BOILER CONDITION ASSESSMENT AND RETROFIT PROGRAM AT SIERRA PACIFIC POWER'S TRACY STATION, UNIT NO. 2

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ABSTRACT

Ensuring that a twenty-three year old gas/oil fired steam generator at Tracy Station, Unit No. 2 would be available to provide another twenty-years of service began with a complete boiler condition assessment program followed by a major alteration in the convection pass, penthouse and steel structure.

This paper discusses the planning and results of the program used on a 700,000 lbs/hr, Riley steam generator built in 1963. The successful completion of the project, together with its cost, schedule, and operating results are discussed herein.

The inspection, non-destructive testing and analytical tasks provided input for a condition assessment report on the boiler, and the feasibility of additional cyclic operation. Performance test data was collected, evaluated and design parameters set which included a redesign and reconstruction of the convection pass heating surfaces and their support systems.

INTRODUCTION AND BACKGROUND

Tracy Unit No. 2 is an 83 MW, gas and/or oil fired, non-reheat unit which has been in commercial operation since October 1, 1965. The Westinghouse turbine-generator is designed for 950°F, 1313 psig, and 1-1/2" HgA.

The boiler is a Riley balanced draft, natural circulation unit, 700,000 lb.hr (750,000 lb/hr - 4 hr. peak), capacity and 1400 psig, 950°F design outlet steam conditions. The boiler originally had tangent tube and tile construction with a welded casing. A side view of the original unit is shown in Figure 1.

As more efficient generation became available and system demand changed, Tracy 2 became a peaking unit. The unit had accumulated almost 3000 start-up cycles. Since original start-up, the compact boiler design had caused steam temperature control problems, especially when gas fuel was fired. During its operating life, cyclic operation, high metal temperatures, and high spray flows had taken their toll.

Nevada's mining boom and population growth had generated enough demand that it was necessary to make the Tracy 2 unit a dependable peaking energy source. The goals of the project were to provide the system with a unit capable of 3000 additional start-up cycles, reduce maintenance costs, and replace obsolete control components. This resulted in the Tracy Unit 2 overhaul consisting of:

- Boiler restoration
- Turbine-generator overhaul
- Boiler feed and circulating water pump overhaul
- Pump and fan motor maintenance
- Control system replacement
- Burner management system replacement

Key milestones of the project schedule and other concurrent tasks are listed in Table 1. Table 2 summarizes project costs.

TABLE 1 - PROJECT SCHEDULE

1988 PRE-OUTAGE WORK

2/88	Boiler Inspection and Assessment
4/88	Boiler Performance Testing
6/88	Budget and Schedule Preparation
	Economic Justification of Project
	Boiler Bid Package. Released
8/88	Bids Due
10/88	Award Boiler Work
11/88	Architect Engineer Selection
12/88	EPA Determination

1989 OUTAGE WORK

	Milestones	Concurrent Tasks
1/23-2/24	Asbestos Removal	
2/27-3/30	Boiler Demolition	Burner Management System Installation
4/1	Start of Boiler Erection	Turbine Generator Overhaul
		Pump Overhaul
6/15	Boiler Hydro	Motor Maintenance
7/5	Boilout	Burner Register Linkage and Drives
7/15	Steam Blow	Control System Replacement
7/24	Main Steam Line	Air Heater Baskets and Seals
7/25	Re-Hydro	Economizer Minimum Flow
7/29	Turbine Roll	Attemperator Piping
		Heat Tracing
		Re-insulation

TABLE 2 - PROJECT COST

	PERCENT OF TOTAL	COST
Initial Work	1	$ 120,000
Performance Testing	1	50,000
Condition Assessment	2	200,000
Asbestos Removal/Reinsulation	9	800,000
Turbine Overhaul & Balance of Plant Work	7	600,000
Boiler Demolition & Restoration	58	5,300,000
Air Preheater Repairs	2	200,000
Burner Repairs	2	200,000
Control System Improvements	6	500,000
Burner Management System	4	350,000
Technical Support	5	430,000
Plant & Company Labor	3	250.000
	100	$9,000,000

INSPECTION AND ASSESSMENT PROGRAM

The first step in the boiler restoration program was to perform a thorough inspection and assessment of the condition of the boiler. The on-site work activities consisted of visual and fiberoptic inspections of pressure parts, ultrasonic thickness testing of furnace water-wall, superheater and economizer tubes, magnetic particle testing of selected header tube nipple welds, and replication on higher stress regions of high temperature headers. Several tube samples were removed for metallurgical laboratory evaluation.

