RECOMMENDED GOOD PRACTICE

GUIDELINES FOR
POST-ESP PROCEDURES
FOR
BLACK LIQUOR RECOVERY BOILERS

THE BLACK LIQUOR RECOVERY BOILER ADVISORY COMMITTEE

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FOREWARD

The activities that take place following initiation of an Emergency Shutdown Procedure (ESP) on a black liquor recovery boiler can have a significant impact on personnel safety, equipment protection, and down time. The following guidelines are intended to identify the essential elements of a Post-ESP Procedure. It is the responsibility of each operating company to use these guidelines to develop a comprehensive set of site-specific procedures covering post-ESP activities. These guidelines are intended to cover situations when there has not been an explosion. In the event that an explosion occurs prior to, during, or following an ESP, the post-ESP procedures may have to be altered to deal with emergency situations.

This guideline reflects nomenclature and functions of current system installation and industry practice. This document should not be used to interpret BLRBAC system design recommendations. For detailed ESP system recommendations refer to BLRBAC document "Emergency Shutdown Procedure (ESP) and Procedure for Testing ESP System for Black Liquor Recovery Boilers".

CHANGES

There are no changes. This is the initial issue of this document.

CHAPTER 1 VERIFICATION OF ESP FUNCTIONS

Immediately following initiation of an ESP, the control room operator should use a customized checklist to verify that all ESP functions took place. This checklist should contain information regarding the desired status of equipment following the ESP. The checklist should include the following equipment/functions, where applicable:

- Warning lights went on
- Siren sounded
- Black liquor pump(s) shut down
- Black liquor diverted
- Auxiliary fuel tripped
- Feed water stop valve closed
- Rapid drain valves opened
- Drum level dropped indicating unit is draining
- Desuperheater stop valve closed (pumped systems)
- Desuperheater control valve(s) closed (sweetwater condenser systems)
- Chemical feed pumps shut down
- Chemical feed flush water system isolated
- Air heater steam supply shut off
- Fuel supply to direct fired air heaters shut off
- Water supply to water coil air heaters shut off
- Soot blower steam supply shut off
- Steam supply to direct and indirect liquor heaters shut off
- Auxiliary fuel atomizing steam supply shut off
- NCG gases diverted
- Waste stream supply valves closed, pumps shut off
- Primary air damper closed
- I.D. Fan maintaining balanced draft
- F.D. Fans and secondary/tertiary air dampers followed ESP logic
- Superheater vent valve opened after appropriate time interval
- Furnace floor thermocouple recording device activated

The above list is not intended to be all-inclusive and each mill should review their system to insure that the checklist covers all ESP functions. A mill may elect to add additional items to this list that are considered to be good operating procedures but are not necessarily covered under the ESP Guidelines. Examples are functions such as: “saltcake feeder screw shut off”, and “precipitator drag conveyors shut off”.

CHAPTER 2 OPERATING PROCEDURES

There should be site-specific operating procedures covering the following:

2.1 Evacuation

There should be procedures covering evacuation of the area and a method for accounting for personnel.

2.2 Failure of ESP Functions

Site-specific operating procedures should be developed to cover failure of each of the ESP functions included on the checklist. The procedures should incorporate information from the BLRBAC ESP guidelines regarding the desired status of the equipment following an ESP. The procedures should also incorporate the instructions from the ESP Guidelines that prohibit restarting any fan, including the I.D. fan, that trips immediately prior to or during an ESP.

2.3 Control of Access

Procedures should be established to control access to the area until re-entry is permitted.

2.4 Closing Remote Isolation Valves

There should be a checklist of remote isolation valves to be closed following an ESP. Operating procedures should designate responsibility for closing the valves. Valves to be closed should include:

- Natural gas supply valve
- Fuel oil supply valve
- Combustible waste streams

Closing these isolation valves will protect against fuel line rupture hazards in the event of an explosion. In addition to isolating fuel lines, consideration should also be given to isolating the feedwater header and all steam headers (with the exception of the header providing steam to the smelt shatter jets) if it can be done safely from remote locations.

2.5 Notification

There should be a list of management personnel, insurance company representatives, and local authorities to be notified in the event of an ESP. The procedures should state who is responsible for making the notifications. If local fire or medical emergency services are summoned, they should be met at the mill gate by knowledgeable personnel who can direct their activities and keep them away from the area of explosion danger.

