GENERATION-OAHU DIVISION
OPERATOR TRAINEE TRAINING PROGRAM

Section 07

BASIC INSTRUMENTATION

OBJECTIVES:

1. Discuss the basic devices used for pressure and temperature measurement and their principles of operation.
2. Discuss the basic devices used for flow measurement and their principles of operation.
3. Describe how measurement information is converted, transmitted, and collected.

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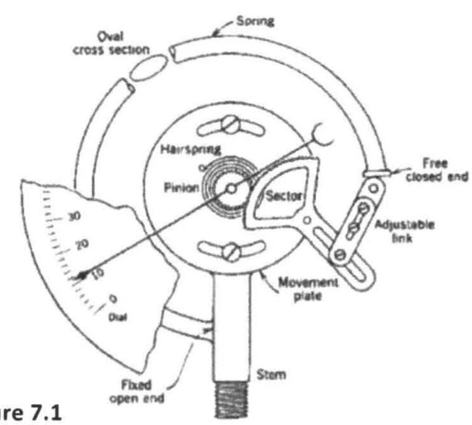
BASIC INSTRUMENTATION

As power plants become larger and more complex, the operator must rely more and more on instruments to provide the information required for safe and efficient operation of the equipment. Some basic knowledge of how instruments function is of considerable value to the operator. This section will discuss the basic devices and their principles of operation.

PRESSURE MEASUREMENT

The range of pressures that must be measured in a power plant is quite large. The instruments required to accomplish this wide range of measurement must be designed for the specific application. As discussed in a previous section, the units commonly used for pressure measurement are: pounds per square inch for most positive pressures; inches of mercury for low positive pressures and inches of water for very low positive pressures; negative pressures or vacuum are usually measured in inches of mercury or inches of water. From the above discussion, we can see that two types of instruments are used, one for measuring pressure directly and one for measuring indirectly by the height of a column of liquid. ***Pressure gauges*** as normally used are instruments for measuring the difference between atmospheric pressure and the pressure in a pipe or vessel. The bourdon tube gauge shown in Figure 7.1 involves a curved metal tube closed at one end and with an oval cross section. When pressure is applied to the inside of this tube, it tends to straighten out causing motion of the free end. This motion is amplified and transmitted



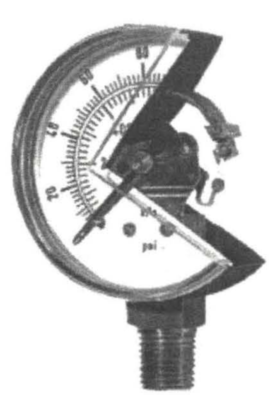


Figure 7.1
Bourdon Tube Pressure Gauge

through a linkage to the pointer.

The pointer indicates gauge pressure directly. Owing to the necessity for considerable mechanical amplification of the tube movement and the likelihood of changes in the mechanism, these gauges require periodic calibration. It is important that a gauge not be subjected to a pressure greater than the maximum scale reading. Damage to the mechanism or failure of the bourdon tube may result from overpressure. Pressure gauges should be treated as delicate instruments and cut in and out of service slowly and carefully to minimize thermal and mechanical shock.

The manometer is a pressure measuring instrument in which the measured pressure is balanced against the weight of a column of liquid. The two most common liquids used are mercury and water. Figure 7.2 shows two common types of manometers. The U tube manometer shown is the most common. The principle of this manometer is applicable to all manometers and is based on the fact that the unbalanced height of liquid is a direct measurement of the pressure. When the liquid level in the manometer reaches an equilibrium value, there must be no unbalanced forces acting upon the liquid column or it would still be in motion. If for instance the manometer is filled with mercury to its center or zero point and the left leg is connected to some pressure, the amount the left side goes down plus the amount the right side goes up will be measured pressure in inches of mercury. The disadvantage of this type of manometer is that two separate readings are necessary, one on each leg of the manometer. This condition can be overcome by using a well or single leg type manometer as shown on the right. In this type, the well actually forms one leg of the manometer; however, its area is large so that very little change in level takes place. This allows the total height of liquid to be read directly on one scale.

As with the pressure gauge, care must be used in handling manometers. The tubes are glass and can be easily broken. If subjected to pressures greater than the range of the manometer, the fluid will be forced out of the manometer, thereby making it worthless. For information, the Table 7.1 of equivalent pressure values is given.

