

**RECOMMENDED GOOD PRACTICE  
SAFE FIRING OF BLACK LIQUOR  
IN  
BLACK LIQUOR RECOVERY BOILERS**

THE BLACK LIQUOR RECOVERY BOILER ADVISORY COMMITTEE

April 2016

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Table of Contents

<b>FOREWORD .....</b>	<b>6</b>
<b>CHANGES .....</b>	<b>8</b>
<b>CHAPTER 1 GENERAL.....</b>	<b>9</b>
<b>CHAPTER 2 DEFINITIONS .....</b>	<b>11</b>
<b>CHAPTER 3 BLACK LIQUOR SAFE FIRING SYSTEM REQUIREMENTS .....</b>	<b>14</b>
3.1 DESIGN.....	14
3.2 INSTALLATION .....	15
3.3 TRAINING.....	15
3.4 PREVENTIVE MAINTENANCE PROGRAM .....	15
3.5 SUDDEN, LARGE TUBE LEAK INDICATION .....	16
<b>CHAPTER 4 REFRACTOMETER BLACK LIQUOR SOLIDS MEASUREMENT SYSTEM.....</b>	<b>18</b>
4.1 GENERAL .....	18
4.2 REFRACTOMETER CONTROL SYSTEM FUNCTIONS .....	18
4.3 REFRACTOMETER CONTROL SYSTEM - CONTROLS & INDICATORS .....	20
4.4 REFRACTOMETER CONTROL SYSTEM - ALARMS AND INDICATORS.....	21
4.5 INSTALLATION REQUIREMENTS .....	21
4.6 REFRACTOMETER PROBLEMS .....	22
4.7 COOLING WATER LOSS .....	22
4.8 PRISM WASH.....	23
4.9 CONDENSATION IN SENSING HEAD.....	23
4.10 REFRACTOMETER CALIBRATION.....	23
<b>CHAPTER 5 BLACK LIQUOR FIRING INTERLOCK SYSTEM.....</b>	<b>25</b>
<b>CHAPTER 6 OFF-LINE BLACK LIQUOR SOLIDS MEASUREMENT (LABORATORY AND FIELD TECHNIQUES) .....</b>	<b>50</b>
6.1 PURPOSE .....	50
6.2 SAMPLING .....	50
6.3 OFF-LINE FIELD MEASUREMENT TECHNIQUES.....	51
6.3.1 <i>Testing Black Liquor Solids.....</i>	52
6.4 GENERAL COMMENTS .....	53
<b>CHAPTER 7 BLACK LIQUOR FIRING .....</b>	<b>54</b>
<b>CHAPTER 8 BLACK LIQUOR AND WATER PIPING SYSTEMS .....</b>	<b>56</b>
<b>CHAPTER 9 SMELT SPOUTS .....</b>	<b>59</b>
9.1 WATER COOLED SPOUTS .....	59
9.1.1 <i>Cooling Water.....</i>	59
9.1.2 <i>System Design Criteria.....</i>	60
9.1.3 <i>Pressurized Systems .....</i>	61
9.1.4 <i>Vacuum Systems.....</i>	62
9.1.5 <i>Operation .....</i>	63
9.1.6 <i>Maintenance and Inspection .....</i>	63
9.2 NON WATER COOLED SPOUTS.....	64

<b>CHAPTER 10 DISSOLVING TANKS .....</b>	<b>69</b>
10.1 PLUGGED SPOUTS.....	69
10.2 DESIGN .....	70
10.3 OPERATION.....	72
10.4 EMERGENCY OPERATION .....	73
10.5 SYSTEM ALARMS .....	75
<b>CHAPTER 11 DIRECT INJECTION OF WATER SOLUTIONS OF CHEMICALS INTO THE RECOVERY FURNACE.....</b>	<b>76</b>
<b>CHAPTER 12 ADDITION OF WATER SOLUTION OF CHEMICALS TO THE BLACK LIQUOR STREAM.....</b>	<b>77</b>
<b>CHAPTER 13 MISCELLANEOUS EXTERNAL WATER HAZARDS .....</b>	<b>78</b>
<b>CHAPTER 14 AUDIBLE ALARM AND INDICATING SYSTEM.....</b>	<b>80</b>
<b>CHAPTER 15 DISCUSSION AND BACKGROUND INFORMATION .....</b>	<b>83</b>
15.1 BLACK LIQUOR HEADER(S) WASH SYSTEM.....	83
<i>15.1.1 Lower Furnace Wash System .....</i>	83
15.2 PURGE CREDIT.....	83
15.3 BLACK LIQUOR GUN POSITION SYSTEM.....	84
15.4 NUMBER OF REFRACTOMETERS .....	84
15.5 BLACK LIQUOR PRESSURE AND TEMPERATURE.....	85
15.6 STABLE FIRING ESTABLISHED .....	85
15.7 SUPERHEATERS CLEARED .....	85
<b>APPENDIX A GENERIC CHECKLIST FOR PRE-FIRING OF BLACK LIQUOR .....</b>	<b>86</b>
<b>APPENDIX B DOCUMENT REVISION HISTORY .....</b>	<b>88</b>

### Table of Figures

Fig. 1. Common Permissive Starting Logic.....	30
Fig. 2. Permissive Starting Logic for Black Liquor Firing .....	33
Fig. 3. Black Liquor Header Wash and Lower Furnace Wash Permissives.....	36
Fig. 4. Common Protective Tripping Logic .....	38
Fig. 5. Protective Tripping Logic for Black Liquor Firing.....	40
Fig. 6. Generic Black Liquor Firing System for Atmospheric Storage .....	43
Fig. 7. Generic Black Liquor Firing System for Pressurized Storage .....	44
Fig. 8. Generic Black Liquor Firing System for Direct Contact Evaporators .....	45
Fig. 9. Recommended Piping Arrangement at Black Liquor Guns .....	46
Fig. 10. Parallel Indirect Liquor Heaters with Recirculation.....	47
Fig. 11. Single Indirect Liquor Heater with Forced Recirculation .....	48
Fig. 12. Single Indirect Liquor Heater without Forced Recirculation .....	49
Fig. 13. Typical Pressurized Smelt Spout Cooling Water System .....	66
Fig. 14. Typical Vacuum (Created by Tank and/or Piping Configuration) Smelt Spout Cooling Water System.....	67
Fig. 15. Typical Vacuum System (Created by Eductors) Smelt Spout Cooling Water System.....	68

### Table of Tables

Table 1. Logic Explanation Chart for Figure 1, Common Permissive Starting Logic .....	31
Table 2. Logic Explanation Chart for Figure 2, Permissive Starting Logic for Black Liquor Firing.....	34

Table 3. Logic Explanation Chart for Figure 3, Black Liquor Header Wash and Lower Furnace Wash Permissives.....	37
Table 4. Logic Explanation Chart for Figure 4, Common Protective Tripping Logic .....	39
Table 5. Logic Explanation Chart for Figure 5, Protective Tripping Logic for Black Liquor Firing .....	41
Table 6. Tabulation of Dilution Sources, Detection Systems, Corrective Actions and Recommendations...55	

## **FOREWORD**

The black liquor recovery boiler presents problems of operation and safety that far exceed those of the conventional power boiler. It is primarily a chemical recovery process unit in which the organic materials in the black liquor are burned while the sodium salt is reduced and drained as molten smelt from the furnace bottom. At the same time the heat released is used for steam generation.

While most of the heat for this process is provided from burning the black liquor, additional heat from gas or oil-fired auxiliary fuel burners is needed to start up the unit, regulate the char bed, avoid blackouts, and to furnish additional steam.

The complexity of the process and the severe environment combine to present a formidable challenge to operators of recovery units. In most cases the recovery boiler operator must depend to a large degree on the thoroughness of their training, their own personal senses and reactions and instrumentation to aid in safe operation. Many times the operators are forced to evaluate a situation rapidly, and it is hoped, correctly, without having all the facts. The burden on the recovery operator is truly great and the industry has realized that they must have help, guidance, and proper tools to promote safety and unit availability.

The continuing occurrence of explosions emphasizes the constant need for action by industry, equipment manufacturers and insurance interests alike. The causes of explosions have been:

1. Reaction between water and molten smelt.
2. Reaction between low solids liquor and molten smelt.
3. Uncontrolled ignition of an accumulation of unburned fuel from the auxiliary burners.
4. Uncontrolled ignition of an accumulation of unburned gases from pyrolyzed black liquor.
5. Dissolving tank explosions due to excessive and uncontrolled smelt runoff or excessive high density in the dissolving tank.

All details of the smelt-water reaction are not thoroughly understood and fundamental information is still lacking. Experience has shown that most black liquor recovery boiler explosions have been due to the reactions with molten smelt and water in some form or low solids liquor. It is obvious that if water or weak liquor can be prevented from reaching molten smelt, the number of explosions occurring can be drastically reduced.

In January 1962, the Black Liquor Recovery Boiler Advisory Committee was formed by representatives of the pulp and paper industry, manufacturers of black liquor recovery boilers and insurance companies providing coverage on black liquor recovery boilers.

The purpose of the committee was stated as follows:

“To work toward improving the safety of recovery boilers and/or furnaces and their auxiliaries through the interchange of technical knowledge, experience, and data on prior and any future casualties.”

To address these problems, the Emergency Shutdown Procedure Subcommittee of the Black Liquor Recovery Boiler Advisory Committee appointed a task force to study the problem of safe firing of black liquor and establish recommended practices.

The task force was subsequently made an independent subcommittee.

The Subcommittee on the Safe Firing of Black Liquor has prepared the following Recommended Good Practice **“Safe Firing of Black Liquor in Black Liquor Recovery Boilers”**.

## **CHANGES**

**April 2016 – Last revision.**

### **Chapter 2 Definitions:**

#### **Revised definition of “Managed System”**

**A documented procedure which includes a checklist of critical manual valves or devices that is completed by the operator prior to start-up and as needed throughout the operation. The checklist shall identify each valve or device and the proper position, condition or state. Any deviation from the checklist shall be controlled and documented through a jumper policy.**

#### **Chapter 4.10 Refractometer Calibration:**

**Revised wording of refractometer calibration and refractometer standardization as presented from the Instrumentation Subcommittee on 10/6/2014. More details were provided on standardization procedure.**

#### **Chapter 13 Item 9. Steam/water mixture for cooling liquor guns.**

**Revised wording to allow steam/water mixture to cool liquor guns as long as proper use of alarms and interlocks are in place to prevent excessive use of water that could enter the furnace.**

For a summary of prior changes to this document refer to Appendix B, Document Revision History.

## **CHAPTER 1 GENERAL**

Recovery boiler explosions fall into four categories -- smelt water explosions, auxiliary fuel explosions, explosions from ignition of unburned gases from pyrolyzed black liquor, and dissolving tank explosions.

Smelt water explosions are the result of water in some form contacting molten smelt within the furnace.

The exact mechanism of smelt water explosions is still being studied, but current knowledge can be used to help prevent furnace explosions. Explosions vary in intensity from "pops" which do no damage, to severely destructive explosions that may virtually destroy a recovery boiler.

Basic causes of explosive contact between molten smelt and water are:

1. Failure of a pressure part -- wall, floor, generating, screen tube, etc.
2. Unsafe firing conditions:
  - a) Firing low solids black liquor (58% or less solids).
  - b) Introduction of poorly atomized liquor into the furnace.
3. Introduction of black liquor into a nonoperating furnace.
4. Introduction of water into the furnace through the black liquor firing system.
5. Introduction of water into the furnace through external means.
6. Excessive smelt run off into the dissolving tank or excessive high density in the dissolving tank, both of which can result in a dissolving tank explosion.

Items 2, 3, 4, 5, and 6 are the subject of this Recommended Good Practice. The provisions of proper instrumentation and a black liquor safe firing system should go a long way toward reducing black liquor recovery boiler explosions attributed to low solids liquor, low solids black liquor firing, and water introduced through the liquor firing system.

The basic causes for combustible gas explosions from pyrolyzed gases are:

1. The introduction of black liquor into the furnace without sufficiently stable combustion to support black liquor firing.
2. Attempting to establish an auxiliary fuel fire with an inventory of black liquor

solids in the furnace without adequately purging the furnace.

The causes and prevention of auxiliary fuel explosions are addressed in **BLRBAC's Recommended Good Practice Safe Firing of Auxiliary Fuel in Black Liquor Recovery Boilers**.

## **CHAPTER 2 DEFINITIONS**

**Automatic Recirculation Shutoff Valve:** On high solids fired recovery boilers, the black liquor is sometimes automatically recirculated to a pressurized black liquor storage tank. On these designs the recirculation line shall be equipped with an automatic shutoff valve that must be interlocked to close in the event of any black liquor trip condition to prevent back feed to the black liquor firing header from the pressurized tank.

**Black Liquor:** Aqueous liquid by-product resulting from the alkaline pulp manufacturing process and containing inorganic and organic substances.

**Low Solids Black Liquor:** Black liquor containing 58% or less total solids.

**Heavy Black Liquor:** Black liquor containing greater than 58% total solids.

**High Solids Black Liquor:** Black liquor containing greater than 75% total solids

**Strong Black Liquor:** Black liquor leaving multiple effect evaporators.

**Weak Black Liquor:** Black liquor before multiple effect evaporators.

**Black Liquor Divert:** Shutting off the black liquor from the black liquor header(s) and the divert of the black liquor from the furnace. A black liquor divert is accomplished by closing the black liquor header valve and opening the black liquor divert valve.

**Black Liquor Divert Valve:** An automatic valve to divert the black liquor from the header.

**Black Liquor Gun:** A pipe with a nozzle at the end through which the heavy black liquor is introduced into the furnace.

**Black Liquor Gun Position Interlock:** One or more switches which indicate the position (in or out of the furnace) of the black liquor guns.

**Black Liquor Header(s):** The piping manifold through which the black liquor is fed to the black liquor guns.

**Black Liquor Header Valve:** An automatic valve that allows or shuts off the flow of black liquor to the black liquor header(s).

**Black Liquor Header Wash Switch:** A multiple position switch that allows the black liquor header valve to open when it is proven that all of the black liquor guns are out of the furnace.

**Black Liquor Divert Valve:** An automatic valve to divert the black liquor from the header.

**Black Liquor Divert:** Shutting off the black liquor from the black liquor header(s) and the divert of black liquor from the furnace. This is accomplished by closing the black liquor header valve and opening the black liquor divert valve.

**Black Liquor Heaters:**

**Direct:** In the direct type, steam is introduced directly and mixed with the black liquor to increase its temperature.

**Indirect:** The indirect type is a heat exchanger where heat from steam is transferred to the liquor through tubes or metal pipes and does not contact the liquor directly.

**Black Liquor Pump:** Any pump that delivers black liquor fuel to the black liquor-firing header.

**Emergency Shutdown Procedure Interlock:** An interlock to prevent the firing of black liquor or stop the firing of black liquor when an emergency shutdown procedure is in process or is initiated.

**Evaporator Outlet Temperature:** Temperature of the flue gases leaving either the cyclone or cascade-type black liquor evaporator of a recovery boiler system.

**Furnace-Pressure Interlock:** A pressure sensing device, set for a predetermined furnace gas pressure, which will automatically initiate a sequence of events to shut down equipment or prevent proceeding in an improper sequence.

**Hot Restart:** Re-establishing liquor firing after a flame out, partial black out or furnace trip with a hot bed and pressure on the unit.

**Interlock:** A device which senses a limit or off-limit condition or an improper sequence of events. It causes shutdown of the offending or related piece of equipment, or it prevents proceeding in an improper sequence, to prevent a hazardous condition.

**Liquor Purge Credit:** An interlock that proves that the black liquor header(s) has been purged.

**Lower Furnace Wash Switch:** A multiple position switch that allows washing of the lower furnace through the black liquor guns once it is determined that the lower furnace has been properly cooled and the boiler proven out of service.

**Managed System:** A documented procedure which includes a checklist of critical manual valves or devices that is completed by the operator prior to start-up and as needed throughout the operation. The checklist shall identify each valve or device and the proper position, condition or state. Any deviation from the checklist shall be controlled



**Moisture Balance:** An analytical instrument used to determine the total solids content of black liquor.

**Monitor:** To sense and alarm a condition requiring attention, without initiating corrective action.

**Non-Operating Water Source:** Any water or weak black liquor that is not part of the process cycle (i.e., wash water, cascade fire protection water, etc.).

**Operating Water Source:** Any water or weak black liquor that is part of the process cycle (i.e., direct contact evaporator dilution water, gland seal water, steam for heaters, and steam out connections, etc.).

**Precipitator Outlet Temperature:** Temperature of the flue gases leaving an electrostatic precipitator of a recovery boiler system.

**Prove:** To establish, by measurement or test, the existence of a specified condition such as flame, level, flow, pressure, temperature, or position.

**Recirculation Valve:** A valve on the black liquor header that when open allows the black liquor to flow through the header(s) and recirculate back to the final evaporator or storage. The recirculation valve can also be a valve that allows black liquor to constantly recirculate from the black liquor firing header back to a pressurized black liquor storage on high solids fired recovery boilers. These recirculation valves shall be interlocked in the safe firing of black liquor firing and tripping logic.

**Recovery Superintendent:** Person having direct operational responsibility for the recovery boiler.

**Refractometer:** An optical instrument that measures the dissolved solids in black liquor; it will not measure suspended solids.

**Smelt Spout:** A metal trough bolted to the lower furnace water wall of the recovery boiler. The trough allows smelt to be removed by gravity from the lower furnace of the recovery to recover the chemicals that have been reduced through the combustion process to smelt. This trough is either water cooled or could be a non water cooled trough. There can be as few as one or multiple smelt spouts on a recovery boiler.

**Supervise:** To sense and alarm a condition requiring attention, and automatically initiate corrective action.

**Total Solids:** All non-water constituents of the black liquor which is the sum of dissolved and suspended material in the liquor.

## **CHAPTER 3 BLACK LIQUOR SAFE FIRING SYSTEM REQUIREMENTS**

### ***3.1 Design***

New recovery boilers should be equipped, and existing units should be retrofitted with the black liquor safe firing system described in this document to prevent unsafe firing conditions, or the inadvertent introduction of aqueous streams into the liquor systems.

The design shall be predicated on the following fundamentals:

1. The installation of a solids monitoring system which shall consist of two in-line refractometers piped in series in the line to the black liquor header. The system shall provide adequate interlocking of the refractometers to ensure at least one is in service at all times. The required auxiliary services shall be supplied from the most reliable sources available. The refractometers shall indicate and alarm at 60% solids or at 70% solids if firing >70% solids per guidelines in Section 6.4. Firing liquor shall be diverted away from the furnace at no less than 58% solids, or at no less than 62% solids if firing >70% solids per guidelines in Section 6.4.
2. Loss of electrical power to the black liquor safe firing system shall divert the black liquor from the boiler.
3. Loss of electrical power or instrument air to the black liquor header valve shall cause the valve to automatically close and the divert valve to automatically open.
4. Interlock systems will prevent the introduction of wash liquids into the heavy black liquor header unless all black liquor guns are proven removed from the furnace.
5. Interlock systems will prevent the introduction of wash liquids into the lower furnace by the black liquor guns unless the FD fans are proven off, the sootblower water wash spool proven in place, and bed proven cool by someone in authority to make that decision.
6. Proper liquor conditions must exist before liquor can be introduced into the black liquor header(s).
7. All nonoperating water sources connected to the liquor system shall be monitored with interlocked position switches that will initiate an automatic black liquor divert if opened during normal firing. This does not include dilution sources required to control firing solids or fire protection system. (See Chapter 8)
8. All new and existing heavy black liquor piping systems shall be carefully reviewed and detailed drawings of the entire liquor system established.  
No

modifications or additions should be allowed without the knowledge and consent of the mill management. (See Chapter 8)

9. The review of the piping shall include a close examination to ensure that all wash water or condensate can be easily and visibly drained from “out of service” instrumentation, such as magnetic flow meter and its bypass.

### *3.2 Installation*

The safe firing system shall be thoroughly tested and countersigned as operational by competent engineers or technicians. A pre-planned test program with operating ranges and trip limits indicated and functionally tested shall be developed.

Care should be exercised to ensure that all devices, valves, meters, and sensors are mounted and located for easy access for regular maintenance. All control devices shall be designed for satisfactory operation in a recovery boiler environment.

### *3.3 Training*

The safe firing system shall have instruction manuals to cover the intent of the system and complete details of how the system will perform. Each individual involved with the firing of black liquor shall be given specific information covering his area of responsibility. The safe firing system shall be included in the overall recovery boiler training program.

The training program shall include the following:

1. Instruction for new employees entering the department.
  - Safe firing system function, purpose and description including logic sequences and interlock settings. It must be updated when changes are made to the system.
2. Instruction for operator and operating supervision retraining.
3. Testing, maintenance and calibration procedures. This would include all electrical and instrumentation personnel working on the Safe Firing System.
4. Complete and detailed instructions covering the “Sampling of Black Liquor and Measuring Solids Concentration”. (See Chapter 6)

### *3.4 Preventive Maintenance Program*

A preventive maintenance program shall be established to meet the following requirements:

1. The black liquor safe firing system shall be inspected, tested and assured operable on a scheduled basis. The inspection shall be predesigned with test limits established and reporting procedures provided.
2. Maintenance procedures shall be established to identify the safe firing system as a No. 1 priority. This will assure prompt attention to problem areas.
3. Necessary spare parts for the entire safe firing system shall be maintained in stock to assure prompt repairs to the system. It is recommended that a spare solids monitoring head be maintained in stores.
4. A prearranged plan shall be established for immediate repair or replacement of an inoperative refractometer.
5. A program of frequent, periodic, reliable tests shall be established to verify refractometer accuracy. Details of the testing program are covered in Chapter 6.

### *3.5 Sudden, Large Tube Leak Indication*

Sudden, large tube leaks in recovery boilers can introduce large quantities of water into the furnace area in a short period of time. Often such leaks result in a low drum level condition concurrent with a high positive furnace pressure. Additionally, even though the boiler is likely to have tripped on either low water or high furnace pressure, if the operator does not intervene, the feedwater control valve is driven towards its full-open position in a continuing effort by the drum level control system to restore drum level, thereby creating a continuing supply of water for the leak. A review of incidents reported to BLRBAC shows that there have been times operators did not recognize low drum level and positive furnace pressure as being caused by a large tube leak and did not immediately initiate an ESP.

For this reason it is recommended to add control logic to recovery boilers to drive the feedwater control valve closed and switch the valve control to manual when both a high furnace pressure Master Fuel Trip (MFT) and a low drum level MFT occur. For this logic:

- The high furnace pressure MFT (+ FD fan trip) setpoint shall be reviewed. Consider involving the OEM and insurance carrier if any time delays are installed.
- The low drum level MFT setpoint shall be reviewed. Consider involving the OEM and insurance carrier if any time delays are installed.

When both trips occur within 45 seconds of each other, the feedwater control valve shall be driven closed and revert to manual. Additionally, an alert/alarm message shall appear to the operator indicating both trip conditions have occurred and that this may be the sign of a large tube leak.

It is recognized that operating upsets other than large tube leaks can result in a concurrent high furnace pressure and low drum water level. After determining an ESP is not required, the operator is not prevented by the control system from opening the feedwater control valve, or from putting the control valve back into automatic. Additional data (leak detection system, other boiler specific parameters) should be evaluated before allowing feedwater back into the recovery boiler.

When this control logic is implemented it remains the operator's responsibility to determine the correct next course of action and additional boiler specific training should be given to all operators regarding the implications and symptoms of a sudden large tube leak.

## **CHAPTER 4 REFRACTOMETER BLACK LIQUOR SOLIDS MEASUREMENT SYSTEM**

### *4.1 General*

The heart of the system for the safe firing of black liquor is the ability to correctly, accurately and reliably measure the solids in the black liquor stream immediately prior to the black liquor guns.

To accomplish this solids measurement, refractometers have proven to be effective for black liquor recovery boiler service. As new techniques in measuring solids are developed and proven, they can be considered. For the solids measurements, two refractometers in series must be used. When both refractometers are in service, the requirement for an automatic black liquor diversion can be satisfied by either of the following options:

1. If either refractometer reads dissolved solids content 58% or below (62% or below if firing >70% solids per guidelines in 6.4 of this document), an automatic black liquor diversion must take place.
2. When both refractometers read dissolved solids content 58% or below (62% or below if firing >70% solids per guidelines in 6.4 of this document), an automatic black liquor diversion must take place.

Either option is satisfactory.

