
Internal Feedwater Treatment and Testing Methods

Learning Outcome

When you complete this module you will be able to:

Discuss the general principles, methods and equipment used in the internal treatment of raw feedwater for steam production in a boiler.

Learning Objectives

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

1. Describe the type of problems associated with internal boiler water contamination.
2. Describe internal boiler feedwater chemical feed systems.
3. List and describe the standard boiler water tests and what they measure.





INTRODUCTION

Boiler feedwater can be treated after it enters the boiler. This is called **internal treatment** and it is achieved through the addition of chemicals to the feedwater.

Boiler water testing is critical to the safe and efficient operation of a steam plant. Poorly or untreated water can produce corrosion, sludge, pitting, scaling and quite possibly catastrophic failure. Six of the most common boiler water tests will be described in this module.

INTERNAL TREATMENT

Internal treatment of boiler feedwater refers to the method whereby the water is softened, deaerated, and conditioned after it has entered the boiler. This is accomplished by adding suitable chemicals to the water in the boiler.

For most low capacity, low-pressure heating boilers this internal treatment is the only method used to prevent scale, corrosion, and sludge formation.

The makeup water for larger boilers is usually treated externally; however, this treatment is seldom perfect and small amounts of impurities may still enter the boiler, making it necessary to apply some additional internal treatment.

When low-pressure steam heating boilers are used mainly for the generation of steam for plant or building heating, practically all the steam condensate is returned from the heating system to the boiler and very little additional water (makeup) is required after the initial filling of the boiler. The internal water treatment for these boilers is usually quite simple.

When part of the steam produced in the boiler is used for purposes other than heating (steam humidifiers, sterilizers, saunas, etc.) resulting in a reduced amount of condensate returning to the boiler, the makeup requirement will increase considerably, and internal water treatment will be more extensive.

Low-pressure hot water boilers form part of closed circulating heating systems. In these systems, the makeup requirements are usually very low and internal treatment requires only proper pH control and corrosion prevention.

Chemicals Used For Treatment

Some of the chemicals commonly used for internal boiler water treatment for low-pressure heating boilers are listed in Table 1.

Inorganic	Organic
Sodium carbonate (soda ash)	Lignin sulphonate
Sodium chromate	Sodium alginate
Sodium hydroxide (caustic soda)	Starch
Sodium nitrite	Tannins
Sodium phosphate	Polymers
Sodium sulphite	
Sodium polyacrylate	
Sodium nitrilotriacetate	

*Table 1
Internal Treatment Chemicals*

Chemicals used for water treatment are usually not sold by their generic names. Most water treatment companies sell the chemicals by trade names and numbers. They are supplied in solid form as balls or briquettes, as a powder, or as a liquid. Often several chemicals are combined to serve multipurpose treatment. For example, phosphate briquettes, used to prevent scale-forming in the boiler, contain sludge conditioning as well as antifoam chemicals in proper proportions. This simplifies the feeding of chemicals to the boiler for the operator.

It must be stressed that any program of water treatment should be undertaken only after the water has been analyzed and the proper type of treatment has been determined by qualified water treatment consultants. The results of improper water treatment may be: caustic embrittlement of boiler metal, foaming of boiler water, corrosion, loosening of old scale which collects in a heap in one location, and sludge deposits.

The use of internal treatment for pH control, scale prevention, sludge conditioning, deaeration, prevention of foaming, prevention of caustic embrittlement and prevention of return line corrosion is discussed in the following sections.



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pH Control

The pH value is a number between 0 and 14, which indicates the degree of acidity or alkalinity of the water. A pH value of 7 is neutral with values below 7 being acid and above 7, alkaline.

If the boiler water is acidic, then corrosion of the boiler metal will occur. To prevent this corrosion, the boiler water should be kept alkaline. It has been found that a pH value of about 10.5 usually provides the necessary alkalinity.

A sodium hydroxide solution is often used to maintain proper alkalinity within the boiler and may be fed directly to the boiler drum or to the feedwater before it enters the drum. Phosphate compounds may also be used to increase the pH value.

Scale Prevention

In order to prevent calcium and magnesium compounds from forming scale within the boiler, it is necessary to precipitate these impurities in the form of a sludge, which can be removed from the boiler by means of the blowoff. The chemicals added to the boiler water to cause this precipitation include sodium hydroxide, sodium carbonate, sodium phosphate and sodium aluminate.

