Abu Dhabi National Oil Co.

ADNOC Technical Institute

INSTRUMENTATIO
N

INSTRUMENTATION

UNIT 5

MEASUREMENT OF LEVEL

UNITS IN THIS COURSE

TABLE OF CONTENTS

5.0 COURSE OBJECTIVES

The student will be able to :

- Explain the use of a dip stick and dip tape.
- Sketch a typical sight glass installation.
- Explain, with the aid of a diagram, typical level measurements using floats.
- Explain, with the aid of diagrams, hydrostatic tank level measurement.
- Explain, with the aid of a sketch, the operation of a typical buoyancy level transmitter.
- Sketch typical float operated level switches.
- Explain, with the aid of a diagram, the bubbler method of level measurement.

5.1 INTRODUCTION

The aim of this unit is to introduce the measurement of level and the devices used in its indication, measurement and control.

5.2 THE DIP STICK

The dip stick shown in Figure 5-1 is the only true measurement of level. It is still used by operators and ships' captains to check that the instrumentation which measures the level of a liquid in a tank is correct.

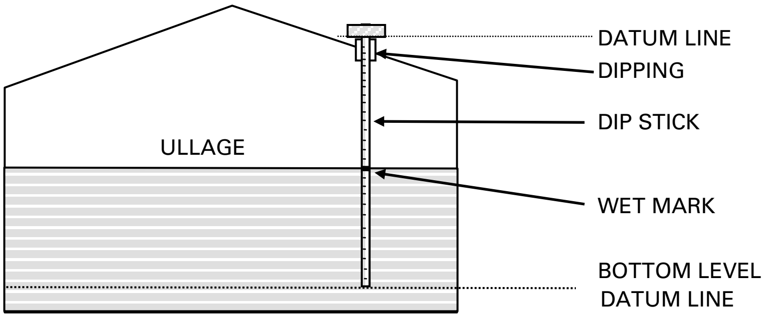


Figure 5-1 The Dip Stick

The dip stick is a long calibrated ruler. The depth of the liquid in the tank is indicated by a WET mark when the stick is removed. It's the same principle as checking the oil level of a car. Because there may be rubbish at the bottom of the tank the level may be taken from a bottom level datum line. A datum line is a base line from which things can be measured. There is also a top datum line which is used to measure the space above the liquid (the ullage).

5.3 THE DIP TAPE

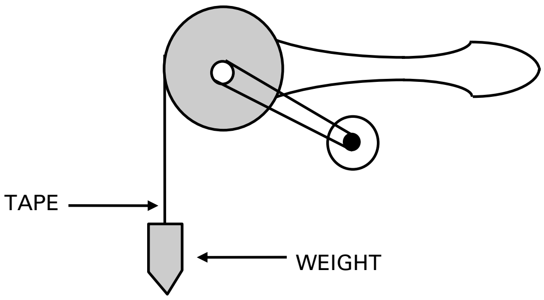


Figure 5-2 Dip Tape

The dip tape shown in Figure 5-2 is a development of the dip stick for finding the level in large tanks. The tape is run out until the weight touches the bottom of the tank. It's then pulled up. The wet mark on the tape indicates the depth of the liquid.

Note :- The dip stick / tape is no good if the liquid does not leave a WET mark. An example of this type of liquid is mercury.

5.4 THE SIGHT GLASS

This is the level indicator used by operators in the plant. The device is connected to the side of a vessel and the level is seen by looking through the glass. A high pressure sight glass is shown in Figure 5-3.