The second phase of the inspection and assessment program comprised the in-house analytical and reporting tasks. The analytical work consisted of a review of maintenance and operating records, and flexibility analyses of selected tube connector and seal designs, component supports, and piping systems. Also thermal transient, fatigue and creep analysis of critical pressure components. The results of the analytical tasks were factored into a condition assessment together with the inspection findings and metallurgical results. This was presented in the form of life expended to date. Riley prepared a final report, which provided accumulated damage values for critical components and presented recommendations for repair, replacement, modification and monitoring items. Budgetary pricing and schedules for the implementation of such items were included in the final report.

1. Assessment Program Conclusions:

The final report concluded that the Tracy Unit No.2 boiler was in reasonably good condition considering the twenty-two years of essentially cyclic operation. Based on the visual inspection, there were a number of problem areas where the physical condition had deteriorated. These included extensive damage due to overheating of casing and insulation on the side and rear convection walls, sagging of the high temperature super-heater elements, bowing of the economizer elements, internal cracking in the economizer inlet header and cracking of the airheater support members. The metallurgical analysis confirmed that the high temperature super-heater tube sample was completely spheroidized indicating long term exposure to elevated temperatures.

The analysis of the economizer tube sample revealed the presence of severe oxygen pitting. The thermal transient and fatigue analyses for components of the economizer inlet header resulted in a fatigue cumulative damage factor of 2.6 for the header/tube junction. Since a fatigue value of 1.0 conservatively indicates the end of useful life, this component was concluded to be in distress, as confirmed by the internal bore hole and ligament cracking, found via the fiberoptic inspections.

2. Assessment Program Recommendations

The program recommendations based on the inspection and assessment findings, and in line with a postulated additional 20 years of operation, involved removal and replacement of the economizer and superheater with components redesigned to meet the requirements of cyclic duty. These recommendations are summarized below:

- Replace the convection pass tube and tile walls with membrane wall construction to eliminate the excessive maintenance in this area.
- Replace the high temperature superheater and upgrade to stringer tube supports. Replace the secondary superheater inlet and outlet headers. Upgrade the outlet header to SA335-P22 material.
- Replace the primary superheater and upgrade to stringer tube supports. Upgrade the outlet header to SA335-P11 material. Replace the crossover piping and attemperator.
- Replace the economizer and inlet header. Upgrade the economizer to a stringer tube support for the primary and secondary superheaters. Locate the inlet header outside the convection pass to reduce thermal shocking during hot restarts.
- Design an economizer trickle feed system for supplying flow to the economizer during startup to prevent steaming and reduce thermal shocking.
- Design a turbine bypass system to provide adequate steam flow through the superheater during startup.
- Schedule an inspection of the airheater during the next annual outage.
- Remove all insulation from expansion joints for inspection and repair of corrosion and cracks. Replace expansion joints within five years.
- Replace the existing burner register assemblies with fixed vane, shrouded registers.

Most of these recommendations were included in the specifications proposed for the boiler restoration work packages.

PERFORMANCE TESTING PROGRAM

During the inspection and assessment program, a review of plant records and Riley service files indicated that the boiler had operated with higher than design flue gas temperatures, and that attemperation requirements had far exceeded the original predictions. Riley recommended that a boiler performance testing program be accomplished. This program was conducted in April of 1988. The tests were done for oil and gas firing, at MCR and reduced load cases, and were undertaken primarily to determine the furnace exit gas temperature (FEGT) and the performance of the convection pass heating surfaces.

The results of the performance testing program indicated the following:

- At Ioads above 60% MCR, the FEGT was higher than originally predicted for both oil and gas firing. At loads below this capacity, the FEGT was lower than predicted on gas firing.
- The steam temperatures leaving the primary superheater were lower than predicted for both fuels. Even so, the superheater attemperator requirements were considerably greater than predicted. This indicated that the primary superheater was not performing as well as predicted, and the sec-

ondary superheater was exceeding predicted performance.

- The water temperatures leaving the economizer were below saturation, but greater than expected for both fuels. Conversely, the recorded flue gas temperatures leaving the economizer were less than originally expected.

The results of the boiler testing program confirmed the findings of the condition assessment program. These results were included in the boiler restoration bid package, forming the basis for the redesign of the economizer and superheater.

