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SOME CURRENT DEVELOPMENTS IN THE DESIGN OF LARGE UTILITY BOILERS

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ENGINEERING & OPERATING SECTION CONFERENCE
BILOXI, MISSISSIPPI
APRIL 8-9, 1965

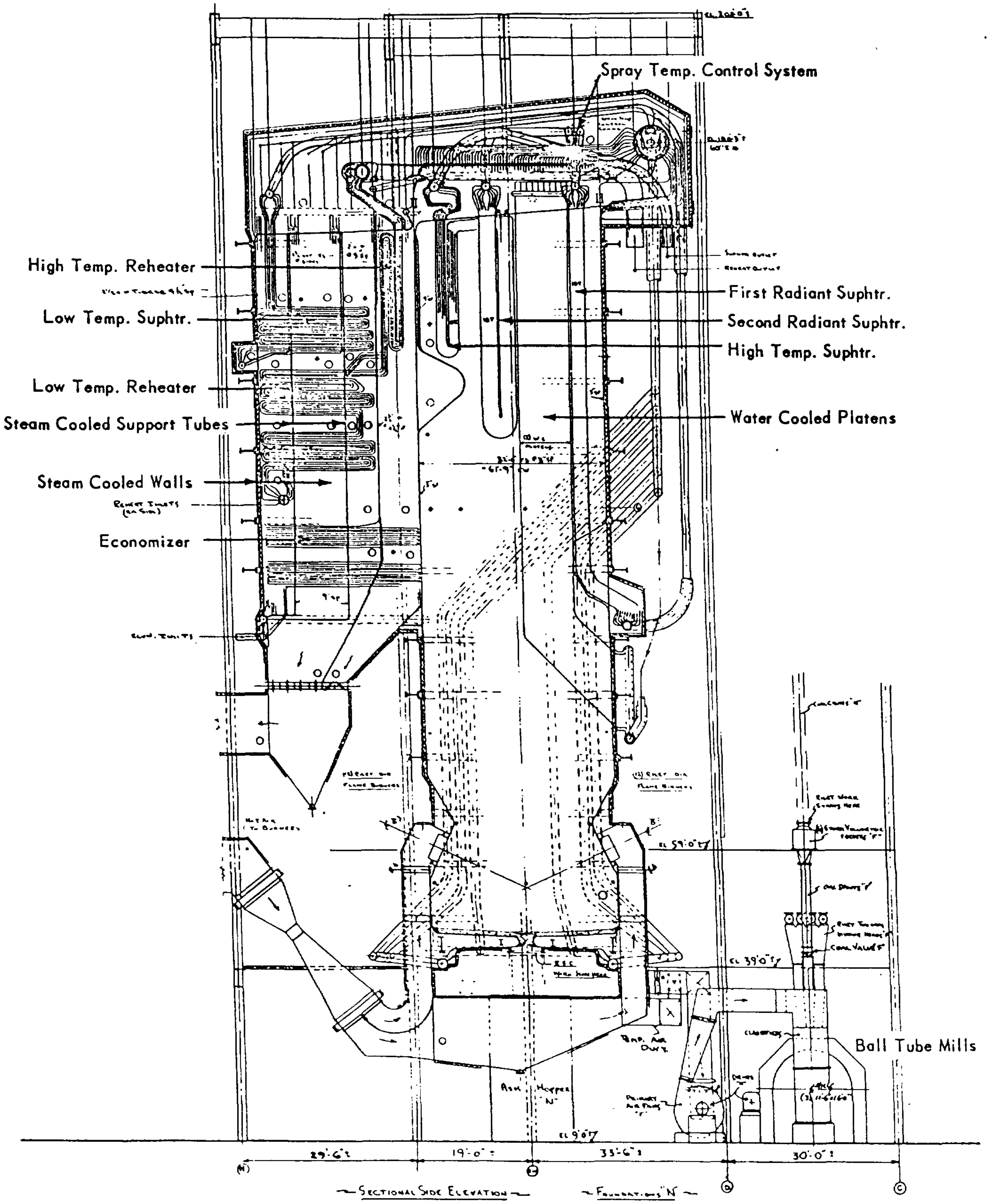

FIGURE 1
RILEY TURBO FURNACE STEAM GENERATOR
TAMPA ELECTRIC CO., GANNON NO 6

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SOME CURRENT DEVELOPMENTS IN THE DESIGN OF LARGE UTILITY BOILERS

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There are a large number of factors that affect the design of a boiler, too many in fact to cover in a short paper. Perhaps the description of the design of a particular boiler might best cover some of the features which have been developed in advancing the state of the art.

A recent design of a utility boiler is that shown in Fig. 1. This Fig. shows the No. 6 Steam Generator currently on order for Gannon Station of Tampa Electric Co., the largest steam generator in the State of Florida. The unit is designed for a peak capacity of 3,000,000 lbs. of steam per hour at 2600 psig and 1000 F. at the superheater outlet and a reheater outlet temperature of 1000 F. It is a single drum pulverized-coal-fired slag tap Turbo Furnace boiler. The geometry of the Turbo Furnace provides for disposing the burners on the inclined portion of the front and rear walls. Pulverized coal is fired thru Directional Flame Burners which are an intertube type similar to that illustrated in Fig. 2. One burner unit consists of three slots. Coal is fired thru burner nozzles in the outside slots. An oil-electric igniter is positioned in the center slot. Fly ash is reinjected thru a pipe at the bottom of one outer slot. Combustion