RECOMMENDED GOOD PRACTICE
FOR DESIGN, OPERATION, AND TESTING
OF THE EMERGENCY SHUTDOWN SYSTEM
FOR BLACK LIQUOR RECOVERY BOILERS

THE BLACK LIQUOR RECOVERY BOILER ADVISORY COMMITTEE

October 2022 For Review

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Table of Contents

Table of Figures

FOREWORD

If, water is known or suspected of entering the furnace cavity of a recovery boiler which contains a bed of molten smelt, the best action to take is to remove the water from the source of the leak, and remove the pressure behind this source, in that order. The following document outlines the design and use of a system to allow the operators to accomplish this with a minimum of effort and delay. The goal is to bring the boiler to a safe state as quickly as possible.

This Emergency Shutdown Procedure (ESP) requires all fuels, water sources and steam sources to be isolated from the boiler, and the boiler waterside contents to be drained. After a predetermined amount of drain, the boiler should be vented to the atmosphere to remove residual pressure. These guidelines presume that there has not been an explosion in the boiler. If an explosion occurs prior to, during, or following the initiation of an ESP, operating procedures will have to be adjusted to deal with the emergency. In this event, the safety of the personnel in and around the boiler must be the highest priority of the operation.

The ESP system must be tested periodically to assure its availability. This document offers guidelines for the commissioning of the newly constructed system, and testing of components, separately and together during the life of the boiler.

It is the responsibility of each operating company to develop a comprehensive set of site-specific procedures covering the use, maintenance and testing of the system. Operators should have guidelines that help them determine the likelihood of a leak, and specific instructions as to how to respond to that leak.

CHAPTER 1 - PURPOSE

1.1 Intended Function

An immediate emergency shutdown must be performed whenever water in any amount is known or suspected to be entering the furnace and cannot be stopped immediately.

Upon initiation of the Emergency Shutdown Procedure, the system shall perform the following automated actions:

- **Activate Alarms**
  Immediately activate audible and visible alarms to clear the recovery boiler area of all personnel.

- **Stop All Fuels**
  Immediately stop firing all fuels and ensure positive isolation of fuels from boiler. Shut off the auxiliary fuel supply at a remote location, manually or automatically.

- **Stop All Water and Steam Supplies**
  Immediately shut off feedwater and all other water and steam sources to the boiler except smelt shatter steam, dilution water for direct contact evaporators, and smelt spout cooling water. (For spout water leaks, see Section 3.19.)

- **Set Air Flows to Stop Combustion and Smelting**
  Immediately shut off all primary air flow. Immediately set other air flows to minimize combustion and smelting in the bed while maintaining purge air flow. Regulate the induced-draft fan(s) speed or damper(s) to maintain a balanced draft in the furnace.

- **Drain the Boiler to an 8-Foot Level**
  Immediately start draining the boiler in accordance with manufacturer's recommendations to a level eight feet above the low point of the furnace floor. Simultaneously start to drain the economizer.

- **Reduce Boiler Pressure**
  After the boiler has drained to the eight-foot level, reduce steam pressure as rapidly as possible.

CHAPTER 2 - DESIGN

2.1 General Principles

The Emergency Shutdown Procedure functions must be "energized to activate" and executed either by means of relay technology and hard-wiring or other Recovery Boiler Safety System as defined in Chapter 4 of the *Checklist and Classification Guide for Instruments and Control Systems.*

