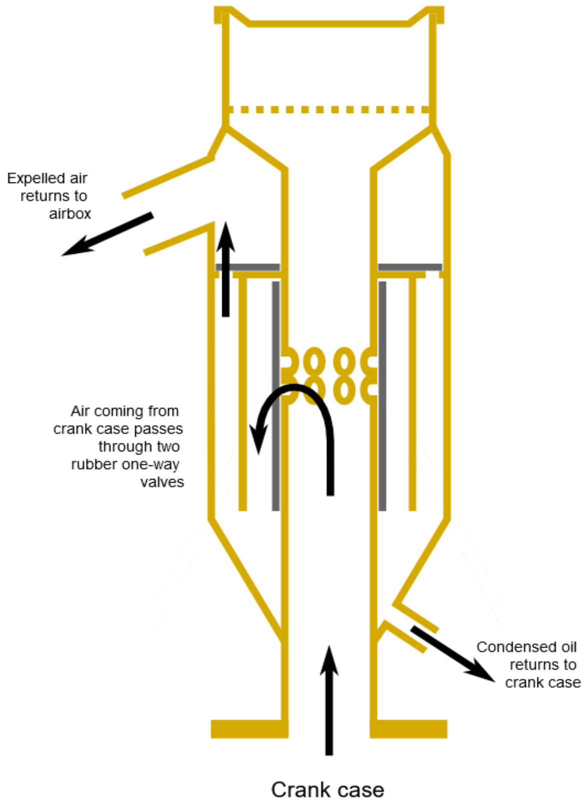

Figure 1. Oil Breather Internal Structure

Thus, during 2CV engine operation, the oil breather ensures the pressure in the crankcase cycles between the limits of nominally zero pressure and negative pressure over each revolution of the crankshaft. The result is that the (viscous) engine oil experiences a net negative pressure in the crankcase of a value around the centre of the two cyclical limits. This small ongoing vacuum ensures the 2CV boxer engine doesn't push its oil out through its engine seals. Problem solved. QED.

Figure 1 on the left shows the internal structure of the 2CV oil breather, including the locations of the two rubber valves (in black). The inner (lower) valve is in the form of a cylindrical rubber sleeve which is pushed open (outwards) by positive crankcase pressure. The outer (upper) valve is in the form of a flat rubber annulus which is pushed open (upwards) by positive crankcase pressure. When engine oil is added to the oil breather, it runs down through the protective mesh at the top and directly down into the crankcase via the open centre tube.

All very simple, very clever, very reliable and so very important for the proper operation of the 2CV engine. Figure 1 is courtesy of Colonel Sponsz's Shared Items with grateful acknowledgement and appreciation. This is the first functional drawing of the internal structures of the oil breather the writer has seen. The basis of its operation can now finally be understood. Refer to the page: https://shared.yellowgrey.com/2016/08/28/testing-2cv-crank-case-vacuum-with-a-manometer/

A small amount of oil vapour in the air inside the crankcase will invariably make its way through the oil breather, along with the air discharged on the positive pressure cycles. The air and oil vapour are taken to the air filter housing and mixed with the incoming fresh air and burned in the engine. Any oil vapour which condenses inside the oil breather is returned to the engine via the small drain tube at the base, which connects to the dipstick tube via a short rubber tube.

During engine operation, air drawn into the engine via the air filter and carburettor results in a small negative pressure being developed within the air filter housing. This small negative pressure reaches the oil breather valves via the rubber tube connected to the oil breather and assists the oil breather to extract the air and oil vapour from the crankcase on the positive pressure cycles. A team effort!

Thus, the proper operation of the oil breather and the rubber tube running to the air filter housing are critical to the operation of the 2CV engine.

Some of the oil in the oil vapour taken to the air filter housing invariably settles in the bottom of the air filter housing. Watch out for it when the air filter housing is being removed!

Photo 2. Disassembled 2CV oil breather. Photo courtesy of the Burton Car Company.

