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Installation and Operation of Boiler Systems

PDH Credits:

5 PDH

Course No.:

OBS101

Publication Source:

US Navy

Engineering Aid Basics
"Chapter 5 – Boilers"
Pub. # NAVEDTRA 14259A

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Chapter 8

Boilers

Topics

1.0.0 Installation of Boilers

2.0.0 Plant Operation

3.0.0 Maintenance

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Overview

As a Utilitiesman (UT), you will be responsible for the general management of a boiler plant. You will be also be asked to supervise personnel in the installation, operation, and maintenance of boilers. This chapter describes the installation, plant operations, and maintenance of the scotch marine boiler, which is the most common type of boiler in the NCF. This chapter provides insight into many skills that you must develop to be a proficient boiler plant supervisor/manager.

Objectives

When you have completed this chapter, you will be able to do the following:

1. Describe the installation procedures associated with boilers.
2. Describe boiler plant operations.
3. Describe the maintenance procedures associated with boilers.

Prerequisites

None.

1.0.0 INSTALLATION of BOILERS

"Scotch marine" is a generic term that refers to a boiler with a furnace, which forms an integral part of the boiler assembly. This configuration allows for compact construction requiring only a small space for the capacity produced. Scotch marine boilers are package units consisting of a pressure vessel, burner, controls, draft fan, and other components assembled into a fully factory fire-tested unit. They are engineered units equipped for quick installation and connection to services.

When preparing to install a boiler, you should consider the following three basic factors:

- Site location
- Accessories
- Fittings

Proper installation of a boiler helps to ensure successful operation. Always refer to the manufacturer's manuals, and follow your prints and specifications closely. By being thorough in your planning and execution of plans, you can prevent many future problems for operators and maintenance personnel.

1.1.0 Site Location

Give careful consideration to site location for the construction of a boiler plant. Primarily, the cost in materials, manpower, and equipment is the most important factor affecting this selection. These costs can usually be reduced by locating the plant site as close as possible to the largest load-demand facility, such as a galley or laundry.

1.1.1 Location

When you are selecting a site for boiler installation, you must consider the availability of the following:

Water

Electricity

Fuel

Natural site drainage

Attempt to avoid high pedestrian and vehicle traffic areas for safety reasons. Another item you should consider is noise level. Noise pollution may cause discomfort for personnel, especially if the site being considered is adjacent to a berthing area.

These are factors that you must consider when you become involved in selecting a boiler plant site. Each situation may include all, part of, or more than these factors. You must look at each installation and evaluate the needs of that job.

1.1.2 Boiler Foundation

Constructing the foundation or platform that a boiler sits on requires skilled engineering and development. Follow the manufacturer's specifications. Boilers may vary in wet weight from 1.5 tons to more than 20 tons. A substantial foundation that can withstand the weight and absorb the vibration is essential.

Reinforced concrete slabs with runners provide for placing and anchoring the boiler. The runners should provide a level, uniform support and be of sufficient height to allow for maintenance and the installation of piping under the boiler. A raised platform also provides easier access for boiler room cleanup.

Generally, a sump in the slab between the runners provides a catchment area for boiler blow-down or draining of the boiler. This sump drains from the building to a suitable dispersal point.

1.1.3 Boiler Room

When considering the requirements of sheltering a boiler, you must ensure there is enough room for the boiler and all of the accessory equipment. This accessory equipment may include condensate tanks and pumps, chemical feeders, water makeup tanks and feeders, and blow-down tanks.

The boiler room must also be large enough to allow for boiler maintenance, for retubing, and for removing and replacing the boiler. The tube length of a boiler may be from 2 feet 6 inches to at least 10 feet, and possibly longer. To simplify the removal of the tubes, ensure the boiler room is long enough or has a door located behind the boiler. The most important source you need to check is the manufacturer's specifications, which will provide you with the proper dimensions for locating the boiler.

Fresh air inlets and louvers allow fresh air to enter and move across the boiler area. This fresh air entering the boiler room removes excess heat and provides adequate makeup air for combustion.

When planning for boiler room construction, you must always consider boiler requirements, maintenance requirements, and manufacturer's recommendations.

1.2.0 Accessories

As a boiler plant supervisor it is important that you know the special requirements for boiler accessory equipment. Select the boiler accessory number in *Figure 8-1* to view the special requirements for that accessory.

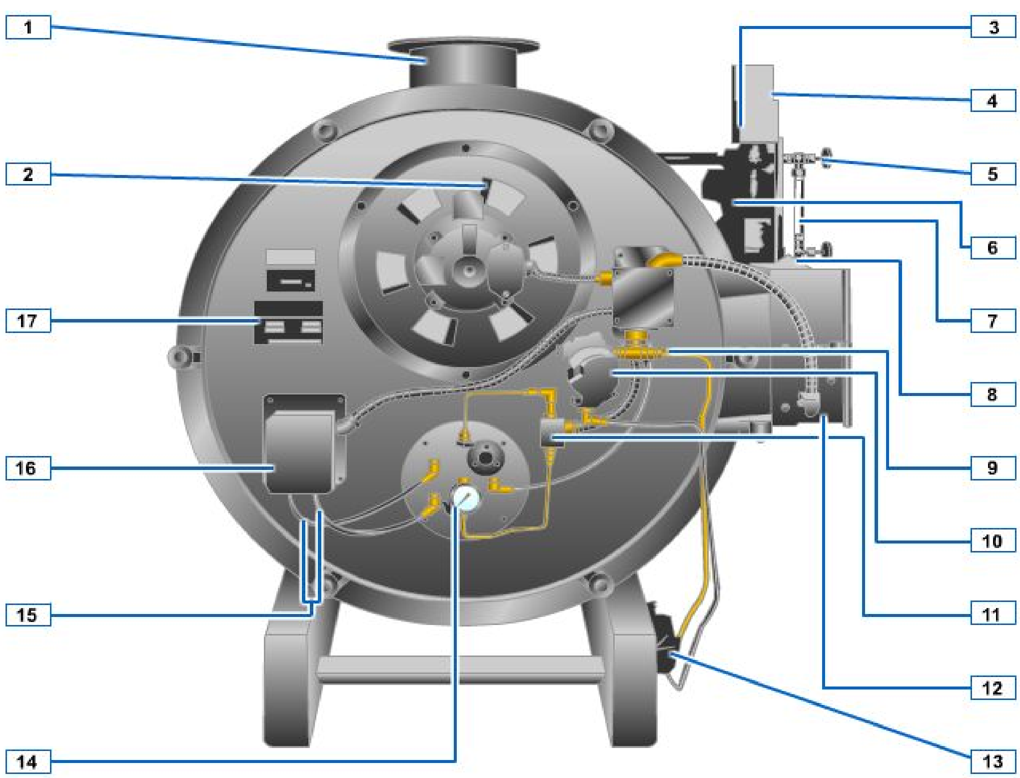

Figure 8-1 — Boiler accessory equipment.

	Item	Special Requirement
1	Boiler.	N/A
2	Main Steam Stop.	Must be outside yoke rising spindle type if it is over 2”. This allows the operator to distinguish the position of the valve by sight.
3	Guard Valve.	When two or more boilers are connected to a common header, the steam connection from a boiler with a manhole opening must be fitted with a main steam-stop and a guard valve.
4	Daylight Drain Valve.	When both eh main steam-stop and guard valves are required, install a daylight drain valve.
5	Main steam line.	Pitch horizontal piping 1/4” per 10’. Do not use galvanized piping.
6	Root Valve.	Normally of gate-valve design, fully opened or closed.
7	Pressure Regulating Valve (PRV).	N/A
8	Steam Trap.	Install traps with unions on both sides for easy replacement. Inlet and outlet piping of trap needs to be equal or larger than trap connections.
9	Drip Legs.	Place at intervals of not mover 200’ for horizontally pitched pipe and at intervals of not over 300’ for buried or inaccessible piping.
10	Temperature Regulating Valve (TRV).	When the valve throttles to a partially closed position, the pressure in the equipment can easily go into a vacuum. This is caused by condensing steam and it holds condensate in the equipment. Use a vacuum breaker to solve the problem.
11	Heat Exchanger.	N/A
12	Strainer.	N/A
13	Condensate Line.	Pitch lines toward boiler 1/4” per 10’. Do not use galvanized piping.
14	Condensate/Makeup Tank.	N/A
15	Feed Pump.	Pump must be capable of pumping higher pressures than that of the boiler pressure.
16	Feedwater Pipe.	Place relief valve, check valve, and stop valve in the feedwater pipe.
17	Relief Valve.	Relief valve opens gradually at a set pressure. Safety valves open fully at a set pressure. Do not use a relief valve in place of a safety valve.

1.2.1 Fittings

As a boiler plant supervisor, you must also know the American Society of Mechanical Engineers (ASME) requirements for boiler fittings. Select a boiler fitting name in *Figure 8-2* to view the ASME requirements for that fitting. *Figure 8-3* shows information applicable to a water column.

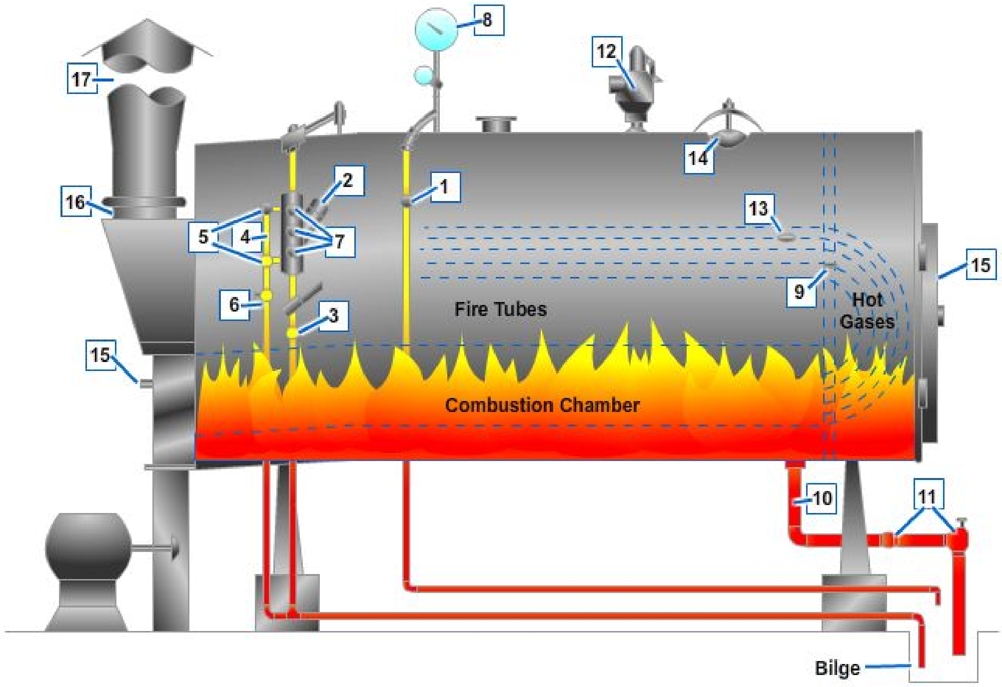

Figure 8-2 — Boiler fittings.

	Item	Special Requirement
1	Air Cock	Open valve when a boiler is initially filling with water during steam buildup and when emptying a boiler.
2	Water Column	Column must be connected to the steam and water space with a minimum size pipe and fittings of 1” and that each right angle turn be made with a cross to aid in inspection and cleaning.
3	Water Column Blowdown Line and Valve	Minimum permissible size for the blowdown piping and valve is 3/4".
4	Gauge Glass	Minimal size of gauge glass is 1/2". Boilers operating at 400 psi of pressure or greater require two gauge glasses and the lowest visible portion of the gauge glass must be at least 2” above the lowest permissible water level.
5	Gauge Glass Shutoff Valves	Gauge glass shutoff valves have a minimal size of 1/2". Some valves may be fitted with an automatic shutoff device, usually consisting of a nonferrous ball that functions to secure or prevent the escape of steam or hot water should the gauge glass break.
6	Glass Blowdown Line and Valve	When under pressure and the gauge glass blowdown line is opened and then closed, the water level should return promptly. If level returns slowly, a partial blockage may be present.

7	Try Cocks	Boilers not exceeding a diameter of 36” or heating surface of 110 square feet need only two try cocks and one gauge glass. Boilers that exceed the above diameter and heating surface require three try cocks regardless of the number of gauge glasses.
8	Pressure Gauge	Dial on gauge is graduated so it reads approximately twice the pressure at which the safety valve is set to open. Test every 6 months or whenever you doubt the accuracy of the gauge.
9	Fusible Plugs	Must be replaced every year.
10	Bottom Blowdown Piping	Minimum size blowdown and fittings for boilers having 100 square feet or less of heating surface require 3/4" pipe and fittings. If the boiler is in excess of 100 square feet, 1” is the minimum and 2 1/2" is the maximum.
11	Bottom Blowdown Valves	Every boiler must have one slow opening valve. A slow opening valve requires at least five complete 360° turns between fully opened and closed positions. Boilers exceeding 100 psi must provide two bottom blowdown valves. One may be of the quick closing type. When using the blowdown line, remember to always open the quick closing valve first and secure it last.
12	Safety Valve	No other valve is permitted to be between the safety valve and the boiler. Every boiler must have at least one. If heating surface is over 500 square feet, two safety valves are required. Lift valves monthly to blow away dirt and prevent disk from sticking. Ensure boiler pressure is at 75% of valve pop setting for removal of debris, and ensure the valve will re-seat.
13	Handhole Plates	N/A
14	Manhole Plates	N/A
15	Access Door	N/A
16	Breaching	N/A
17	Stacks	Stacks are required to be high enough to comply with health requirements.

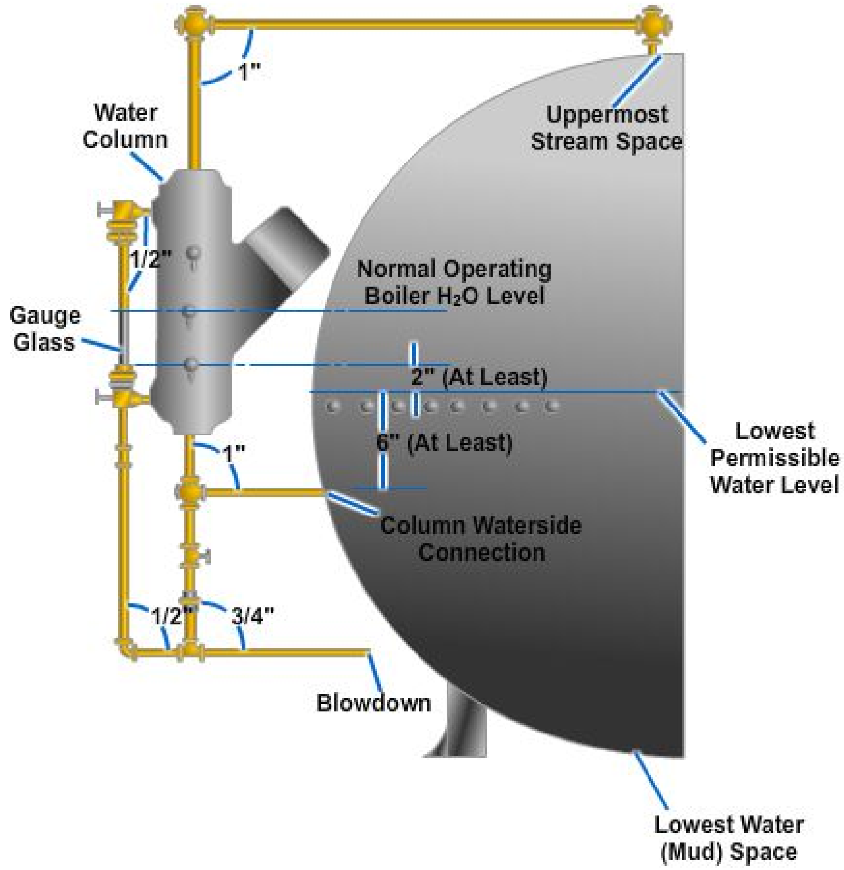

Figure 8-3 — Water column.

1.3.0 Inspecting and Testing Responsibility

The commanding officer of an activity is responsible for ensuring that boilers and unfired pressure vessels installed at their facility are certified. Inspection and testing of boilers and unfired pressure vessels are done by a boiler inspector certified by Naval Facilities Engineering Command (NAVFACENGCOM) and/or licensed by a NAVFACENGCOM Engineering Field Division (EFD). This inspector is on the rolls, except for the following:

- Inspection responsibility has been assigned to the commanding officer of a Public Works Center.
- The commanding officer of a major or lead activity is responsible for doing the maintenance of public works and public utilities at adjacent activities.
- It is impractical to use qualified personnel for such inspections because of the limited work load. In such situations, assistance for inspection services should be obtained by an EFD inspector or an activity inspector located near the requested activity which has qualified perso nnel, or by contract. When assistance is required by the EFD, such assistance is on a reimbursable basis. The requesting activity is responsible for providing the finds to accomplish the inspections.

