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Guideline specification for procurement of an economizer for a recovery boiler

Scope

The economizer installed on a Kraft recovery boiler is the component responsible for the greatest number of tube leaks that result in lost production for the pulp and paper industry. This technical information paper provides the engineer with a guideline specification and supporting information for economizer procurement. The TIP is based on reports from a comprehensive study initiated by the AF&PA Recovery Boiler Committee (1). The study was presented at a TAPPI Conference in 2006 (2). The guideline specification addresses design, materials of construction, manufacturing and shipping recommendations for vertical tube economizers. It is formatted as a procurement specification that can be used as a basis for discussion with suppliers and obtaining quotations. The guidelines are not intended to be applied for a horizontal tube economizer, although there is some information that has merit when applied to a horizontal tube design.

Definitions

A definition of the terminology as used in the TIP is necessary for understanding the general description of the economizer on a modern day recovery boiler as well as the guideline specification.

Bank: a specified number of vertical tubes connected between headers and having inside the tubes an upward flow of water and over which there is a downward flow of flue gas. The following definitions for hot bank and cold bank apply where there are two or more banks.

Hot bank: the bank where the flue gas exiting the generating (boiler) bank enters.

Cold bank: the final group of water cooled vertical tubes from which the flue gas temperature is at its lowest leaving the boiler envelope. Incoming feedwater enters at the bottom header and exits at the top header of the bank.

Crossflow: the tubes are oriented perpendicular (at a right angle) to the gas flow.

Longflow: the tubes are oriented parallel to the gas flow.

Countercurrent flow: gas and water flow in opposite directions, such as, upward flow of water and downward flow of gas in a bank.

Spray attenuator: a device in which water is directly contacted and mixed with superheated steam to control the steam temperature.

Finned tube: as used throughout this TIP, is a design to extend the tube heat transfer surface by welding steel strip on opposite sides of the tube for its full length.

Mini-header (bottle header) economizer design: a design in which straight, vertical tubes are arranged with fins in one plane and attached at the bottom to an inlet header and at the top to an outlet header to form a sheet, or platen.

Header OD ≥ 63.5 mm (2.5 in.), ≤ 101.6 mm (4 in.); see Fig. 1.

Large header economizer design: an economizer made up of shop assembled modules with finned or bare tubes that are bent to enter a large pipe header radially in rows along the header length. Header OD $\geq$ DIN 150 (6 in.), $\leq$ DIN 450 (18 in.). Module size proscribed by shipping clearances.



Fig. 1. Mini-header sheets pre-assembled for shipment in groups of five with upper headers vertical.

Safety precautions

There are no safety precautions required as this TIP is a recommendation for specification of equipment

Description of economizer

The typical economizer is made up of one or more banks of vertical, longitudinal finned tubes with each bank having an upward flow of water inside the tubes and a downward flow of flue gas outside of the tubes. The large majority of economizers are arranged in two banks. Fig. 2 illustrates a typical, large header economizer profile of modules arranged in two banks; it is used herein as a model for tracing the flow path of flue gas and water.

The flue gas exiting the generating bank enters the 'hot' bank of the economizer at the top in crossflow (normal to the tube), then turns in the bank to flow downward (longflow) to again turn and exit in crossflow. The gas then flows upward in a cavity formed by the rear baffle wall of the 'hot' bank and the front baffle wall of the 'cold' bank to enter at the upper end of the 'cold' bank, which has the same flow arrangement as the 'hot' bank. Each bank is enclosed by four walls, with an opening in the upper part of the front wall as an inlet to the bank and an opening at the lower end of the rear wall as an outlet. There is a sealed casing 'roof' at the top, and an ash hopper under the bank. The flue gas leaves the recovery boiler at the outlet from the 'cold' bank and passes through flue gas ducting to an electrostatic precipitator for dust collection.

The feedwater flows countercurrent to the gas flow. Water enters the lower headers of the 'cold' bank and discharges to the steam drum from the upper headers of the 'hot' bank. The typical recovery boiler includes a separate heat exchanger in which feedwater is used to cool and condense a portion of the steam generated to be used as atomizer spray water to control final steam temperature. This heat exchanger (also called sweetwater condenser) is generally cooled to condense steam using the feedwater flowing from the lower temperature economizer bank to the higher, that is, from the 'cold' bank outlet to the 'hot' bank inlet.