If the instrument readings disagree on the percent solids by 2% absolute value, an audible and visual alarm must be given.

If one refractometer fails, or is removed from service, black liquor diversion must then be controlled by the remaining in-service instrument; and if this remaining instrument reads 58% or below solids, an automatic black liquor diversion must take place (62% or below solids if firing >70% solids per guidelines in 6.4 of this document). Black liquor shall not be fired if neither refractometer is in service.

The refractometers should be part of a specifically integrated system adapted to the black liquor service, and include a system to monitor their operation and indicate trouble or failure of the individual refractometer.

Refractometers used without such a monitoring system can fail unsafe and can give improper and unsafe dissolved solids readings under certain conditions.

### *4.2 Refractometer Control System Functions*

The refractometer control system shall be capable of performing the following functions:

1. Monitor the positive (+) and negative (-) supply voltage of each refractometer independently. The refractometer's supply voltage shall be maintained within the predetermined minimum and maximum limits for safe operation.
2. Monitor the lamp voltage or lamp output of each refractometer independently. The refractometers' lamp voltage must be within the predetermined minimum and maximum limits for safe operation.
3. Monitor the signal amplitude (if chopper circuit devices are used) of each refractometer independently. Each refractometer's signal amplitude must be maintained within the predetermined minimum and maximum limits for safe operation.
4. Monitor the liquor temperature at each refractometer's sensing head independently assuring that each refractometer's liquor temperature is within the predetermined minimum and maximum limits for safe operation.
5. Monitor the automatic prism cleaning timer system of each refractometer. The sensor output circuit, prior to the hold circuit, should go negative or adequately decrease during the purge cycle.
6. Monitor the automatic prism cleaning timer system to assure that the purge occurs within the predetermined time.
7. Monitor the cooling water to each refractometer sensing head to assure that cooling water is not lost to a sensing head.

If any of these malfunctions (Items 1 through 7) occur, the following action shall be initiated:

- a) An alarm shall be activated, identifying the refractometer and circuit at fault.
- b) The refractometer shall be electrically removed from the refractometer control system.
- c) The remaining "good" refractometer shall remain in service.

8. Compare the refractometer meter outputs. If a difference of 2% (absolute value) solids or greater exists between refractometer readings, an alarm shall be activated.
9. Performs a black liquor diversion, if one refractometer is removed from service or fails in prism wash, and the remaining refractometer fails or reads a solids of 58% or less.

10. Monitor all cables from the refractometer and the components of the control system. If any cable is cut or removed, an alarm shall be activated.
11. Provide primary alarm or diversion functions by a means other than the refractometer indicating meter's contacts.
12. Have the capability to allow the manual removal of either refractometer from service retaining the remaining refractometer in full service for diversion purposes.
13. Require a manual reset following a black liquor diversion or malfunction of the refractometer control system.
14. Monitor the position of the sensing head isolation valves. A partially closed or closed valve shall activate an alarm and remove the refractometer from service.
15. Initiate a low solids alarm signal from each refractometer at 60% solids or at 70% solids if firing >70% solids per guidelines in 6.4 of this document.
16. Prohibit the simultaneous washing of the individual refractometers.
17. Require manual restoration of a refractometer which has been removed, either automatically or manually, from service.
18. Have provisions for manual prism washing.
19. Require an automatic switch to single refractometer diversion (for systems set to require both refractometers read low solids to divert – dual refractometer diversion) when one refractometer is in a prism wash cycle. Automatic return to the chosen dual refractometer diversion will occur after completion of the prism wash cycle.

All of the above functions may not apply to all refractometer control systems since some refractometers:

- a) Do not utilize cooling water,
- b) Have sensing heads that are not affected by liquor temperature, etc.,
- c) May have differences in electronic circuitry.

#### *4.3 Refractometer Control System - Controls & Indicators*

The refractometer system shall be equipped with the following controls and indicators:

1. Reset switch.
2. Switch or other means to manually remove either refractometer from service.
3. Visual solids display for each refractometer.
4. Status lights indicating “in service”. “inoperative” and/or “malfunction” for the individual refractometer and status of diversion valve.

#### *4.4 Refractometer Control System - Alarms and Indicators*

The recommended alarms and indicators of the refractometer control system are:

<u>Condition</u>	<u>Audible</u>	<u>Indicator</u>
1. Refractometers reading more than 2% absolute difference	X	X
2. Black liquor solids at or below 58%	X	X
3. Refractometers inoperative and/or malfunction	X	X
4. Black Liquor solids at 60%	X	X
5. Black Liquor solids at or below 62% if firing >70% solids per guidelines in 6.4 of this document	X	X
6. Black Liquor solids at 70% if firing >70% solids per guidelines in 6.4 of this document	X	X

#### *4.5 Installation Requirements*

1. The refractometers shall be installed in series.
2. The refractometer sensing heads shall be installed in such a manner that the individual sensing heads can be taken out of service or removed without having to valve off the liquor piping or open bypass valves.
3. All cabinets, wiring, etc., shall be suitable for the atmosphere and service conditions normal to a recovery boiler installation.
4. The refractometer sensing heads shall be installed so that they are accessible and readily serviceable.

5. The refractometer sensing heads may be installed in any position on a vertical pipe run. On a horizontal run of pipe, the sensing heads must be installed on sides of the pipe. The reason for this is to ensure that the prisms are always covered with liquor.
6. The electrical power supply to the refractometer control system shall be from a dependable (stable) source.
7. A dependable supply of cooling water of satisfactory capacity must be provided for refractometers requiring sensing head cooling water.
8. Dry oil-free instrument air shall be provided to the refractometer sensing heads to prevent and control condensation in the heads.
9. A steam supply source of sufficient capacity shall be provided to meet flow, and minimum and maximum pressures requirements.

All installation requirements may not apply to all refractometers and refractometer systems.

#### *4.6 Refractometer Problems*

The three major causes of refractometer trouble or failure are:

1. Loss of cooling water and its effect on the sensing head.
2. Lack of reliability of the prism wash.
3. Condensation in the sensing head.

These may not apply to all refractometers due to differences in construction and circuitry.

#### *4.7 Cooling Water Loss*

It is of vital importance that the loss of cooling water be detected. This may be done through a temperature sensing element or flow monitor which shuts down the refractometer involved.

Damage to the sensing element of a refractometer does not occur instantaneously, but it is essential that the system detect abnormal temperatures due to cooling water loss, flow blockage, etc., and that the cooling water be promptly restored.

The individual refractometer manufacturer's instruction and maintenance manuals shall be consulted with reference to: potential damage to the sensing element; identification of a damaged element; how and when to replace a damaged element.

#### **4.8 Prism Wash**

The time interval between prism washes may vary with the black liquor composition. It is recommended that the minimum wash period be 7-10 seconds of wash every 20 minutes. Short duration washes at more frequent intervals are more effective than long washes at long intervals. Ideally, steam pressure for prism washing should be 35 psig above the black liquor pressure, plus the pressure required to open the protective check valve.

Awareness must be maintained of the effect of changes to the prism wash programming variables. Various refractometer systems have the capability to adjust: condensate drain time, steam on time, recovery time and interval between wash time. It may be possible to configure the system to have the total time that both refractometers are in their wash cycle represent a significant percentage of operating time. If one refractometer is out of service for repairs and the remaining refractometer is in prism wash, black liquor solids are not being monitored. Prism wash should be minimized to that needed to maintain the system.

If high pressure steam is used, it may abrade the prism. If only high pressure steam is available, a reducing valve shall be used.

The refractometer prism must have a clear polished optical surface, and if it becomes abraded, it must be replaced.

If the prism wash system has not operated properly and the prism becomes coated, it must be removed and properly cleaned.

#### **4.9 Condensation in Sensing Head**

Condensate may build up in the refractometer sensing head and if this occurs, the instrument operation will be erratic.

The procedure for determining this condition and for the elimination of excessive moisture in the sensing head is not the same for all refractometers. The manufacturer's instruction and maintenance manuals shall be consulted and followed carefully.

#### **4.10 Refractometer Calibration Standardization (Zero Offset) to Off-Line Test**

A Refractometer Standardization ("zero shifting" or "bias adjustment") is an adjustment of the refractometer calibration curve to an off-line test to account for un-dissolved solids and/or changes in the black liquor chemistry. This is normally performed while the instrument is actively measuring black liquor solids.

All refractometers shall be verified against a reliable periodic off-line test. (See Chapter 6 – Off-Line Black Liquor Solids Measurement)

The refractometers shall be standardized:

1. On initial start-up of the recovery boiler.
2. At any time it is felt or known that one of the refractometers may be

deviating from the known black liquor solids content.

3. Any time there is a 2% difference between refractometers.

The reading of the refractometers shall be checked against the moisture analyzer or microwave analyzer at two hour intervals (8 hour intervals if firing above 70% solids), and the moisture analyzer or microwave analyzer shall be checked by the TAPPI Standard Method, T650-om-05, weekly.

All refractometer standardization changes shall be entered in the recovery boiler “log book.”

#### *4.11 Refractometer Calibration*

A Refractometer Calibration involves placing two or more “samples” onto the sensor to generate a refractive index vs. dissolved solids curve. This is typically performed utilizing calibration oils or electronically (depending on supplier) in a controlled environment, while the sensing head is off of the process line.

Calibration procedures shall be done in a manner that does not affect the system’s ability to automatically perform a black liquor diversion utilizing the remaining (active) in-service refractometer. Improper procedures, or those that defeat the monitoring system described in Chapter 4, can result in the system failing in an unsafe condition. Refer to the manufacturer’s appropriate procedures

If the continuous solids monitor refractometer differs from the off-line test field measurement by more than 2% on an absolute basis, the off-line test results must be confirmed and then if required the continuous monitor refractometer should be standardized and/or recalibrated according to the manufacturer’s recommended procedures. Repeated errors may indicate a failure of a refractometer component. Refer to the manufacturer’s recommendations for repair or replacement.

## **CHAPTER 5 BLACK LIQUOR FIRING INTERLOCK SYSTEM**

An interlock system shall be provided to protect operating personnel and equipment from explosion hazards while providing maximum boiler availability. The interlock system functions to ensure that the boiler operations follow a safe pre-established sequence of operations by excluding improper actions when starting-up and operating with black liquor fuel and by initiating black liquor diversion before an unsafe operating condition is reached.

Essential functions of the interlock system are:

### **1. Black Liquor Automatic Divert**

When an unsatisfactory black liquor firing condition is detected, an automatic divert from the furnace will occur. The specific conditions are identified in the Protective Tripping Logic for Black Liquor Firing, Figure 5.

### **2. Black Liquor Header(s) Purge**

Due to lack of knowledge of the contents of the black liquor header(s) at start-up or following a black liquor divert, it is necessary to purge the black liquor header(s).

To achieve the purge, it is necessary to establish black liquor conditions with respect to supply flow, percent solids, temperature and pressure in the black liquor header(s). The black liquor header recirculation valve must be proven open and the black liquor header shall be purged for a minimum 2-minute time period with the prescribed black liquor conditions proven.

Some newer large recovery boilers have subheaders on each individual wall to supply the liquor guns. In some instances these subheaders could contain unknown liquids because they are sometimes not included in the black liquor header purge. The owner/operator must be aware of the risks of un-purged sections of the black liquor firing system and develop SOP's or include these sections of piping in an automated purge system to assure there are no sections of piping that contain unknown quantities of liquids.

### **3. Black Liquor Gun Position**

Black liquor guns must be proven out of the furnace prior to the reopening of the black liquor header valve for the admittance of black liquor to the header or start of the black liquor header wash cycle.

**4. Black Liquor Gun Purge**

Black liquor guns shall not be purged, scavenged, or steamed out into the furnace after a liquor divert or furnace trip. Initial purge or steam-out of the gun should be external to the furnace. Thereafter, steam-out into an operating furnace is permissible.

**5. Manual Trip Provisions**

The black liquor divert interlock system shall include manual trip buttons or equivalent, located in the control area to permit divert of black liquor. A complete loss of fire - blackout - is a situation that requires immediate manual divert of black liquor.

The manual trip shall directly cause the black liquor header valve to close and the divert valve to open independent of any other interlock circuit.

**6. Black Liquor Temperature and Pressure**

Proper black liquor spray characteristics are established by the relationship of black liquor spray temperature and pressure. If either the spray pressure or temperature drops below predetermined values for a given time span, it shall be alarmed. Satisfactory black liquor pressure and temperature are permissives to purge the black liquor firing system (see Figure 2). Note: These permissives can be proven before or after the liquor header valve is opened.

**7. Black Liquor Header Divert System**

The divert valve must open and the header valve close and “lockout” when any liquor divert is initiated and must require manual reopening after correcting the fault that caused the black liquor divert condition. This function can be accomplished mechanically or electrically.

The recirculation discharge line must be run separately from the divert valve discharge line to its discharge point to avoid flow reversal in the recirculation line(s). The discharge point shall be lower than the black liquor header(s) and be under no pressure. Recirculation lines back to a pressurized black liquor storage tank (common on high solids applications) must be equipped with a safety shutoff valve that is interlocked in the permissive starting logic and protective tripping logic for safe firing of black liquor systems.

## **8. Black Liquor Header Wash and Lower Furnace Wash Permissives**

For routine washing of the black liquor firing header to be allowed, certain liquor system permissives are required to be met in order to open the black liquor header valve and close the divert valve. Refer to figure 3.

During annual outages or fireside cleaning of recovery boilers many locations utilize the black liquor guns and firing header to wash the lower furnace with water or wash liquids. Figure 3 shows the logic sequences required to allow lower furnace washing of the recovery boiler without the use of jumpers.

## **9. Black Liquor Interlock System**

The system shall be designed so that no interlock can be bypassed or otherwise defeated by means of a hard wired switch.

In order to provide for orderly maintenance of the safe firing system, it may be necessary at times to temporarily install jumpers on individual devices. This should only be done with the approval of the Recovery Superintendent, or the designee. Control of this process must be established by an administrative system (Jumper Log) that identifies when the jumper was installed and when it was removed. The use of a jumper must be considered an emergency condition and repairs must be initiated immediately. This program must be the same for either hardwire jumpers or software forced conditions.

The interlock control system shall provide the sequencing and protection indicated in the following permissive starting, washing and tripping logic and piping schematics:

Figure 1.	--	Common Permissive Starting Logic.
Figure 2	--	Permissive Starting Logic for Black Liquor Firing.
Figure 3	--	Black Liquor Header Wash and Lower Furnace Wash Permissives
Figure 4	--	Common Protective Tripping Logic.
Figure 5	--	Protective Tripping Logic for Black Liquor Firing.
Figure 6	--	Generic Black Liquor Firing System for Atmospheric Storage.
Figure 7		Generic Black Liquor Firing System for Pressurized Storage.
Figure 8	--	Generic Black Liquor Firing System for Direct Contact Evaporators.
Figure 9	--	Recommended Piping Arrangement at Black Liquor Guns.
Figure 10	--	Parallel Indirect Liquor Heaters with Recirculation.
Figure 11	--	Single Indirect Liquor Heater with Forced Recirculation.

Figure 12 -- Single Indirect Liquor Heater without Forced Recirculation.

The “Common Permissive Starting Logic” and “Common Protective Tripping Logic” diagrams and the Logic Explanation Charts are shared with the Safe Firing of Auxiliary Fuel guidelines. The “Starting Logic” diagram graphically shows the sequence of operations required to safely place the black liquor fuel system in operation. In reading this diagram, all items leading to an “AND” block must be in service and/or within proper limits before any subsequent operation leading out of and following the “AND” block can be performed. A typical pre-firing checklist is shown in Appendix 1.

The Black Liquor Header Wash and Lower Furnace Wash Permissives Logic Diagram shows graphically what permissives must be met to allow water or wash liquids to be safely admitted in the black liquor firing header.

The “Tripping Logic” diagram shows graphically the malfunction or misoperation that will divert black liquor from the furnace. In reading this diagram, any malfunction or misoperation leading into an “OR” block automatically shuts down everything following the “OR” block.

The “Schematic Piping” diagrams show the various valves, etc., in the piping that are mentioned in the starting and tripping logic diagrams. For clarity, miscellaneous valves, gauges, etc., normally provided, have not been shown.

No valve or similar shut-off should be installed in the sensing line to any interlock device, such as, a pressure or temperature switch, that could defeat the interlock function if accidentally closed. In a limited number of cases, it could be considered safer to install an isolation valve to allow repair(s) to be performed on interlock device(s) promptly. This could minimize the amount of time the safety interlock will be out of service in cases where an outage would have to be scheduled to make repairs. Isolation valves shall be allowed in these cases only. Examples could be drum level probe columns, black liquor pressure switches, auxiliary fuel system pressure switches, etc. If valves are installed, they must be utilized in a “managed system.”

Whenever a “managed system” is utilized on sensing line isolation valves and it is necessary to defeat an interlock by closing a safety interlock sensing line isolation valve, the jumper policy must be followed.

Prior to placing a unit/system in service, a checklist of all the safety interlocks with valves in the sensing lines shall be completed by the operator, documenting that the valves are in the open position and secured per the “managed system.”

The items and functions listed on the logic diagrams are tabulated and explained, with suggested limits where applicable, in the logic explanation charts following the diagrams.

## **10. Protection Against Pyrolysis Gas Explosion During Hot Restarts**

Pyrolysis gas explosions are combustible gas explosions where the source of combustibles is from pyrolysis of an accumulation of unburned black liquor solids in the furnace. The common factor in the occurrence of these explosions is continued introduction of black liquor into a hot furnace without combustion of the black liquor. The best means of protection against pyrolysis gas explosions is to immediately stop liquor firing and pull the liquor gun(s) if fire is lost or if liquor is not igniting or burning properly.

If either black liquor flow to the guns or boiler steam flow drop below 30% maximum continuous rating (MCR), and sufficient hearth burners are not in service, this will prove loss of stable black liquor combustion, and a divert of black liquor will occur. Furnace purge credit will be lost if no auxiliary fuel burners are in service, and all permissives must be met before firing auxiliary fuel.

Any time a divert of black liquor has occurred, a problem exists and must be investigated. The permissive logic shown on Figures 1 and 2 is intended to ensure that stable firing conditions exist before liquor can be reintroduced into the furnace on a hot restart. If auxiliary fuel was not in use at the time of the divert, sufficient hearth burners must be put in service. There must be sufficient heat available to support the drying, ignition and burning of liquor that will be introduced into the furnace.

When a blackout, flameout, or trip occurs, the five minute furnace air purge required for auxiliary fuel firing may not be adequate, as this does not address the continuous generation of pyrolysis gases from an accumulation of unburned black liquor. Care must be taken to ensure an adequate purge before lighting an auxiliary burner. Monitoring flue gas combustibles (e.g. with a CO meter) can provide guidance on when the purge is adequate.

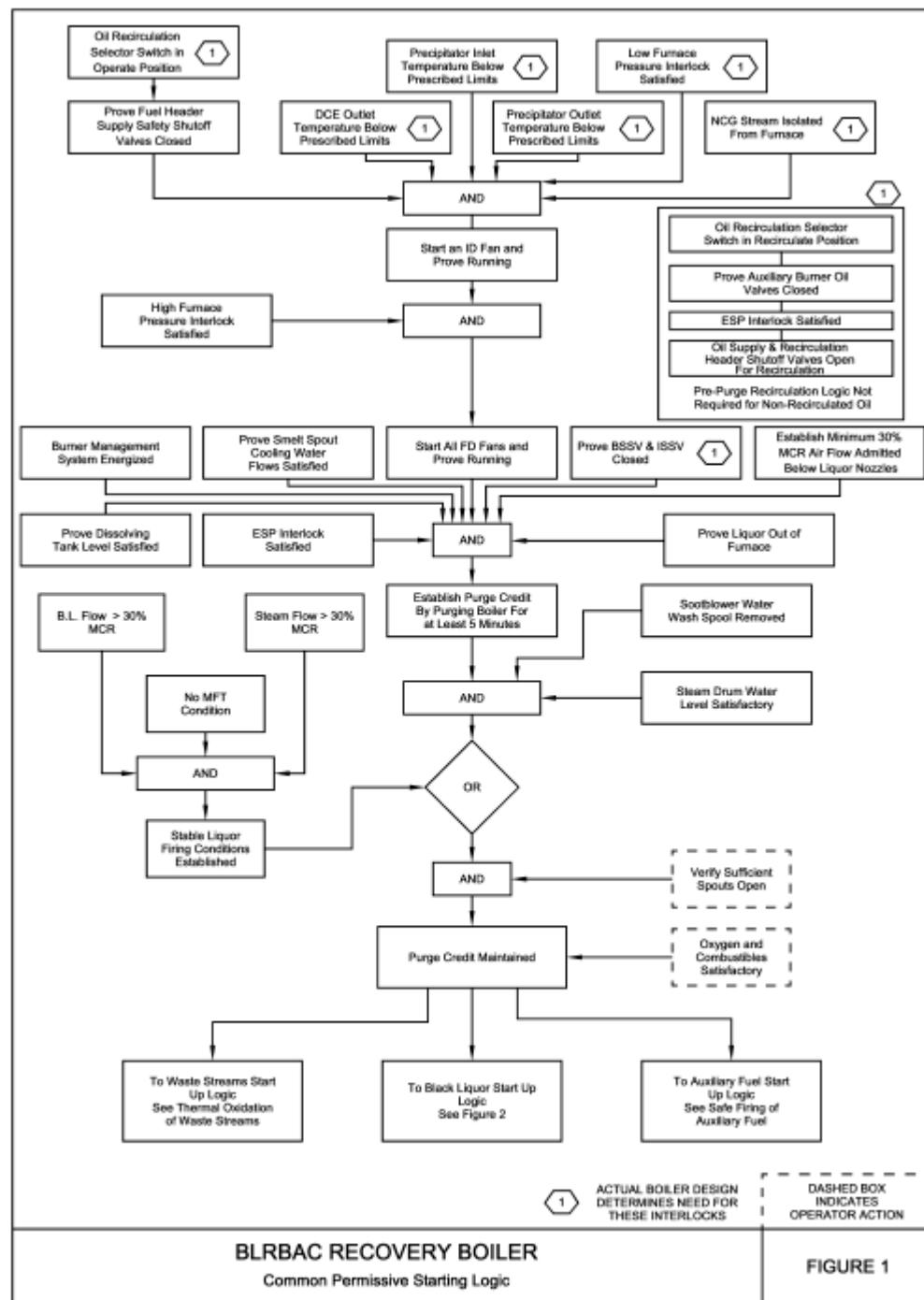


Fig. 1. Common Permissive Starting Logic

Table 1. Logic Explanation Chart for Figure 1, Common Permissive Starting Logic

<b>Refer to Figure 1</b> <b>Logic Explanation</b> <b>Chart</b>		
<b>Logic Diagram Block</b>	<b>Purpose</b>	<b>Hazard Protected</b>
Oil Recirculation Selector Switch In “Operate” Position	Prevent circulation of oil around furnace boiler during furnace purge.	Possible leakage of oil into furnace during furnace purge.
Prove Fuel Header Supply Safety Shutoff Valves Closed	Prevent start-up if any auxiliary fuel explosion safety shut-off valve is not closed.	Possible fire from furnace during start-up into idle
DCE Outlet Temperature Below Prescribed Limits	Prevent start-up of boiler if con temperature is 200°F or more above design temperature at rated capacity.	Fire in direct evaporator
Precipitator Outlet Temperature Below Prescribed Limits	Prevent start-up of boiler if contact temperature is 200°F or more above design temperature at rated capacity.	Fire in precipitator with direct evaporator system.
Precipitator Inlet Temperature Below Prescribed Limits	Prevent start-up of boiler if contact temperature is 200°F or more above design temperature at rated capacity.	Fire in precipitator with direct evaporator system.
Low Furnace Pressure Interlock Satisfied	Detect abnormally low furnace pressure. Set at a minimum of 80% of furnace design pressure (negative).	Possible structural damage from furnace implosion.
NCG Stream Isolated From Furnace	Prevent start-up of boiler if non-explosive condensables are entering furnace.	Possible fire from ignition of gases.
Start An I.D. Fan And Prove Running	Prove at least one induced fan operating for purge and flue gas	Potential fire from improper operating
High Furnace Pressure Interlock Satisfied	Detect abnormally high furnace pressure. Set at a maximum of 80% of furnace design pressure (positive).	Possible structural damage from furnace pressure.
Start All F.D. Fans And Prove Running	Prove all forced fans operating for improper purge and air supply functions to purge all ducts and windboxes.	Potential explosion from impaired air supplies.
Burner Management System Energized	Provide power to burner safety control circuits.	
Prove BSSV & ISSV Closed	Ensure individual burner valves closed before opening main trip furnace burner valve.	Possible fire from fuel explosion before entering furnace light-off.
Establish Minimum 30%. MCR Air Flow Admitted Below Liquor Nozzles	Sufficient air for purge requirements, a minimum of 30% of black liquor which fail MCR air flow.	Possible fire from improper purge to clear furnace of flue gas.
ESP Interlock Satisfied	Prevent start-up if Emergency Shutdown Procedure interlock has not been reset.	
Prove Dissolving Tank Level Satisfied	Prevent accumulation of undissolved explosive smelt in dissolving tank.	Possible fire in dissolving tank.
Prove Smelt Spout Cooling Water Flows Satisfied	Ensure proper spout cooling prior to firing auxiliary fuel.	Possible loss of spout and uncontrolled flow of smelt from furnace.
Prove Liquor Out Of Furnace	Prevent start-up if black liquor is entering furnace.	Possible fire during start-up from pyrolysis.
Establish Purge Credit By Purging Boiler For At Least 5 Minutes	Ensure removal of unburned combustibles from furnace.	Possible explosion from accumulation of combustibles in furnace.
Steam Drum Water Level Satisfactory	Ensure water level correct before firing light-off.	Damage to pressure parts from improper water level.