2.6 Adjacent Equipment

There should be procedures for operating and/or shutting down adjacent equipment.

2.7 Lower Furnace Water Level

The water level remaining in the lower furnace following an ESP should be measured to help determine the potential for overheat damage to floor and lower sidewall tubes. There should be site-specific procedures for collecting this information. Some boilers are equipped with permanent systems for measuring the water level over the full height of the furnace and it will only be necessary to assure that the information is recorded. On units that are not equipped with a permanent system, it will be necessary to install temporary clear tubing on a lower furnace drain connection after it is safe to re-enter the area following the ESP. There are instructions for doing this posted on the BLRBAC Web site. The water level data should be included as part of the BLRBAC incident report.

2.8 Operating Data Collection

Operating parameters before and after an ESP are often used to evaluate an incident. Each site should include a methodology to capture and document the operating parameters. Depending on the type control and monitoring equipment installed this may be either hard copy (charts) or soft copies of data that pertains to the boiler. It may include items such as:

- Combustion air system flows, temperatures, and pressures
- Flue gas temperatures and drafts
- Floor tube temperatures
- Feedwater, blowdown, and steam flows
- Drum level
- Drum pressure
- Feedwater, boiler water, and blowdown analytical data (conductivity, pH, etc)
- Oil, gas, and black liquor flows and pressures
- Superheater temperatures
- Sequence of event print outs
- First out print outs

CHAPTER 3 OPERATOR INTERVIEWS

All operators on duty at the time of the ESP should be interviewed before leaving the mill to assure all information relating to the ESP is available for making subsequent decisions. The interview should include:

- Events and/or conditions that led to the decision to ESP
- Any problems encountered during or following the ESP

CHAPTER 4 ESP SYSTEM RESET

The ESP system should not be reset until re-entry into the area is permitted. The ESP system reset logic/procedures may result in automatic movement of controls to undesired positions. Proper caution should be taken to position controls where intended. Examples of valves that may need isolation or manual positioning prior to reset include the feedwater to the economizer and the steam to the steam coil air heater(s).

The audible ESP alarm should be silenced after sounding for a minimum of 15 minutes if it is a distraction to operating personnel and impedes communications. Procedures to control access to the area should be in effect prior to silencing the alarm. Silencing the alarm should be completely independent of the ESP system reset. Visual alarms are to remain in effect until the ESP system is reset.

CHAPTER 5 ESP RE-ENTRY WAITING PERIOD

Post-ESP procedures should include rules covering the length of the waiting period for re-entry into the recovery boiler area following an ESP (no explosion). BLRBAC has not set a minimum waiting period and has left this decision to the operating companies. At the fall 1993 BLRBAC Meeting, a paper was presented summarizing BLRBAC recovery boiler explosion history including data on the time interval from water entry into the furnace until explosion. (See Appendix A) This information can be used as the basis for establishing a safe waiting period.

The industry currently utilizes two types of rules – fixed time periods and condition based.

5.1 Fixed Time Period

A number of companies set a fixed time period that personnel must remain outside the building following an ESP.

5.2 Condition Based Rules

With condition-based rules, the information available to operating personnel is used to determine the minimum-waiting period that personnel must remain outside the area following an ESP. The following conditions should be considered when determining the waiting period:

- **Location of leak** (Water could / could not enter the furnace.)
- **Size of leak** (Large / Small)
- **Was the boiler successfully ESP'd?** (Yes / No)
- **Evidence of floor tube damage resulting from the ESP** (Yes / No)

Use of condition-based rules will require establishing a minimum waiting period for each of the possible combinations of conditions listed above. Procedures should designate who is responsible for making the decision regarding the waiting period.

Example 1: After the boiler was ESP'd, it was determined that there was a small leak in the economizer (no possibility of water entering the furnace), the boiler was successfully ESP'd and there was no evidence of floor tube damage from the ESP. These conditions would require minimal waiting time before re-entering the building.

Example 2: After the boiler was ESP'd, it was determined that there was a large leak in the lower furnace, the boiler did not drain**,** and there was no evidence of damage to the floor due to the ESP. These conditions would require maximum waiting time before re-entering the area.

Inadequate Information. If any of the information required to make a decision is not available or the accuracy is questionable, the worst conditions should be assumed and the maximum waiting period should be used.