air enters in parallel streams and the direction is determined by the adjustable dampers in the slot. The burners are operated as opposed pairs. The opposing streams intermix producing a highly turbulent furnace condition in the hearth below the furnace throat. Combustion is substantially completed in the hearth and there is relatively little flame above it. With this type of firing there is no tendency for flame impingement on the furnace walls because the turbulence is of a rolling "linear" type instead of a spinning centrifugal type. The gases leaving the hearth are constricted as they pass thru the furnace throat and move up away from the furnace front and rear walls. The upper vertical furnace walls are thus relatively free of flame impingement and consequently are also relatively free of ash deposits. Only 10 wall deslaggers will be required in the furnace.

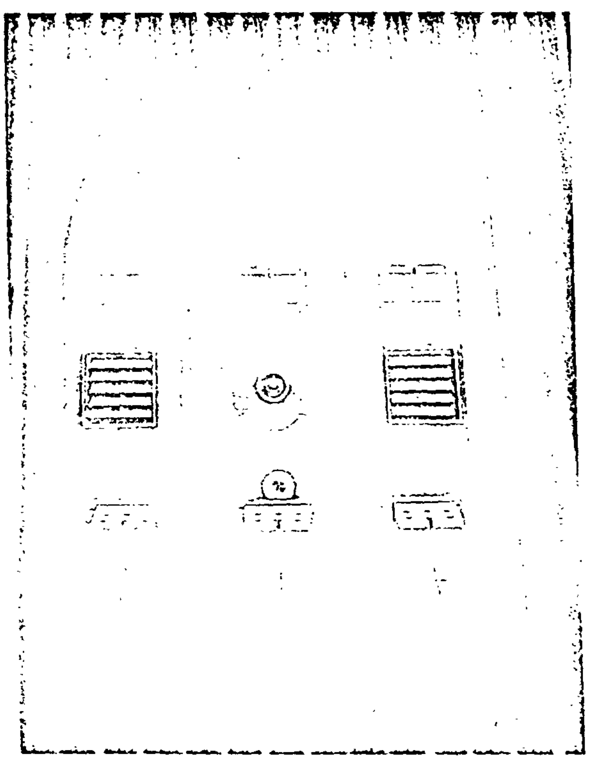

FIGURE 2
TYPICAL DIRECTIONAL FLAME BURNER

The furnace geometry and burner design and arrangement assist in the maintenance of ignition and flame stability over a very wide load range. Orning's (1) comments on burner adjustment and flame control in the Turbo Furnace at Blaine Island are of interest:

"The furnace responded to burner adjustments. Visual observation showed that the flame position could be shifted by changing the relative mass flow thru front and rear burners; the flame shape could be altered by directing one set of burners more toward the slag pool; and the temperature distribution could be changed by a shift of secondary air from front to rear burners. The response was such that the boiler operators had learned to use burner adjustments to move the flame for control of slag accumulation just above the melting zone."