1.4.0 Frequency of Inspection and Tests

Table 8-1 provides a list of the different types of equipment and the frequency of boiler testing requirements. For frequency and testing requirements concerning unfired pressure vessels, refer to NAVFAC MO-324, *Inspection and Certification of Boilers and Unfired Pressure Vessels*.

Table 8-1 — Boiler Inspection and Test Frequencies.

ITEM	INTERNAL INSPECTION	EXTERNAL INSPECTION AND OPERATION TESTS	HYDROSTATIC TESTS
Boilers, wet or dry lay-up	At least annually. At resumption of active service.	At least annually. At resumption of active service.	Tightness test at resumption of active service.
Boilers, heating and LTW LTW boilers within at least once every 3 years if output is less than 5 million Btuh	At least annually. After any repair or alteration of pressure parts.	At least annually. After any alteration or modification to boilers, control equipment, or auxiliaries.	Strength test at least once every 6 years. Tightness test all other years. Strength test after repair or alteration of pressure parts. Additional times at the discretion of the inspector.
Boilers, power, high pressure, HTW, and MUSE	At least annually. After repair or alteration of pressure parts.	At least annually. After any alteration or modification to boilers, control equipment, or auxiliaries.	Strength test at least once every 3 years. Tightness test all other years. Strength test after repair or alteration. Additional times at the discretion of the inspector.

Notes:

1. Additionally, Mobile Utility Support Equipment (MUSE) boilers and other portable boilers must be inspected externally and internally and certified each time they are moved from one place to another. A MUSE steam coil type of boiler is exempt from annual inspections while in dry or wet lay-up.
2. All manhole and handhole gaskets must be replaced after a strength test unless they are made of non-compressible steel.

1.5.0 Preparing for Inspection

The activity that operates and maintains pressure vessels provides all of the material and labor required to prepare the vessels for inspection. You are responsible for providing the inspector with help during the inspection. An inspection on pressure vessels located on a naval base in a foreign country must comply with NAVFAC MO-324.

1.6.0 Waterside Inspection of Boiler Tubes

Regular waterside inspection of boiler tubes provides the information required to determine the effectiveness of water treatment, maintenance procedures, diagnosis of boiler operating troubles, and an overall condition of the boiler.

Tube failures generally occur in the outer half of the tube nest from external corrosion just above the water drum. When such failures have occurred, either in operation or under hydrostatic test, or when the examination of tubes in the exploring block shows that the tube thickness is less than half the original thickness, complete renewal must be made of all tubes from the center row to the outer row (inclusive) over a fore-and-aft length of the tube bank sufficient to completely cover the affected area. This renewal must be made regardless of the condition of the tubes that were not included in the exploring block.

The existence of slight scattered pitting does not necessarily require the complete retubing of the boiler, even if the thickness of the tubes at some of the pits is less than 50% of the original tube thickness. When pitting is observed, tubes should be split and examined to see whether the pitting is (1) moderately heavy, and (2) general throughout the boiler.

Internal pitting resulting from improper treatment of boiler water is most likely to occur in tubes that receive the most heat (screen tubes, fire row tubes, and so forth) and in areas that are particularly subject to oxygen pitting. In general, oxygen pitting tends to occur most commonly in down-comers, in superheaters, and at the steam drum ends of generating tubes. If active oxygen pits (that is, pits that are still scabbed over, rather than clean) are found when the boiler is inspected, or if oxygen pitting is suspected because of the past operating history of the boiler, one or two tubes should be removed from the areas in which oxygen pitting is most likely to be found.

After the tubes are removed, they should be split and examined. If as many as 25% of the pits are deeper than 50% of the tube wall thickness, and if at least a few of the pits are deeper than 65% of the tube wall thickness, a sample of about 20 tubes from the screen and last rows of the generating bank should be cut. These tubes should be split and examined, and their condition should be evaluated on the same basis as before. If as many as 25% of the pits are deeper than 50% of the wail thickness, and if at least a few are deeper than 65%, the oxygen pitting is considered to be general throughout the boiler and moderately heavy.

With these findings, complete tube renewal should be considered. However, it is possible that complete tube renewal may be postponed in the following cases:

1. The boiler can be successfully cleaned by a chemical cleaning.
2. The boiler can successfully withstand a 125% hydrostatic test.
3. Future boiler water treatment, use of blow-down, and laying-up procedures can be expected to be in strict accordance with NAVFAC requirements.

Before you make a detailed waterside inspection of boiler tubes, you should be familiar with some of the *waterside cavities* and *scars* that can be recognized by visual examination.

Localized pitting is the term used to describe scattered pits on the watersides. These pits are usually—though not always—caused by the presence of dissolved oxygen.

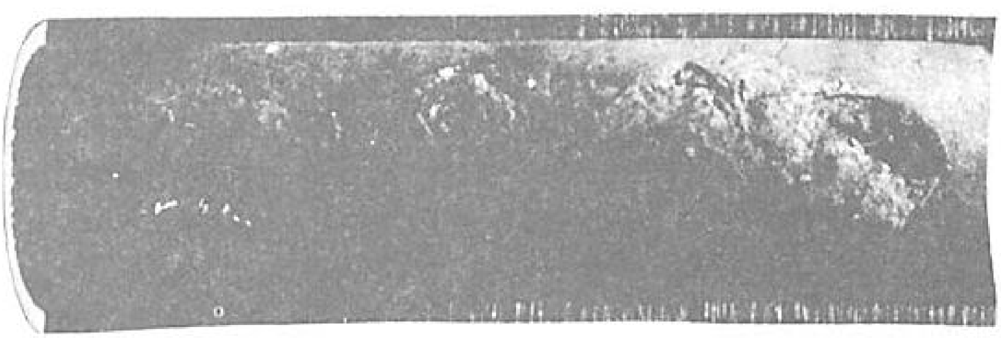

Figure 8-4 — Waterside grooving in a generating tube.

Waterside grooves are similar to localized pits in some ways, but they are longer and broader than the pits. These types of grooves tend to occur in the relatively hot bends of the tubes near the water drum; they may also occur on the external surfaces of the superheater tubes. Some waterside grooves are clean, but most contain islands of heavy corrosion scabs. A typical example of waterside grooving is shown in *Figure 8-4*.

Corrosion fatigue fissures are deep-walled, canyon-like voids. They have the appearance of being corroded rather than fractured, and they may be filled with corrosion products. These fissures occur in metal that has been fatigued by repeated stressing, thus making it more subject to corrosion than it would otherwise be.

General waterside thinning can occur if the boiler water alkalinity is too low over a long period of time, if the boiler water alkalinity is too high, or if acid residues are not completely removed from a boiler that has been chemically cleaned. The greatest loss of metal from general waterside thinning tends to occur along the side of the tube that is toward the flame. The entire length of the tube from steam drum to water drum may be affected. *Figure 8-5* shows general waterside thinning.

Waterside burning may occur if the temperature exceeds about 750°F in plain carbon steel tubes or about 1,000°F in most alloy superheater tubes. The effect of waterside burning is the oxidation of the tube metal to a shiny, black, magnetic iron oxide known as high-temperature oxide.

Waterside abrasion is the term used to describe waterside cavities that result from purely mechanical causes rather than from corrosion. For example, tube brushes or cutters may cause abrasion spots at sharp bends in economizer, superheater, and generating tubes. The surface markings of such abrasions indicate clearly that they result from mechanical abrasion rather than from corrosion.

Die marks appear as remarkably straight and uniform longitudinal scratches or folds on the watersides of the tube. They are the result of faulty fabrication. Die marks may extend for the full length of the tube (*Figure 8-6*). Localized corrosion occurs quite often along the die mark.

Figure 8-5 — General waterside thinning.

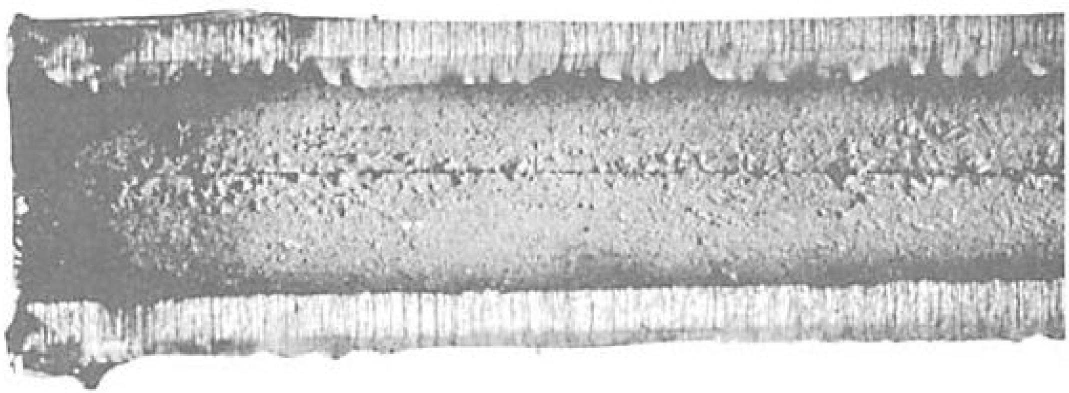

Figure 8-6 — Die marks on the waterside of a tube.

Tube corrugation is a peculiar type of heat blistering that occurs when the boiler water is contaminated with oil. Corrugation may consist of closely spaced, small-diameter, hemispherical bulges, as though the tube metal had been softened and then punched from the inside with a blunt instrument. It may also exist as a herring-bone or chevron pattern on the tube wall nearest the flame (*Figure 8-7*). It is not known exactly why oil contamination of the boiler water tends to cause this patterned corrugation.

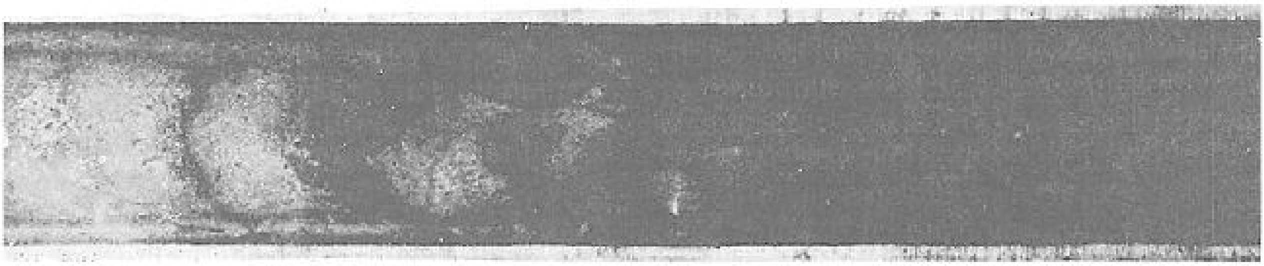

Figure 8-7 — Tube corrugation resulting from oil on waterside.

1.6.1 Waterside Inspection of Drums and Headers

Whenever a boiler is opened for cleaning and overhaul, the internal surfaces of the drums and headers should be carefully inspected for evidence of cracking. Particular attention must be given to steam drum manhole knuckles, knuckles at corners of drum heads, corners of cross boxes and headers, superheater header vent nozzles, and handhole openings. Any defect found must be recorded in the boiler water treatment log and in the maintenance log. These defects should also be reported to the maintenance office so that appropriate repair action can be taken.

1.6.2 Hydrostatic Tests

Boilers are tested hydrostatically for several different purposes. In each case, it is important to understand why a test is being made and to use—but NOT to exceed—the test pressure specified for that particular purpose. In general, most hydrostatic tests are made at one of the following three test pressures:

1. Boiler design pressure
2. 125% of design pressure
3. 150% of design pressure

Other test pressures may be authorized for certain purposes. For example, a test pressure of 150 psi is required for the hydrostatic test given before a boiler undergoes chemical cleaning. The hydrostatic test at design pressure is required upon the completion of each general overhaul, cleaning, or repair that affects the boiler or its parts and at any other time when it is considered necessary to test the boiler for leakage.

The purpose of the hydrostatic test at design pressure is to prove the tightness of all valves, gaskets, flanged joints, rolled joints, welded joints, and boiler fittings. The test at 125% of design pressure is required after the renewal of pressure parts, after chemical cleaning of the boiler, after minor welding repairs to manhole and handhole seats, and after repairs to tube sheets, such as the correction of gouges and out-of-roundness. The “renewal of pressure parts” includes all tube renewals, rolled or welded, except down-comers and superheater support tubes.

The test at 150% of design pressure is required after welding repairs to headers and drums, including tube sheet cracks and nozzle repairs, after drain and vent nipple repairs, and after renewal or rewelding of superheater support tubes and down-comers. The hydrostatic test at 150% of design pressure is basically a test for strength. This test may be (but is not necessarily) required at the 5-year inspection and test.

Before making a hydrostatic test, rinse out the boiler with freshwater. Using at least 50-psi pressure, play the hose onto all surfaces of the steam drum, the tubes, the nipples, and the headers. Examine the boiler carefully for loose scale, dirt, and other deposits. Be SURE that no tools or other objects are left in the boiler. Remake all joints, being sure that the gaskets and the seating surfaces are clean. Replace the handhole and manhole plates, and close up the boiler.

Gag all safety valves. Boiler safety valves must NEVER, under any circumstances, be lifted by hydrostatic pressure. When gagging the safety valves, do not set up on the gag too tightly or you may bend the valve stems. As a rule, the gags should be set up only hand tight.

Close all connections on the boiler except to the air vents, the pressure gauges, and the valves of the line through which water is to be pumped to the boiler. Be sure the steam-stop valves are completely closed and that there will be no leakage of water through them.

After all preparations have been made, use the feed pump to fill the boiler completely. After all air has been expelled from the boiler, close the air vents and build up the hydrostatic pressure required for the particular test you are making. A hand boiler test pump can be used in building up the hydrostatic test pressure. If you do not have a hand test pump, build up the required test pressure by continuing to run the feed pump after the boiler has been filled. In any case, be very careful that you do not exceed the specified test pressure. After the boiler is full, it takes very little additional pumping to build up pressure.

To avoid complications arising from changes in pressure caused by changes in temperature, you should use water that is approximately the same temperature as the boiler and the fire room. In any case, the temperature of the water must be at least 70°F.

While the hydrostatic pressure is being built up, you should carefully check the boiler for signs of strain or deformation. If there is any indication of permanent deformation, stop the hydrostatic test and make the necessary repairs. If it is not possible to make the repairs right away, give a second hydrostatic test, progressing slowly up to 20 psi less than the pressure at which the first test was stopped.

If the boiler passes this second test successfully, the new working pressure of the boiler must be two-thirds of the test pressure reached on the second test, and all safety valves must be set accordingly.

Do not make any attempt to set up on leaky handhole or manhole plates until the pressure has been pumped up to within 50 psi of the test pressure. After all manhole and handhole leakage has been remedied, pump the pressure on up to test pressure. Check the pressure drop over a period of time. If all valves have been baked off, the maximum acceptable pressure drop is 1.5% of the test pressure over a period of 4 hours.

If connected valves are merely closed and left installed, a drop test will not indicate the true condition of the boiler. The pressure drop test is conducted at boiler design pressure.

A tube seat should not be considered tight unless it is bone dry at the test pressure. Any tube that cannot be made tight under a hydrostatic test should be renewed or rerolled. If there is an excessive pressure drop when there is only a slight leakage at tube joints, handholes, and manholes, the loss of pressure is almost certainly caused by leakage through valves and fittings. Valves and fittings should be overhauled and made tight.

1.6.3 Five-Year Inspection and Test

At 5-year intervals, each boiler must be inspected for integrity of welds and nozzle connections. Lagging must be removed from drums and headers sufficiently to expose the welded joints and the nozzle connections. The welds and nozzle connections must be inspected visually from both inside and outside. If there is any doubt about the welds, they should be inspected by magnetic particle inspection or dye penetrant inspection. After examination, if any area reveals that a 150-percent boiler design pressure hydrostatic test is warranted, and the area proves to be tight under test pressure, further investigation of the suspected area should be conducted. The investigation should continue until the true condition of the area is known, and if necessary, appropriate repairs are made.

1.7.0 Inspection of Firesides

Boiler firesides should be inspected for signs of damage to the refractory lining, tubes, protection plates, baffles, seal plates, support plates, and other metal parts. This type of inspection is usually conducted when the boiler is secured for fireside cleaning, but it should also be conducted each time the boiler is secured.