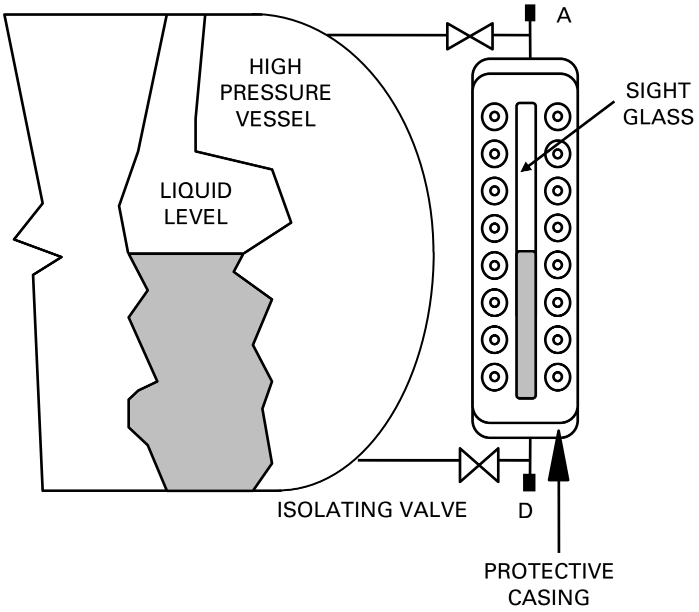


Figure 5-3 High Pressure Sight Glass

There are many different types of sight glasses. A single glass tube is strong enough for low pressures. For high pressures you need a reinforced glass tube with a steel case, as shown in Figure 5-3. Most industrial sight glasses can be cleaned on site by closing the isolating valves, draining the tube via valve D and rodding through valve A. Good sight glasses also have an automatic shut-off valve. This operates if the glass breaks. It stops all the liquid draining out of the vessel.

High pressure sight glasses have very specific instructions about how they are put together and taken apart. You must use the manufacturer's manual. A high pressure sight glass should never be used again because re-tensioning will make the glass break.

5.5 FLOATS

5.5.1 The Simple Float

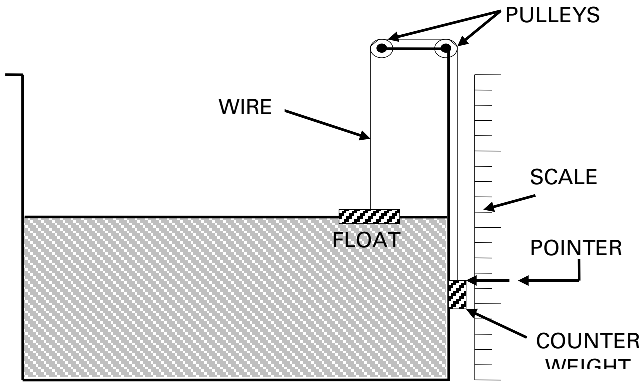


Figure 5-4 Simple Float Indicator

Figure 5-4 shows a simple float level indicator. It is still used by water departments and on chemical tanks on older oil platforms. It is cheap to install and easy to operate.

Operation

The float and counter weight are connected together by a wire on pulleys. The system is in balance with the float on the surface of the liquid. If the level rises, the float rises and the counter weight falls to the new balance point. If the level falls the counter weight rises. The counter weight has a pointer which indicates the level on a scale on the outside of the tank. The scale shows "full" when the pointer is at the bottom and "empty" when it is at the top. The scale can be very large so that, for example, water tower levels can be seen from the ground.

5.5.2 Industrial Float Systems

The simple float is not very accurate and can be very difficult to read. If the surface of the liquid has waves then the float starts to swing. This problem is solved by fitting special devices inside the tank as shown in Figure 5-5.

