Chapter

3

Short-Term Overheating

Locations

Failures caused by short-term overheating are confined to steam- and water-cooled tubes including downcomers, waterwalls, roofs, screens, superheaters, and reheaters. Because of their high operating temperatures, superheaters and reheaters are common failure sites. Failures due to short-term overheating almost never occur in economizers, where temperatures are limited.

When low water level is the cause, failures will often occur near the top of waterwalls near steam drums. A single ruptured tube in the midst of other apparently unaffected tubes suggests pluggage or other flow-related problems.

Poor attemperation usually will not cause short-term overheating, although long-term overheating may occur. Failures of superheaters and reheaters can also occur during start-up, when steam flow is limited.

General Description

Short-term overheating occurs when the tube temperature rises above design limits for a brief period. In all instances, metal temperatures are at least 850°F (454°C) and often exceed 1350°F (730°C). Depending on temperature, failure may occur in a very short time. Failure is usually caused by a boiler operation upset. Conditions leading to short-term overheating are partial or total tube pluggage and insufficient coolant flow due to upset conditions and/or excessive fire-side heat input.

Critical Factors

An occurrence of short-term overheating is caused by an unusual set of circumstances, such as an upset, occurring during a brief period. Therefore, pinpointing unusual events immediately preceding failure may be extremely important in identifying the cause of failure.

Since short-term overheating frequently has little to do with water chemistry, efforts should be concentrated on operating procedures and system design. Did failure occur on start-up or shutdown? Was there a recent acid cleaning? Were headers or U-bends filled with debris upstream of the failure? Did another failure immediately precede this one? Was the firing pattern changed? Was there an unusually large load swing? Was water level normal? Was blowdown unusually severe before or during failure?

Identification

Short-term overheating frequently can be identified by metallographic examination. Such analysis requires sectioning of the tube for microscopic examination. Most other identification techniques are less effective.

Several factors often present in failures caused by short-term overheating are uniform tube expansion, absence of significant internal deposits, absence of large amounts of thermally formed magnetite, and violent rupture.

Short-term overheating may produce bulging. In very rapid overheating, a thick-walled longitudinal rupture (Fig. 3.1), or a longitudinal fish-mouth rupture (Fig. 3.2), can occur.

At elevated temperatures metal strength is markedly reduced (Fig. 2.1). In fact, if temperatures rise to very high levels, failure will occur quickly. If failure happens rapidly, bulging may be absent and the rupture can be violent, sometimes bending the tube almost double and causing secondary metal tearing (Fig. 3.3). In the case of thick-walled ruptures, the tube circumference at the rupture is sometimes nearly exactly equal to the tube circumference away from the rupture. Tube circumference can be roughly measured with a piece of string.

Rupture edges may be blunt and retain most of their original wall thickness or gradually taper to knifelike or chisellike edges. In some cases, the tube diameter may be uniformly expanded with no rupture occurring.

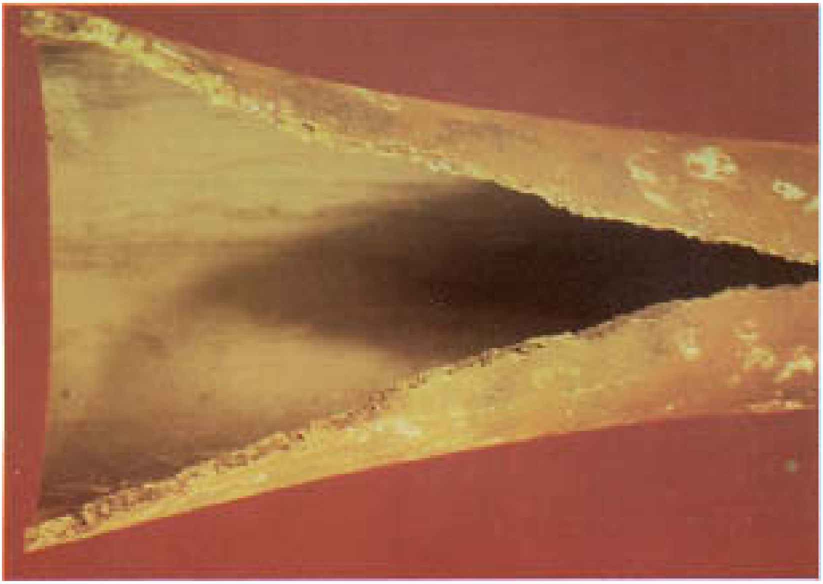

Figure 3.1 Longitudinal rupture in a superheater tube caused by partial pluggage upstream of failure, which in turn caused short-term overheating. Note the thick-walled rupture edges. Virtually identical tube circumferences are present at the rupture and away from the burst. Such failures often occur when temperatures exceed 1350°F (730°C).

Figure 3.2 Short-term overheating in which bulging occurred before rupture. Note the chisel-like rupture edges.

Figure 3.3 Violent rupture caused by short-term overheating. The tube is bent almost to a right angle, caused by the severity of the burst.

Multiple bulges are usually absent, although a single bulge containing a rupture may occur, especially if long-term overheating has occurred previously (Fig. 3.4).

In general, heavy internal deposits will not be present in a short-term rupture since these deposits are not likely to be the cause of the rupture. Further, if deposits do occur, they usually will be friable and easily removed by gentle probing, rather than baked on to the surface as is typical in long-term overheating. Thick accumulations of thermally deteriorated metal will be absent.

