RECOVERY BOILER SAFETY AND AUDITS

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The recovery boiler is the heart of the kraft recovery process and a major recovery boiler explosion is probably the most catastrophic event that can occur at a kraft pulp mill. There is a risk of fatalities or serious injuries and the economic consequences of lost production and repair can be severe, even with insurance. In a few cases, a major recovery boiler explosion has resulted in the permanent closure of the mill. Thus it is very important to take effective measures to minimize the likelihood of experiencing a recovery boiler explosion.

EXPLOSION EXPERIENCE

Records of the recovery boiler explosion experience in the United States and Canada have been maintained by the Black Liquor Recovery Boiler Advisory Committee (BLRBAC) since the 1960s. The current BLRBAC criterion for an explosion is an event that causes discernable damage to the boiler. No damage, no explosion.

The industry has made major progress in reducing the frequency of recovery boiler explosions. Recovery boilers are a lot safer than they were 30 or 40 years ago. The number of recovery boiler explosions that occurred in each decade is shown in **Slide 9**. The explosion frequency dropped from nearly 4 explosions per year in the 1960s and 1970s, to about 2 per year in the 1980s, 1 per year in the 1990s, and is currently running about 0.3 per year in the current decade. This is more than a ten-fold reduction in explosion frequency. It may be noted that the recent experience has not been as favorable in some other countries. It should also be noted that there have been several recent “near misses” in which explosions could easily have happened.

Types of Explosions

There are two different types of recovery boiler explosions; smelt-water explosions and combustible gas explosions. Smelt-water explosions are caused by extremely rapid steam generation when molten smelt and liquid water come together. They are non-combustible in nature Combustible gas explosions occur when an air-fuel mixture, <u>that is within the explosive concentration limits</u>, accumulates within the furnace and is then exposed to an ignition source. As seen in **Slide 12**, smelt-water explosions have accounted for nearly 75% of the explosions in the BLRBAC record.

Smelt-Water Explosions

Prevention of smelt water explosions is based on keeping smelt and water apart. Since molten smelt is essentially always present in an operating recovery boiler, prevention requires keeping liquid water out of the furnace. This is best done proactively, but an emergency shutdown procedure that includes rapid-draining the boiler has been developed to minimize water entry is a leak should occur

It is helpful to subdivide water sources for recovery boiler smelt-water explosions into three different categories:

- pressure part failures (tube leaks)
- water entering through the black liquor system
- external sources.

The distribution of explosions among these three sources is shown in **Slide 14**.

<u>Tube Leaks</u>

Tube leaks are responsible for just over half of the smelt-water explosions and just under 40% of the total explosions. The common perception is this is by far the most important factor in recovery boiler safety, but the explosion problem is much broader than just tube leaks.

Leak size matters. The likelihood and potential magnitude of an explosion increases with leak size and location relative to the hearth. The exception to the rule on leak size is a floor tube leak. Large magnitude explosions have occurred from relatively small floor tube leaks.

Based on 45 years experience with smelt-water explosions, it is possible to rank the relative risk of a tube leak:

1. large failure in wall, screen or roof
2. floor tube leak of any size
3. large leak in generating bank
4. small leak in lower furnace
5. other leaks

No explosions have occurred from small leaks in wall tubes above the lower furnace, small leaks in screen tubes, roof tubes and generating bank tubes, and economizer tubes of any size. The risk of a small leak in the upper furnace is thinning an adjacent tube which can then rupture resulting in a sudden, large, high risk leak.

Two steps can be taken to prevent explosions from tube leaks:

1. eliminate tube leaks, focusing on the ones carrying the highest risk
2. minimize water entry to the furnace by initiating an emergency shutdown (ESP).

The first step requires identifying the cause of the tube leaks and taking preventive measures. The second requires the operator to recognize that an emergency situation exists and initiate the ESP.

The ESP involves immediate evacuation of the area around the boiler, immediately stopping all fuel firing and draining the water out of the boiler (rapid drain) to the eight-foot level. This is done by a fully automatic system with manual backup from the control room.

The ESP helps in two ways.

1. it reduces the amount of water that enters the furnace, and
2. it reduces the effects of an explosion should one occur.

The second results from removal of the stored energy in superheated water and steam inside the boiler that could be released into the surroundings if the boiler is opened up by an explosion. This has been a factor on most of the fatalities and serious burn injuries from recovery boiler explosions.

