Water Columns and Gage Glasses

Learning Outcome

When you complete this module you will be able to:

Describe different types of direct and inferential level gages or indicators.

Learning Objectives

Here is what you will be able to do when you complete each objective:

1. Describe direct type water level indicators.

2. Describe indirect or inferential water level indicators.

INTRODUCTION

The methods used to sense and display liquid levels in open and closed vessels is quite varied depending on the type of process involved. No single method is universally suitable for the entire range of applications. Solids, liquids, corrosive and explosive conditions, extremes of heat and cold, and variation in pressure are some of the conditions encountered in level measurement and indication.

Liquid level may be measured and indicated directly or indirectly. Common examples of direct level measurement and indication are the dipstick, gage glass, and float gage. Some indirect or inferential level measurement and indication may use some form of pressure sensing devices to measure the pressure exerted by the liquid. The dial or scale of the gage is calibrated to indicate level. Others may use electrical sensing devices. Examples of the indirect method are bubbler systems, differential pressure level meters, electrical capacitance level gages, and ultrasonic level gages.

DIRECT METHODS

One of the simplest techniques for indicating liquid level is by means of a transparent device through which the level can be seen visually. A common method of providing such visual indication is by installing transparent ports in the vessel itself. These transparent ports are placed at different locations or points to indicate the liquid height. More often, separately mounted gage glasses are used to provide a continuous indication of level over a certain vertical distance on the vessel.

Tubular Gage Glass

The simplest and least costly method of liquid level indication is the tubular gage glass. Two slightly different designs are illustrated in Figs. 1 and 2. Both are simply transparent vertical tubes with their lowest visible point connected to the tank or boiler at the lowest level of interest. The top of the glass may be open to the atmosphere if the tank is open or to the unfilled part of a closed vessel above or at the highest level permitted. Isolating valves are placed above and below the gage glass connections.

Fig. 1 shows a gage glass with slow closing valves. In Fig. 2, the valves shown are the quick closing type where a one quarter turn of the valve spindle will change the valve from the fully open to the fully closed position. The valve spindles are fitted with levers to which chains may be attached in order to operate the valves from ground level if the vessel is located at a higher position. Drain valves or cocks may also be installed below the gage glass to remove any solid material that may collect.

Figure 1
Gage Glass

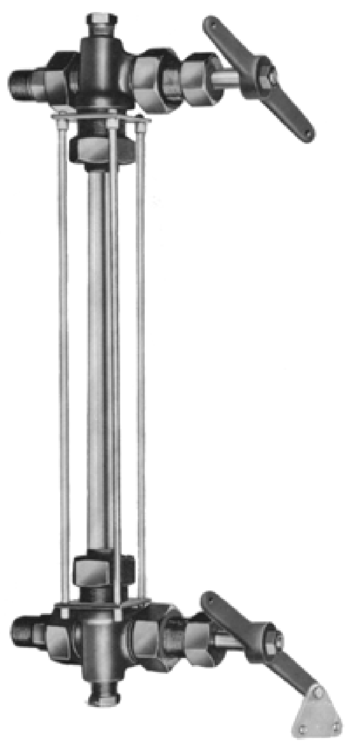

Figure 2
Water Gage with Quick-Closing Valves
(Courtesy of Jerguson Gage and Valve Co.)

Since many tanks and pressurized vessels are not under continuous supervision, a broken gage glass may allow a large amount of fluids to escape. To prevent this, the lower valve on the gage glass is often equipped with a safety shutoff device consisting of a stainless steel ball which closes off the fluid passage when the glass breaks. Fig. 3 shows one type of installation. One disadvantage of this type of safety device is that it requires more maintenance.

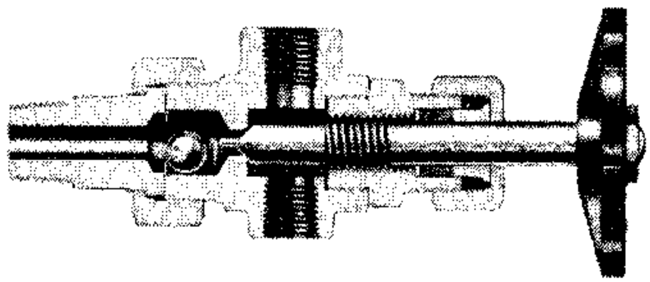

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Figure 3
Safety Shutoff Gage Valve
(Courtesy of Jerguson Gage and Valve Co.)

Under normal conditions, the steel ball remains in the recess in front of the valve seat. However, when the gage glass breaks, the sudden rush of fluid through the valve will force the ball against the valve opening. This shuts off the flow out of the broken glass.

The gage glass is usually surrounded by a number of metal rods or transparent shield to protect the glass from breakage and the operator from flying particles in case the gage glass shatters.

The use of tubular gage glasses is limited to lower pressures and temperatures, and restricted to non-toxic and non-hazardous material. Tubular gage glasses should not exceed 750 mm in length. If the level range to be observed exceeds this length, then two or more gage glasses should be installed so that they overlap as shown in Fig. 4. In this system, the gages are mounted on the vessel.

The glass tube is held tightly in place at each end by a washer or packing ring and a nut. If the gage glass should leak, the isolating valves should be closed and the drain opened before any maintenance is done to prevent injuries.