1.7.1 Refractory Inspection

Frequent inspection of refractories, together with early repair of any weak or damaged places, can do a lot to prevent refractory failure and to postpone the need for complete renewal. It is a good maintenance practice to inspect the refractories every time the boiler is opened up. Such inspections should be very detailed if you believe the boiler has been operated under the following severe service conditions:

- Steaming at high rates
- Burning low-grade or contaminated fuel
- Undergoing rapid fluctuations of temperature

Severe conditions cause rapid deterioration of refractories, increasing the need for frequent inspections.

To make a proper inspection of boiler refractories, you should have considerable knowledge of the causes of refractory deterioration. Also, you should know how to tell the difference between serious damage, which may require a complete renewal of brickwork, and less serious damage, which may be dealt with by patching.

Slagging and spalling are two of the main causes of refractory deterioration. Slag is formed when ash and other unburnable materials react with the brickwork. Although the ash content of fuel oil is low, there is always enough present to damage the refractories. The most damaging slag-forming materials are vanadium salts and sodium chloride.

If the slag that forms on the brickwork would remain in place, it would not cause any particular trouble; however, the slag does not remain in place. Instead, it peels off or melts and runs off, taking some refractory with it and exposing a fresh layer of refractory to further slag attack. When deterioration of the brickwork has progressed until only a 3-inch thickness of firebrick remains, the wall should be replaced. When sufficient slag has accumulated on the deck to cause striking with resultant deposits of carbon, the slag should be removed. The entire deck must be replaced if less than 1 ½ inches of firebrick remain after the slag has been removed.

Another type of slag that results from using contaminated fuel oil is usually more damaging than peeling slag. This type of slag is very glassy in appearance, and when this slag melts, it usually covers the entire wall or deck.

Firebrick shrinkage is another cause of furnace deterioration. True shrinkage (permanent shrinkage) is quite rare in firebrick approved for naval use. However, this defect can occur even in approved firebrick. In any case, it is important to recognize the appearance of true firebrick shrinkage because of the extremely dangerous condition it could create if it should occur. When the firebrick shrinks, the hot-face dimensions of each brick become measurably smaller than the cold-face dimensions. This condition leaves an open space around each brick, and the entire wall or floor becomes loose. A wall or floor having this appearance is DANGEROUS and should be completely renewed as soon as possible.

Also, during your inspection, look for signs of unequal stresses that are caused by rapid-raising of the furnace temperature while raising steam too rapidly. Emergencies may arise that require the rapid raising or lowering of furnace temperatures, but it is important to remember that the refractories cannot stand this treatment often. As a rule, you will find that raising the furnace temperature too rapidly causes the firebrick to break at the anchor bolts, and lowering the temperature too rapidly causes deep fractures in the firebrick.

Next, you should look for signs of mechanical strain caused by poor operation of the boiler. Continued panting or vibration of the boiler can cause a weakened section of the wall to be dislocated so that the bricks fall out onto the furnace floor. Improper oil-air ratio is the most common cause of boiler panting and vibration. Proper operation of the boiler, with particular attention to the correct use of the burners and forced draft blowers, generally prevents panting and vibration of the boiler.

Inspection should also be made of the lower side of the floor pan. Any overheating indicates a loss of insulation and excessive heat penetration. Under normal conditions, the brickwork in a boiler should last for a number of years without complete renewal.

Expansion joints should be inspected often for signs of incomplete closure. It is important to keep the joints free of grog, mortar, and refractory particles so that the joints can close properly when the boiler is fired. You can tell if an expansion joint is closing completely when it is heated by inspecting it when it is cold. If the inside of the expansion joint is light in color when the furnace is cold, the expansion joint is closing properly. If an expansion joint does not close properly when heated, the inside is dark and discolored.

The same method can be used to tell if cracks in refractory materials are closing properly when the furnace is fired. If the cracks are dark, showing that they do not close, they should be repaired.

Since the first firing of a plastic or castable burner front does more damage than any other single firing, the first inspection after installation is a very important one. The unfired burner front may appear to be in perfect condition while actually containing defects of material or workmanship that will show up immediately in the first firing.

After the boiler has steamed for several hours, slabs of plastic about 1/2 to 1 inch thick may separate from the burner's front surface and fall off. This is because the surface layer is more densely rammed during installation than the remainder of the material.

Radial cracks in the burner fronts may be found on the first inspection. These cracks are not harmful. They are caused by stresses resulting from the normal expansion and contraction of the refractory as it is heated and cooled. After the radial cracks occur, the stresses are relieved and there should be no further cracking of this type.

The cracks that eventually result in extensive damage run approximately parallel to the surface of the burner front, and they are called parallel cracks. Parallel cracks usually appear at or slightly behind the leading edge of the bladed cone. They are not dangerous until they actually loosen pieces of the burner front. Improper installation and boiler operation are usually the cause of parallel cracking.

A slanting crack in the narrow section between the burners sometimes joins a radial crack. When this occurs, pieces of plastic tend to break off. This type of damage can usually be repaired by a plastic patch.

If during your inspection you find that a castable burner front is breaking up after very little service, it is likely that too much water was used in mixing the material during installation. Sometimes the material is already partially set before installation; a common cause of this trouble is that the castable material, while in storage, reacted with moisture in the air and started to set. When castable material sets before it is used, it can never reach full strength.

Castable material is also subject to spalling after several hours of service. The peeling material, usually in 1/8-inch strips, should not be removed unless it is in the burner cone and is interfering with combustion. If a castable front is chalky or crumbly, find out how deep the condition goes. If no more than the surface can be rubbed off, the burner front is not seriously damaged. Do not remove the crumbly material. The condition is serious only if the burner cone is affected or if the casing shows signs of overheating.

Burner tile should be inspected for loose segments and broken pieces that might cause improper cone angles. The broken or damaged segments can be repaired by patching with plastic fireclay refractory. In some cases a new segment of tile can be installed.

When you inspect boiler refractories, it is a good idea to keep in mind the possibility that damage may occur because of operational problems. Although boilers must occasionally be operated under very severe and damaging conditions, a lot of damage to refractories (and, in fact, to other boiler parts as well) is caused by poor operating procedures that are really not necessary under the circumstances. It may be helpful to show operating personnel any refractory damage that appears to be directly related to poor operation of the boiler.

1.7.2 Tube Inspection

When inspecting the exterior of boiler tubes, look for signs of warping, bulging, sagging, cracking, pitting, scaling, acid corrosion, and other damage. All tube sheets should be inspected for signs of leakage, especially the superheater tube sheet.

Inspection of boilers sometimes shows an unexpected condition in which adjacent boiler tubes are warped in such a way that they touch each other. When this condition exists, the tubes are said to be married. Tube marriages can result either from overheating of the tubes or from stresses developed in the tubes during installation. For the latter reason, newly erected boilers and boilers that have been retubed should always be inspected for tube alignment after the initial period of steaming.

When inspection reveals one or more tube marriages, the decision as to whether or not the married tubes should be renewed is based on the following considerations:

1. If the tube marriage occurs in screen tubes 1 1/2 inches or larger, or if the furnace side wall or rear wall tubes are bowed, tube replacement is usually required.
2. If 1-inch or 1 1/4-inch tubes in the main bank of generating tubes are married, replacement is usually not required if the tube joints are tight under hydrostatic test.
3. Inspect the external surfaces of the tubes. If they show blistering or other signs of overheating, the tubes should be renewed.
4. Inspect the watersides. Wherever tube marriages exist, a poor waterside condition may indicate hard scale or oil within the affected tube. If hard scale or oil does exist, the married tubes should be replaced, and all appropriate steps should be taken to remove the scale or oil from the rest of the boiler. If the condition of the tubes is uncertain, or if a large number of tube marriages have occurred, remove one or more sample tubes, split them, and examine them carefully.
5. Tube marriages may cause gas laning, which can result in local overheating of the inner casing, the bottom part of the economizer, and other parts. Inspect the boiler carefully for signs of local overheating that might have been caused by gas laning resulting from the tube marriages. If the local overheating from this cause is found, renew the married tubes.
6. On single-furnace boilers, a lane more than 1 1/2 inches wide may allow overheating of the superheater and of the superheater supports. If a large lane (1 1/2 tubes-wide or wider) exists near the superheater outlet header end of the boiler, the married tubes that caused such a large lane should be renewed.

To identify the cause of the tube failure by visual inspection, you will need to know something about the various ways in which tubes rupture, warp, blister, and otherwise show damage. Tube failures must be reported, and they must be reported in standard terminology. The following sections of this chapter deal with the inspection techniques required for determining the causes of tube failure and with the various ways in which boiler tube damage is classified and identified.

The inspection techniques required for determining the cause of tube failure must naturally vary according to the nature of the problem. For example, a rupture in a fire row tube can usually be described adequately on the basis of simple visual observation, but the cause of damage to a tube that is deep in the tube bank cannot usually be determined without removing the intervening tubes. When a blistered tube suggests a waterside deposit, the nature and extent of the deposit can be determined only by removing and splitting the tube so that the waterside can be examined.

For a field inspection of damaged or fouled pressure parts, the following equipment is required:

- Devices for measuring tube diameters' depth of pits, and thickness of deposits
- Instruments for separating deposits and corrosion product, such as a sharp knife, chisel, steel scribe, or vise to crack deposits loose from the tube samples
- An approved type of portable light
- A supply of clean bottles for collecting samples of deposits
- A mirror for viewing relatively inaccessible places

Many of these items of equipment can be improvised if necessary. For example, a simple gauge for measuring the depth of waterside pits may be made by pushing a straight pin or a paper clip through a 3- by 5-inch card so that the point of the pin or clip projects beyond the card, at right angles to the card (*Figure 8-8*). A section of string can be wrapped around a deformed tube and then laid along a ruler to obtain a measure of tube enlargement or tube thinning.

Of course, special tools such as calipers, depth gauges, and scale thickness indicators give more accurate results and should be used if they are available, but the improvised tools, if used with care, can also give good results.

The four major classifications of boiler tube damage are the following:

1. Fireside cavities and scars
2. Waterside cavities and scars
3. Tube deformities and fractures
4. Tube deposits

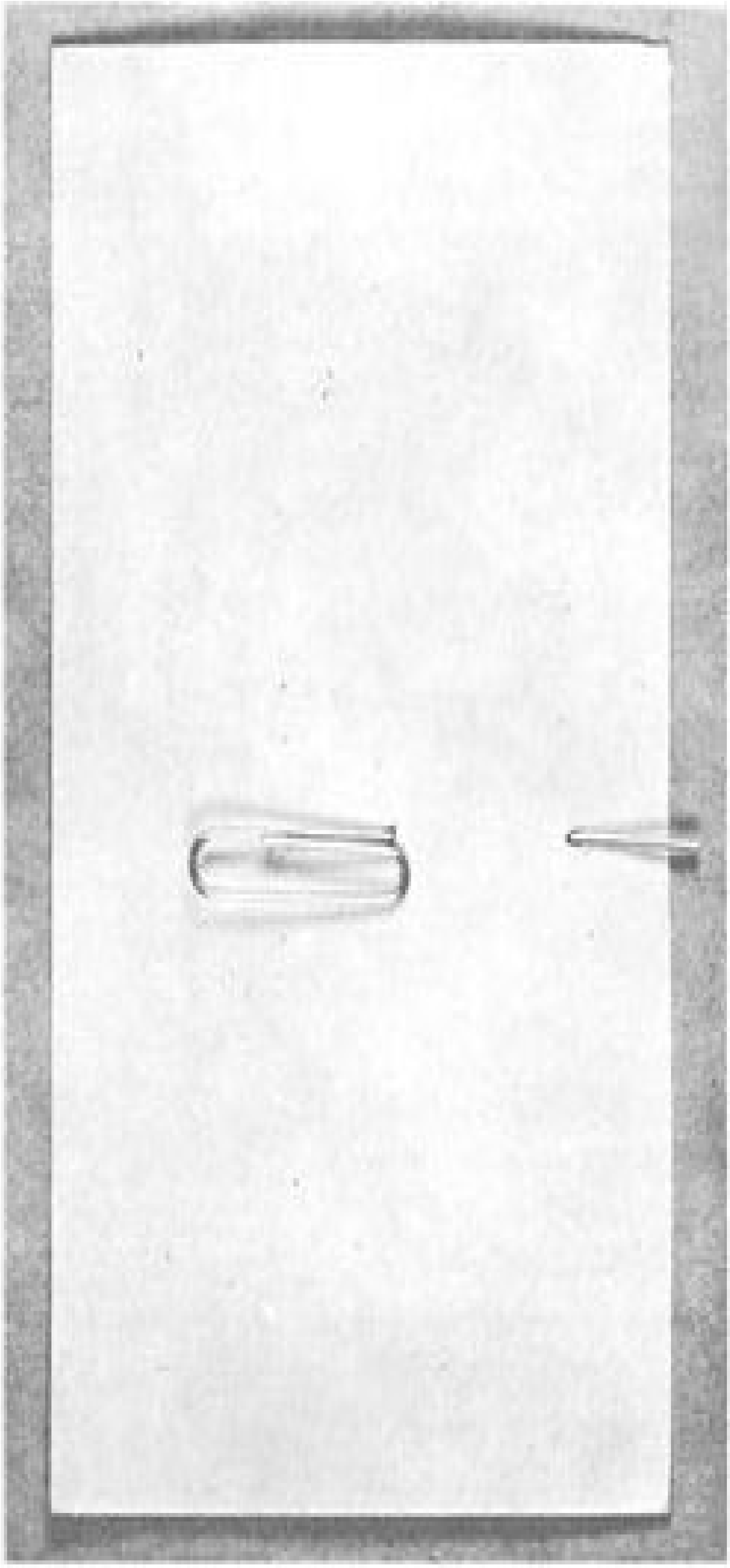

Figure 8-8 — Improvised depth gauge.

Fireside cavities and scars on the tube firesides often indicate the reasons for tube failure. The term ***circumferential*** groove is used to describe the metal loss that occurs in bands or stripes around the circumference of a tube. Fireside grooving of this type often occurs at the header ends of horizontal tubes such as superheater tubes. The most common cause of this damage is leakage from tube seats higher in the tube bank. The grooving occurs as the water runs down the header and onto the tube ends, or as it drips directly onto the tubes. This kind damage is greater on the top of the tube than on the underside, but the groove may extend the entire circumference.

Fireside circumferential grooving may also occur on vertical generating tubes as a result of thin, damp deposits of soot on horizontal drums or headers. In fact, this kind of grooving can occur in any part of the boiler where leakage provides a sufficient supply of water. Large quantities of water trapped between the water drum and the boiler casing—as, for example, from a serious economizer leak—can produce general fireside grooving around the bottom of the rear generating tubes. *Figure 8-9* shows an example of general fireside circumferential grooving.

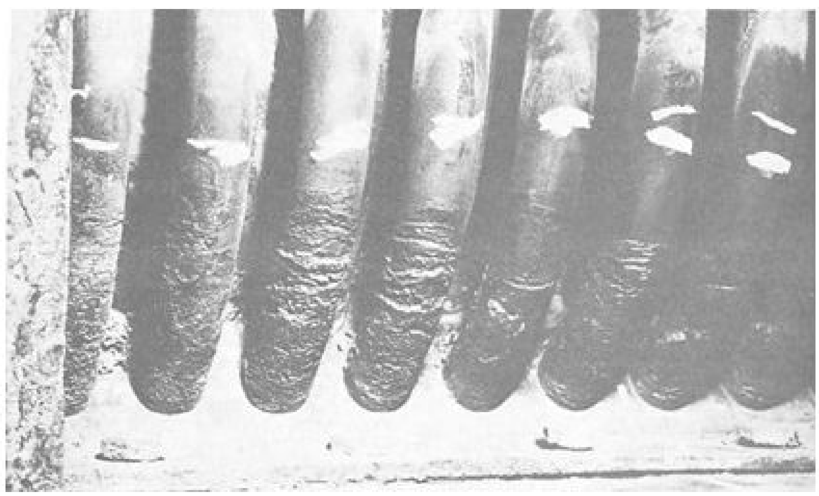

Figure 8-9 — General fireside circumferential grooving.

Craters are deep, irregular, straight-walled cavities in the tube metal. *Water tracks* are closely related to craters; the tracks consist of wandering, straight-walled, canyon-like cavities in the tube metal. Craters and water tracks are caused by water becoming trapped between the tube metal and the surrounding refractory. Both occur almost exclusively at the header ends of water wall tubes and division wall tubes that are surrounded by refractory. A frequent cause of craters and water tracks is water washing of boiler firesides without proper drying out. However, any leak higher in the boiler can also cause this type of damage. The size of the leak around and the angle of the tube upon which the water leaks determine, to a large extent, whether the resulting damage will be circumferential grooving, cratering, or water tracking. *Figure 8-10* shows examples of both craters and water tracks.

