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12 Ways To Avoid Boiler Tube Corrosion

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Corrosion troubles in low pressure heating boilers -- which usually operate at a steam pressure below 15 psig or water pressures below 30 psig and are often of the horizontal fire tube type -- often occur unnecessarily.

During the past 60 years we have had many occasions to examine boiler tubes to determine the reason for their failure. In very few cases have any defective qualities in the tubing been the cause of the corrosion. In the vast majority of instances, the necessity for replacement has been traced to conditions of environment.

In power boilers, it is a rare occurrence to find corrosion of the type common to heating boilers. This is because operators of power boilers realize the importance of proper water and fire side conditions and take care to avoid such problems.

The users of heating boilers are, first of all, usually not aware of the possibilities of corrosion. Often they have little idea what causes it and lack the know-how and experience to combat it. Fortunately, scale is not a major factor in low pressure boilers, although a buildup of scale at tube ends has occasionally resulted in failure by grooving next to the tube sheet.

Let us first consider the various mechanisms which lead to pitting or water side corrosion since this is the most common type. This accounts for 75 percent of the tubes examined in our laboratory.

Steel does not corrode appreciably in dry air, but only in the presence of moisture. Likewise, steel will not corrode in clean, alkaline, freshly-boiled water, if air is kept away.

This has been proven to our satisfaction by placing samples of tubes in ordinary tap water in flasks and boiling the water, causing the steam to condense and run back into the flask. When we allowed the condensed drops of water to be free to contact the air, corrosion of the tubes took place. When we took the oxygen out of the air in the flask and condenser by running the air through pyrogallic acid (which is an oxygen-absorbing liquid), no corrosion of the tubes took place.

Oxygen and Velocity Factors

This proves that the presence of oxygen is an important factor in corrosion problems. It

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was also found that if the heaters were shut down at night, the corrosion was much more rapid than if the apparatus were kept boiling. In effect, some of the oxygen was excluded from the flask by the steam space over the boiling water. In low pressure heating boilers, however, the return water usually enters at the bottom, which does not afford the oxygen reduction which would be obtained if it would drop through the steam space.

Pitting is probably the most destructive form of corrosion that affects the water side of boiler tubes. Frequently, only a few pits are present and most of the surface is unattacked. In other cases, the pits cover most of the surface, and as a further extreme, the pits all run together and the corrosion takes the form of uniform attack. The frequency of the pits is determined to a large extent by the degree of acidity or alkalinity of the water.

Acidity and alkalinity are dependent upon the amount of hydrogen-ion concentration found in the water. Both would be expressed in terms of the pH scale. A strong acid solution -- strong muriatic or sulfuric acid -- is rated as 1; a strong alkaline solution -- concentrated caustic soda -- is rated as 14. A neutral water has a pH value of 7.

Below a pH of 5, the water is actually sufficiently acid to dissolve the steel, and under these conditions no pits form. Instead, the corrosion is relatively uniform and the steel gradually gets thinner until it is too weak to hold the pressure, or a small hole develops.

Between a pH 5 and 9.4, pitting takes place at a rate depending on the concentration of oxygen in the water. Therefore, while operating the boiler, it is necessary that all air or as much air as possible be excluded from the boiler water.

It has been shown that a strip of steel hung in the middle of a fast moving stream did not rust, while an identical piece hung in a stagnant pool along the edge of the same stream pitted badly when connected to the first by a wire. This proves that velocity and air content have an effect on the corrosion of steel. In most cases, the pitting in horizontal fire tube boilers takes place along the top of the tubes on the outside, and it is our belief that this may in part be due to the difference in velocity of the rising water and steam bubbles, creating an eddy effect along the top of the tube and accelerating the corrosion, much as did the experiment of the flowing stream. In any event, pitting would not occur in this type of boiler if no oxygen were present in the water.

Practically all ground surface supplies of water contain dissolved air in quantities depending on its source, time of exposure and its temperature. Cold water will retain more air than warm water, as can be seen by filling a clear bottle with cold water from a tap and allowing it to stand overnight. Small air bubbles will form on the sides, demonstrating that as the water warms up the gas is liberated.