BOILER RESTORATION

After completion of the condition assessment, a project budget and schedule were prepared. Project justification required comparison with alternative sources of power. Replacing the superheater and economizer to utilize the remaining life of the unit was, by far, the most attractive alternative.

A specification for the removal, redesign and replacement of the economizer and superheater was prepared by SPPCo and Stone & Webster Engineering Corporation (SWEC). To make use of the remaining life of the plant, the boiler had to be restored.

Riley Stoker Corporation was awarded both the design and erection contracts on a competitive bid basis. The table below presents the design changes incorporated in the new economizer and superheater. Figure 2 shows the changes in the design of the restored unit.

TABLE 3 - SUMMARY OF DESIGN CHANGES

	Original Unit	Restored Unit
Tube Supports	End Supports	Stringer Tube
Support Lugs	Inconel, 304SS	50Ni/50Cr, Inconel
Wall Construction	Tube and Tile	Welded Membrane
Convection Pass Walls	Sidewalls-Economizer Rear Wall Superheater	Side & Rear walls Superheater
Tube materials	Code Allowable	Upgraded Throughout
Economizer	Bare Tube, Staggered	H-Fin, in line
Economizer inlet	In Gas Stream	Outside Gas Stream
Attemperation	Single Nozzle	Dual Nozzles in Each of Two Crossover Pipes
Header Outlet Legs	Rigid	Flexible

1. DESIGN AND FABRICATION

Project schedule dictated that Riley complete its contract within two hundred eighty calendar days of which one hundred twenty-nine days were used to design and fabricate material. Long lead items such as tubing and header materials were ordered within the first fifteen days to ensure fabricated components would be delivered on site by April, 1989.

Three hundred fifty thousand dollars was expended completing engineering and drafting of structural steel, boiler design, stress analysis and boiler controls.

a. Structural Steel Design

Riley's structural redesign added forty tons of steel to compensate for the added weight of sootblowers, welded wall construction, refractory , heavier buckstays and seismic guides needed to meet specified NFPA85G code requirements, and changed load points.

Long retract sootblowers replaced the existing IK sootblowers mounted on the rear wall. New sootblowers were installed on one side of the unit that required platforms be extended and columns reinforced to support the added load.

Existing tangent tube design was changed to a welded wall configuration with refractory poured seal boxes used at element penetrations. Seal boxes were completely welded to the tubes with flexible tube connections provided on both sides. A poured refractory wall replaced an existing tile baffle at the bottom of the screen between furnace and convective surfaces to eliminate side lanes and gas short circuiting. The added weight was supported down through the columns to the foundation.

Implosion protection was factored into the new design which changed the physical size of the buckstays. Larger seismic guides were added to the new alteration.

Structural design and detailing was completed at Riley then bid to steel fabricators. Fabricated members were sand-blasted and spray painted to save time during erection. New design components matched existing design.

b. Convection Pass Alterations

Performance tests had confirmed that FEGT exceeded predicted levels in the convection pass of the boiler. Riley redesigned the convection pass heating surfaces to meet the worst service conditions. A top supported stringer tube system was used to suspend superheater and economizer elements rather than use conventional wall supports. Also, steam cooled lug materials, supporting individual elements, were upgraded to assure extended support life.

The stringer support system required that steam flow be maintained. This was accomplished by a minimum flow system which routes a portion of the feedwater from the economizer outlet to the condenser. Control interlocks prevent reverse flow from the steam drum which could drain the drum and contaminate the condenser hot well.

Also, a small turbine bypass system was added to the unit. The turbine bypass enables SPPCo to avoid multiple starts on the boiler feed pumps, better match steam and turbine temperatures on warm and hot re-starts, provide flow through the superheater and restrict drum swell during start-up.

The amount of superheater and economizer surface required to meet the desired outlet conditions was determined by analysis of the furnace exit gas temperatures. Temperature profiles were calculated for both natural gas and residual fuel oil over the whole steam load range. SPPCo specified seven possible operating ranges where actual test data was collected.