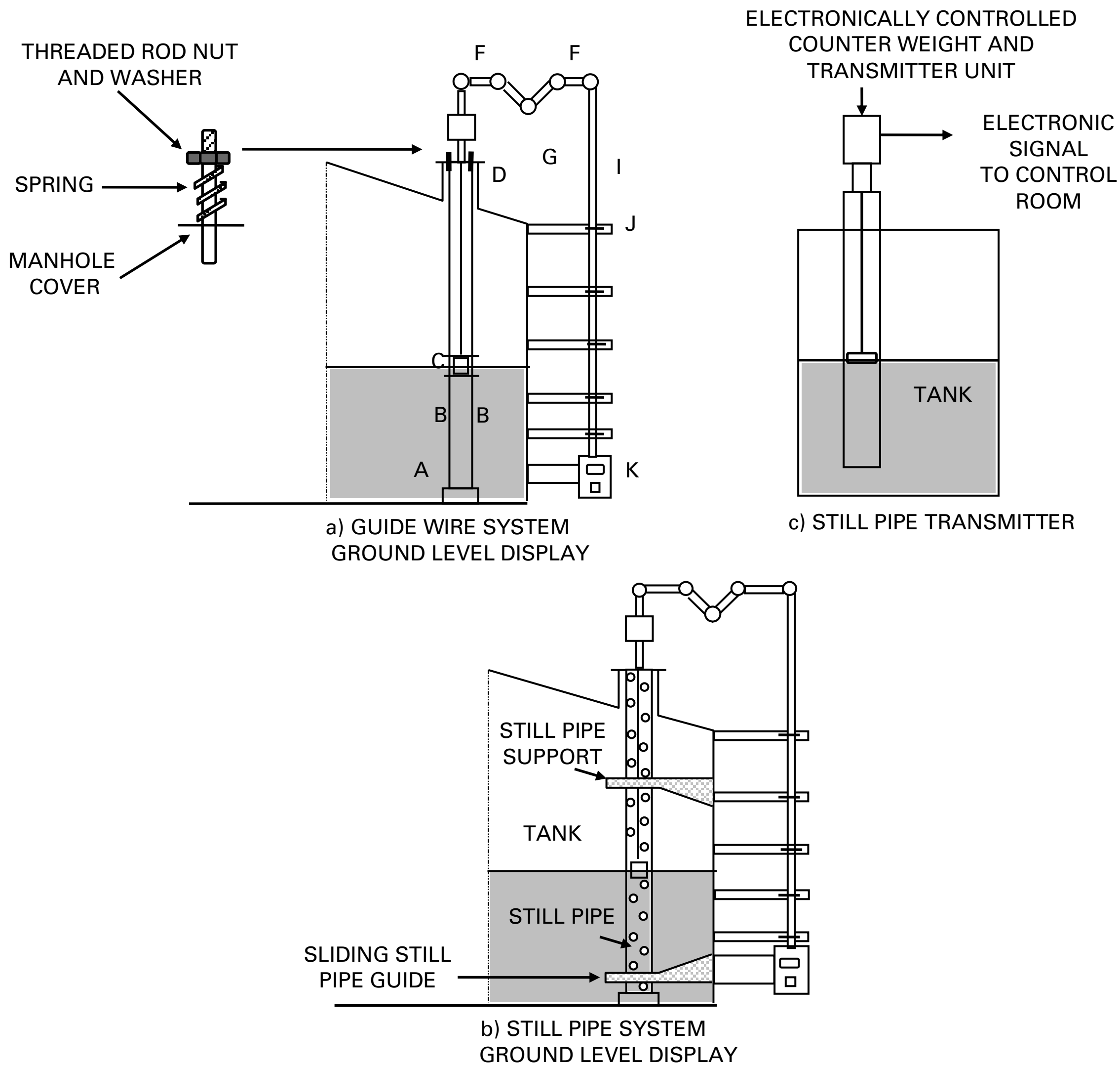


Figure 5-5 Tank Constructions

- Guide wire system (Figure a)

This is the cheapest system. The float; C, is held in place by wires; B. These are fixed to the bottom by a concrete block; A, and tightened by a spring; D.

The float is connected by a wire (to the indicating unit K) via a pulley system (FGF) and pipe (I) supported on brackets (J). The indicating unit is the counter-weight and the level is indicated by a mechanical counter.

- Still pipe system (Figure b and c)

This is a more expensive method but it is more accurate. The float is contained inside a still pipe (a steel pipe with holes in it). The level inside the pipe doesn't move so it gives very accurate measurements of level. Figure b shows the older mechanical indication method. Figure c shows the modern method (Entis-Enraf). The system is electronically controlled and the level measurement is sent as an electronic signal to the control room.

5.6 HYDROSTATIC TANK GAUGING (HTG)

5.6.1 Introduction

Many of the modern oil storage tank facilities (tank farms) use hydrostatic tank gauging to indicate the level in a tank. HTG is good because there is no equipment inside the tank. It is cheaper to install and maintain than float installations.

BASIC PRINCIPLE

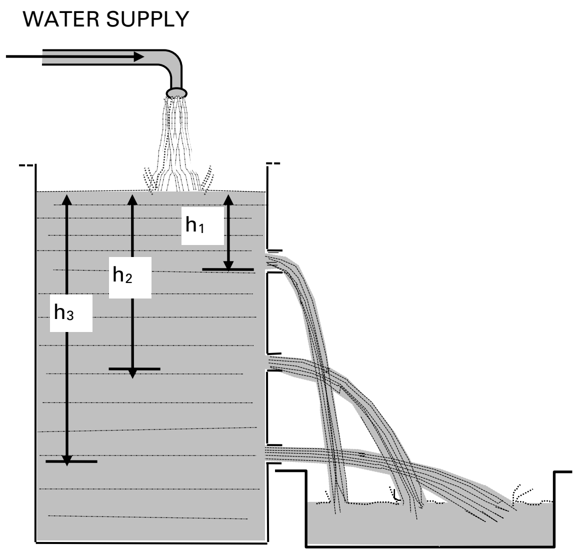


Figure (a)