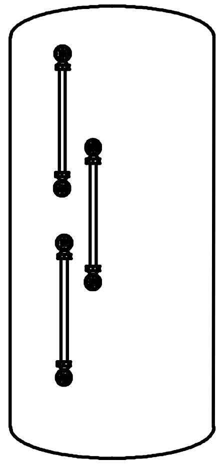

Figure 4
Multiple Gage Mounting

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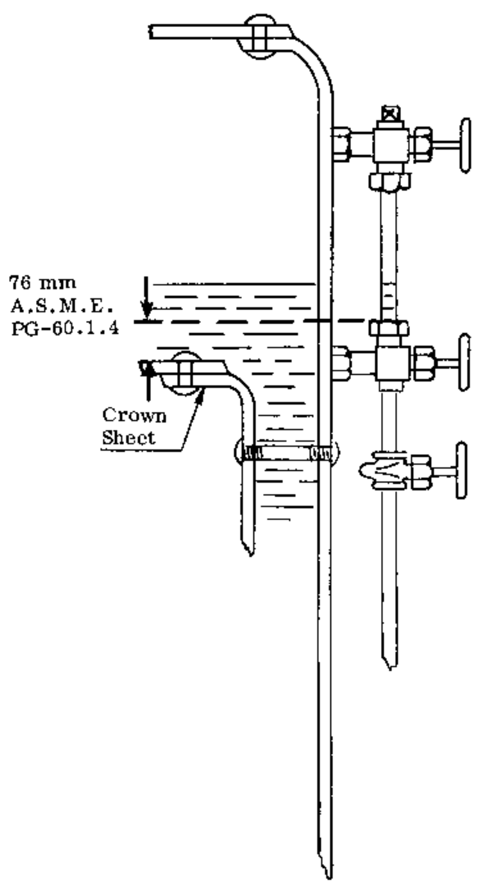

Figure 5
Direct Connected Gage Glass

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Boiler Gage Glass Installations

Steam generating boilers are equipped with at least one gage glass. It indicates the level of water in the boiler so the operator can be assured that the level is within safe limits. The level must be high enough to completely cover all parts of the heating surface to prevent overheating and low enough so that water is not carried over with the steam. All such boiler installations must comply with ASME and CSA regulations.

The installation in Fig. 5 is similar to the one in Fig. 1. Note the drain valve which permits all the connections to be blown through daily to be sure that they are not plugged with sludge or sediment. The valves can be slow or quick opening. This method of attachment is commonly used only on boilers that provide a straight vertical surface, unobstructed by reversing chamber or smoke box, such as the cast-iron heating boiler or some types of vertical boilers.

A more usual construction is to have the gage glass connected to a water column which in turn is connected to the boiler. This arrangement is shown in Fig. 6. The water column acts as a reservoir to dampen agitation in the water. In addition, the column traps any sludge or sediment and prevents it from collecting in the glass connections. The column also provides a place for installation of high and low level alarms and controls. Try cocks are installed on the column to provide a means of point level detection when the gage glass is being replaced.

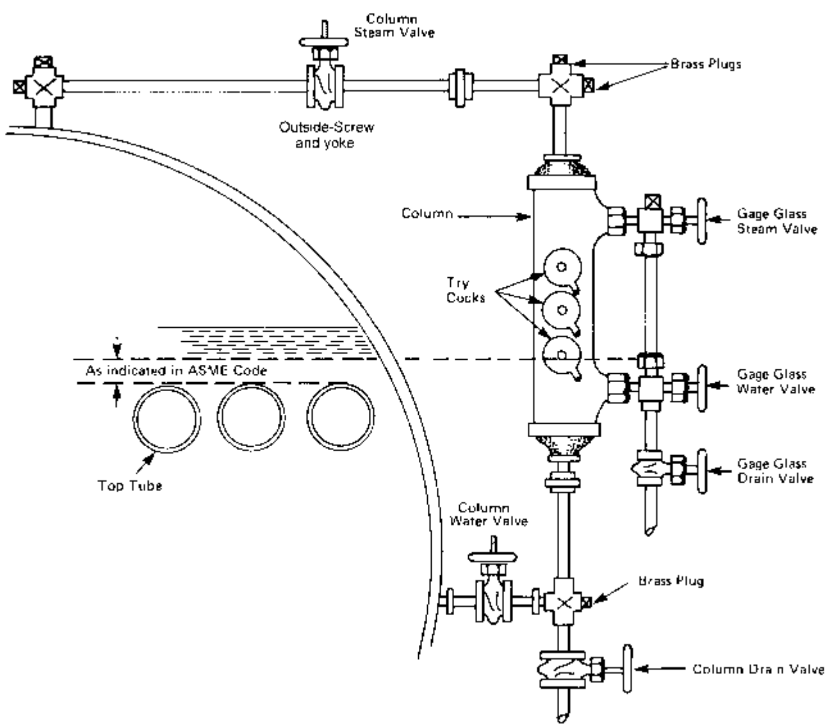

Figure 6
Water Column and Gage Glass

Note: ASME codes require that, for a firetube boiler, the bottom of the gage glass must be a minimum of 76 mm above the top of the highest row of firetubes (or the highest heating surface, such as a crownsheet), to prevent overheating. Heating boilers have a lowest permissible water level marked by the manufacturer. The lowest visible level in the gage glass should be 50 mm or more above this marker. For watertube boilers, the lowest level in the glass must be at least 50 mm above the highest heating surface.