(1) "An Investigation of the Variation in Heat Absorption in a Pulverized Coal-Fired-Slag-Tap Steam Boiler at Blaine Island Charleston West Virginia" by A. A. Orning, M. Weintraub, C. H. Schwartz, E. A. Mihok, C. R. McCann and W. C. Harrold, Trans. ASME, Vol. 80 pg. 1240.

A Turbo Furnace is equally applicable to oil and gas firing and is particularly suited to multi-fuel operation. In addition to the ease of changing from one fuel to another, a significant operational advantage of the Turbo Furnace is the fact that all burners are on one level. The monitoring of furnace flames and furnace conditions is simplified and all burners are readily available for adjustment and inspection. Also of particular interest is the use of the Directional Flame Burners in Turbo Furnaces to produce a minimum of objectionable oxides of nitrogen when burning oil or gas.

The Gannon No. 6 Steam Generator is pressurized. The furnace is of all-welded Fire-Wall construction consisting of tubes and fins alternately welded together longitudinally to form solid metal furnace walls. Where openings are provided for observation, access, instrument connections, etc., boots made of 10 gauge metal plates are welded to the outside of the panels to form a pressurized enclosure. Fig. 3 is an illustration of a pressurized window. Connections on this window provide air at forced draft fan air pressure for keeping the glass port clean and the opening in the wall free of ash. When it becomes necessary to clean the glass window, opening the left hand knob automatically introduces compressed air into aspirating jets to contain the furnace gas pressure while the window is pulled away for mechanical cleaning.

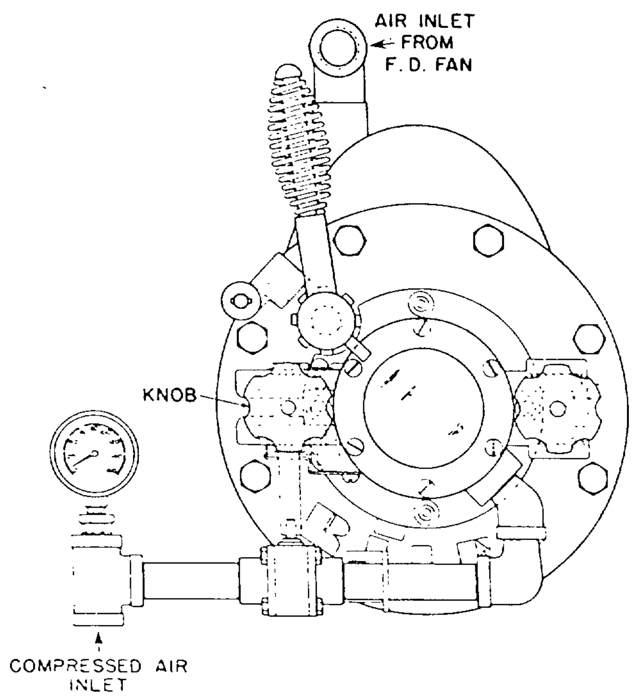

FIGURE 3
PRESSURIZED DOOR & WINDOW ASSEMBLY

Where water cooled and superheater tubes penetrate the roof, scalloped plates are welded to the vertical penetrating tubes and to the roof tubes. Similar construction is used to close the junction between the side wall and roof. Since the superheater headers and tubes are at higher temperatures than the water walls provision is made in the construction for sufficient flexibility to accommodate the expansion difference.