This release of the air in the form of bubbles creates a problem in a newly filled boiler. In

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a new boiler, or in one which has been drained and refilled with cold water, as the water warms up, air bubbles form on the tubes. In a very short time pits develop under these bubbles, due to the difference in oxygen concentration under the bubbles and the oxygen concentration in the water surrounding the bubbles. Penetration as high as 50 percent of the tube wall has been known to take place in one stagnant period of two weeks duration. Once these pits form, they proceed rapidly even under operating conditions.

Why New Tubes Corrode

Sometimes a set of new tubes installed in a boiler has been found to last less than a year, whereas the former tubes lasted five to ten years. Obviously, something has changed. Often the tubes are blamed for the failure, when actually there have been changes associated with the operation and maintenance of the boiler. A different method of starting up may have been used. Circumstances may have been such that the boiler was immediately fired when the old set of tubes were put in, while the new set may have been exposed to the fresh water for some time and air bubble pitting may have started, leading to the eventual failure of the tubes. The temperature of the fill-up water may have been different; and, therefore, more air was present in the new installation. The composition of the fill-up water may have changed; a thin scale may have been laid down at the beginning of the life of the old tubes, which served as a protection. Changes in electrical connections may have induced stray currents, leading to possible electrolytic corrosion. Small air or steam leaks around pipe joints and valves may have let air into the new setup. Air vents may have become plugged due to jarring of the piping. In short, any number of things may have happened and caused the failure.

A large number of boiler tube failures take place in the fall when starting up for winter operation. These are due to both the air bubble pitting previously mentioned, and to oxygen sucked into the system through packing and other sources.

Remove Air From Water

The bottle test shows that air can be removed by heating both the fill-up water and the regular feed water. After every filling, a steam boiler should be heated to bring the water to a good boil and the steam so produced should be vented off to carry the released gases out of the boiler. Before this boil out, water treating chemicals should be added so as to get good mixing. After the boil-out, the vents should be closed and the boiler used or cooled down if not needed.

In hot water systems, production of steam is not desirable, so the water temperature should be raised to 180° to 200° F for a short time to allow most of the air to be driven off through vents.

In larger boiler installations, air is removed from the feed water by heating it to the

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boiling point and venting off the dissolved gases. In small installations, this is hardly practical.

However, in steam systems requiring large quantities of make-up water, it may be possible to fit the return condensate tank with a steam coil to preheat the water to near the boiling point. This tank would have to be vented to release the gases.

Another method suggested by F. N. Speller, a noted authority on corrosion, is to pass the feed water through a de-activator, which is a tank containing steel scrap, such as turnings or wires. The oxygen in the water attacks the steel in the tank so that corrosion properties are neutralized. The process is satisfactory if the tank is big enough to permit complete de-activation and if the scrap steel is renewed often enough. The practice is not frequently followed in steel heating boiler installations because other methods of control are usually more desirable.

In addition to the air carried in by make-up water, substantial quantities may be pulled into the system during operation by the vacuum in the condensate line, or by the vacuum formed when the boiler is shut down or the fire is allowed to die off. In small heating boilers, warm days during spring and fall and even in the winter often result in cooling down a boiler and radiators. Condensing steam creates a vacuum which pulls air into the system through leaking pipe connections, traps, vents, valves and packing. Proper maintenance of the entire heating system is a *must*.

Hot water systems should not suffer from air entering with make-up water because make-up water should not be required. We say *should*, but there are cases when it is required because cleaning people are drawing off hot water, garage men are washing cars with it, circulating pumps leak, floats become water-logged or automatic feed systems stick.

Systems are sometimes designed to be pressurized with compressed air in such a way that a large area of water is exposed, allowing dissolving of air to take place. We have seen systems where well water was pumped into a horizontal cylindrical tank which was pressurized with air across its whole surface. Another system had hot water from three boilers pumped to an overhead horizontal tank of about 5,000 gallons capacity, which was pressurized with compressed air from a pump in another building. No one had any idea of how much air was being pumped into this system. Eighty pounds of sodium sulfite (an oxygen scavenger) added per day to this system could not keep up with the dissolved oxygen being pumped into it.

Any pressurizing of this type should be in an offshoot of the system, not in the main stream. If it must be in the main stream, nitrogen gas should be used for pressurizing.

Obviously, there are many ways air can get into boiler water; it's difficult to keep it out. Fortunately, however, there are methods for rendering it inactive.