A heat balance across the convection surfaces was modeled by Riley. Boiler efficiency was calculated and fuel and gas weight generated. After establishing an FEGT for each of the tests, a computer model of the furnace was developed in order to determine the expected FEGT at any operating condition. The amount of primary and secondary superheater heating surface required to achieve the desired outlet conditions was determined through the use of heat transfer computer programs. SPPCo required that the unit be capable of achieving full temperature of 950°F at 350,000 pph when firing natural gas. It was this condition that determined the exact amount of surface required. Desuperheater spray is used to control outlet temperature at higher loads.

c. Desuperh eater Spray

The steam temperature control system provided is a two-path parallel flow system that incorporates a "crossover" of the superheated steam to promote better side-to-side distribution. The two-path system has the advantage of decreasing steam side pressure drop while increasing steam piping length to ensure adequate spray water evaporation before the steam enters the secondary superheater. Increased spray water turndown capability in each of the flow paths was achieved by incorporating two spray nozzles. The first spray nozzle is a low capacity, variable orifice nozzle that provides excellent spray water atomization at low spray flows. In series with the first nozzle is a high capacity, fixed orifice spray nozzle with a separate spray water control valve. The two nozzle arrangement provides steam temperature control over the load range with turndown capabilities of 20 to 30:1 or better, depending on the control scheme incorporated into the system.

d. Economizer Selection

Once the proper heating surfaces had been established for the primary and secondary superheaters, an economizer design was selected to decrease the temperature entering the airheater to as low as possible for improved unit efficiency, while maintaining an outlet water temperature with sufficient margin below saturation temperature to ensure economizer steaming would not occur at any operating condition. Due to space limitations it was decided to use an extended surface (finned) economizer.

e. Material Selections

After establishing the required heating surface to achieve the desired outlet conditions, the proper wall thickness and material grades were established for each pressure part component.

Heat transfer calculations were performed at various loads with different excess air to establish the optimum operating condition for material selection. As a further check, the FEGT for the maximum continuous rating of 700,000 lb/hr., when firing natural gas, was increased by 200°F and heat transfer calculations were performed under this condition. Appropriate margins were added to the steam side temperature to account for tube bundle flow unbalance.

f. Riley Fabrication

Except for the purchased economizer surface, all components were fabricated at Riley's facility in Erie, PA. Frequent shop visits were made by SPPCo personnel and their representatives to monitor progress and confirm that fabrication conformed with design.

Modular components were shop assembled to reduce the time required to complete erection. Riley sequenced fabricated material to assist field construction. A roof module was assembled with economizer outlet headers and stringer tubes attached. Membranes were welded and roof seals completed in the shop. This module comprised the entire width of the unit. When the module was hung, the roof above the convection pass was complete. Furnace roof tubes were fabricated to close the roof above the superheater outlet and furnace screen tube penetrations above the furnace area.

2. CONSTRUCTION

Riley's scope of work included demolition and re-construction of the convection pass heating surfaces during five months of the six month outage. Construction work represented $2.4 million of the $5.3 million dollars expended for boiler restoration. Riley averaged twenty-eight men per shift for one hundred five available days, each shift working ten hour days, five days each week, which assured completing the work ahead of schedule.

TABLE 4 - CONSTRUCTION STATISTICS

		Manhours	Percent of Total
1.	Demolition	9,000	15
2.	Structural Steel	4,200	7
3.	Hanging Pressure Parts	21,000	35
4.	Install Sootblowers	1,500	2.5
5.	Welding Pressure Parts	13,200	22
6.	Testing Support	1,100	2
7.	Work Extras	10,000	16.5
Total Riley Construction Hours		60,000	100

Riley sub-contracted insulation, lagging, painting, and electrical work.

Riley established an erection scheme that was rigidly adhered to throughout the work period. Few schedule changes were necessary. Good dialogue between the Owner's implementors, plant personnel and Riley's contract team resolved issues before costly mistakes were made.

Sierra Pacific planned other outage work around Riley's boiler restoration schedule. This outage included a turbine overhaul, asbestos abatement work, and a burner management and boiler controls replacement. A critical path schedule was utilized that identified milestone dates and all interface points.

Sierra Pacific set up a construction management and plant maintenance staff supported by Stone and Webster field personnel that monitored boiler, turbine, burner, air heater, controls and balance of plant work.

Riley completed boiler demolition early. This work involved removal of all superheater and economizer surface in the convection pass between the economizer feed pipe and the high temperature superheater outlet pipe. Structural steel, suspension level steel, headers, partial roof panels and side and rear wall panels were removed. The Figure 3 photo graph shows the condition of the secondary superheater just prior to its removal.

Sootblowing equipment was removed from the rear wall and later replaced with long retract blowers on the sidewall. All existing header drain piping and burner register drives were removed.

