

TACOMA STEAM PLANT NO. 2 REPOWERING PROJECT: A MULTIFUELED SOLID WASTE FACILITY

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ABSTRACT

Steam Plant No. 2 of the municipal utility system of Tacoma, Washington is being rehabilitated to restore its nominal 50 Mwe capability. This project, for the Tacoma Public Utilities—Light Division, is converting two existing pulverized coal boilers to waste heat boilers and adding external fluidized bed and upgrading the remainder of the facility to meet current environmental requirements. The completed facility will burn a mixed fuel consisting of coal, waste wood, and municipal Refuse Derived Fuel (RDF).

INTRODUCTION

The Tacoma Steam Plant No. 2 is a two unit plant originally built in 1931 by the City of Tacoma for use as a backup power supply for their normal hydroelectric system. This facility consisted of two pulverized coal four drum boilers and a single 25 Mwe turbine generator. In 1953, the plant was heavily modified to increase boiler capacity, changing the primary fuel to No. 6 oil while retaining the pulverized coal capability, and adding a second 25 Mwe turbine generator. In 1973, the plant was shut down and mothballed after experiencing superheater tube failures. The City of Tacoma has been working since 1979 to put the facility

back in service, and the present project is the culmination of that effort. The project goals are to burn all of the RDF which is produced by the City of Tacoma, burn a significant portion of the wood waste generated in the local area, and to provide 40–42 Mwe of net electrical power to the City's system which will reduce the municipal utilities dependence on outside sources of electricity.

The design basis for the facility is to burn a fuel mixture of 50% coal, 35% wood, and 15% RDF on an assumed Lower Heating Value (LHV) basis (approximately 27.4% coal, 53.0% wood, and 19.6% RDF by weight) and to produce 528,000 lb/hr (239,497 kg/h) of steam at nominal outlet conditions of 400 psig (2758 kPa) and 750°F (399°C). An assumed set of fuel analyses was used to establish the design fuel heating values and feed rates. The assumed fuel analyses and design mixture analysis are shown in Table 1. General schematics of the major systems and equipment are presented in Fig. 1—Fuel Handling/Feed Systems; Fig. 2—Combustion Air and Gas Systems; and Fig. 3—Water and Steam Systems. Figures 2 and 3 are marked with several flags designated E or N. These flags indicate the approximate boundaries between original (E-Existing) plant equipment which is being refurbished and put back into operation and equipment which is being purchased and installed as part of the Repowering Project (N-New Construc-

TABLE 1 DESIGN FUEL MIXTURE

Fuel Component % Weight	Coal	Wood Waste	RDF	Fuel Mix (1)
				50% Coal 35% Wood 15% RDF
1. Carbon	57.6	26.00	28.24	35.08
2. Hydrogen	3.9	3.00	3.76	3.41
3. Nitrogen	1.2	0.05	0.42	0.44
4. Sulfur	0.5	0.05	0.17	0.20
5. Oxygen	11.8	20.50	21.89	18.39
6. Chlorine	0.05	--	0.42	0.09
7. Ash (Solid non-combustibles)	11.95	0.40	8.60	5.17
8. Moisture	13.00	50.00	36.50	37.22
TOTAL	100.00	100.00	100.00	100.00
(HHV)	10,080	4,250	4,725	5,939
btu/lb(LHV)	9,550	3,451	4,000	5,228

(1) Fuel mixture percentage is based on a Lower Heating Value Btu Basis. Mixture by weight is approximately 27.4% coal; 53.0% wood, and 19.6% RDF.

tion). All of the equipment shown on Fig. 1 is New Construction.

The major modifications to the facility fall into five areas:

(a) Addition of external Atmospheric Fluidized Bed Combustors (AFBC) and auxiliaries and modifications to the existing boilers.

(b) Addition of two (2) fuel receiving, storage, and handling systems and a fuel feed and metering system.

(c) Addition of flue gas fabric filters, induced draft fans, emission monitoring equipment, a stack, and ash handling system.

(d) Modification of the open cooling water system to a closed loop system.

(e) Replacement and additions to the medium and high voltage electrical systems and modernization of the plant controls.