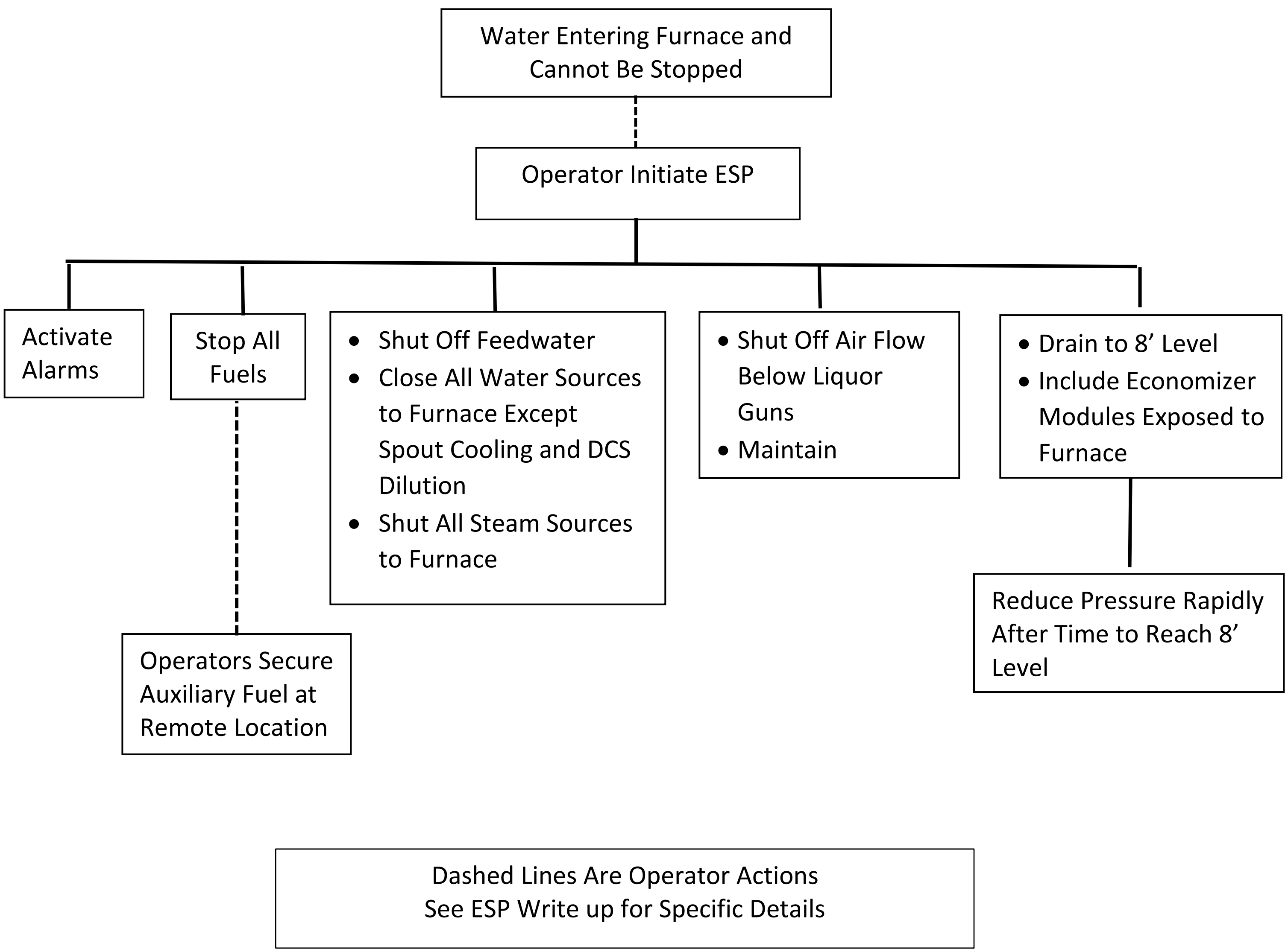
It must not be possible to alter the ESP system unintentionally or to alter the system during operation of the boiler. Any time maintenance is done or modifications are made to the system, the system shall be functionally tested prior to putting the unit back on line. Whatever technology is utilized, the BMS or DCS systems can be used to monitor operation of the functions.

Alternate means - It is critical that proper and complete execution of the Emergency Shutdown Procedure should not depend on the performance of a single system. Alternate means to accomplish each of the intended functions of the Procedure should be provided in accordance with sections 2.5 and 2.9. Trained personnel should remain in the safe recovery boiler control room or other designated safe area to monitor and ensure completion of the ESP.

2.2 Logic

The ESP wording is intended to be implemented according to the following logic diagram: The actions described in the blocks are abbreviated descriptions. See Section 1.1 for complete explanations

Fig. 1. ESP logic diagram.



2.3 Permissives

It is important that all ESP functions be completed in a timely manner upon initiation. No permissives whose failure could prevent the successful implementation of an ESP should be incorporated into the system.

2.4 Initiation

The recommended embodiment for initiation requires only one operator action to initiate the entire ESP (such as pushing two buttons simultaneously), rather than individual steps.

2.5 Monitoring for a Successful ESP

Those monitoring the ESP must utilize proper follow-up procedures. Properly trained operators should be standing by in the safe control room or other designated safe areas, monitoring the ESP against a check list, and using available alternate means (in most cases these are normal operating controls) to operate individual steps of the procedure if they fail to perform automatically.