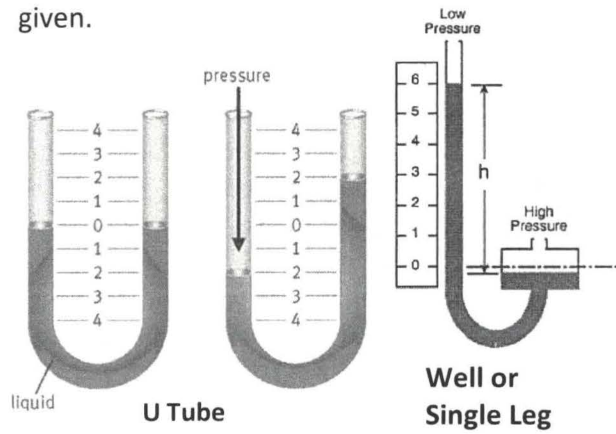


Figure 7.2 Typical Manometers

TABLE 7.1 Equivalent Pressure Values

1 inch of water	0.0734 inches of mercury
1 inch of water	0.036 pounds per square inch
1 inch of mercury	13.62 inches of water
1 inch of mercury	0.491pounds per square inch
1 pound per square inch	2.036 inches of mercury
1 pound per square inch	27.73 inches of water
1 standard atmosphere	29.92 inches of mercury
1 standard atmosphere	14.696 pounds per square inch

TEMPERATURE MEASUREMENT

The range of temperatures encountered in a power plant is also quite large, just as with pressures. As a result, there are several classes or types of instruments that are used for measuring temperature. The normal temperature scale used is the Fahrenheit scale; the Centigrade scale is used only for measuring the temperature of electrical equipment. There is no way to directly measure temperature so we must rely on measuring the effect of temperature on various other properties of substances. Some of these effects areas follows: When a solid material is heated, it expands. We can measure this expansion and convert it to temperature. A liquid behaves in much the same way and we can use its expansion as a measure of temperature. If a fluid is sealed in a container, its pressure will increase with an increase in temperature. We can measure the pressure change and convert it to temperature. Changing temperature also has an effect on the electrical properties of some metals. The resistance to the flow of electricity changes with temperature and can be used for measurement. Some dissimilar metals when joined together will produce an electrical force or voltage when heated and this voltage can be measured and converted to temperature. Each of the methods is commonly used in the power plants. A brief description of the various applications follows.

Liquid in glass thermometers utilize the difference in expansion between a liquid sealed in a glass tube and the tube. A liquid reservoir is usually located at one end of the tube. When this type of thermometer is heated, the glass tube expands very slightly while the liquid expands much more and rises in the tube. A scale is either etched onto the glass tube or a separate scale is attached next to the tube. Many liquids can be used in this type of thermometer; however, mercury is the most common due to its high boiling point and low freezing point. Liquid in glass thermometers should never be subjected to a temperature in excess of their maximum scale since the rapidly expanding liquid will fill the tube and pressurize it to the point of breaking the glass tube.

Dial thermometers are also used in the plants. These devices have a round face very similar to a pressure gauge except that it is calibrated in temperature units rather than pressure units. A moveable pointer indicates the temperature on the dial. There are two general types of these devices in use; one is mounted directly on the line or equipment whose temperature is being measured while the other is located at a convenient spot some distance away from the point of measurement. The locally mounted type generally utilizes the ***bimetallic strip*** principle. In this device, two pieces of dissimilar metal are attached to each other to form a strip. The two metals are in contact over their entire length. The metals are chosen so that they have different coefficients of thermal expansion. As the temperature of the strip is increased, one of the metals expands more than the other. This action causes the strip to bend or deflect. This motion is amplified and transmitted to the pointer by a gear and linkage arrangement. The remote mounted dial thermometers are known as ***capillary tube temperature devices.*** In these units, the indicating dial is connected to the sensing device by a length of capillary tubing. These devices operate on the principle of fluid expansion. A bulb filled with some fluid is the temperature detector which is connected by the capillary tubing to the indicator. The