Experience has shown that operators often fail to recognize tube leaks, even large tube leaks, in a timely manner. This has been a factor in two-thirds of the explosions caused by tube leaks over the last 25 years and remains a problem. It can only be addressed by effective operator training.

<u>Black Liquor System</u>

The black liquor system is a common path for water entry into the furnace. This includes firing weak black liquor (nominally below 58% solids), wash water, or inadvertent dilution of the black liquor. BLRBAC has developed recommended procedures for safe firing of black liquor. The heart of the procedure is continuous monitoring of the solids content of black liquor coming to the furnace header and automatic diversion of the liquor if the solids content falls below 58% solids. It also includes start up and trip logic that ensure that proper conditions for black liquor burning are maintained. Liquor gun out of furnace interlocks and logic are used to prevent water from entering the furnace when the liquor system is being washed with water. These procedures have been very effective. The last explosion from water through the liquor system was in 1992 on a boiler that was not equipped with gun-out-of-furnace interlocks.

<u>External Sources</u>.

This is a catch-all category that includes such things as;

- non-operating dilution water
- water-washing the furnace
- smelt spoutd
- water entering through NCG incineration system
- other miscellaneous sources.

These remain a concern. There has been one relatively recent explosion while washing a furnace after an ESP and a couple of near misses. The decision on when to initiate water washing is still very difficult to make.NCG incineration systems provide another path for water entry and experience with these is still limited. Spouts equipped with a proper cooling water system are not a likely cause for explosions.

Combustible Gas Explosions

These explosions require accumulation of an explosive air-fuel mixture within the furnace followed by exposure to an ignition source. There are three possibilities:

- auxiliary fuel
- black liquor pyrolysis gas
- NCG incineration.

<u>Auxiliary Fuel</u>

Gas and oil burners are used during startup and shutdown, during periods of low liquor firing rates or unstable liquor combustion, and sometimes to help make steam. In the early years, auxiliary fuel explosions were the most common cause of recovery boiler explosions. This was addressed by BLRBAC and procedures for safe firing of auxiliary fuel involving the use of monitored burners were available by the mid to late sixties. These were successful in combating these types of explosions as can be seen in **Slide 25**.

Most of the explosions that have occurred were on units that were not equipped with monitored burners. Two were on units where the monitoring system was not installed or maintained properly, defeating the interlock protection. Two others had unrecognized tube leaks present, which interfered with combustion in the furnace.

<u>Pyrolysis Gas</u>

Pyrolysis gas is a combustible gas formed by the thermal decomposition of black liquor solids. They are generated when black liquor is introduced into a hot furnace environment without burning. The most common scenario for pyrolysis gas explosions was during a hot restart after a loss of fire without shutting off black liquor to the furnace.

Pyrolysis gas explosions were first recognized as a cause of recovery boiler explosions in the early 1980s and procedures for preventing their occurrence were built into the Black Liquor Safe Firing. These procedures have been successful. The last U.S. explosion of this type occurred in

1992, when faulty divert logic allowed black liquor to enter the furnace and accumulate on the bed.

NCG Incineration

Up until now, no recovery boiler explosion involving NCG incineration has occurred in the USA or Canada. These remain a concern because this is a source of fuel with considerable variability and potentially some very explosive components (e.g. turpentine) and the industry is still in the early stages of gaining experience with them. BLRBAC has developed guidelines for waste gas incineration in recovery boilers which can be very helpful in avoiding problems.

Dissolving Tank Explosions

Smelt-water explosions can occur in the dissolving tank where smelt and water are necessarily brought together. The key to safe smelt dissolution is effective break up of the smelt stream and agitation in the tank. Dissolving tank explosions have historically gotten less attention. They are much less costly than recovery boiler explosions and reporting has been spotty. BLRBAC started a list of dissolving tank explosions in 1973 and there are now 27 incidents on the list (not counting 2006). The frequency of reported dissolving tank explosions is shown in **Slide 30**.

These data suggest that dissolving tank explosions are increasing at an alarming rate, but this is most likely an artifact. The apparent increase is mostly due to an increase in reporting, as the number of more serious recovery boiler explosions have declined.

The most common cause (80%) of dissolving tank explosions is heavy smelt runoff after a plugged spout is opened up. Loss of agitation or density control was a factor in most of the others. One was due to jelly-roll smelt.