**Refer to Figure 1**  
**Logic Explanation Chart**  
**Common Permissive Starting Logic**

<b>Logic Diagram Block</b>	<b>Purpose</b>	<b>Hazard Protected</b>
Black Liquor Flow > 30% MCR	Prove combustion of black liquor.	Maintaining purge credit with unstable furnace conditions.
Steam Flow > 30% MCR	Prove combustion of black liquor.	Maintaining purge credit with unstable furnace conditions.
Sootblower Water Wash Spool Removed	Ensure water cannot enter the furnace through the sootblower water wash connection.	Smelt water explosion.
No MFT Condition	Prove all conditions are safe.	Combustion of fuel with unsafe furnace condition.
Stable Black Liquor Firing Conditions Established	Maintain purge credit from black liquor firing.	
Verify sufficient spouts open	Ensure spouts are open to prevent smelt accumulation and allow molten smelt flow from boiler upon start-up.	Protect personnel and equipment from smelt rushes and potential dissolving tank explosions.
Oxygen and Combustibles Satisfactory	Confirm removal of combustibles from furnace.	Potential explosion from ignition of combustible gases.
Purge Credit Maintained	Ensures all interlocks are satisfied.	
Oil Recirculate Selector Switch in Recirculate Position	Permit opening of main oil trip valves for recirculation in a safe manner.	
Prove Auxiliary Burner Oil Valves Closed	Prevent oil from entering furnace during recirculation.	Possible explosion during start-up from auxiliary fuel leaking into furnace.
ESP Interlock Satisfied	Prevent oil recirculation if emergency shutdown procedure interlock has not been reset.	Possible fire from fuel line rupture as a result of a smelt water reaction.
Oil Supply & Recirculation Header Shutoff Valves Open for Recirculation	Supply oil to header system in safe sequence to ensure adequate oil temperature and viscosity for proper atomization.	

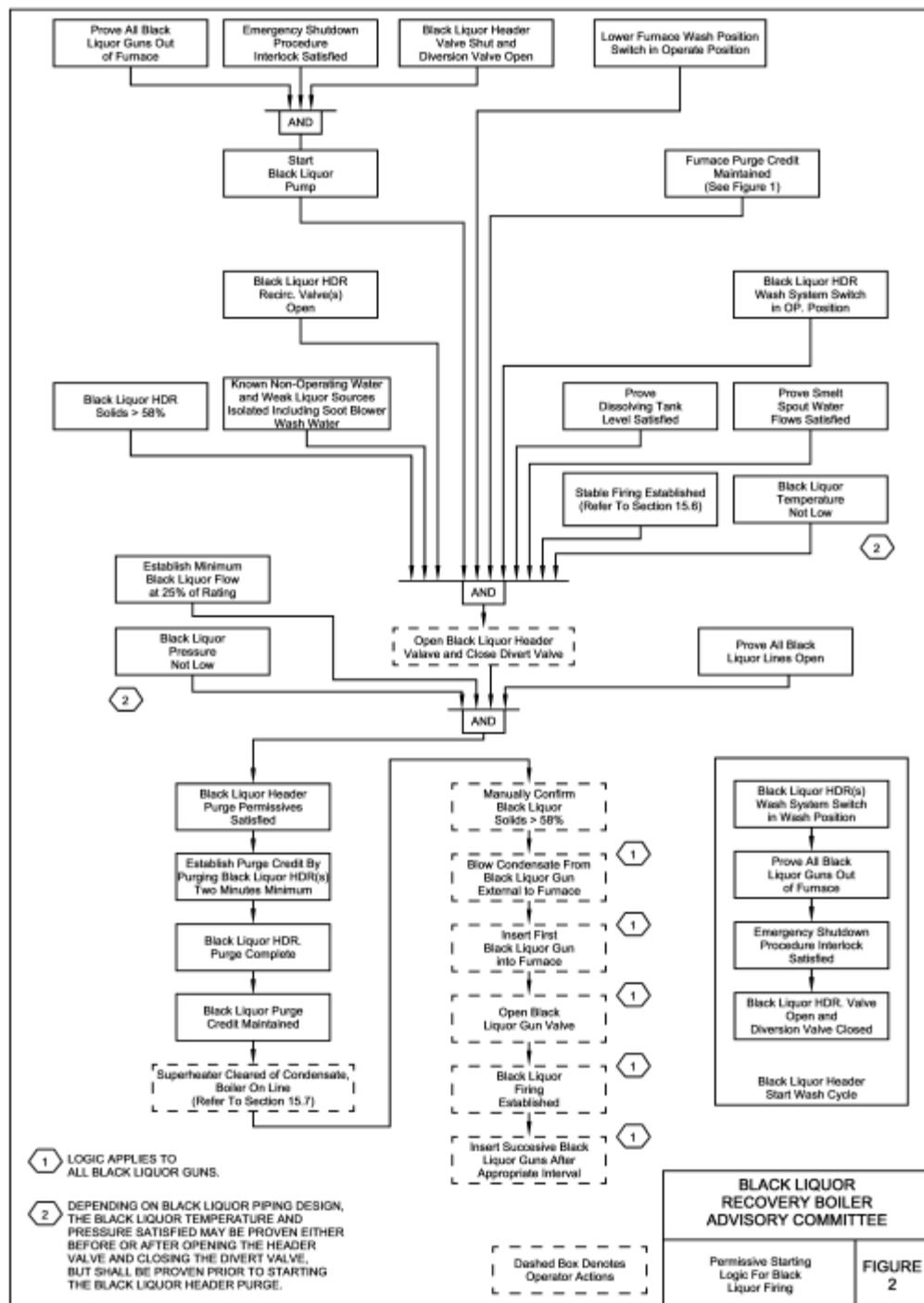


Fig. 2. Permissive Starting Logic for Black Liquor Firing

Table 2. Logic Explanation Chart for Figure 2, Permissive Starting Logic for Black Liquor Firing

<b>Refer to Figure 2</b> <b>Logic Explanation Chart</b> <b>Black Liquor Starting Logic</b>		
<b>Logic Diagram Block</b>	<b>Purpose</b>	<b>Hazard Protected Against</b>
Prove All Black Liquor Guns Out of Furnace	Prevent unsafe firing of black liquor and prevent wash water from entering furnace.	Prevent smelt-water explosion, prevent combustible gas explosion.
Emergency Shutdown Procedure Interlock Satisfied	Confirm that no Emergency Shutdown Procedure is in progress.	
Black Liquor Header Valve Closed and Divert Valve Open	Shutoff black liquor to furnace header(s) and divert liquor flow.	Possible introduction of low solids into furnace.
Start Black Liquor Pump	Black liquor pump started as first step in establishing black liquor flow.	
Boiler Purge Credit Maintained (from Figure 1)	Verify furnace is ready for fuel introduction.	Possible explosion, combustibles in furnace.
Black Liquor Header Recirc. Valve(s) Open	Black liquor recirculation valve(s) opened in preparation for black liquor header purge.	
Prove Dissolving Tank Level Satisfied	Prevent accumulation of undissolved smelt in dissolving tank.	Possible explosion in dissolving tank.
Prove Smelt Spout Cooling Water Flows Satisfied	Ensure proper spout cooling prior to firing liquor.	Possible loss of spout and uncontrolled flow of smelt from furnace.
Black Liquor Header Wash System Switch in Operate Position	Ensures wash system is inactive during black liquor firing.	Prevent low solids black liquor and wash liquor from entering furnace.
Black Liquor Solids >58%	Establish safe firing solids level of black liquor. (see Chapter 7)	Possible introduction of low solids liquor into the furnace.
Black Liquor Temperature Not Low	Ensure proper liquor spray characteristics.	Accumulation of unburned black liquor on hearth.
Known Nonoperating Water and Weak Liquor Sources Isolated Including Sootblower Wash Water	Prevent dilution of black liquor.	Possible introduction of low solids liquor or water into the furnace.
Stable Firing Established Refer to Section 15.6	Ensure adequate furnace temperature for black liquor ignition and firing.	Accumulation of unburned black liquor on hearth.
Lower Furnace Wash Position Switch in Operate position	Ensures wash system is inactive during black liquor firing	Prevent low solids black liquor and wash liquor from entering furnace
Open Black Liquor Header Valve and Close Divert Valve	Operator Action	Prevent Automated Function of Resetting the Divert System
Establish Minimum Black Liquor Flow At 25% of Rating	Ensure minimum black liquor flow for black liquor header purge.	
Black Liquor Pressure Not Low	Ensure proper black liquor spray characteristics.	Accumulation of unburned black liquor on hearth.
Prove All Black Liquor Lines Open	Ensure black liquor header(s) are open to permit proper purge.	Possible introduction of low solids liquor into furnace.
Establish Purge Credit by Purging Black Liquor Header(s) 2 Minutes Minimum	Purge black liquor header of possible low solids (see Chapter 15).	Introduction of low solids liquor into furnace.
Black Liquor Header Purge Complete	All interlocks satisfied. Ready to fire black liquor.	

**Refer to Figure 2**  
**Logic Explanation Chart**  
**Black Liquor Starting Logic**

<b>Logic Diagram Block</b>	<b>Purpose</b>	<b>Hazard Protected Against</b>
Superheater Cleared of Condensate, Boiler on-Line Refer to section 15.7	Superheater loops/platens all cleared of condensate. Boiler on-line and in the header producing steam. Ensure boiler is stable on auxiliary fuel firing.	Prevent possible short term overheat of superheater tubes as a result of water/condensate blocking cooling steam flow through the superheater circuits.
Manually Confirm Black Liquor Solids >58%	During start up at least one operator off-line solids test shall be performed immediately prior to firing black liquor to confirm solids are above 58% and the refractometers are reading correctly.	Possible introduction of low solids liquor into furnace.
Blow Condensate From Black Liquor Gun External to Furnace	Remove condensate from the black liquor gun and the line.	Possible introduction of water or low solids liquor into furnace.
Insert First Black Liquor Gun Into Furnace	Fire black liquor.	
Open Black Liquor Gun Valve	Fire black liquor.	
Black Liquor Burning Established	Observe ignition of black liquor.	Accumulation of unburned black liquor at hearth, unstable firing.
Insert Successive Black Liquor Guns After Appropriate Interval	Raise load in an orderly fashion, maintain stable ignition, drum level, steam production and smelt flow from spouts.	Accumulation of unburned black liquor at hearth, unstable firing.

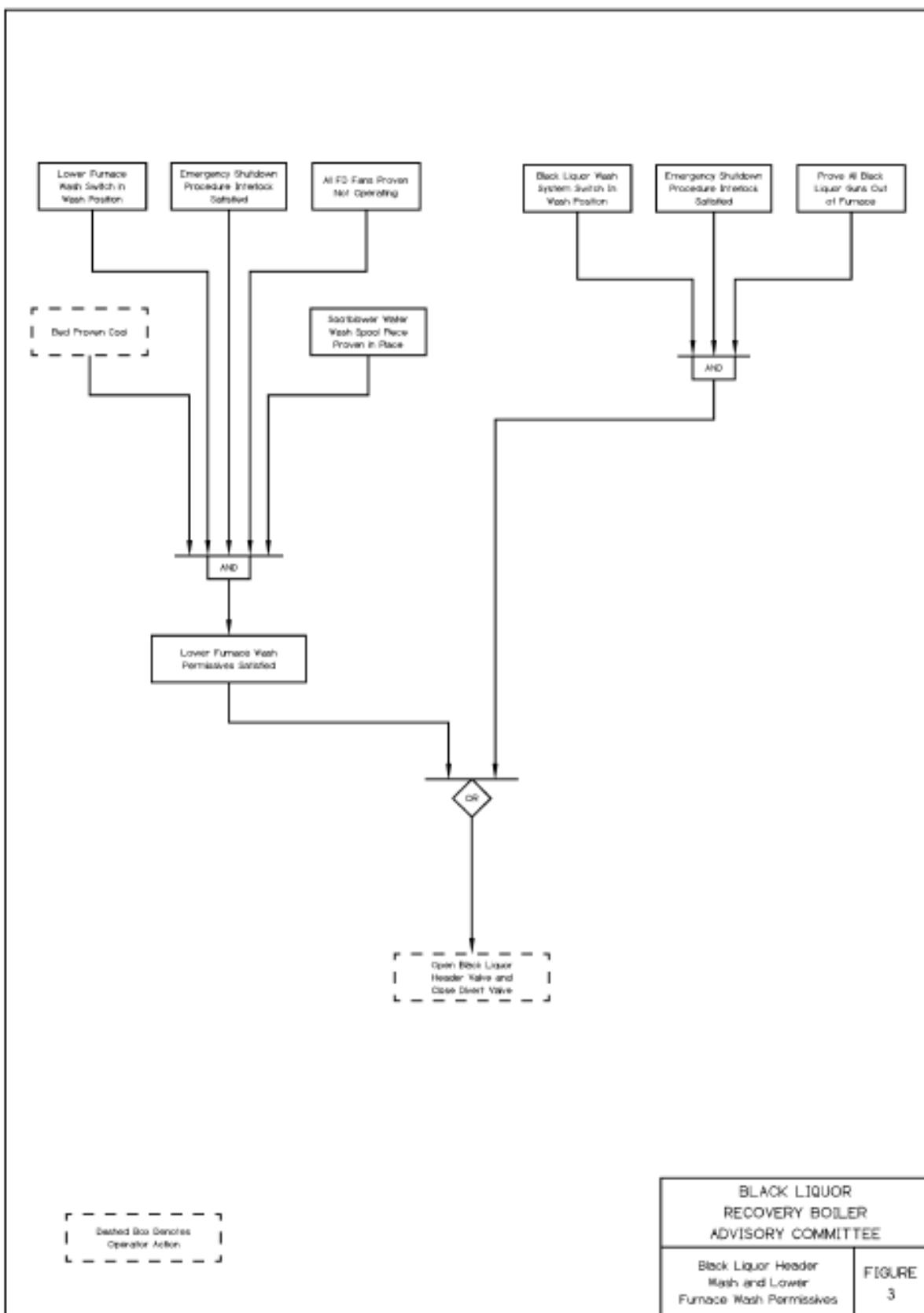


Fig. 3. Black Liquor Header Wash and Lower Furnace Wash Permissives

Table 3. Logic Explanation Chart for Figure 3, Black Liquor Header Wash and Lower Furnace Wash Permissives

<b>Refer to Figure 3</b> <b>Logic Explanation Chart</b> <b>Black Liquor Header Wash and</b> <b>Lower Furnace Wash Permissives</b>		
<b>Logic Diagram Block</b>	<b>Purpose</b>	<b>Hazard Protected Against</b>
Lower furnace wash switch in wash position	Allow admission of water or low solids liquor to the B.L. ring header and the furnace under controlled conditions during a boiler outage.	Possible introduction of low solids liquor into furnace when lower furnace is not cooled properly.
Emergency shutdown procedure interlock satisfied	Confirm that no Emergency Shutdown Procedure is in progress.	
All FD fans not operating	Verify boiler is not in operation.	Water washing the lower furnace while the boiler is in operation.
Sootblower water wash spool piece proven in place	Verify that boiler is being washed through to the lower furnace.	Water washing the lower furnace while the boiler is in operation.
Bed proven cool	Operations verification by probing with thermocouples or other means that the smelt bed is below identified temperatures and no “hot spots” remain in the smelt bed.	Water washing the lower furnace prior to the bed being proven cool.
Lower furnace wash permissives satisfied	Lower furnace is cool and ready to be washed using the liquor guns.	Possible introduction of low solids liquor into furnace.
Black liquor wash system switch in wash position	Allow admission of water or low solids liquor to black liquor firing header under controlled conditions.	Possible introduction of low solids liquor into furnace.
Prove all black liquor guns out of furnace	Prevent accidental entry of low solids liquor to the furnace.	Possible introduction of low solids liquor into furnace.
Open black liquor header valve and close divert valve	Confirm operation of valves.	Possible introduction of low solids liquor into furnace.

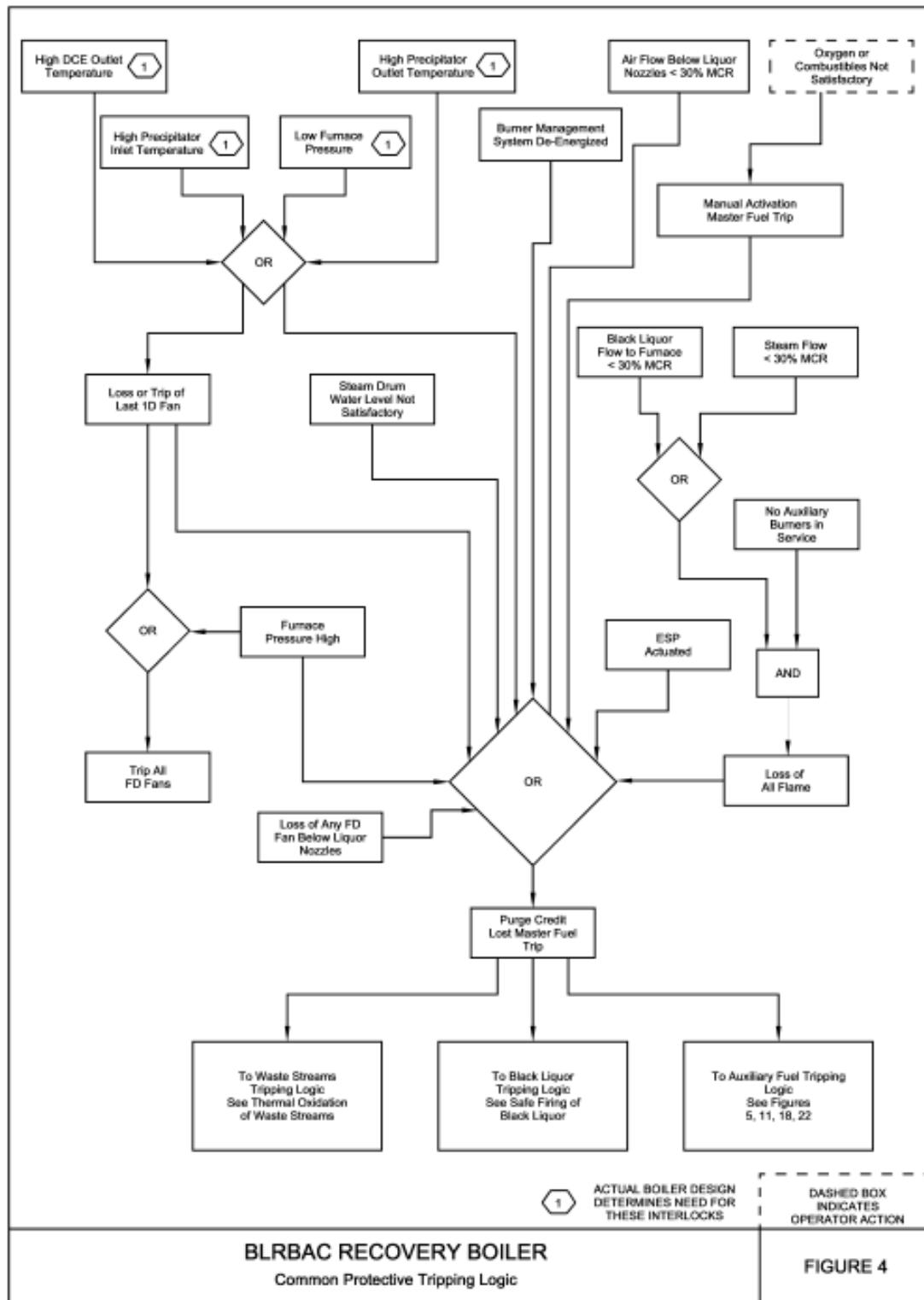


Fig. 4. Common Protective Tripping Logic

Table 4. Logic Explanation Chart for Figure 4, Common Protective Tripping Logic

<b>Refer to Figure 4</b> <b>Logic Explanation Chart</b> <b>Common Protective Tripping Logic</b>		
<b>Logic Diagram Block</b>	<b>Purpose</b>	<b>Hazard Protected</b>
High DCE Outlet Temperature	Shut down induced draft fan(s), forced draft fan(s) and all fuels at 200°F above design temperature at rated capacity.	Fire in direct contact evaporator.
High Precipitator Outlet Temperature	Shut down induced draft fan(s), forced draft fan(s) and all fuels at 200°F above design temperature at rated capacity.	Fire in precipitator with direct contact evaporator system.
High Precipitator Inlet Temperature	Shut down induced draft fan(s), forced draft fan(s) and all fuels at 200°F above design temperature at rated capacity.	Fire in precipitator with direct contact evaporator system.
Air Flow Below Liquor Nozzles Less Than 30% MCR	Shut off all fuel if airflow below liquor nozzles drops below 30% of MCR black liquor airflow.	Possible explosion from improper fuel-air mixture.
Oxygen or Combustibles Not Satisfactory	Operator terminates all firing when conditions exceed safe operating limits.	Explosion of pyrolysis or unburned fuel gas.
Low Furnace Pressure	Shut down induced draft fan(s), forced draft fan(s) and all fuel.	Possible structural damage from implosion.
Burner Management System De-Energized	Shut off fuel to furnace upon loss of electrical power to burner management control circuits.	Possible explosion during unsupervised firing conditions.
Manual Actuation Master Fuel Trip	Stop firing all fuels.	
Loss or Trip of Last I.D. Fan	Shut off all forced draft fan(s) and all fuels.	Pressuring of furnace creates unsafe firing conditions and fire hazard to personnel and equipment.
Steam Drum Water Level Not Satisfactory	Stop firing all fuels when water level is improper.	Damage to pressure parts from firing with improper water level.
Black Liquor Flow to Furnace < 30% MCR	Remove purge credit for black liquor firing.	Possible explosion from pyrolysis gasses.
Steam Flow < 30% MCR	Remove purge credit for black liquor firing.	Possible explosion from pyrolysis gasses.
Furnace Pressure High	Shut off all forced draft fan(s) and all fuels if a hazardous or unstable draft condition exists or if an explosion occurs.	Pressurizing of furnace creates unsafe firing conditions and fire hazard to personnel and equipment.
ESP Actuated	Shut off all fuel to furnace during ESP.	
No Auxiliary Burners in Service	Require furnace purge prior to ignition after loss of all flame.	Possible explosion due to pyrolysis gasses. Note: Igniters are not to be classified as a burner.
Trip All FD Fans	Shut down FD fans with loss of ID fans or high furnace pressure.	Prevent possible structural damage.
Loss of any FD Fan Below Liquor Nozzles	Shut off all fuels if any FD fan below the liquor guns trips.	Possible explosion from accumulations of explosive mixtures.
Loss of all Flame	Stop firing all fuel.	Possible explosion from unburned combustibles.
Purge Credit Lost Master Fuel Trip	Shut off all fuels to furnace.	Combustion of fuel with unsafe furnace condition.
Isolate NCG Waste Steams	Stop introduction of NCG into furnace.	Possible explosion.