FLUIDIZED BED COMBUSTORS

The atmospheric fluid bed combustors for this project are bubbling bed type with hot cyclones to recycle the larger particles carried out of the combustion zone to the bed for improved carbon combustion. The expected carbon conversion is 96.5% at the design conditions. The combustors operate with the freeboard at a slight positive pressure in order to allow the old boiler furnaces to be maintained at a slight negative pressure for draft control. The combustors have a design turn-down ratio of 2:1 and are capable of operation with a wide range of fuel mixtures with some derate on capacity. The expected ranges of fuel mixtures which can be handled are 85% coal, 0% wood, and 15% RDF at one end and 0% coal, 85% wood, and 15% RDF on the other end on a Lower Heating Value (LHV) basis. Fuel feed to each of the combustors is by three

overbed air-swept stokers or spouts located across the front walls. The coal is ¾ in. (0.019 m) minus while the wood and RDF are 3 in. (0.076 m) minus. Each combustor is provided with a combustion air preheater which is only used to preheat the bed during startup of the combustor. During normal operation the combustion air temperature to the combustors is ambient plus the compression heating. The recycle of material from the hot cyclones is controlled by variation of the removal rate from the hot cyclone hoppers through water cooled screw conveyors to the ash handling system. The schematic arrangement of this equipment is shown on Fig. 2.

The bed drawdown system is designed to remove large quantities of oversize noncombustible materials such as rocks, metal, and glass which are present in the fuels being used. The system continuously removes bed material from the combustors, screens it, and returns the properly sized material to the combustors. Oversize material, consisting primarily of rocks and agglomerated material, is dumped in a storage area for disposal. Limestone is fed, along with the properly sized bed material, through the drawdown system as required to maintain the sulfur dioxide emissions below the desired levels. Sulfur capture for the facility is required to be at least 70%. Limestone is delivered by self unloading truck and stored in a 100 ton (91 t) silo next to the combustors.

The combustors and hot cyclones are entirely refractory lined with the combustors having forced flow in-bed cooling utilizing boiler water to help maintain the bed temperature in the desired range of 1400–1600°F (760–871°C). This bed temperature maximizes sulfur removal and reduces generation of nitrogen oxides. The higher density fraction of the fuel burns within the bed while the lighter fraction burns in the freeboard area. This results in the exit temperature from the combustors approaching 1800°F (982°C). The combustion gases are routed through two (2) hot cyclones per combustor to remove the larger entrained material for reinjection. Upon discharge from the cyclones, the combustion gases are routed through refractory lined ducts to new superheater sections mounted in front of the original boilers. Anticipated heat losses in the cyclones and ducts will reduce the temperature of the flue gases to 1725°F (941°C) before reaching the superheaters.

The superheaters are mounted at the front of the existing boilers to improve the heat transfer from the relatively low temperature flue gas. The superheaters are designed for an inlet gas velocity of 45 fps (13.7 mps), and are arranged in two sections to allow for a steam attemperator and mid point sootblowers.