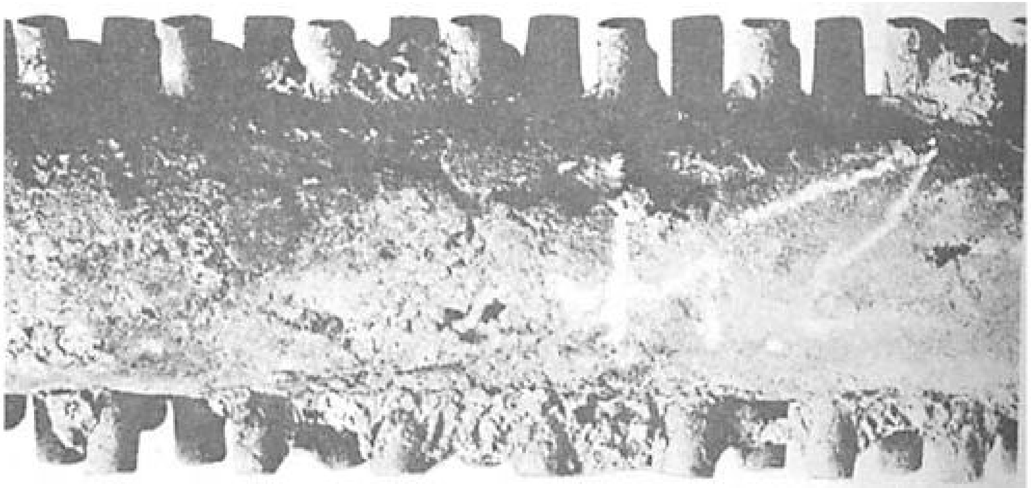

Figure 8-10 — Fireside craters and water tracks.

General fireside thinning consists of a uniform loss of metal over a relatively large area on the outside of the tube. Soot corrosion is by far the most common cause of general fireside thinning. The parts that are particularly subject to this kind of damage are superheater tube ends between the headers and the seal plates, water drum ends of generating tubes, and return bends in economizer tubes. *Figure 8-11* shows an example of general fireside thinning of a generating tube.

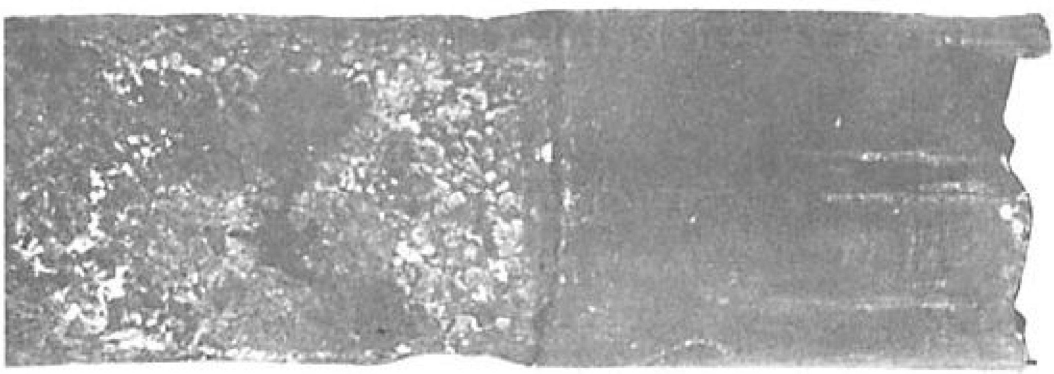

Figure 8-11 — General fireside thinning of a generating tube.

A rather unusual type of general fireside metal loss sometimes results from the combination of extremely high tube temperatures and the burning of fuel oil that contains vanadium compounds. The vanadium compounds carried in the flame can cause rapid oxidation of metal at high temperatures. This type of damage is unusual in water-cooled parts of the boiler, since critical temperatures are not usually attained. *Figure 8-12* shows a stainless steel superheater tube that has suffered this type of general thinning as a result of fuel ash damage.

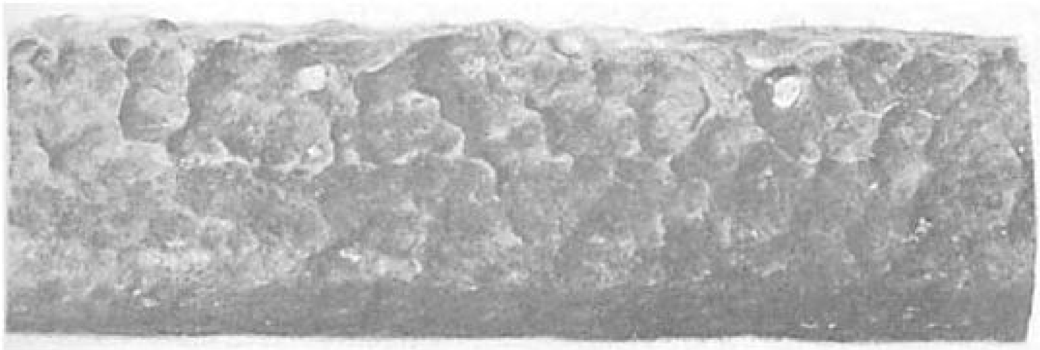

Figure 8-12 — General fireside thinning of a stainless steel superheater tube (results of fuel ash damage).

Fireside burning occurs when the rate of heat transfer through the tube wall is so reduced that the metal is overheated. Waterside deposits can cause fireside burning, but most serious fireside burning occurs when a tube becomes steam-bound or dry. *Figure 8-13* shows the coarse, brittle appearance of tube metal that has suffered fireside burning.

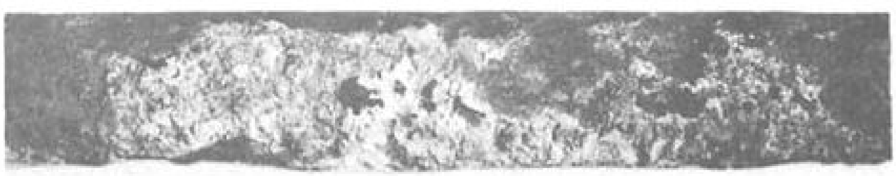

Figure 8-13 — Fireside burning.

Steam gouging occurs when steam jets out of a hole in an adjacent tube. Steam gouging can be identified by the extremely smooth surface of the cavity, together with the irregular shape of the cavity. A steam gouge looks as though the metal has been blasted away and the cavity polished (*Figure 8-14*).

Tool marks, such as chisel cuts or hammer scars, can usually be identified without too much trouble. Tool marks do not resemble corrosion effects in any way (*Figure 8-15*).

Figure 8-14 — Fireside steam gouge.

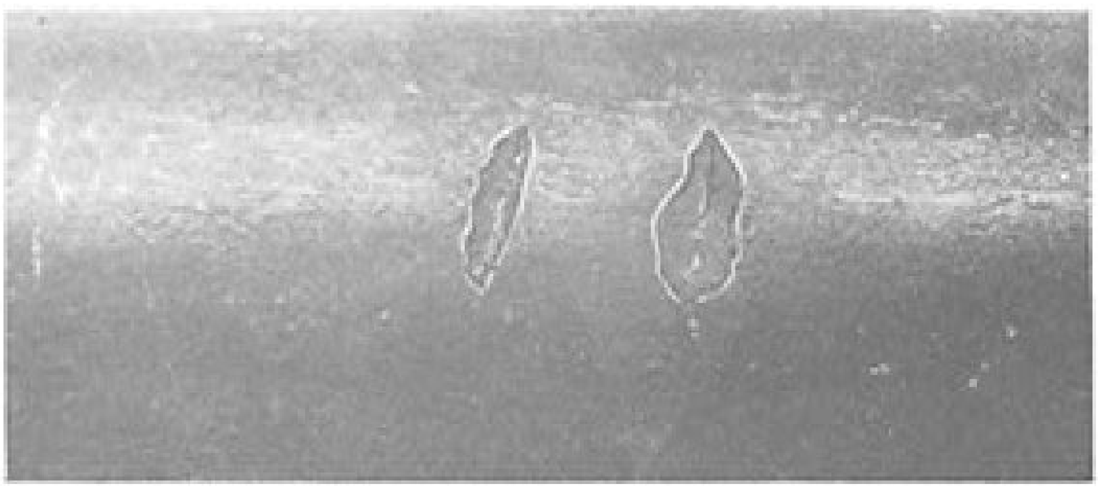

Figure 8-15 — Fireside tool marks.

Tube deformities and fractures comprise another category of boiler tube damage that covers abnormal bends, blisters, bulges, cracks, warps, sags, and other breaks or distortions. Like the cavities and scars previously discussed, tube deformities and fractures are fairly easy to distinguish by visual observation.

Figure 8-16 shows a *thin-lipped rupture*, which is a fairly common tube deformity. The rupture resembles a burst bubble; the open lips are uniformly tapered to sharp, knifelike edges, with no evidence of cracking or irregular tearing of the metal. True thin-lipped ruptures occur in economizer tubes, in generating tubes, and, to a much lesser extent, in superheater tubes. Ruptures of this type indicate that the flow of steam or water was not adequate to absorb the heat to which the tube was exposed; consequently, the tube metal softened and flowed and then burst. Thin-lipped ruptures may be caused by a sudden drop in water level or by tube stoppage from plugs, tools, and so forth, that were accidentally left in the boiler.

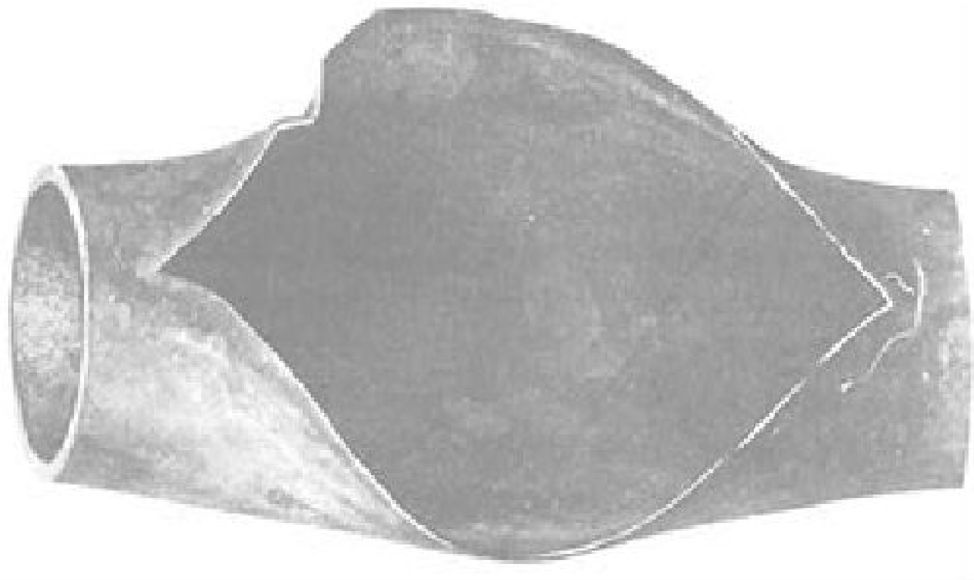

Figure 8-16 — Thin-lipped rupture in a generating tube.

Serious *thick-lipped ruptures* resemble the thin-lipped ruptures except that the edges are thick and ragged rather than tapered and knifelike. Thick-lipped ruptures that occur in mild steel generating tubes indicate milder and more prolonged overheating than the overheating that leads to thin-lipped ruptures. Abnormal firing rates, momentary low water, flame impingement, gas laning, and many other causes can produce mild but prolonged overheating that can eventually lead to thick-lipped ruptures. *Figure 8-17* shows a typical thick-lipped rupture in a generating tube.

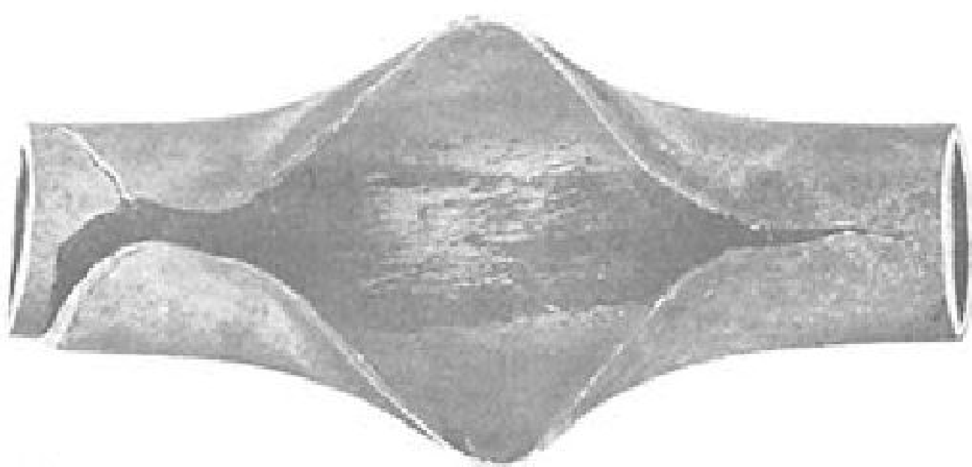

Figure 8-17 — Thick-lipped rupture in a generating tube.

Perforation is the term used to describe any opening in a tube (other than a crack) that is NOT associated with tube enlargement. The most common kind of perforation is probably the pinhole leak. In many cases, the first evidence of tube failure is a pinhole leak.

Thermal cracks or *creep cracks* result from prolonged mild overheating or repeated short-time overheating. Cracks of this type are found most often in alloy superheater tubes, but they can occur in mild steel tubes as well. The tube is not usually enlarged when a thermal crack exists; the cracked wall has normal thickness, and the break has a dark crystalline appearance. *Figure 8-18* shows a typical example of a thermal crack.

Figure 8-18 — Thermal crack in a superheater tube.

Tube enlargement is relatively common in superheater tubes but rare in generating tubes (*Figure 8-19*). This uniform enlargement of a portion of the tube is caused by milder overheating than that which produces cracks or ruptures. If an enlarged tube is continued in service, it will almost certainly crack or break.

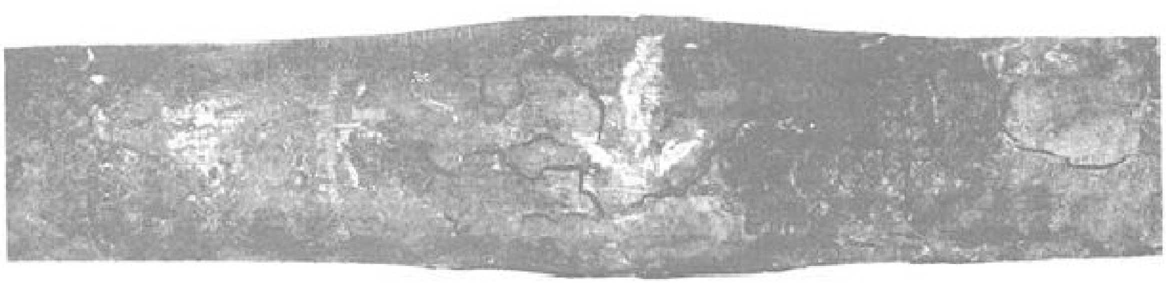

Figure 8-19 — Enlarged tube.

Heat blisters differ from tube enlargements in that they affect only one side of the tube, usually the side toward the fires. Blisters appear as egg-shaped lumps on the fireside. They indicate that the tube has been heated to the softening point and has blown out under boiler pressure. Heat blisters always indicate the presence of waterside deposits. If the deposit is brittle, as scale or baked sludge, blistering breaks the deposit and allows the boiler water to quench the hot metal before the tube bursts. Heat blisters are most commonly found on fire row generating tubes; they are rarely found on superheater tubes or economizer tubes. *Figure 8-20* shows a typical heat blister.

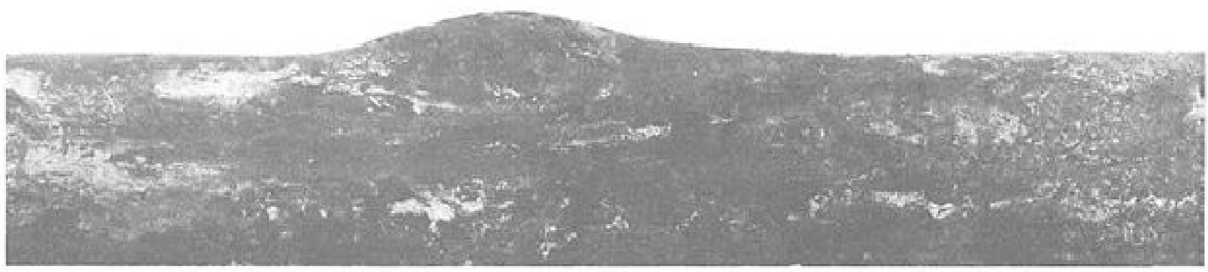

Figure 8-20 — Heat blister on a fire row tube.