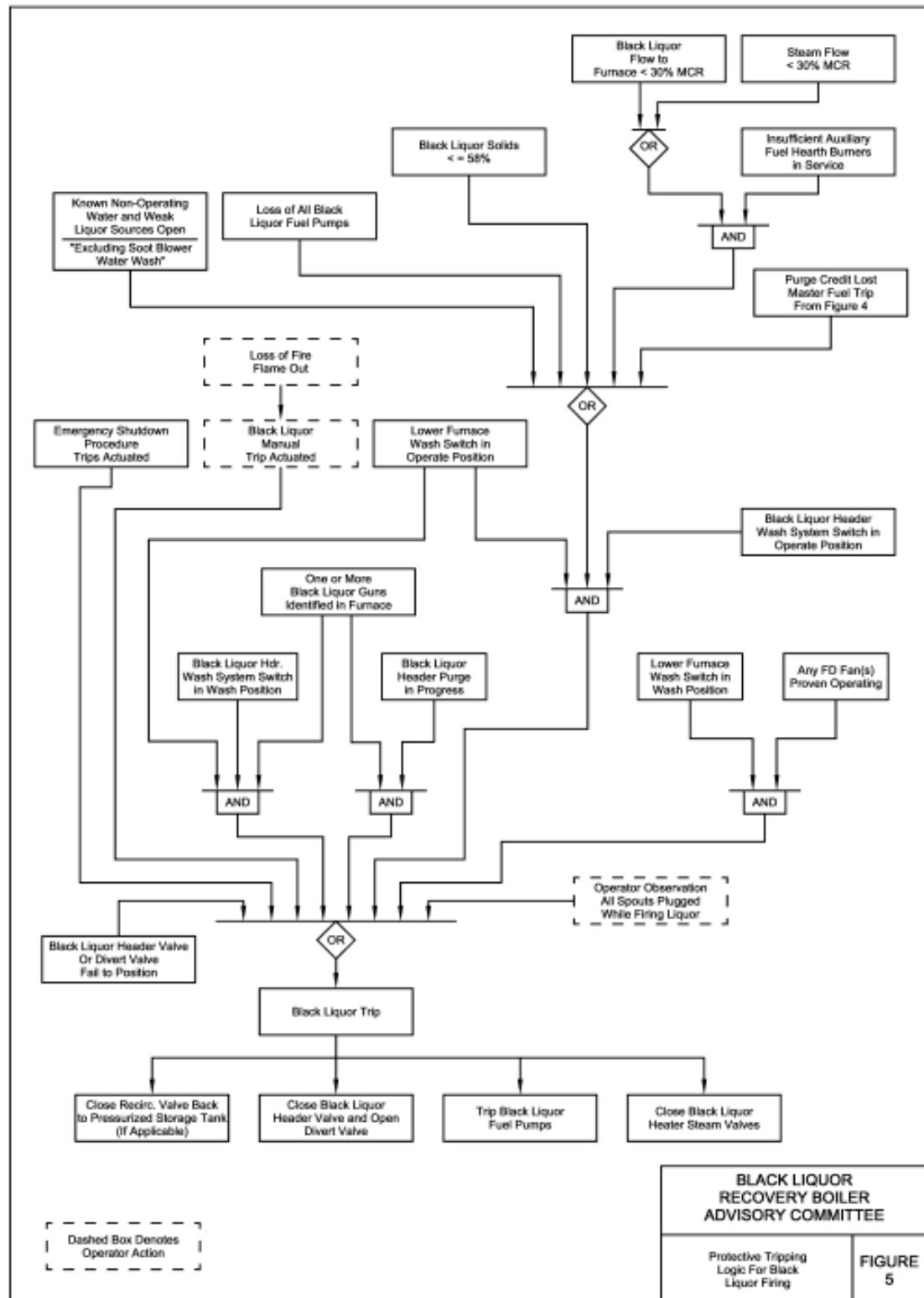


Fig. 5. Protective Tripping Logic for Black Liquor Firing

Table 5. Logic Explanation Chart for Figure 5, Protective Tripping Logic for Black Liquor Firing

<b>Refer to Figure 5</b> <b>Logic Explanation Chart</b> <b>Black Liquor Tripping Logic</b>		
<b>Logic Diagram Block</b>	<b>Purpose</b>	<b>Hazard Protected Against</b>
Known Nonoperating Water or Weak Liquor Source Open (excluding sootblower water-wash)	Prevent introduction of any liquor into the furnace if any nonoperating water or weak liquor source is opened.	Smelt-water explosion.
Purge Credit Lost – Master Fuel Trip (from Figure 4)	Stop liquor firing when a master fuel trip/purge credit loss occurs.	
Black Liquor Solids Less Than or Equal to 58%	Divert low solids black liquor from furnace.	Smelt-water explosion.
Loss of All Black Liquor Fuel Pumps	Prevent reintroduction of liquor to furnace before startup conditions are satisfied.	Possible combustible gas explosion.
Black Liquor Flow to Furnace <30% MCR	Input to system indicating possible unstable liquor firing condition.	Possible combustible gas explosion.
Steam Flow <30% MCR	Input to system indicating possible unstable liquor firing condition.	Possible combustible gas explosion.
Insufficient Auxiliary Fuel Hearth Burners in Service	Auxiliary fuel fire not sufficient to stabilize black liquor firing.	Possible combustible gas explosion. Note: Igniters are not to be classified as a burner.
Black Liquor Header Wash System Switch in Operate Position	Enable introduction of liquor into the furnace.	Smelt-water explosion.
Lower furnace wash switch in operate position	Prevent inadvertent switching of the lower furnace wash switch to Wash position during normal operation	Possible introduction of low solids liquor into the furnace.
Black Liquor Header Purge in Progress	Prevent premature introduction of black liquor into the furnace until liquor headers are properly purged.	Possible introduction of low solids liquor into the furnace.
One or More Black Liquor Guns Identified in Furnace	Prevent introduction of any liquor into the furnace and divert flow from the furnace.	Smelt-water explosion.
Black Liquor Header Wash System Switch In Wash Position	Prevent introduction of any liquor into the furnace and divert flow from the furnace.	Smelt-water explosion.
Loss of Fire, Flame Out Black Liquor Manual Trip Actuated	Operator input to prevent introduction of black liquor into unstable furnace.	Possible combustible gas explosion.
Emergency Shutdown Procedure Trip Actuated	Shut off all black liquor to furnace in the event of emergency shutdown.	
Lower furnace wash switch in wash position	Prevent introduction of low solids to the liquor header until boiler proven not in operation	Possible introduction of low solids liquor into the furnace.
Any FD fan operating	Prove boiler is not in operation	Possible introduction of low solids liquor into the furnace.
Operator Observation All Spouts Plugged While Firing Liquor	Ensure spouts are open to prevent molten smelt accumulation in the lower furnace.	Protect personnel and equipment from smelt rushes and potential dissolving tank explosions.
Black liquor trip condition	Remove black liquor from furnace when conditions dictate an unstable lower furnace	Smelt-water explosion and combustible gas explosion.
Close Black Liquor Header Valve and Open Divert Valve	Ensure immediate and positive shutoff of black liquor to furnace when required.	Smelt-water explosion and combustible gas explosion.

<b>Refer to Figure 5</b> <b>Logic Explanation Chart</b> <b>Black Liquor Tripping Logic</b>		
<b>Logic Diagram Block</b>	<b>Purpose</b>	<b>Hazard Protected Against</b>
Trip black liquor fuel pumps	Possible introduction of black liquor into the furnace in case divert system fails	Continued introduction of black liquor to the furnace after a black liquor trip condition.
Close black liquor heater steam valves	Close steam to indirect and direct black liquor heaters	Potential personnel safety issue if steam valves continue in operation by flashing of black liquor storage tanks or overheating indirect heaters with no liquor flow
Close recirc valve to pressurized storage tank	Prevent back flow of black liquor to a non-operating furnace	Possible combustible gas explosion.
Black liquor header valve or divert valve fail to position	Ensure that header valve is always open when required to be open. Ensure that divert valve is always closed when required to be closed.	Prevent re-introduction of black liquor to the furnace following an interruption due purge and/or black liquor headerpurge.