The existing structure had not been designed to support the added weight of new boiler components, so the structure was modified from the suspension level down to the foundation. Load changes and specified structural load calculations, code up-grades, and increased component weights controlled the early work sequencing. Structural reinforcement had to be completed before more weight was added to the unit.

After the structural reinforcement work was completed new beams and hanger rods were installed at the suspension level. Then the new boiler components were installed beginning with all headers above the new furnace roof, then roof panels and loose tubes, side wall and rear wall. Access was limited to two paths from the rear of the unit, so sequencing of material flow was critical throughout the construction phase.

Alignment of the walls and roof tubes had to be finished and membrane welding completed before proceeding. Roof, side walls and furnace screen work was sequenced before the high and low temperature superheater and economizer elements could be **hung** out in the convection pass cavity. Figure 4 shows the installation of superheater and economizer elements in the convection pass cavity. A window was cut in the new rear wall through which all remaining materials were fed.

New primary and secondary superheater headers, crossover piping and economizer inlet and outlet headers were installed outside of the gas stream and then connected to new surface elements.

Riley completed over three thousand field welds in less than one month. Riley performed separate hydrostatic tests on old and new systems to avoid subjecting the existing steam drum and furnace to the 150% of maximum allowable working pressure hydro test required for the new components.

Isolation of the old and new components was achieved by **using** hydro plugs. Welds tying the old and new components were subjected to 100% examination by radiography followed by a hydro test at operating pressure.

Work on new spray piping, economizer minimum flow piping and by-pass piping systems was implemented. Existing gas and oil burners were rebuilt and new airheater baskets and seals installed.

Riley completed construction and unit testing earlier than scheduled. Unit start up and testing began in late June of 1988 and extended through July. The new boiler and existing furnace went through a chemical boilout and steam blows in order to safeguard the overhauled turbine.

OPERATION SINCE MODIFICATIONS

After thirteen months in service, the unit is fulfilling its role as a reliable peaking unit for SPPCo. To date the unit has been **through** 168 cycles, operated 2906 hours, with an average capacity factor of 15%. Unit load has varied from off line to minimum load to maxi-mum load as required through economic dispatch.

The operation of Tracy Unit 2 since the overhaul has been very satisfactory.

