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OPERATIONS & MAINTENANCE SUBCOMMITTEE
RECOVERY BOILER SAFETY AUDIT GUIDELINES

March 1990
Revised July 2004

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FOREWORD

These Recovery Boiler Safety Audit Guidelines were developed by the API Recovery Boiler Safety Audit Task Force* for the use of member companies in developing or upgrading black liquor recovery boiler audit programs. These new guidelines include expansion and revision of the "Inspection (Audit) Review Procedures - Recovery Boiler Safety Program" published by API in 1976.

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I. AUDIT PURPOSE AND SCOPE

The purpose of the recovery boiler audit program is to reduce the risk of explosions by evaluating the overall safety and reliability of black liquor recovery boiler operations.

The scope of the audit program should be inclusive of, but not necessarily limited to, the following physical limits:

- Liquor System - heavy black liquor storage through dissolving tank and smelt spout cooling system.
- Boiler Water - boiler makeup treatment facilities and condensate return systems through recovery boiler steam outlet non-return valve.
- Furnace Gas - Combustion air fan inlet through flue gas stack outlet including sootblower.
- Auxiliary Fuel - Complete recovery boiler system.
- Waste Streams – NCG, SOG
- Control Systems – DCS, Safety Instrument Systems, PLC
- Support Systems and Utilities – Electrical, Air, Water

Note that at a few locations with unusual recovery boiler configurations somewhat modified limits may apply.

The following are the recommended major areas of focus for the audit program:

- Personnel safety.
- Pressure part integrity (materials, welds, corrosion/erosion monitoring).
- Boiler water treatment programs.
- BLRBAC recommendations (latest edition).
- Safety interlock systems and fail-safe designs.
- Operation and emergency procedures.

- Manning
- Training.
- Maintenance.
- Operating reliability.

II. AUDIT ORGANIZATION AND PROCESS

1. Each black liquor recovery boiler operation should be audited on a regularly scheduled basis. It is recommended that audits be performed on either an annual or biennial basis, but not to exceed a thirty-six month frequency.
2. A high level corporate executive or management team should sanction the audit process. An annual report, summarizing the audit results and recommendations should be distributed to enterprise management. All operating units should understand the guidelines and requirements for the audit process.
3. Each audit team should include qualified off-site members, at least two having substantial knowledge and experience regarding safe operation of black liquor recovery boilers. Specialist in areas such as metallurgy and welding, maintenance, instrumentation and controls and water treatment can add valuable insights.
4. The audit should be scheduled during a normal operating period of the recovery boiler(s). Shutdown inspections are also extremely important, but should be handled separately.
5. The following is a suggested list of documents for the plant being audited to provide the audit team. These documents should be current and up-to-date:
 - Design, performance, and downtime data;
 - Logic diagrams and written procedures for auxiliary fuel, liquor firing, and Emergency Shutdown Procedure (ESP) systems;
 - Piping and flow diagrams for auxiliary fuel, black liquor, and green liquor systems;
 - Piping and flow diagrams for water treatment, feedwater supply, and recovery boiler steam systems;
 - Emergency procedures;
 - Normal operating procedures;
 - Shutdown and maintenance procedures;
 - Operating logs (recovery boiler and water treatment);
 - Inspection reports, including tube thickness readings;

- ESP and leak reports;
- Tube analysis reports;
- Insurance company recommendation reports;
- Operator training materials and records;
- Injury records;
- Shutdown maintenance reports;
- Preventive maintenance documentation;
- Safety relief valve repair reports and settings;
- Work order backlog;
- Water treatment consultants' reports;
- Previous year's audit report and mill response memo;
- Completed pre-audit questionnaire;
- Environmental records;
- Interlock instrumentation calibration records;
- Interlock functional testing records (ESP, drum level, low solids and flame safety);
- Zero energy, lockout/tagout procedures;
- Documentation of emergency drills;

III. AUDIT REPORT FORMAT

The audit report should include the following:

- A summary of overall impressions on the recovery boiler operation, both positive and negative.
- The names of the audit team members.
- Carryover recommendations from the previous audit which still represent areas of concern to the audit team, including description of current status.
- New recommendations covering all significant deficiencies which the audit team has identified.