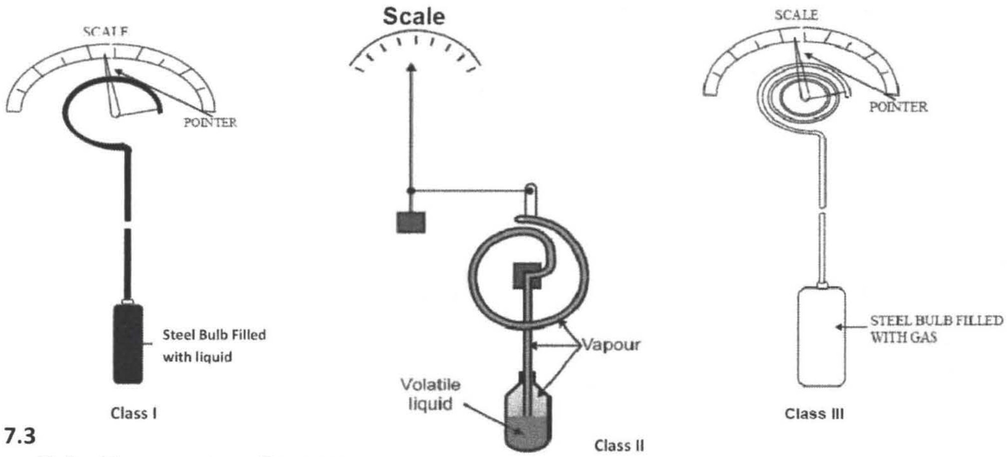


Figure 7.3
Capillary Tube Temperature Detectors

indicator is basically a bourdon tube. The bourdon tube, capillary tube, bulb combination is a completely scaled unit. When the temperature of the bulb increases, the fluid expands and since the unit is scaled a pressure rise occurs. The pressure is transmitted through capillary tubing to the bourdon tube. The pressure increase causes the bourdon tube to move, and through a linkage move the pointer and indicate the new temperature. A simplified diagram of several typical units is shown in Figure 7.3. The fluid used may be a liquid, a gas, or a mixture of these two depending on the particular application. These devices have two disadvantages: they are slow to respond, particularly when the capillary tubing is long. If the temperature being measured changes rapidly, the indication will lag behind for some time. Also, the reading may be affected by the ambient temperature through which the capillary tubing runs. These disadvantages may be overcome in part by keeping the length of capillary short and selecting the correct filling fluid.

Thermocouples are commonly used in all plants for many purposes. They are seldom direct indicating devices but are usually connected to multipoint recorders. When the fused junction of two dissimilar metal wires is heated, a voltage is produced. This voltage is quite small and a sensitive meter is required to accurately measure it. Thermocouples are frequently used since they cover a wide temperature range, have fast response, are quite accurate, and are reasonably inexpensive. Thermocouples are excellent for monitoring remote and inaccessible points since the length of the wire has very little effect on the accuracy or speed of response of the unit. A simplified diagram of a thermocouple is shown in Figure 7.4. The meter reading is proportional to the difference in temperature between the hot and cold junction. The temperature of the cold junction is known and is usually fairly constant so the meter reading indicates the temperature existing at the hot junction. For high accuracy testing, the cold junction is usually placed in an ice bath to insure that it stays at a known constant temperature. Many different kinds of wire can be used; however, the most commonly used are iron-constantan, chromelalume and copper-constantan.

Resistance Temperature Devices (RTD) make use of the principle that changes in temperature result in changes in the electrical resistance of a conductor. In these devices a coil of wire of a pure metal,

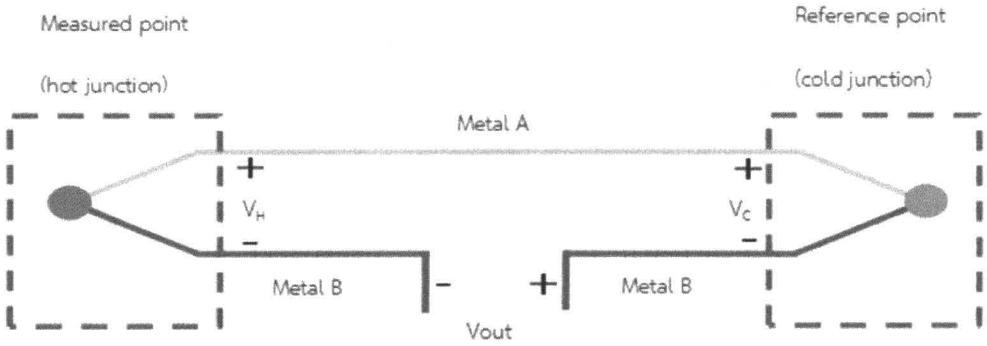


Figure 7.4
Basic Thermocouple Circuit

usually platinum, is the temperature detecting unit. The coil has a known resistance at a standard temperature. As the temperature changes, the resistance of the coil of wire changes. For any temperature, the resistance can be measured and the temperature determined. Like the thermocouple, the resistance temperature devices are seldom direct reading but are usually connected to a recorder. The change in resistance associated with a normal temperature change is quite small and a sensitive measuring device is required for accurate temperature measurements.