Sagging is the term applied to tubes that appear to have dropped downward toward the furnace under their own weight. This type of deformation results from semi-plastic flow of the tube metal, caused by extremely mild overheating. A momentary condition of low water is probably the most common cause of sagging. If the boiler has been cooled slowly, and if the distortion is not so severe as to interfere with the designed flow of combustion gases, sagged tubes may still be continued in service.

Warping is similar to sagging except that the distortion is haphazard rather than in one direction. Warping usually occurs as a result of sudden cooling of the tubes after they have been overheated. Cooling a boiler too rapidly after a low-water casualty is a typical cause of warped tubes.

Melting can occur as a result of a serious low-water casualty. If the tube temperature becomes high enough, the tube metal actually melts and runs down into the furnace. *Figure 8-21* shows a cluster of fused tubes that resulted from melting. Melting of aluminum economizer parts can cause tremendous damage to a boiler. The molten aluminum from overheated economizer parts reacts so violently with the iron oxide coating on the steel tubes below that the heat of the chemical reaction may melt the steel tubes even though the furnace temperature is not high enough to melt them.

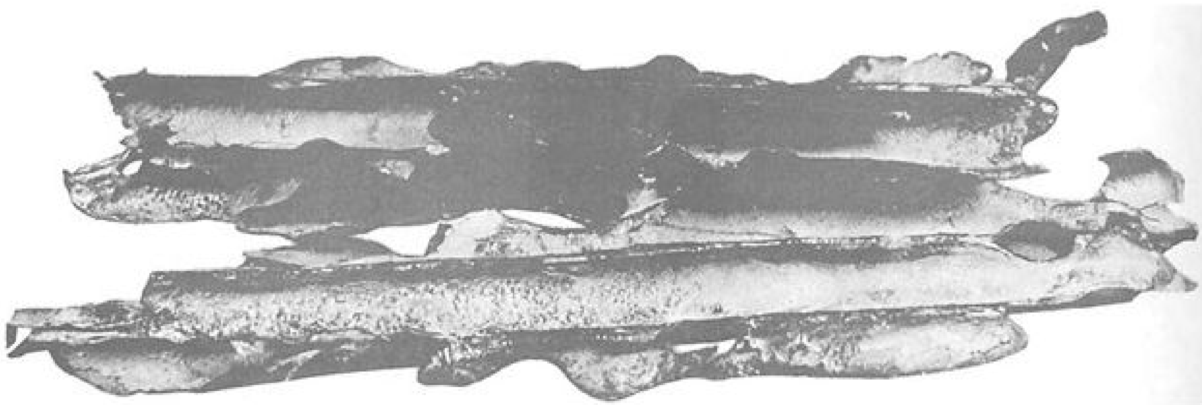

Figure 8-21 — Melted cluster of tubes.

Mechanical fatigue cracks occasionally occur in boiler tubes from such purely mechanical processes as flexing. Cracks of this type can usually be identified by a clean, bright break through a major portion of the metal thickness. These cracks begin on the outside circumference of the tube.

Tube wall lamination is shown in *Figure 8-22*. This lamination or layering occurs during the fabrication of the tube. It is the most common material defect found in boiler tubes.

Figure 8-22 — Lamination of a tube wall (fabrication defect).

Folded or *upset tubes* are a result of defective fabrication (*Figure 8-23*). This defect resembles a heat blister in appearance, but the folded tube shows no wall thinning and has a depression on the side of the tube opposite the bulge.

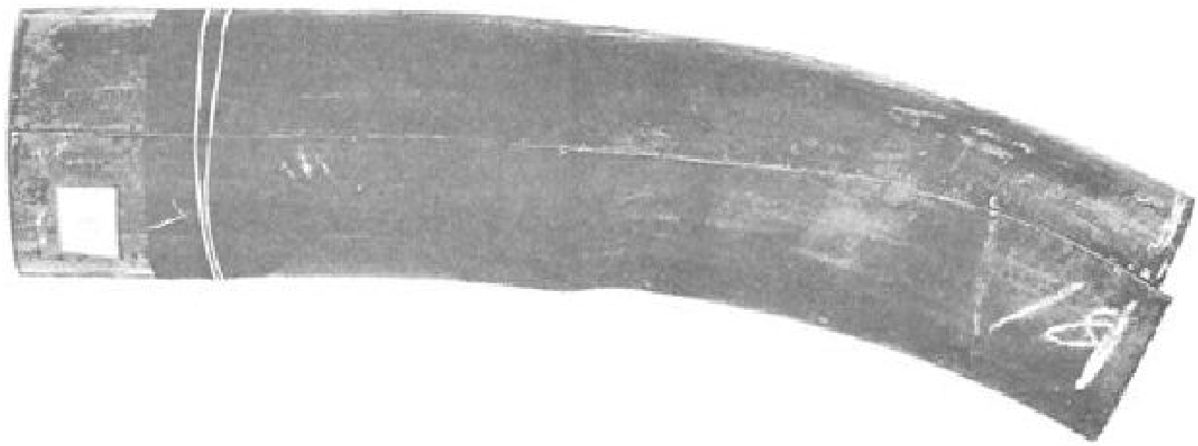

Figure 8-23 — Tube fold (fabrication defect).

Stretched or *necked* tubes are also a result of defective fabrication. *Figure 8-24* shows a stretched or necked tube.

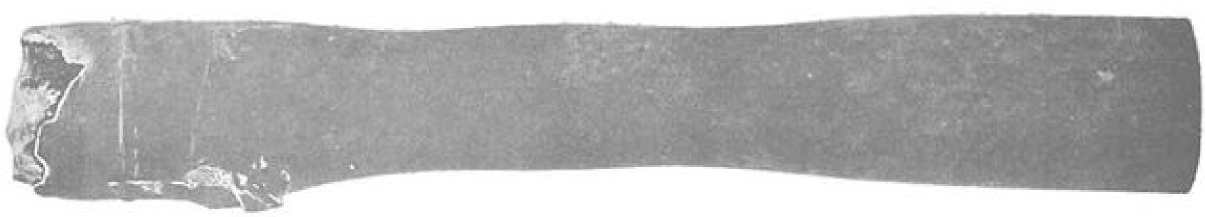

Figure 8-24 — Stretched or necked tube (fabrication defect).

Fireside tube deposits can produce many of the scars and deformities just described. Basically, tube deposits cause tube failure because they lead to localized overheating of the tube metal. The accurate identification of tube deposits is often a necessary part of determining the cause of tube failure. Fireside tube deposits include soot, slag, corrosion products, and high-temperature oxide.

- *Soot* is a broad term used to cover all of the ash products (other than slag) that result from combustion. These ash products include carbon, sand, salts such as sodium sulfate, and other materials. Soot deposits are usually powdery or ashy on the tube surfaces near the top of the boiler; however, they tend to be packed solid on drums, headers, and the lower ends of the tubes.
- *Slag* is not a powdery or packed ash-like soot; rather, it is a salt-like material that is fused to the tube surfaces. Slag is objectionable on boiler tubes because it retards the transfer of heat to the tube metal and because it may cause gas channeling, with consequent local overheating of tube metal that is not covered by the slag. Most slags on boiler tubes are soluble enough to be controlled by periodic washing of firesides. The main way to prevent slag is to avoid burning fuel oil that is contaminated with seawater.
- *Corrosion deposits* seldom form major fireside deposits. Occasionally, however, bulky deposits of ferrous sulfate may form as the result of the combination of soot and large amounts of water. These deposits have been known to travel away from their original location and adhere to remote rows of generating tubes. The deposits can usually be removed by water washing and mechanical cleaning. The source of the water leakage should be found and corrected. Also, the location of the original deposit should be found, and the area should be carefully inspected for signs of corrosion.
- *High-temperature oxide* is the term applied to heavy fireside layers of mixed iron oxides formed by overheating of the tube metal. Low water is a frequent cause of high-temperature oxide on the tube firesides. The high-temperature oxide has a rather layered appearance; it resembles corrosion products and is often wrongly called scale.

1.7.3 Exterior Inspection of Drums and Headers

The uptakes and smoke pipes are examined according to a maintenance system. Check the uptake expansion joints to be sure they are not clogged with soot. Look for ruptures and for loose reinforcing ribs or Z-bar stiffeners. Check the rain gutters to see that they are not plugged with soot. Check the top of the economizer to see if it is clean.

1.7.4 Inspection of Protection, Seal, and Support Plates

All corrosion-resisting steel plates such as baffle plates, seal plates, superheater support plates, steam drum protection plates must be carefully inspected whenever firesides are opened. These steel plates are subject to damage from overheating, particularly if clogged gas passages interfere with the designed flow of combustion gases and allow extremely hot gases to flow over the plates. Since failure of these parts could have extremely serious consequences, the plates should be inspected at every opportunity and should be renewed when necessary.

1.7.5 Inspection of Uptakes and Smoke Pipes

The uptakes and smoke pipes are examined according to a maintenance system. Check the uptake expansion joints to be sure they are not clogged with soot. Look for ruptures and for loose reinforcing ribs or Z-bar stiffeners. Check the rain gutters to see that they are not plugged with soot. Check the top of the economizer to see if it is clean.

1.8.0 Operational Inspection and Tests

Following the hydrostatic test, the boiler should be fired and brought up to operating pressure and temperature. All automatically and manually operated control devices provided for control of steam and water pressure, hot-water temperature, combustion, and boiler water level should be inspected and caused to function under operating conditions. All associated valves and piping, pressure- and temperature-indicating devices, metering and recording devices, and all boiler auxiliaries should be inspected under operating conditions. All safety valves and water-pressure relief valves should be made to function from overpressure.

Inspections and tests may be made with the main steam or hot-water distribution valves closed or open as necessary to fire the boiler and operate it under normal operating conditions. Testing the function of automatically or manually controlled devices and apparatus that may interfere with distribution requirements should be done with main steam or hot-water distribution valves closed, as applicable.

The purpose of these inspections and tests is to discover any inefficient operation or maintenance of the boiler or its auxiliaries that may be observed under operating conditions. All deficiencies requiring adjustment, repair, or replacement, and all conditions indicating excessive operating costs and maintenance costs should be reported.

1.8.1 Firing Equipment

The operation of all firing equipment, including oil burners, gas burners, fuel injectors, fuel igniters, coal stokers and feeders, and other such equipment provided to introduce fuel into the boiler furnace and ignite the fuel should be inspected for any deficiency that may be observed under operating conditions. In particular, igniters and burners should be checked to ensure that burner protrusion, angle, setting, and so forth are such that light off and operation are as effective as possible.

1.8.2 Controls

Inspect the operation of combustion controls, steam pressure controls, water temperature controls, and feed-water controls. Assure that the ability of the combustion control and steam pressure control to maintain proper steam pressure (or water temperature in high-temperature water installations) and air-fuel ratio is demonstrated throughout the capacity range of the boiler. Air-fuel ratio should be checked by CO^2 or O^2 measuring devices. On smaller boilers the appearance of the fire may be used as a guide for inspection of air-fuel ratio.

Check the automatic boiler controls for proper programming sequence and timing with respect to pre-purge, ignition, pilot proving, flame proving, and post-purge periods, Check the operation of flame failure and combustion air failure devices to assure that they properly shut off the supply of fuel; do this by simulating a flame failure (manually shutting off the fuel or by other means) and observing the operating of the controls, solenoid valves, and diaphragm-operated valves that are to operate during a flame failure. Inspect feed-water controls and check the ability of the controls to maintain proper water level throughout the range of capacity with first load swings.

Check the operation of low-water fuel cutoff and automatic water-feeding devices by draining the float bowl, lowering the boiler water level, or by performing other necessary steps to cause these devices to function, to assure they operate properly. The low-flow cutout on high-temperature water boilers should be tested by reducing the flow until cutout occurs.

For additional information on the inspection of the operating conditions of the controls, refer to the section of this RTM that deals with *water columns* and *gauge classes*.

1.8.3 Steam and Water Piping

While the boiler is operating, examine all steam and water piping, including connections to the column, for leaks. If you find any leaks, determine if they are the result of excessive strains caused by expansion and contraction or other causes. Listen for water hammer, and if found, determine the cause. Look for undue vibration, particularly in piping connections to the boiler. When you find excessive vibration of piping, examine the connections and parts for crystallization.

1.8.4 Water Columns and Gauge Glasses

With steam on the boiler, blow down the water columns and gauge glasses, and observe the action of the water in the glass to determine if the connection to the boiler or the blowoff piping is restricted or not properly free. This will help you determine the true condition of high- and low-water alarms and of the automatic combustion equipment.

1.8.5 Devices

While the boiler is operating, cause the individual mechanisms of *low-water fuel cutoff* and/or *water-feeding devices* to operate to assure they function properly.

Where a float-operated, low-water cutoff or water-feeding device or a combination low-water fuel cutoff and water-feeding device is provided, test its operation by opening the drain to the float bowl and draining the bowl to the low-water level of the boiler. When the low-water point is reached, the mechanism of the low-water fuel cutoff should function and shut off the fuel supply to the boiler until boiler water is added to the proper level. Also, at the low-water point, the mechanism controlling the feed-water supply should function to start the feed-water.

Where there is a low-water fuel cutoff device controlled by excess temperature generated in a temperature element located inside the boiler, you can test its operation by blowing off the boiler to its allowable low-water level. On or before the low-water level is reached, the device should function to shut off the boiler fuel supply until boiler water is added to the proper level.

On high-temperature water boilers, the flow through the boiler should be restricted to the minimum allowed, as shown by the manufacturer’s operating data. Note the point at which fuel cutoff takes place and make adjustments as required.

With steam on the boiler, observe the *steam gauge pointer* for sticking or restriction of its movement. Blow down the pipe leading to the gauge to assure that it is free. Attach an approved test gauge to the pipe nipple provided for this purpose, and compare the accuracy of each steam gauge on the boiler with that of the test gauge.

When inaccuracy of any gauge is evidenced or suspected, it should be removed and calibrated by means of a deadweight gauge tester or other device designed for this purpose. When several boilers are in service and connected to a common steam main, compare the readings of the separate gauges. All *temperature-indicating devices* should be observed for indications of excessive temperature, particularly during and immediately after the time high-load demands are made on the boiler.

While the boiler is operating under normal conditions, observe the operation of all *metering* and *recording devices*. When there is evidence that any such device is not functioning properly, it should be adjusted, repaired, or replaced as necessary.

1.8.6 Blowoff Valves

Test the freedom of each blowoff valve and its connections by opening the valve and blowing off the boiler for a few seconds. Determine if the valve is excessively worn or otherwise defective and if there is evidence of restrictions in the valve, or connected piping preventing proper blowoff of the boiler.

1.8.7 Stop and Check Valves

While the boiler is operating, inspect the operating condition of each stop and check valve where possible. Serious defects of externally controlled stop valves may be detected by operating the valve when it is under pressure. Similarly, defects in check valves maybe detected by listening to the operation of the valve or observing any excessive vibration of the valve as it operates under pressure.

1.8.8 Pressure-Reducing Valves

While there is pressure on the system, open and then close the bypass valve as safety and operating conditions permit. Also, observe the fluctuation of the pressure gauge pointer as an aid in determining possible defects in the operation of the pressure-reducing valve or the pressure gauge. Look for any evidence that may indicate improper condition of the relief or safety valves provided for the pressure-reducing valves.

1.8.9 Boiler Safety and Water-Pressure Relief Valves

Test the blowoff setting of each safety valve for steam boilers and each water-pressure relief valve for hot-water boilers by raising the boiler pressure slowly to the blowoff point. In turn, test the releasing pressure of each valve, gagging all other safety or relief valves except the one being tested. Observe the operation of each valve as blowoff pressure is reached. Compare the blowoff setting with setting requirements specified in paragraph 1 or 2 of this section, and make adjustments where necessary. When the steam discharge capacity of a safety valve is questionable, it should be tested by one of the methods given in paragraph 3 of this section. When the pressure-relieving capacity of a pressure-relief valve is questionable, it should be tested according to the procedures given in paragraph 4 of this section.

1. *Safety Valve—Setting Requirements*. <u>Note this word of caution</u>: Before adjusting safety valves on electric steam generators, be sure that the electric power circuit to the generator is open. The generator may be under steam pressure, but the power line should be open while the necessary adjustments are being made. At least one safety valve should be set to release at no more than the maximum allowable working pressure of the steam boiler. Safety valves are factory set and sealed. When a safety valve requires adjustment, the seal should be broken, adjustments made, and the valve resealed by qualified personnel only. When more than one safety valve is provided, the remaining valve or valves may be set

within a range of 3% above the maximum allowable working pressure. However, the range of the setting of all the safety valves on the boiler should not exceed 10% of the highest pressure to which any valve is set. Each safety valve should reseat tightly with a blow-down of not more than 2 psig or 4% of the valve setting, whichever is greater.