Citroen provides a specification for the crankcase vacuum, stating it must be not less than 50 mm Water Gauge (WG) at idle and should never fall to zero at any engine speed above idle. For reference, 50 mm WG vacuum is around −0.07 PSI, a very small, almost imperceptible figure. How do we check this figure to confirm the proper operation of the oil breather? Well, because it is such a small (negative) pressure, a typical pressure gauge is not suitable for the task. It requires measurement by a water manometer, a much more sensitive pressure gauge for such small pressures.

Er, measurement by *what??*
Before continuing, the reader is referred to the section titled Manometer Principles at the end of this article for further information about manometers.

The reader is also referred to the Wikipedia article:
https://en.wikipedia.org/wiki/Pressure_measurement#Liquid_column_(manometer)

The writer suggests reading the remainder of this article at least a couple of times before conducting the manometer tests to ensure a solid understanding is gathered of the overall process and the steps involved.

The Engine Oil Leak Problem:
One reason why we may be drawn to consider checking the crankcase vacuum is because of the appearance of unexplained oil on the outside faces of the engine or on the floor under the engine. Either of these will usually get our attention! However, as oil leaks can occur for several reasons, we need to determine the underlying cause of the leaks.

Initial Diagnostic Steps:

1. If your engine is showing signs of an oil leak, the first step in the diagnostic process is to run a compression test on each cylinder.
   a. Run engine to reach operating temperature.
   b. Stop engine.
   c. Disconnect one of the two wires from the ignition coil primary winding terminals (not the plug leads). This is a vital step!
   d. Remove both spark plugs.
   e. Do the compression test on each cylinder in turn with the throttle **held wide open**. (We want to achieve the maximum compression pressure possible in the combustion space). Record the pressure readings.
   f. Refit both spark plugs and attach the plug leads.
   g. Reconnect the wire to the ignition coil primary winding terminal.
   h. If the compression test **passes**, then either an engine oil seal is faulty or the crankcase vacuum is low, so continue to step 2.
   i. If the compression test **fails**, then it indicates wear in the rings, pistons, cylinders and/or the valves and valve seats. An engine repair is imminent.
2. Do a water manometer test on the crankcase vacuum per the steps below.
   a. If the manometer test fails, then the oil breather is faulty and needs to be repaired or replaced.
   b. If the manometer test passes, then an engine oil seal will be faulty and needs to be replaced.

Essential Preliminary Checks for the Manometer Test:

Before proceeding with the manometer tests to check for the proper operation of the oil breather, it is essential the following three items are checked and confirmed to be doing their jobs perfectly, otherwise the manometer tests will be invalid. These must be correct.

1. Check that the rubber ring inside the top cover of the oil breather is in a sound condition and it properly seals the oil breather when the cover is closed.
2. Check that the short length of rubber hose connecting the oil breather drain tube to the dipstick tube is in a sound condition and properly seals against the two metal tubes.
3. Check that when the dipstick is in place, the small plastic “plug” at the top of the dipstick fully seals off the dipstick tube opening.

If air is allowed to enter the crankcase through any of these openings, **the crankcase vacuum will be reduced and not show the true reading**. Be satisfied that these three items **do not** allow air to enter and impair the crankcase vacuum.

The Manometer Test Procedure:

After you have confirmed the preceding three items are correct, then using Photo 3 on the next page as a guide, it is easy to make a water manometer from around four metres of 12 mm inside diameter (I.D.) clear polythene tubing. The length and diameter of the tubing are unimportant. The writer selected 12 mm I.D. tubing because it fitted nicely over the dipstick tube opening (after the dipstick was removed!).

The path of the **continuous (uncut) length of tubing** is shown by the orange lines in Photo 3, starting at the dipstick tube.

Remove the dipstick and fit one end of the polythene tube over the open end of the dipstick tube and ensure it is properly sealed off by running a few turns of electrical tape around the end of the polythene tube. If the tubing is not properly sealed off at the dipstick tube, the manometer readings will not be accurate.