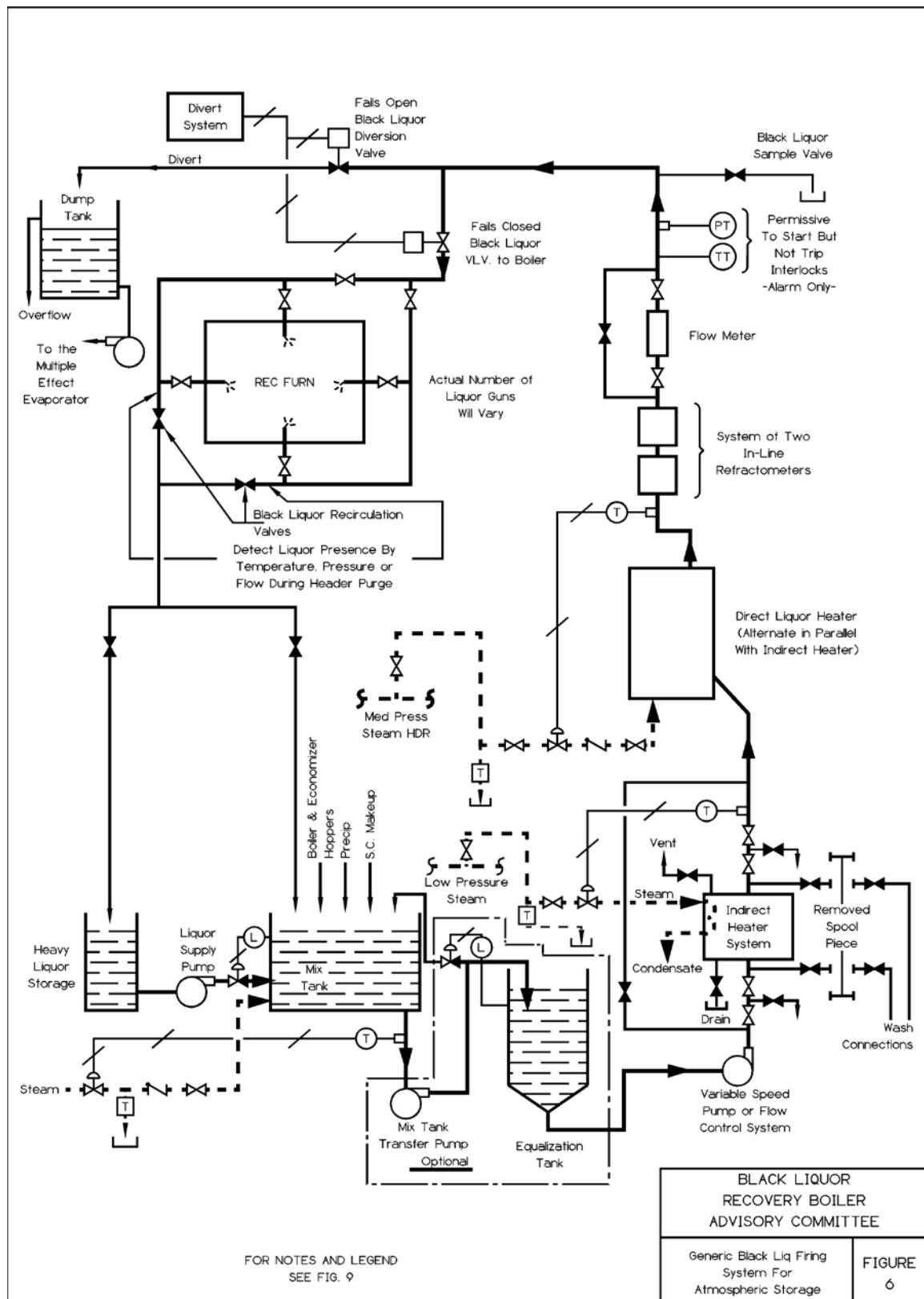


Fig. 6. Generic Black Liquor Firing System for Atmospheric Storage

Fig. 7. Generic Black Liquor Firing System for Pressurized Storage

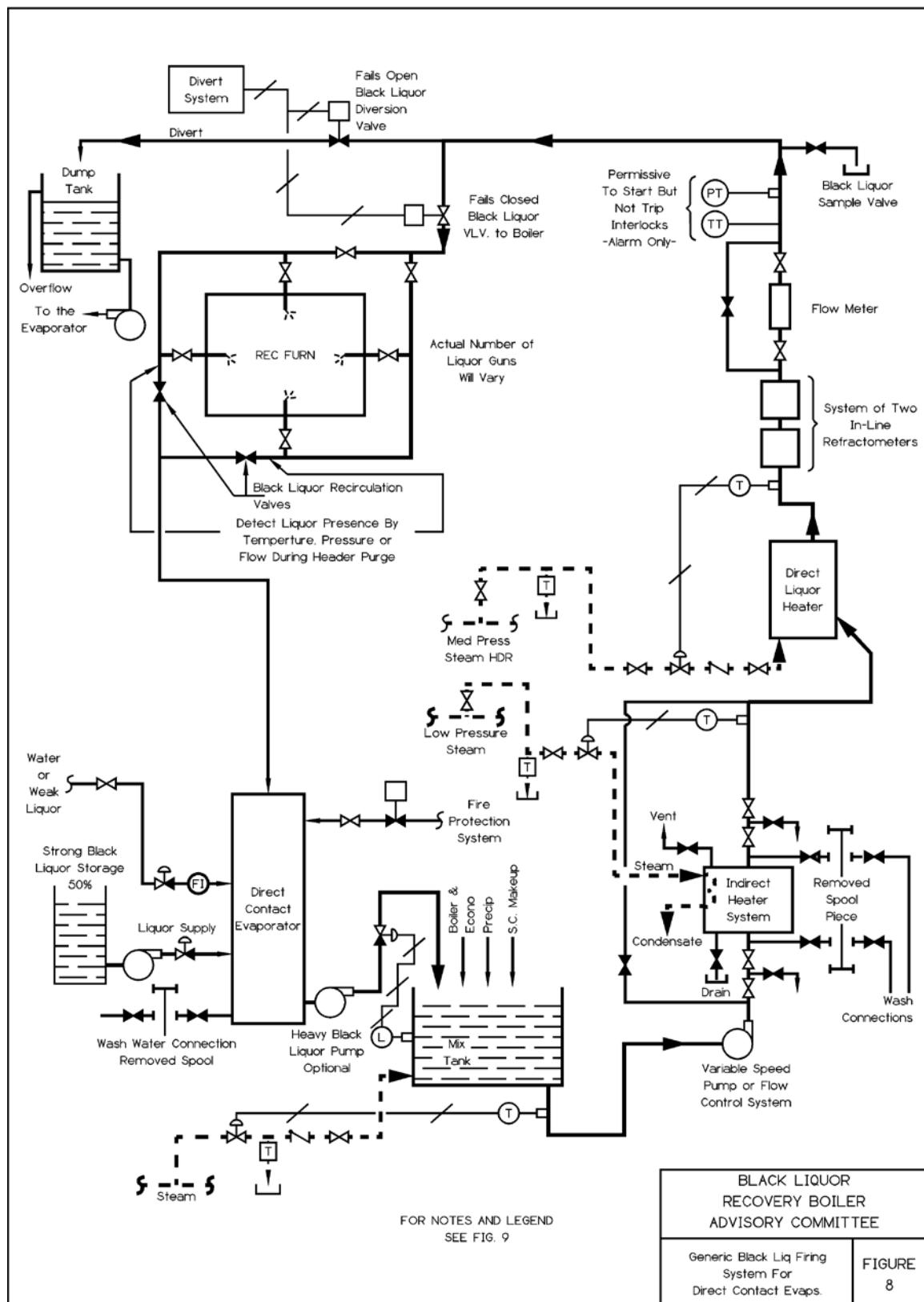


Fig. 8. Generic Black Liquor Firing System for Direct Contact Evaporators

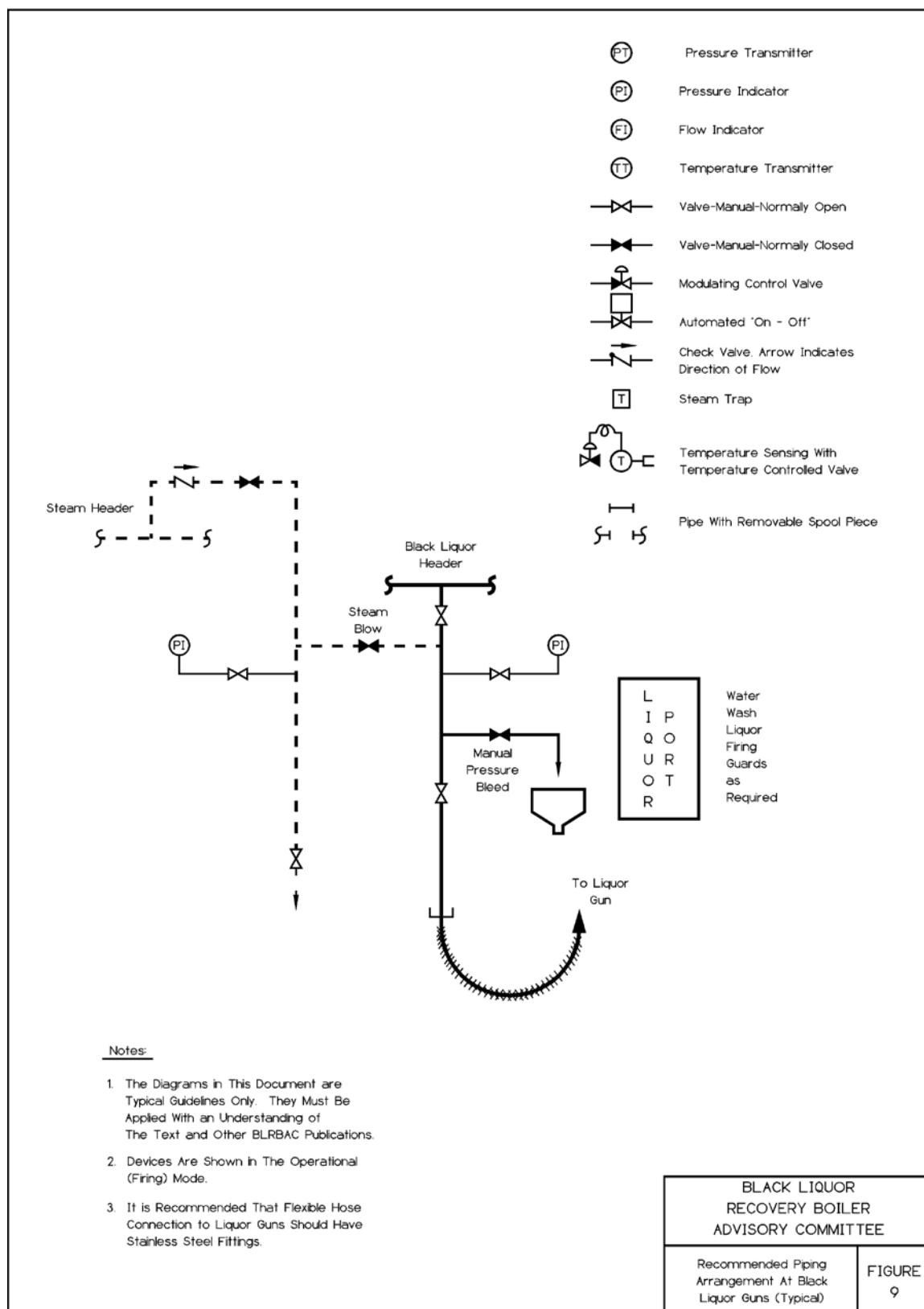


Fig. 9. Recommended Piping Arrangement at Black Liquor Guns

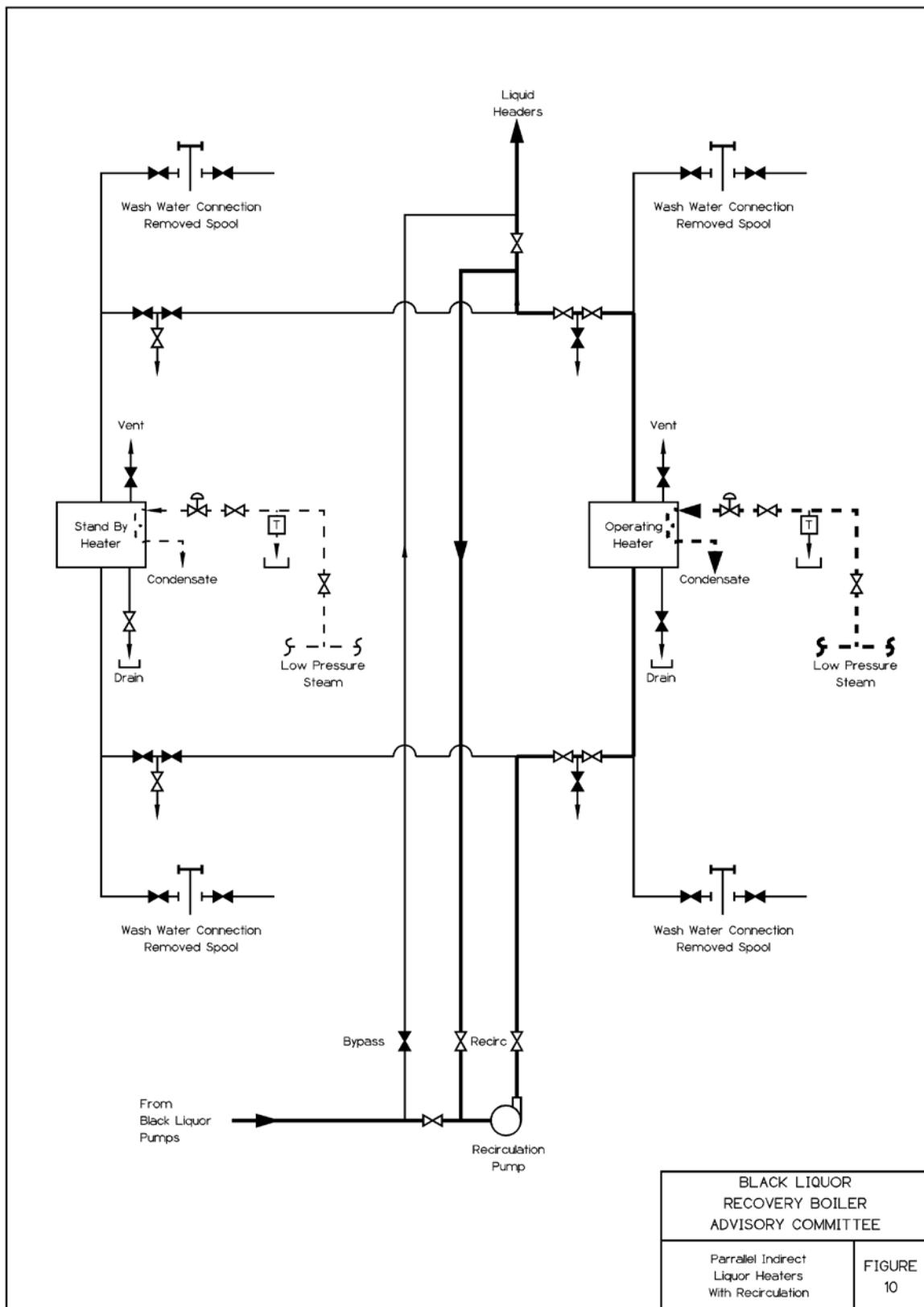


Fig. 10. Parallel Indirect Liquor Heaters with Recirculation

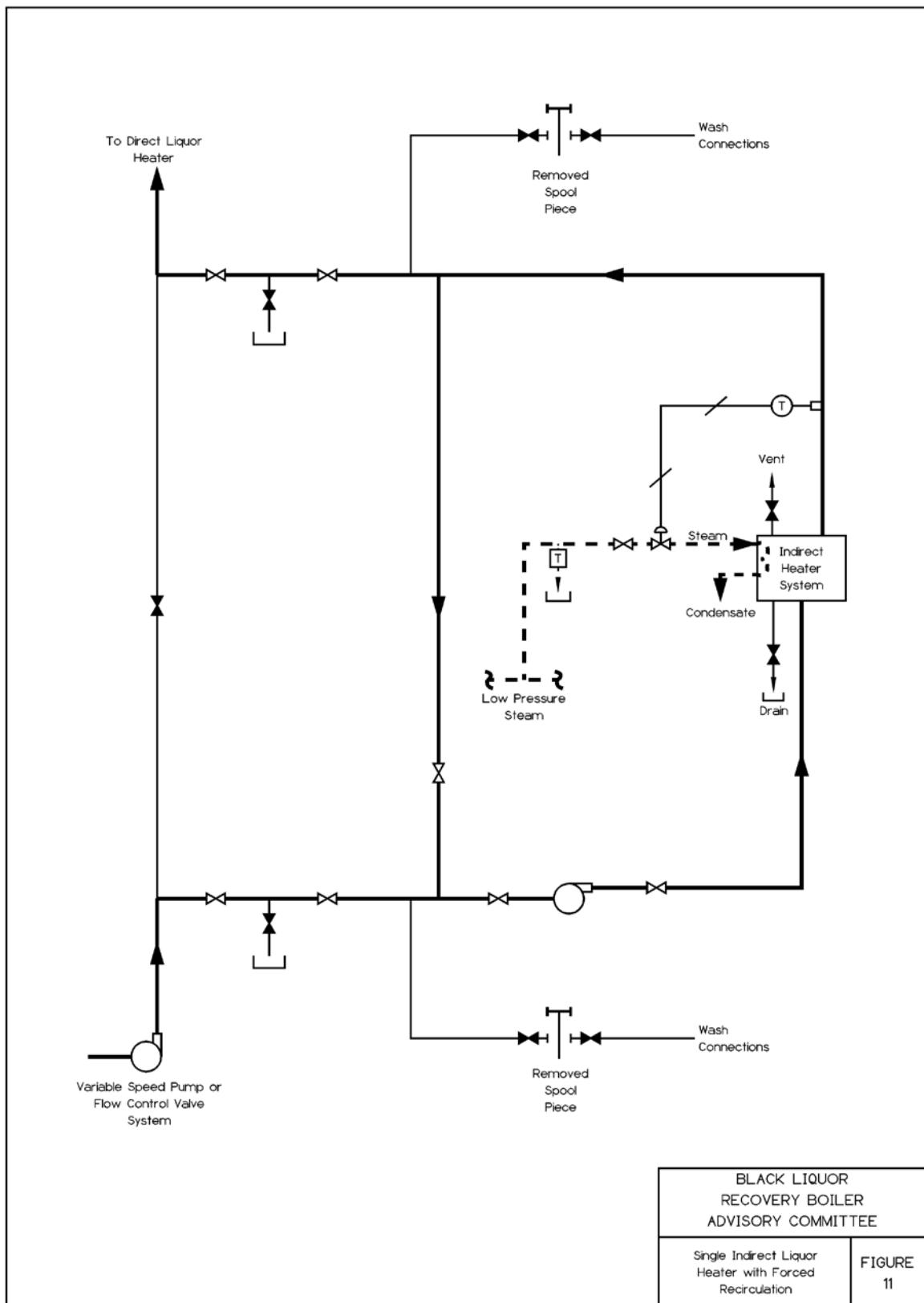


Fig. 11. Single Indirect Liquor Heater with Forced Recirculation

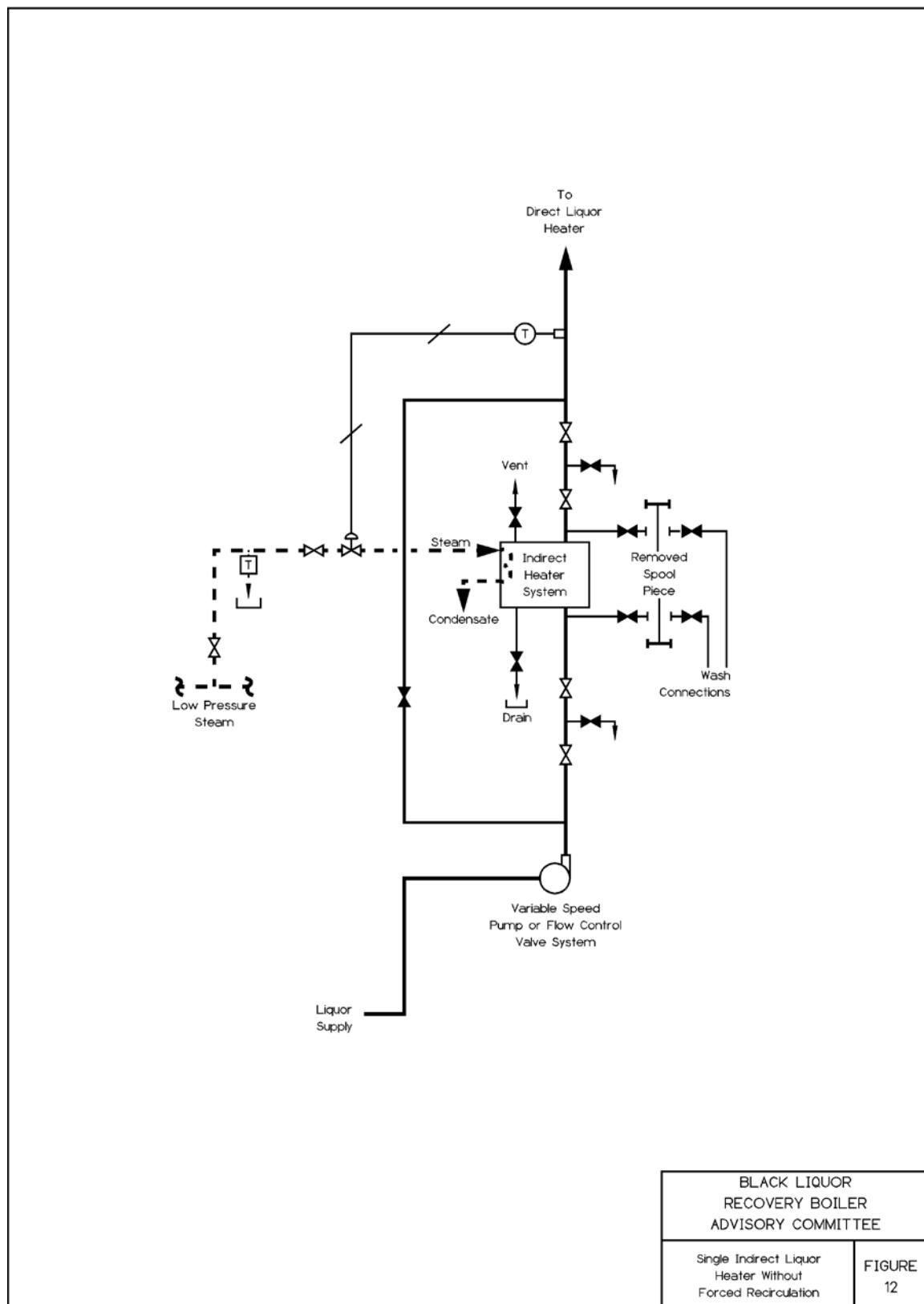


Fig. 12. Single Indirect Liquor Heater without Forced Recirculation

## **CHAPTER 6 OFF-LINE BLACK LIQUOR SOLIDS MEASUREMENT (LABORATORY AND FIELD TECHNIQUES)**

### *6.1 Purpose*

The procedures and interlocks described in this recommended good practice take action to remove black liquor from the furnace or prevent its introduction if the liquor solids fall below a predetermined, absolute value (58%). The reference method for determining absolute values for black liquor solids is the TAPPI Standard Method, T650-om-05.

Actions taken to prevent low solids black liquor from entering the recovery furnace are based on readings from continuous recording black liquor solids monitors (normally referred to as refractometers). These continuous monitors measure a property of the black liquor (e.g. refractive index) that is proportional to the dissolved black liquor solids content. In order to convert the continuous solids monitor reading to an absolute basis, it is necessary to calibrate the continuous solids monitor with respect to T650- om-99. T650-om-05 is a laboratory method. It is time consuming and requires skilled laboratory techniques. The recommended practice is to verify the continuous solids monitor reading through periodic, off-line field tests. The field test measurement technique, in turn, should be checked against T650-om-05 at least once per week.

This chapter discusses off-line black liquor solids measurement and makes recommendations as to how this should be carried out. Correct procedures for both collection of samples and sampling techniques are essential for good results. Both of these are discussed in this chapter.

### *6.2 Sampling*

It is essential that the black liquor sample is representative of the black liquor that is being fired into the furnace and that is being measured by the continuous solids monitor. The sampling location should be on the line to the furnace header or on the header itself. There should be no sources of dilution or chemical addition downstream of the sampling point. Use of liquor samples from other locations (such as the cascade flow box), chosen for convenience, can give erroneous results.

The black liquor sample will be under some pressure and could be at a temperature above the boiling point. Precautions need to be taken to deal with the possibility that the liquor may flash. Flashing could result in spattering of hot black liquor and will cause some evaporation of water (and an erroneously high solids content). If flashing is excessive, it may be necessary to cool the sample or use a pre-dilution technique that will be described later. In all cases, the sample line must be adequately flushed before taking a sample for analysis.

Field solids measurements should be made as soon as possible after the sample is taken. Firing strength black liquor normally contains suspended solids that are insoluble at that

concentration. These particles can settle rather quickly in hot black liquor and are difficult to re-suspend uniformly once they have settled out. The sample of black liquor should be stirred just prior to removal of a small representative portion for testing. The black liquor sample should not be allowed to cool below 140°F (60°C) before the test portion is taken since suspended saltcake particles can absorb moisture from the liquor on cooling and form large hydrate crystals that are difficult to disperse. In low-odor units without direct contact evaporators, the black liquor sample should be kept closed. This will minimize contact with air which could oxidize some of the sulfide in the liquor and give an erroneously high solids value. One convenient sampling container is a pint-size, screw-capped, wide-mouth, vacuum-jacketed bottle.

Special precautions need to be taken for the laboratory T650-om-05 sample. The relatively long time involved before the measurement is made will lead to extensive settling of un-dissolved solids. It is recommended that the pre-dilution technique be used in taking this sample. After flushing the sample line, about 200 ml of heavy black liquor is drawn into a tared (weighed) sample bottle of at least 400 ml volume. A second weighing establishes the liquor sample weight. The sample can then be diluted with a known amount of water to a working concentration in the 30-40% solids range where all liquor constituents are soluble. The solids concentration in the original undiluted liquor can be calculated from that measured in the diluted sample using the formula given in T650-om-05.

### *6.3 Off-Line Field Measurement Techniques*

There are a number of solids measurement techniques that are reasonably straightforward and suitable for field use. A partial listing includes:

moisture balances,	-Acceptable
microwave oven drying,	-Acceptable
density (Baumé) readings	<b>not recommended</b>
hand held refractometers	<b>not recommended</b>

All of these methods are procedure dependent. The accuracy and repeatability of results depends strongly on small (but important) details of the equipment and procedures used. Frequently, the absolute value of the solids obtained will vary with the operator running the test regardless of the analytical equipment being used. It is important to have written black liquor solids test procedures that are accurate and are consistently followed to produce repeatable operator solids test results. For best results, post the test procedure at the operator test station and perform periodic audits of the test procedure as compared to the laboratory T650-om-05 test.

Moisture balances are probably the most common method for field solids testing. Moisture balance results can give variable results based on the age or brand of infrared bulb used, the height of the heating element above the sample, the amount of sample used, and the distribution of the sample on the sample pan. In recent years, automated

moisture balances have become available and help to take some of the variation out of field solids measurements.

Experience has shown that microwave oven drying can give variable results with black liquor. Overheating of samples can result in pyrolysis of liquor organics and erroneously low values for the measured solids. Microwave fields in most ovens are not uniform and the heat absorbed by the sample may depend on its exact position and orientation in the oven.

Specific gravity (Baumé) readings are not recommended for making calibration adjustments to continuous solids monitors. This technique measures the specific gravity on a pre-diluted sample of firing strength black liquor and uses a conversion chart to determine the percent solids. This is not a direct measurement of solids content. The Baumé vs. solids curve is dependent on liquor composition. Experience has shown that this method lacks the accuracy of other methods when applied to a wide variety of black liquors and liquors subject to changes in makeup rate, recycled dust load, and chemical addition rates.

Hand-held refractometers are also not recommended for making calibration adjustments to continuous solids monitors, especially if the continuous device is also a refractometer. The field test should provide a cross-check on the continuous device and should be a direct measurement of the solids content, not a measure of a property that depends on solids content. Refractive index depends on liquor composition as well as solids content and does not respond to the suspended solids that would be present in firing strength black liquor. For these reasons, confirmation by direct solids measurement is needed.

Moisture balance techniques and microwave testing are both reliable methods for field solids measurement but it is necessary to recognize that the values obtained can be dependent on procedural details. These details need to be standardized as much as possible. It is recommended that a standard, detailed solids testing method be written up for each recovery unit and a copy posted at the testing station. The procedure should specify the liquor sampling point, treatment of the sample before weighing, sample size, and all equipment parameters found to influence the result.

### 6.3.1 Testing Black Liquor Solids

**During start up, at least one operator off-line solids test shall be performed immediately prior to firing black liquor to confirm solids are above 58% and the refractometers are reading correctly. These test results must be recorded.** The sampling location should be on the line to the furnace header or on the header itself. There should be no sources of dilution or chemical addition downstream of the sampling point. Use of liquor samples from other locations (such as the cascade flow box), chosen for convenience, can give erroneous results.

#### *6.4 General Comments*

Field solids measurements should be made at regular, frequent intervals. During start-up and periods of upset, more frequent field testing is recommended.

- Boilers with an as-fired solids less than or equal to 70% BLS:
  - Every two hours is a recommended minimum frequency during normal operation.
- Boilers firing Black Liquor solids greater than 70% BLS:
  - Manually test the black liquor solids a minimum of every eight (8) hours if the following conditions are met:
    - The refractometers must be within 2%.
    - The boiler must be in an established stable firing condition.
    - The weekly TAPPI test procedures must be in agreement with the refractometers.
    - The low solids divert should be increased to 62% BLS.
    - An audible alarm should sound if the solids drop to 70% solids or below.
    - If the Black Liquor solids drop to 70% or below the two hour testing frequency shall be resumed.

All solids measurement methods should be checked against the TAPPI Standard, T650-om-05, on a regular basis. Once per week is a recommended minimum frequency.

Refractometers do not see suspended solids while direct solids measurements do include them. The liquor composition should be as stable and representative as possible when taking samples for off-line solids measurement. There should be no deliberate changes in salt cake makeup, or chemical addition when the refractometer is being checked against an off-line measurement.

## **CHAPTER 7 BLACK LIQUOR FIRING**

It has previously been established that the proper use and maintenance of a correctly designed and installed black liquor interlock system will prohibit low solids liquor from reaching the furnace and possibly causing an explosion. While such a system is undoubtedly the final safety measure, it should not be construed as a substitute for proper operation of the liquor firing system. With adequate knowledge of the system good training and foresight, the hazardous condition requiring the use of the automatic divert system may be avoided or eliminated.

For recovery boilers with direct contact evaporators, an additional degree of security can be achieved by installing a storage tank between the direct contact evaporator and the saltcake mix tank. The volume of this tank will average out changes in the solids content of the black liquor going to the furnace and thus provide additional time to correct a condition that might otherwise cause an automatic divert of the black liquor.

A thorough understanding of the total system, from the multiple effect evaporators (or concentrators) to the boiler, including the normal operating flow rates, temperatures, pressures, etc., will help to minimize hazardous conditions from occurring within the system and the necessity for using the automatic divert system. Obviously, good operator training plays an important role in this area, and instrumentation must be in good condition and calibration.

The source of black liquor to the recovery boiler is from either multiple effect evaporators or concentrators. Any one or a combination of incoming dilutents may reduce black liquor solids concentration, for example: (See Figures 6 - 11)

1. Low solids to or from the multiple effect evaporators or concentrators.
2. Cascade or cyclone evaporator dilution.
3. Gland seal water on pumps.
4. In-line direct black liquor heaters.
5. Leaking wash lines into liquor header(s).
6. Steam-out connections.
7. Steam and/or condensate

These upsets are gradual in nature rather than instantaneous. Since this is true, it is possible to gather trend information from operating charts which can give advance information about impending problems and allow the operator to take corrective action. As the solids drop, steam flow will drop a proportionate amount, excess O<sub>2</sub> will rise and the unit will develop a tendency to black out.

Table 6 is a tabulation of dilution sources, detection systems, corrective actions, and recommendations to avoid exposure.

**Table 6. Tabulation of Dilution Sources, Detection Systems, Corrective Actions and Recommendations**

<b>Dilution Source</b>	<b>Detection System</b>	<b>Corrective Action</b>	<b>Recommendation to Avoid Exposure</b>
1. Low solids from concentrators and evaporators	Refractometer	Correct Operating problem.	None
2. Leaking storage tank heaters	Refractometer	Valve off Heaters.	Use external heaters "only".
3. Dilution by spent acid stream or other chemicals (if used)	Refractometer	Correct ratio of stream to liquor flow.	<ul style="list-style-type: none"> <li>a) System should be designed to provide flow ratio control.</li> <li>b) Proper mixing system to avoid precipitation of solids.</li> <li>c) No aqueous stream added downstream of heavy storage tank or directly introduced into furnace.</li> </ul>
4. Returning wash water to storage	Refractometer	Shut-off source of dilution.	Remove all wash water connections from heavy storage tank.
5. Overflowing high level precipitator during water wash	Refractometer	Shut-off wash water or overflow.	Overflows should be routed to dump tank.
6. Pump gland seal water – operating and shutdown	Refractometer	Proper operating procedures. Shut-off flow during shutdown.	<ul style="list-style-type: none"> <li>a) Use mechanical seals.</li> <li>b) Proper operating procedures.</li> </ul>
7. Precipitator (wet bottom) left with wash water not drained	<ul style="list-style-type: none"> <li>a) Refractometer</li> <li>b) Low power to agitator drive.</li> </ul>	Proper operating procedure to assure bottom drained.	None
8. Steam out lines condensate	Refractometer	Proper operation & maintenance	<ul style="list-style-type: none"> <li>a) Double block and bleed valving</li> <li>b) Proper piping design, etc.</li> </ul>
9. Mix tank & inline direct liquor heater	Refractometer	<ul style="list-style-type: none"> <li>a) Proper operation.</li> <li>b) Maintenance of traps.</li> </ul>	Proper piping configuration to avoid introducing condensate or water into steam system.
10. Leaking tubes in indirect liquor heater or wash water	Refractometer	Shut steam off heater.	<ul style="list-style-type: none"> <li>a) Proper piping configuration to provide off-line washing.</li> <li>b) Proper trap system with atmospheric (open) blow off.</li> </ul>
11. Wash water in liquor header	None	<ul style="list-style-type: none"> <li>a) Take liquor guns out of furnace.</li> <li>b) Establish recirculation flow.</li> </ul>	Interlocks to ensure recirculation and drainage of wash water and purge header.
12. Boiler water leaks into boiler & economizer hoppers.	<ul style="list-style-type: none"> <li>a) Refractometer</li> <li>b) Audible &amp; Visual</li> </ul>	Shut boiler down	<ul style="list-style-type: none"> <li>a) Maintenance</li> <li>b) Water Treatment</li> <li>c) Inspection</li> </ul>
13. Cascade dilution make up	<ul style="list-style-type: none"> <li>a) Refractometer</li> <li>b) Power consumption</li> </ul>	Adjust dilution.	Monitor flow & indicate.
14. Wash water in cascade evaporator	<ul style="list-style-type: none"> <li>a) Refractometer</li> <li>b) Power consumption</li> </ul>	Shut off water and drain.	Install a removable spool piece in wash connection.
15. Direct Contact Evaporator fire protection water system (if used)	Refractometer	Shut-off fire system.	Use steam/water as BLRBAC recommends.
16. Cyclone dilution makeup	Refractometer	Adjust dilution flow.	Monitor flow.
17. Precipitator during water wash	Refractometer	Ensure overflow is open to drain.	Monitor wash conditions.
18. Condensate in auxiliary steam heater	Refractometer	Shut off steam.	<ul style="list-style-type: none"> <li>a) Proper piping configuration</li> <li>b) Proper maintenance</li> </ul>
19. Wash water system for cyclone upper umbrella	Refractometer	Shut off wash water and drain.	Use removable spool piece.

## **CHAPTER 8 BLACK LIQUOR AND WATER PIPING SYSTEMS**

As the basic requirement to ensure good practice in the piping aspects of black liquor handling, each mill shall prepare and maintain updated black liquor flow schematics for each boiler. The schematics and piping layout drawings should be accurate and complete in every detail, showing location of valve stations and equipment, and all connections. Relevant operating information should be included. These drawings will provide the basis for system analysis, technical upgrading and hazards evaluation.

All subsequent changes to the system shall comply with these Good Practices, authorized by at least the department superintendent and recorded on all appropriate drawings. A hazard evaluation shall be made prior to any system changes.

Physical design of piping, such as sizing, materials, etc., can be determined by qualified designers, by references to mill, and industry experience and good practices.

Certain fundamental procedures, however, are recommended to achieve a safer system.

The procedures required to ensure a safe black liquor system are dependent upon the location of the dilution source connections.

Dilution sources may be permanently connected to the black liquor system up to and including the last tank which feeds the suction line of the black liquor furnace feed pump(s). The main black liquor dilution source to the direct contact evaporators, usually consisting of continuously available water or weak black liquor through permanent connections, shall be flow monitored with flow indicators at the operators' station.

The requirements for connecting dilution sources from the last tank to the refractometer shall be as follows:

1. Operating water sources which conceivably could dilute the heavy black liquor shall be connected to the black liquor system with strict adherence to safe piping and valving practices, proper trapping, drainage and control of flow quantity. This category would generally include auxiliary services, such as steam for liquor heaters and gland seal water.

Standby liquor pumps shall be drained and left open to prevent accumulating condensate or gland water. Operating procedures should verify that the standby pumps are free of dilutents before placing in service.

2. Non-operating dilution sources shall not be connected to the black liquor system directly or permanently. These sources consist primarily of water or weak black liquor used for washing out the system. The recommended connections for these fluids are quick disconnect fittings or removable spool piece. These connections shall be monitored and interlocked using valving position switches or equivalent

devices to divert heavy black liquor from the recovery boiler furnace when they are in use.

As an exception to this, black liquor equipment, such as indirect heaters that require routine washing while the boiler is burning liquor, should be isolated from the liquor lines with “double block and bleed” valving or removable spool pieces. The wash connections should be quick disconnect or removable spool pieces. Extreme care should be taken under these conditions to insure that the equipment can be properly drained; idle equipment should be left with the drains open. Refer to Figure 10 for details.

There shall be no fixed piping dilution source connections after the refractometer(s).

The following additional items of recommended piping practices are intended to assist the recovery boiler owner, operator, and designer:

1. Elevated equipment, such as precipitators, mix tanks, and cascades that can be isolated and washed while the boiler is in service, shall be arranged so as not to overflow into the operating liquor system. Drains and overflows shall be connected to dump tanks.
2. Steam-out supply lines shall not originate from the bottom of the steam supply main and shall be fitted with double block and bleed valving for positive shutoff and draining of the line before each use. The steam supply main must be correctly pitched and adequately trapped to remove condensate.
3. Black liquor valving shall be close-coupled at piping mains and at equipment to minimize dead-ending and pluggage.
4. Avoid low points, particularly at valve stations, which can result in restrictions due to black liquor solids deposits.
5. Each boiler’s black liquor header system shall have its own separate recirculation or return line.
6. Black liquor valving shall be readily discernible for open and closed positions.
7. Steam-out piping and its connection to the black liquor piping shall be insulated, and fitted with a double valve and free-blow to purge the steam supply of accumulated condensate before introducing steam into the liquor lines.
8. Black liquor distribution piping, particularly heavy liquor at the furnace header, shall be as symmetrical as possible to equalize flows and pressures for multiple liquor gun boilers.

9. Provide a bleed valve between liquor-firing nozzle and the liquor supply valve to relieve residual pressure. This valve should be opened prior to breaking the hose connection at the liquor gun.
10. Direct mixing of water and steam, such as direct water heaters, shall be designed with due attention to pressure difference and proper valving to prevent the back-up of water into the steam lines and subsequently into black liquor system by way of a direct liquor heater.
11. The black liquor piping arrangement should be similar to that shown in Figures 6 to 12.
12. Length of piping from liquor supply valve to liquor gun should be minimized to facilitate proper purge.
13. Manual valves in the Black Liquor Divert system piping should be secured in the open position prior to and during liquor firing. These valves should be part of a managed system.
14. Use of a Keyed interlock switch for the Lower Furnace Water Wash (Refer to Figure 3): During water washing of a recovery boiler, many mills use the liquor guns to aid in washing the fireside of the lower furnace. In order to run water through the liquor guns and into the furnace, several safety features will have to be defeated. This creates the potential for a smelt water explosion should the defeat be inadvertently left in place or the defeat be installed before the bed has cooled to a safe condition. In order to wash the furnace with water through the liquor guns, the refractometers must be bypassed with the header valve open and the divert valve closed.