In those cases where the boiler is supplied with feedwater directly from the pressure main without the use of feeding apparatus (not including return traps), no safety valve should be set at a pressure greater than 94% of the lowest pressure obtained in the supply main feeding the boiler.

2. *Pressure-Relief Valve—Setting Requirements*. At least one pressure-relief valve should be set to release at not more than the maximum allowable working pressure of the hot-water boiler. When more than one relief valve is provided on either hot-water heating or hot-water supply boilers, the additional valve (or valves) may be set within a range not to exceed 20% of the lowest pressure to which any valve is set. Each pressure-relief valve should reseat tightly with a blow-down of not more than 25% of the valve setting.
3. *Safety Valve—Capacity Test*. When the relieving capacity of any safety valve for steam boilers is questioned, it may be tested by one of the three following methods:
   - Performing an accumulation test, which consists of shutting off all other steam-discharge outlets from the boiler and forcing the fires to the maximum. The safety valve capacity should be sufficient to prevent a pressure in excess of 6% above the maximum allowable working pressure. This method should not be used on a boiler with a superheater or re-heater.
   - Measuring the maximum amount of fuel that can be burned and computing the corresponding evaporative capacity (steam-generating capacity) upon the basis of the heating value of this fuel. These computations should be made as outlined in the code.
   - Measuring the feedwater capacity to determine the maximum evaporative capacity.

When any of the above methods are employed, the sum of the safety valve capacity should be equal to or greater than the maximum evaporative capacity (maximum steam-generating capacity) of the boiler.

If you discover that the relieving capacity is inadequate because of deficiencies in the valve, the valve should be repaired or replaced. If the relieving capacity of the valve is found to be satisfactory within the proper relieving range of the valve but inefficient for the steam-generating capacity of the boiler, additional safety valve capacity should be provided.

4. *Pressure-Relief Valve—Capacity Test*. When the relieving capacity of any pressure-relief valve for hot-water boilers is questioned, the capacity can be tested by turning the adjustment screw until the pressure-relief valve is adjusted to the fully open position. The pressure should not rise excessively. When the test is completed, reset the pressure-relief valve to the required setting. This test is made with all water discharge openings closed except the pressure-relief valve being tested. When the discharge is led through a pipe, determine at the time the valve is operating if the drain opening in the discharge pipe is not properly free, or if there is evidence of obstruction elsewhere inside the pipe. If deemed necessary to determine the freedom of discharge from the valve, the discharge

connection should be removed. After completing tests and adjustments, the inspector should seal the safety adjustment to prevent tampering.

1.8.10 Boiler Auxiliaries

While the boiler is operating under normal conditions, observe the operation of all boiler auxiliaries for any defects that may prevent proper functioning of the boiler or indicate a lack of proper maintenance of auxiliary equipment. The unnecessary use of multiple auxiliaries or the use of a large auxiliary during a light-load period (when a smaller auxiliary could be substituted) should be discouraged. The maximum use of steam-driven auxiliaries short of atmospheric exhaust should be encouraged. Steam leaks, wastage to atmosphere, and so forth should be called to the attention of operating personnel. Particular attention should be given to de-aerator venting practice. Venting should be held to the minimum required to preclude oxygen entrainment in the feedwater.

When intermittently operating condensate pumps are used, look for any tendency toward creation of a vacuum when a pump starts. If this happens, recommend installation of a small, continuously operating, float-throttled, condensate pump (in parallel with intermittently operating pumps) to assure a condensate flow at all times. If there are a number of intermittently operating condensate pumps, it may be possible to convert one of them (if of small enough capacity) to continuous throttled operation.

Test your Knowledge (Select the Correct Response)

1. **(True or False)** When selecting a site for boiler installation, the availability of water, electricity, fuel, and natural drainage should be considered.

   A. True
   B. False

2. When must boilers be inspected for integrity of welds and nozzle connections?

   A. Once every year
   B. Every 5 years
   C. Every 6 months
   D. None of the above

2.0.0 PLANT OPERATION

To operate boilers or be a plant supervisor, you need to know all the mechanical details of the boiler you are operating and its associated auxiliaries. However, just knowing this information is not enough. To be a professional boiler operator or plant supervisor, you must develop a keen eye for trouble, a finely tuned ear, and an overall sense of awareness concerning boiler plant operation at all times.

As an operator and/or supervisor of a boiler plant, you must learn to tell the difference between normal and abnormal operating conditions. By training yourself to notice and analyze strange noises, unusual vibrations, abnormal temperatures and pressures, and other indications of trouble, you will be better able to prevent any impending trouble or casualty to the plant.

2.1.0 Operators

During the hours that a boiler plant operator is on duty, it is very important that you ensure that the operator is maintaining accurate records.

2.1.1 Logs

Logs provide a means of recording continuous data on boiler plant performance and analysis of operation. Logs are arranged for use over a 24-hour period, consisting of three 8-hour shifts. Log entries should be carefully made in columns. Commands will establish information required but the following info is typical of the info found in boiler logs.

2.1.2 Turnover and Watch Relief

When an operator comes on duty, an operational inspection should be done to ensure that everything is operating normally. The points that the operator should check are as follows:

- Check the water level in the gauge glass on each boiler by opening and closing the try cocks.
- Check the low-water cutoffs and the boiler feed equipment by blowing down the water columns on each boiler.
- Check the steam pressure and compare it with the steam pressure that the plant should deliver.
- Check the boilers for leaks or other conditions that can affect plant operation.
- Check for proper operation of the boiler room accessories.
- Check the fuel supply and the firing equipment.
- Check the condition of the fires to determine if they are clean.
- Check the general appearance of the boiler room, fixtures, piping, and insulation.
- Check the boiler room record sheets to determine if any troubles were encountered by the previous shift operator.
- Question the operator being relieved about plant operation and the troubles encountered.
- Check for any verbal or written orders with which you are to comply.

2.2.0 Plant Supervisor

As a boiler plant supervisor you are expected to organize and manage the overall operation of the boiler. Your duties and responsibilities include but are not limited to the following:

- Ensuring that daily logs are maintained by operators
- Submitting monthly operation reports and logs
- Checking maintenance requirements
- Providing personnel with required training

Each boiler plant has its unique requirements. Only through operating your specific plant and completely familiarizing yourself with it can you establish a comprehensive management program.

This chapter cannot cover all the aspects of supervising a boiler plant. You must refer to current Navy publications, command instructions and manufacturer’s manuals that pertain to your specific plant. When you are assigned as a boiler plant supervisor, you should establish an on-site library of the required publications and manuals.

2.3.0 Water Chemistry

The effects of inadequate or improper water conditioning can cause major problems in the operation of boilers. Manufacturer's specifications must be strictly adhered to. *Table 8-2* outlines the effects and results of poor water treatment of boiler water. By establishing an aggressive water-treatment program, you can greatly reduce inefficient boiler operation and high maintenance costs.

Table 8-2 — Effects of Inadequate or Improper Water Conditioning.

EFFECT	CONSTITUENT	REMARKS
Scale	Silica	Forms a hard, glassy coating on internal surfaces of the boiler. Vaporizes in high-pressure boilers and forms deposits on turbine blades.
	Hardness	$CaSo_4$, $MgSo_3$, $CaCO_3$, and $MgCO_3$ form scale on the boiler tubes.
Corrosion	Oxygen	Causes pitting of metal in boilers, and steam and condensate piping.
	Carbon dioxide	Major causes of deterioration of condensate return lines.
	O_2 – CO_2	Combination is more corrosive than either by itself.
Carryover	High boiler water concentrations	Causes foaming and priming of the boiler and carryover in steam, resulting in deposits on turbine blades and valve seats.
Caustic embrittlement	High caustic concentration	Causes inter-crystalline cracking of boiler metal.
Economic losses	Repair of boilers	Repair of pitted boilers and cleaning of heavily scaled boilers are costly.
	Outages	Reduce efficiency and capacity of plant.
	Reduced heat transfer	High fuel bills.

2.4.0 Chemical Makeup of Water

Water is called the *universal solvent.* The purer the water, that is, the lower its dissolved solids content, the greater the tendency to dissolve its surroundings. If stored in a stainless steel tank after a short contact time, pure water has a very small amount of iron, chromium, and nickel from the tank dissolved in it. This dissolving of the tank does not continue indefinitely with the same water.

The water, in a sense, has satisfied its appetite in a short time and does not dissolve any more metal. Pure water, if exposed to air, immediately absorbs air and has oxygen from the air dissolved in it. A glass of tap water at 68°F contains 9.0 ppm of oxygen. Tap water heated to 77°F contains 8.2 ppm of oxygen, because some oxygen is driven out of the water. The higher the temperature of the water, the less dissolved oxygen it can hold.

Conversely, the higher the pressure imposed on the water, the greater the dissolved oxygen it can hold. Water, when boiled, produces steam. The steam contains some liquid water. There is never a perfect separation of pure steam from the boiling water. The steam above the boiling water always has some boiling water entrained with it. These three concepts—that water is a universal solvent, that water dissolves oxygen when in contact with air, and that boiling water is always entrained with steam--should help you understand the nature of feedwater.

As it enters the boiler steam drum, the feedwater is now considered boiler water. Complete understanding of the nature of boiler water can be gained by temporarily making the assumption that no water treatment, chemical addition, or blowdown is applied to the boiler water. The character of the boiler water continually changes as the boiler operates. The dissolved and suspended solids contained in the feedwater concentrate in the boiler water at the rate of eightfold every hour if the boiler is producing steam at 50 percent of its normal capacity. Three damaging conditions arise in the boiler as the boiler water continues to steam without treatment. *Scale formation* on the steam generating surfaces, *corrosion* of the boiler metal, and boiler water *carry-over* with the steam due to foaming are the three results of untreated boiler water.

To prevent scale formation on the internal water-contacted surfaces of a boiler and to prevent destruction of the boiler metal by corrosion, you must chemically treat feedwater and boiler water. This chemical treatment prolongs the useful life of the boiler and results in appreciable savings in fuel since maximum heat transfer is possible when no scale deposits occur.

2.5.0 Chemical Treatment (External and Internal)

The method of using chemicals may take the form of external treatment, internal treatment, or a combination of both. The principal difference between these forms of treatment is that in external treatment the raw water is changed or adjusted by chemical treatment outside of the boiler so a different type of feedwater is formed. In internal treatment, the water is treated inside the boiler by feeding chemicals into the boiler water, usually through the feed lines. Again, in external treatment the main chemical action takes place outside the boiler, while in internal treatment the chemical action takes place within the boiler.

2.6.0 Internal Treatment and Prevention

At many Navy installations, the boilers are not large and do not operate at high pressure. When the makeup water is not too high in hardness or dissolved solids, good operation is possible with only internal treatment. Under this condition, external treating equipment is unnecessary. Chemical treatment covered in this chapter applies primarily to internal treatment.

2.6.1 Scale

When water evaporates in a boiler, the hard components that were in the water, such as calcium salts, magnesium salts, and other insoluble materials, form deposits on the tubes and other internal surfaces. These deposits are known as scale. Actually, the temperature of the water determines how well the different salts dissolve and how long they remain dissolved. Some salts are such that the hotter the water, the better they stay dissolved. Other salts stay dissolved while the water is at a relatively low temperature but form solid crystals (scales) that come out in increasing amounts as the water gets closer to becoming steam.

The scale-forming salts stay dissolved in the water and in the cooler parts of the boiler, but when the water reaches the hot tubes, these salts start forming solid particles that come out of the water and stick to the hot metal parts as scale deposits. These deposits are highly objectionable because they are poor conductors of heat, actually reduce efficiency, and are frequently responsible for tube failures. Some of the principal scale-forming salts to be considered in most cases are as follows:

- Calcium sulfate $CaSO_4$
- Calcium silicate $CaSiO_3$
- Magnesium silicate $MgSiO_3$
- Calcium hydroxide $Ca(OH)_2$
- Calcium carbonate $CaCO_3$
- Magnesium hydroxide $Mg(OH)_2$

Scale is made up of three main parts: calcium sulfate, calcium carbonate, and silicates of calcium and magnesium. Scales that are principally calcium sulfate or chiefly of the aforementioned silicates are very hard; those scales that are principally calcium carbonate with little silicate are somewhat softer. A scale consisting chiefly of calcium carbonate may appear only as a thin, porous, soft scale that does not build up in thickness.

Scale can be prevented by the intelligent use of proper water treatment, and that is one of the objectives of the boiler water test and treatment program.

2.6.2 Prevention and Treatment for Scale Control

Scale-forming substances cannot always be prevented from entering the boiler, but they can be made to form a fluid sludge. The problem then is simply one of proper chemical treatment and blowdown.

The selection of chemicals for internal treatment is determined by many factors: the kind of feedwater hardness (whether carbonate or sulfate); the ability of feedwater to build up required causticity; the type of external treatment, if used; the pH and percentage of condensate returns; the location of chemical feed injection; and the cost and availability of chemicals.

The first two chemicals to be considered for boiler water treatment of shore-based boilers are caustic soda and sodium phosphate (*Table 8-3*).

Table 8-3 — Chemicals Used by NAVFAC for Internal Boiler Water Treatment in Shore-Based Boilers.

CHEMICAL	PURPOSE	COMMENT
Sodium hydroxide NaOH (caustic soda)	Increase alkalinity, raise pH, precipitate calcium sulfate as the carbonate.	Contains no carbonate, therefore does not promote CO_2 formation in steam.
Sodium carbonate Na_2CO_3 (soda ash)	Increase alkalinity, raise pH, precipitate magnesium.	Lower cost, more easily handled than caustic soda. But some carbonate breaks down to release CO_2 with steam.
Sodium phosphates HaH_2PO_4, $HaHPO_4$, Na_3PO_4, $NaPO_3$	Precipitate calcium as hydroxyapatite ($Ca_{10}(OH)_2(PO_4)_6$).	Alkalinity and resulting pH must be kept high enough for this reaction to take place (pH usually above 10.8).
Sodium aluminate $NaA1_20_4$	Precipitate calcium, magnesium.	Forms a flocculent sludge.
Sodium sulfite Na_2SO_3	Prevent oxygen corrosion.	Used to neutralize residual oxygen by forming sodium sulfate. At high temperatures and pressures, excess may form H_2S in steam.
Hydrazine hydrate $N_2H_4.H_2O$ (35%).	Prevent oxygen corrosion.	Remove residual oxygen to form nitrogen and water. One part of oxygen reacts with three parts of hydrazine (35% solution).
Filming amines; Octadecylamine, etc.	Control return-line corrosion by forming a protective film on the metal surfaces.	Protects against both oxygen and carbon dioxide attack. Small amounts of continuous feed will maintain the film. Do not use where steam contacts foods.

Table 8-3 — Chemicals Used by NAVFAC for Internal Boiler Water Treatment in Shore-Based Boilers (cont.).

CHEMICAL	PURPOSE	COMMENT
Neutral amines; morpholine, cyclohexylamine, benzylamine	Control return-line corrosion by neutralizing CO_2 and adjusting pH of condensate.	About 2 ppm of amine is needed for each ppm of carbon dioxide in steam. Keep pH in range of 7.0 to 7.4 or higher.
Sodium nitrate $NaNO_3$	Inhibit caustic embrittlemerit.	Used where the water may have embrittling characteristics.
Tannins, starches, glucose and lignin derivatives	Prevent feed line deposits, coat scale crystals to produce fluid sludge that will not adhere as readily to boiler heating surfaces.	These organics, often called protective colloids, are used with soda ash and phosphates. They also distort scale crystal growth, help inhibit caustic embrittlement.
Seaweed derivatives (sodium alginate, sodium mannuronate	Provide a more fluid sludge and minimize carryover.	These organics are often classified as reactive colloids since they react with calcium and magnesium and absorb scale crystals.
Antifoams (polyamides, etc.)	Reduce foaming tendency of highly concentrated boiler water.	Usually added with other chemicals for scale control and sludge dispersion.
Proprietary compounds (of ball or brick type)	Do not use for water treatment. May be used for water treatment.	Boilers 125 psig and above, all power plant boilers, all boilers using intermittent blowdown. Low makeup boilers (under 125 psig) for space heating. High makeup boilers (under 125 psig) with continuous blowdown and stable feedwater, if cost saving is affected.

The caustic soda prepares the way by making the water definitely alkaline (high pH). The sodium phosphate can then attack the calcium magnesium and silica salts and convert them into a fluid sludge that can be removed by blowdown.

Caustic soda is used when the feedwater cannot build up the required causticity residual in the boiler water. Use of soda ash (Na_2CO_3) is not authorized in steaming boilers because it breaks down under heat to form undesired carbon dioxide (CO_2). This gas is corrosive to condensate return lines. The Navy boiler compound customarily used aboard ship is not authorized because it contains about 39% soda ash.