When a water column houses an alarm, a water level control, or a low-water fuel cutoff device, isolating valves are not permitted in the piping between the column and the boiler. Where shut-of valves are allowed they must be outside screw and yoke or lever-lift type and must be locked and sealed in the open position.

Armored-Type (Flat) Glass Gage

Round tubular gage glasses are not recommended for pressures above 2800 kPa. For higher pressures, a flat type glass gage is used that consists of glass plates bolted in a steel forged housing. A flat gage glass is shown attached to a water column in Fig. 7.

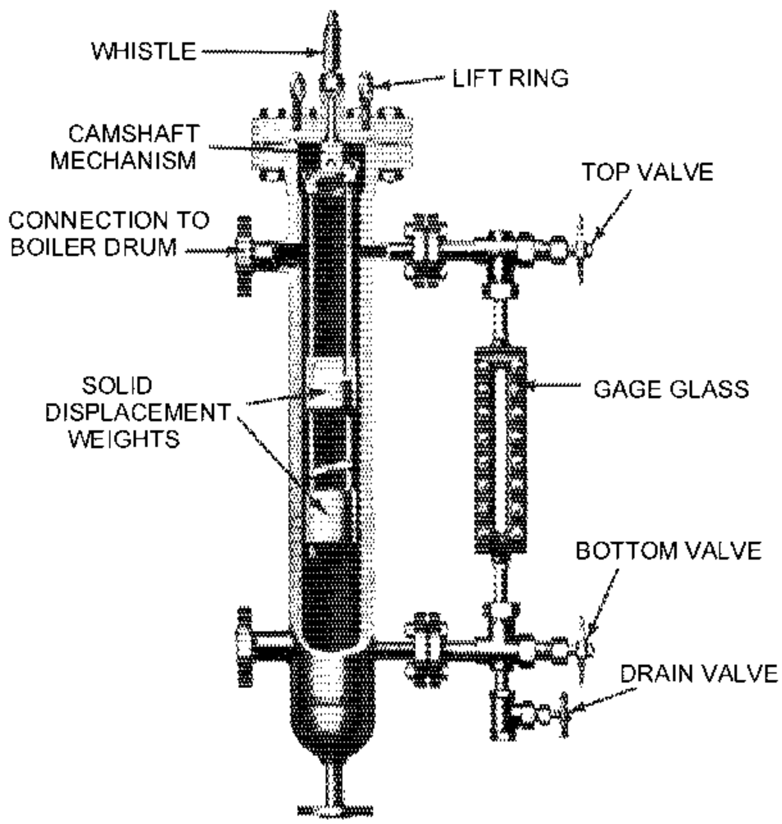

Figure 7
Water Column with Flat Glass
(Courtesy of Jerguson Gage and Valve Co.)

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The armored glass gage may be the transparent or the reflex type. Both are suitable for temperatures exceeding 250°C and pressures up to 70 000 kPa.

1. Transparent Glass Gage

The transparent glass gage, illustrated in Fig. 8, consists of a one piece central chamber with cover plates on each side that hold the two glass windows. The chamber and cover plates have machined recesses that keep all the parts aligned and prevent the gaskets and cushions from shifting. When the level of caustic or acidic fluids is indicated, the inside surfaces of both glasses are lined with a protective coating of transparent mica. After prolonged exposure to high temperature, chemically-treated water, the mica will become opaque. This discolouration indicates that the mica has failed and water is now in direct contact with the glass. When this happens, the glass should be changed, before it fails.

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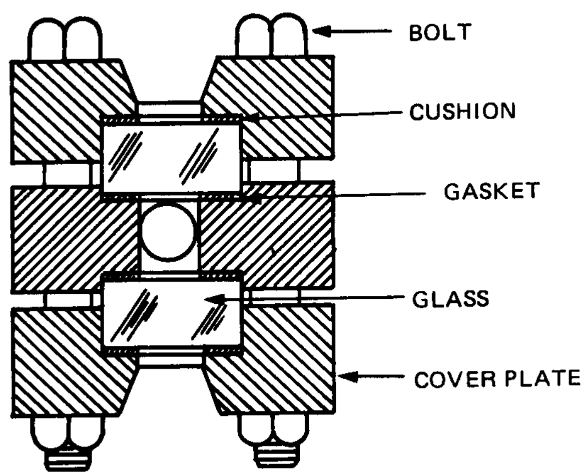

Figure 8
Gage Glass

The glass itself is also tempered for resistance to both mechanical and thermal shock. Care must be taken when assembling the unit and tightening the bolts to prevent glass failure. It is safest to use the crossover method of tightening by starting at the center and working outwards.

Besides being suitable for caustic and acidic liquids, the flat glass is also suitable for dirty materials, high pressure steam applications and other service where it is necessary to illuminate the glass from the rear.

2. Reflex Glass Gage

The reflex gage, illustrated in Fig. 9, is best suited for clean, colourless, non-viscous, and non-corrosive fluids including light and heavy hydrocarbons. This gage has special optical properties that create a sharp line of demarcation at the liquid level. A dark area represents the liquid in the glass gage contrasted by a light area above the liquid.