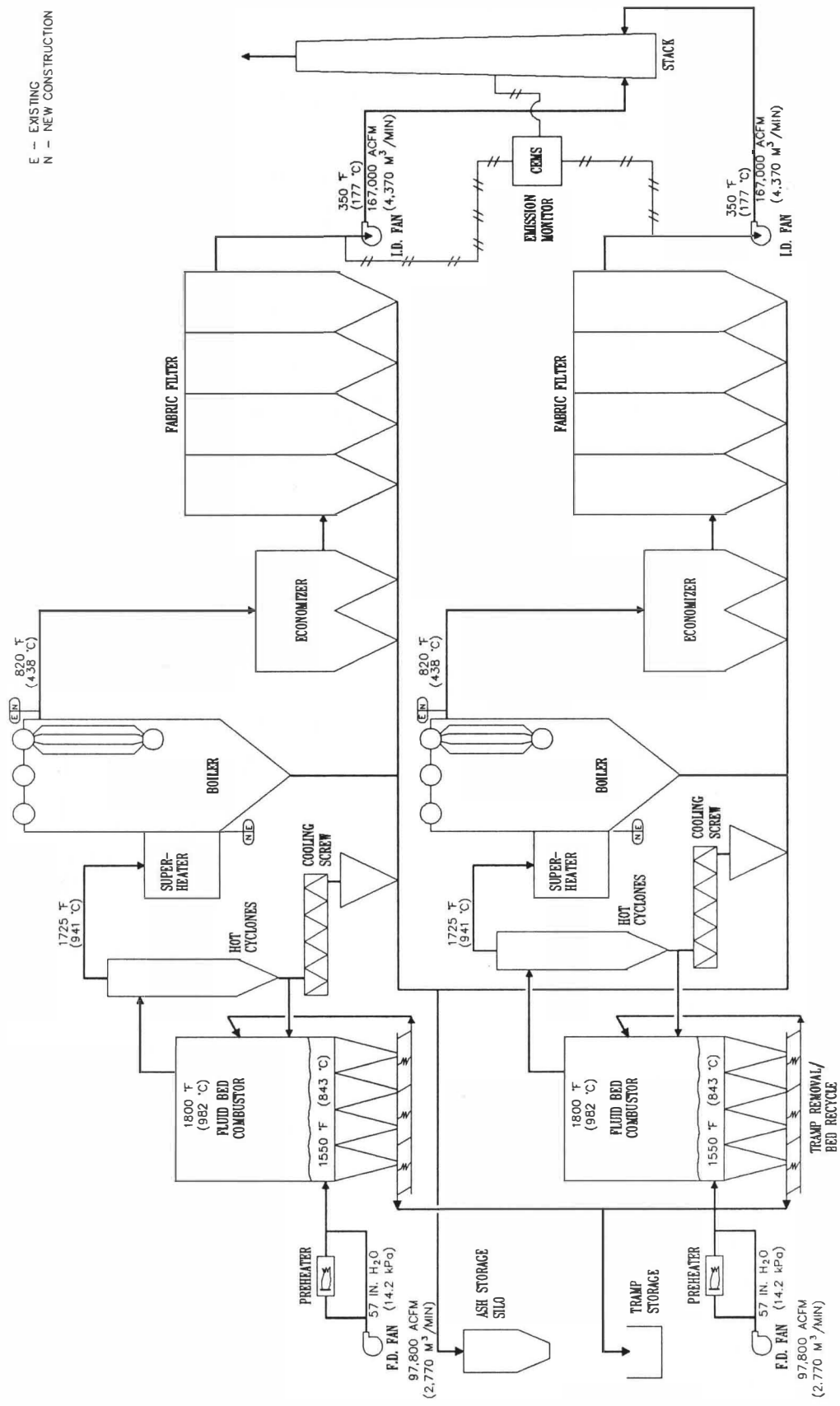
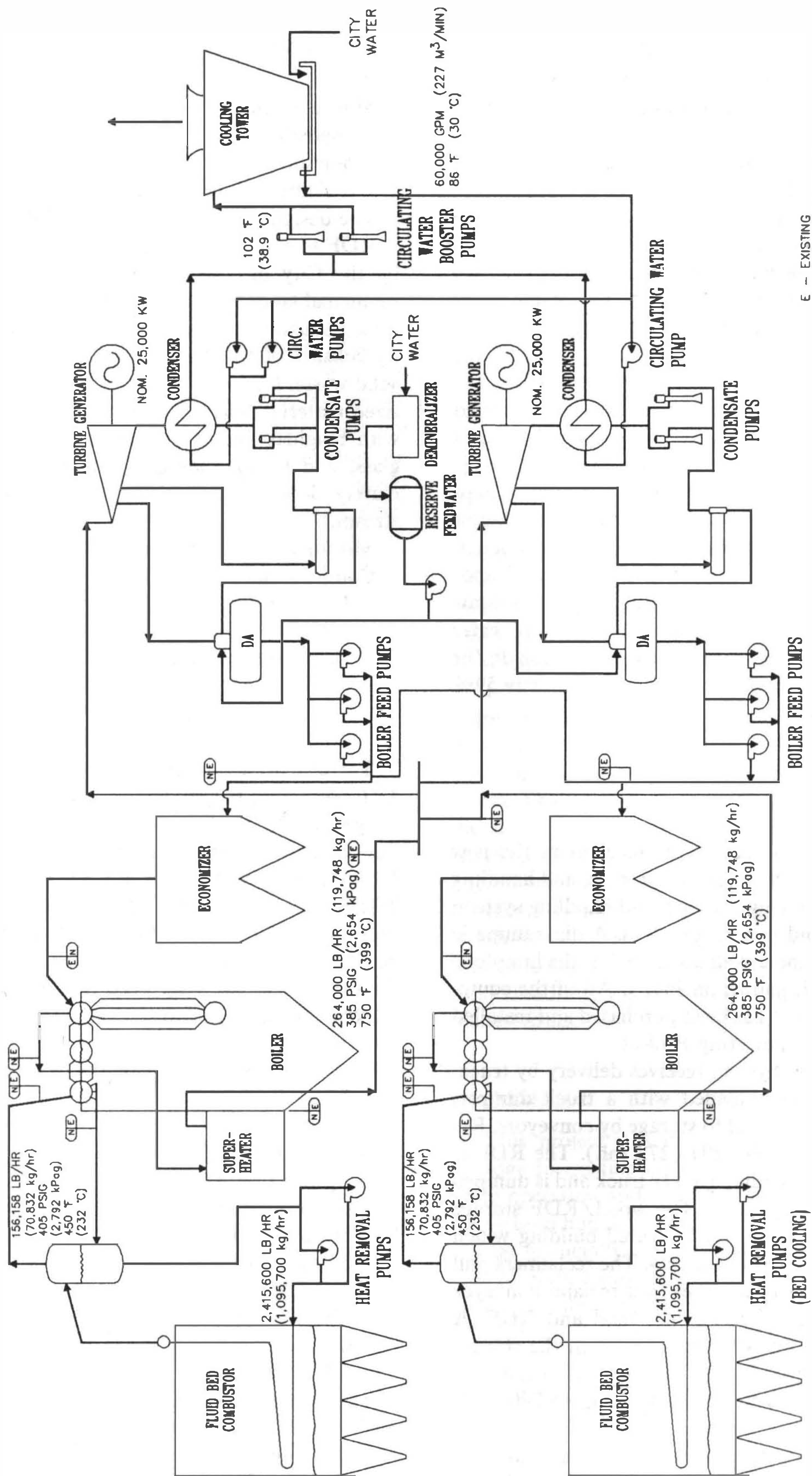