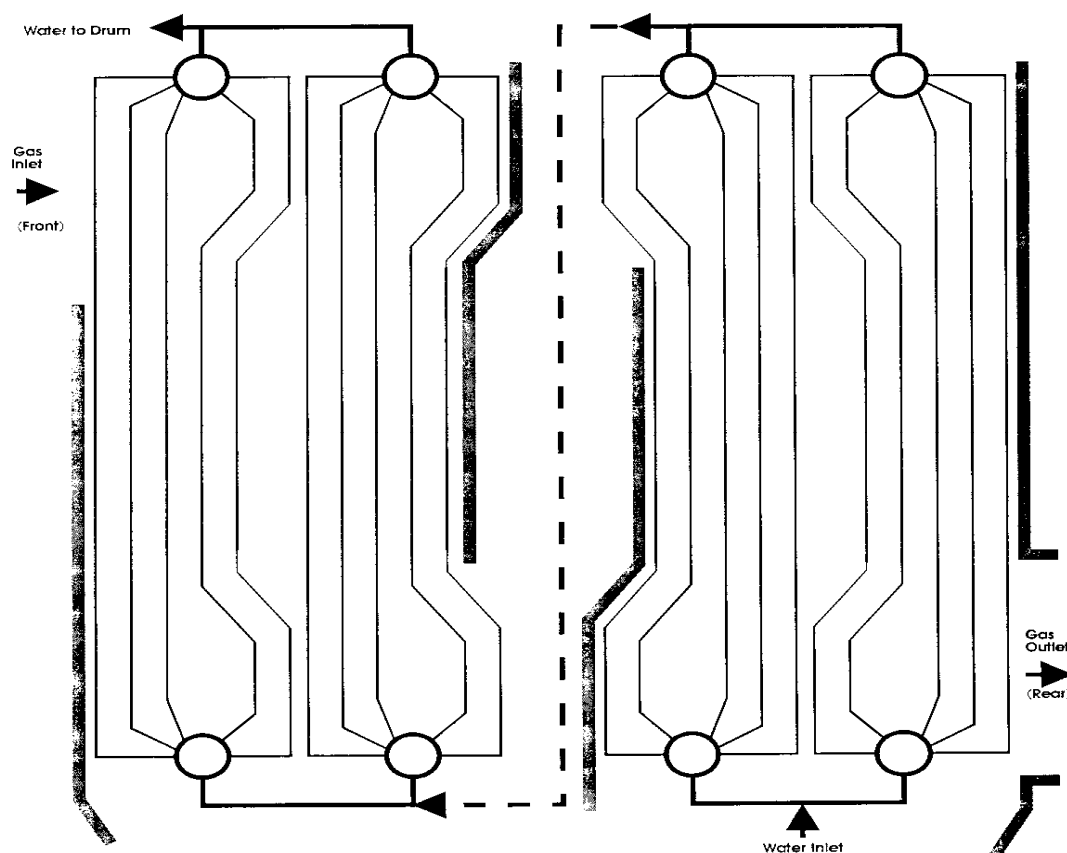


Fig. 2. Economizer arrangement with two banks. The hot bank is on the left; cold bank on right

The four vertical walls forming the bank enclosure are of both casing and watercooled construction. The sidewalls are casing and this casing is a continuation of the total economizer enclosure. The front and rear walls of the flow cavity, described in the first paragraph of this section, are generally watercooled by a portion of the incoming feedwater. The front wall of the 'hot' bank is watercooled, whereas the rear wall of the 'cold' bank enclosure is casing which supports externally enclosure insulation and lagging.

The dimensions of a bank enclosure are circumscribed by 1) a width that is normally the boiler width, 2) a depth that can be cleaned by sootblowers located in a central cavity and that provides a gas velocity at or near the manufacturers design limit, and 3) a length that provides the heat transfer surface required to cool the gases to the desired final temperature. The length of a bank, inlet to outlet, is generally constrained by the maximum length of tubes available from the steel mill. This length is around 18 to 20 meters (60 to 65 feet). The usual design solution is two banks using the tubes up to the maximum length. Longer requires that two tubes be butt welded together and this large number of butt welds is not acceptable to some operating companies. A two bank economizer generally provides a compact arrangement of building and equipment that is economical and permits installation of ash and liquor systems consistent with good engineering practice. There are some installations with three banks and very few with a single bank exceeding 20 meters.