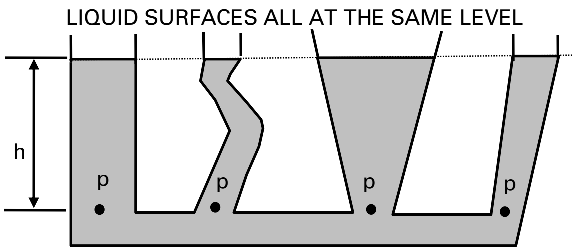
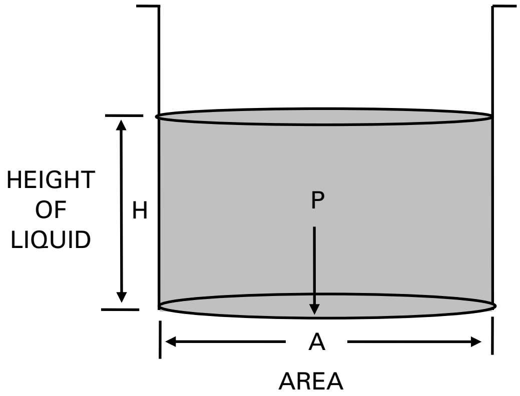


Figure (b)

The higher the level of a liquid in a tank, the higher the pressure on the bottom of the tank. The nearer the outlet is to the bottom of the tank, the greater the pressure and the further the flow stream will reach. Figure (a) shows this effect.

The pressure on the bottom of a tank only depends on the level of the liquid in the tank. Figure (b) shows this effect. No matter what the shape of the tank, the pressure (P) at the bottom of the tank is the same.

Proof :



$$\text{PRESSURE} = \frac{\text{FORCE}}{\text{AREA}}$$

The force on the bottom of the tank is the weight of the liquid.

WEIGHT OF LIQUID = VOLUME x DENSITY x GRAVITY

but VOLUME = AREA (A) x HEIGHT (H)

Therefore

WEIGHT OF LIQUID =

AREA (A) x HEIGHT (H) x DENSITY (ρ) x GRAVITY (g)

$$\text{but PRESSURE} = \frac{\text{FORCE(WEIGHT)}}{\text{AREA}}$$

$$= \frac{\cancel{\text{AREA} \times} \text{HEIGHT} \times \text{DENSITY} \times \text{GRAVITY}}{\cancel{\text{AREA}}}$$

The areas cancel so that

PRESSURE (P) = HEIGHT(H) x DENSITY (p) x GRAVITY (g)

or $P = \rho g H$

This equation shows that the pressure at the bottom of a column (level) of liquid does not depend on the shape of the container.

Hydrostatic Tank Gauging (HTG) uses the pressure of a column of liquid to measure the level. The diagram below shows the basic layout of the system (see Figure 5-6)

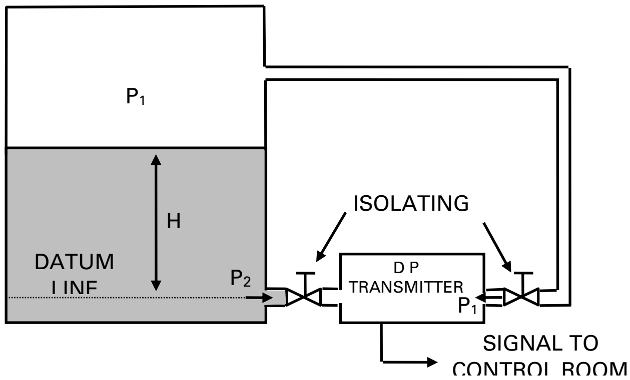


Figure 5-6 Hydrostatic Tank Gauging

Theory

P_1 = Pressure above the liquid level

P_2 = Pressure at inlet to differential pressure transmitter

$P_2 = P_1$ + Pressure of liquid above the datum line.

The pressure of the column of liquid above the datum line is given by the formula:

P = Density x Gravity x Height

Gravity is a constant and providing the density of the liquid does not change then