The report should be structured such that the most serious deficiencies or issues stand out clearly and cannot be overlooked.

The following additional areas may also be covered in the audit report:

Comments

Non-critical or routine maintenance items identified for the benefit of the operating department.

Downtime Analysis

Downtime analysis can help identify significant safety and reliability issues. Analysis of both off-liquor and reduced firing rate periods should be considered.

Performance Review

A review of current operating performance and current design limits can lead to discovery of equipment and operation deficiencies which can affect safety and reliability of the recovery boiler operation.

Audit Checklists

The checklists used by the audit team in reviewing recovery boiler operations, manning, and maintenance/inspections may be included for reference.

VI. AUDIT REPORTING AND FOLLOW-UP

1. The audit team should hold an exit conference with plant management. Discussion should focus on recommendations.
2. The draft version of audit recommendations should be reviewed by plant management for correction of factual errors (if any).
3. A final audit report should be distributed.
4. The mill should respond in writing to all audit recommendations. This response should include both the proposed actions and the anticipated timing. A copy of this response should be sent to the audit coordinator.
5. Each company should have a method for follow-up on audit recommendations.

V. AUDIT CHECKLIST GUIDELINES

Detailed audit review checklists should be developed for use by the audit team in their evaluation of the three major areas to be investigated:

- recovery boiler operations review,
- manning review,
- maintenance and inspection practice review,

These checklists should be upgraded on an on-going basis, as additional guidelines are developed for safety of the recovery boiler operation.

The following are suggested guidelines for use in developing these checklists. It is suggested that each pulp and paper company utilizing an audit program organize a team of operating, maintenance, and technical people to write the individual checklists based on these guidelines. The checklist write-ups should be structured in a way that will encourage meaningful evaluations from experienced audit team participants.

Recovery Boiler Operations Review

Checklist questions should be structured in a way that addresses safe operation recommendations from AF&PA, BLRBAC, water treatment consultants, insurance carriers, and the boiler OEM. Checklists should address equipment reviews, document reviews, and interviewing of operators and supervisors.

A. Feedwater Supply System:

- Review softener/demineralizer plant facilities, capacities, records, and operating procedures.
- Review condensate return system: filtration, chemical treatment.
- Review provisions for continuous monitoring and manual testing of water quality for both return condensate and make-up water.
- Review provisions for monitoring condensate return system corrosion and procedures for corrosion control.
- Review automatic dump systems, including calibration and testing of equipment.
- Review deaeration plant equipment condition, capacities, records, and inspections.
- Review feedwater pumping facilities, capacities, and operating procedures.
- Review provisions and operating results for continuous monitoring and manual testing of dissolved oxygen content of feedwater to the recovery boiler.

B. Boiler Water System:

- Review boiler internal treatment program: type of program, parameters measured, frequency of manual tests, control targets and limits, chemical feed equipment.
- Review drum level indicators, alarms, and trips: types of indicators, alarm and trip settings, test procedures.
- Review attemperation system: type of system, water quality, steam purity monitoring, inspections.
- Review emergency procedures (e.g., low pH, organic contamination).
- Review provisions for maintaining clean tubes (e.g., acid cleaning, tube sectioning and deposit analyses, chordal thermocouple records).
- Review tube failure records and analyses.

C. Smelt Spout System:

- Review spout cooling system equipment condition, layout, instrumentation, and alarms. Refer to BLRBAC “Safe Firing of Black Liquor”, “Chapter 9 Smelt Spouts.”
- Review chemical treatment program and make-up water quality for spout cooling system.
- Review layout of spouts, hoods, showers, shatter jets, and provisions to protect boiler tubes from corrosive spray.
- Review provisions for spout replacement, spout inspections, and spout opening inspection/replacement program.
- Review procedures for clearing a plugged spout including procedures for all spouts plugged.

D. Auxiliary Fuel System:

- Review equipment condition, layout, instrumentation, alarms, trips, and firing permissives. Refer to BLRBAC “Safe Firing of Auxiliary Fuel”.
- Review provisions for burner cleaning, operational checkouts, and preventative maintenance.
- Review procedures and reports for regular functional testing of permissive and trip interlocks.
- Review procedures and reports for calibration of instrumentation.
- Review piping and valving (e.g., safety shutoff valves, line venting provisions, identification provisions, remote shutoff valve provisions, tight shutoff checks).

E. Black Liquor Supply System

- Review condition of black liquor storage facilities.
- Review provisions for makeup chemical addition and associated safety interlock systems.
- Review systems for ash mixing into black liquor.
- Review provisions to prevent inadvertent dilution of fuel liquor, particularly during washes or boil-outs of upstream systems.
- Review the direct contact evaporator equipment, piping, and instrumentation. Refer to BLRBAC “Fire Protection In Direct Contact Evaporators”.
- Review piping system (e.g. shutoff valve provisions, identification provisions).

F. Black Liquor Firing System

- Review equipment condition, piping and valving layout, instrumentation, alarms, trips and firing permissives. Refer to BLRBAC “Safe Firing of Black Liquor”.
- Review operational and emergency procedures (e.g., hot restarts, disabled refractometers).
- Review provisions to prevent inadvertent dilution of fuel liquor.
- Review procedures and reports for regular functional testing of permissive and trip interlocks.
- Review procedures and reports for calibration of instrumentation.
- Review piping system (e.g. shutoff valve provisions, identification provisions).

G. Precipitator and/or Scrubber

- Review equipment condition, controls, trips/permissives, and operating records.

H. Green Liquor System

- Review equipment condition, instrumentation, and alarms. Refer to BLRBAC “Safe Firing of Black Liquor”, Chapter 10.
- Review operating data, liquor test frequency and records.
- Review stack scrubbing facilities and records.
- Review auxiliary/emergency dissolving tank dilution and agitation provisions.
- Review ability to safely isolate all sources of weak wash and water to the tank if solidification/molten smelt occurs.

I. Instrumentation & Controls:

- Review overall condition of all equipment: field devices, control cabinets, control room panels, conduit and wiring.
- Review operational mode (manual or automatic) for all control loops.
- Review “fail-safe” configuration for all critical control components upon loss of air

and/or electrical power supply to the final control element, and also for loss of control signal.

- Review provisions for backup protection: redundant instrumentation (e.g., drum level), emergency power supply, distributed control operator stations.
- Refer to BLRBAC “Instrumentation Checklist And Classification Guide For Instruments And Control Systems used in Operation of BLRB’s”.
- Review preventative maintenance and calibration programs.
- Review procedures and documentation for maintaining close supervision of any need for interlock bypassing.
- Review provisions for flue gas monitoring (e.g., gas analyzers, furnace pressure trips).
- Review provisions for control room and electrical rooms air quality (e.g., pressurization, purification).
- Review alarm priority management.
- Review provisions for maintaining backup control system software.
- Verify interlock logic configuration for auxiliary fuel, liquor firing, flue gas, and ESP systems. Check for configuration changes or jumpers.
- Review freeze protection provisions.

J. Combustion Air and Flue Gas Systems

- Review provisions to prevent water from inadvertently draining into furnace (e.g., flooded ash hopper, air heaters, sootblowers).
- Review installation of any feedwater coil air heaters to assure adequate protection for preventing water leakage into furnace
- Review fans and drive equipment condition, capacities, controls, records, and operating procedures.
- Review provisions to prevent either over-pressure or implosion of recovery furnace.

K. Waste Stream Incineration

- Review delivery system for proper installation in accordance with BLRBAC “Recommended Good Practice Thermal Oxidation of Waste Streams in Black Liquor Recovery Boilers”.
- Review system of introduction of NCG into the furnace to assure that the transport system eliminates possibility for introduction of water into the furnace.
- Review the system for venting and purging the transport system to assure that water will not accumulate in line during venting.
- Confirm that the proper interlocks are installed and that they are functionally tested.
- Review the burner system for CNCG’s to assure proper flame monitoring and stability (continuous igniter).

L. Sootblowers

- Review equipment condition, layout, capacities, and records.
- Review condensate removal system and water wash connections.
- Review pressure settings, nozzle design and sizes, and travel speeds.
- Review maintenance procedures and records.
- Review safety related items (e.g., lockout, poppet valve shields, asbestos, grease/oil leaks).

M. Operating Procedures and Records

- Review logs and records as to extent, frequency, and storage.
- Review operating and emergency procedures files as to extent, availability, and how up-to-date. (See Attachment A for examples of typical procedures.)
- Review operational inspection procedures (walk-downs).
- Evaluate operating crews' knowledge of correct procedures and recognition of the symptoms of emergency situations.

N. Shutdown, Start-ups, and Hydrostatic Test Procedures

- Review procedures file as to extent, availability, and how up-to-date.
- Review shutdown/start-up procedures compliance with OEM's recommendations.
- Review hydrostatic test procedures, particularly water quality used and provisions to protect superheaters.
- Review use of start up curves and superheater clearing procedures.

O. Emergency Shutdown Procedure (ESP)

- Compare plant procedures and logic diagrams with BLRBAC recommendations.
- Review post-ESP procedures (e.g., personnel accountability, waiting period before re-entry, operation of adjacent equipment, bed cooling and washing). Refer to BLRBAC Guidelines for Post ESP Procedures.
- Review functional test procedures, actual test checklists, and preventative maintenance of the ESP system.
- Compare escape route provisions and building construction standards with BLRBAC "Recommended Rules for Personnel Safety".
- Review ESP report file.
- Review leak detection procedures and emergency provisions for various types of leaks (e.g., wall tubes and screen, generating bank, superheater, economizer).
- Review ESP training program.
- Evaluate operating crews' knowledge of ESP and post-ESP procedures.
- Review operators' post-ESP checklist.
- Review ESP initiation responsibility/authority.

Manning Review

Checklist questions should be structured to recommend both document reviews and interviewing of operators, supervisors and managers.

A. Manning

- Review education and experience level of key operating department personnel.
- Compare actual manning versus authorized manning.
- Review anticipated attrition (e.g., retirement, transfers) and succession plans.
- Review “set-up” or replacement procedures to insure qualified personnel at all times.
- Review provisions for pre-screening of new department employees.

B. Training

- Review training programs for recovery personnel as to extent and frequency (e.g., formal classroom, informal crew meetings, on-the-job, operating scenario, upset and emergency refresher training).
- Review operator training materials for completeness, accuracy, and clarity.
- Review programs to improve supervisory and technical skills.
- Review individual employee training records.
- Review provisions for job progression qualification.

C. Relationship and Morale

- Review relations of recovery operation personnel with the maintenance department and with other operating departments.
- Review operator morale (e.g., working conditions, hours of work, pay scale, etc.).

D. Personnel Safety

- Review plant and department safety programs.
- Review department accident record.
- Review fuel system safety procedures.
- Review lockout and vessel entry procedures.
- Review use of personal protective equipment.
- Review recovery area safety systems (e.g., eyewashes, fire extinguishers, flammable material storage, area lighting, overall cleanliness).
- Review fire fighting provisions.
- Review safety provisions for liquor firing (e.g., rodding air ports, cleaning spouts, checking ash hoppers).

Maintenance and Inspection Practice Review

Checklist questions for maintenance and inspection guidelines should be structured in a way that recognizes ASME and National Board Inspection Code requirements, and recommendations from

AF&PA, water treatment consultants, and the boiler OEM. Checklists should address both document reviews and interviewing of operating and maintenance personnel. Inspection results and maintenance records need to be organized so as to facilitate both the short-term and long-term planning process. This review should include all fields of maintenance, including electrical and instrumentation.

1. Responsibilities

- Review personnel responsibilities for initiating maintenance work and inspections.
- Review personnel responsibilities for prioritizing and completion of maintenance and inspections.
- Review personnel responsibilities for project management and engineering modifications and/or replacement.

2. Maintenance Records

- Review work order system and backlog.
- Review individual equipment maintenance and repair records.
- Review preventative maintenance programs and records, including vibration analysis and lubrication program.
- Review emergency work orders as to extent and frequency.
- Review outage records. Check whether causes are identified and corrective action initiated, where possible.
- Review pressure part repair/replacement procedures and records (e.g., tube materials, welding procedures, NDT)

3. Inspection Records

- Review inspection guidelines and procedures as to extent and frequency, both waterside and fireside. Check whether AF&PA Recovery Boiler Manual inspection guidelines are being utilized.
- Review timeliness of response to inspection recommendations.
- Review last few inspection in detail.
- Review NDT testing procedures as to extent, frequency, and documentation (e.g., boiler pressure parts, deaerator, fans).
- Review safety valve test frequency and documentation.
- Review internal inspection procedures as to extent, frequency and documentation (e.g., tube sectioning, boroscopes, photographs, video taping).
- Review corrosion monitoring program including precipitators.

4. Spare Parts

- Review critical spares availability for major equipment.
- Review storeroom stocking and inventory provisions.

5. Waterwashing

- Review waterwashing and dry-out procedures.
- Review frequency of waterwashes and their effect on boiler corrosion.

6. Maintenance Personnel Qualifications & Manning Levels

- Review education and experience level of key maintenance personnel.
- Compare actual versus authorized manning levels.
- Review anticipated attrition and succession plans.
- Review provision for pre-screening of new maintenance employees.
- Review maintenance personnel training programs.
- Review personnel qualified for boiler pressure part welding, including certification and documentation (ref. ASME Boiler & Pressure Vessel Code, Section IX).

ATTACHMENT A

OPERATING PROCEDURES

1. Start-up checklists for control room and auxiliary operators
2. Shutdown checklists for control room and auxiliary operators
3. Emergency drain system tests and verification
 - Frequency and type of tests
4. Black liquor solids testing
 - Procedure and frequency
5. Green liquor density testing
 - Procedure and frequency
6. Plugged smelt spouts or high smelt flow
7. Burner management/flame safety system
 - Description of interlocks
8. Combustion control system (air, liquor, drum level, temperature, etc.)
 - Description of control loops
9. Dissolving tank level/density control
 - Upper limits
10. Alarm summary and normal control range parameters
 - Critical process variables
 - Normal range
 - Alarm and trip values

11. Liquor system clean-up (addition of water)
 - Hazards of water introduction
12. Sootblower failure
 - Hazard of steam impingement
13. Partial blackouts

EMERGENCY PROCEDURES

1. Emergency shutdown (ESP/rapid drain)
 - Condition requiring shutdown
 - Who has the authority
 - List of system functions
2. Emergency shutdown without rapid drain
 - Conditions requiring shutdown
 - List of system functions
3. Orderly shutdown
 - Conditions requiring shutdown
4. Manual back-up of automatic ESP (if auto system fails, do not compromise operator safety)
 - Operator checks of emergency shutdown
5. Dissolving tank solidification or high density
 - Upper density limit
6. Smelt spout cooling jacket leak
7. Low liquor solids (diversion and liquor system recirculation)

8. Blackouts (total)/lost of ignition/combustible gas explosions
9. Loss of or low spout cooling water flow
10. Loss of feedwater supply
11. High/low drum level trips
 - Tripping points
 - System function
12. Cyclone/cascade/precipitator fires
 - Trip limits
13. Electrical power failure
 - Operator duties
14. Loss of instrument air
 - Valve failure mode
 - Operator duties
15. Failure of burner management/flame safety system
 - Operator response
 - Failure modes
16. Failure of combustion control (air/liquor/drum level, etc.) system
 - Failure modes
17. Dissolving tank agitator failure
18. Loss of smelt shatter steam
19. Smelt leak in furnace bottom

20. Feedwater and/or boiler water contamination
 - Shutdown limits
21. Safety valve operation or failure
22. High/low superheater temperature
 - Upper and lower limits
 - Shutdown limits
23. Stuck sootblower in boiler, reduce steam flow promptly
24. Tube leak scenarios, including large, sudden tube leak.