FIG. 2 COMBUSTION AIR AND FLUE GAS SYSTEMS



E - EXISTING
 N - NEW CONSTRUCTION

FIG. 3 WATER AND STEAM SYSTEMS

The boilers have been modified for the new service by removing the original superheater sections and internal baffles to reduce gas velocities through the tube banks. The coal pulverizers, oil burners, boiler controls, combustion air ductwork, and coal handling equipment have all been removed. Final temperature reduction was also changed from air heaters to feedwater economizers. The original air heaters were retired in place and new feedwater economizers installed to reduce the flue gas temperature to acceptable levels for the fabric filter and improve the boiler efficiency. See Fig. 3 for the diagrammatic arrangement of the plant water and steam systems. The front drums of the boilers have been modified to accept the evaporated steam from the combustor in-bed cooling loop and provide the makeup water. The combustor heat removal system is a forced flow loop through the bubbling bed sections of the combustors. A circulation (water to evaporated steam) ratio of approximately 15:1 is maintained through the combustors. Evaporated steam is routed to the existing boilers for combination with the steam generated in the boiler water walls. The combustors each generate 156,158 lb/hr (70,832 kg/hr) of steam which is approximately 59% of the total evaporation.

FUEL SYSTEMS

Three fuel systems are being installed in the new facility; a wood/RDF receiving, storage, and handling system; a coal receiving, storage, and handling system; and a fuel feed and metering system. A diagrammatic representation of these systems as well as the limestone handling system is shown on Fig. 1. All of the equipment shown in Fig. 1 has been purchased and installed as a part of the Repowering Project.

The wood/RDF System receives delivery by truck. The waste wood is unloaded with a truck dumper, screened, and transported to storage by conveyors. Receiving Capacity is 300 TPH (272 tph). The RDF is delivered by self unloading packer truck and is dumped directly in the storage area. The wood/RDF storage area consists of a three sided covered building which also houses the five (5) reclaimers. The reclaimers pull material from the storage piles to a reclaim conveyor which also controls the ratio of wood and RDF. A transfer conveyor takes the mixture from the storage area to the Fuel Feed System at the front of the fluid bed combustors. Transfer capacity is up to 240 TPH (218 tph).

The design parameters for the wood are as follows:
Wood = hogged waste wood and bark, splinters,

whole tree chips, sawdust and shavings. Species type varies.

Moisture content = nominal 50%; range up to 55%
Composition =
nominal 3 in. (0.076 m)
maximum 6 in. (0.152 m)

The design parameters for the RDF are as follows:
RDF = a processed municipal solid waste, produced by the City of Tacoma in a facility located at the municipal landfill. The material is shredded to size and noncombustibles are substantially removed. The facility consists of two hammer mills in series to size the solid waste, followed by screening and recycle of oversized material. The sized material has metal removed with magnets and is air classified to remove inerts, glass, and heavy materials. The product is approximately 50% of the original municipal solid waste stream.

Moisture Content = nominal 26%, maximum 40%
Composition =
100% less than 6 in. (0.152 m)
95% less than 3 in. (0.076)
glass content less than 0.5%
ferrous metal content less than 0.1%
nonferrous metal less than 1.1%
total noncombustibles less than 11%

The coal system receives delivery by 5500 ton (4993 t) ocean-going barge. The coal is received from the barge at 300 TPH (272 tph) and is transferred by conveyor to the coal storage pile. The coal is reclaimed by front end loader to a reclaim pit. Transfer conveyors take the coal to a 300 ton (272 t) day bunker. Transfer conveyor capacity is 60 TPH (54 tph). From the day bunker, variable speed en masse typed conveyors transfer the coal to the Fuel Feed System at the front of the combustors. The transfer rate can be up to 40 TPH (36 tph).