Run the tubing upwards (tube section 1 in the photo) from the dipstick tube. Using a length of cord, tie and support the tubing at the front nose of the bonnet, *as high as possible from the ground*. Keeping this section of the tubing high will help to ensure the water in the tubing won't be drawn into the engine, otherwise an engine oil and filter change will be the next immediate task to be done after the engine is **very quickly** switched off!

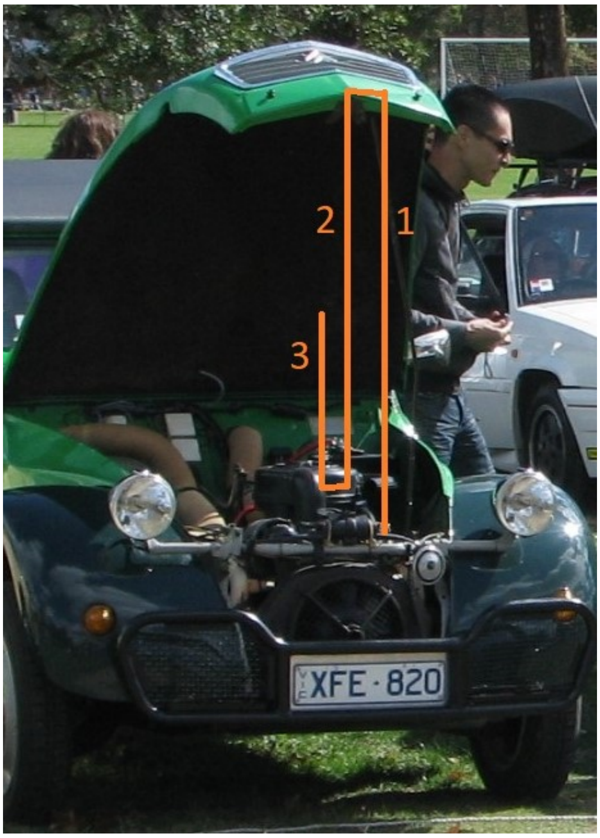

Photo 3. Manometer tubing arrangement

Now, after ensuring the tubing isn't pinched off at the top, allow the tubing to drop downwards (tube section 2). Forming a "U" bend at the bottom of tube section 2 without pinching off the tube, run the last section of tube (tube section 3) upwards for a length of around 600 mm, running it alongside tube section 2. Wrap some electrical tape around tube sections 2 and 3 to keep them close together for easy management and measurement of the difference in heights of the two water columns.

Ensure the bends in the tubing do not pinch off the tubing. Some amount of air must be able to flow through the top bend and some amount of water must be able to flow through the bottom bend. It doesn't have to be much, but it does have to be some! The upper end of tube section 3 **must remain open to atmosphere.**

The one and only critical part is that **tube section 3 and the part of tube section 2 taped to it are held vertical at the point where the height measurement is taken**, ie the water columns must be vertical. The rest of the tubing doesn't have to be vertical. In fact, the loop of tube at the bottom of tube sections 2 and 3 could be formed from a loop of tube lying loosely on the ground. The length of tubing and quantity of water have no bearing on the operation or accuracy of the manometer. An exceedingly simple but sensitive and accurate pressure measuring instrument!

When all is ready, add sufficient water to the open end of tube section 3 until the top of the water column is around half-way up tube section 3. The tops of the two water columns must be clearly visible so the height difference between them can be easily observed and measured with a ruler. Note: The quantity of water added is unimportant.