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Sludge Conditioning

The sludge that is produced by the precipitating of the scale forming compounds in the boiler must be conditioned so that it will stay fluid and well dispersed. In this way the sludge will be easily removed from the boiler through the blowoff connections. The chemicals used for this purpose are usually organic compounds such as starch, tannin, lignin and alginates. Starch is produced from corn or potatoes, lignin and tannin from wood, the alginates from seaweed. These organic materials coat the scale precipitates, preventing them from adhering to the boiler plates and tubes.

Chemical Deaeration

Although mechanical deaerators are almost always used to remove dissolved gases from the feedwater, there are usually some traces of oxygen remaining in the water after mechanical deaeration. These traces of oxygen can be removed by the use of chemicals which are fed to the boiler feedline or to the storage space of the deaerator. These chemicals have the ability to absorb the dissolved oxygen.

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Two chemicals that are commonly used for this purpose are sodium sulphite Na_2SO_3 and hydrazine N_2H_4 .

Foaming Prevention

A high concentration of dissolved and suspended solids in the boiler water will tend to cause foaming within the boiler. Organic materials in raw water can pass through external treatment and can also cause foaming within the boiler. This is very undesirable because when it occurs, the water level in the boiler is difficult to determine. Foaming may cause the boiler to prime, that is, to carry over water with the steam leaving the boiler outlet.

The high concentration of solids in the boiler water can be reduced by the use of the blowoff and, in addition, the tendency for the water to foam can be reduced by adding antifoam compounds to the boiler.

Caustic Embrittlement Prevention

A disadvantage of adding sodium hydroxide (caustic soda) to the boiler for scale prevention and pH control is the fact that it may cause embrittlement and cracking of the boiler metal particularly at riveted seams and at tube ends. This cracking occurs when metal under stress is attacked by a concentrated caustic solution. In order for this to occur there must be a point where steam may escape and cause the boiler water in that location to become concentrated.

It has been found that the addition of certain materials such as sodium nitrate, lignins and tannins to the boiler water is effective in preventing caustic embrittlement.

Return Line Corrosion Prevention

Corrosion of return lines and steam lines is caused by oxygen and/or carbon dioxide in the presence of moisture. If both these gases are present, the corrosion will take place much more rapidly than if only one was present. Both carbon dioxide and oxygen can be removed from the feedwater by raising the water temperature to the boiling point in a deaerator, however, there is a possibility that more carbon dioxide may be released within the boiler by the decomposition of bicarbonates contained in the water. In addition, air may leak into return lines, particularly in vacuum and gravity systems, resulting in oxygen being absorbed by the condensate.

Therefore, to prevent corrosion of return lines due to these gases, chemicals may be fed to the boiler which pass off with the steam and either neutralize and raise the pH value of the condensate or else form a film over the return line surfaces and thus prevent corrosion. These chemicals are known as **amines** and in the first case are called **neutralizing amines** and in the second case are called **filming amines**.



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Internal Treatment Feed Systems

The method usually used to supply the necessary chemicals to the boiler water is by means of a small, positive displacement, motor driven pump. This may be arranged to pump the chemicals directly to the boiler drum or, in some cases, to the feedwater line or to the storage compartment of the deaerator. The pump is a high pressure, low capacity type and is usually designed so that the volume pumped may be varied by adjusting the stroke of the pump.

The chemical feed line to the boiler should be equipped with a shut-off valve next to the boiler and a check valve. Also, as the pump is a positive displacement type, a relief valve is installed on the pump discharge line to prevent damage in case the shut-off valve is closed while the pump is running.

Fig. 1 shows the general arrangement of a chemical pump having an adjustable crank pin by means of which the pump stroke can be changed. Fig. 2 illustrates the action of the pump piston within the cylinder during the suction and discharge strokes.