$P = KH$ where K is a constant

and $P_2 = P_1 + KH$

The differential pressure (DP) across the transmitter is

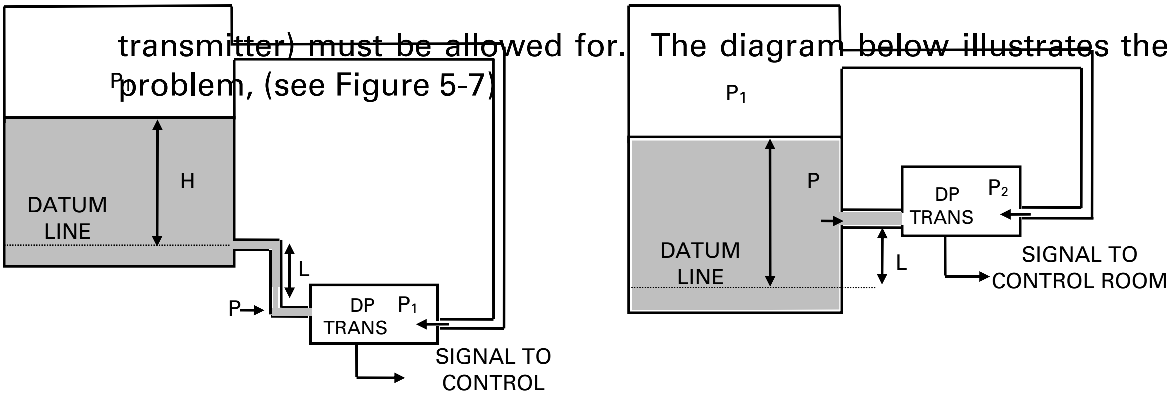
$P_2 - P_1 = P_1 + KH - P_1$

$DP = KH$

This means that the DP transmitter signal gives a direct indication of level.

5.6.2 Offset Datum Lines

The above system works well if the transmitter can be placed at the same level as the datum line. This is often not possible and the off-set (the difference between the levels of the datum line and the transmitter) must be allowed for. The diagram below illustrates the problem, (see Figure 5-7)



(a) Transmitter Below Datum **(b) Transmitter Above Datum**

Figure 5-7 Transmitter Off-set

In figure (a) the transmitter is lower than the datum line. "L" is the difference in height between the transmitter and the datum line. So, the transmitter will give the wrong reading, it will be "L" units too high.

Figure (b) shows the transmitter above the datum line. In this case the transmitter will give a level which is "L" units too low, because the pressure of the liquid above the transmitter is less than the pressure of the liquid above the datum line.

Differential pressure transmitters have special units added to allow for the above problem. They are called elevation/depression units. These units move the zero to allow for the height difference between the transmitter and the datum line. Manufacturers use different methods for elevation/depression. The manual must be used when setting up a differential pressure transmitter on a tank.

5.6.3 Wet Legs

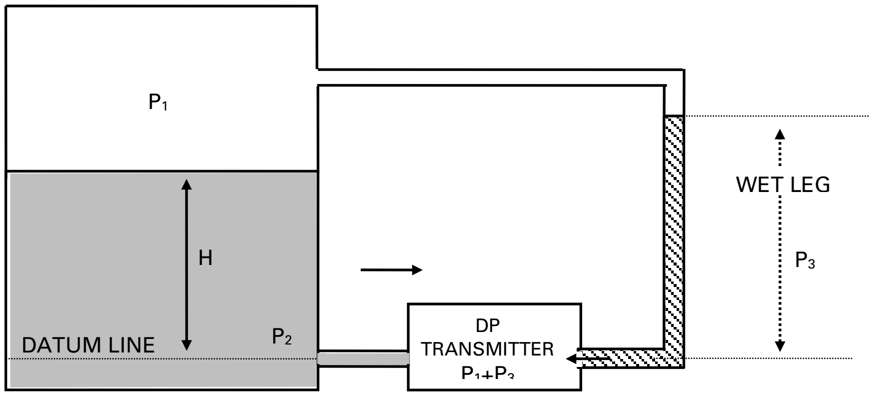


Figure 5-8 Wet Legs

Some liquids produce heavy vapours. These vapours may condense to liquid in the pipe between the differential pressure cell and the top of the tank. This condensate can cause the transmitter to give the wrong reading. To stop this, the pipe is filled with a known liquid (eg glycol). This is called the "Wet Leg". The differential pressure transmitter is adjusted using the elevation/depression units to offset the pressure caused by the height of the liquid in the wet leg (P_3).

5.7 DISPLACERS AND LOCAL LEVEL CONTROL

The displacer is a locally mounted device which controls the level in a vessel. It is used on remote sites where it is too expensive to return signals to the control room. The most common types in use are manufactured by Fisher or Masoneilan. Figure 5-9 shows a Fisher device (The Level-Trol).