The general goal is to allow remote-from-unit backup options to make the unit safe. Under no condition should anyone go out to the boiler to perform a back-up option.

2.6 All Fuel

The system should prove that all fuels, including black liquor, auxiliary fuel, NCG, and other waste fuels have stopped entering the furnace. Stop all black liquor firing pumps and any other pumps that tie directly into the liquor firing system such as the indirect black liquor heater recirculation pump(s) and any macerator (gorator) in the black liquor firing system. Stop any black liquor pump supplying flush liquor to boiler bank or economizer hoppers. Divert liquor. Liquor firing systems that recirculate to a pressurized tank require an automated shutoff valve in the recirculation line.

Obtain positive feedback from motor starters and valve proof-of-closure or position indicator switches.

2.7 Remote Auxiliary Fuel Shut-Off

The purpose of shutting off auxiliary fuel at a remote location is to protect against fuel line rupture hazards in the event of an explosion; not just to stop fuel entry into the furnace. It is not necessary for the remote auxiliary fuel valve to be automated into the ESP logic, as long as it can be reached by a safe path and is in a designated safe area.

2.8 Shut Off All Water and Steam Sources

These include, but are not limited to:

- Feedwater Stop Valve (Do not rely upon closure of the feedwater control valve.)
- Desuperheater Water Stop Valve (Do not rely upon closure of the desuperheater control valve, except from sweet water condenser.)
- Chemical Feed Pump and any Flush Lines connected downstream of the feedwater stop valve
- Steam Coil Air Heater (prevents condensate leaks into unit; allows cooler air to unit)
- Soot Blowers (Steam off, automatically retract)
- Steam to Direct Liquor Heaters
- Auxiliary Fuel Atomizing Steam (if not closed automatically with fuel trip)

This does NOT include Spout Shatter Steam, Dilution Water for Direct Contact Evaporators, and Spout Cooling Water.

2.9 Rapid Drain Valves

2.9.1 Valve Local Selector Switch

The actuators on the rapid drain valves and all other valves that operate during an ESP should be wired to move the valves to the ESP position upon initiation of the ESP system regardless of the position of the local selector switch on the valve actuators. Documentation of a managed change, if needed, and/or a functional test of the system to prove that the remote switches will not prevent a valve from opening is recommended.

2.9.2 Alternative Actuation

The following are acceptable means for complying with the requirement for an alternative means of actuating rapid drain valves:

- A switch or group of switches in the control room;
- A boiler control PLC (independent of the ESP system) providing an independent signal to each rapid drain control relay;
- Manual actuation of the individual rapid drain relays; or
- Manual actuation of the individual valve operator motor starters.

When individual switches are provided in the control room, they can serve the dual function of testing rapid drain valves as well as the alternate means of actuation. When manual actuation of the relays or motor starters is chosen, the relays or starters must be in a location that is designated safe and accessible during an ESP and the boiler operators must be trained to locate and actuate them.

2.9.3 Alternate Power

Historically, power supply to rapid drain valve operators has been sufficiently reliable that an alternate power supply is not a recommendation. Care should be taken in selecting and protecting the reliability of the power source to these valve operators.

2.9.4 Torque Limits

The torque limits, and any other device internal to the actuator, designed to protect the motor or valve, should not be included in the motor control open circuit for the rapid drain valves so that the motor will exert maximum effort to open the valves until the open position limit is reached. The torque limits may be used in the valve test mode if desired.

2.9.5 Number of ESP Drain Valves

The ASME code allows the ESP drain valves to be installed with one root valve and one electric-operated valve in any given series path leaving the boiler. The rapid drain piping is not considered “blowoff piping”, per December 6, 1989 ASME finding BC86-316. The reasons that two electric valves became the industry standard were: the critical and severe duty required that the stations have minimum out-of-service valves due to maintenance; valve seat cutting and therefore leakage of such critical valves be minimized); and associated maintenance costs be minimized.

Experience has shown that the valves are not exercised so frequently as to make them vulnerable to valve seat cutting. The entire system will be more reliable if only half the number of electric valves are being depended upon to open. Maintenance replacement by change-out of a single electric valve can be easily accomplished by using the manual root valve for isolation if allowed by the mill Lock Out Tag Out Safety Policy.