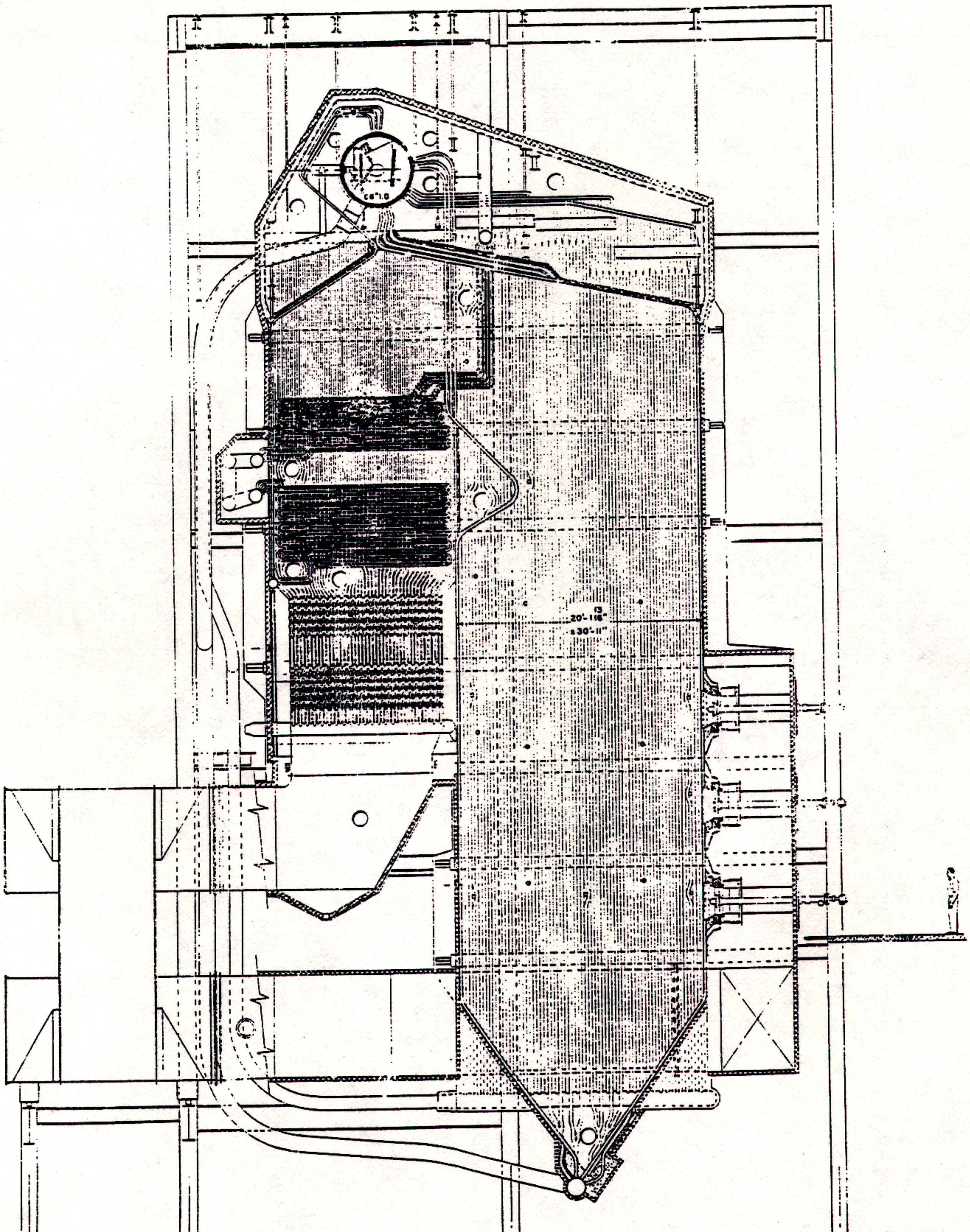


Fig. 1 — Original Boiler Side View

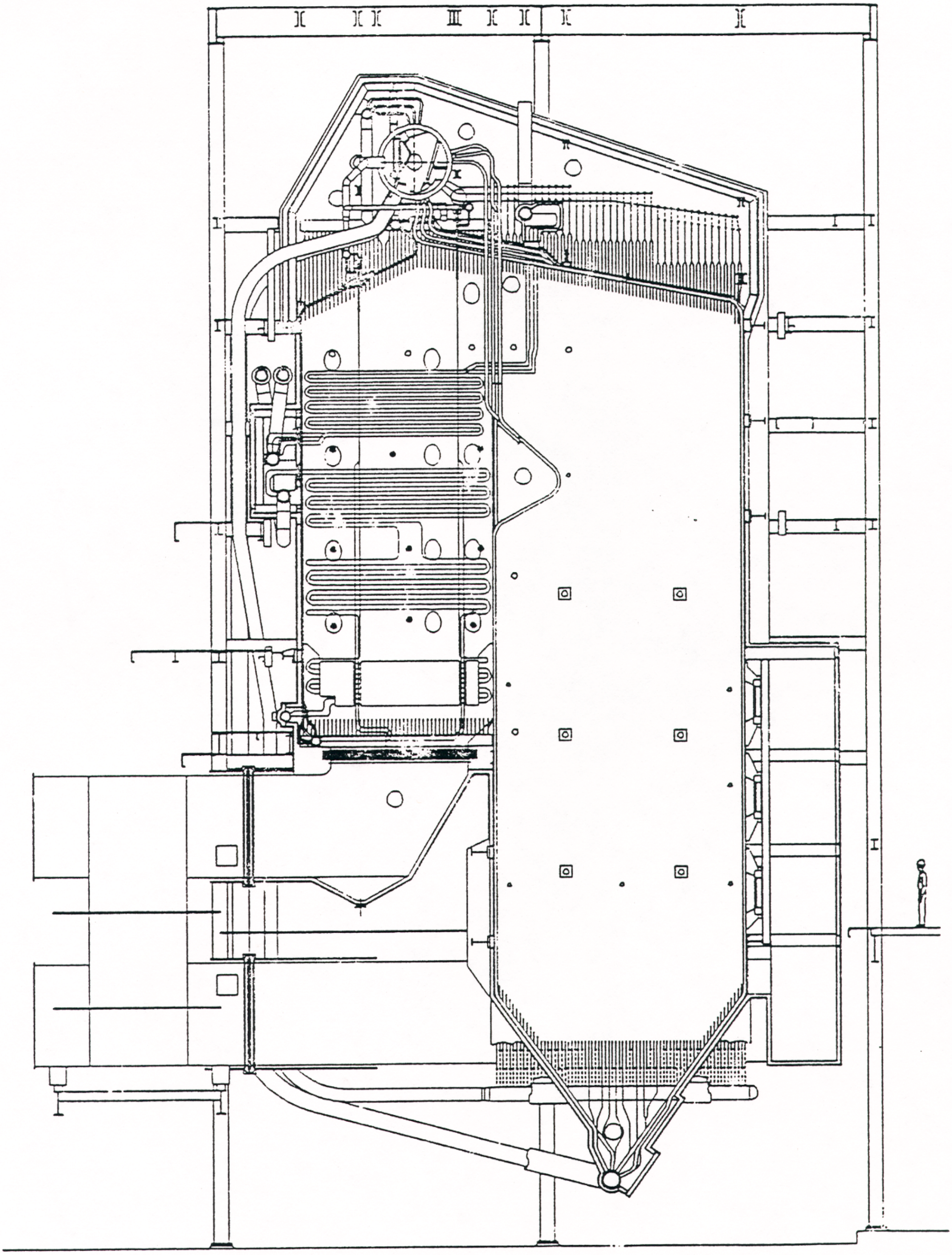