CHAPTER 6 RE-ENTRY INTO RECOVERY BOILER AREA

Once the waiting period has expired, one or two qualified personnel should enter the recovery building to determine if there are any conditions that require extending the waiting period. If there are not, then required operating and maintenance personnel can be allowed back into the area.

If there is any evidence of accumulation of water on the bed, operating and maintenance personnel should be kept out of the area until all indications of any hot spots in the bed are gone. The surface of the bed fractures as it cools and the potential exists for accumulated water to enter one of these fractures and cause a smelt water explosion.

CHAPTER 7 CONDITION ASSESSMENT

After re-entry into the area, it will be necessary to assess the condition of the boiler to determine what steps are required to make repairs and get the boiler ready to return to operation. This assessment should include the following:

- Assessment of the condition of the char bed and determination of whether supplemental bed cooling will be used
- Determination of whether it will be necessary to water wash
- Determination of whether a hydrostatic test will be required to locate the leak
- Identification of the location of the leak and extent of damage
- Evaluation of floor thermocouple data and any information regarding lower furnace water level to determine if the floor boiled dry and the potential for floor tube damage

The normal sequence of events following condition assessment will be:

- Char bed cool-down
- Probing bed to check for hot spots
- Water washing
- Hydrostatic test for determination of leak location
- Leak repair
- Floor cleaning and inspection
- Final hydrostatic test

CHAPTER 8 CHAR BED COOL-DOWN

Before the furnace can be water-washed or hydrostatically tested, it is necessary to determine that the char bed / smelt pool has cooled sufficiently to ensure that there is no longer the possibility that molten smelt is present. A char bed is highly insulating and pockets of molten smelt can exist in a large bed for several days after an ESP. Before the furnace can be water-washed, the bed should be probed with thermocouples to make certain that no hot spots remain that could contain molten smelt. A hard crust will normally form on the surface of the bed and some hand lancing will usually be necessary to break up the crust to allow checking subsurface material for hot spots. Under no circumstances should water washing begin if there are any visible, glowing hot spots present in the char bed.

The char bed can be allowed to cool on its own or it can be broken up and cooled down using hand lances to inject a cooling medium such as nitrogen propelled sodium bicarbonate, liquid carbon dioxide, or low pressure dry steam. The use of hand lances with cooling medium facilitates break-up of the bed crust - disrupting the bed and exposing hot material to the cooling medium. In addition to significantly reducing the cool down time, breaking up the bed makes it much easier to probe the bed with thermocouples and determine that all hot spots have been eliminated. Under no circumstances should water - including “fog” nozzles - be used for bed cooling.

Each mill should have a written char bed cool-down procedure that includes the following:

Procedures for use of bed cooling mediums such as sodium bicarbonate, liquid carbon dioxide or low-pressure steam (if they are to be used). If low-pressure steam is to be used, the procedures need to include provisions to prevent any condensate from entering the furnace.

- Type of thermocouple equipment and procedures to be used for probing the bed to check for hot spots.
- Maximum bed temperature allowable to start water washing in the furnace. For units with hearth designs that retain a residual pool of smelt, the procedures may also include a minimum time interval before water washing can commence.

The melting temperature for smelt is normally around 1400° F but it can be as low as 1000° F depending on the chemistry. The maximum bed temperature allowable to start water washing should provide enough safety-margin to take into account potential variations in smelt chemistry, the potential for localized hot spots, and the inability to probe 100% of the bed. The maximum bed temperature used by the majority of companies that provided input for these guidelines is 800° F.

CHAPTER 9 WATER WASHING

Following completion of cool down of the bed including any minimum time interval requirements, water washing of the furnace can begin using the mill's normal water wash procedures. These procedures should include the following:

- The differential between wash water temperature and pressure part metal temperatures does not exceed manufacturer's recommendations
- An adequate number of smelt spouts are open to drain wash water
- Procedures to protect personnel from burn hazard due to exposure to hot water
- Procedures to prevent flooding and collapse of flues, ducts, hoppers, etc. due to plugged drain lines or openings

As an additional precaution, consideration should be given to having all but essential personnel leave the area for a pre-established period of time starting prior to the introduction of wash water into the furnace.