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How To Remove Oxygen

One method of removing oxygen from boiler water is through the use of an oxygen-absorbing chemical such as sodium sulfite. If only small quantities of oxygen are present, the addition of this chemical is practical. It is impractical, however, to try to remove large amounts of oxygen by using this chemical in large quantities, because constant additions would cause foaming. Control of alkalinity of the water must be maintained in conjunction with the use of sodium sulfite. The pH should be 9.5 or higher.

Hydrazine is a chemical frequently used in large utility boilers to remove dissolved oxygen. However, it is not recommended for heating boilers because it must be closely controlled. Very seldom is such chemical control available in these installations.

Inhibitors are a class of chemicals which deposit a coating on the surface of the steel or react with it in some way to protect it against attack. These inhibitors, usually composed mainly of sodium chromate, are available from most water treating companies. When added to the water in the recommended quantities, they will protect the boiler surfaces during either operations or standby. Since they are harmful if taken internally, and may stain other products, they should not be used wherever the steam is to be used for process work. These compounds have the advantage of imparting a yellow color in the water, which the boiler user can see in the gage glass, and thus readily determine if more is needed.

Some trouble has been experienced from use of these compounds in hot water systems due to the formation of sodium chromate crystals in pump seals, resulting in leakage. Concentrations lower than the 2.2 pounds per 100 gallons recommended for steam boilers have been suggested for hot water boilers.

The value of this compound, and of another inhibitor containing sodium nitrite and sodium nitrate, was established in a series of tests performed at the Babcock & Wilcox Research & Development Center. These tests proved that both the sodium chromate and the sodium nitrite-nitrate inhibitor were effective not only in preventing attack by dissolved oxygen, but also in stopping further attack after it had started. There are some limitations on the amount of chlorides or sulfates that can be tolerated, but these are seldom a factor in waters used in heating boilers.

A few years ago, there was a flurry of "gadget" type water conditioning cure-alls being offered. One such device, designed to fit into a supply line, was purchased and tested. It proved ineffective in either preventing or stopping corrosion of the tubes.

Don't Drain Chemicals

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Many boiler owners completely drain their boilers once or twice a season under a mistaken belief that the water in the boiler is dirty. Actually, this practice, and the practice of periodically draining small quantities of water from the boiler, should be discouraged. It causes loss of chemicals and requires make-up water, which brings in more oxygen. However, if additional chemicals are added each time to compensate for losses, little harm will be done. Insurance companies require periodic tests of the low water cut-off, and at such time protection should be insured by the addition of such chemicals.

Instead of inhibitors, alkalizers such as caustic soda may be used. It is recommended that 2 oz. of caustic soda per 100 gal. of boiler water be added at the time of a fill up. This will insure a pH of 11 to 11.5, which will greatly reduce the pitting effect of dissolved oxygen. Some prefer a lower concentration, down as low as 1.3 oz. per 100 gal.; but, except for the possibility of foaming, the larger quantities can do little harm, and act as a safety factor should losses take place by draining. However, alkalizers will not stop pitting once it has started.

In new boilers, or in old boilers which have been retubed, a boiling out using cleaning compounds is suggested. This is necessary to remove oils and other coatings put on the tubes by the manufacturer prior to shipment or storage. These materials are put on the tubes to protect them from rusting during storage and transit, and have no place in a boiler. Since they may shield portions of the tube from direct contact with the water, pitting may be accelerated. A good boil-out is recommended, using a cleaning compound such as one of the newer detergents, or a mixture of 2-1/2 lb. of caustic soda and 2-1/2 lb. of soda ash per 100 gal. of boiler water.

Fire Side Corrosion

Approximately 15 percent of the tubes we have examined have failed by fire side attack. Corrosion on the fire side of boiler tubes is caused by moisture condensing from the atmosphere during periods of shutdown, or from flue gas condensation during operation. This type of corrosion is especially troublesome in boiler installations near bodies of water, or where the atmosphere is otherwise humid. Fire side corrosion is accelerated by the use of high sulfur fuels. Sulfur gases may condense on tube surfaces during operation; depending upon the kind of fuel, its sulfur content and the methods of firing.