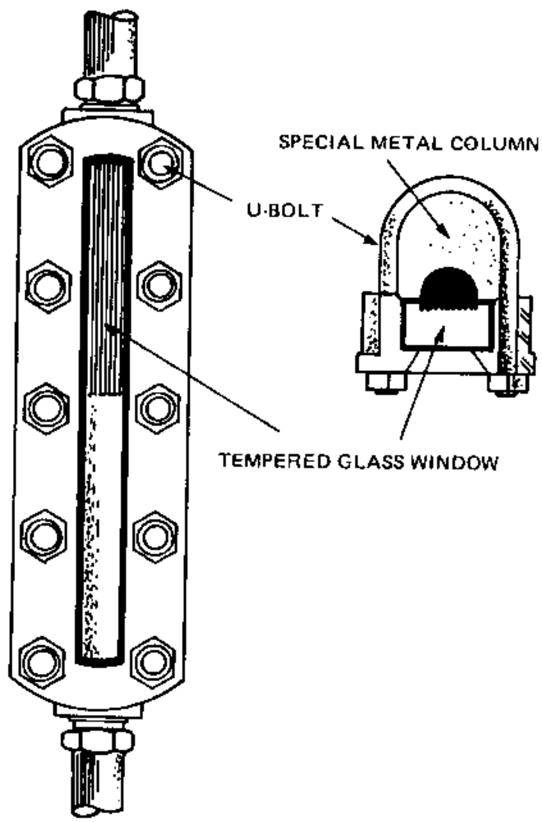

Figure 9
Reflex Gage Glass

Bicolour Glass Gage

Fig. 10 is an illustration of one type of bicolour multiport gage glass using the point level method of indication. Instead of a water column, this gage is attached to a circulating tie bar that has top and bottom connector blocks with gage valves plus a bottom connection for a drain line. The gage glass consists of a number of sealed circular glasses or double bullseye assemblies with spot lights connected at the back. The steam space is indicated in red while the water space is green.