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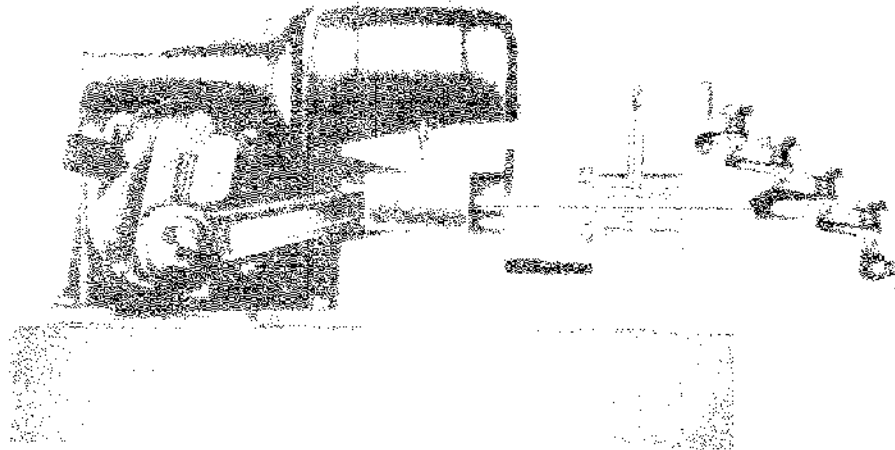
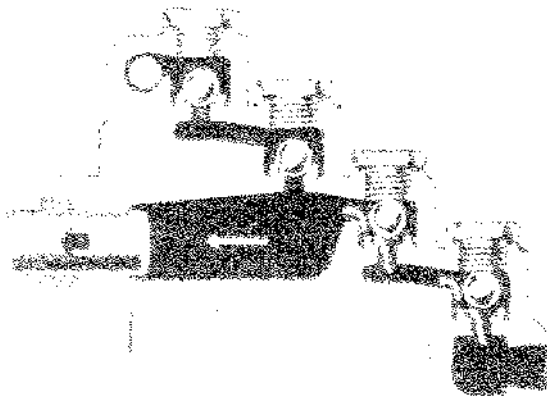


Figure 1
Adjustable Stroke Chemical Pump



(a) Discharge Stroke



(b) Suction Stroke

Figure 2
Chemical Pump Cylinder

Chemical Feeders

Chemical feeders are required to feed the water treatment chemicals either into the feedwater line, the supply or return line of a hot water circulating system, or directly into the boiler.

In general, the feeders used for closed heating systems with low makeup are quite simple since, after the initial treatment of the water, only small quantities of chemicals have to be fed into the system periodically.

The bypass feeder, shown in Fig. 3, is used to feed chemicals, supplied in briquette or ball form, into the feedwater or circulating line.

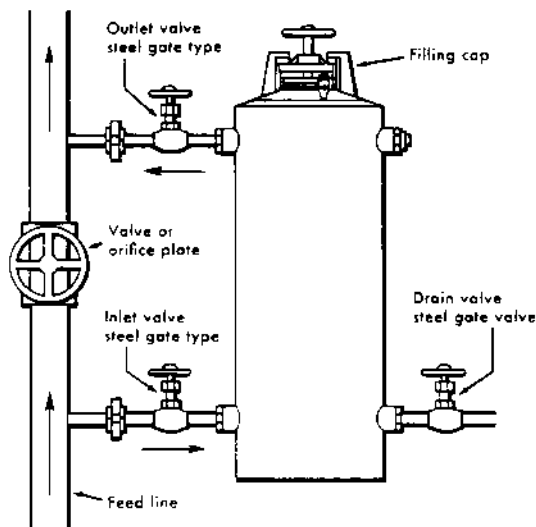


Figure 3
Closed Type Bypass Feeder

The briquettes or balls are placed in the pot and a slipstream of water flows through the pot feeder. The water slowly dissolves the briquette and carries the chemicals into the feedwater line.

The gravity drip feeder, Fig. 4, is used to feed powdered or liquid chemicals into feed or circulating lines. The chemical solution slowly drips by gravity into the pipeline and gradually washes into the system.

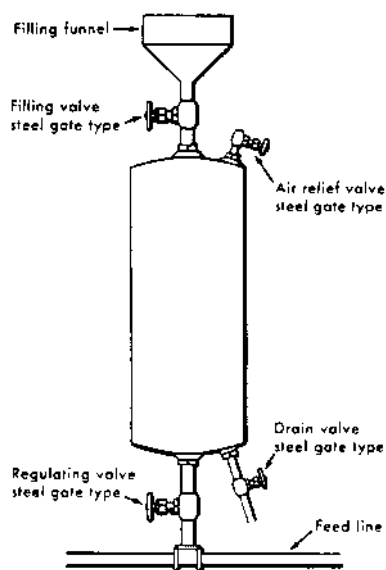


Figure 4
Closed Type Gravity Drip Feeder

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TESTING METHODS

In order to determine the nature and the amount of the impurities present in the boiler water or in the feedwater being supplied to the boiler, it is necessary to obtain samples of this water and subject them to various tests.

The sample containers must be clean and should be rinsed out with water from the sampling line. Also water should be allowed to run from the sampling line for sufficient time to ensure that any stagnant water in the line is not taken as the sample. The sample should be allowed to cool to room temperature and suspended solids should be filtered or allowed to settle out. The testing of the sample should be done as soon as possible after obtaining the sample.