If leakage is a concern, a number-one mill-wide priority could be established to ensure rapid response. The boiler manufacturers’ current recommendations are to use only one electric valve. THEREFORE, a design using one manual and one electric valve on a given path is acceptable. New installations and retrofits may consider this. There is no intent to “require” a retrofit to eliminate valves already installed which are satisfactory. Consideration should be given to permanently locking open one of the motor-operated drain valves. If an existing system incorporates a time delay between openings of the two valves, the time delay should be eliminated.

Since there is no longer a “blowoff piping” requirement, individual valves could be made larger than 2½", with corresponding decrease in number of valve locations required to meet the drain time. It is recommended that the valve size NOT be increased beyond 3".

2.10 Atmospheric Vent

Experience in North America has demonstrated gravity drain flash tank systems permit draining of the boiler even if the ESP is initiated after boiler pressure has been significantly or completely lost. Provision of a flash tank rapid drain system is recommended for all new installations. Atmospheric vent (flash-to-the-sky) rapid drain systems may not drain the boiler as quickly as flash tank systems under reduced pressure conditions and may not permit any draining in some cases. Existing atmospheric vent systems should have some means to drain the boiler to the 8 ft. level under low or no pressure conditions (no specific drain time). This alternate drain does not have to be a part of the automated ESP system and may be an operator-initiated action.

2.11 Final Pressure Reduction

In order to implement the last (pressure-reducing) step of the ESP, it is intended that only automated, remote-actuating valves such as Electromatic relief valves, superheater vent valves, etc., be used. It is not intended nor acceptable for personnel to enter unprotected areas to operate valves or other equipment. When valves like this are used for another purpose, such as over-pressure protection, care must be taken to assure that the valve will function as required in the event of an ESP, and not be impeded by another control system.

2.12 Economizer Drains

At least the hot economizer bank should have emergency drain valve(s) to start the economizer draining. This will help prevent flow of water into the steam drum or furnace in the event of a feedwater valve leak-by or failure. It will also handle swelling and burping of water over to the drum as the pressure falls. This is to avoid feeding a furnace leak any longer than necessary and to prevent undue thermal shock to the drum. It is not necessary to drain the economizer as fast or as completely as the furnace, as long as the economizer water level is heading downward during the ESP. This condition is also favorable if a leak occurs in the upper, hot (front) economizer, facing forward toward the furnace, as discussed below.

Some economizer configurations allow certain economizer tube ruptures to direct a water leak forward into the furnace cavity through the generating bank. This has been verified by critical incident reports. Also, some hopper sluice systems and refractometer liquor divert system failures could allow economizer leaks to send water to the furnace via the black liquor piping. ESP's should be performed except when it is known at that time to be impossible for water to get to the furnace. If an economizer leak occurs, where water is known not to be entering the furnace, cease firing liquor and initiate an orderly shutdown immediately. One can NOT rely on the theoretical installation based on drawings of baffles to make this determination. One must KNOW that such baffles are in place and functioning with no damage or disrepair. Case histories exist where leaks have entered the forward furnace through voids in a baffle less than six months old.

2.14 Optional Items to Consider

- Steam to Indirect Liquor Heaters (so as not to bake the residual liquor)
- Isolating soot blower condensate system (as precaution against water backup)
- Automatic shut-off of power to precipitator (as precaution against igniting possible combustible gas mixture)
- For boilers with a motorized main steam stop valve, it is considered Good Practice to close the motorized valve when an ESP is initiated. (Can be through the DCS.)

2.15 Endorsement

The ESP write-up should be endorsed by policy-making mill management, giving the operators the authority to perform an ESP as per BLRBAC guidelines. A signed and dated copy should be permanently posted at each recovery unit control station.

2.16 Feedwater Coil Air Heater Leaks

Some configurations may allow water from a ruptured air heater tube to enter the furnace through combustion air ductwork. The potential for leakage to enter the furnace may be mitigated by the location of the feed water air heater coil and design of the ductwork. The configuration may include a system of air duct low points and drains, water detection alarms, and if necessary, air heater waterside isolation as part of an ESP.

2.17 Fans and Dampers

The shutdown strategy for the FD fans and dampers will depend upon the number of fans and the number of elevations of combustion air. The preferred (but not the required) embodiment of this requirement is to shut off all air below the liquor guns as per logic diagram, except in the case of low load operation described below. Air blowing on the bed will prolong combustion and smelting, extending cool-down time and increasing the potential to damage the floor and wall tubes. Purge air should be provided through the combustion air ports located at elevations above the liquor guns. The appropriate FD fan(s) should remain running to provide purging and cooling air through the upper furnace zones following an ESP.