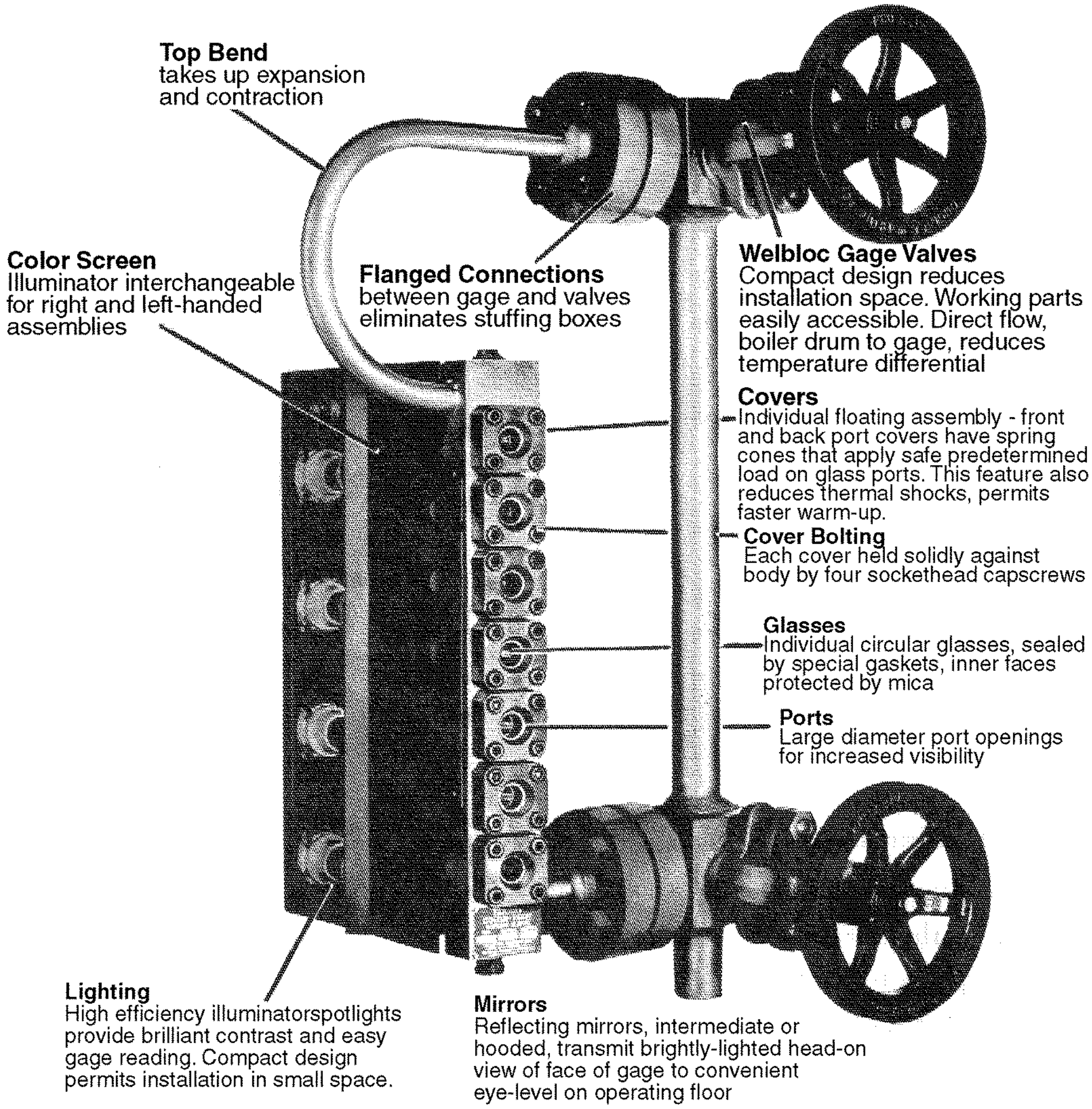

Figure 10
Multiport Gage with Tie-Bar
(Courtesy of Jerguson Gage and Valve Co.)

Fig. 11 illustrates the method used for indicating the drum level. A green and red filter or screen is placed between a lamp and each double bullseye or circular glass. These circular glasses are placed at a slight angle so the light can be diffracted in the proper direction.

Fig. 11(a) shows the passage of light through the water in the gage glass. Green light is allowed to pass through both glasses and this colour becomes visible to the operator. The red light is bent or diffracted so it is not visible.

In Fig. 11(b) the red light is visible through the steam space while the green light is not allowed to pass through. By proper design, the different refractive indexes for steam and water can be made to indicate red in the circular glass when steam is present and green if water is at that level.

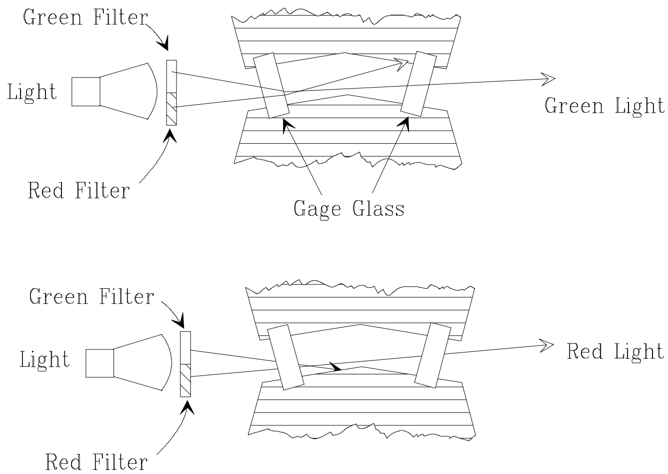

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Figure 11
Bicolour Gage Glass Operation

Fig. 12 shows one method that this bicoloured gage glass can be used to indicate the drum level to a person on the operating floor below. A hooded mirror is connected directly to the front of the gage glass and adjusted to a proper angle so it will reflect the red and green light to another mirror on the operating floor.

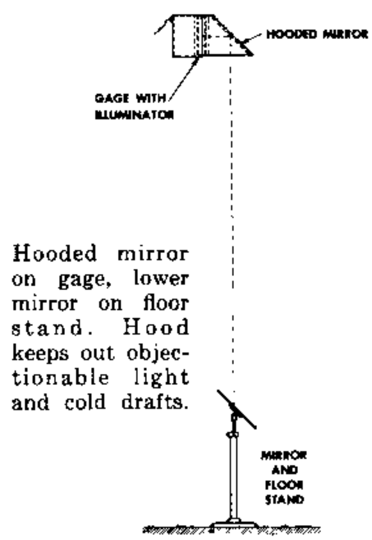

Figure 12
Mirror Arrangement

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Gage Glass Error

During normal boiler operation the gage glass generally indicates water level lower than the actual level in the boiler drum. This is because the water in the gage glass and in the water connection from the gage glass to the drum is cooler and denser than the water within the drum.

This error may be quite substantial. For example, in a boiler operating at 13 800 kPa, the level in the gage glass may be 20 percent lower than the actual level in the drum. The amount of the error depends upon the temperature difference between the water in the gage and its connection and the water in the drum. Error is affected by such factors as the ambient temperature, velocity of the air flowing past the gage, the amount of gage surface radiating heat to the atmosphere, length of the gage glass and level of the liquid in the gage glass.

Tubular Gage Glass Replacement

Although it may seem unbelievable, gage glasses are susceptible to corrosion caused by alkalinity and silica at higher temperatures. Alkalinity causes thinning of tubular glasses above the water line, and its effect increases drastically as the pH of the water rises. Condensate formed due to cooling of steam in the gage glass dissolves some of the silica in the glass and weakens it. Both cause eventual failure of the glass. Misalignment of fittings also causes failure of gage glasses.

The following steps should be taken when a gage glass fails:

1. Shut off the steam and water valves on the gage. These valves are usually equipped with chains and levers so they can be closed from the operating floor.

2. Open the drain valve on the gage.

3. Unscrew the nuts at each end of the glass and remove the washer and broken glass.

4. Crack open the gage glass valves to blow out any fragments of glass and then close the valves again. A suitable face shield should be used to avoid injury.