Large welded Fire-Wall panels are shipped from the shop to the job site in widths to 8' and in lengths to 60' or 65'. Where conditions permit, panels are sub-assembled on the ground and raised in larger sections. Fig. 4 is a picture of the boiler for Gannon No. 5 showing the upper rear boiler wall in place. This wall was shipped in 6 panels. Pairs of panels were field assembled on the ground and the three 16' wide sections, 56' in length, were raised in position in one day. Panel construction materially reduces field erection time by about 20% and erection cost by about the same amount.

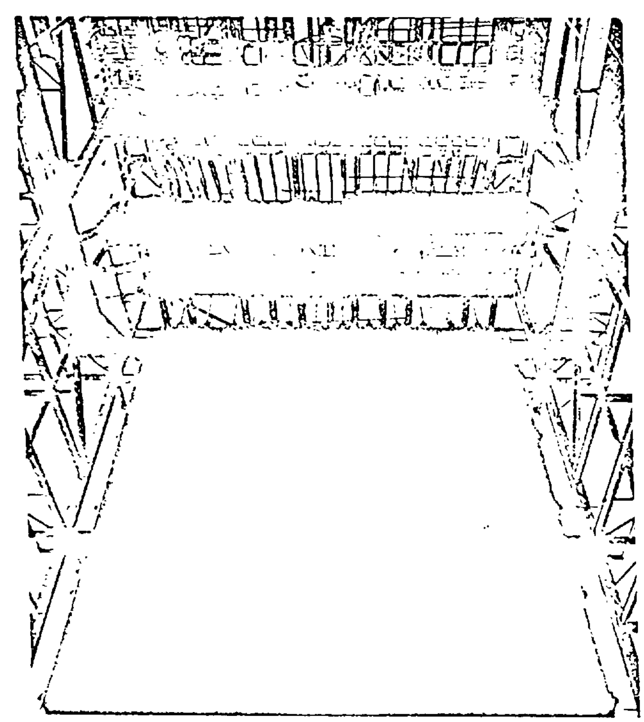

FIGURE 4
CONSTRUCTION OF UPPER REAR BOILER WALL
GANNON NO 5

In addition to the furnace cooling surface in the welded furnace walls, the additional cooling required to reduce furnace exit gas temperature to slightly over 1900 F. is provided by water cooled and radiant superheater platens. The radiant superheater platens are spaced across the furnace on 27" centers. They are far enough apart to prevent bridging of the ash and provide sufficient lane width to permit furnace gas cooling by radiation. Fig. 5 shows water cooled platens for Gannon No. 5. They were shipped in partial panels to the field and the panels completed and welded to the headers on the ground. The seven platens were raised in position in two days.