EXTERNAL RESOURCES

There are two very useful resources available to help prevent recovery boiler explosions, These are

- Black Liquor Recovery Boiler Advisory Committee (BLRBAC)
- American Forestry and Paper Association (AF&PA) Recovery Boiler Committee

BLRBAC was formed in the early 1960s and is made up of companies operating recovery boilers, recovery boiler manufacturers, and insurers. BLRBAC maintains effective records of the experience and makes recommendations on safe operation of recovery boilers. Recommended procedures include

- safe firing of auxiliary fuel
- safe firing of black liquor
- emergency shutdown
- personnel safety and training
- waste streams in recovery boilers
- instrumentation and control system guidelines.

BLRBAC meets twice a year (April and October) in Atlanta, GA. The meeting includes reviews of incidents that occurred and actions on procedures and guidelines. BLRBAC maintains a web site, www.blrbac.org that can be accessed by anyone. The recommended procedures can be reviewed and downloaded as well as meeting minutes. The latter include summaries of all of the recent incidents that were reported and discussed.

The AF&PA Recovery Boiler Committee was started in the mid 1970s and is restricted to companies operating recovery boilers. It has evolved a cooperative relationship with BLRBAC and has resources that allow it to carry out various projects.

Among resources available from AF&PA are Reference Manuals covering inspections and NDT, maintenance and repair analysis, and operating effects with case histories; a 9-module training program with extensive reference material and instructor guides; results of studies of industry experience on furnace design and explosion damage, floor tube failures, and economizers (a study on superheaters is in progress); and annual safety seminars aimed primarily at operators.

Further information on AF&PA resources can be obtained by contacting Tom Grant at (914) 776-6697 or e-mail at tom_grant@afandpa.org .

PREVENTION OF EXPLOSIONS

Prevention of recovery boiler explosions is a management function. Recovery boiler explosions are not inherent in the process nor an act of god. The know-how of how to eliminate them already exists, what is needed is a firm commitment to do what it takes not to have an explosion. This commitment by management must extend from the top down. This is especially critical in the present environment when we have to operate, maintain, and manage an aging fleet of recovery boilers.

A recovery boiler integrity management program includes the following elements:

- effective inspection and maintenance program
- shutdown planning and followup
- well trained operators
- audits

A proper integrity management program involves a responsible team that accepts the responsibility of maintaining the asset. The team should include in-house personnel such as the steam and recovery superintendent, maintenance supervision, and engineering staff (if available). External resources are also needed such as corporate staff (if available), inspection company, maintenance coordinator and water consultant.

Audits

Audits are a key element in the management of risk. They are basically a guided peer review. A good audit program has the following elements:

- it is done on a regular basis
- is taken seriously and supported by management
- has formal documentation and followup
- involves some resources from outside the mill.

Shortly after it was formed, the AF&PA Recovery Boiler Committee adopted a resolution that recommended that each operating company establish a corporate audit program directed at recovery boiler safety and reliability. The original resolution called for an annual audit of each recovery boiler, but the audit frequency has increased over the years as the problem has come under control.

AF&PA developed audit guidelines that included the following focus areas:

- personnel safety
- pressure part integrity
- boiler water treatment
- BLRBAC recommendations
- safety interlock systems and fail-safe design
- normal and emergency operating procedures
- training
- maintenance
- operating reliability.

A typical audit committee might include;

- company audit coordinator
- recovery boiler superintendent
- recovery boiler operations supervisor
- maintenance coordinator or director
- others such as technical service, hourly operator or consultant.

The keys to an effective audit are:

- commitment from top management
- consistent standards for recommendations
- written response plan from the mill with a schedule
- company-wide followup procedures

Continued carryover of the same recommendations from year-to-year is a sign of a flawed audit process.

Pitfalls that need to be avoided include;

- lip service from higher management
- lack of belief in the process by operations
- adversarial relationships – retaliation
- lack of standards to audit against
- superficiality
- lack of follow-up plan.

In closing, I'd like to teach you the audit song which can be sung at either the department Christmas party or the department meeting the week before the audit team comes to the mill.

The Audit Song
(Sung to the tune of Santa Claus is Coming to Town)

Oh you better clean up, they'll look low and high
The department must look sharp, I'm telling you why
The audit team is coming to town

Fix the steam leaks, sootblowers better run dry
Mark the escape routes, the paint has to be dry
The audit team is coming to town

They'll find your dirty linen, they'll review each outage too
They'll look at water and pressure parts, and how well you've trained your crew

So, you better shape up, got to get on the beam
One that you nailed last year is on this years team
The audit team is coming to town