Units with alternate operating scenarios, such as extended low load operation with no tertiary air, may devise alternate air shutdown strategies provided the BLRBAC ESP intent of minimizing extended heat production and subsequent smelting is addressed. Units burning NCGs must meet these requirements when NCGs are tripped.

If any fans, including the ID fan(s), trip immediately prior to initiating an ESP or during an ESP, leave them tripped. Restarting the fans can cause excessive heat release, or cause a combustibles explosion. The system should be checked to make sure that other control logic could not override ESP logic except in the event of an actuation of the DCE Fire Protection System.

2.18 Drain Time to 8-Foot Level

The drain system should be designed to drain to the 8-foot level in approximately 20 minutes starting at normal operating pressure. The actual time should be recorded during the "Initial System Checks" described in "Recommended Procedure for Testing Emergency Shutdown System". A nominal acceptable range is from 15 to 25 minutes. If over 30 minutes, additional drain capacity should be installed. Twenty-five years of experience confirm that the 8-foot level provides sufficient water to protect the lower furnace tubes while the smelt bed cools. Granted, if a leak existed in that region, water would still be behind it, but the pressure would be greatly reduced and decreasing rapidly because of the pressure-relieving step.

2.19 Spout Leaks

Known smelt spout water leaks do not require an ESP. Shut off the cooling water to the leaking spout and plug the spout. If the spout is required for operation, conduct an orderly shutdown to replace the spout.

2.20 Thermocouples

Recovery boilers should be equipped with floor thermocouples. The thermocouple readings should be monitored and recorded during an ESP as a means for evaluating the potential of floor tube overheating damage.

2.21 Definitions

Designated safe area: means that the mill has responsibly determined that the area is blast-safe, and therefore has defined it as such for purposes of ESP.

CHAPTER 3 - POST ESP PROCEDURES

3.1 Verification

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. Where feasible, a dedicated page of the Distributed Control System should be available to the operator, listing the ESP functions, and displaying their status. This checklist or screen 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
- Drum pressure is dropping indicating that the steam header valve and/or non-return valve is closed
- 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
- Dissolving tank vent gases to be diverted for units that burn vent gases in the furnace
- DNCG including chip bin vent 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
- Verification that Primary Air Flow has stopped
- Superheater vent valve opened after appropriate time interval
- Furnace floor thermocouple recording device activated
- Precipitator remains energized (or not) based on mill policy

- Water supply to cascade dilution and cascade /cyclone recirc liquor pumps remain on
- Dissolving tank maintained in level and density control
- Spout cooling water maintained on.
- Steam to shatter jets maintained on

The above list is not intended to be all-inclusive and each mill should review their system to ensure 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".

3.2 Operating Procedures

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

3.2.1 Evacuation

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

3.2.2 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 Chapters 1 and 2 regarding the desired status of the equipment following an ESP. The procedures should also incorporate the instructions from Section 2.17 that prohibit restarting any fan, including the I.D. fan, that trips immediately prior to or during an ESP.

3.2.3 Control of Access

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

3.2.4 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.

3.2.5 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.

3.2.6 Adjacent Equipment

There should be procedures for operating and/or shutting down adjacent equipment that may be within the area of danger.

3.2.7 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
- Dissolving Tank density and Green liquor flow (indication of excessive smelt run)
- Leak detection system displays
- Sequence of event print outs
- First out print outs

3.2.8 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

3.2.9 Alarm Silencing

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.

3.2.10 System Reset

The ESP system should not be reset until re-entry into the area following an incident 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).

3.2.11 Re-Entry

Once the waiting period has expired (Chapter 4), 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.

3.3 Initial Assessment Following Re-Entry

After re-entry into the area, it will be necessary to assess the condition of the boiler to determine if repairs are necessary 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 (if not obvious) and for previous unknown defects aggravated to failure.
- Leak repair
- Floor cleaning and inspection if determined to be necessary
- Final hydrostatic test

3.3.1 Assuring the Bed is Cool

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.

3.3.2 Water Wash-down

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.