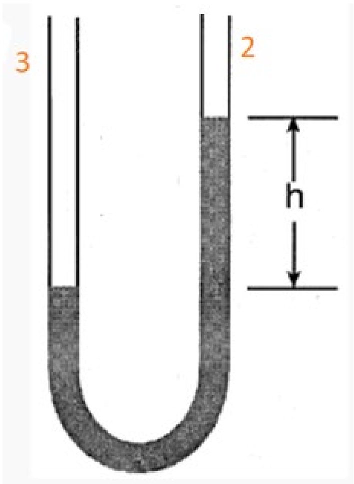

Figure 2

Ladies and Gentlemen, start your engines, er, engine, **but don't take it above idle at this stage.** As an initial Mk. I eyeball check, with tube sections 2 and 3 being held vertical, the crankcase vacuum, at idle, should cause the water level in tube section 2 to rise **above** the water level in tube section 3 per Figure 2 at left, indicating the presence of a vacuum in the crankcase. All good so far.

If the tops of the water columns are at the same level, it indicates zero vacuum is present, while if the water level in tube section 2 is **below** the water level in tube section 3, it indicates positive pressure is present, and you may find oil on the ground under the engine! Yikes!! The latter two indications confirm the oil breather is faulty and needs **immediate** repair or replacement.

So long as some amount of crankcase **vacuum** is present, ie, the water column in tube section 2 is above the water column in tube section 3, we'll continue on. While tube sections 2 and 3 are being held vertical, measure the height difference *h* between the tops of the water columns in the two tubes with a ruler (per Figure 2). The reading in millimetres is the measure of the crankcase vacuum in millimetres WG. Per Citroen's specifications, the vacuum should be greater than 50 mm WG at idle, i.e. height *h* in Figure 2 should be greater than 50 mm. If it is less than 50 mm, the oil breather needs repair or replacement.

If the vacuum reading is greater than 50 mm WG at idle, all is good so far. Preferably using a tachometer, increase the engine speed in steps of say 1000 RPM up to a maximum of 5000 RPM, pausing between steps to allow the water levels in the columns to stabilise as much as possible and then measure the height *h* between the two columns. Record all height readings.

Per Citroen's specifications, the vacuum should never fall to zero at any engine speed above idle, i.e. height *h* should never fall to zero. If it does, the oil breather will need to be repaired or replaced.

All done. You now have a detailed record of the performance of the oil breather in your 2CV.

If the manometer test confirms the oil breather is faulty, it will need to be repaired or replaced. The 2CV parts supplier Der Franzose sells an oil breather per Photo 1 as part number 10031. The writer fitted this product to the new engines in his two 2CVs. Perfect results. For reference, the manometer readings for both new engines with Der Franzose oil breathers was approx. 250 mm WG at idle.

Another option is to repair it. The Burton Car Company sells a repair kit for the oil breather as part number A1.4456. Refer to the following video link for information. Also shown in the video are the two rubber valves inside the oil breather – the inner valve is a rubber sleeve and the outer valve is a rubber disc as previously noted and as shown in Photo 2. The height difference on another 2CV which had the oil breather rebuilt using the Burton kit was around 450 mm WG at idle. The *maximum* value of the height difference *h* is not the issue. It's the *minimum* value.

https://www.youtube.com/watch?v=DDoUHrvPyJk

Finally and importantly, *always* ensure the oil breather cap is securely closed during vehicle use, otherwise oil can be ejected from the oil breather and deposited over the engine, the engine bay and the underneath face of the bonnet. An unwanted mess!

In conclusion, the oil breather in your 2CV is now over 30 years old, and its rubber valves may well have lost their resilience and become stiffened to the point where they are no longer able to retain the crankcase vacuum to ensure retention of the engine oil. If the vacuum in your engine crankcase is outside of Citroen's specifications, engine oil leaks will be starting very soon in a 2CV near you, so keep the drip tray under the car and carry spare oil!

Look after the crankcase vacuum in your 2CV. Is yours working to specifications?

PRESSURE CONVERSION FROM MM WATER GAUGE TO PSI

Citroen's specification for the minimum allowed crankcase vacuum (negative pressure) at idle is 50 mm Water Gauge (WG). What is that figure in psi? Easy, but first we need to do some calculations.