The design parameters for the as received coal are as follows:

Total Moisture = 13%
Air Dried Moisture = 5%
Hargrove Grindability Index = 43
Size Consistency =

50 to 25 mm	5%
25 to 5 mm	35%
5 to 2 mm	30%
2 to 0.5 mm	20%
0.5 to 0.2 mm	6%
0.2 to 0.0 mm	4%

The Fuel Feed System receives the wood/RDF and coal in separate surge hoppers. Each hopper feeds two (2) vibrating metering conveyors, one for each combustor, which feed the three air swept stokers on each

combustor. The wood/RDF conveyors each have a capacity of 0–25.7 TPH (0–23.3 tph). The coal conveyors each have a capacity of 0–9.5 TPH (0–8.6 tph). The two fuel streams combine and go through rotary valves located above the stokers. The valves are required to prevent backflow of gasses from the combustors during operation.

FLUE GAS AND ASH SYSTEMS

The flue gas system consists of ductwork, pulse jet fabric filters, induced draft fans, a common emission monitoring system, and a common stack. The fabric filters remove fly ash from the flue gasses and are designed to meet the project air quality permit requirement for particulate emissions to not exceed 0.0068 g/DSCF (0.0156 g/m³). The induced draft fans are sized to make up for pressure losses through the economizer, ductwork, and fabric filters and to maintain the boiler furnace pressure slightly below atmospheric and discharge into the stack. The boiler draft balance point is located in the furnace area of the original boilers to minimize air infiltration as the boilers are 1931 vintage brick set construction. The common stack is a single flue, dual wall, insulated steel design with a height of 213 ft (65 m). The emission monitoring system utilizes dilution probes in the ductwork of each unit to continuously sample for nitrogen oxides, sulfur dioxide, carbon monoxide, and oxygen. The monitoring system alternates analysis between the two units on a continuous basis. Opacity is monitored in the stack as a common emission point for the facility.

A new vacuum pneumatic ash handling system has been installed to collect cyclone and fly ash from the combustor cyclones, boiler furnaces, economizers, and fabric filters. The ash is stored in a silo for trucked disposal in an off site landfill.

CIRCULATING WATER SYSTEM

The original circulating water system originally consisted of a once through loop design taking suction from and discharging to the adjacent Hylebos Waterway. Thermal plume limitations in the waterway required that the system be converted to a closed loop design. See Fig. 3 for the diagrammatic arrangement of the system. In order to limit increases in pressure on the existing condensers, booster pumps have been installed to pump the circulating water over the cooling tower. The new tower is mechanical draft countercurrent design. The low summer design wet bulb tem-

perature, 66°F (18.9°C) allowed the conversion without a major loss in condenser backpressure.

ELECTRICAL SYSTEMS AND CONTROLS

The original plant electrical system consisted of 13.8 kV generator circuit breakers, 2400 V switchgear, and 480 V combination starters. A portion of the 2400 V switchgear is being refurbished and reused to power in plant Unit No. 1 auxiliaries which are being refurbished. Also, most of the 480 V motor control equipment for the Unit No. 2 auxiliaries are being refurbished and reused. Two new outdoor lineups of 13.8 kV switchgear contain new generator breakers and feeder breakers which serve the site 13.8 kV distribution system. New 4160 V motor controllers serve the new large motor driven equipment; the induced draft fans, the forced draft fans, and the cooling tower booster pumps. New 480 V motor control centers have been located around the site to serve the rest of the plants power requirements. One of the 2400V equipment and electrical system has been retained.

A new distributed control system (DCS) for the plant has also been installed. The system consists of eight (8) field panels which contain the control boards and logic. This system controls a majority of the plant systems and equipment from the new central control room. The control room has two operator control stations and an engineer's console. Several independent systems are provided with their own programmable logic controllers (PLCs) with monitoring and some control functions provided from the DCS. The major systems with their own PLCs which communicate with the DCS are Coal Handling, Wood/RDF Handling, Ash Handling, Fabric Filters, and the Feedwater Demineralizers.

SUMMARY

This project is a unique application of new technology to existing equipment to place a facility back into operation and to utilize local waste which would have been buried in landfills. The project is considered to be financially viable by the City of Tacoma in a region with historically low electric power rates and is technically and environmentally sound. It is expected to provide the City of Tacoma with an economical, safe, and reliable source of electricity for the next 20 years while reducing the volume of waste which must be buried in landfills.

Key Words: Energy; Fluidized Bed; Power Generation; Refuse-Derived Fuel; Rehabilitation