In the automatic sampling arrangement sketched in Fig. 5, the sample line is connected to the continuous blowdown line and the sample water is obtained from this source. The sample water passes through a cooler where its temperature is reduced to about 24°C and then flows to a sample header. From the header, the individual sample lines run to automatic analyzers which continuously test the samples for dissolved solids content, excess sulphite, and excess phosphate.

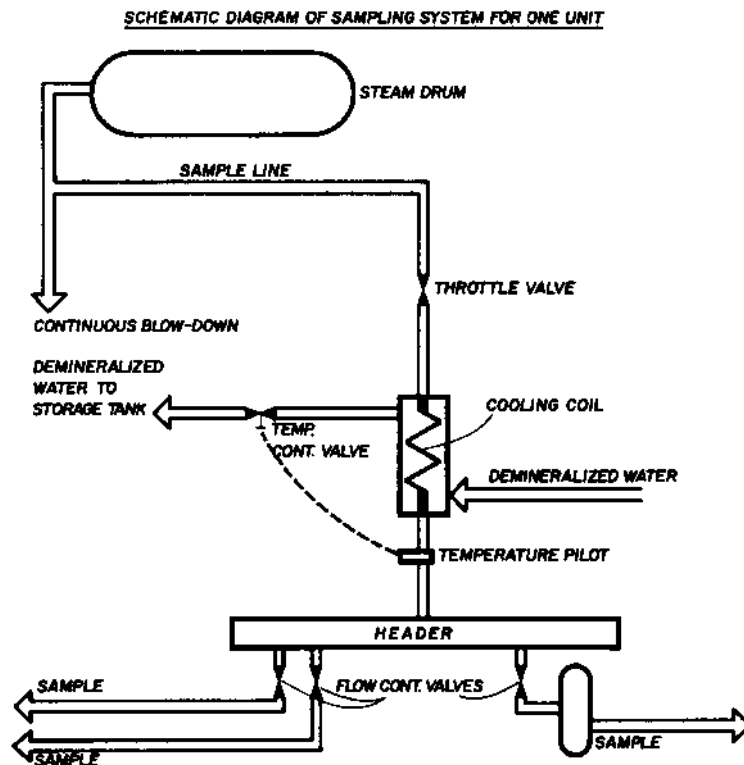


Figure 5
Sampling and Cooling Arrangement



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In many plants, however, the tests are carried out manually rather than by automatic analyzers and the most common of these tests are briefly described in the following sections.

Hardness Test

Hardness of the water is due to impurities or salts such as those of calcium and magnesium which are dissolved in the water. These will cause scale in the boiler unless properly treated. There are two methods to determine hardness. One is the soap test, the other is a titration test.

Soap Test: Impurities in the water combined with soap to form a scum and retard the formation of a lather. Therefore the amount of soap needed to combine with all the impurities will give an indication of the amount of impurities present.

The soap test procedure is to obtain a sample of the water and filter it or let the suspended solids settle out. Add a measured amount of the filtered water to a clear glass bottle equipped with a glass or rubber stopper. Small, measured amounts of a standard soap solution are added to the water with the bottle being shaken vigorously after each addition of soap. When just enough soap is added to produce a lather that lasts five-minutes, all the mineral impurities are considered to have combined with the soap and the amount of soap used will indicate the hardness of the water.

Titration Test:

This test, if done carefully, will show a hardness of between 5 ppm and 1200 ppm within a two-percent accuracy. Hardnesses less than 5 ppm can only be determined with an accuracy of about ten-percent using this test.

1. Measure 50 mL of the filtered water sample and pour it into a casserole.
2. If necessary, adjust the sample to a pH range of 7 to 10 with either dilute ammonium hydroxide or dilute hydrochloric acid.
3. With a brass measuring dipper, add one level measure (0.2 g) of hardness buffer reagent to the sample and stir.
4. Add one level measure of hardness indicator and stir again. If hardness is present, the sample will turn red.
5. Add hardness titrating solution slowly from the measuring burette while stirring continuously. When approaching the endpoint, some blue coloration will appear in the sample but the sample will still show a reddish tinge. As soon as this reddish tinge disappears, the endpoint is reached and titrating should be stopped.

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6. Read the amount of titrating solution fed from the burette (in mL) and multiply this reading by 20 to find the hardness in ppm as CaCO_3 .

Alkalinity Test

The alkalinity of the water may be due to hydroxides, carbonates and bicarbonates of calcium, sodium, and magnesium. The water can be tested to determine the amounts of these alkalies by the following methods.