In old units, consider a column of air of **one square inch cross-section** and of a height to the outer limit of our atmosphere (say 300 miles). **It weighs 14.7 pounds**. This is the basis of the definition of standard atmospheric pressure and is how the value comes about. It is the weight or downward force resulting from gravity acting on the air molecules in the 300-mile high column of air of one square inch cross-section.

Thus, atmospheric pressure exerts a **weight (force) of 14.7 pounds** on every square inch of surface of the planet, i.e. it exerts a **pressure of 14.7 pounds per square inch** or 14.7 psi.

Now consider a column of water also of one square inch cross-section. What column height will have a weight of 14.7 pounds?

Now, one cubic inch of water has a weight of 0.0361 pounds (you knew that!), therefore the height of a column of water of 1 square inch cross-section is:

Height = weight of column / weight of one cubic inch

= 14.7 / 0.0361

= 407.2 inches (approx. 33.93 feet)

Thus a column of water of one square inch cross-section and 407.2 inches high weighs 14.7 pounds, the same weight as a column of air of one square inch cross-section and 300 miles high! Thus, as each of these one square inch columns weighs 14.7 pounds, both exert a pressure of 14.7 pounds or 1 atmosphere on every square inch.

Therefore pressure can be reported in units of psi, where 1 atmosphere = 14.7 psi, or in units of Water Gauge (WG), where 1 atmosphere = 407.2 inches WG. Therefore 14.7 psi = 407.2 inches WG, which is the basis for the conversion from one measurement to the other.

As Citroen's specification for the minimum crankcase vacuum at idle is 50 mm WG at idle, and as 1 inch = 25.4 mm, the conversion from mm WG to psi is given by:

= 50 / 25.4 / 407.2 x 14.7

= 50 / 704

= 0.07 psi

Knowing that Citroen's WG figure represents a vacuum or negative pressure, the crankcase pressure specification becomes −0.07 psi, as reported earlier in this article.

All done!

MANOMETER PRINCIPLES

The manometer, one of the earliest pressure-measuring instruments, is very accurate when used correctly. Standards organisations recognise the U-tube manometer as a primary standard due to its inherent accuracy and simplicity of operation, being that it has no moving parts subject to wear, age, or fatigue. Manometers operate on the Hydrostatic Balance Principle: a liquid column of known height will exert a known pressure when the weight per unit volume (density) of the liquid is known.

The fundamental relationship for pressure expressed by a liquid column in a U-tube is

$$p = P1 - P2 = \theta\, g\, H$$

p = pressure exerted by the liquid column
P1 = pressure at the higher-pressure connection
P2 = pressure at the lower-pressure connection
θ = density of the liquid
g = acceleration of gravity
H = height of the liquid column (i.e. height difference between the column surfaces)

In all forms of manometers there are two liquid surfaces and the pressure measurements are made by measuring how the surfaces of the fluid move when subjected to a pressure source. If the fluid height in the tube connected to the pressure source rises above the fluid height in the other tube, a negative pressure (vacuum) is being asserted, whereas if the fluid height in the tube connected to the pressure source falls below the fluid height in the other tube, a positive pressure is being asserted.

For gauge pressure, i.e. to make a pressure gauge, one side of the manometer is open to atmosphere, which we refer to as being zero (relative) pressure, and the other side connects to the positive or negative pressure source, simplifying the equation for p with respect to atmospheric pressure or

$$p = \theta\, g\, H$$

U TUBE MANOMETERS

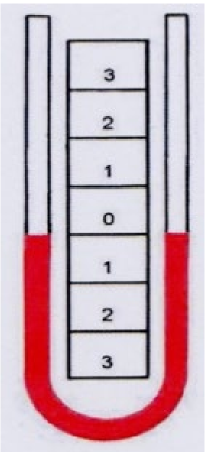

Figure 1

The principles of manometry are most easily demonstrated in the U-tube manometer shown in Figure 1 at left. It is made from clear glass or plastic tubing, bent to form the shape of the letter U and partially filled with some liquid such as oil or water. With both legs of the instrument open to atmosphere or made subject to the same pressure, the liquid maintains exactly the same level in each leg as a zero reference.