3.4 Condition Assessment

3.4.1Floor Inspection

The floor thermocouple data and any information regarding lower furnace water level should be evaluated to determine if there is 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

Some conditions that may indicate a floor inspection is necessary include:

- Continued combustion air flow to the lower furnace following the ESP
- If leak was located below the ESP rapid drain valve level
- Heavy smelt runs following the ESP
- High smelt bed, especially one that falls against the side wall
- Continued introduction of black liquor or aux fuel following the ESP

3.4.2 Hydrostatic Testing

The ESP procedure subjects the boiler to thermal stresses, so it is recommended that after any ESP that the boiler be hydrostatically tested prior to restart. This is to identify any previous unknown defects that may have been aggravated to failure during the ESP. A final hydrostatic test should be conducted following completion of repairs and inspection of the unit.

CHAPTER 4 - RE-ENTRY TO THE BOILER AREA FOLLOWING AN INCIDENT

4.1 Time 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.

4.1.1 Fixed Time Period

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

4.1.2 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 See Section 3.4.1** (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 ESP was initiated, it was determined that there was a small leak in the economizer (no possibility of water entering the furnace), the boiler was successfully shutdown and drained, 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 ESP was initiated, 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 5 RECOMMENDED PROCEDURE FOR TESTING EMERGENCY SHUTDOWN SYSTEM

5.1 Initial System Checks

The entire ESP system, including the rapid drain portion, should be put through an initial operational check to assure that the ESP logic system will function properly and safely. This initial operational check will determine drain time, confirm that rapid drain valves open, drain lines are clear, emergency feedwater stop valve closes, blowdown system is adequate, determine blowdown tank pressure, etc. This check should be made prior to firing black liquor in the Kraft recovery unit. If liquor has been fired in the unit prior to ESP tests, make sure the bed has been burned down completely and the furnace hearth is free of molten smelt. Considerable experience has shown that the initial system check will not damage the recovery boiler.

The following test procedure is recommended:

1. Check out the complete ESP logic system electrically to assure each component is wired to operate as intended.

2. Bring the boiler to operating pressure, firing auxiliary fuel.

3. Stop all auxiliary firing. Check drain lines, one at a time, by manually opening the motor-operated drain valves fully. If two motor-operated valves are used, open the one closest to the boiler first and close it last. Maintain drum level during these tests and only keep the valve(s) open long enough to be sure that the line is clear and adequately supported.

4. Be sure all motor-operated valves are returned to the closed position and selector switches are returned to “remote” or “remote/manual” position. It should be noted that the rapid drain valves should be configured to open on an ESP regardless of the position of the selector switches.

5. Bring the unit back to operating pressure firing auxiliary fuel. Push the emergency shutdown button(s) to initiate a complete ESP. The ESP will activate alarms to clear the recovery area of unnecessary personnel. Abide by this - only those people necessary to monitor the test from a safe distance should be in the area! From this initial test, establish the actual drain time curve to the eight-foot level by plotting drum pressure vs. time. In particular, make note of the time taken to get to the eight-foot level. This time may be marked by a “knee” in the curve or a distinctive sound change. Use this value to establish the required time delay in the ESP logic before the remaining pressure is automatically relieved.

6. Following completion of the ESP test, open the superheater vent valves to take pressure off the unit and facilitate cooling. Do not refill the boiler until the temperature differential between feedwater and drum shell is less than 100°F. A hydrostatic test to at least the operating pressure of the unit should be performed prior to restarting the unit.

7. The proper functioning of the bypass of the "Remote / Manual" selector switches on the Rapid Drain Valves should be tested by resetting the ESP system and putting the selector switches in the Manual position and then reactivating the ESP to confirm that the Rapid Drain Valves open.

5.2 Routine Operational Checks

It is recommended that the motor-operated drain valves be checked at least once per month to assure that they are still in working order. This can be done by going to each station, closing the hand-operated valve and individually energizing the motor-operated drain valves to be sure they will open and close, and the indicator lamps read correctly. Following the check, and after closing the motor-operated valves, be certain the hand-operated valves are locked open. Only one drain line at a time should be isolated for the monthly motor-operated valve tests; this will allow the remaining drain lines to function as designed if an ESP is required during the testing period.

It is recommended that the entire ESP sequence, except for draining the boiler, be checked as opportunity arises, but at least once per year. This may be done from a reduced pressure. With the hand-operated valves closed, use the ESP buttons to shut the unit down. This will assure that the rapid drain valves operate properly and are not stuck, all fuel to the furnace shuts off, the correct dampers close, the preset fan conditions are achieved, the emergency feedwater stop valve closes, floor and steam drum thermocouple recorder prints correctly, etc. Also, at least annually verify that the "alternate means" to actuate individual ESP elements will transmit a signal to the intended ESP element. Physical actuation of the ESP element by the alternate means is not necessary during the test, only verification that a signal is transmitted to the device. Similarly, for those locations with any "remote" means to initiate the ESP or actuate individual ESP elements, verify the remote means will transmit a signal to the intended ESP element(s).