The guidelines provide for two configurations of the economizer bank for which the only significant difference is the size and arrangement of headers. Other characteristics are mostly the same. For both, the heating surface of the tubes in contact with the flue gas is extended by welding two longitudinal fins on opposite sides of a tube. Any reference herein to 'fins' should be understood to refer to 'longitudinal fins'.

The first configuration is the large header design where tubes are attached to large pipe headers to form a module. Fig. 3 pictures a large module prepared for shipment. The header length is limited by shipping clearances of the assembled module. Several modules are arranged side-by-side with headers oriented from sidewall-to-sidewall (at a right angle to the gas flow). The tubes are bent to enter the header radially; the number is limited by header diameter. An economizer 'bank' might consist of two modules deep, thus, a two bank economizer would have four modules deep; this is the arrangement shown in Figure 2. The large header economizer was common into the early 1980's.



Fig. 3: Large header module

The second configuration is the mini-header design, in which straight tubes are arrayed vertically in sheets, or platens, with the fins extending to the front and to the rear. Fig. 4 illustrates a typical mini-header economizer profile of sheets arranged in two banks. The flow path of gas and feedwater is the same as described for the large header configuration. The diagonal lines indicate the ends of baffles and the allocation of surface for heat transfer calculations-inlet crossflow surface, longflow surface from inlet to outlet and crossflow at the outlet.

The tubes in each sheet are arranged in one plane and attached at the bottom to an inlet header, and at the top to an outlet header as shown in Fig. 1. These individual, small diameter headers are oriented parallel to the flow of gas; the length of header is set by the number and spacing of tubes in a sheet. The sheets are suspended side-by-side across the width of the boiler. The lower headers are connected to a large feedwater pipe through an arrangement of interconnecting pipes/ piping manifold, which arrangement varies considerably among the suppliers.

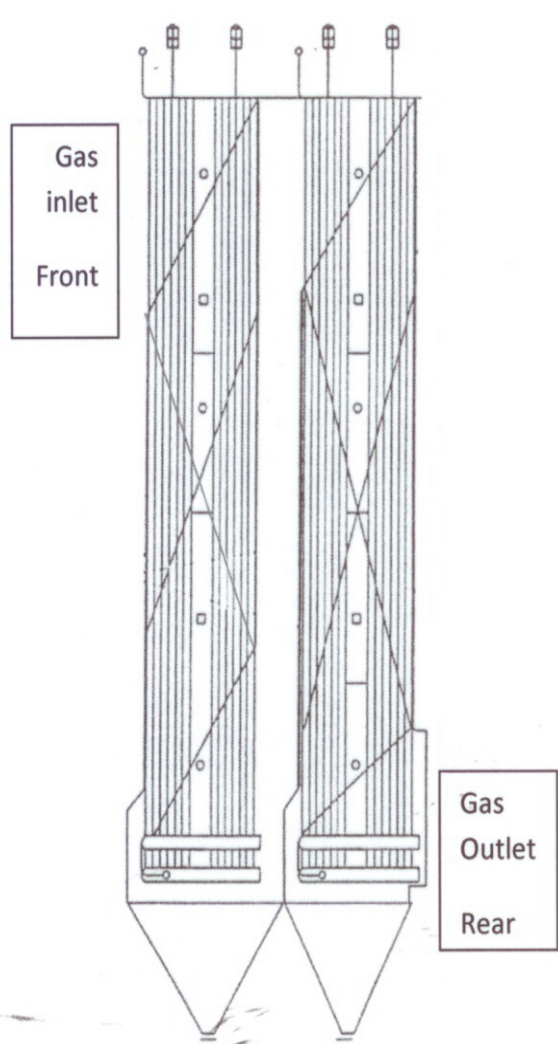


Fig. 4: Economizer arrangement with mini-header banks

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 only 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 prepared for the AF&PA Recovery Boiler Committee (1).

Tube to header weld joint

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. These are equally suitable for small and large headers. Table 1 describes these two designs.