To conduct a water wash through the liquor guns the following permissives should be met as a minimum before allowing the divert valve to close and the header valve to open while the system is in a low solids liquor divert signaling condition (refer to Figure 3):

- a. No ESP
- b. No FD fans running
- c. Sootblower water wash spool in place position switch
- d. Safe furnace bed temperature as determined by knowledgeable individual such as the recovery boiler superintendent. Ensuring the bed is cooled can be accomplished in many ways. The preferred method is to probe the bed with thermocouples to measure the temperature throughout all areas of the bed. A formal written procedure (SOP) for determining the bed is at a safe temperature should be available at the mill and be followed at all times. Once it is determined the bed is cooled sufficiently the keyed furnace wash switch can then be operated.
- e. Furnace wash switch in “wash” or “furnace wash” position.
- f. Black liquor header wash position switch in “wash” position.

## **CHAPTER 9 SMELT SPOUTS**

This chapter provides recommendations for proper smelt spout cooling system design, operation, and maintenance.

The smelt spout represents a potential source for the accidental introduction of cooling water into the furnace:

1. Smelt spout cooling water leaks may put water directly into the furnace or the smelt stream.
2. Using a rodding bar carelessly to open a plugged spout may result in furnace tube wall failures.
3. Lack of maintenance in the smelt spout area may contribute to smelt, green liquor, or weak wash leaks which in turn may cause tube wall wastage or failures.

### *9.1 Water Cooled Spouts*

Treated water is the only accepted cooling medium for use in the spout water system. Back-up systems for spout cooling must be water sources only.

#### **9.1.1 Cooling Water**

One of the most important factors in the safe and efficient operation of a water cooled smelt spout system design is the condition of the spout cooling water. Four vital aspects of the cooling water are:

1. **Quality:** Because of the severe service the smelt spouts endure (very high heat absorption rates -- much more than furnace wall tubes; high temperature differential, corrosion and erosion) the cooling water must be of high quality. It must be demineralized water, steam condensate, or equivalent. The water should be chemically treated, and monitored to minimize corrosion and deposition. Use of anything less may lead to fouling, oxygen corrosion, or deposits within the water jacket which will decrease heat transfer. Overheating and resultant leaks may occur.
2. **Temperature:** The smelt spout cooling water shall be maintained per the manufacturer's recommendations (approximately 140 -150° F inlet temperature and a maximum of 180°F outlet temperature).

It is important to maintain the proper temperature of the inlet water to minimize condensation on the spout(s). Too low a smelt spout cooling water temperature may result in condensate droplets on the sides of the spout(s) coming into contact with the exiting smelt flow. There is chance that spattering of smelt will occur

from contact with condensation that may cause or aggravate buildup in the spout housing. The spattering could also cause personnel injury. There is chance of formation of acids that can occur in this humid atmosphere associated with low spout cooling water supply temperatures.

Higher than normal spout cooling water temperatures can contribute to steaming in the spouts should unexpected and excessive smelt flow be experienced in a spout(s). Steaming in spouts can lead to spout cooling water flow interruption which in turn can severely overheat and damage spouts.

Each spout cooling water discharge line should be equipped with a direct reading temperature indicator and with a temperature-measuring element with an audible and visual alarm in the temperature range as specified by the manufacturer (approximately 185-200°F.). It should be noted on vacuum systems, the alarm point must be checked against the actual boiling point of the water at the measured spout discharge pressure, to ensure adequate margin is provided.

3. **Flow:** The spout cooling water system must be designed to provide the cooling water flow specified by the manufacturer. Low flow could lead to overheating and eventual failure of the spout. A flow measuring element with a low flow alarm shall be installed on the discharge line from each smelt spout. It should alarm at a minimum flow recommended by the manufacturer.
4. **Pressure:** The pressure at the inlet of the spout should be as low as possible and consistent with delivering recommended flow. The pressure should be minimized by not exceeding the recommended maximum flow and by minimizing restrictions and line losses downstream of the spout. Lower water pressure at the spout inlet will reduce the quantity of water which could enter the furnace in the event of a spout leak.

#### 9.1.2 System Design Criteria

Both low pressure and vacuum or siphon systems can be used for providing the proper cooling of the smelt spouts. The following design criteria should be followed for both type systems (refer to Figures 13, 14, and 15):

1. The systems shall be closed loop with high quality treated water and designed to provide adequate cooling while minimizing corrosion. However, once-through systems utilizing demineralized water or condensate of the proper temperature may be used provided they are designed to meet the intent of the design criteria in this chapter. Since once-through systems are generally pumped instead of gravity head tank systems, design precautions must be taken to positively limit the cooling water pressure to the spouts.

In addition, consideration should be given to providing adequate cooling water flow to the spouts during a total power outage when smelt flow would continue even though fuel firing is interrupted.

2. An emergency water supply is recommended. This emergency cooling water should be supplied to the inlet side of each spout or to an appropriate supply tank depending on the type or configuration of the cooling system. The activation of this water source should be initiated automatically by the low supply tank level or low system supply pressure, and be alarmed when activated.
3. The emergency water should be provided from a source available during periods of electric power outages.
4. Loss of any operating smelt spout cooling water pump should be alarmed.
5. Each spout discharge should be equipped with a direct reading temperature indicator, a high temperature alarm, a low cooling water flow alarm, and a local flow indicator. A local flow indicator may be installed upstream of each spout as long as there is a low flow alarm on the down stream side.
6. Satisfactory spout cooling water flow permissive start interlock is required.
7. The cooling water tank level should be controlled with makeup of demineralized water or steam condensate and provided with an alarm for low level.
8. In most systems a cooling water heat exchanger will be required to maintain the spout manufacturer's cooling water inlet temperatures.
9. Isolation valves should be provided at a safe location for each spout inlet. These isolation valves should be CLEARLY identified for EACH spout to prevent the inadvertent isolation of the cooling water to the wrong spout during an emergency situation.
10. Any new spouts to be installed on recovery boilers should clearly state the inlet and outlet connections on the spout.
11. **IMPORTANT** - To insure that the smelt spout cooling water system performance can be maintained, any changes should be made by or in consultation with the cooling water system designer.

#### 9.1.3 Pressurized Systems

(Refer to Figure 13)

The spout cooling water discharge may be piped to an optional overflow funnel arrangement, located so that operators can quickly and conveniently check for flow

through each spout. The system should be designed to prevent foreign debris from entering the system.

There should not be any valves in the cooling water outlet piping downstream of the spouts in pressurized systems.

The use of threaded piping, fittings, and valves should be minimized inside doghouses and/or mini-hoods to reduce the potential for leaks which could introduce water into the smelt stream or into the furnace proper.

There have been incidents in the industry where a suspected leak has occurred in the spout or spout piping. The operators reacted appropriately by securing the cooling water to the spout in question and observing the leak to continue for several minutes. This led the operators to believe there was a pressure part leak and a subsequent ESP followed. Upon inspection there were no pressure part leaks, but a very small leak in the spout jacket caused by a weld defect. What was learned with these incidents was that operators need to be aware that in the case of a small spout cooling water leak, water from the outlet of the spout can back flow into the leak if the cooling water piping is arranged such that the water flows up to an observation funnel. In these cases, the operator training program and procedures should outline the possibility of this occurring on their system.

#### 9.1.4 Vacuum Systems

(Refer to Figures 14 and 15)

Most recovery boiler manufacturers can also provide vacuum type smelt spout cooling water systems which further reduce the possibility of cooling water from a spout leak coming into contact with smelt. These systems are designed to provide a slightly negative pressure within the spout cooling water jacket. A small spout leak would therefore leak into the jacket.

Some designs require valving on the spout discharge to establish the vacuum or create the initial siphon effect. These valves should be locked or secured in position to prevent an inadvertent adjustment and improper cooling water flow.

The use of threaded piping, fittings, and valves should be minimized to reduce the potential for leaks which could reduce the vacuum, possibly affecting the cooling water flow.

The installation of a conductivity sensor with alarm at an individual spout outlet or at a common point in the vacuum cooling water system can be helpful in the early detection of a spout leak, since the initial stages of a spout leak could allow small amounts of smelt to leak into the spout, slightly contaminating the purity of the cooling water prior to the leak becoming large enough to “break” the vacuum or siphon interrupting cooling water flow to the affected spout.

Transfer or recirculating pumps used within the vacuum cooling water systems should be arranged in a dual redundant manner. The pump controls should be configured to automatically start the standby pump in the event of loss of the primary pump.

The system pressure drop should be minimized. As the pressure drop increases, the boiling temperature of the water drops significantly. Steaming in the spout can severely disrupt cooling water flow.

#### 9.1.5 Operation

##### 1. Smelt Spout Leaks or Flow Interruptions

Smelt spout leaks may occur because of a loss of cooling water flow, excessive wear of the trough, spout defect, improper installation or maintenance. Recovery boiler operating personnel must be trained to recognize a spout leak. When a leak occurs and has been positively identified as a smelt spout cooling water leak, isolate the water to the leaking spout by closing and locking out the inlet cooling water supply valve.

If cooling water flow to a smelt spout is interrupted for any reason, **DO NOT ATTEMPT TO RESTORE COOLING WATER FLOW**. If the spout is required for boiler operation, the boiler must be taken off line and the spout replaced. If the spout is not required, the opening should be securely plugged before operation is resumed. The plugging technique should ensure that the opening will remain closed until the next scheduled outage at which time the spout can be replaced.

##### 2. System Alarms

Operators must immediately investigate and rectify the cause for any of the system alarms:

	<u>Audible</u>	<u>Indicator</u>
1. Emergency water makeup on	X	X
2. Loss of any spout cooling water pump	X	X
3. High spout cooling water outlet temperature	X	X(local)
4. Low spout cooling water outlet flow	X	X(local)
5. High cooling water conductivity		(Optional)

#### 9.1.6 Maintenance and Inspection

Inspect the smelt spouts during every scheduled outage. If a spout fails an inspection, replace it. All spouts should be replaced at least once a year with a new spout.

Replacement spouts should be field hydro tested to manufacturer's specifications prior to use. **NEVER REBUILD, REPAIR OR MODIFY A SMELT SPOUT!**

Each year, cut up at least one removed smelt spout. Inspect the cooling water jacket internals to ensure adequacy of the cooling water quality and the corrosion/deposition control program. Furthermore, a periodic inspection of sections of the cooling water piping should be made to ensure the absence of internal buildup or scale that could restrict cooling water flow. Sections of piping with scale or buildup should be replaced.

When replacing spouts with dual outlet connections (either right or left) care must be taken to ensure that the unused discharge connection is properly sealed.

Proper maintenance of and alignment between both the smelt spout and the smelt spout tube wall opening will help ensure problem free operation and will reduce smelt leak potential. The joint and seal between the smelt spout and spout tube wall opening must be properly maintained to reduce any potential for excessive spout water or smelt leakage. Contact the respective boiler manufacturer for proper repair and maintenance recommendations.

Both smelt spout cooling water head tanks and collection tanks should be inspected and cleaned annually.

#### *9.2 Non Water Cooled Spouts*

Some manufacturers fabricate and supply non water cooled spouts. Functionally, these spouts perform the same duty as water cooled spouts. As the name implies, this spout design eliminates the need for water or other fluids to cool or control the temperature of the spout during operation. These spouts eliminate the hazard of introducing cooling water into the furnace or into the smelt stream to the dissolving tank.

During start-up of the boiler, the initial temperature of the non water cooled spout may not be hot enough to prevent some freezing of the smelt. More frequent cleaning efforts may be required during this period of time, until a steady, unobstructed flow of smelt is attained. Once the metal temperature is up to normal operating levels, expected rodding requirements would be less than normal with this spout design. If the spouts do become plugged such that the smelt flow becomes significantly impeded, the spout should be mechanically cleaned to restore unobstructed flow. A plugged spout will increase the flow volume and velocity through the other unplugged spouts. This could potentially result in overflow and/or an increase in the wear-rate of the non water cooled spout material. (Refer to Chapter 10.1)

Non water cooled spouts should never be sprayed with water, hood wash, weak wash, etc. at any time the spout metal is above ambient temperature. Repeated contact with aqueous

solutions when the spout is at normal operating temperatures could cause the spout casting to crack due to thermal shock. The non water cooled spout casting and surrounding smelt spout enclosure should be cool enough for water washing following shutdown approximately four hours after smelt stops flowing from the spouts and boiler.

Caution should still be taken to avoid washing into the furnace when washing the non water cooled spouts and spout enclosures if smelt temperatures in the bed have not cooled below 800° F.

Adjustment of the individual steam shatter jets should be made as operation dictates.

Non water cooled spouts should be visually inspected in the trough, lip and beard during the boiler shutdown for excessive wear or cracking that could affect the integrity or service life of the spout. The refractory materials at the furnace opening for the spouts should also be inspected for excessive decay that may impact the seal at the tube opening as well as the potential wear to the spout, seal box or mounting plate.

When installing replacement non water cooled spouts it is important to inspect the integrity and condition of the existing spout opening tubes, seal box and mounting sleeve.

Due to the higher operating temperatures, proper refractory materials must be used to ensure the refractory material performs for the life of the non water cooled spouts.

Proper maintenance of and alignment between both the smelt spout and the smelt spout tube wall opening will help ensure problem free operation and will reduce smelt leak potential. The joint and seal between the smelt spout and spout tube wall opening must be properly maintained to reduce any potential for excessive smelt leakage. Contact the respective boiler manufacturer for proper repair and maintenance recommendations.

The service life of the non water cooled spout is dependent on wear rates and may vary depending on the smelt conditions, black liquor loading and spout maintenance. The replacement cycle should be determined by the site-specific operating experience.

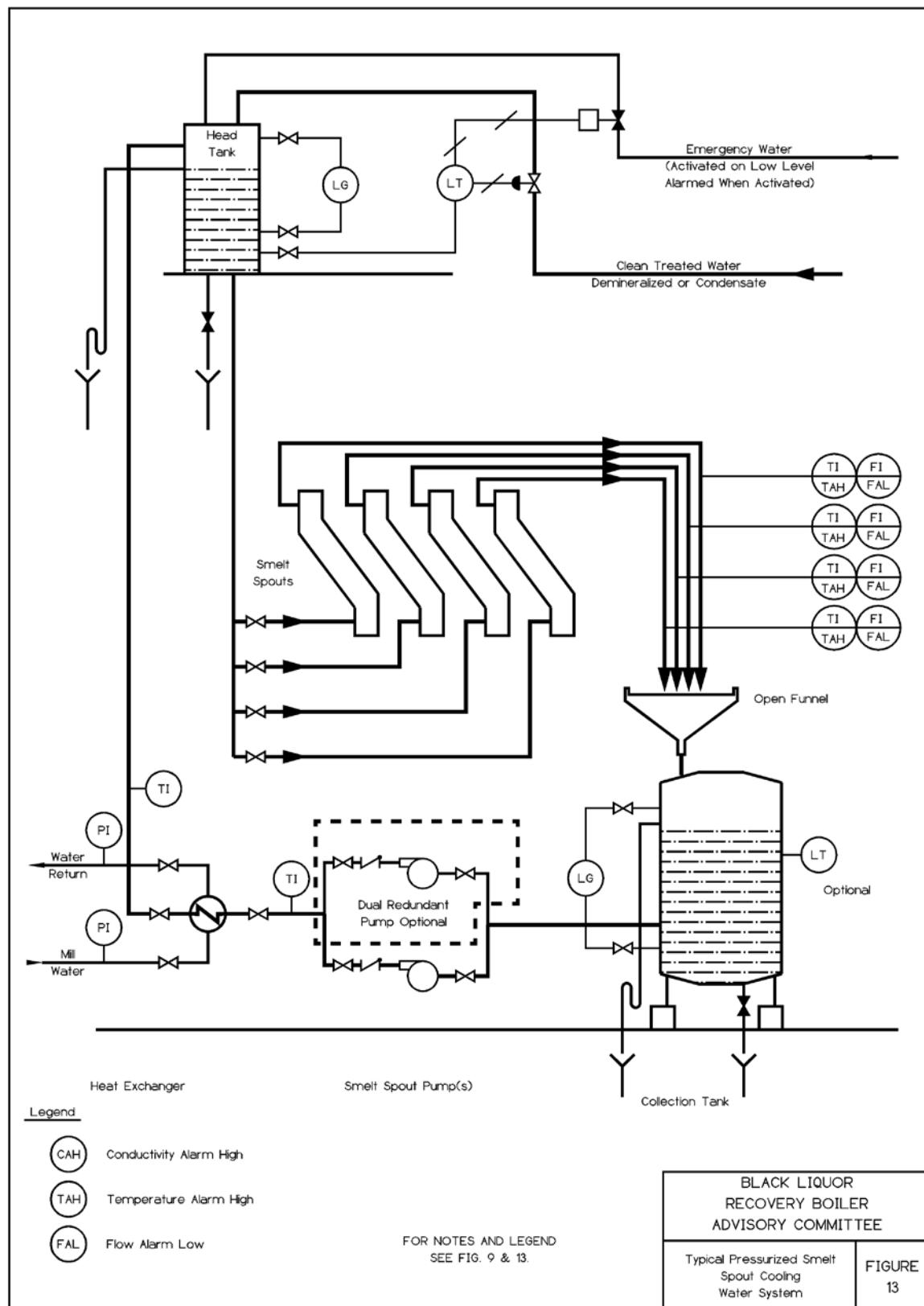


Fig. 13. Typical Pressurized Smelt Spout Cooling Water System.

Fig. 14. Typical Vacuum (Created by Tank and/or Piping Configuration) Smelt Spout Cooling Water System.

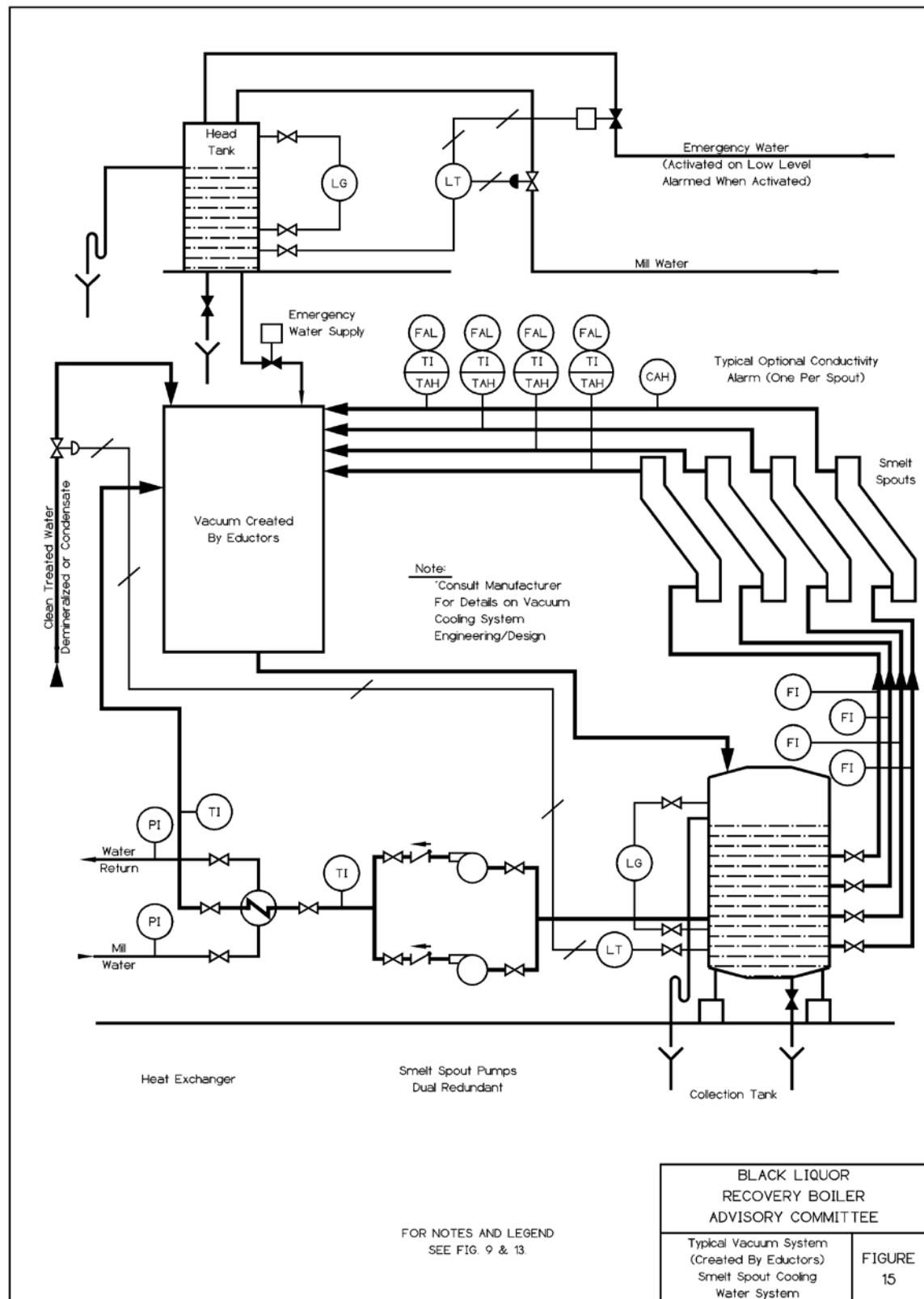


Fig. 15. Typical Vacuum System (Created by Eductors) Smelt Spout Cooling Water System.

## **CHAPTER 10 DISSOLVING TANKS**

This chapter provides recommendations for dissolving tank operation, troubleshooting plugged spouts, and alarming functions.

### *10.1 Plugged Spouts:*

Safety should be a top priority when dealing with plugged spouts. Face shield, long sleeves, “burn jackets”, coats, and leather gloves are examples of personal protective equipment that should be considered while on the spout deck. Care must be taken when working on clearing plugged spouts. Current and changing bed conditions (smelt pools, bed height, etc) need to be monitored while working on a plugged spout(s). The concern is a heavy and uncontrolled smelt runoff when the spout(s) begins to open that cannot be fully shattered, resulting in a potential dissolving tank explosion.

There are many operating scenarios in which the recovery boiler is forced down with a full char bed, i.e.; tube ruptures in the economizer, master fuel trips, auxiliary failures, etc. This frequently results in plugged spouts that must be dealt with appropriately. To help avoid a large inventory in the char bed, retract the sootblowers and stop the sootblower sequence on an MFT.

Smelt spout openings may also plug occasionally due to low loads or varying operating practices and liquor characteristics. Spouts will also be more apt to plug during periods of start-up and shutdown of liquor burning. There is a good likelihood of plugged spouts after a boiler trip while burning liquor or during “chill and blows”, when the upper furnace sheds large amounts of tube deposits. More frequent inspection of spouts for pluggage and checks of dissolving tank density must be made at these times. Upon difficulty of maintaining smelt flow, liquor firing should be reduced or stopped until spouts are open and the smelt flow is reestablished. During periods of spout pluggage, the recovery boiler bed and furnace should be carefully observed to avoid accumulation of large smelt pools and until normal bed conditions are achieved. Closely inspect and evaluate the char bed and smelt indications in the furnace as you first try to open a spout with a rod or with a torch.

When the unit is down and contains a full bed, the bed will need to be burned down to a manageable level prior to resuming normal operation. If the spout openings are plugged, a sufficient number of spouts must be opened before resuming auxiliary fuel or liquor burning. Just because spout(s) are opened does not mean that a large smelt pool cannot be formed. Careful observations of the bed conditions; i.e., bed height, evidence of smelt pools or damming, are required during the start-up period. If smelting does occur in the lower furnace as a result of auxiliary fuel or black liquor combustion with all the spout openings plugged, a heavy smelt rush can result, which can lead to personnel injury or equipment damage when one or more are finally opened, possibly causing a dissolving tank explosion. **DO NOT** fire black liquor if all smelt spouts are plugged! Firing rate should be dependent on bed and spout conditions, with production pressures having

minimal impact on the decision making process. Should a large molten smelt inventory accumulate that cannot be safely removed from the furnace for fear of excessive smelt runoff, operating procedures should exist that instruct operating personnel to shut down the boiler, cool the bed and water wash the material out of the furnace.