5. If there is no gage glass of correct length, cut a new glass to the correct length using a glass cutter.

6. Place the nuts and new washers on the glass. Install the gage in the gage fittings. Put graphite on the washers to act as a lubricant between the washers and nuts. This will prevent the glass from turning when tightening the nuts. The nuts should be only hand tightened. Tighten the nuts alternately by holding one while tightening the other. If “O” rings are used instead of washers, tightening with a wrench will be required.

7. Heat the glass slowly by cracking open the steam valve and leaving the drain valve open. Then close the drain valve and partially open the water valve. Open the gage steam and water valves fully when the water level in the glass stabilizes.

If the gage valves are not equipped with chains so they can be operated remotely, the operator should wear a face shield or use a portable shield when opening the valves. This is needed if the new glass should burst when put into service.

If the gage glass leaks when put into service, do not tighten the nuts while the glass is under pressure. Always close the steam and water valves on the gage and open the drain before tightening the nuts.

During the time that the gage glass is out of service, the boiler drum level may be checked by means of try cocks, second gage glass, or drum level recorder if so equipped.

Normally, tubular gage glasses are not used for pressures above 2100 kPa. Their high pressure limits will decrease as the length of the glass increases. For higher pressures and added protection against corrosion, it is best to use flat glasses protected with mica.

The following procedure is recommended when changing the glass:

1. Close the steam and water valves on the gage glass. Open the gage glass drain.

2. Remove the bolted covers, glass, gaskets, and the mica. At this time the threads on the studs should be coated with graphite and the nuts run down to clean the threads.

3. Remove any remaining gasket material, being careful not to create low spots on the surfaces of the joints. Scraping the gasket off the metal surfaces may form burrs.

4. Clean both ends of the gage so gasket material will not plug the valves on the gage.

5. Polish the gage surfaces perfectly smooth. Check the surfaces to be sure that they are perfectly level with no high or low spots. This includes the surfaces of the gage body and the bolted covers.

6. Apply molybdenum disulphide on the contact surfaces of the new glass. This permits the glass to slip into place easily. Never reuse old gage glasses. Be sure that the glass is suitable for high temperature service.

7. Install a new asbestos gasket, new mica, and new glass on one side and install the cover. Replace the nuts on the cover.

8. Tighten the nuts on the cover evenly. It is best to start at the center of the glass and tighten evenly on both sides of the glass.

9. Repeat steps 6, 7 and 8 on the other side of the glass.

10. If the boiler is in service, allow the new glass to warm up gradually by conduction of heat. Never open the gage valves until the new glass is heated up.

11. With the drain valve still open, crack open the steam valve and permit steam to slowly blow through to heat the glass further.

12. When the glass is at operating temperature, close the drain valve and crack open the water valve to allow water into the glass.

If everything appears normal, and a water level is visible in the glass, open the steam and water valves fully.

On high-pressure boilers, many gage glass failures occur because the new glass was not heated gradually.

Testing a Directly Connected Gage Glass

In order for a gage glass to indicate the correct level, all connections to the gage and the gage glass itself should be free of any obstructions. To be sure that this condition exists, each connection should be cleared in the following manner:

1. The gage is assumed to be in service; that is, with the drain valve shut, and the steam and water valves both open.

2. Close the water valve on the gage glass and open the drain valve. Blowing of steam through the top connection will prove that this connection and the gage glass are clear. Close the drain valve.

3. Close the gage glass steam valve, open the gage water valve, then the drain valve. This forces water through the lower connection and proves that it is clear.

4. Close the drain valve on the gage and open the steam valve to put the gage glass back into service.

When safety shutoff valves are used on the water gage, the opening of the drain valve during the testing procedure would cause a surge of steam or water through the valves and the balls would be forced against their seats. This would prevent proper flow through the respective passages. To prevent the balls from seating during testing procedure, each valve is fitted with a pin, which extends through the valve seat. During the testing procedure, the valve is only partially opened, thus keeping the ball off its seat. This permits the steam or water to flow freely.

Testing of Water Column and Gage Glass During Operation

Refer to ASME Section I for the requirements concerning the placement of column isolation valves in the steam and water lines connecting the column to the boiler. This testing procedure is for connections having the isolation valves installed (as shown in Fig.6).

When a gage glass is connected to a water column, the connections to the column from the boiler, in addition to the gage connections, must be proven clear. The following procedure is recommended for high-pressure boilers. NOTE: Be aware that a boiler shutdown will occur if a low-water cutout is part of the column.

1. Close the gage steam valve and water valve in order to isolate the gage before checking the column connections.

2. Close the column water valve, then open the column drain valve. This permits steam to blow through the steam connection and the column to prove them clear. Close the column drain valve.

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3. Close the column steam valve, open the column water valve, then the column drain valve. Water flow through the water connection proves that this passage is clear.

4. Close the column drain and open the column steam valve. This puts the column back in operation.

5. Open the gage steam valve, then the gage drain valve. This permits steam to blow through the top gage connection proving it is clear. Close the gage drain valve.

6. Close the gage steam valve, open the gage water valve, then the gage drain valve. Water flow from the drain proves that the lower connection is clear.

7. Close the drain valve on the gage and open its steam valve to put the gage glass back in operation.

All the connections to both the column and gage have now been proven clear. As a final check, the try cocks may be operated in turn to verify the water level.