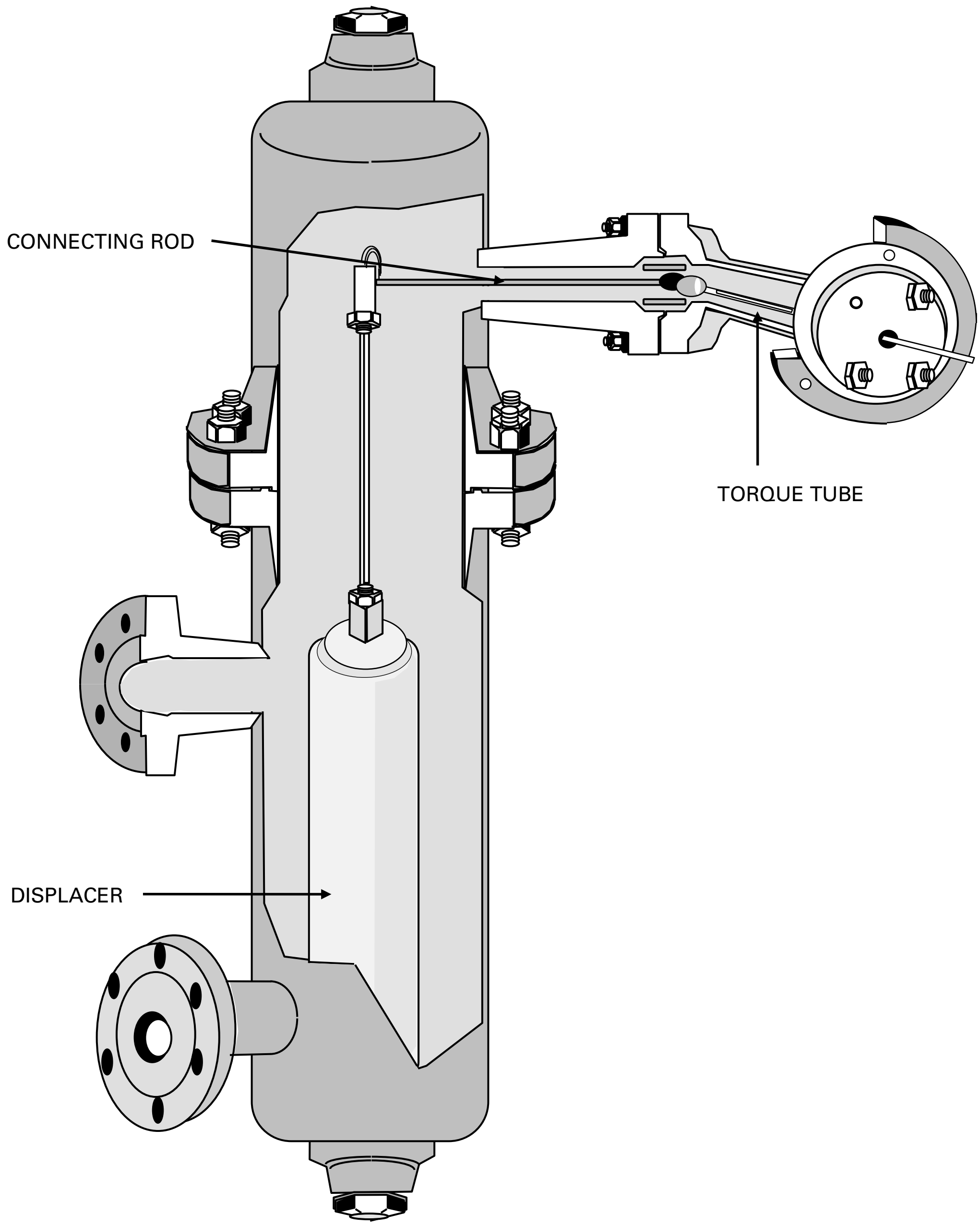


Figure 5-9 The Displacer

The displacer unit is connected to both the vessel and the control valve. This makes a self contained local control loop as shown in Figure 5-10.

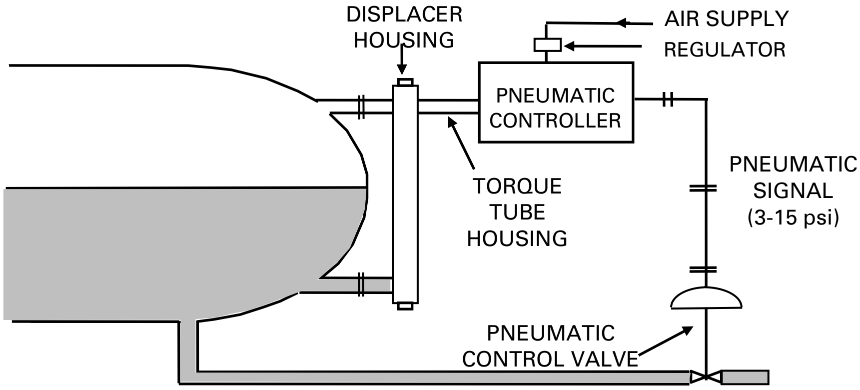


Figure 5-10 Self-contained Local Control Loop

Operation

- The weight of the displacer changes as the level rises or falls in the displacer housing.
- The displacer hangs on the torque tube via the connecting rod.
- The changing weight of the displacer makes the torque tube twist or untwist.
- The twisting motion of the torque tube moves a flapper against a nozzle. This sends a control signal to the pneumatic control valve.
- The pneumatic control valve opens or closes to keep the level constant at the set point.