CHAPTER 10 FLOOR INSPECTION

The floor thermocouple data and any information regarding lower furnace water level should be evaluated to determine if the floor boiled dry and the potential for floor tube damage. If there is evidence of potential damage, then the floor should be cleaned and inspected prior to starting back up.

CHAPTER 11 CHECK OF DRUM INTERNALS

There have been several reports of loose drum internals found after an ESP. Drum internals should be checked prior to putting the boiler back in service.

CHAPTER 12 HYDROSTATIC TESTS

A final hydrostatic test should be conducted following completion of repairs and inspection of the unit. The ESP procedure subjects the boiler to significant thermal stresses so the boiler should be thoroughly inspected for any resultant damage. In a number of cases, leaking generating bank tube seats were found in two-drum recovery boilers following an ESP, so the generating bank should be carefully inspected for leaks.

APPENDIX A RECOVERY BOILER EXPLOSION HISTORY

Recovery Boiler Explosion History
Thomas M. Grace
Presented at Fall 1993 BLRBAC Meeting

Table 1 shows all of the recovery boiler explosions on the BLRBAC Explosion List that did damage in the US and Canada from 1960 to the present. There is clear evidence that the explosion frequency was about cut in half in the 1980s. If trends continue, a similar reduction in the 1990s is possible. Explosions due to pressure part failures were also cut in half.

Table 2 shows the specific causes of the pressure part failures that led to explosions. Overheat, due to operation with low water or due to waterside pluggage has been a major cause.

Table 3 shows the water sources for smelt-water explosions. It is significant that all of the major and moderate intensity explosions from pressure part failures involved large failures except for the case of floor tubes. Floor tubes leaks can allow a relatively large amount of water to accumulate on the hearth even if the leak is small. In general, an accumulation of a substantial amount of water on the hearth is an essential element of a smelt-water explosion.

Table 4 shows the time delays that have occurred between water entry and the explosion. With one exception, in the case of a successful rapid drain to the eight foot level, the explosion either occurred in about the time frame that the drain occurred or it didn’t happen. The one exception involved a floor tube leak and a disturbance to the furnace some hours after the ESP. Cutting off the entry of water into the furnace by draining the boiler is effective in preventing explosions. In those cases where water entry to the furnace is not stopped, explosions can occur for hours after the first entry of water.

Table 5 shows the odds of having an explosion for a given leak size and location. Explosions occur only 30% of the time even when large quantities of water reach the hearth. The chance of an explosion clearly depends on the likelihood that large amounts of water reach the hearth.

Table 1. Recovery Boiler Explosion History

	1960s	1970s	1980s	1990s
Pressure Part Failure	9	19	10	2
Black Liquor System				
wash water	1	2		1
black liquor	10	5	2	
Spout Leaks		2	2	1
Wash Water	2	4		
Miscellaneous	3			
Pyrolysis Gas			4	1
Auxiliary Fuel	10	6	2	
TOTAL	35	38	20	5

Table 2. Explosions From Pressure Part Failure

1990s

Water Source	Cause of Pressure Part Failure
Floor Tubes (2)	stress corrosion at attachment weld
	overheat – reason unknown

1980s

Water Source	Cause of Pressure Part Failure
Wall Tubes (3)	overheat – blockage – debris
	overheat – low drum – flame impingement
	corrosion – spalled coating
Screen Tubes (3)	overheat – low drum level (2)
	overheat – blockage – debris
Floor Tubes (2)	overheat – circulation problem
	hole – attachment weld split
Roof Tube	erosion from small leak – bad well
Generating Bank Tube	corrosion fatigue at mud drum

1970s

Water Source	Cause of Pressure Part Failure
Wall Tubes (9)	overheat – blockage – sludge/debris (4)
	broke – backside corrosion
	hole – faulty repair weld
	hole – rod through tube
	holes – corrosion
	holes – attachment weld pullout
Screen Tubes (5)	overheat – blockage – sludge (3)
	broke – struck by falling slag
	broke – internal corrosion at header
Floor Tubes (3)	hole – faulty field weld
	hole – faulty shop weld
	hole – attachment weld pullout
Generating Bank Tube	corrosion/erosion from sootblower
Superheater Tube	tube sheared circumferentially
	refilled boiler to burn out bed

Table 3. Water Sources For Smelt-Water Explosions (1970 – 1993)