Since shutoff valves are not permitted in the connecting piping of a water column on a low-pressure heating boiler, the following procedure is used to clear the passages on the column and gage glass:

1. Close the gage water valve to prevent steam from bypassing through the gage glass.

2. Open the column drain. This allows steam and water to blow through the connections and the column to drain.

3. Close the column drain valve and open the drain on the gage glass to prove that the steam connection and the glass are clear.

4. Close the gage steam valve, and open the gage water valve to prove that the water passages on the gage glass are clear.

5. Close the gage glass drain and open the gage steam valve to put the gage glass back in service. The water should rise quickly to its true level indicating that all the passages are clear.

The water column and gage glass should be blown down every shift to remove any sediment that may collect. This is highly recommended on smaller high-pressure boilers. On large boilers where the gage glass contains mica, blowing down of the gage glass would be less frequent. Frequent blowing down will shorten the life of the mica and increase maintenance costs.

Gage glasses should be renewed if they become obscured by internal corrosion or deposits. Every plant should carry a substantial reserve of gage glasses and washers or packing rings. These gage glasses should be stored in a safe place where they will not be damaged.

INDIRECT OR INFERENTIAL LEVEL INDICATORS

Although numerous types of indirect level indicators are used in industry, only the more common types used on larger boilers will be described.

Remote Water Level Indicators

Fig. 13 illustrates a remote water level indicator that can be located at the operating floor. The operating element consists of a large sensitive diaphragm with the top side connected to the steam space of the boiler and the bottom to the water space.

A condenser at the boiler drum is provided to maintain a fixed head pressure of water on the steam side. The water side is connected at the minimum permissible water level in the drum and is subjected to a varying head pressure as the drum level changes. The difference in head pressure on the two sides of the diaphragm is balanced by a spring, when the level is at minimum so the diaphragm moves up and down in accordance with the water level. As the water level in the drum rises, the pressure due to the varying head of water increases causing the diaphragm to rise and move the indicator upwards. As full boiler pressure is exerted equally on both sides of the diaphragm, boiler pressure has no effect upon its movement.

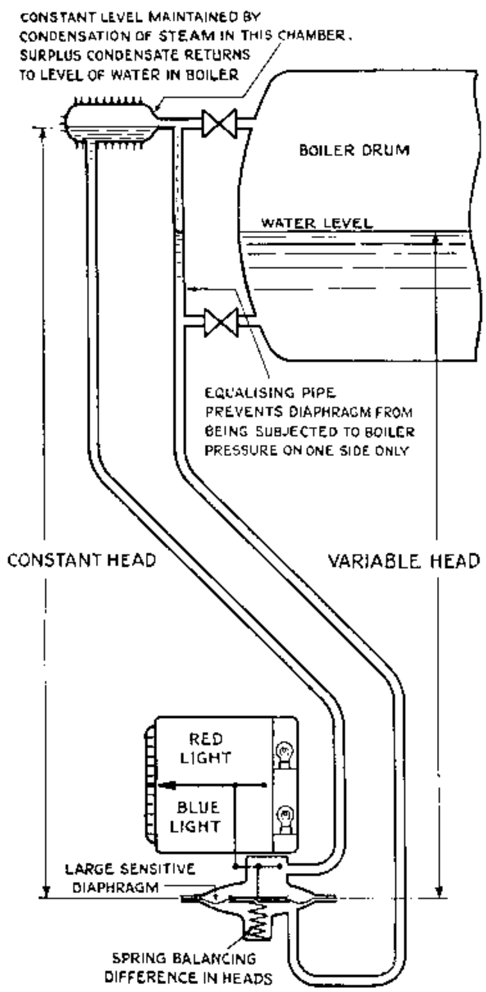

Figure 13
“Hopkinsons” Remote Water-Level Indicator

Coloureded screens illuminate the inside of the indicator with blue in the lower portion, representing the water level, and red in the upper part to represent steam. These two colours are separated by the reflecting shutter, which moves the indicating pointer.

The motion of the diaphragm is transmitted to a shutter through a lever mechanism connected to the diaphragm. If the drum level rises, the increased force under the diaphragm causes the diaphragm to rise and move the shutter upwards so more blue and less red is indicated. This action is reversed when the drum level drops.

The shutter may also be used to energize high and low drum level alarms. Fig. 14 is a sectional view of the indicator with all its parts numbered and named.