Fig. 2 — New Side View

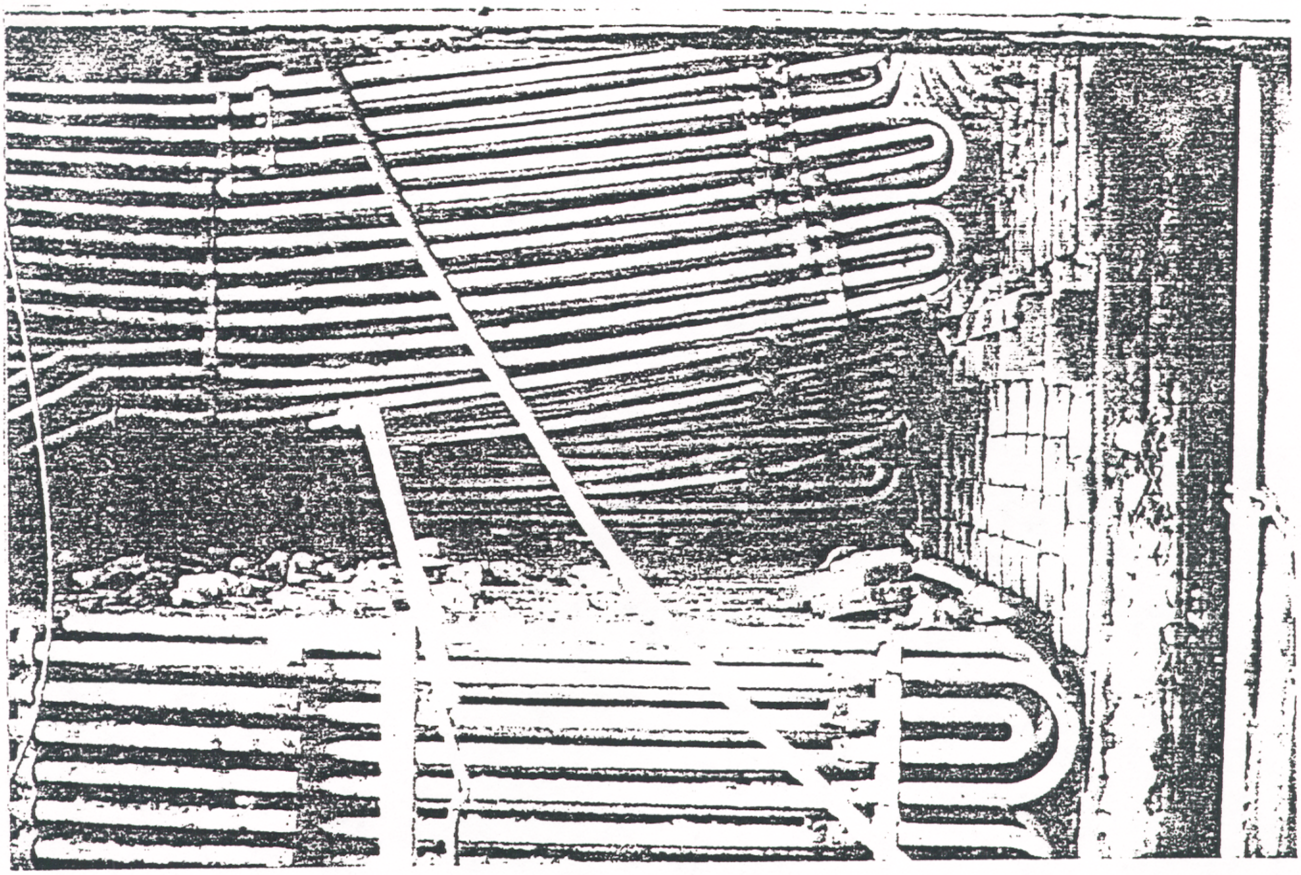
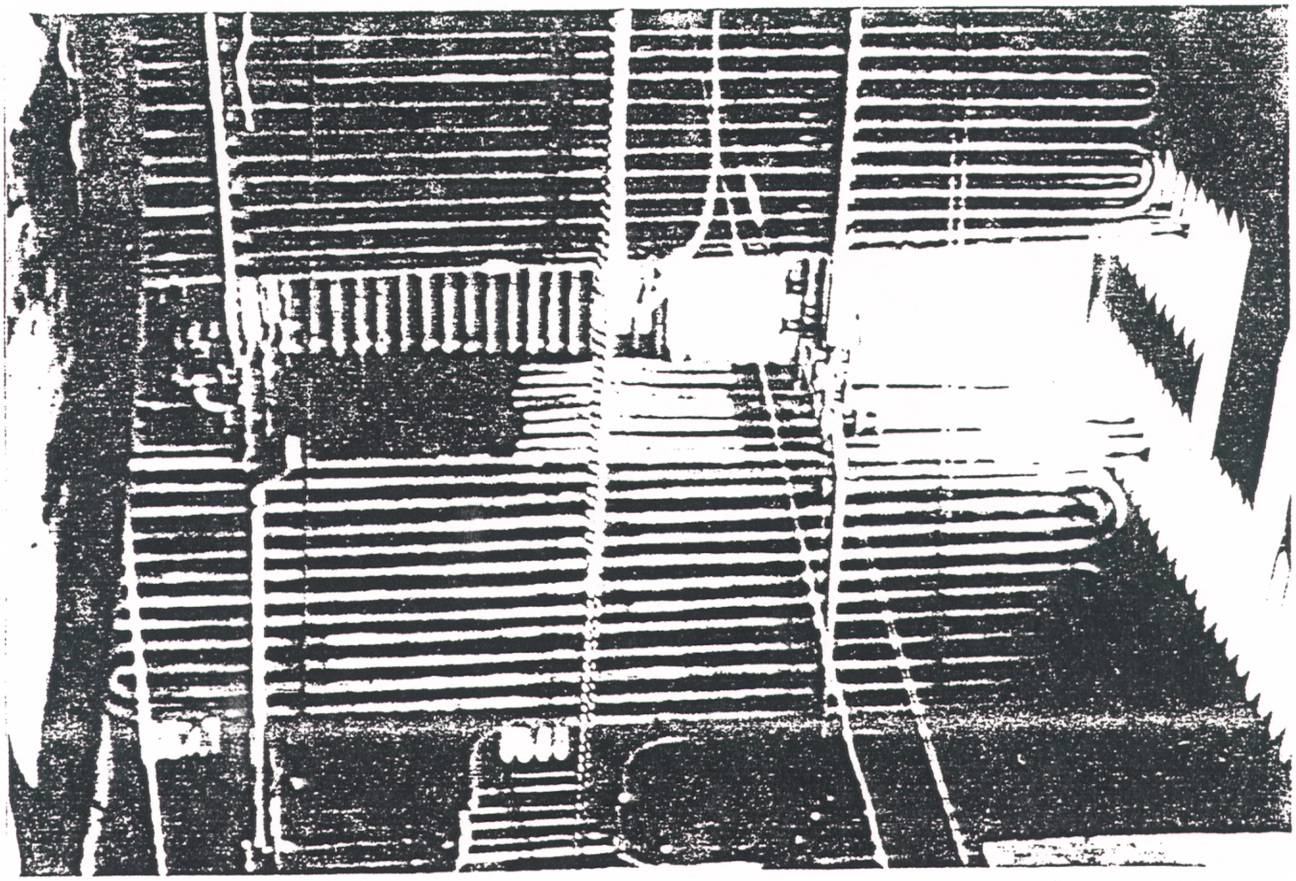


Fig. 3 — Side View of Sagged Superheater Tubes



[illegible] of Replacement Tubes