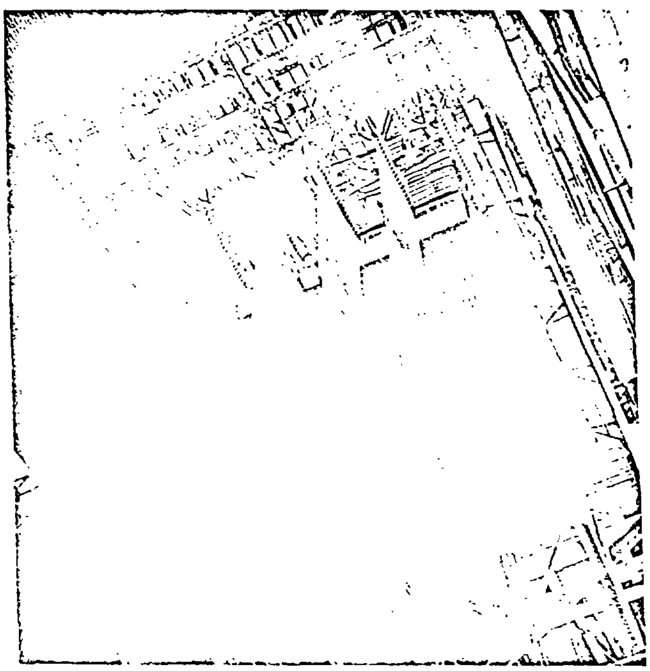

FIGURE 5
CONSTRUCTION OF WATER COOLED PLATENS
GANNON NO 5

Coal is pulverized in three double-ended pressurized Ball Tube Mills. The Ball Tube Mill is noteworthy because of its high availability and the uniformity of fineness of the coal pulverized. High combustion efficiency and low fouling characteristics of a furnace depend on uniform fineness of the pulverized fuel. Uniform fineness is obtained when grinding surface in the mill remains constant. When parts wear on most mills, grinding surface is lost and fineness falls. In the case of the Ball Tube Mill the periodic addition of balls maintains the grinding surface constant and results in uniform fineness. The ease with which grinding surface is maintained and the fact that each of the two feeders is capable of furnishing full Ball Tube Mill capacity so that loss of one feeder has no effect on mill pulverizing capacity, explains the high availability of the Ball Tube Mill.

One feature of interest is the means provided for the addition of balls. Fig. 6 shows the ball charge hopper of a pressurized mill. The hopper consists of a charging hopper and a stop valve which permit the addition of make-up for maintaining the ball charge while the mill continues to operate.

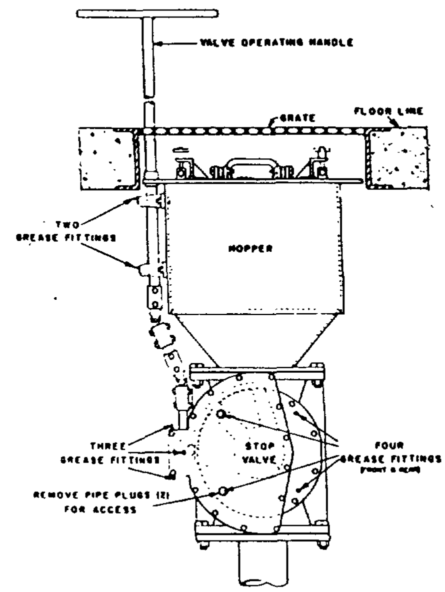

FIGURE 6
BALL CHARGING HOPPER SYSTEM

The pumping power required in this natural circulation boiler is furnished by gravity, the availability of which exceeds that of a mechanical pump. Even with a high steam density at a drum pressure of 2749 psig and 2600 psig at the superheater outlet the circulation ratio is 4. In other words, the mixture leaving the walls and entering the drum is 1/4 steam and 3/4 water. In the furnace hearth at the bottom of the furnace where the heat absorption rate is greatest the proportion of steam in the mixture varies from 0% to 5%.

Steam is purified by the internals shown in Fig. 7. Steam from the water walls is released uniformly along the drum length to both sides of the drum. The primary separators remove the steam from the water which is then mixed with the incoming feed and the steam-free sub-cooled water flows thru vortex arrestors into the downcomers. The moist steam flows across a finned tube condenser screen which is cooled by feed water. Some steam is condensed on the fins. The moist steam is purified and the silica vapors substantially removed by scrubbing the finned surfaces which have been wetted by condensate. The steam is finally dried in the drier cartons thru which the steam flows at relatively low velocities. Water is drained from the drier cartons into the downcomers thus assuring positive drain action. Feed water entering thru the feed pipe flows thru the finned tubes and on leaving the tubes is directed toward a downcomer. By directing the feed water toward a downcomer, use is made of its kinetic energy and this reduces the potential energy required to drive the water toward the downcomer. As a result and because the downcomers are spaced along the drum length, level gradients along the drum axis are relatively small. The drum internals are particularly efficient at the low fluid velocities for which they are designed. A particular advantage of the low velocities is the low pressure drop and hence the negligible effect on the circulation rate.