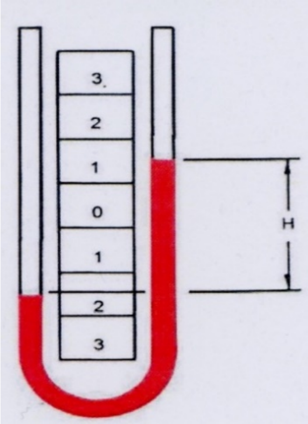

Figure 2

As illustrated in Figure 2 at left, if a pressure is applied to the left side of the instrument, the fluid level falls in the left leg and rises in the right leg. The fluid moves until the weight of the fluid on the right side, indicated by H, exactly balances the pressure being applied to the left side. This is known as hydrostatic balance. The height of fluid from one surface to the other, H, is the height of the fluid opposing the pressure in the left leg.

The pressure is always with respect to the height of the fluid *at one surface* in comparison to the height of the fluid *at the other surface*, regardless of the shape or size of the tubes, as illustrated in Figure 3 below. The left-hand manometer has a uniform tube, the centre one has one enlarged leg and the right-hand one has one irregular leg. The manometers in Figure 3 are open to atmosphere on both legs so the fluid level is the same in both legs. It makes no difference if the lengths of the tubes are different or if the fluid volumes are different. **It is all and only about the height H between the two fluid surfaces.**

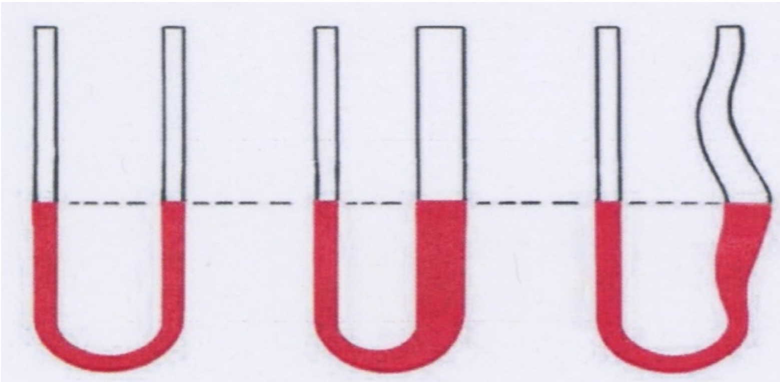

Figure 3

Say we impose an identical pressure in the left leg of each manometer, as shown in Figure 4 below. This causes the fluid level in each manometer to change. Because of the variations in volume of the manometer legs, the distances the fluid *surfaces* move in each manometer will be different, but the **height H between the fluid levels in each of the three manometers is the same!** Height H is constant in all three manometers when the same constant pressure is applied to *either* leg of the three manometers. Magical? No, physics!

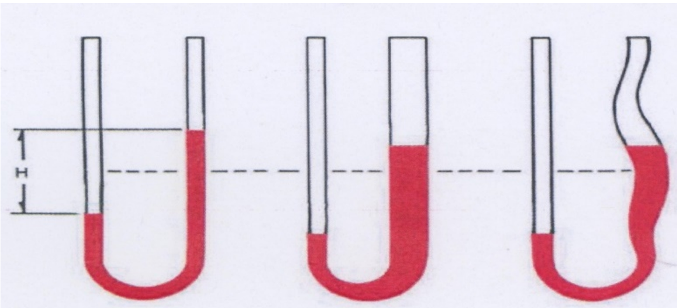

Figure 4

Reference:

The diagrams above were taken from the following document with grateful acknowledgement and appreciation:

Using Manometers to Precisely Measure Pressure, Flow and Level.

Meriam Instrument Company, Cleveland, Ohio, USA. April 1997

Available at: https://www.meriam.com/assets/eng/050-MHB-1.pdf

The writer would appreciate advice of errors or suggestions for improvements. Please forward to: gdennes@gmail.com

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