5.3 Additional Considerations

When conducting ESP system checks in the Recommended Procedure for Testing, the ESP is done while firing auxiliary fuel. Added attention must be given to assure that black liquor functions perform as expected.

When manually opening the motor-operated valves for line blowdown in Step 3 of the initial testing, initially open the valves quickly to avoid wire-draw or damage to the seat.

CHAPTER 6 REFERENCES

For further information, refer to BLRBAC "Recommended Good Practice" publications:

Safe Firing of Black Liquor in Black Liquor Recovery Boilers;

Safe Firing of Auxiliary Fuel in Black Liquor Recovery Boilers;

Installation Check List and Classification Guide for Instruments and Control Systems Used in Operation of Black Liquor Recovery Boilers.

Personnel Safety & Training

Application of Rotork Actuators on Black Liquor Recovery Boilers

CHANGES TO THE GUIDELINES, BY REVISION DATE

October 2022
2.9.4 Added clarification that only the motorized valve protective devices internal to the actuator should be bypassed when initiating an ESP.

3.3 After re-entry into the area, it will be necessary to assess the condition of the boiler to determine if repairs are necessary and get the boiler ready to return to operation.

- Hydrostatic test for determination of leak location (if not obvious) and for previous unknown defects aggravated to failure.

3.4.2
The ESP procedure subjects the boiler to thermal stresses, so it is recommended that after any ESP that the boiler be hydrostatically tested prior to restart. This is to identify any previous unknown defects that may have been aggravated to failure during the ESP. A final hydrostatic test should be conducted following completion of repairs and inspection of the unit.

CHANGES (Pre 2022)

October 2018
Recommended Emergency Shutdown Procedure (ESP) & Procedure for Testing ESP System for Black Liquor Recovery Boilers was combined into a single document with Guidelines for Post-ESP Procedures for Black Liquor Recovery Boilers, titled Recommended Good Practice for Design, Operation, and Testing of the Emergency Shutdown System for Black Liquor Recovery Boilers
Chapter 2 – Clarified that all motorized valves in ESP system should be wired to bypass any local selector switches and any change be functionally tested.
Chapter 2 – The torque limits, and any other device designed to protect the motor or valve, should not be included in the motor control open circuit for the rapid drain valves.
Chapter 2 – Valves used for final pressure reduction that may be used for other functions must function in the event of an ESP.
Chapter 3 – A DCS page showing ESP functions and their status is suggested.
Chapter 3 – A leak located below the ESP rapid drain valve level (8') is added to conditions for consideration of floor inspection after and ESP.

January 2015

Recommended Emergency Shutdown Procedure (ESP) & Procedure for Testing ESP System for Black Liquor Recovery Boilers was **combined** into a single document with Guidelines for Post-ESP Procedures for Black Liquor Recovery Boilers, titled Recommended Good Practice for Design, Operation, and Testing of the Emergency Shutdown System for Black Liquor Recovery Boilers

October 2012

Chapter 1:
Clarified requirements of the Emergency Shutdown Procedure (ESP) System.
Deleted requirement for "dedicated, stand alone".
Added DCE dilution water as a specific exception to "stopping all water and steam supplies".

Chapter 3:
Section 3.8, *Shut Off All Water and Steam Sources*: Added DCE Dilution water as a specific exception to "stopping all water and steam sources".
Section 3.11, *Fans and Dampers*:
Deleted phrase "or allowing them to seek full flow" from Sentence starting with "Restarting the fans, or allowing…"
Added allowance for DCE Fire Protection System to override ESP logic.
Deleted definition for "Dedicated Stand Alone".

October 2009

Guidance added to Section 2.2, Routine Operational Checks, to recommend only one drain line be tested at a time.

Summary of the April 2009 Changes

Guidance added to Section 2.2, Routine Operational Checks, to recommend at least annual testing of the alternative and/or remote means of actuating ESP elements.

October 2006

Chapter 1,
Clarified smelt spout cooling water is not to be isolated as a normal part of an ESP.

