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Guidelines for operating and maintenance practices impacting an economizer on a recovery boiler

Scope

The economizer installed on a recovery boiler is the component responsible for the greatest number of tube leaks that result in lost production for the pulp and paper industry. This technical information paper is based on a comprehensive study initiated by the AF&PA Recovery Boiler Committee (1). A condensation of the report was presented at a TAPPI Conference in 2006 (2). The study determined primary causes of economizer tube damage are stress or fatigue cracks, poor quality welds, internal and external corrosion and thinning, and mechanical design. The knowledge of failure mechanisms was applied to relate operating and maintenance practices that could contribute to failures and then apply these in a review of economizer failure incidents to seek confirmation of practices detrimental to economizer integrity. These guidelines are a summary of those analyses.

Definitions

A comprehensive description of the economizer and definitions are a part of TIP 0416-21, Guideline specification for procurement of an economizer for a recovery boiler (3).

Safety precautions

This TIP provides guidelines that can be applied to review and establish the operating and maintenance practices in a manner that will minimize economizer failures. Practices that result should be examined for compliance with the BLRBAC “Recommended Practices” and other guidelines related to safety (4).

Synopsis of failures

Stresses contributing to cracking problems are generally of three types: thermal stresses, vibratory stresses, and mechanical loadings. Of these, the most insidious and most germane to economizer problems are thermal stresses. Since the economizer is basically a feedwater heater, there is a major difference in metal temperature between the feed end and the discharge end which, because of thermal expansion, can develop stresses. If the temperature profile of the parallel tubes connected to a given header is sufficiently different, differential thermal expansion can lead to stresses tending to flex the header (or bend the tubes) and this stress will be concentrated in the area where the tubes are welded to the header. The temperature profile along any given economizer tube is determined by the flow rate of water within the tube and the rate of heat transfer from the gas side. Thus any operating variables that contribute to differences in water flow rate and heat transfer rates in economizer tubes connected to the same header or otherwise jointly restrained can contribute to thermal stress generation. There are even cases where the water in an economizer bank recirculates with downflow in some of the tubes. Feedwater distribution to and within headers is primarily determined by design factors as discussed elsewhere. The total feedwater flow rate is determined by the drum level control system and can be subject to cycling and surges. Heat transfer rates are primarily determined by local gas temperature, local gas velocities and turbulence, and the degree of fouling on the tube exterior.

Many cracks are associated with cyclic fatigue caused by tube vibration. The amplitude and frequency of the vibration are critical factors. These in turn are influenced by tube dimensions (particularly length), number and location of restraints, interactions with sootblower jets, gas velocities (especially across tubes) and vortex shedding. Although the buildup of deposits on the tube exterior can act to dampen vibrations, deposits can also contribute to vibration in other areas of the economizer by causing gas channeling.

Other mechanical loads contributing to stresses are usually associated with how the economizer elements are supported and are basically design (and possibly maintenance) issues.

External corrosion leading to tube thinning and pitting is an important failure mechanism in economizers. Such corrosion commonly involves attack by wet saltcake and/or sulfuric acid. The presence of liquid water plays a key role in accelerating corrosive attack and is normally the most important factor. Sources of moisture include sootblowers, condensation on cold metal surfaces, external sources, and small leaks in economizer tubes. Air infiltration through casing leaks can drop local temperatures below the dew point and cause local condensation. Boiler water washing practices can leave residual moisture and contribute to pitting. Another key factor is the concentration of SO_3 in the flue gas, which in turn depends on concentrations of SO_2 and O_2 in the flue gas. The SO_2 concentration depends on furnace operation and black liquor sulfur content. The O_2 concentration depends on the amount of excess air used and on the extent of air infiltration through casing leaks and other openings.

The waterside environment has a significant effect on economizer integrity. A considerable number of cracks originated and propagated from the waterside and there were also a number of incidents of waterside thinning. The most widespread problem encountered was oxygen pitting; the O_2 content of the feedwater is clearly an important factor. Deaerator operation and the use of oxygen scavengers to control residual O_2 are very important. The frequency and extent of excursions in feedwater quality is probably more important than steady state levels. pH excursions can have major impact in a short time.

Considerations for operation and maintenance practices; recovery boiler operation

External corrosion

The three biggest factors influencing external corrosion in the economizer are moisture, SO_2 concentration, and O_2 concentration. Of these, the most important is moisture. Any source of liquid water is detrimental to economizer life. Moisture entering through sootblowers was discussed in the section above. Another, less frequent source is entry from external sources.

Often an important source of water is from a small tube leak. It is a very common experience that a small leak in economizers sprays on and thins an adjacent tube which ruptures. Because of the difficulties in inspection and in repairing small tube leaks and plugging tubes in economizers, it is not uncommon that once an economizer starts experiencing tube leaks that the problem grows and leaks become more frequent because of thinning experienced from the earlier leaks or defective repair welds. If a leak occurs in the economizer, it is critical to inspect the nearby areas for any signs of local wastage and repair it where found.