		Explosion Magnitude		
Water Source	Amount of Water	Major	Moderate	Minor
12 Wall Tubes	8 Large (Ruptures, etc.)	3	5	0
	4 Small Leaks	0	0	4
8 Screen Tubes	8 Large	4	2	2
2 Generating Bank Tubes	2 Large	0	1	1
1 Roof Tube	Large	1	0	0
1 Superheater Tube	Large (Boiler Refilled)	1	0	0
7 Floor Tubes	1 Large (Two Ruptures)	0	1	0
	6 Relatively Small	3	3	0
5 Spouts	4 Low Pressure	0	2	2
	1 Pressurized	1	0	0
6 Black Liquor System	Various Solids Levels	4	1	1
3 Wash Water	Miscellaneous Large Amounts	3	0	0

Table 4. Time Delays in Smelt-Water Explosions

(with successful rapid drain initiated)
(all times in minutes)

Water Source	Leak Size, in.	Time Delay to Initiate Rapid Drain	Time From Water Entry to Explosion	Explosion Delay After Start of Rapid Drain	Damage
Screen	2.5 broke	0.1	0.1	≈0	Minor
Floor	two ruptured	0.5	0.5	≈0	Moderate
Wall	9 × 2.5	0.5	0.5	≈0	Moderate
Wall	2 × 14	2	2	≈0	Major
Wall	7 × 2.5	1	3	2	Moderate
Gen. Bank	rupture	5	5	≈0	None
Screen	2 broke	2	5	3	Moderate
Gen. Bank	broke	2	10	8	Slight
Screen	6 × 3	11	13	2	Major
Wall	5 × 2.5	5	20	15	Moderate
Floor	2.5 split	5	20	15	Moderate
Wall	5.5 × 2.5	6	20	14	Major
Roof	8 × 2.5	5	25	20	Major
Wall	pinhole	10	30	20	Slight
Wall	8 × 3	22	34	12	Moderate
Screen	3/16 × 1	25	35	10	None
Bullnose	6 × 1.25	40	45	5	None
Screen	8 × 2	70	85	15	Moderate
Floor	½ crack	0	195	195	Extensive

(drain to mud drum only)

Water Source	Leak Size, in.	Time Delay to Initiate Rapid Drain	Time From Water Entry to Explosion	Explosion Delay After Start of Rapid Drain	Damage
Floor	1/32 hole	5	8	3	None
Gen. Bank	2.5 broke	9	9	≈0	Moderate
Screen	1.5 × 3/8	3	30	27	Major
Wall	½ crack	1	90	89	Slight

(no successful drain intiated)

Water Source	Leak Size, in.	Explosion Time Delay, min.	Damage	Comments
Wall	5 × 2.2	0.5	None	no drain system
Wall	1/8 × 3/16	3	None	no drain system
Wall	6 × 3	6	Major	no drain system
Screen	7 × 2	10	Moderate	leak not recognized
Screen	2 × 4	15	Major	no drain system
Floor	1 × 1/4	65	Major	leak not recognized
Screen	Four ruptures	70	Major	ESP system failed to operate
Screen	2.5 broke	95	Major	no drain, drum level maintained
Superheater	2.5 broke	120	Major	burned out bed with leak there
Wall	1/8 hole	210	None	no drain, burned bed out
Superheater	2.5 broke	225	Moderate	boiler filled and fired on gas
Wall	1/4 × 1/16	735	Minor	no details available

Table 5. Categories of Incidents

Class I	Large leaks where water is certain to reach the hearth. Fractures and ruptures of floor, wall, screen, and roof tubes.
Class II	Small leaks located where there is a high likelihood water will reach the hearth. Small leaks in floor tubes and lower furnace wall tubes, and spout leaks.
Class III	Large leaks located where water is unlikely to reach the hearth. Generating bank tube ruptures.
Class IV	Small leaks located where there is little likelihood water will reach the hearth. Small leaks in screens, generating bank tubes, wall tubes high in the furnace, and external leaks in non-membrane wall units.

Relative Likelihood of Explosions

Class I		Class II		Class III		Class IV	
explo.	critical expos.	explo.	critical expos.	explo.	critical expos.	explo.	critical expos.
14	32	10	102	2	36	0	113
30%		9%		5%		0%	

APPENDIX B DOCUMENT REVISION HISTORY

This document has no revision history.