Sodium phosphate ($NaPO_4$) has a special affinity (attraction) for calcium, and in boiler water the phosphate joins with calcium to precipitate calcium phosphate ($CaPO_4$). Phosphate prevents the formation of calcium scales, such as calcium sulfate, calcium carbonate, or calcium silicate. The precipitate of calcium phosphate develops as a finely divided fluid material that can readily be removed by blowdown. The sodium phosphate dosage should be regulated to maintain a residual reading of 30 ppm to 60 ppm.

2.6.3 Sludge

Another source of tube coating is *baked sludge*. This sludge comes from dirt, oil, or water-treatment chemicals that are suspended in dirty feedwater. The solids settle on tube surfaces and absorb the heat intended to be transferred to the water. The heat then cooks the sludge into a hard coating on the tube walls. These deposits are as hard or harder to remove, than *true scale* and should be recognized as a completely different problem. Methods of preventing and combating baked sludge are different from methods of preventing and combating scale.

Baked sludge is very hard to remove by mechanical means, and boiler compound has no effect on it at all. The best method found to combat sludge is to know where it comes from, make it gather by proper treatment, and blow it out before it cooks.

2.6.4 Prevention and Treatment for Sludge Control

When the proper causticity residual is maintained and phosphate is fed in correct amounts, the scale-forming impurities in boiler water become sludge and should be easy to blow out. Sometimes, however, the characteristics of the precipitated chemicals are such that the sludge formed does not go along with the water and leave the boiler with the blowdown. It has been discovered that additives called sludge conditioners cause the sludge to flow better.

Most sludge conditioners are organic substances that act as dispersants. They keep the sludge in a fluid state by holding the precipitates as finely divided particles. As the precipitated chemicals settle, a loose fluid mass that is easy to blow out is formed. The only sludge dispersant approved by NAVFAC for use in shore-based boilers is ***quebracho tannin***.

Generally, when quebracho tannin is used, sufficient quantities are fed to the boiler to give the boiler water a medium tea color. If the causticity residual is high, a darker color should be maintained. This darker color for high causticity aids in preventing hardening of metal in the boiler. As the tannin particles become part of the sludge and are blown out, the brown color, given to the water by the initial dose of tannin, becomes a lighter color, and more tannin must be added.

Proper blowdown is important because some sludges are almost always in the boiler water. When only parts of the boiler are badly sludged, blowdown may not be complete or there may be areas of poor circulation. The boiler design may be such that even good blowdown does not clear all the parts. Another concern is that frequency, time, and the kind of blowdown being used may not be complete or correct to maintain optimum conditions.

A small amount of seawater in the feedwater causes heavy sludging. Where seawater is likely to contaminate feedwater or where evaporated seawater is used for feedwater, every precaution should be taken to prevent saltwater contamination of the feedwater.

Regular daily boiler water tests will show up contaminated feedwater so that it can be corrected before serious harm is done.

Where makeup water is clean and not much sludge shows at bottom blowdown, tannin may not be necessary. Where there is a lot of sludge, the addition of tannin is a big help in keeping the boiler free and clean. Also, much less sludge-forming materials are required when the raw water makeup is upgraded by external treatment.

2.6.5 Corrosion

Corrosion is the deterioration of metal by chemical action. When dissolved oxygen is present in the boiler water, corrosion begins and continues until all metal has been transformed into iron oxide or, commonly stated, rust. When rust forms in the boiler, it may drop out as sludge or cling to other metal surfaces. It is not economically possible to prevent at least some of the iron in the boiler from going into solution. All iron not protected by a coating or film of something that keeps out moisture and air is sooner or later going to become *rust*. The idea is to slow down the process as much as possible by *keeping oxygen out* and by maintaining a proper causticity residual.

The pH level of boiler water is also a factor in corrosion. The active agent in the corrosion of the internal water surface of boilers is oxygen; however, the combined action of oxygen and the acid action of the water are required for the corrosion process. To suppress the acid action of the water, you can raise the pH value of the water by adding caustic soda. The lower the pH value the stronger the acid concentration. The higher the pH value the weaker the concentration. Economically, acid corrosion cannot be stopped completely, but it can be suppressed by keeping oxygen out of the boiler and by maintaining a proper pH value and causticity range.

2.6.6 Prevention and Treatment for Oxygen Corrosion

The chemical most commonly used in oxygen removal is sodium sulfite, and it is quite often referred to as an oxygen scavenger. It is an example of a chemical that actually reacts with the harmful constituent. It reacts with oxygen, forming a neutral compound—sodium sulfate.

When enough sodium sulfite is fed into a boiler so that a surplus of the chemical is maintained, any of the oxygen getting into the boiler water is taken up by the chemical, and the boiler water is kept virtually free of oxygen. By maintaining a suitable residual, little, if any, corrosion due to oxygen occurs. Common practice in feeding sodium sulfite is to maintain a surplus residual of about 20 ppm to 50 ppm in the boiler water. This is generally enough sodium sulfite to react with normal amounts of oxygen that might get into the boiler. Higher concentrations of sodium sulfite are unnecessary.

Sodium sulfite dissolves readily in water and must be fed at a point between the feed heater and the boiler so that it is used to take up only the oxygen that gets by the deaerator or heater. If the sodium sulfite is fed through the feed lines by continuous feeding, it is always present in the feed lines and takes up oxygen in the feedwater in addition to maintaining a surplus in the boilers.

Another advantage of using sodium sulfite is that if, for any reason, a feedwater heater or deaerator becomes inoperative or efficient operation is temporarily interrupted, the sodium sulfite residual present in the boiler water can take up the larger amounts of the oxygen getting in. At the same time, the concentration of sodium sulfite drops.

This is shown by test analysis of the boiler feedwater. This test gives the operator ample warning of an existing malfunction within the boiler feedwater supply system. Immediate steps should be taken to correct this off-standard condition.

Feedwater or makeup water tanks should be heated to a temperature of 180°F to 200°F. This heat alone helps to dispense of most of the dissolved oxygen before it can enter the boiler. It also allows for more economical use of sodium sulfite.

The prevention of corrosion in the boiler means regulating the alkalinity of the water, producing protective films, and removing dissolved oxygen. These preventive measures are accomplished by maintaining the proper chemical residuals in the boiler water and by proper deaeration.

2.6.7 Carryover—Foaming and Priming

The word *priming* is used rather loosely to express the action of the water and steam in a boiler when an unusual amount of water is being carried over with the steam. For a given boiler installation, a certain amount of water or moisture in the steam is tolerated. The amount depends upon the use of the steam, the boiler construction, and the facilities for removing the water from the steam. The mechanical causes include the following:

- Deficiency in boiler design
- High water level
- Improper method of firing
- Overloading
- Sudden load changes

A poorly designed boiler may have insufficient steam-disengaging space. It is fairly obvious that the faster the steam is produced in a given vessel, such as a boiler, the more violent is the boiling effect. But when the steam space above the water level is large enough, the steam leaving the boiler does not show any evidence of carryover. The size of the steam header and the velocity of steam leaving the boiler are, therefore, important elements in boiler design.

As the rate of steam production goes up, so does the tendency for steam contamination. The sudden opening of a steam valve or the cutting in of a boiler too quickly speeds up the production of steam, which can cause violent bubbling and carryover. The primary chemical causes of carryover are high concentrations of totally dissolved and suspended solids in the boiler water, excessive alkalinity, and the presence of oil.

Foaming is the production of froth or unbroken bubbles on the surface of the boiler water. The froth may be thin, with few bubbles overlying each other, or it may build up throughout the steam space. Under such conditions it is difficult to free the steam of the liquid films, and the moisture content increases. When certain substances are dissolved in water, they concentrate somewhat more in the body of the liquid than on the surface; others concentrate more on the surface than in the body. In either case, the surface tension of the water is affected, and bubble film develops.

The formation of froth depends upon the tenacity of the films of liquid that form the shells of the bubbles. A tough film can develop that refuses to break and release the steam. Apparently, finely divided solids in suspension increase the stability of the film so that the combination of salts in solution and finely divided solids cause foaming to develop more readily than when either one is present by itself.

Soaps getting into the boiler from outside sources or formed within the boiler from oils or animal greases intensify the foaming action. Water can be carried over in the steam without formation of froth. When pure water that does not foam is boiled, it frequently "bumps" as unstable steam bubbles are formed. These rapidly reach the surface of the water and instantaneously burst through. Parts of the water tend to become superheated and suddenly turn to steam. Fine solid particles released in water under these conditions cause the immediate production of much steam. This may occur in a boiler when particles of scale suddenly become loose.

When a boiler is foaming or priming, it is difficult and quite often impossible to read the true level of the boiler water on the gauge glass. The slugs of boiler water can wreck turbines or engines. The carryover of boiler water solids usually caused by foaming and priming disrupts operation of the equipment coming in contact with the steam. Deposits form in steam piping, valves, superheaters, engines, or turbines. These solids erode the turbine blades and frequently create out-of-balance conditions to the rotor. They often clog tubing, a pipe, and other apparatus following the boiler.

When live steam is used for processing purposes or for cooking, the solids can seriously damage the final product. It is important for you to remember, any moisture carryover with the steam is an additional heat loss through the steam line.

2.6.8 Prevention and Treatment for Carryover—Foaming and Priming

There are two kinds of solids present in most boiler water—the dissolved solids, or substances that are in solution, and suspended solids. Suspended solids are finely divided solid particles floating around in the water. This is material left over after the scale-forming and corrosive salts have been changed into sludge by chemical treatment.

When a boiler is steaming, the feedwater continuously carries dissolved mineral matter into the boiler. However, the steam leaving the boiler carries very little mineral matter with it. The concentration of dissolved solids in the boiler water, therefore, keeps building up unless properly controlled by continuous or intermittent blowdown.

In water tube boilers, concentrations are generally highest at the place where the mixture of steam and water from the tubes spills over into the steam drum. Where total concentrations are not reduced sufficiently by the bottom blow, another blowdown line should be installed to remove water from the drum at the point where TDS (total dissolved solids) concentrations are the highest. This blowdown is generally operated continuously when the boiler is in service and is called a continuous blowdown.

The best remedy for foaming and priming carryover is the proper blowdown of TDS. The continuous blowdown should be regulated to maintain the TDS at 3,000 to 4,000 ppm. The greater the number of TDS that can be carried without trouble, the less water, fuel, and chemicals are required or wasted in the TDS blowdown.

2.7.0 Chemical Treatment Determination

Because raw water conditions vary so greatly with locale, it is impossible to recommend a single, specific water treatment. Whenever possible, you should consult with a water treatment chemist and follow their recommendations concerning chemical treatment of boiler water. The degree of success of any water treatment program depends upon how well the recommendations for treatment are monitored.

When the services of a qualified water treatment chemist are obtained, their recommendations should include the following:

- The treatment formula
- The treatment ingredients
- Instructions to the boiler operator in the use of the treatment
- Periodic visits to the plant to check on the results of the treatment plan

When the operator follows instructions and uses the proper blowdown procedure, scale and sludge in the boiler are reduced to a minimum. Blowdown limits the amount of dissolved and suspended solids in the boiler water.

Consulting a chemist is an ideal situation. Seabees seldom operate under ideal situations, particularly during contingency operations. Below are some general guidelines to follow in order to determine the initial chemical treatment for a boiler, and how to establish an effective treatment program.

The first determination you have to make is the steaming rate of the boiler, expressed in pounds per hour. This is a fairly simple computation. You first determine the boiler horsepower (bhp), and then multiply the result by 4.5 pounds. For example, if you have a 100 horsepower boiler operating at one-half fire, your steaming rate is 1,725 pounds of steam per hour.

- 1 BHP = 34.5 lb steam/hour
- 100 x 34.5 = 3,450 steam/hour at high fire
- 3,450 ÷ 1/2 = 1.725 lb steam/hour at one-half fire

To determine the initial chemical dosage, you must know the hardness of the raw water. A chemist can tell you this; however, in the field you must determine it by experimentation. The harder the water, the more phosphates you must add during treatment to obtain correct phosphate residuals. The example that follows assumes zero hardness of the raw water and uses a 1,725-pound steaming rate.

1. Mix the following chemicals in 28 gallons of water:
    - 1 1/4 pounds of sodium sulfate
    - 1/2 pound of trisodium phosphate
    - 1/2 pound of caustic soda
2. Adjust the chemical feed rate to 3 gallons per hour (allows for 8 to 10 hours of steaming).

The chemical dosage varies with the steaming rate of the boiler. To establish your water treatment program, use the following steps every hour of operation for the duration of your initial chemical batch.

1. Determine the hourly steaming rate.
2. Test for phosphate residual (30-60 ppm).
3. Test for sulfite residual (25-50 ppm).
4. Test for pH (9.5 to 11.5).
5. Test for TDS (3,000 to 4,000 ppm).

You should make a log entry of these test results every hour. This establishes a history of the test results. At the completion of the initial chemical dosage, you can either add or subtract chemicals, based on your log. It may take several batches fed over an 8 to 10-hour period to get a consistent chemical requirement for boiler water treatment. Once the boiler has stabilized and treatment test results remain reasonably balanced, testing may be required only every 4 hours.

At this time you can chart your chemical requirements based on load demand of the boiler. By establishing this history through experimentation, your operators are able to treat the boiler water with fairly accurate results. At this time note that boiler blowdown has a big effect on your treatment program. Proper blowdown practices cannot be overemphasized. Too little blowdown causes TDS readings to be high; too much blowdown causes a high demand for chemicals and results in lost efficiency of the boiler.

Test your Knowledge (Select the Correct Response)

3. Operator boiler plant logs are arranged for use over a 24-hour period, consisting of how many shifts?

   A. Two 6-hour
   B. Three 8-hour
   C. Four 10-hour
   D. Five 12-hour

4. What effect of inadequate or improper water conditioning causes pitting of metal in boilers, and steam and condensate in piping?

   A. Carryover
   B. Scale
   C. Corrosion
   D. Caustic embrittlement

5. What chemical is used for internal boiler water treatment to prevent oxygen corrosion in boilers?

   A. Sodium sulfite
   B. Sodium carbonate
   C. Sodium aluminate
   D. Sodium nitrate

3.0.0 MAINTENANCE

As a boiler plant supervisor/manager, you need to know that boiler maintenance covers a wide range of topics.

Major repairs that involve welding of pressure parts of the boiler are done by Steelworkers in strict adherence to the procedures in section IX of the ASME, *Boiler and Pressure Vessel Code*. This section is concerned with operator and preventive maintenance and major considerations for the maintenance and care of firesides and watersides. Procedures for laying up idle boilers are also discussed.

3.1.0 Operator Maintenance

Operator maintenance is the necessary, routine, recurring maintenance work performed by the operators to keep the equipment in such condition that it may be used continuously at its original or designed capacity and efficiency for its intended purpose. The operator is actually the most important member of the boiler plant maintenance team. A well informed and responsible operator can do the following:

1. Keep equipment in service for maximum periods of time.
2. Detect any flaws so equipment can be removed from service in time to prevent serious damages.
3. Perform minor repairs on equipment removed from service to minimize outage time.

It is sometimes difficult to determine where operator duties end and maintenance crew work begins. However, the operator must realize that he or she has the keenest interest in the condition of the equipment. A well kept plant not only reflects the operator's interest (and the desire to better his or her position) but it also is vital to the safety of equipment and personnel. It is essential for every person in the operating aisle to perform the following duties:

1. Clean. Dirt is the principal cause of equipment failure. Whether it is fly ash in the switch gear, oil on the deck, cloth lint, or dust, it causes trouble. No matter the form in which dirt appears, it should be removed immediately by the operator.
2. Lubricate. Any two surfaces brought together develop friction. If not properly lubricated, these surfaces wear one another down, change clearances, and cause equipment breakdowns. A well placed drop of oil or a thin layer of grease can go a long way toward keeping a much used piece of equipment in good condition.
3. Cool. Every piece of equipment has an operating temperature range. The operator should be informed on this matter. An unusual change in temperature that the operator cannot correct should be reported immediately to the plant supervisor. When the temperature of a piece of equipment rises rapidly, an immediate shutdown is recommended.
4. Tighten. Vibration is another major source of equipment failure. A simple step taken in time, such as tightening bolts, can prevent a serious failure. Equipment that is not secured properly vibrates, causes an unbalance, vibrates further, and compounds a cycle that can only lead to further trouble. In making rounds, the operator should put his or her hand on the bearings, touch the fan housing, and feel the motor casing. When any unusual sound is heard, vibration felt or motion seen, the proper steps should be taken by the operator to correct the condition.