There are several methods employed in the industry to help facilitate unplugging of smelt spouts, these include:

1. Spouts may be unplugged by burning the blockage out using a gas torch
2. Mechanically removing the blockage using a rodding bar
3. Inserting curved rods into the spout(s) that can reach up into or above the char bed shortly after a boiler trip. The technique of using curved bars and utilizing auxiliary fuel burners in conjunction with these rods to create a smelt flow path to help clear blocked spouts is widely used.
4. **UNDER NO CIRCUMSTANCES SHOULD AIR LANCES BE USED!**

Use of gas torches to unplug spouts can result in overheating or cyclical thermal stresses to boiler pressure parts around the spout opening area. If gas torches are used, care must be taken to avoid flame impingement on the pressure parts. Intense flames should be avoided. These gas torches should not be left unattended or left in place for long periods of time.

1. Gas torches must not be utilized in spout openings unless all furnace purge permissives are met.
2. If the gas supply for torches comes from the auxiliary fuel system, it must come off the header after the burner header safety shut-off valve(s).

When mechanically cleaning plugged smelt spout openings, care must be taken not to damage the spout, or the water wall tubes that form the opening, or the furnace floor tubes. When mechanically removing blockage, use only a blunt tipped mechanical rodding bar. Do not drive the bar into an adjacent tube. Mechanical force other than hand force should be used only with proper supervision.

#### *10.2 Design:*

To minimize the exposure to dissolving tank explosions, the following equipment and features should be provided for all dissolving tanks:

1. A fixed high level suction for green liquor transfer pumps.
2. Adequate steam shatter jets for all smelt spouts with manual steam control valves in an accessible, safe location. To assist the shattering of smelt during the heavy run off on auxiliary fuel or black liquor, an auxiliary steam shattering system should be available and ready to provide back-up in case the in-place systems' capability is exceeded.

3. Adequate agitation and sufficient emergency back-up system to prevent solids accumulation in tanks.
4. A green liquor density control system that is periodically verified with standard manual tests.
5. A reliable level control device.
6. Emergency dilution water supply (fire water).
7. Adequate dissolving tank level permissive for black liquor header purge interlock and low tank level alarm are required.
8. Dissolving tank explosion relief should be designed into the system. The explosion relief should be designed to minimize exposure of operating personnel during heavy runoff or potential crystallization of the dissolving tank. Explosion relief is typically designed into the vent stack scrubber system in the form of counter weighted explosion relief dampers. These dampers may be in the vent piping to the scrubber or they may be located in the demister section of the scrubber vent system. These dampers are typically designed to open with an over pressurization of the dissolving tank system and remain open until reset manually by an operator.

Operations should verify that the explosion relief dampers are in the correct operating position during each operating shift and should verify that the dampers are in good operating condition during scheduled outages.

Explosion relief dampers mounted to the top of the dissolving tank should be avoided since these dampers have experienced distortion during excursions that may prevent them from operating correctly during upset conditions. These dampers are typically not serviceable during operation without risk to operating personnel.

9. As recovery boilers are upgraded a thorough review of dissolving tank design, agitation, and density controls should be undertaken.
10. A safe means must be provided to isolate all dilution sources to the dissolving tank in case of suspected crystallization or if live smelt is seen in the dissolving tank. The intent is to allow operators to isolate dilution sources from the dissolving tank with either an automatic valve or manual valve without being exposed to the dissolving tank that is in a dangerous condition, live smelt present, dangerous run-off condition, crystallization imminent, etc. This should include all liquid and steam sources.

Typical sources include:

- Hood showers
- Overflow from scrubber seal water
- Dissolving tank agitator seal water
- Any emergency water make-up to the dissolving tank
- Weak wash supply to the dissolving tank

- Emergency dissolving tank agitation such as steam spargers

*10.3 Operation:*

1. Low suction and drain valves shall be verified closed for black liquor and/or auxiliary fuel firing.
2. Confirm the tank overflow is clear of any obstructions.
3. Ensure there is adequate weak wash or water level in the dissolving tank prior to initiating boiler purge.
4. Ensure that spout cooling water flows are adequate prior to initiating boiler purge.
5. Operators should have instructions or procedures on how to recognize and deal with:
  - high green liquor density
  - loss of dilution flow
  - loss of agitation
  - loss of shattering steam
  - impending or actual crystallization in the dissolving tank.
6. Each mill should have guidelines/emergency procedures on when to perform a Master Fuel Trip (MFT) on the recovery boiler due to excessive green liquor density and impending crystallization or suspected live smelt in the dissolving tank. The high density/crystallization point varies due to liquor chemistry and should be calculated to understand the saturation point for green liquor at each mill. There is an April 2009 AF&PA research document, “CALCULATIONS OF GREEN LIQUOR DENSITY VS. TTA AS A FUNCTION OF COMPOSITION” detailing the effects of liquor cycle composition and how it impacts changes in green liquor density calculations.
7. When a low smelt flow or upset condition occurs, the operating personnel must immediately do everything possible to keep the spouts open while the bed is still hot. Spout burners, manual rodding of the spouts, or inserting spout rods into the spouts are all techniques that can be used to facilitate this process while the bed is still hot enough to smelt.
8. Manual spout trough flow restriction devices have been successfully utilized to limit heavy smelt spout runoff during initial unplugging of spouts. Operating personnel involved in the opening of the spouts should be prepared to utilize smelt spout flow restricting devices (depending on spout and boiler design and history of boiler) to avoid the sudden rush of smelt that can occur when a plugged spout or spouts open up unexpectedly. The restrictor is a steel plate welded on the end of a steel bar with a half moon cut in the bottom of the plate to allow smelt to flow. This restrictor is shoved into the spout against the surface opening and

prevents the sudden gush of smelt that exceeds the shattering systems capability and could lead to dissolving tank explosions/incidents. If considering the use of flow restrictors keep them readily available on the spout deck, when inserted into the spout they should be dogged off so the operator does not have to hold in place, and do not utilize these restrictors to reduce smelt flow if heavy runoff is in progress - **AVOID THE SMELT SPOUT AREA**. At least one location has successfully used a mechanical flow restrictor that is dropped into place in the spout opening and secured prior to starting up the boiler on auxiliary fuel when it is known there is an accumulation of smelt and salt cake in the lower furnace. It is suggested that contact be made with the boiler manufacturer for details on such devices.

9. High amp alarms on agitator motors, dissolving tank high temperature alarms, and dissolving tank high density alarms are tools that can be used by the operator to alert him/her of the potential indication of a high smelt runoff or potentially dangerous condition in the dissolving tank.
10. During serious upset conditions in bed control or smelt rushes to the dissolving tank, the operating personnel may want to consider activating the recovery warning alarm system to alert support personnel of the emergency conditions and assure that all unnecessary personnel are warned and prevented from entering the affected area of the recovery boiler. This could include activation of the ESP warning sirens (or department equivalent for dissolving tank emergency) along with a verbal announcement to recovery boiler operating personnel stating the nature of the emergency.

#### *10.4 Emergency Operation*

##### **Background Information:**

Molten smelt can solidify rapidly as it cools in the dissolving tank if the tank is not adequately agitated or if the solution in the tank has reached saturation. If molten smelt is not continuously dissolved and agitated in water/weak wash as it cools it can form solid mounds in the dissolving tank below the liquid level in the tank. If operators are not aware of this occurring, smelt can continue to accumulate and potentially pose a live smelt hazard in the tank. If weak wash or water is not supplied in adequate quantities green liquor density may rise to an unacceptably high level. As the density rises it may reach the point where the smelt will no longer dissolve in the tank. This can lead to smelt pooling and a live smelt hazard in the dissolving tank. Repeated green liquor line pluggage and excessive build-up of deposits in the dissolving tank are indications of poor green liquor density control and can lead to the before mentioned conditions.

The two methods in which live smelt can accumulate in the dissolving tank are:

1. Smelt from the boiler does not dissolve in the dissolving tank and builds a solid mound in the tank.
2. Dissolving tank high density that leads to crystallization and subsequent accumulation of live smelt on top of the crystallized green liquor.

If crystallization occurs or if live smelt is known to be present in the dissolving tank, an Immediate Shutdown should be initiated. The specific Immediate Shutdown requirements should be as follows:

- **Sound Alarm**

Sound evacuation sirens and switch on emergency evacuation lights and clear the recovery area of unnecessary personnel.

- **Stop All Fuels/Primary Combustion Air**

Immediately stop firing all black liquor and auxiliary fuel (operator initiated MFT – master fuel trip).

Shut down primary air fan and close off primary combustion air to the furnace to reduce smelting.

- **Stop All Liquid and Steam Sources**

Cut off all sources of emergency dilution water, hood wash supply, weak wash, dissolving tank scrubber water supplies that overflow to the dissolving tank, or heating steam (leave shatter jets on) to the dissolving tank from a remote, safe location.

**DO NOT** raise the level in the dissolving tank to “smother” or cover the molten smelt. A smelt-water reaction with damaging consequences may occur if this is done.

- **Secure Area**

Secure the dissolving tank area to the degree necessary to correct the condition that caused the immediate shutdown. Rope off the dissolving tank area at all levels.

Do not allow any personnel near the tank until ample cooling time has passed.

Account for all personnel.

Minimum cooling time shall be set by the Recovery Superintendent, or his designee, after thorough review of the incident.

- **Do Not Disturb Live Smelt**

Do not, under any circumstances, attempt to dissolve live smelt in the dissolving tank, or on the floor with wash up hoses. Take steps to prevent live smelt from contacting water in sewers or open drains.

Shut off the agitators in the affected dissolving tank.

- **Resume to Normal Operation**

After an adequate cool down period, an inspection should be made. Inspection should continue until smelt temperature is less than 800°F by hand-held pyrometer (if there is a hard crust of cooled smelt on the surface the hand held pyrometer may give a false sense of security that all smelt is cooled), or temperature probing with thermocouples before water is added to dissolve the smelt. (If there is evidence of live smelt in the dissolving tank then probing should be discontinued as further probing could dislodge smelt down into remaining liquid in the tank.)

The decision to begin dissolving the smelt accumulation will be made by the Recovery Superintendent. At this point, the following method may be used for dissolving the smelt accumulation.

- a. Pump or drain liquid from dissolving tank
- b. Make a visual inspection to assure that no live smelt remains - Wear proper personal protective equipment
- c. Fill tank with water/weak wash
- d. Start agitators - If agitators will not run, free up around agitator with steam and air lances
- e. Empty tank periodically to check progress

The Recovery Superintendent will determine at what point, while the buildup is being dissolved, that auxiliary fuel may be re-fired if spouts are clear and the dissolving tank is deemed ready for service.

The Recovery Superintendent should then arrange to have the involved crew members attend a meeting to investigate thoroughly the events leading up to the emergency situation. A formal report to BLRBAC should be submitted.

#### *10.5 System Alarms:*

Operators must immediately investigate and rectify the cause for any of the system alarms:

	<u>Audible</u>	<u>Indicator</u>
1. Dissolving tank agitator high and low amps	X	
2. Dissolving tank level		X
3. Dissolving tank low level alarm	X	
4. Dissolving tank density		X
5. Dissolving tank high density alarm	X	
6. Dissolving tank dilution (weak wash) flow low	X	X

## **CHAPTER 11 DIRECT INJECTION OF WATER SOLUTIONS OF CHEMICALS INTO THE RECOVERY FURNACE**

The preceding sections have dealt with procedures for safe firing of black liquor in a recovery boiler. Water solutions of other chemicals can cause smelt-water explosions if they come in contact with smelt. Several damaging smelt-water explosions in kraft recovery boilers have been caused by spraying water solutions of various chemicals, such as, spent acid, directly into the furnace. The object of these practices has been to recover the sodium and sulfur values from the chemicals while avoiding problems caused by addition of the chemical to the black liquor stream.

Black liquor soap has sometimes been burned in the recovery furnace using separate guns. Soap, itself, is not a water solution, but its separate addition can result in water entering the furnace. An aqueous layer separates from soap on storage and can build up in the bottom of the storage tank. It can then be accidentally pumped into the furnace if care is not taken to frequently draw off the aqueous layer from the bottom of the tank. Separate firing of soap has led to recovery boiler explosions.

For these reasons, the Black Liquor Recovery Boiler Advisory Committee strongly recommends that water solutions (other than black liquor above 58% solids concentration) should never be injected directly into a kraft recovery furnace.

## **CHAPTER 12 ADDITION OF WATER SOLUTION OF CHEMICALS TO THE BLACK LIQUOR STREAM**

Water solutions of chemicals are sometimes added to the black liquor stream as a means for supplying makeup sodium and sulfur to the chemical cycle. Spent chemicals from chlorine dioxide generators or soap acidulation are examples of such streams.

There are some potential problems with the addition of such streams. Excessive addition of acidic streams can result in high viscosity black liquor which can affect liquor spray characteristics and could result in liberation of poisonous hydrogen sulfide gas. In addition, if aqueous chemicals are added to the mix tank, there is a possibility that an imbalance or upset could result in the liquor dropping below the 58% solids limit which would cause black liquor to be tripped from the boiler.

The impact of water solutions of chemicals on the black liquor is diminished if the addition point is upstream in the evaporation train. There is less likelihood that the addition will adversely impact the recovery boiler operations. For this reason, the Black Liquor Recovery Boiler Advisory Committee recommends against the addition of any aqueous chemical stream to the black liquor downstream from the final black liquor evaporator. Under no circumstances should any aqueous chemical stream be added downstream from the continuous solids monitor (refractometers).

## **CHAPTER 13 MISCELLANEOUS EXTERNAL WATER HAZARDS**

This chapter studies some possible water sources external to the recovery process or boiler that could be accidentally introduced into the recovery boiler furnace or allowed to contact molten smelt.

Previous chapters have dealt with process water sources, such as low solids liquor, cascade dilution water, wash water, chemical solutions, smelt spout cooling water, etc.

The entire recovery boiler installation shall be reviewed and all miscellaneous external water hazards identified and evaluated.

External water hazards must be controlled. Extreme caution and proper procedures shall be used in and around the recovery boiler to prevent water from contacting molten smelt or diluting firing liquor.

Examples of possible external water hazards are:

1. Water cooled probes.
2. Steam lances due to the possibility of condensate in piping.
3. Hoses used for washing.
4. Sluicing solutions for elevated hoppers that could directly enter the ring header liquor system.
5. Water used to unplug hopper ash pipes that could enter the mix tank if proper manual double block and bleed valving is not provided.
6. Salt cake that has absorbed moisture due to its hygroscopic characteristics and is thrown into the furnace cavity.
7. Water lines close to port openings.
8. The use of the properly designed water-cooled gas test probe, comparable to one supplied by boiler manufacturers to obtain boiler performance data, is permissible as long as it is under constant supervision of a qualified technician. These probes shall not be used below the highest fuel admission point in the furnace.
9. The use of a properly designed steam/water mixture cooled liquor gun assembly, is permissible as long as the proper use of alarms and interlocks are in place to prevent the excessive use of water that could enter the furnace. There must be SSV's in place to isolate the steam and water sources in case of ESP, MFT or black liquor divert. The water entering the furnace through the gun cooling system during normal operation or in the event of a liquor gun failure shall not exceed 0.7 GPM as liquid H<sub>2</sub>O per liquor gun. The design must ensure that water amount that can be introduced into the furnace is limited even if the gun jacket or

other parts of the gun fail while in service. The system should rely on system design to limit water flow (needle valve or mechanical orifice). The liquor gun cooling system operation should be designed with alternate means for isolation of water supply valve for ESP initiation.

Alarms;

High total water flow with shutoff interlock, no water flow with alarm, low steam flow with alarm.

10. Condensate from a leak in a steam coil air heater or a feedwater air heater should be removed via a visual drain system to prevent its introduction into the furnace through the combustion air system. The duct should be equipped with a dam downstream of the heaters at the low point of the ducting and a loop seal or seal pot to provide both a visual indication and a removal path for any accumulated

condensate. The drain line must be large enough to remove all water from a large leak.

. The sootblowers and piping should be designed to prevent condensate from collecting and being injected into the boiler.

**The following hazards are identified as prohibited and should not be permitted:**

1. Water cooled doors
2. Air lances
3. Hoses used for hot spot testing or for misting to cool the bed, prior to confirmation that no molten smelt is present.

## CHAPTER 14 AUDIBLE ALARM AND INDICATING SYSTEM

A number of operating conditions, abnormal variations, or failure of an auxiliary or supporting unit, can produce a potentially hazardous or dangerous condition for a black liquor recovery boiler. To assist the recovery boiler operator in the proper supervision of all functions, the control system shall include audible alarms and indicators.

The purpose of this system is to bring specific conditions to the attention of the operator and to identify the condition. Alarms and indicators may be used to designate equipment malfunction, hazardous conditions, mis-operations, and operations required.

The alarm and indicator system shall be designed so that the operator receives audible, as well as visual, indication of the condition being monitored. Means may be provided to silence the audible alarm, but the visual indication should remain until the condition has been returned to normal. A “memory” feature shall be incorporated in the alarm and indicator system so that the indication of a transient condition, which exists just long enough to cause an alarm and/or indication and then corrects itself, will be retained until the operator acknowledges it. This system shall also include a “first-out” feature, for the sequenced interlocked functions only, which indicates what occurred first in a chain of events.

The required alarms and indicators for the safe black liquor firing system are listed below. This list complements the audible alarm and indicator system recommendations contained in **Recommended Good Practices for Safe Firing of Auxiliary Fuel in Black Liquor Boilers**.

<u>Condition</u>	<u>Audible</u>	<u>Indicator</u>	<u>“First Out” Feature</u>
1. All black liquor guns out of furnace		X	
2. Black liquor header valve shut and divert valve open	X	X	
3. Black liquor header recirculation valve open		X	
4. Black liquor solids at 58%	X	X	X
5. Black liquor solids at 60%	X	X	
6. Black liquor solids at 70% (if firing at >70% solids per guidelines in section 6.4 of this document)	X	X	

<u>Condition</u>	<u>Audible</u>	<u>Indicator</u>	<u>“First Out” Feature</u>
7. Black liquor solids at 62% (if firing at >70% solids per guidelines in section 6.4 of this document)	<b>X</b>	<b>X</b>	<b>X</b>
8. Low black liquor temperature	<b>X</b>	<b>X</b>	
9. Low black liquor pressure	<b>X</b>	<b>X</b>	
10. Black liquor header purge in process		<b>X</b>	
11. Black liquor header purge complete		<b>X</b>	
12. Non-operating water sources open	<b>X</b>	<b>X</b>	<b>X</b>
13. Black liquor header wash system switch in wash position	<b>X</b>	<b>X</b>	<b>X</b>
14. Minimum black liquor flow established		<b>X</b>	
15. Prove all black liquor lines open		<b>X</b>	
16. Refractometers reading more than 2% absolute difference	<b>X</b>	<b>X</b>	
17. Refractometer out of service	<b>X</b>	<b>X</b>	
18. Mix tank level low	<b>X</b>	<b>X</b>	
19. Black liquor fuel pump stopped	<b>X</b>	<b>X</b>	<b>X</b>
20. Mix tank agitator stopped	<b>X</b>	<b>X</b>	
21. Oscillator drive failure	<b>X</b>	<b>X</b>	
22. Dissolving tank density		<b>X</b>	
23. Dissolving tank high density alarm	<b>X</b>		
24. Cyclone circulating pump stopped or cascade drive stopped	<b>X</b>	<b>X</b>	
25. Dissolving tank agitator(s) stopped	<b>X</b>	<b>X</b>	
26. Sufficient auxiliary burners in service		<b>X</b>	
27. Manual black liquor trip			<b>X</b>

<u>Condition</u>	<u>Audible</u>	<u>Indicator</u>	<u>“First Out” Feature</u>
28. Emergency spout cooling water makeup on	<b>X</b>	<b>X</b>	
29. Loss of any spout cooling water pump	<b>X</b>	<b>X</b>	
30. High spout cooling water outlet temperatures	<b>X</b>	<b>X</b>	
31. Low spout cooling water outlet flow	<b>X</b>	<b>X</b>	
32. Dissolving tank dilution (weak wash) flow low	<b>X</b>	<b>X</b>	
33. Low black liquor flow (<30%)	<b>X</b>	<b>X</b>	
34. Lower furnace wash switch in wash position	<b>X</b>	<b>X</b>	<b>X</b>
35. Dissolving tank level low	<b>X</b>	<b>X</b>	
36. ESP interlock satisfied	<b>X</b>	<b>X</b>	
37. Low boiler steam flow (<30%)	<b>X</b>	<b>X</b>	
38. Black liquor recirculation line safety shutoff valve (for high solids systems)			<b>X</b>

## **CHAPTER 15 DISCUSSION AND BACKGROUND INFORMATION**

In the preparation of these recommendations by the Subcommittee on the Safe Firing of Black Liquor in Black Liquor Recovery Boilers, many of the items were discussed at length. Believing that the reasoning behind some of the decisions would be helpful in the use of these recommendations, the following is submitted:

### *15.1 Black Liquor Header(s) Wash System*

The wash cycle logic system was included to ensure that all conditions required for a safe wash exist and that an operator must initiate a switch to introduce water into the black liquor header.

#### **15.1.1 Lower Furnace Wash System**

The lower furnace wash system has been included to ensure that all conditions required for a safe wash of the lower furnace, utilizing the black liquor firing header and the black liquor guns exist. The operator must initiate a switch to introduce water into the lower furnace. Logic has been added to prove the recovery boiler is out of service and the bed proven cooled prior to allowing the black liquor header valve to be opened (see Figure 3). This logic allows weak solids or water into the firing header for washing the lower furnace with the black liquor guns without defeating interlocks on the liquor gun doors.

### *15.2 Purge Credit*

The logic calls for maintaining a flow of 25% of rated liquor on the liquor headers to ensure that a sufficient volume of liquor is being pumped to adequately purge the black liquor header.

The two minute minimum purge time was arrived at by calculating the average volume of liquor contained in the black liquor piping system that would be changed adequately to remove any diluted liquor accumulated during a wash cycle.

Each leg of the ring header must be isolated in turn and flow verified (at 25%) for a minimum of two minutes to obtain the purge credit.

All legs can be purged at the same time if flow can be verified independently for each leg.

Flow can be verified with a combination of flow meters, temperature and recirculation valve position switches. The flow meter on the inlet to the ring header can be used.

### *15.3 Black Liquor Gun Position System*

As mentioned in the interlock system, black liquor guns must be proven out of the furnace prior to the reopening of the black liquor header valve for the admittance of black liquor to the header or start of the wash cycle. This is a must for the prevention of diluted black liquor or wash water from entering the furnace.

There are several methods of interlocking the black liquor guns to show they are not in the firing position.

The recommended method involves the use of a liquor gun door which covers the gun opening in the furnace wall when guns are removed from their holders. When the liquor gun door is in position closing the opening and preventing gun insertion, a limit switch is activated by the gun door to prove the system.

In liquor gun designs, which utilize a yoke assembly, removal of the gun barrels still leaves the potential for admitting low solids material, or water, into the furnace. With the gun barrel removed, the yoke assembly points to the center of the gun opening. For this style liquor gun it is recommended to use a solid door which covers the gun opening in the furnace wall. Consideration should be given to inserting a “dummy” gun barrel, which either directs flow away from the gun opening, or blocks the flow.

### *15.4 Number of Refractometers*

The black liquor firing interlock system is based on the installation of two in-line refractometers in series to measure the solids in the black liquor stream immediately prior to the black liquor guns with the black liquor automatically diverted from the furnace if **both** refractometers indicate 58% or below (62% or below if firing >70% solids per guidelines in 6.4 of this document).

The reason for the installation of two meters is to have a redundant unit in the event that one meter fails and is removed from the interlock system either automatically or manually. With the redundant meter, the interlock system can continue to remain in service and if the black liquor solids content is above 58% (above 62% if firing >70% solids per guidelines in 6.4 of this document), the black liquor will not be diverted from the recovery furnace. Otherwise, the recovery boiler would automatically be shutdown.

The second refractometer also allows one meter to be taken out-of-service for scheduled maintenance without the recovery boiler having to be out-of-service.

Refractometers, as such, can fail and fail in an unsafe mode. The refractometer integrated control system recognizes this and is designed to remove an improperly operating meter from the firing interlock system. With two meters there is low probability that both will fail simultaneously and thus nuisance shutdowns of the black liquor firing system are avoided.

The interlock system is also designed to fully function with only one refractometer in service. Operating with only one unit in service is not recommended as a norm. It should be realized that when operating on one refractometer the solids are not monitored during prism wash on the “meter in service”. Whenever a refractometer must be taken out-of-service for repair or maintenance, it should either be replaced with a spare unit or restored to service as soon as possible.