Accumulations of soot on the tubes should be periodically removed. Soot attracts moisture; and air, moisture and steel together result in attack of the tubes. Cleaning may be daily, weekly or monthly, depending on the fuel used and the method of firing.

Some hot water boilers -- for example, those in greenhouses -- may operate at water temperatures of 140°F to 150°F. Under such conditions, the condensing gases from coal or oil firing form sulfurous acid which attacks the tubes and results in a more uniform type of corrosion. If the percentage of sulfur in the fuel is high, this situation is worse. Even in the

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absence of sulfur compounds, corrosion may occur during shutdown periods because of high humidity in the air. When shutting down the boiler under such conditions, the fire side tube surfaces should be brushed and flushed to remove the winter's accumulation of soot and other products of combustion. This should be followed by blowing air through to dry out these surfaces. A light coat of oil should be applied for further protection. Also, in extremely humid locations, the stack should be disconnected, or at least the damper should be closed, and a tray of unslaked lime placed in the ash pit to keep the fire side dry. This lime must be renewed whenever it becomes mushy, so the drying effectiveness will not be lost.

Many samples of scale removed from fire side surfaces have been found to be acid when mixed with water. The presence of this acid may cause the tube metal to eat away to eventual failure.

Often, boiler rooms are in damp cellars, some with water on the floor constantly. During the summer months, in particular, humid air tends to build up in basements, causing clothes and leather to mildew from the dampness. Similarly, humid air may have ready access to the fire side of boiler tubes in basement installations if the tubes are not properly protected.

Even with gas firing of hot water boilers, serious fire side attack can take place. Some installations employ outdoor-indoor thermometers to control system water temperatures as outdoor temperatures fluctuate. Low water temperatures can result in condensation of moisture from the flue gas and lead to serious corrosion of the tubes. High water temperatures reduce the probability of attack.

Some horizontal tube boilers suffer from a mechanism called "necking" and "grooving." This shows up as a circumferential groove around the outside of the tube where it enters the tube sheet. It usually occurs at the beginning of the first pass, which is the hottest end of the tubes. In all cases, there is some corrosion in evidence in other areas, but it concentrates at the ends because of strains from two sources. When tubes are rolled in, some unavoidable expansion takes place back of the tube sheet. Secondly, when a boiler heats up, the metal in the tubes expands and lengthens. Consequently, strains are set up at the ends, which are fixed in the tube sheets. Sometimes these expansions are so severe that the tubes loosen in the sheets. Scale forming at the tube ends tends to flake off, exposing fresh steel to further attack. This problem can be reduced by more gradual firing, more gradual changes in temperature, and maintaining the boiler water free of oxygen and under proper control.

Following the precautions and controls described in this article should result in many years of trouble-free, economical operation.

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Follow These Rules

Out-of-Service Factors

1. Boil out the boiler with an alkaline cleaner after installing new tubes to remove oil or other coatings from the tube surfaces. These protective coatings are commonly applied to new tubes to prevent rusting during storage and transit, and will cause corrosion if left on the tubes during operation of the boiler.
2. Bring a steam boiler to a good steam output as soon as it is filled to deaerate the water. Heat the water in a hot water boiler to 180°F for the same reason. A temperature of 180°F will not remove all the air, but the majority will be driven off.
3. Add sodium chromate or sodium nitrite - nitrate inhibitors to the water in the quantities recommended.
4. In greenhouses or in damp locations, put a tray of unslaked lime in the ash pit to absorb moisture, and close the boiler. Inspect this lime occasionally and renew when it becomes mushy.

In-Service Factors

1. Keep all boiler and system fittings airtight.
2. Add sodium chromate or sodium nitrite - nitrate inhibitors to the water in the quantities recommended.
3. Preferably, use a fuel with low sulfur content to avoid the corrosive action of sulfur gases.
4. Brush, flush and dry out the insides of fire tubes as often as possible to remove soot and other products of combustion, and to prevent the accumulation of moisture and condensed sulfur gases.
5. Use sodium sulfite regularly in the boiler feed water to remove dissolved oxygen.
6. Use suitable feed water heater or deaerator to reduce the oxygen content of the boiler feed water.
7. Prevent water leakage and avoid draining water from the system. Addition of make-up water results in loss and dilution of the treatment, and introduces air into the system.
8. Don't pressurize a hot water system with compressed air over large areas of water.