Elimination

The solution of short-term overheating, which is often caused by brief upset conditions, is to eliminate the upset. If restricted coolant flow due to tube pluggage is suspected, drums, headers, U-bends, long horizontal runs, and other areas where debris may accumulate should be inspected and cleaned. This is especially true if a failure occurs shortly after a boiler cleaning. The drum water level, firing procedures, and blowdown and start-up procedures should be carefully monitored. Suspicion should be aroused if a short-term failure occurs immediately after another failure. A

Figure 3.4 A rupture at a single bulge. The tube had experienced long-term overheating, followed by a brief episode of severe overheating.

failure may disturb circulation, dislodge deposits, and dislodge corrosion products. This, in turn, may affect heat transfer.

Cautions

A thick-walled longitudinal rupture by itself is not sufficient to warrant a diagnosis of short-term overheating. Be extremely wary if the rupture occurs at a weld or a tube seam or if any evidence of metal wastage occurs near the failure. Thick-walled failures due to short-term overheating can easily be confused with failures from long-term overheating involving creep (stress rupture), failures from hydrogen embrittlement, and failures from certain tube defects. The absence of deposits near a rupture may be due to the scrubbing action of escaping fluids during rupture. Also, short-term overheating may occur after long-term overheating. Such involved mechanisms usually require metallurgical examination to determine failure modes.

Microstructural changes occurring during short-term overheating do not always lead to failure. In addition, tubes that have experienced short-term overheating do not always have to be replaced. Mechanical properties are not necessarily altered significantly by the overheating.

Related Problems

See Chap. 2, "Long-Term Overheating."

CASE HISTORY 3.1

Industry:	Utility
Specimen Location:	Waterwall, nose arch
Specimen Orientation:	Slanted
Years in Service:	5
Water-Treatment Program:	Coordinated phosphate
Drum Pressure:	1800 psi (12.4 MPa)
Tube Specifications:	2½ in. (6.4 cm) outer diameter, internally rifled
Fuel:	Pulverized coal

This section of the internally rifled waterwall nose arch contains a large, thick-wall rupture. Rupture edges are 12 in. (30 cm) long and have a jagged contour (Fig. 3.5). Both internal and external surfaces are smooth and are

Figure 3.5 Large, fish-mouth rupture of rifled nose-arch tube. Rupture edges are thick, blunt, and ragged. Note the absence of significant deposits.

covered with thin, tenacious, dark oxide layers. No significant deposits are present anywhere.

Rupture occurred shortly after start-up. Microstructural evidence indicated that the tube metal near the rupture exceeded 1600°F (870°C). No significant accumulation of thermally formed oxide was found anywhere on the received section.

Internal rifling is sometimes used to reduce steam channeling and inhibit steam blanketing. No steam blanketing or liquid/vapor interface was found on internal surfaces. There was no change in microstructure on the cold side indicating that the tube contained water at the time of the rupture. Rather, the burst was caused by insufficient coolant flow on start-up.

CASE HISTORY 3.2

Industry:	Refinery
Specimen Location:	Powerhouse, target tube near steam drum
Specimen Orientation:	Slightly curving from vertical
Years in Service:	25
Water-Treatment Program:	Phosphate
Drum Pressure:	800 psi (5.5 MPa)
Tube Specifications:	3¼ in. (8.3 cm) outer diameter

The boiler from which the tube was removed has been subject to wide load swings since the installation of new major waste-heat generators. The boiler often remains on "ready standby," where it is kept either on very low fire or off-line. Low-pressure steam is returned to the steam drum for some heat (and no circulation).

A massive thin-lipped longitudinal rupture is present. A thin, straight through-fissure runs longitudinally down the tube from the corner of the rupture mouth (Fig. 3.6). Internal surfaces are smooth, except for shallow mandrel markings. A thin, uniform layer of light-colored deposits is present away from the rupture.

Failure was caused by severe overheating resulting from coolant starvation. A minor defect (mandrel marking) guided the rupture line but was not a significant contributing factor to failure.

Figure 3.6 Longitudinal fissure running from the edge of a large, wide-open rupture.

CASE HISTORY 3.3

Industry:	Utility
Specimen Location:	Superheater from a waste-heat boiler
Specimen Orientation:	Vertical
Years in Service:	10
Water-Treatment Program:	Polymer
Drum Pressure:	600 psi (4.1 MPa)
Tube Specifications:	3 in. (6.6 cm) outer diameter with spirally wound 7/16-in. (1.1-cm) by 3/16-in. (0.5-cm) fins
Fuel:	Waste heat from gas turbines

A rupture 4¼ in. (10.8 cm) long by 1⅝ in. (4.1 cm) wide is present at a bulge (Fig. 3.7). A thick, black layer of thermally formed oxide is present on both internal and external surfaces and is thicker along the hot side. Deposits containing sodium, calcium, silicon, and iron are present in the tube. Deposit loading is 38 g/ft^2 (41 mg/cm^2). Carryover of boiler water into the superheater due to water-level excursions and foaming was common. The boiler had never been cleaned.

Temperatures of waste-heat gases ranged from 1200 to 1800°F (650 to 980°C). The tube failed during several other tube failures. Tubes nearby

Figure 3.7 Large, wide-open rupture in a superheater tube of a waste-heat boiler. The tube experienced long-term overheating followed by a brief episode of short-term overheating when nearby tubes ruptured.

failed as a result of long-term overheating (creep rupture), while others failed as a result of short-term overheating. It was determined that the section had been mildly overheated for a considerable period, but had failed during a brief episode of severe overheating when temperatures exceeded 1350°F (730°C). The short-term overheating probably occurred because of coolant starvation, caused by leakage from other failed tubes upstream.