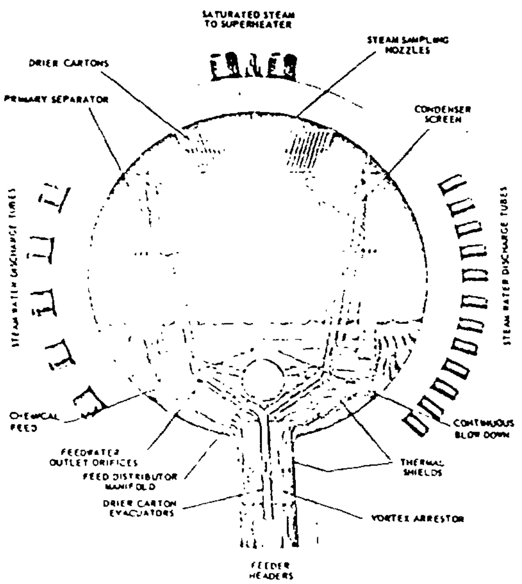

FIGURE 7
STEAM DRUM INTERNALS

The superheater consists of 3 steam cooled walls in the rear boiler pass, followed by vertical support tubes supporting the economizer, reheater and superheater; then a horizontal tube drainable section of low temperature primary superheater; a first radiant platen superheater; a spray section for steam temperature control; and an outlet bank consisting of a second radiant pendant superheater platen followed by a high temperature pendent superheater loop at the furnace outlet. The use of radiant and convection surfaces in a superheater produce a relatively flat steam temperature characteristic over a wide control range. Fig. 8 shows the quantity and the percentage of spray water required for the control of steam temperature. It is interesting to note that the control requirements reach a peak at about two-thirds load and drop steadily to peak load.

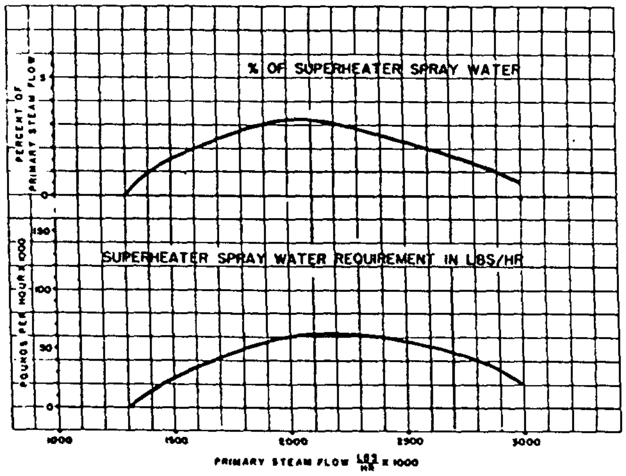

FIGURE 8
STEAM TEMPERATURE CONTROL
SPRAY WATER REQUIREMENTS

The reheater consists of a low temperature section of several loops of horizontal tubes in the main pass section of the rear of the boiler followed by a high temperature vertical loop outlet section. Reheat steam temperature is controlled by damper control of gas flow thru the main pass and the bypass. Spray water in the reheater inlet piping will be used as an overriding control.

Horizontal bare tube economizer elements are provided in the main pass and bypass. The economizer outlet tubes form the baffle between the main pass and bypass. As previously stated, superheater tubes form the vertical supports for the horizontal loops of the economizer, reheater and low temperature superheater. Since 4-1/2" spacing is used and since the elements supported range in diameter from 1-3/4" to 2-1/2", clear lanes having a minimum width of 2" increasing to 2-3/4" in some sections, are provided from the uppermost tubes clear down thru the economizer. This is an important feature of the design and permits efficient mechanical cleaning of all surfaces. The ample spacing of the full height lanes and the positive positioning of the elements in perfectly vertical in-line rows provided by the support arrangement is a particularly valuable feature for cleaning, inspection and operation.