Most of the temperature detecting devices described above are fragile and require protection. Whenever one of these devices is installed in a line or vessel, a protective well is used. The well protects the sensing element from the erosive or corrosive action of the fluid and also allows removal and/or replacement of the sensing clement without shutting down the system. The use of a well slows down the rate of response of the detector to temperature changes; however, this disadvantage is more than compensated by the protection and replaceability that is gained.

LIQUID LEVEL MEASUREMENT

It is frequently necessary to know the liquid level existing in a closed vessel. The vessel may contain very high pressure such as the boiler or it may be under considerable vacuum such as the condenser hotwell. To cover this wide range of conditions, many types of level measuring devices are used; some of the more common are described below.

Gauge glasses are the most common level measuring device. They permit visual observation of the level in the vessel. In its simplest form the gauge glass consists of a small diameter glass tube which is connected to the top and bottom of the vessel. The liquid level inside the glass changes directly with any change in level inside the vessel. Special types of glass and construction make this device usable for practically any type of service. Provisions are usually incorporated for cutting out and draining the gauge glass for replacement or cleaning.

Float operated level indicators are commonly used on large storage tanks where it is impractical to use a gauge glass. In this type of device, the float rides on the surface of the liquid and operates through a wire and pulley arrangement to an indicator mounted on the outside of the tank. This arrangement is used on lube oil, raw water and distilled water storage tanks. On fuel oil tanks where more accurate measurements are necessary, the wire connecting the float

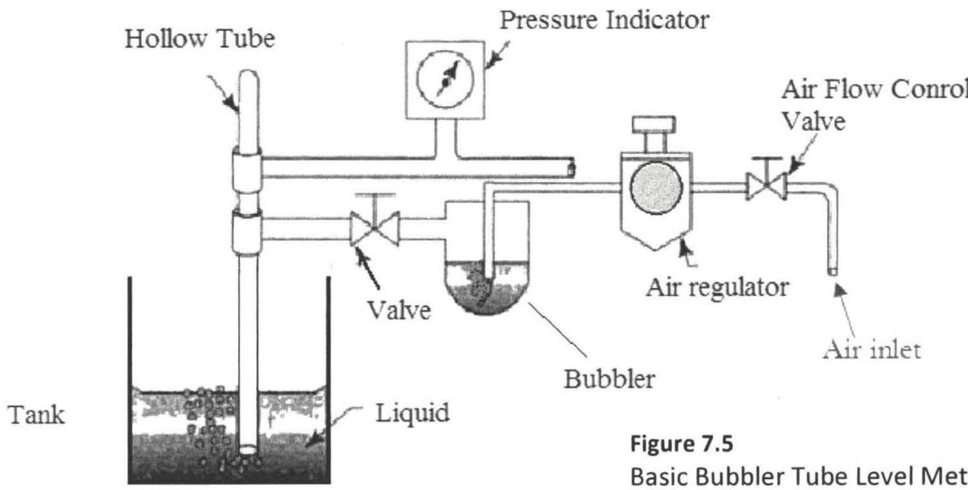


Figure 7.5
Basic Bubbler Tube Level Meter

and indicating mechanisms is replaced by a steel tape with small graduations that may be calibrated to read accurately.

Bubbler tubes are utilized for level measurement in inaccessible areas, and where the vessel or tank is below ground level. This device balances the pressure with either a manometer or a pressure gauge. Figure 7.5 illustrates the principle of operation. Air pressure is supplied to the bubbler tube which extends below the surface of the liquid. The air pressure increases and forces the liquid out of the tube; when all the liquid is out of the tube, the air bubbles pour out and no further pressure increase takes place. The air pressure is equal to the difference in level between the bottom of the bubbler tube and the surface of the liquid. The manometer or pressure gauge can be located at any convenient point and can be calibrated to read directly in any units such as feet of liquid, inches of liquid or gallons.