Theory

A displacer works on "Archimedes Principle".

"The weight of a body immersed in a liquid depends on the weight of the volume of liquid displaced". In other words , if the displacer displaces a volume of liquid which weighs 1 kg, the displacer will seem to weigh 1 kg less than it weighs when it's not in the liquid.

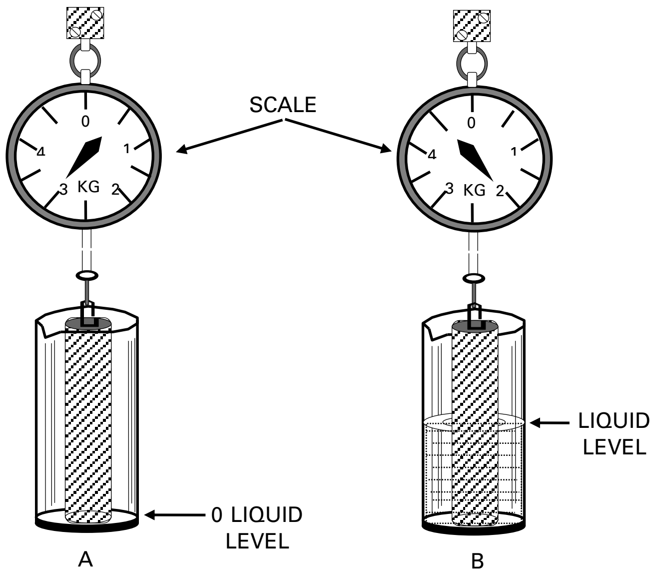


Figure 5-11 Simple Example of Archimedes Principle

Figure 5-11 shows a simple example of Archimedes' principle. In 'A', the scale shows 3 Kg weight. The displacer weighs 3 kg. In 'B' the displacer has displaced a volume of water which weighs 1 kg. So, the scale shows a weight of 2 kg i.e. 3 kg minus 1 kg for the liquid displaced.

The diameter of the container and displacer are kept constant. So, the weight loss on the displacer is directly proportional to the liquid level in the displacer housing. If the displacer weighs less then the torque tube is twisted less. The amount the torque tube twists depends on the level of liquid in the displacer housing.

Note :- The weight of the liquid displaced is given by the formula

Weight = Volume x Gravity x Density

So, changing the density of the liquid in the vessel means the Level-Trol must be recalibrated.

5.8 LEVEL SWITCHES

A level switch is the last safety device when controlling level.

If the level controller stops working the vessel can overfill. This can be dangerous. A level switch uses a float to operate a switch to shut down filling pumps in an emergency. The diagrams below show two typical examples.

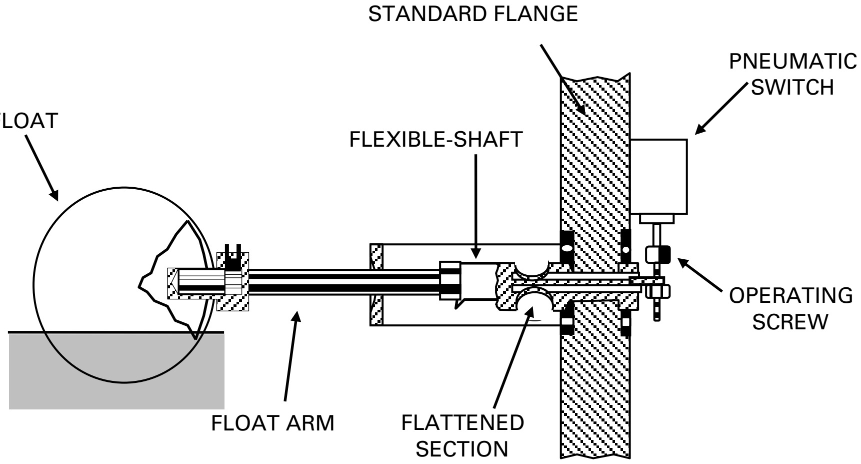


Figure 5-12 Flexible-Shaft Float Switch

Figure 5-12 shows a pneumatic level switch. When the level of liquid is low the float hangs down. The operating screw on the end of the flexible shaft holds the flapper tight against the nozzle. The output signal is a maximum so the pumps continue to fill the vessel. If the level rises and lifts the float the screw on the end of the flexible shaft moves down. The flapper moves away from the nozzle and the output signal falls to zero. This shuts down the pumps so no more liquid comes into the vessel.