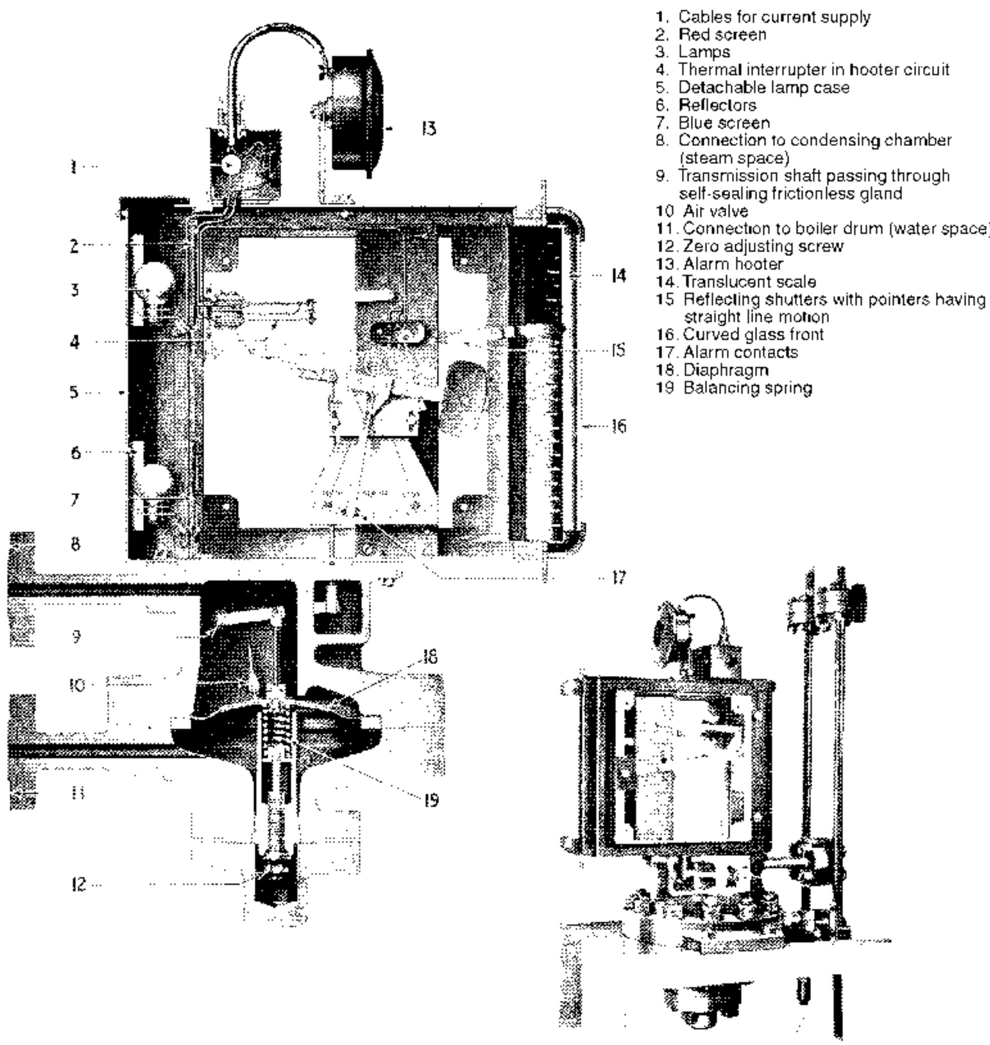

Figure 14
"Hopkinsons" Remote Water-Level Indicator, Section

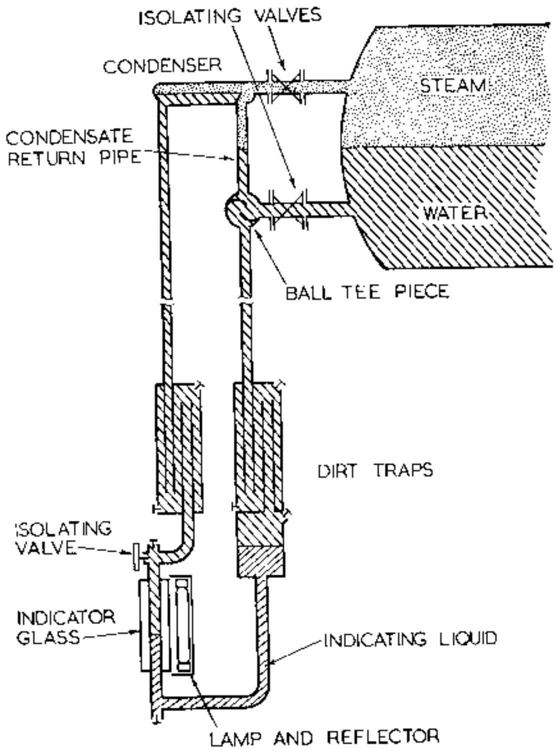

Figure 15
"Igema" Remote Water-Level Indicator

Fig. 15 shows another remote level indicator operating on a similar principle to the one in Fig. 14. It is widely used on high pressure boilers. The steam condenser maintains a constant head of water acting at the top of the indicator glass that contains a coloured indicating liquid. The right column of water or varying head is exposed to the liquid level in the drum and the right side of the U-tube containing the indicating liquid (usually blue or green in colour). When the level in the boiler steam drum is at minimum, the pressure differential between the two heads will be the greatest.

The indicating liquid will be forced downward to the bottom of the indicator glass. As the level rises in the drum, the indicating liquid will also rise in the glass, giving a coloured indication of level to the operators on the operating floor.

Dirt traps are installed on both connections to the indicating glass to prevent contamination of the indicating liquid. A special liquid, whose relative density is greater than water, is used. One must be careful when adding this liquid as overfilling will cause the level indication to be higher than necessary.

A great advantage of this remote indicator is that there are no moving mechanical parts.

References and Reference Material

For more information on this topic, the following are recommended:

Liptak, Bela G., *"Instrument Engineer's Handbook, Volume 1, Process Measurement"*, New York, Chilton Book Company, 1985.

O'Higgins, Patrick, *"Basic Instrumentation, Industrial Measurement,"* Toronto, McGraw Hill, 1966.