The sulfuric acid dew point plays a major role in external wastage in economizers. Localized corrosion is likely when metal temperatures are lower than the sulfuric acid dew point, which is a function of the concentrations of SO_2 , O_2 , and H_2O in the flue gases. Increased concentrations of any of these gases, raises the dew point temperature and increases the potential for corrosion. Any metal surface that is below the dew point temperature is subject to wastage. This is most prevalent at the cold end of the economizer where relatively cold feedwater is introduced, and in areas near and on the casing, where external cooling can occur. The temperature of feedwater entering the economizer should be no less than 120°C (250°F) and preferably higher. For an operation with elevated SO_2 concentrations in the flue gas, the feedwater temperature should be increased to minimize the possibility for acid corrosion. Insulation of the external casing and on pipes and lines entering the economizer should be maintained to minimize external cooling.

High concentrations of SO_2 in the flue gas (> 200 ppm) clearly aggravate economizer corrosion and it is expedient to try to minimize SO_2 . This is a function of liquor sulfur content and firing solids content, and furnace operating conditions. Recovery boilers employing "high solids firing" are capable of operating with essentially no SO_2 in the

flue gas and are much less likely to experience external corrosion. Even for those boilers operating with moderate liquor firing solids, it is beneficial to keep SO_2 as low as possible.

The other important variable is the O_2 concentration, which should be kept as low as possible consistent with environmental limits. O_2 is determined by the amount of excess air used within the furnace (which should be the minimum needed to keep TRS and other combustible gases within limits) and by the amount of infiltration air. Infiltration air is detrimental from two standpoints; it increases the O_2 concentration and lowers local gas temperatures toward the sulfuric acid dew point. It is probably impossible to keep all infiltration air out of the economizer, since negative drafts are highest here, but it can be minimized. Keeping upstream gas passages clean and free from plugging will minimize the amount of negative draft and thus the amount of air infiltration. Openings in the external walls should be patched in a timely manner. Doors that are not tightly closed are a major source of infiltration and should be routinely checked

Boiler water wash procedures

Pitting as a result of residual moisture following water washing the recovery boiler can be a fairly common problem in economizers included in the study. The most critical areas were those locations where the wash water was unable to drain properly and which stayed wet longest. The BLRBAC Guidelines for Personnel Safety recommend drying out the boiler after water washing to minimize out of service corrosion (5).

Economizers are also susceptible to out of service corrosion if residual saltcake in the economizer is exposed to humid air. This usually takes the form of localized pitting in areas where accumulated saltcake traps moisture. The most vulnerable area is at the flue gas outlet in economizers whose design does not allow the saltcake to fall readily into the ash hopper. The solution of problems of this type is to get rid of the saltcake accumulations, by manual washing if necessary. Water washing should never be carried out when the boiler is in service.

Startup procedures

Boiler manufacturers provide startup procedures and startup curves for bringing the boiler on line and these should be followed. Attempts to speed up the startup can be detrimental to many boiler components, including the economizer. On a cold startup, the boiler goes from a non-boiling condition to a boiling condition and develops voidage in the water walls (swell) as steam generation begins. Feedwater flow will be negligible until levels are established with some steam generation, and then the flow control valve will begin to open. This can lead to relatively cold feedwater flowing into hotter tubes, particularly if flow surges develop.

There are effective methods for keeping the economizer full of water during startup to prevent thermal shock when the boiler comes on line. If the economizer is provided with a recirculation line, it should be used to provide some flow through the economizer during startup. Another option is to open the mud drum blowdown line in which case some flow through the economizer is needed in order to maintain drum level.

The practice of “burping” the superheater to shorten the time to clear condensate from superheater loops can be detrimental to the economizer. This was suspected of contributing to the multiple failures in Case 173 as described in Appendix 5. The “burping” procedure involves establishing a steam flow and then suddenly opening the superheater vent valve completely. This causes a drop in pressure, an increase in drum level and the feedwater control valve closing to stop water flow to the economizer. When the vent valve is subsequently closed, pressure rises, drum level falls and the feedwater valve opens. This sequence can lead to fluctuations in water flow paths in the cold bank of the economizer and to pronounced temperature fluctuations in the economizer tubes. A bypass valve around the feedwater flow control valve can be used to maintain some flow to the economizer while the superheater is “burped”. It might be noted that a similar set of conditions can develop when drum safety valves open as described below.

Shutdown procedures

Normal shutdowns that involve reducing fuel loads and burning out the bed with auxiliary fuel are generally not harmful to the economizer. However, some shutdown related procedures have the potential for inducing considerable stresses.