Level meters or as they are more correctly known, head meters, are used where considerable accuracy is required over a small range of level. They are basically used for control purposes on boiler drum level, hotwell level and deaerator level. These meters are seldom direct reading but usually transmit a signal to a remote located recorder. The meter consists of a leak proof housing which must be designed to withstand the same pressure as exists in the vessel. The housing contains a moveable float or bell that senses level changes and a sealing fluid which is usually mercury. The float or bell moves in response to changes in the mercury level which in turn responds to small changes in differential pressure. The principle is similar to a U tube manometer in which the mercury goes down in one leg and up in the other. In this case, the movement of the mercury causes a bell or float to move. This movement is vertical and is converted by a mechanical linkage to an indicator or transmitter. This mechanism is similar to that used in the head type flow meter which is discussed in more detail later in this section. This type of meter is capable of measuring differential pressure changes equivalent to one inch of water even in the presence of pressures greater than 2000 pounds per square inch. This is due to using the U tube principle where the absolute pressure on each side is balanced out and only the small differential pressure due to water level is felt by the meter.

FLOW MEASUREMENT

Measurement of the rate of fluid flow or the total quantity of flow is of considerable importance in the power plants. It is necessary to meter many different fluids such u water, steam, air, fuel oil and fuel gas. Depending on the fluid involved and the accuracy required, several methods of measurement are available. The type of flow meter used also depends on whether a continuous indication of flow rate is required or whether the total quantity of fluid passing through the meter during some time interval is required. In many instances, both of these requirements must be met. These two requirements permit dividing flow meters into two basic types known as rate meters and quantity meters.

Transducer. A transducer is an electromechanical device which changes a temperature, pressure, flow, or position to an electrical output signal. The electrical signal is then transmitted to be used as a control signal, recording signal, multi-pointer gauges, charts, and computer inputs. The transducers are placed as near the source of needed information as practical. Usually several transducers are placed in one cabinet convenient to several pickup points. The word transducer is not a trade name but a function, that is, transducing a temperature to an electrical signal. Enclosed in the case are the mechanical and electrical components used to transduce and transmit the needed information.

RECORDERS

It is frequently desirable to have a permanent record of various pressures, temperatures, levels and flows and to be able to observe how they change. This is accomplished by automatically recording this information on a chart. In most cases, the sensing device includes a transmitter which transmits either an electrical or pneumatic signal to the recorder which is located in the control room. It is desirable from a safety viewpoint to have all the signals entering the control room be low pressure pneumatic or low voltage electric. If high pressure steam and water lines are brought to the control room, a break or leak could be disastrous.

CONTROLLERS

In many instances, it is desirable to automatically control pressure, temperature, level or flow at some standard value. This can be accomplished by utilizing the same basic sensing elements as were discussed previously. As well as recording, they produce a pneumatic or electrical signal which can be used to position a valve or other final control element.

SWITCHES

The same basic sensing devices are frequently used to open and close electrical switches. The switches may be used to bring in an alarm or start and stop equipment.

NOTES:

Section 07

BASIC INSTRUMENTATION

Study Questions

1. What are the three units commonly used for pressure measurement?

   a.

   b.

   c.

2. Instruments normally used for measuring the difference between atmospheric pressure and the pressure in a pipe or vessel are called ______________________ .

3. The two most common liquids used in a manometer are _____________________ and ______________________ .

4. Balancing the measured pressure against the weight of a column of liquid is the basic principle of the manometer. True \ False

5. The normal temperature scale is the ________________________ scale, while the ______________________ scale is used for measuring the temperature of electrical equipment.

6. Changing the temperature has an effect on _________ .

   a. solid material
   b. liquid
   c. the resistance to electrical flow
   d. all of the above

7. What is the most common liquid used in a thermometer? Why?

8. State three (3) reasons for the frequent use of thermocouples.

   a.

   b.

   c.

9. What is the most common liquid level measuring device?

10. Bubbler tubes are utilized for liquid level measurement

    a. on large storage tanks

    b. in inaccessible areas

    c. for control purposes on boiler drum level

    d. none of the above

11. Level meters are used where considerable accuracy is required over a small range of level. True \ False

12. The two basic types of flow measurement meters are known as _____________ meters and ___________________ meters.

13. The electromechanical device that changes temperature, pressure, flow, or position to an electrical output signal is called a ______________________________ .