1. Phenolphthalein Alkalinity Test

This test indicates alkalinity due to carbonates and hydroxides dissolved in the water. It does not indicate alkalinity due to bicarbonates.

Phenolphthalein is a liquid which is used as an indicator of carbonate and hydroxide alkalinity. When a drop of this indicator is added to a sample of the water it will cause the water to become pink in color providing the water contains carbonates or hydroxides or both.

To conduct the test, a small amount of phenolphthalein is added to a measured sample of the water. If a pink color appears, then sulphuric acid is added drop by drop to the water until the pink color just disappears. While this is being done, the sample must be stirred constantly. The amount of acid required to make the pink color just disappear will indicate the amount of alkalinity known as phenolphthalein or “P” alkalinity. The sample is then put aside for the following test.

2. Total Alkalinity or Methyl Orange Test

This test is used to determine the amounts of all the dissolved materials which cause alkalinity of the water. The indicator used for this is methyl orange and it will give a yellow color to alkaline water.

To perform the test, a small amount of methyl orange is added to the same sample as used in the previous test. If a yellow color is produced then this means that the sample is still alkaline due to bicarbonates present. Sulphuric acid is then added drop by drop until the yellow color turns to a salmon pink. This indicates that all the alkalinity has now been neutralized by the sulphuric acid and the total amount of acid used, namely that used for the methyl orange test plus that used for the phenolphthalein test will indicate the total alkalinity of the sample. This total alkalinity is also called methyl orange alkalinity or “M” alkalinity.



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Dissolved Solids Test

To determine the amount of dissolved solids in the water, the ability of the water to conduct an electric current is measured. The greater the amount of dissolved solids present in the water the greater will be this ability to conduct or the greater the **conductance** of the water.

To perform the test, a sample of water is taken and a small amount of phenolphthalein is added. If a pink color appears, then sulphuric acid is added drop by drop until only a faint tinge of pink remains. This is done to neutralize the hydroxide alkalinity as it has a very high conductivity compared to neutral salts and if not neutralized would render the conductance test inaccurate.

The conductance of the neutralized sample is now measured by means of an electrical instrument and the reading, when multiplied by a conversion factor, will give the amount of dissolved solids. The amount of dissolved solids will largely determine the amount of blowoff required.

pH Testing

The pH value of a water sample may be determined by the use of an electrical instrument known as a pH meter. Two electrodes are immersed in the sample and a voltage is supplied to the electrodes by means of a battery or a power pack. The voltage between the electrodes will vary according to the acidity or alkalinity in the sample and this voltage is indicated on the pH meter which is calibrated to read in pH numbers.

Sodium Sulphite Test

In cases where sodium sulphite is fed to a boiler in order to prevent pitting due to dissolved oxygen, it is necessary to ascertain that sufficient amounts of sulphite are supplied. Usually if there is an excess of sulphite maintained in the boiler water, then the complete removal of any dissolved oxygen will be assured.

In determining the amount of excess sulphite in the boiler water, the following procedure is used:

Obtain a sample of boiler water without allowing it to come in contact with the air. Cool the sample to room temperature but do not filter it. A measured amount of the sample is then put in a porcelain dish and turned slightly acidic by the addition of sulphuric acid. A small amount of starch solution is added to the sample and then a potassium-iodide-iodate solution is added drop by drop until a permanent light blue color is attained. During this procedure the sample is stirred constantly. The amount of the potassium-iodide-iodate solution necessary to produce the permanent light blue color will indicate the excess sodium sulphite in the boiler water.

Phosphate Test

A common form of internal treatment for the prevention of scale in a boiler is the addition of sodium phosphate compounds to the boiler water. These will precipitate the scale forming materials as a sludge, which may be blown off from the boiler through the blowoff line. In order to assure this precipitation of the scale forming materials, it is necessary to have an excess of phosphate in the boiler.

To determine the amount of excess phosphate present, a sample of boiler water is thoroughly filtered. A measured amount is then poured into a mixing tube and molybdate reagent is added. The tube is then stoppered and vigorously shaken. The next step is to add dilute stannous reagent, which has been freshly prepared from concentrated stannous reagent and distilled water, to the mixture in the tube. This will produce a blue color and the lightness or darkness of the blue will indicate the amount of phosphate in the water. The tube is compared with standard colored glass slides, which are marked in amounts of phosphate.

The apparatus used in all of the foregoing tests should be thoroughly cleaned after using and then rinsed again with distilled water or with part of the water to be tested just before the testing is carried out. The testing room or laboratory should be equipped with a sink, hot and cold running water, electrical outlets, equipment cabinets and the necessary desks and tables.



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Notes: