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Guidelines and Checklist for Specification and Construction of Black Liquor Recovery Boilers

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Introduction

The AF&PA Recovery Boiler Operations and Maintenance Subcommittee has developed the following list of items considered to be important in recovery boiler specification and construction procedures. This list has been compiled, taking into account past and current boiler failures and associated operating problems, and through discussions with industry operating personnel, equipment manufacturers' design and engineering, and construction personnel. Consideration of these items is intended to improve existing procedures and lead to a safer, more reliable recovery boiler.

There are many codes and standards such as the ASME Boiler and Pressure Vessel Code, the Standard Building Code, and BLRBAC Recommended Good Practices, which may apply to or cover the design and construction of Black Liquor Recovery Boilers and peripheral equipment. These codes, standards and industry recommendations should be reviewed and included as a part of a specification for a new recovery boiler and applied as a part of a specification for new components on an existing recovery boiler.

The purchaser of a recovery boiler should be aware that the ASME Boiler Code is a minimum standard. Due to the nature of operating conditions of recovery boilers, these minimum requirements may not be sufficient. These Guidelines include items for consideration that exceed the Code. It is recommended that owners examine their particular conditions with this in mind.

In preparing these guidelines and checklists, the following, while not complete, is a general outline of items under discussion and is intended to point out major areas of consideration. This document is not intended to serve as a complete boiler specification, but can serve as a checklist of major topics and items to be resolved by the manufacturer and the user during boiler specification and proposal discussions.

Item 1 Boiler Tubing - Procurement, Manufacturer, Quality Control

1.1 The ASME Code, Section I, Power Boilers, sets forth the minimum requirement for boiler design. All purchased raw materials for boiler manufacturers and tubing manufacturers must conform to ASME and/or ASTM requirements. All boiler manufacturers maintain a quality control or quality assurance system covering all phases of tubing and boiler manufacture. It is recommended that purchasers' specifications and manufacturers' proposals provide for a review of the respective boiler manufacturer's proposed quality control program. The following typical items should be considered by the purchaser:

1.1-A. Manufacturers' vendor qualification requirements and raw materials control system.

- 1.1-B. Manufacturers' quality control organization and specification control system
 - 1.1-C. Manufacturers' inspection and quality assurance procedures to be performed on each material and each item of manufacture
 - 1.1-D. Manufacturers' welding control procedures
 - 1.1-E. Types and extent of non-destructive examinations to be employed and items or areas of manufacture on which each test will be conducted. All testing tolerances and acceptance criteria under the manufacturers' proposed design standard program should be reviewed
- 1.2 The manufacturers' responsibilities for raw materials quality, component fabrication, and quality control programs should be clearly defined.
- 1.3 Typical carbon steel tubing and allowable stress values are as follows:

Carbon Steel

WLD. TB. SA-178A

SMS. TB. SA-192

WLD. TB. SA-178-C

SMS. TB. SA-210-A-1

SMS. TB. SA-210-C

WLD. TB. SA-226 (withdrawn in 1997)

SMS. TB. SA-210-SS

Composite or Weld-clad³

WLD. TB. (Welded Tubing, ERW)

SMS. TB. (Seamless Tubing)

¹Verify for compliance with ASME Code, latest edition.

²Expected Minimum Value.

³Pressure and temperature limits apply to carbon steel portion only. Composite or Weld-clad layer disregarded for MWP determination

1.4 Boiler tube wall minimum thicknesses are determined by the manufacturer in accordance with ASME Code requirements. Each tube wall thickness selection should be reviewed. In some areas, minimum tube wall thickness (MWT) greater than the code minimum, is determined by structural and/or fabrication requirements rather than design pressure requirements. Special consideration should be given to the structural load bearing and slag fall resistance requirements of the furnace floor tubes and the fabrication requirements for forming the membrane furnace enclosure. Tube corrosion allowance should also receive special consideration. A thickness increase above the ASME Code requirement of 0.040 inches or 20%, whichever is greater, should be considered as a minimum corrosion allowance requirement for all tubing. Composite tubing requires no additional allowance for corrosion in the carbon steel portion of the tube. The cladding is the corrosion allowance. A thorough discussion is recommended between user and manufacturer relative to corrosion allowance required for the specific boiler design. While not necessarily all-inclusive, consideration should be given to tabulating tubes being proposed by the manufacturer in a manner as noted below. At the proposal stage, some items may be listed as “typical” or “preliminary only.” It should also be noted that the ASME Code allows less than nominal tube wall thickness on the outside radius of a tube bend which should be recognized when specifying MWT. This mainly applies to larger radius bends in superheater tubes..

Tube Wall Thickness Selection

The supplier should complete the following table and information should be agreed to by the purchaser.

<u>Tube Location</u>	<u>Mat'l.</u>	<u>OD/MWT</u>	<u>MWT Code Reqm'ts. @ Design PSI</u>	<u>Allowance Above Code Req'mts.</u>
Furnace Floor				
Furnace Lower Walls				
Furnace Upper Walls				
Boiler Side Walls				
Boiler Bank				
Screen Tubes				
*Water Wall Supply				
*Water Wall Riser Tubes				
*Screen Supply & Riser				
*Superheater Conn. Tubes				
Superheater ¹				
Economizer ¹				

*Tubes located outside gas pass. ¹MWT on these and possibly other tubes should show torus bend MWT. (See Appendix A)

- 1.5 After design and specifications are complete, the manufacturers normally order specific tubing from the tube mill as required by each boiler component. The manufacturer should be responsible for properly qualifying tubing suppliers. ERW tubing is either hydrostatically tested or given a full circumference non-destructive examination (NDE) in order to meet the ASTM/ASME specification requirements.

ERW tubing shall be tested using UT and/or eddy current testing as per ASTM E213 or E273 with reject criteria referenced in ASTM A450, either by the tube supplier or the boiler manufacturer.

The ERW tube specifications adopted by the ASME Code require, as a minimum, a flange test, a flattening test, and a reverse flattening test, which provide some control of steel quality and welding procedures. However, these required tests are only done on a frequency basis. Individual tube suppliers may perform additional destructive examinations for quality control purposes. Visual examination is also normally a part of the tubing manufacturers' quality control program.

ERW tubes must be heat treated by the tubing manufacturer following welding. ERW tubes are generally more uniform than any other type of tubing manufacture.

Heat treatment should be applied to cold worked swaged tube ends which are to be used in the recovery boiler. The Rockwell Hardness of the original tube material should be maintained in the swaged sections.

- 1.6 Seamless tubing has no welds and is generally thicker than specified due to manufacturing procedures. However, seamless tubing generally has more surface defects, material lap-over groove during manufacture, and greater likelihood of internal discontinuities. (Seamless tubing also presents more difficulties in obtaining proper roll in the drums or headers due to variations in wall thickness.

Laminations are possible in seamless tubes and in ERW tube stock. Purchaser and manufacturer should review and mutually agree upon tube lamination acceptance/rejection criteria prior to procurement and fabrications. Consideration should be given to rejecting any tube material found with laminations.

Item 2 **Corrosion Protection**

- 2.1 Structural requirements normally establish minimum tube wall thickness in the furnace floor and lower furnace wall areas. Corrosion allowance in all areas is most important and should be considered and tabulated as noted

previously (Item 1.4). In addition to this extra tube wall thickness, the following other methods should be considered to protect tubing in the lower furnace against corrosion:

2.1-A. Pin Studding

Where the manufacturer provides pin studding of the floor and furnace wall tubes as a method of corrosion protection, the pin studding may extend from the floor to above the uppermost air port zone. Experience indicates an increased rate of stud wastage with pin studs of less than ½ inch in diameter. Tube metal wastage can be materially affected by the density of pin stud placement. The density of the studs should be as great as possible. Experience has indicated good results with ½-inch diameter pin studs with up to 14 square inches of contact area per foot of tube length. Increased rates of wastage can also be expected at the higher boiler operating pressures and at the higher as-fired solids concentrations. Pin stud diameter and density should be thoroughly discussed with the manufacturer. Suitable refractory covering should be considered below the primary air ports and on the floor tubes. Recommendations for future maintenance and replacement of pin studs and refractory should also be discussed with the manufacturer. Refer to “Installation and repair of pin studs in black liquor recovery boilers, TAPPI TIP 402-15 for additional information regarding pin stud installation.

2.1-B. Metallizing

Metallizing (metal spray coating) is a method of corrosion protection for carbon steel tubes. Application methods, composition, future maintenance and inspection procedures, and long-term viability are areas of concern and should be discussed with the manufacturer. Special attention should be given to specifications for coating thickness, surface preparation, and surface profile.

2.1-C. Composite Tubes

Composite tubes are supplied for protection against corrosion in the lower furnace, and may extend above the uppermost air port zone. Some problems have been experienced with cracking of the composite layer in floor tubes, cracking in boiler openings, wastage of the composite layer around the primary air ports, and cracking of stacked and fin studs in smelt spout openings. Fabrication and construction details should, therefore, be carefully reviewed. Consideration should be given to specification of full-length tubing rather than random length which results in extra butt welds. Consideration should be given to specifying height of composite tube in the furnace. The construction of the membrane filler bar should be reviewed with the manufacturer and the corrosion protection provided, i.e., full stainless steel filler bar, weld overlay, etc. The width of the membrane filler bar should be reviewed with the manufacturer. A width of ½-inch membrane has shown to be successful in recovery boiler construction. If tangent tube construction is utilized, techniques for tube sectioning and/or repair should be reviewed with the manufacturer. Special precautions should be employed in rigging, storage, handling, weld preparation, and welding to avoid and prevent damage to the stainless steel composite tubes and membrane materials and to prevent carbon steel contamination of stainless steel welds and tube components. Non-metallic slings and other tools should be used.

Corrosion protection can also be provided by applying the alloy layer with a welding procedure, that is, "weld-clad." The considerations and issues in the application of the clad tubes is basically the same as for the tubes with a composite layer.

2.1-D. Chromized Tubes

Chromized tubes may be used for corrosion protection. Review of manufacturer's determination of corrosion allowance, heat treatment, handling techniques, and welding techniques and methods should be included. Special precautions should be employed in rigging, storage, handling, weld preparation and welding to avoid and prevent damage to the chromized portion of the tubes and to prevent carbon steel contamination of the chromized tube welds and tube surface. Non-metallic slings and other tools should be used. The specifications for the minimum allowable surface chromium should be reviewed with the supplier along with the quality control procedures used to assure the minimum content is achieved.

Item 3

Tube Rolling

3.1 The TAPPI Technical Information Paper TIP 0416-08 “Guidelines for replacement of generating bank tubes with expanded joints in two drum boilers” provides an excellent reference for proper tube rolling procedures. The problems associated with tube rolling in drums deserve prime consideration in boiler specification and erection procedures. Drum tube hole and tube end protection in shipment and storage are most important. Some lubricant preservatives and protection methods currently in use are hard to remove from tube holes and seats. Various new methods of protection are being investigated. Consideration should be given to shipping tube ends and tube seats dry but capped. The specifications should require the manufacturer and erection contractor to provide recommended procedures and equipment proposed for tube rolling. The following should be considered in arriving at such procedures and equipment.

3.1-A. Rolling procedure

3.1-B. Sequence of tube placement

3.1-C. Expander size and identification number

3.1-D. Expander drive motor, horsepower and rpm (torque minimums, if available)

3.1-E. Air volume and air pressure requirements.

3.1-F. Rolling all tubes the same day they are placed in position.

3.1-G. Cleanliness requirements and recommended methods of cleaning the tube seats and the OD of the tube sections to be expanded:

- a. The surface should appear “metal clean” after buffing when examined without magnification under normal lighting level.
- b. The surface should be free of particulate contaminants such as sand, metal chips, weld slag, etc.
- c. The surface should be free of organic films and contaminants such as oils, paint, and preservatives as determined by a visual examination, a solvent-dampened white cloth, or an equivalent alternative method.
- d. When a visual inspection is not possible and the surfaces are accessible, a dry white-cloth wipe, followed by a solvent-

dampened white-cloth wipe, may be used to evaluate the cleanliness of the surface. If either cloth exhibits indications of contamination, the system should either be recleaned or the specific contaminant analyzed for its potential deleterious effect.

3.1-H. The ID of the tube section to be rolled should be free of particulate contaminants such as sand, metal chips, weld slag, etc.

3.1-I. Rolling tubes completely through the tube seat. The tube seat may be less than the thickness of the drum shell plate.

3.1-J. Establish procedure for determining adequate and uniform rolling of each tube.

3.1-K. Determine number and size of drum seat serrations to be provided.

3.2 The elongation method of gauging tube rolling involves measurement of the actual plastic flow of the tube metal. When the elongation method is to be utilized, proper equipment, proper measuring procedures, and specific acceptable elongation ranges should be reviewed prior to boiler construction.

3.3 The compound gauge is a mechanical method for comparing the rolled and unrolled ID of a tube. Tolerances between tube OD and tube wall thickness and drum hole diameter can possibly cause over-rolling or under-rolling. If rolling is to be checked by the compound gauge or other mechanical device properly, the tolerance or variance of each tube wall thickness, tube OD, and drum hole diameter must be known and recorded for each individual tube.

3.4 Proper supervision and visual inspection of tube rolls are most important. Field erection personnel should be properly informed as to the specified procedures to be followed. Rigid procedures should be established to ensure that proper field tube rolling instructions and manufacturer's recommendations are followed. Designs incorporating seal welding of boiler bank tubes after rolling should be thoroughly reviewed with the manufacturer and procedures established to ensure that manufacturer's guidelines are followed in the field.

Item 4 **Welding**

4.1 Boiler manufacturers maintain comprehensive quality control programs covering all aspects of shop weld procedure qualifications and individual welder qualifications as covered by ASME Code. Boiler specifications should provide for review and monitoring of the manufacturer's welding quality control program. Such specifications should state the amount of

non-destructive testing to be performed in each area and at each step of boiler fabrication.

4.2 The following are recommendations for consideration in users' specifications.

4.2-A. All pressure-part butt welds in the furnace or any weld that could admit water into the furnace should be inspected 100% of the weld length using an inspection technique approved by the ASME code such as shear wave ultrasonics or radiography. Radiographic inspection should employ a minimum of two radiographs per weld with acceptance standards per mutual agreement. The TAPPI Technical Information Paper TIP 0402-33 "Guideline for Obtaining High Quality Radiographic Testing (RT) of Butt Welds in Boiler Tubes" provides a good reference for tube inspections. All other pressure containing welds, as a minimum should be examined in accordance with ASME code requirements.

4.2-B. All fillet and socket welds on pressure parts should be examined by magnetic particle or dye penetrant method(s) in addition to visual inspection.

4.2-C. Circumferential resistance butt welds may have been used in existing recovery boilers, but these welds should not be used in new or replacement components for recovery boilers.

4.2-D. The carbon steel portion of all composite tube butt welds should be radiographically inspected 100% of the weld length employing a minimum of two radiographs per weld. Once the composite weld has been completed, the weld should also be inspected 100% of the weld length employing the dye penetrant procedure.

Composite tube butt welds and composite tube to carbon steel butt welds require a cap pass using a weld metal compatible with the cladding material. Special review should be given to manufacturer's procedure for butt welding of composite tubing and membrane/filler plate termination weld.

4.2-E. On any tube-to-tube weld, especially on membrane wall panel inserts or on joining wall panels, the first weld pass (or root pass) should be completed around the full periphery of the tube prior to application of a second pass to any part of the weld. Subsequent passes should always provide continuous overlap of previous points of starting or stopping on previous weld pass. Backing rings should not be used in butt welds.

- 4.2-F. All welds of permanent attachments to pressure parts, including welds of the membrane bar to the tube, should have a visual inspection. If the visual inspection shows areas of concern, more NDE testing such as MT or PT can be conducted.
- 4.2-G. All specifications regarding procedures, materials, etc., involved in shop welding should be provided by the manufacturer.
- 4.2-H. Minimize attachment welds to pressure parts. If possible, attachments should be made to membrane or other locations than on the tubing. Tangent or circumferential welds should not be used for attachment. Temporary welded attachments to carbon steel or composite tubes should be minimized or avoided. Methods utilized in making or removing any such attachments should be reviewed.
- 4.2-I. Welding procedures and acceptance criteria for the application of pin studs on tubes should be reviewed with the fabricator.

- 4.3. Proper identification of procedures, welding materials, pre-weld and post-weld treatment requirements, and the qualifications of supervision are important considerations in recovery boiler construction. Procedures and means for welder testing and applicable ASME qualification should be clearly defined and understood. All welding discussion items noted herein would also apply to the erection contractor specifications. If the erection contractor is not the manufacturer, the manufacturer should provide adequate information to allow the erection contractor to qualify proper weld combinations and procedures in accordance with the manufacturer's design and material furnished. Provision must be made to ensure the erection contractor's personnel are properly prequalified to perform the specified welding procedures for all pressure parts to the contractor's quality control manual. All field welding on pressure parts, including butt welds and permanent attachments, should be stamped for identification of the welder.

Item 5 **Furnace**

- 5.1. Consideration should be given to providing, as a minimum, a handhole near each end of each header to facilitate thorough visual inspections and removal of debris. Due to the number of handhole leaks in headers reported at BLRBAC, consideration should be given to new designs for header inspections, such as caps, etc. to reduce handhole cap leaks after commissioning.
- 5.2. Determine number and size of chemical cleaning connections required for chemical cleaning in order to reduce the outage time required.

- 5.3 Any external bracing which could possibly interfere with proper expansion, such as earthquake braces and/or any attachment requires special attention and review.
- 5.4 Retractable maintenance beams should be considered at the furnace nose elevation for repair and inspection platforms.
- 5.5 Proposed provisions for access for inspection, maintenance, and cleaning of all boiler furnace, superheater, generator, and economizer surface areas should be regarded as a prime proposal consideration. Consider 24-inch minimum OSHA manways to hearth and maintenance deck elevation. Access for cleaning the corners at the furnace ceiling and the sidewalls should be provided. Consideration should be given to installing openings in the furnace wall that can be used to inject chemical for bed cooling into the bed and for probing for temperature prior to water washing.
- 5.6 It is recommended that the supplier's proposal use the criteria of dual pressure design for the structural design of the boiler walls and ductwork:
- a. sustained furnace pressure to cover normal operating conditions
 - b. high transient pressure to deal with abnormal conditions, such as a high furnace pressure excursion.
- 5.6-A. The static pressure is typically to be +/- 7 in. w.g. to calculate a uniform load on the furnace walls, equivalent to 36.4 lb/sq. ft. or 178 kg/sq. meter. The allowable stress at the yield point of the material at design temperature should be used. The design temperature should be the temperature of the tiebar and buckstay when the boiler is operating at the normal pressure.
- 5.6-B. The transient condition will normally set the size and arrangement of the buckstay/tiebar system that stiffens the walls. The recommended design transient pressure is +/- 25 in. water gauge. The negative transient is a major factor as it places the outer flange of the buckstay in compression thereby requiring the addition of stiffeners or vertical posts between buckstay levels to prevent the beam from buckling. The negative pressure also establishes the number of clips attaching the tiebar to the furnace wall as the inward force pulls the wall away from the tiebar and buckstay. An increase in the allowable stress for designing the buckstay for transient load should be applied by using a safety factor of 0.8, and thereby, a tensile stress of 0.8 times the yield strength of the material at design temperature.
- 5.6-C. The above shall be applied considering that the furnace corner design for pressure containment should maintain the integrity of the corner for furnace pressures up to the transient design pressure.

- 5.7 The design of the tiebar and buckstay system for the furnace should be reviewed with the manufacturer
- 5.8 The sidewall to floor tube seal should be designed to minimize stresses and reduce the potential for stress assisted corrosion (SAC) due to attachment welds on tubes.
- 5.9 The structural support of the furnace floor and the connection between the floor and the furnace sidewalls should be a design that will maintain the integrity of the enclosure in the event of an explosion or a smelt-water reaction.
- 5.10 Furnace openings should be designed to minimize the size of membrane sections to help reduce maintenance items, such as cracking and overheating due to a wide membrane.
- 5.11 The design for mounting windboxes and smelt spouts should be reviewed to minimize attachments to the wall tubes and the resultant stresses that can result in SAC.
- 5.12 Furnace corners should be designed to minimize the potential for tube tearing in the event of an explosion or smelt water reaction. Boiler general arrangements should be designed to minimize exposure of personnel to the areas adjacent to the boiler corners. Consideration should be given to routing steam and other stored energy piping away from these areas as well.
- 5.13 Seals at the junction of furnace pressure part panels, such as the nose arch to sidewall seal and the roof to sidewall seal, should be designed to minimize the potential for tube tearing in the event of an explosion or smelt-water reaction.
- 5.14 The furnace floor should not contain any tube swages and the tube butt weld should be minimized where possible

Item 6. Superheater

- 6.1 Superheater tube thickness and material selection is not as straightforward as water filled sections of the boiler due to the variations in steam temperature through the superheater elements. The design basis and results of temperature modeling should be reviewed with the vendor to assure proper location for any transitions in tube thickness or material. Utilization of one tube material and nominal thickness throughout each superheater section, as dictated by the highest metal temperature conditions of the section, should be considered to minimize confusion in

future tube monitoring and repairs. Corrosion allowance should still meet the requirements in section 1.4.

- 6.2 Superheater design should be reviewed by the purchaser to acquaint himself with the supports, corrosion, and erosion protection, gas tight roof seal design, method of ties employed and side spacing utilized by the manufacturer. The gas tight roof seal should be designed so that casing is not welded directly to pressure part tubes, for example, it should be welded to a sleeve that is welded to the tube.

The location and design of SH restraints should be reviewed. These restraints help ensure alignment and proper thermal expansion of the tubes during operation.

- 6.3 Steam temperature control and proposed operating range for conforming to specified steam temperature should be reviewed. Dolezal or "Sweetwater" condensers are the preferred source of attemperation water. Storage volume of attemperator water during upsets should be provided. If feedwater or condensate is utilized for attemperation, proper quality needs to be assured to prevent deposits in the superheater or on turbines downstream.

- 6.4 The selection of tube material for the condenser should be a subject of review considering the possibility of water quality or pH to be corrosive.

Item 7 **Boiler Generator Section**

- 7.1 General experience indicates that tubes in boiler banks having 28 feet or greater drum center-to-centers should have anti-vibration restraint systems. The restraint system design and experience should be reviewed with the manufacturer. Consideration should be given to use a clamp arrangement (handcuff style) for preventing movement instead of a flat bar system. Flat bar restraints can cause localized wear at the contact points of the flat bar to the tubes.

- 7.2 There should be an allowance for a possible reduction of the boiler bank tube thickness as a result of rolling in two drum units. Manufacturer suggested minimum wall thicknesses (MWT) for this purpose should be verified for adequacy in accordance with Item 1.4. If design requires boring of swaged ends of tubes, special consideration should be given to proper quality assurance measures including bore concentricity and depth and the influence upon proper tube rolling. Heat treatment should also be applied to cold worked swaged tube ends which are to be roll expanded to provide adequate ductility in the tube rolling operation.

- 7.3 Boiler bank tubes should be designed to minimize stress from expansion within and between tube panels in single drum units and between tubes and drums in two drum units. If possible, tubes along the drums' centerline in two drum units should be offset so that there are no straight tubes drum to drum. This will provide more flexibility for differential expansion and more uniform load distribution among tubes.
- 7.4 The manufacturer's proposal should be reviewed to insure that positive drainage is provided for all boiler tubes (especially swaged tubes) at the lower drum and to ensure that any possibility of water pockets which cannot drain from tubes has been minimized.
- 7.5 Sootblower cavities should have access doors on both sides of the boiler and be wide enough (15 inches clear space) for personnel access, inspection, and maintenance.
- 7.6 Where possible, single drum generating sections should be provided with header-to-header tubes; that is, no butt welds in the panels. The exception to this is a design in which the nozzles to which tubes are connected by butt welding are formed by upsetting the header tube wall. For this upset header design, or if it becomes necessary to build panels with header centers beyond the practical length of tubes, all butt welds should receive non-destructive examination as per Item 4.2 above. All tube to header welds should be examined with magnetic particle or dye penetrant. All fillet welds to panel headers should be stress relieved as required by the ASME Code. Consideration should be given to stress relieving tube to header welds even if not required by the ASME code. All shop fabricated panels should be hydrostatically tested in the shop utilizing the ASME Code as a guideline. Consideration should be given to providing access and room for plugging tubes at the headers without removal of sound tubes.
- 7.7 Tube fins should be tapered at top and bottom. Fin welds should be continued around end of the fin termination and carried down the opposite side for a distance to connect with the fin weld on the other side of the fin.

Item 8 **Economizer**

- 8.1 Economizer leaks are a major source of trouble for the industry. The TAPPI Technical Information Paper (TIP) 0416-21 "**GUIDELINE SPECIFICATION FOR PROCUREMENT OF AN ECONOMIZER FOR A RECOVERY BOILER**" provides a summary of the issues and recommendations for economizer specification and design. There is an accompanying Appendix that can be downloaded from the TAPPI website

that provides a form for specifying a new economizer and a recommended NDT program for quality assurance of economizer fabrication.

- 8.2 It is recommended that the minimum economizer tube wall thickness be sufficient to minimize welding problems associated with economizer construction and provide a corrosion allowance of at least 20% above ASME Code thickness requirements.
- 8.3 General experience indicates that baffling, or other approved means of stiffening economizer tube sections, should be provided for anti-vibration purposes. The design of the antivibration system should be reviewed closely with the supplier. Fin tip-to-fin tip stitch welds for front to rear ties should be avoided, if possible, because they have a history of breaking over time and are difficult or impossible to repair.

Minimize welding of buckstays, casing, tie bars, etc. to economizer pressure parts.

- 8.2 The recommended economizer selection for future installations is the mini-header design, irrespective of a new boiler or a replacement economizer on an existing boiler. The large header design may be preferred by some for duplication of an existing economizer where the optimum approach is duplication.

The mini-header design of economizer should be considered for installation with vertical, straight tubes attached to horizontal oriented headers. Arrangements where the tubes are bent at the lower end of the economizer and the header attached to the tubes in any position other than horizontal should not be considered. A full explanation of the basis for this and other recommendations can be found in the report **“Investigation of the Causes of Recovery boiler Economizer Failures and Identification of Means for Preventing Their Occurrence”** prepared for the AF&PA Recovery Boiler Committee.

- 8.4 Operating experience with economizers on recovery boilers has shown the welded connection of the tube to the header can be subjected to high stress warranting special attention in design and construction. There are two basic designs for welding the tubes to the header. The first is to machine on the header surface a seat, or socket, for the end of the tube that is then welded to the header. The other is to drill through the thickness of the header wall a hole that is slightly larger than the tube OD, insert the tube and weld the tube to the outside surface of the header.
- 8.5 The tube-to-header welds are recommended for 100% post-weld heat treatment in the fabrication shop. Stress relief of the tube to header weld

joints will provide the best fatigue resistance at a point of stress concentration.

- 8.6 Where possible, economizers should be provided with header-to-header tubes; that is, no butt welds should be allowed in economizers. If it becomes necessary to build economizers with header centers beyond the practical length of tubes, the purchaser and supplier should agree on the required QC inspections of the welds. All socket welds on economizers should be examined with magnetic particle or dye penetrant
- 8.7 All shop fabricated economizers should be hydrostatically tested in the shop utilizing the ASME Code as a guideline. Consideration should be given to chemically cleaning the economizer as part of the boiler before being placed in service. Consideration should be given to providing access and room for plugging tubes at the headers without removal of sound tubes.
- 8.8 Tube fins should be tapered at top and bottom at about a 30 degree angle. Fin welds should be continued around end of the fin termination and carried down the opposite side a distance to connect with the fin weld on the other side of the fin.
- 8.9 Sootblower cavities should have access doors on both sides of the boiler and be wide enough (15 inches clear space) for personnel access, inspection, and maintenance.
- 8.10 Review the design for adequate provision for differential expansion between piping penetrating the boiler casing enclosure and the casing where piping is fixed relative to the downward expansion of the boiler, for example, feedwater piping to the economizer.
- 8.11 Consider using T11 or minimum .25% chromium content for the feedwater piping and feedwater coil air heater piping to minimize the possibility for Flow Accelerated Corrosion (FAC). Chromium in steels has shown a resistance to FAC damage.

Item 9 **Auxiliary Systems**

- 9.1 Smelt spouts and spout cooling water requirements should be given special consideration and should comply with the latest BLRBAC Guidelines and require definite specifications and guidelines. Smelt spouts must be hydrostatically tested by the manufacturer and the user supplied with a testing certificate and identification for each spout.

Design/Layout of smelt spout decks to afford maximum protection for rod-out and maintenance personnel.

- 9.2 The sootblower system proposed by the manufacturer should include the following items:
 - 9.2-A. Number and location of blowers, sequence, and frequency of blowing. Consideration should be made for sootblowers in the area upper front corners below the roof to prevent excessive build-up over the floor of the boiler.
 - 9.2-B. Nozzle Type
 - 9.2-C. Nozzle Size
 - 9.2-D. Blowing angle
 - 9.2-E. Blowing pressure, temperature and flow
 - 9.2-F. Lance travel speed
 - 9.2-G. Possible effect on adjacent tubes, especially when using fully expanded nozzles
 - 9.2-H. Steam source and trapping, drainage, and piping arrangement
 - 9.2-I. Construction and metallurgy of lance, nozzle block, and nozzle including welding quality control procedures and methods
- 9.3 Review overall boiler design for adherence to accepted industry good practices such as rapid drain system, means of explosion relief, etc.
- 9.4 The purchaser should also consider for review and/or specification the following:
 - 9.4-A. Dissolving tank explosion relief
Emergency back-up agitation systems in the dissolving tank to prevent crystallization in the event of an agitator failure.
Emergency back-up shatter jet systems to assist operations during a heavy smelt run.
 - 9.4-B. Insulation and lagging specifications. Special attention needs to be given to windbox insulation to minimize ambient temperature in that building area.
 - 9.4-C. Boiler support steel design

Item 10 **Instrumentation and Controls**

- 10.1 Instrumentation and Controls systems should be installed in accordance with BLRBAC Instrumentation Checklist. As a minimum, BLRBAC Class 1 instrumentation should be installed. Installation of Class 2 instrumentation is highly recommended.
- 10.2 A minimum of six suitable thermocouples should be installed across the bottom of the boiler to monitor floor tube metal temperatures, especially following an ESP as required by BLRBAC. Proposed locations should be thoroughly reviewed. All thermocouples should be wired to a permanent recorder. Consideration should be given installing chordal thermocouple sections on each wall to monitor internal tube deposits. The chordal thermocouples should be located in the areas of highest heat flux.
- 10.3 Installation of a retractable thermoprobe, or other means of measuring gas temperature entering the superheater, should be considered, especially for boilers over 800 psi drum pressure. This could be single or double as required to give complete coverage. The thermoprobe is used to limit gas temperature during start up to a maximum of 900 deg F until the superheater tubes are proven clear of condensate.
- 10.4 It is recommended that the superheater be equipped with permanent thermocouples attached to the individual tubes entering the section outlet header inside the penthouse. Where there is more than one section, such as primary and secondary, each should have thermocouples attached to the tubes entering the outlet header. The manufacturer should recommend the number and location of superheater tube thermocouples. The thermocouples should be located to monitor the platen in question and not a nearby header or other component. As a minimum, thermocouples should be installed on the outer tube of each platen and on the tube in the platen receiving the least heat from the combustion gasses. Thermocouples on all superheater sections should be adequate to provide representative monitoring of metal temperatures. These thermocouples will provide indications of adequate clearing of superheater loops by indicating metal temperatures at some margin above the steam saturation temperature for the operating drum pressure. Superheater tube temperature monitoring is only one component of proper warm-up and venting procedures. The boiler manufacturer should provide adequate drains and vents and recommended procedures to ensure proper blowing and clearing of the superheater. Stainless steel tubing or stainless steel sheathing, or other suitable means, should be used to shroud thermocouple leads.

- 10.5 Consideration should be given to installation of a power actuated atmospheric relief valve on the superheater outlet, ahead of the non-return valve, and set to relieve at the minimum steam flow allowable and for superheater clearing during start-up.
- 10.6 The user should review all safety features and consider recommended procedures and provisions proposed for emergency shutdown, as well as all other safety features specified or proposed.
- 10.7 Consideration should be given to the installation of smelt bed imaging systems flue gas particle counters and tube leak detection systems.
- 10.8 Provide adequate ASTM steam sampling nozzles and connections for determination of steam purity. Connections for saturated steam sampling should be provided on the steam drum downstream of all separation devices. This is usually the tubes or pipes conveying saturated steam to the first section of the superheater. Iso-kinetic sampling nozzles to sample superheated steam should be installed in the outlet steam header.
- 10.9 Advanced operating control strategies should be reviewed with the boiler and control system suppliers to assure that the system will maintain stable operation of the boiler and will operate reliably. Similar systems operating on other units should be reviewed to determine percent of time the system is in full automatic control.

Item 11 **Technical Evaluation, Operating Conditions and Boiler Performance**

- 11.1 Consideration should be given to the following general items for new recovery boilers (we do not do this on replacement components):
 - 11.2. Purchaser specifications should include complete fuel analysis, operating information, and performance guarantee requirements. The items below should be included.
 - 11.2-A. Fuel Analysis - Wood Mix - Type Digester - Cooking Procedure - Mode of Operation and Complete Description of Liquor System. Any known waste chemical additives, spent acid, etc., and point of addition to liquor system should be clearly defined. Where possible, actual liquor samples should be provided. Liquor specifications should consist of a minimum of the following:
 - a. Total black liquor dry solids/24 hours. (Recycle ash and salt cake free)
 - b. Lb of black liquor solids/ton of pulp

- c. Avg. and range of black liquor heating value, Btu/lb Dry Solids
- d. Liquor elemental analysis (corresponding to heat value)
 - Na - Sodium
 - S - Sulfur
 - H - Hydrogen
 - C - Carbon
 - N - Nitrogen
 - O - Oxygen
 - Inerts
 - Cl - Chlorine
 - K - Potassium
- e. Percent dry solids, liquor temperature and active residual alkali as delivered to the recovery boiler system at the battery limit.
- f. Expected fiber yield, on bone dry basis, and typical cooking chemical analysis.
- g. Any other special liquor properties, such as sand content, which may be expected to be present.
- h. Any future anticipated changes in the process which might alter these values such as pulping and bleaching sequences, oxygen delignification, etc. Closing up the mill could cycle up Cl and K in the liquor.

11.2-B. Other conditions required are steam operating pressure and temperature, feed water temperature, ambient air temperature, exit gas to precipitator temperature, and amount of continuous blowdown. If steam attemperation is proposed, the amount of attemperation expected and the amount and quality of water required should be clearly defined in the manufacturer's proposal. Consideration should be given to utilization of a "sweetwater condenser" for attemperation.

Additional information required by the supplier are pressure and temperature of low and medium pressure steam; the superheater control load, that is, the percent of full load at which the superheater shall provide steam at the operating temperature; source and conditions for sootblower steam; cooling water temperature; plant elevation; and electrical characteristics.

11.2-C. Auxiliary fuel analysis and steam production required from auxiliary fuel only.

11.2-D. Provide feed water specifications and type of treatment utilized.

11.2-E. Provide a list of sample point locations for steam and water.

11.3 Performance guarantees based upon the above information should be agreed upon by the purchaser and supplier. Provisions should be agreed upon for adjusting the predicted performance and guarantees based upon actual versus specified liquor analysis and other conditions. The guarantee should include criteria specifying an uninterrupted run time at rated load which can be achieved without shutting down the unit for cleaning.

11.3-A. Suggested areas for discussion and agreement are, but not necessarily limited to, the following parameters:

- i. Liquor solids throughput
- j. Heating value and elemental analysis on which the guarantees of performance are to be based.
- k. Thermal input
- l. Liquor fuel thermal Btu heat input capacity
- m. Steaming throughput (steam side limits/capability)
- n. Thermal performance (net steam flow after sootblowing)
- o. Cleanability (run length) and sootblower steam consumption
- p. Turndown (minimum liquor heat input)
- q. Chemical reduction
- r. Gas temperatures entering and exiting superheater, boiler bank, and economizer (exit gas temperature)
- s. Emissions
- t. Outlet steam pressure, temperature, temperature control point, and steam purity.

- u. Surface temperature of insulation and lagging on the boiler setting, including separately the face temperature of the windbox.
- 11.3-B. For purposes of evaluating proposals, each manufacturer should provide design data and basis for calculations pertaining to furnace volume, and square feet of heating surface including calculation method and Btu input. The manufacturer should also provide the same information pertaining to the design and maximum furnace hearth heat release rate.
- 11.3-C. Gas temperature profiles and gas velocities from the furnace through the last pass of the economizer should be reviewed.
- 11.4 The manufacturer should provide training aids, problem-solving service, boiler performance checks during the first year, recommendations for chemical cleaning prior to placing unit in service, pre-operational steam path cleaning, and specific guidelines for setting of safety valves.

Item 12 **Erection**

- 12.1 The project site and general arrangement design should be reviewed for proper access during erection and for future maintenance.
- 12.2 The proposed project schedule should be reviewed to include provisions for proper sequence of erection.
- 12.3 Project plan should be reviewed to assure that sufficient storage space is available for staging material and components during erection stage.

Item 13 **Quality Assurance**

- 13.1 The supplier should provide a written quality plan for fabrication and/or erection.
 - 13.1-A All applicable codes will be identified.
 - 13.1-B Vendor and Customer Quality Assurance organization should be identified.
 - 13.1-C Fabrication and erection inspection requirements should be identified.
 - 13.1-D Key fabrication inspection points should be identified and customer inspection points defined.

13.1-E Customer inspection activities should be defined to include fabricated equipment surveillance plan.

13.1-F Procedures for disposition of non-conformities should be developed.

13.1-G Quality reporting procedures should be established.

13.2 Owners should consider supplying their own quality control inspectors to monitor the project.

References:

Investigation of Industry Experience With Floor Tube Failures in Recovery Boilers, Grace, T. M., Clement, J. L., AF&PA Report, 2003

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Dissolving Tank Explosions, A Review of Incidents Between 1973 and 2008 Final Report, S. Lien and N DeMartini, AF&PA Report, 2008.

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Guidelines for specification and inspection of electric resistance welded (ERW) and seamless boiler tube for critical and noncritical service, 0402-13

Guidelines for evaluating quality of boiler tube butt welds with ultrasonic testing, 0402-31

Guideline for obtaining high quality radiographic testing of butt welds in boiler tubes, 0402-33

Recovery boiler performance calculation – short form, 0416-01

Keys to successful chemical cleaning of boilers, 0416-06

Guidelines for replacement of generating bank tubes with expanded joints in two-drum boilers, 0416-08

Installation and repair of pin studs in black liquor recovery boilers, TAPPI TIP 402-15

Recovery boiler sootblowers: the basics, 0416-19

Recovery boiler sootblowers: practical guidelines, 0416-20

Guideline specification for procurement of an economizer for a recovery boiler,
0416-21

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a recovery boiler, 0416-22