#### *15.5 Black Liquor Pressure and Temperature*

The time of unit start-up or restart is the time when control excursions are most prevalent. Because of this it is felt that both black liquor pressure and temperature should be under reasonably good control.

The permissive system on the black liquor system is designed to obtain stable conditions, namely, liquor solids above 58% (above 62% if firing >70% solids per guidelines in 6.4 of this document), liquor temperature satisfied and black liquor pressure satisfied. These conditions must be proven prior to completion of the black liquor header purge to achieve a satisfactory “Liquor Purge Complete”.

#### *15.6 Stable Firing Established*

Prior to initiating black liquor firing; sufficient auxiliary fuel hearth burners must be in service, boiler on line and stable firing conditions established. Each facility must establish the number of hearth burners to reliably establish combustion of black liquor as it is initially introduced into the furnace. Some locations utilize a minimum steam flow (10-30% of original design MCR) as a proxy for the number of hearth burners in service to satisfy the black liquor header purge permissive.

#### *15.7 Superheaters Cleared*

Prior to the recovery boiler coming on line and producing steam, flue gas temperatures entering the superheater must not exceed OEM recommended levels (typically < 900°F). The initiation of liquor firing will typically result in a significant increase in steam flow from the boiler, along with a jump in flue gas temperatures into the superheater. Operators should ensure that all superheater tubes have been cleared of condensate allowing cooling steam flow through all superheater tubes prior to allowing flue gas temperatures to exceed the manufacturer’s recommended level. Most recovery boilers are equipped with superheater outlet tube thermocouples. These thermocouple readings will tell the operator when the individual platen clears of condensate with a characteristic “pop” or jump of approx. 50-75°F in the metal temperature. Operating procedures and practices should be developed and operators trained to recognize that the boiler should not be placed in the header until all superheater tubes are cleared of condensate.

## APPENDIX A GENERIC CHECKLIST FOR PRE-FIRING OF BLACK LIQUOR

This generic checklist is to be used as a guide for the creation of a boiler specific check list for the safe introduction, or reintroduction, of liquor into a recovery furnace. It assumes that a stable operation on auxiliary fuel has been established. It is not comprehensive in regard to other critical boiler systems such as the feedwater, and fuel or air systems. It does not supersede the safe firing or other BLRBAC documents.

### TYPICAL BLACK LIQUOR SYSTEM PRE-FIRING CHECK LIST

1. Check status of jumper log and ensure that all elements of the safe firing logic are available.
2. Check that the ESP system is ready, all manual drain valves open and locked.
3. All non-operating water sources verified to be **isolated**.
  - Black liquor header wash switch in the “operate” position.
  - The FD fan duct condensate dam seal should be checked for proper operation.
  - Lower furnace wash position switch in “operate” position.
  - Water wash spool piece (if applicable) proven removed.
4. Sootblower steam header is drained of all water, charged with steam, and the condensate removal system is working.
5. Liquor gun assemblies checked and in good order.
6. All liquor guns confirmed out of the boiler and steamed out in accordance with “Safe Firing” procedures. Liquor header block valves for each gun closed.
7. Physically confirm that liquor header stop valve is closed and divert valve is open; verify valve position limit switch indications in the control room. Verify recirculation valve(s) are open.
8. Confirm both refractometers operating (or one meter operating and one under immediate repair) and reading above 58% solids or above 62% solids if firing >70% solids. Liquor divert systems checked and in service.
9. Liquor temperature within range       °F to       °F. Liquor heater properly valved in and working.
10. Manually reset the divert system, confirming that limit switches indicate “header valve open” and “divert valve closed.” Confirm a minimum of 25% ( gpm) liquor flow through the ring header for a minimum of two-minute purge; confirm flow in each branch line.

11. Liquor pressure within range \_\_\_\_ psig to \_\_\_\_ psig liquor.
12. Verify that refractometer readings are \_\_\_\_ Percent of off-line field within measurements test readings and above 58% solids.
13. Stable furnace conditions established with sufficient auxiliary fuel hearth burners in service, boiler on-line, and stable firing established.
14. Dissolving tank inspected, level is ft/% or greater and verify density with manual test. Green liquor pumps are ready. Density meter is operating. Agitators are operating. Vent stack scrubber is operational with proper flow. Emergency and weak wash supply available. Verify the low suction and drain valves are closed. Emergency water supply for the dissolving tank lined up properly.
15. Smelt spouts inspected and sufficient spouts confirmed open for smelt flow; cooling water system in operation at required flow rate and temperature. Hood wash and shatter jets are on. Emergency water supply to the spout cooling water system lined up properly.
16. Ash handling system in operation.
17. The Recovery boiler hearth conditions should be evaluated by the operator to determine the appropriate gun(s) to introduce or reintroduce liquor. Particular care should be taken with a large char or ash bed.
18. Confirm that all double block and bleed steam-out valves are in proper position.
- 19. Immediately prior to firing black liquor, at least one operator off-line solids test shall be performed to confirm solids are above 58% or above 62% solids if firing >70% solids and the refractometers are reading correctly. These test results must be recorded.** The sampling location should be on the line to the furnace header or on the header itself. There should be no sources of dilution or chemical addition downstream of the sampling point. Use of liquor samples from other locations (such as the cascade flow box), chosen for convenience, can give erroneous results.
20. Blow any condensate from liquor gun assembly external to the furnace. Insert first liquor gun into furnace. Open liquor supply valve. Confirm that liquor is burning.

## **APPENDIX B DOCUMENT REVISION HISTORY**

### **April 2016 – Summary of Changes.**

Chapter 2 Definitions:

Revised definition of “Managed System”

A documented procedure which includes a checklist of critical manual valves or devices that is completed by the operator prior to start-up and as needed throughout the operation. The checklist shall identify each valve or device and the proper position, condition or state. Any deviation from the checklist shall be controlled and documented through a jumper policy.

Chapter 4.10 Refractometer Calibration:

Revised wording of refractometer calibration and refractometer standardization as presented from the Instrumentation Subcommittee on 10/6/2014. More details were provided on standardization procedure.

Chapter 13 Item 9. Steam/water mixture for cooling liquor guns.

Revised wording to allow steam/water mixture to cool liquor guns as long as proper use of alarms and interlocks are in place to prevent excessive use of water that could enter the furnace.

### **October 2013 - Summary of Changes**

Table 5, Logic Explanation Chart for Figure 5, Black Liquor Tripping Logic:

Revised hazard protected against for logic block diagram “Black liquor header valve or divert valve fail to position.”

Chapter 8, Black Liquor and Water Piping Systems

Added a new item 13 addressing manual valves in the black liquor divert system.

Chapter 10, Dissolving Tanks Added text to Section 10.1, Plugged Spouts, recommending retracting sootblowers and stopping the sootblower sequencing on an

## **October 2012 – Summary of Changes**

### **Chapter 5: Black Liquor Firing Interlock System**

- Updated logic and explanation table to clarify role of stable firing in permissive starting logic
  - Figure 2, Permissive Starting Logic for Black Liquor Firing
  - Table 2. Logic Explanation Chart for Figure 2
- Added failure of black liquor header valve and/or black liquor divert valve to be in the correct position for normal operation as a input to the black liquor trip logic.
  - Figure 5, Protective Tripping Logic for Black Liquor Firing
  - Table 5. Logic Explanation Chart for Figure 5

### **Chapter 9: Smelt Spouts**

- Added a sentence that treated water only to be used for spout cooling water systems.

### **Chapter 10: Dissolving Tanks**

- Added a recommendation to review dissolving tank design, agitation, and density controls when recovery boilers are upgraded.
- Added a recommendation for mills to have guidelines/emergency procedures for initiating an MFT of the recovery boiler when green liquor density is too high, there is impending crystallization, or when the dissolving tank is known or suspected to contain live smelt.
- Added guidance as a new Section 10.4 for recommended actions when green liquor density is too high, there is impending crystallization, or when the dissolving tank is known or suspected to contain live smelt.

### **Chapter 15: Discussion and Background Information**

- Added a new Section 15.6, Stable Firing Established
- Added a new Section 15.7, Superheaters Cleared.

## **February 2012 – Summary of Changes**

“Notice of Disclaimer of Liability” has been added to page 2.

## **October 2010 – Summary of Changes**

In Fig. 1, *Common Permissive Starting Logic*, and Fig. 4, *Common Protective Tripping Logic*, the box stating: “Note: Incineration of Non-Condensable Gas Waste Streams is Not Encouraged by BLRBAC” has been deleted.

## **April 2010 – Summary of Changes**

- Figure 7 revised to show liquor return line entering to of 80% Liquor Storage Vessel
- Title in title box of Figure 14 corrected to match figure caption

### April 2009 – Summary of Changes

- The Foreword and Chapter 1 have been modified to include dissolving tank explosions as a type of recovery boiler explosion. Clarification is also made that this document addresses dissolving tank explosions.
- A definition for “Smelt Spout” has been added to Chapter 2.
- Chapters 3, 4, and 15 and Appendix A have been revised to address high solids firing (>70% solids) including recommended minimum divert values consistent with the guidelines in Chapter 6, Section 6.4.
- Anew section 3.5 has been added to Chapter 3 to provide guidance on recommended logic to detect a sudden large tube leak and limit the amount of water that could potentially enter the furnace.
- Figure 1 (Common Permissive Starting Logic) and Table 1 (Logic Explanation Chart for Figure 1) have been revised to add permissives for dissolving tank level, spout cooling water flow, and smelt spouts being open. Also, a new logic block titled “Precipitator Inlet Temperature Below Prescribed Limits” was added to Figure 1 with a corresponding change to Table 1 to match the change made in Safe Firing of Auxiliary Fuel in the April 2007 revision of that document.
- Figure 2 (Permissive Starting Logic for Black Liquor Firing) and Table 2 (Logic Explanation Chart for Figure 2) have been modified to show spout cooling water flow as a starting permissive.
- Added a new Logic Block titled “High Precipitator Inlet Temperature” to Fig. 4, *Common Protective Tripping Logic* with a corresponding change to *Table 4*, the accompanying logic explanation chart to match the change made in Safe Firing of Auxiliary Fuel in the April 2007 revision of that document.
- Table 4 (Logic Explanation Chart for Figure 4, Common Protective Tripping Logic) and Table 5 (Logic Explanation Chart for Figure 5, Protective Tripping Logic for Black Liquor Firing) have notes added to clarify that an igniter should not be considered a burner.
- A logic block has been added to Figure 5, Protective Tripping Logic for Black Liquor Firing, and to Table 5, Logic Explanation Chart for Figure 5, to show that Operator observation of all smelt spouts being plugged while firing liquor should result in an operator initiated trip of the black liquor firing system.
- All references in Chapter 6 to TAPPI Standard Method T650-om-99 have been changed to T650-om-05 to reflect the latest revision to that document.
- Guidance on the use of non-water cooled spouts has been added to Chapter 9.
- In Chapter 10, guidance on actions to be taken in response to plugged spouts in section 10.1, Plugged Spouts, has been revised and expanded; in Section 10.2, Design, a recommendation for dissolving tank explosion vents has been added; in Section 10.3, Operation, the upsets conditions in dissolving tanks that operators need to recognize and respond to has been expanded along with a more detailed discussion of manual

smelt spout flow restrictors; and in Section 10.4, System Alarms, an audible alarm and indication for low dissolving tank dilution flow has been added.

- In Chapter 14, alarms and indicators have been added consistent with the changes in the other chapters.

### **April 2008 – Summary of Changes**

In October 2006 a change was made in Figure 2 and the accompanying logic explanation table 2 that incorrectly amplified the permissive starting logic block for “Sufficient Auxiliary Fuel Hearth Burners in Service.” The April 2008 revision reverts the wording to that which appeared prior to the October 2006 revision. {Note: Since this is a “correction” to the document and not a “technical change,” these changes are not being shown in red. The October 2007 changes as summarized below remain as red text.}

### **October 2007 – Summary of Changes**

- Chapter 5 – Added text to highlight concerns with black liquor header purging when subheaders are present.
- Chapter 9 – For consistency with Figure 2, added satisfactory spout cooling water flow as a required starting permissive interlock for black liquor header purge.
- Chapter 10, Section 10.2 – For consistency with Figure 2, added adequate dissolving tank level as a required starting permissive interlock for black liquor header purge and added dissolving tank low level as a required alarm consistent with dissolving tank system alarms in section 10.4.

### **October 2006 – Summary of Major Changes**

- Chapter 3: Amplified scope of new employee training.
- Chapter 4: The recommendation to recalibrate refractometers when the readings differ by more than 2% was relocated from Chapter 6 to Section 4.10, Refractometer Calibration.
- Chapter 5:
  - Black Liquor Header Purge requirements were expanded.
  - Clarified the requirement for sufficient auxiliary fuel hearth burners in service as a starting permissive for firing black liquor. A similar clarification was also added to Appendix A.
- Chapter 8: Added a requirement that the black liquor header wash position switch be in the “wash” position as a permissive for water washing through the liquor guns. This is consistent with the addition of a keyed interlock system for using liquor guns for water-washing the lower furnace that was part of the April 2005 revision.
- Chapter 9: Explanation added regarding the hazard of high temperature smelt spout cooling water.
- Appendix A: Added removal of water wash spool piece to the Typical Black Liquor System Pre-Firing Check List.

### **October 2005 – Summary of Major Changes**

- Modified Figure 6 to apply only to atmospheric storage of black liquor.
- Added new Figure 7 for black liquor firing systems with pressurized storage of black liquor. Renumbered subsequent figures accordingly.

### **April 2005 – Summary of Major Changes**

#### **Chapter 2 – Definitions**

- Definitions added for:
  - Automatic Recirculation Shutoff Valve
  - Black Liquor – High Solids Black Liquor
  - Black Liquor Header Wash Switch
  - Black Liquor Pump
  - Lower Furnace Wash Switch
  - Managed System
- The term “Black Liquor Diversion Valve” was changed to “Black Liquor Divert Valve”
- The term “Black Liquor Diversion” was changed to “Black Liquor Divert” with some editorial revision to the definition.
- Deleted the sentence “Direct signals rather than transmitted signals shall be used wherever possible to actuate interlocks.” from the definition of “Interlock.” This was done at the request of the Instrumentation Subcommittee to make the documents consistent.
- Revised the definition of Recirculation Valve
- Deleted the term and definition for “Wash Position Switch”

#### **Chapter 3 – Black Liquor Safe Firing System Requirements**

##### **3.1 Design**

- Added a new item 5.

#### **Chapter 4 – Refractometer Black Liquor Solids Measurement System**

##### **4.10 Refractometer Calibration**

- Editorial revision to the paragraph following item 3 for consistency with Chapter 6 on frequency of testing.

#### **Chapter 5 – Black Liquor Interlock Firing System**

- Corrected the figure reference in item 1.
- Deleted “Caution” in item 3.
- Editorial fixes to item 6.
- Added need for shutoff valve in recirculation line back to a pressurized tank in item 7.
- Added a new item 8 for wash permissives
- Revised Figure 2.

- Added new Figure 3 and accompanying description to item 9.
- Added block logic for Figure 3, Black Liquor Header Wash and Lower Furnace Wash Permissives.
- Added Logic Explanation Chart for Figure 3.
- Revised Figure 5 and corresponding block logic table.
- Revised Figure 6 to show isolation valve in recirculation line when a pressurized storage tank is used. Added note explaining dashed box.

#### Chapter 6 – Off-Line Black Liquor Solids Measurement

- 6.3, *Off-Line Field Measurement Techniques*, revised to show moisture balances and microwave oven drying as the two acceptable techniques with neither being “preferred.” Additional text revisions made for consistency with this change.
- Requirement for testing at start-up added as a new 6.3.1, *Testing Black Liquor Solids*. Also additional guidance provided on sampling location.

#### Chapter 7 – Black Liquor Firing

- Added item 7, Steam and/or condensate, to list of example dilutents
- Table TT: Modified item 18 by adding the term “steam heater.”

#### Chapter 8 – Black Liquor and Water Piping Systems

- Added item 13, Use of a keyed interlock switch for the lower furnace water wash.

#### Chapter 14 – Audible Alarm and Indicating System

- Added items 28 – 33 to list.

#### Chapter 15 – Discussion and Background Information

- Added new item 15.1.1, *Lower Furnace Wash System*.

#### Appendix A – Generic Checklist for Pre-Firing of Black Liquor

- Changes made as needed for consistency with body of document.

### **March 2004**

Some of the changes made in the March 2003 and June 2003 revisions of this document were not carried over into the October 2003 release. This has been fixed.

### **October, 2003 – Summary of Major Changes**

Figures 1 – 5 have been editorially modified to provide consistency with each other as well as with text currently in the body of the document and the logic description tables. The more significant changes are summarized below.

For Figure 1, Common Permissive Starting Logic:

- The middle box on the bottom was changed to reference Figure 2.
- The right box on the bottom was changed to delete the reference to specific figures in Safe Firing of Auxiliary Fuel.

For Figure 2, Permissive Starting Logic for Black Liquor:

- Boxes that were duplicates of the boxes in the Common Permissive Starting Logic (Figure 1) were deleted and replaced with a single box in the upper right with the text “Boiler Purge Credit Maintained, From Figure 1.”

For Figure 4, Common Protective Tripping Logic:

- The middle box on the bottom was changed to reference Figure 5
- The right box on the bottom was changed to delete reference to specific figures in Safe Firing of Auxiliary Fuel.

For Figure 5, Protective Tripping Logic for Black Liquor Firing:

- Boxes that were duplicates of the boxes in the Common Protective Tripping Logic were deleted and replaced with a single box in the middle right with the text “Purge Credit Lost, Master Fuel Trip, From Figure 4.”
- Boxes and the associated logic were added in the upper right for:
  - Black Liquor Flow to Furnace < 30% MCR\*
  - Steam Flow < 30% MCR\*
  - Insufficient Auxiliary Fuel Hearth Burners in Service\*

\*Logic explanations for these boxes were in Table SS in the previous revision, but were not included in the logic diagram.

### **June, 2003 – Summary of Major Changes**

Chapter 6: Text was modified to permit longer intervals between field solids measurements of black liquor solids when operating at greater than 70% BLS.

Editorially, all references to TAPPI Method T650-om-89 were changed to T650-om-99. TAPPI updated the solids test method and T650-om-99 is the current number.

### **March 2003**

Some of the changes identified below for October 2002 were inadvertently not included in that revision. This was fixed.

### **October, 2002 – Summary of Major Changes**

Editorially, this document has been revised to provide a consistent format.

Chapter 5: Text has been modified to permit isolation valves in sensing lines of critical instruments.

Technical changes to Chapter 9, Smelt Spouts:

- The recommended range of inlet temperature for smelt spout cooling water has been “tightened” to 140-150°F.

- A paragraph has been added explaining the hazard of higher than normal smelt spout cooling water inlet temperatures.
- Connections on smelt spouts should be clearly marked as “Inlet” and “Outlet” to ensure proper cooling of smelt spout during operation.
- Additional recommendations and operating experience have been added for pressurized systems.
- The need to lock open valves located in the smelt spout cooling water system on the outlet side of the spout in vacuum systems has been added.
- The need for annual inspection of cleaning of smelt spout cooling water head tanks and collection tanks has been identified.

Technical changes to Chapter 10, Dissolving Tanks:

- This chapter has been significantly expanded to better explain the recommended practices related to dissolving tanks.
- Material related to dissolving tanks that was in Chapter 9 was relocated to Chapter 10.
- Recommended operating practices have been added to prevent dissolving tank upsets and explosions.
- Dissolving tank System Alarms have been added.

### **March, 2001 – Summary of Major Changes**

#### **Chapter 4**

- Added Refractometer Control System Function no. 19 to require automatic switch to single refractometer diversion when one head is in prism wash and the system is set for dual head diversion.
- added cautions on adjusting prism wash variables.

#### **Chapter 5**

- Explanation of blackout protection.
- Common permissive starting logic (Fig. 1) and common protective tripping logic (Fig. 4) removed from SFBL logic and moved to new logic drawings shared with Auxiliary Fuel subcommittee. Logic Explanation charts for these figures are shared with Auxiliary Fuel.
  - note common tripping logic will trip all fuels, including BL on “Air Flow Below Liquor Nozzles < 30% MCR.”
  - MFT (master fuel trip, aux. fuels and BL) if either “Black Liquor Flow to Furnace < 30% MCR” or “Steam Flow < 30% MCR”; and “**No** Auxiliary Fuel Hearth Burners in Service” occur, indicating loss of all flame.
- New logic diagrams and explanation charts for black liquor permissive and tripping logic.
  - added trip if either “Black Liquor Flow to Furnace < 30% MCR” or “Steam Flow < 30% MCR”; and “**Insufficient** Auxiliary Fuel Hearth Burners in Service” occur, indicating loss of stable BL combustion.

**Chapter 6**

- All references to TAPPI Standard Method for black liquor solids testing corrected to T650 om-89.

**Chapter 13**

- Miscellaneous External Water Hazards:
  - deleted one possible external water hazard “4. Hoses used for testing and washing out the bed.”
  - addition of prohibited hazard “3. Hoses used for testing the bed.” This is in agreement with the ESP subcommittee.
  - added reference to air heaters which use feedwater as their heat source, it is important that the installation be designed to handle a large tube leak, without allowing water into the boiler via the air duct.

**1993 - Summary of Major Changes**

- Added Appendix A

**Chapter 1**

- Deleted the failure of a pressure part as a cause of recovery boiler explosion which is covered within the scope of the Recommended Good Practice. Revised to address improper liquor atomization as an unsafe firing condition.

**Chapter 5**

- Rewrote the section on black liquor gun purge. Revised Item 8 to add “by means of a hardwire switch.” Revised to acknowledge addition of Appendix A, “Pre-firing Checklist”. Revised the paragraph to reflect only one “starting” and “tripping” logic and revised Figures 2 and 5 to reflect single logic. Revised diagrams and figures to add “Excluding sootblower water wash” from non-operating water source. Revised Figure 8. Corrected errors in title headings for the starting and tripping logic explanation page.

**Chapter 8**

- General rewrite to define requirements for dilution sources.

**Chapter 9**

- Prohibited the reuse of old spouts when replaced annually.

**Chapter 10**

- General rewrite of introduction and section to address overflows, drains, and low pump suction in dissolving tanks.

**Chapter 13**

- Added prohibition of water cooled doors and air lances. Revised to prevent the possibility of water contacting molten smelt. Revised to identify hoses used for testing or washing out the bed.

### Chapter 15

- Revised to require purging of each leg of liquor ring header. Revised section addressing liquor gun position system and liquor gun port design to use solid doors as required.

### Appendix A

- Added generic checklist for pre-firing of black liquor.

## **1991 - Summary of the Major Changes**

### Forward

- Recognized that explosions can occur from accumulations of unburned gases from pyrolyzed black liquor.

### Chapter 1

- Identified the causes of combustible gas explosions from pyrolyzed gases from black liquor.

### Chapter 2

- Identified the recovery superintendent as the individual having the direct responsibility for the operation of the recovery boilers.

### Chapter 3

- Acknowledged that refractometers are currently the proven method of on line measuring of black liquor solids, but as new technology is proven, it can be considered.

### Chapter 5

- Revised Figure 2 - Permissive Starting Logic for Black Liquor Firing - by adding stable black liquor temperature and pressure to obtain a purge.
- Revised Figure 5 - Protective Tripping Logic for Black Liquor Firing - eliminated black liquor temperature and fuel pressure as trips, and added "Loss of Black Liquor Fuel Pumps" and "Loss of Flame" as trips. Modified the "Header Wash Logic" to permit the system to trip.
- Revised Figures. 6, 7, and 8, the piping diagrams, to represent generic concept rather than vendor specific. Also added diagrams for specific use of indirect beaters and how they should be configured for on-line washing.

### Chapter 6

- General rewrite of Chapter 6 - Off-Line Solids Measurement - and identified preferred testing methods.

### Chapter 7

- The Inconclusive charts (former Figures 9, 10 and 11) have been deleted.

**Chapter 8**

- General rewrite specifically addressing the requirement for using removable spool pieces, or double block and bleed valving to isolate equipment from black liquor piping; stating that the wash water connection must be by either a quick disconnect or by a removable spool piece, for routine “on-line” washing of equipment, such as indirect heaters, macerators, and pumps.

**Chapter 10**

- General rewrite addressing the use of vacuum and low head spout cooling systems. The requirements for cooling water quality and system design criteria were rewritten; specific operational problems were addressed covering plugged spouts, How interruption, and maintenance/inspection requirements.

**Chapter 14**

- Revised audible alarms, and indicating systems, to cover changes made during this review.