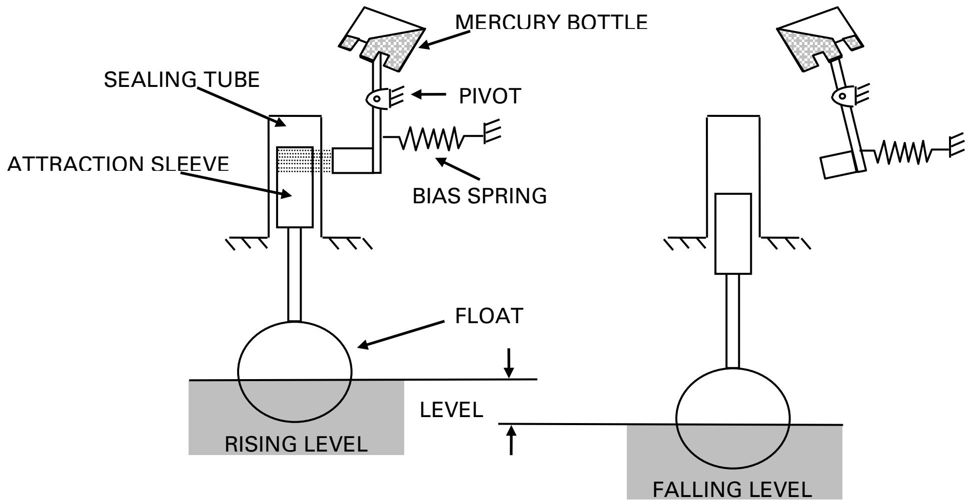


Figure 5-13 Float Operated Mercury Switch

Figure 5-13 shows a typical electrically operated level switch. The mercury bottle has three connections, the mercury (a good conductor) acts as the switch to change over the contacts. The switch is operated magnetically, the two different positions being clearly shown. When the level is high the switch is in one position. When the level falls, the switch is in the other position.

5.9 AIR BUBBLE METHOD

The air bubble method is one of the oldest and simplest methods used to indicate and or transmit a sign iagram below shows a simplified layout of the method (see 14).

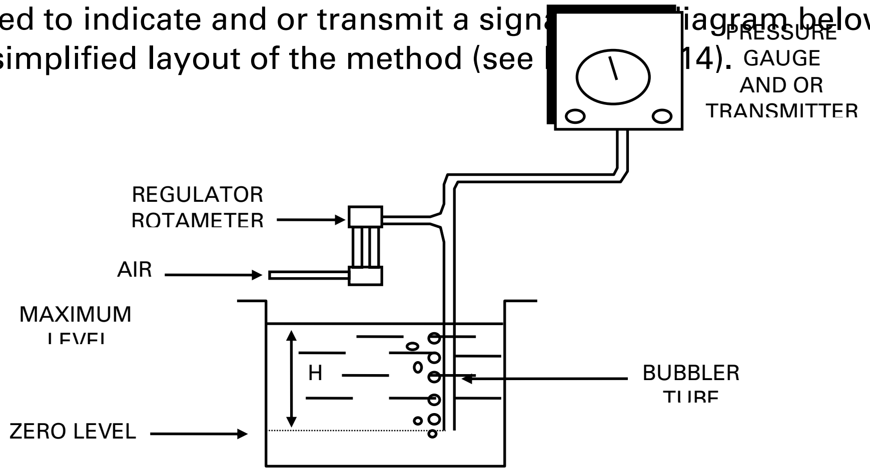


Figure 5-14 Liquid Level Measurement by Air Bubbler Method

Operation

- An inert gas (air or nitrogen) is passed down the bubbler tube. There is just enough gas pressure for the bubbles to appear when the liquid is at the maximum level in the vessel.
- When the vessel is full the pressure gauge or transmitter will read a maximum back pressure equal to the hydrostatic head (H), (the pressure of the liquid above the zero level).
- At the zero level the back pressure will be zero and the gauge or transmitter will read zero.
- The back pressure between zero and maximum levels is proportional to the liquid level in the vessel. The pressure gauge or transmitter can be calibrated to indicate the liquid level.
- The gas pressure is adjusted by the regulator to give a steady flow of gas down the bubbler tube. The gas flow is indicated on the Rotameter.

- This method can be very accurate. A modern differential pressure transmitter, open at one side, can easily be calibrated to give a span of 0-6" H_2O.

5.10 OTHER METHODS OF LEVEL MEASUREMENT

In this unit we have introduced some common methods of measuring level used on most installations.

There are many other methods using various types of high technology. These will be special for only one or two installations. You will have to learn them on the job. A few examples are:

(a) Radar, ultrasonic, gamma and infrared detectors.

(b) Capacitive sensors.

(c) Resistive sensors.