3.2.0 Preventive Maintenance

Preventive maintenance inspection (PMI) is a system of routine inspections of equipment recorded for future reference on some type of inspection record. The purpose of PMI is to anticipate and prevent possible equipment failures by making periodic inspections and minor repairs in advance of major operating difficulties. Preventive maintenance directed specifically toward maintaining boiler efficiency is the exception rather than the rule. Rising fuel costs have placed an increasing emphasis on conscientious maintenance because it results in higher boiler operating efficiency. Preventive maintenance practices are easily justified from an economical and safety standpoint. *Tables 8-4* and *8-5* reflect NAVFACENGCOM recommendations for PMI.

Table 8-4 — PMI Checklist for Steam Boilers 350,000 Btuh or Less.

STEP	IF	THEN	WHEN
Observe condition of flame.	Flame is smoky, flame impinges on furnace walls or burner starts with a puff	Make appropriate repairs or adjustments.	Weekly
Test low water and fuel cutoff.	Boiler does not secure during tests	Locate problem and repair.	Weekly
Test water column or gauge glass.	Gauge glass is dirty, has an obstruction, or leaks are present including gauge cocks	Clean, remove obstruction or repair leaks, or replace.	Weekly
Observe operation of condensate of vacuum pumps.	Pump is defective or leaking	Repair or replace defective equipment.	Weekly
Check operation of chemical feed pots and pumps.	Leaks or improper operation exists	Repair or replace defective equipment	Weekly
Test flame detection devices and associated automatic fuel cutoff valves.	Loss of flame does not shut off fuel to burner	Repair or replace defective equipment.	Monthly
Inspect steam supply and condensate return piping.	Problems with valves, radiators, trap leaks, or excessive rust	Repair or replace defective equipment.	Monthly
Inspect fuel supply systems and piping. Include adjustment of oil pressure and ensure both oil supply and return lines have a fusible in-line valve.	Discrepancies are leaks, or insulation is missing	Repair or replace for corrective action.	Monthly
Check condition of safety valves.	Valves are obstructed to flow, are inoperative, or fail to meet code requirements	Repair or correct problem.	Monthly
Check boiler room drains.	Drains are not operating properly	Repair.	Monthly
Inspect burner assembly.	Evidence of improper fuel nozzle wear, plugging, or carbon building exists	Replace nozzle and adjust equipment after new nozzle is installed.	Monthly
Check transformer.	Transformer is replaced for any reason	Do not interchange transformers of different capacities.	Annually

Table 8-4 — PMI Checklist for Steam Boilers 350,000 Btuh or Less (cont.).

STEP	IF	THEN	WHEN
Inspect burner assembly, replace fuel filters and nozzle on oil burning equipment, clean and adjust electrodes.			Annually
Make internal and external inspection of heating surfaces after cleaning.			Annually
Inspect gas piping valves for proper support and tightness.	Leaks are present	Secure piping to the boiler and contact the gas company.	Annually
Remove trash.			Annually
Check draft, manifold pressure, and combustion. Over-fire draft should be .02" water gauged for oil burners.	Deficiencies are noted	Repair, adjust, or replace defective mechanism.	Annually
Inspect control equipment for proper sequence and operation.	Covers are missing, controls are dirty, or electrical contacts are fouled	Replace, clean, or repair.	Annually
Calibrate and check operation of gauges and meters.	Gauges are defective, cracked, have broken glass, or bent pointers	Have gauges calibrated or repaired, or replace.	Annually
Check shell for cleanliness, excessive rust, corrosion streaks, deformations, and cracks.			Annually
Check stack and breaching for integrity and tightness.			Annually

Table 8-5 — PMI Checklist for Hot-Water Boilers.

STEP	WHEN
Observe condition of flame.	Weekly
Check fuel supply and note oil level.	Weekly
Observe operation of circulating pumps. Lubricate pump motor bearing assembly and flex coupling.	Weekly
Test flame detection devices and associated automatic fuel cutoff valves.	Monthly
Inspect fuel supply systems and piping in boilers for leaks and loss of insulation.	Monthly
Check boiler room drains for proper functioning.	Monthly
Inspect burner assembly.	Monthly
Make internal and external inspection of heating surfaces after cleaning.	Annually
Inspect gas piping and valves regularly for proper support and tightness.	Annually
Check transformer.	Annually
Inspect area around boiler for cleanliness.	Annually
Inspect hot water supply and return piping and valves.	Annually
Check expansion tank and air eliminator equipment.	Annually
Check control equipment for proper sequence and operation.	Annually
Calibrate and check operation of gauges and meters.	Annually
Check breaching and stack for integrity.	Annually
Check shell for cleanliness, excessive rust, corrosion streaks, deformations and cracks.	Annually

3.3.0 Efficiency Maintenance

Efficiency-related boiler maintenance is directed at correcting any condition that increases the amount of fuel required to generate a given quantity of steam. Thus, at a specified boiler load, any condition that leads to an increase in flu-gas temperature, flue-gas flow, combustible content of flue gas or ash, convection or radiation losses from the boiler exterior, ductwork, or pipe, or blowdown rates is considered an efficiency-related maintenance item. Generally, attention to items can eliminate more serious consequences, such as damage to equipment and/or injury to personnel.

The boiler tune-up is the best method of improving efficiency. The primary objective of a tune-up is to achieve efficient combustion with a controlled amount of excess air, thus reducing the dry gas loss and the power consumption of forced- and induced-draft fans.

3.4.0 Care of Boiler Firesides

The boiler firesides must be kept clean. The burning of any petroleum product tends to be incomplete, thus leaving soot and carbon deposits on the boiler firesides. These deposits seriously reduce the efficiency of the boiler. Slag contributes greatly to failure of such parts as superheater support plates, baffles, protection plates, and soot blowers. Deposits also act as insulation and prevent the transfer of heat to the water or steam in the tubes.

Soot and slag accumulations that block the gas passages through the tube banks require the use of high air pressures to force the combustion gases through the boiler, thus reducing fire-room efficiency. Accumulations that block the gas passages also interfere with the designed flow of combustion gases and cause extremely hot gases to pass over protection plates, baffles, seal plates, and other parts that are not designed for such high-temperature gases; in some cases, early failure of these parts can be blamed directly on blocked gas passages and the resulting overheating of the parts.

When soot is allowed to remain on the boiler firesides for any length of time, the sulfur in the soot combines with moisture and forms sulfuric acid. This acid attacks tubes, drums, and headers. The extent of the damage caused by acid attack depends upon the length of time the soot remains on the tubes and upon the amount of moisture present during this interval. Moisture may be present as a result of high atmospheric humidity, rain or snow coming down the stack, leaky boiler tubes, and steam or water leakage through the boiler casing joints, particularly from machinery and piping installed above the boiler.

One indication of soot corrosion is the development of pinhole leaks at the point where the tubes enter the water drums and headers and at other points where it is difficult to clean the tubes properly. When soot corrosion is allowed to proceed unchecked, extensive deterioration of the boiler metals results.

You will find that keeping the firesides clean actually saves work, as well as saves the boiler. Clean tubes do not collect deposits as readily as dirty tubes do. It is a good deal easier to clean the firesides several times when they are only slightly dirty than to clean them once when they are heavily coated with soot and carbon.

Local instructions usually specify steaming intervals after which the boiler firesides must be cleaned. In addition to this upkeep, the firesides are normally cleaned just before the annual internal inspection.

Although there are a number of cleaning methods available (such as hot water washing, wet steam lancing, and so forth), mechanical cleaning should be considered the basic and preferred method of cleaning firesides. The other methods are generally used only when mechanical cleaning cannot adequately remove the fireside deposit.

Mechanical cleaning is accomplished within the boiler, in the furnace, and from outside the boiler through access doors by using various types of scrapers, probes, and wire brushes to remove soot and other deposits. In most instances, these cleaning tools can be obtained from the boiler manufacturer.

In addition to scrubbing and cleaning the firesides of the generating tubes, other areas of the firesides should receive scrupulous cleaning as well. Give particular care to those more or less inaccessible portions of the firesides that are not cleansed by the soot blowers. Remove any encrusted soot from burner impeller plates, bladed cones, and drip pans.

The furnace refractory must also be cleaned. This operation is perhaps best done last to remove not only original deposits from the brickwork but also soot and dust deposited after other parts of the boiler were cleaned. It is important to keep the brickwork clean for two reasons: first, soot and foreign matter lodged in expansion joints can prevent proper expansion of refractories when hot, and can ultimately cause serious cracking of the brickwork; second, soot and other deposits left on the brickwork will lower the melting point of the refractories.

3.5.0 Care of Boiler Watersides

Failure to keep boiler watersides clean reduces the efficiency of the boiler and contributes to overheating, and can lead to serious damage. Experience has shown that tube failures resulting from defective materials or poor fabrication are rare. The majority of all tube failures, other than those associated with water-level casualties, are caused by waterside deposits or accumulations.

Some tube failures are caused by waterside deposits of hard scale. More frequently, however, tube failures occur as the result of an accumulation of relatively soft materials such as metal oxides, the residue of chemicals used for boiler water treatment, the solids formed as a result of the reactions between scale-forming salts or other impurities, and the chemicals used for boiler water treatment.

As in the case of fireside cleaning, waterside cleaning is usually accomplished after specified steaming intervals and also before the annual internal inspection.

The need for cleaning watersides or firesides is often signaled by a gradual rise in the stack gas temperature. In other words, deposits on either the firesides or watersides of generating tubes reduce heat transfer from the furnace to the water. A good part of the non-transferred heat is, as you know, retained by the fireside or waterside deposit. However, some of the heat not properly carried away by the water and not absorbed by the deposits remains with the combustion gases. Therefore, the temperature of the stack gas rises.

When working in the watersides of a boiler, you should take all possible precautions to keep tools, nuts, bolts, cigarette lighters, and other small objects from sliding down into the tubes. Some advisable precautions are as follows:

1. Remove all small objects from your pockets before entering the boiler.
2. Keep an inventory of all the tools and equipment you take into the boiler. Ensure that you remove each item and check it off the inventory before closing up the boiler.
3. Do NOT set tools or other articles down in places where you are likely to forget them. For example, you should not leave tools on top of the steam separators or in other places that are easy to reach but hard to see.
4. When an article is lost in the boiler watersides, you must NOT close up or operate the boiler until the article has been located and removed. Even a very small article can interfere with boiler circulation and cause tube ruptures.

Additional precautions for waterside work include the following:

1. Close, wire, and tag all steam, water, and air valves that could possibly admit fluid to the boiler. Disconnect (or otherwise render inoperative) the remote operating valves as well.

2. Ensure that adequate ventilation is provided before entering the waterside of a boiler.
3. Ensure that all portable extension lights are of the watertight globe type, with the globe encased in a rubberized, metal cage. Be sure all lights are grounded and wires are not broken. Examine the wires from end to end to be sure that the insulation is not broken or cracked, exposing the bare wire.
4. Station a person outside the drum whose ONLY duty is to act as tender and to assist personnel working in the drum.

Boiling out is a special waterside cleaning technique. There are two approved methods for boiling out boilers—the sodium metasilicate pentahydrate method and the trisodium phosphate method. The method used depends upon the purpose of the boiling out. The sodium metasilicate pentahydrate method is used to remove rust-preventive compounds and other preservatives; consequently, this method is used for boiling out (1) newly erected boilers, (2) reactivated boilers, and (3) boilers that have had major tube renewals. The trisodium phosphate method is used when you are boiling out for the removal of oil and for scale softening in preparation for mechanical cleaning.

3.6.0 Laying-Up Idle Boilers

Many operators carefully follow all boiler water treatment procedures and regulations only to find that the watersides may still experience corrosion and pitting. It should come as no great surprise that the fault is not with the treatment methods, but rather with the manner in which the boiler is permitted to stand idle. After the pressure drops within an idle boiler, air gradually seeps into the boiler, carrying oxygen with it.

The air also contains carbon dioxide that combines with the boiler water to form carbonic acid, which lowers the residual causticity of the boiler water. Gradual in-leakage of feedwater can dilute and lower the causticity of the boiler water even further. In addition, condensation within the boiler, on both waterside and firesides, can produce water droplets that are saturated with oxygen and contain no causticity. Conditions within the boiler are now ideal for active and rapid corrosion. This means the need for protecting boilers that are left idle for any length of time is very important.

3.6.1 Laying-Up a Boiler by the Wet Method

A wet lay-up is done after a thorough cleaning of both firesides and watersides. The feedwater used to fill the boiler is deaerated as much as possible. While the boiler is being filled, add caustic soda in sufficient quantities to maintain a pH reading of 9.5 to 11. Additionally, add approximately 0.03-0.06 pounds of sodium sulfite per 1,000 gallons of boiler holding capacity to maintain 30-60 ppm. When equipment is installed in a plant and used in acid treatment of feedwater, it should never be used to fill a boiler for idle standby; this results in a low pH in the boiler as concentration by boiling is taking place. To ensure the boiler is filled completely, you should add water until it overflows at the top of the boiler through any convenient outlet, and then close the outlet. When there is a superheater on the boiler, add water to fill it completely. If appreciable air is dissolved in the water, you should boil the water to vent out any air after the boiler is nearly filled.

When the installed chemical feeding system is not suitable for continuous feeding and it is necessary to slug feed the chemical while the boiler is being filled, the boiler water must be mixed to obtain uniform distribution of the chemical throughout the boiler. This can be achieved by pumping water from one section of the boiler to another using a circulating pump. When such a pump is not available, mixing can be accomplished by heating the boiler just enough under low fire to set up natural circulation.

After a boiler has been filled for standby, it must be kept filled as long as it is idle with no water flowing in or out. Leakage out, as through a leaky blowdown valve, can admit air and form a waterline in the boiler. A method sometimes used for keeping a boiler completely full consists of using a small tank placed above the boiler with a line connected to any outlet of the boiler or the superheater header. This method also shows when any leakage occurs into or out of the boiler. The small tank is provided with a vent and a water column. When the boiler is filled, water is added up into the tank. Then, if water leaks out of the boiler, water from the tank flows in, keeping the boiler full. When the level in the tank rises, it shows that water is leaking into the boiler, either through the feed line or the steam line.

Water in an idle boiler should be sampled and analyzed weekly. When the causticity or the concentration of sulfite drops considerably, you should ensure additional chemical is fed and the boiler water circulated to distribute the chemical uniformly.

One disadvantage of using the wet method is when the temperature of the water in the boiler is lower than the outside temperature, condensation or moisture occurs on the outside of a metal boiler, causing corrosion. Some engineers coat the outside of a metal boiler with light oil to help protect it from corrosion.

3.6.2 Laying-Up a Boiler by the Dry Method

Dry lay-up should be used when a boiler is scheduled to be out of service for a long period of time or when a boiler is in danger of freezing. The first step is to clean both firesides and watersides of the boiler thoroughly. After the boiler is cleaned, the watersides must be completely dried because any moisture remaining on the surface will cause corrosion. Take precautions to preclude entry of moisture in any form from steam lines, feed lines, or surrounding air.

To start this method, place a moisture-absorbing material such as quicklime in the boiler at a rate of 2 pounds, or silica gel at the rate of 5 pounds, for 30 cubic feet of boiler volume. Place the chemical-absorbing material in trays and insert it in the drums or manholes. Remember, air carries moisture so make sure you close all of the manholes and handholes. This method requires that you check the moisture-absorbing material every 3 months.

One method of dry lay-up for a large utility type of boiler is to simply feed nitrogen through the boiler vents while draining the boiler. With using this method, you should maintain the nitrogen pressure at 5 psig during the storage period.

Test your Knowledge (Select the Correct Response)

6. What boiler operator maintenance responsibility is required to keep a boiler running continuously at its original capacity and efficiency?

   A. Keeping equipment in service for maximum periods of time.
   B. Determining any flaws so equipment can be removed in time to prevent serious damage.
   C. Performing minor repairs on equipment that has been removed from service to minimize outage time.
   D. All of the above

7. How often should a PMI be done on the boiler room drains of a hot-water boiler?

   A. Daily
   B. Weekly
   C. Monthly
   D. Annually

8. **(True or False)** Water that is contained in an idle boiler should be sampled and analyzed monthly.

   A. True
   B. False

Summary

This chapter covered the procedures for boiler installation, plant operations, and maintenance. You were also provided information on the purpose, types, and components of gaseous and chemical extinguishing systems.

Ensuring the installation, operation, and maintenance procedures for boilers meet the necessary standards is an important requirement for fulfilling your duties as a boiler plant worker, supervisor, and manager.

Additional Resources and References

This chapter is intended to present thorough resources for task training. The following reference works are suggested for further study. This is optional material for continued education rather than for task training.

Inspection and Certification of Boilers and Unfired Pressure Vessels, NAVFAC MO-324

American Society of Mechanical Engineers (ASME), *Boiler and Pressure Vessel Code*