Chapter 3,
Revised section 3.6 to conform to the Safe Firing of Black Liquor Recommended Practice. Also in section 3.9 deleted shutting down the black liquor pumps and macerators as an optional item to consider.
Revised section 3.8 to clarify smelt spout cooling water is not to be isolated as a normal part of an ESP.
Revised section 3.9 to add closing the main steam stop valve as an optional good practice to consider where practical when these valves are present.

October 2004

Chapter 1 reworded the Stop All Fuels section

Chapter 3,
Reworded the 3.6 All Fuel section
Changed title from 3.13 Rapid Drain Valves to 3.13 Valves
Changed title from 3.13.1 Local Selector Switch to 3.13.1 Valve Local Selector Switch
Reworded the 3.13.1 Valve Local Selector Switch section
Changed title from 3.21 ESP System Reset to 3.21 System Reset
Reworded the 1st sentence of section 3.21 System Reset
Reworded the 3.23 Thermocouples section

October 2003

Added a new section 3.13.4 Torque Limits

October 2002

This document has been revised to provide a consistent format.

Chapter 3,
Changed the heading for section 3.9 from "Additional Items to Consider" to "Optional Items to Consider."
Added paragraph on "Feed Water Coil Air Heater Leaks" as Section 3.10 and renumbered section numbers that follow.
Reformatted section 3.13, Rapid Drain Valves, to create section 3.13.1, Local Selector Switch, and added a new section 3.13.2, Alternative Actuation, and 3.13.3, Alternative Power.
Provided new guidance in section 3.15, Atmospheric Vent.

October 2000

Chapter 1 reworded the Emergency Shutdown Procedure entire 4th bullet on Air Flows.
Chapter 3, Section 3.10 "Fans and Dampers" reworded the entire paragraph.

October 1993

Combined "Emergency Shutdown Procedure (ESP) for Black Liquor Boilers" with "Recommended Procedure for Testing Emergency Shutdown System" into one document and added Chapter 3 "Background and Installation Notes Regarding the Emergency Shutdown Procedure (ESP)"

Chapter 1 "Emergency Shutdown Procedure (ESP) for Black Liquor Recovery Boilers" reworded to include the following:

Elimination of reference to "external" leaks
Addition of visible alarms

Addition of black liquor divert
Clarification of spout cooling water leaks action
Restriction of total air entering furnace and portion below liquor guns
Addition of economizer drain valves
Requirement for alternate means to be provided
Requirement that personnel monitor and complete the ESP

Chapter 2 "Recommended Procedure for Testing Emergency Shutdown System" reworded to include the following:

Clarification of conditions for Initial System Checks
Clarified steps in the initial test procedure
Identified method to determine time to reach 8-foot level
Changed routine test interval to yearly minimum

Chapter 3 "Background and Installation Notes Regarding the Emergency Shutdown Procedure (ESP)" added this new chapter to include the following:

Diagram of intended logic
Clarification of alternative logics requirements
Acknowledgment of some water and steam sources
Suggested drain times
Elimination of requirement for two electric drain valves in series
Discussion of atmospheric vent systems
Specific economizer drain and leak background
Handling of reset

APPENDIX A RECOVERY BOILER EXPLOSION HISTORY

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

Table of Tables

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 and a slightly greater reduction in the 1990s. Explosions due to pressure part failures have made a significant reduction but have reached a plateau since 2000.

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	2000s	2010s
Pressure Part Failure	9	19	10	2	1	2
Black Liquor System						
wash water	1	2		1		
black liquor	10	5	2	1		
Spout Leaks		2	2	2		
Wash Water	2	4				
Miscellaneous	3				1	
Pyrolysis Gas			4	2		
Auxiliary Fuel	10	6	2	1	1	
TOTAL	35	38	20	8	3	2

Table 2. Explosions from Pressure Part Failure

2010's

Water Source	Cause of Pressure Part Failure
Screen Tube (1)	saltcake lump sheared tube
Gen Bank Tube (1)	fatigue

2000's

Water Source	Cause of Pressure Part Failure
Gen Bank Tube (1)	vibration from sootblower

1990s

Water Source	Cause of Pressure Part Failure
Floor Tubes (2)	stress corrosion at attachment weld
	failed from aux fuel explosion
	overheat – reason unknown
Gen Bank Screen (1)	vibration fatigue

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 – 2016)

		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
9 Screen Tubes	9 Large	4	3	2
4 Generating Bank Tubes	4 Large	2	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)			
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 initiated)

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%	