In Fig. 9 is a plot of gas temperature and steam temperature in the superheater at peak load. This figure illustrates the various temperature environments to which superheater tubes are exposed. The inlet tubes forming the 3 walls and the support tubes are exposed to gas temperatures which vary from the top to the bottom of the rear boiler gas pass. The low temperature elements are counterflow. The radiant superheater sections are exposed to furnace gas temperatures and the high temperature outlet superheater loop is heated in parallel flow by furnace exit gas. The reason for using parallel flow is to reduce the gas temperature to which the tubes having the highest steam temperature are exposed. The reason for crossing the tubes from the front of the radiant pendant platen to the outlet superheater loop is to permit connecting the outside tube of the platen to the inside tube of the outlet bank, and the inside tube of the platen to the outside tube of the bank. By this means heat absorption is equalized and inequalities of steam and metal temperatures are minimized.

The tube diameter at the bottom of the radiant pendant section is reduced to increase the rate of steam flow which improves the cooling of that portion of the high temperature elements exposed to direct furnace radiation. Another feature which helps to equalize steam temperatures among the parallel elements is the crossing of the two spray pipes between the radiant superheater sections, and the provision for the biasing of the spray water to the two pipes.

It is worthy of note that except for the rear furnace water screen and the economizer tube baffle between the main pass and the bypass, the surfaces between the furnace outlet and the economizer, are all steam cooled. The heat duty of the superheater and reheater is such that the bulk of the heat must be extracted from the gases for this duty alone. In addition, since the furnace exit gas temperature at peak load is only a few degrees above 1900 F., additional heat must be absorbed from the furnace by the radiant superheater platens.

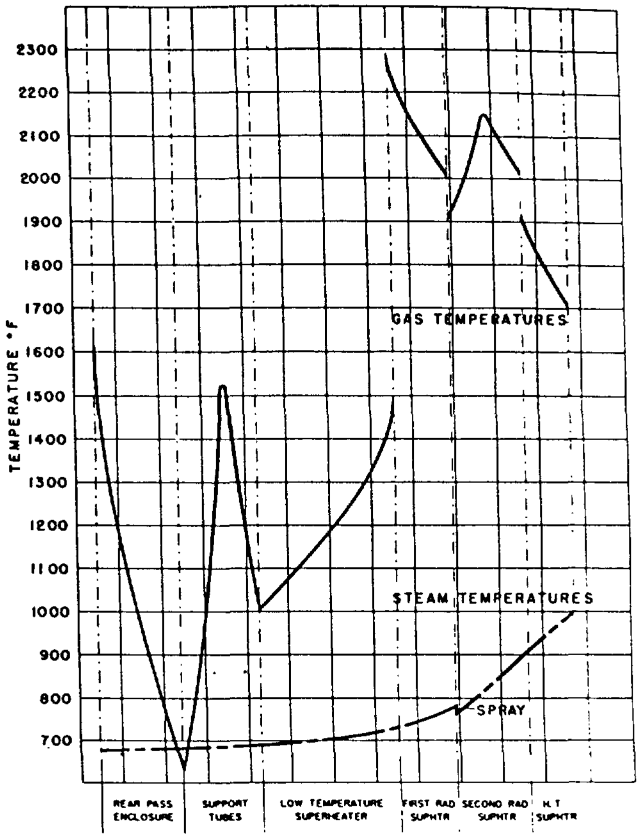

FIGURE 9
STEAM AND GAS TEMPERATURE DISTRIBUTION IN SUPERHEATER AT LOAD OF 3,000,000 LBS PER HOUR

The heat recovery downstream of the economizer is of particular interest since it consists of a single regenerative type air heater which is one of the largest on order. This unit is 42 feet in diameter and 7 feet 6 inches in depth and has a heating surface of 343,700 square feet.

The design of the No. 6 Steam Generator for Gannon Station incorporates many of the best features that have been developed for subcritical coal fired utility boilers. Some of these features have been highlighted in an effort to show how designers have benefited from past experience and to illustrate some of the steps that have been taken to improve reliability and performance.