

# MODESTO WHOLE TIRE BURNING POWER PLANT

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## ABSTRACT

A discussion of a power plant designed, built and operated at Modesto, California to incinerate whole discarded automobile and truck tires to produce electricity for sale is presented. Systems engineering design features to achieve optimum thermal performance, environmental emissions, control operability, maintenance and reliability are discussed.

## INTRODUCTION

Approximately 40 million discarded, used tires have been accumulated at the Modesto tire disposal site. Disposal of discarded whole tires is a national problem. Landfilling is unsatisfactory because tires tend to re-surface after burial and because landfill fires are difficult to extinguish and clean up. In addition, the Federal Center for Disease Control has linked whole tires to infestations of disease-carrying mosquitoes. Recycling of tires has not yet been proven commercially. However, another option for tire disposal is to burn them in a power plant as fuel.

The Modesto plant is the world's biggest whole tire burning power plant utilizing the world's largest pile of whole tires and annual inflows as fuel to produce electricity and help solve a tough national disposal

problem. Tires can be a clean burning fuel (see Emissions) and constitute a well defined uniform heating value fuel (approximately 14,650 Btu/lb LHV) which is substantially higher than the best bituminous coal. However, tires contain quantities of ash and trace elements which must be treated and controlled.

The significant feature of the Modesto plant is the opportunity for recycling of process by-products. For example, steel from the incineration of steel belted radials is salvaged from the slag residue and sold for scrap. Fly ash collected from the plant's baghouse contains zinc (used in tire manufacturing) which is recovered and sold for resmelting. Gypsum from the plant is sold to cement manufacturers.

The Modesto plant technology of whole tire incineration is based on technology developed in West Germany. The design of each boiler/incinerator is patterned after three existing German tire burning units in service for 15, 12 and 5 years, respectively, and several wood burning units. The boiler/incinerator rating at Modesto has been modestly extrapolated by doubling the number of grates from one to two and proportionally increasing the boiler envelope. Consequently, there has been no major change in basic grate design, materials or size from the West German plants. Stresses and thermal duty are within existing experience, and the equipment size and rating is well within industry experience.

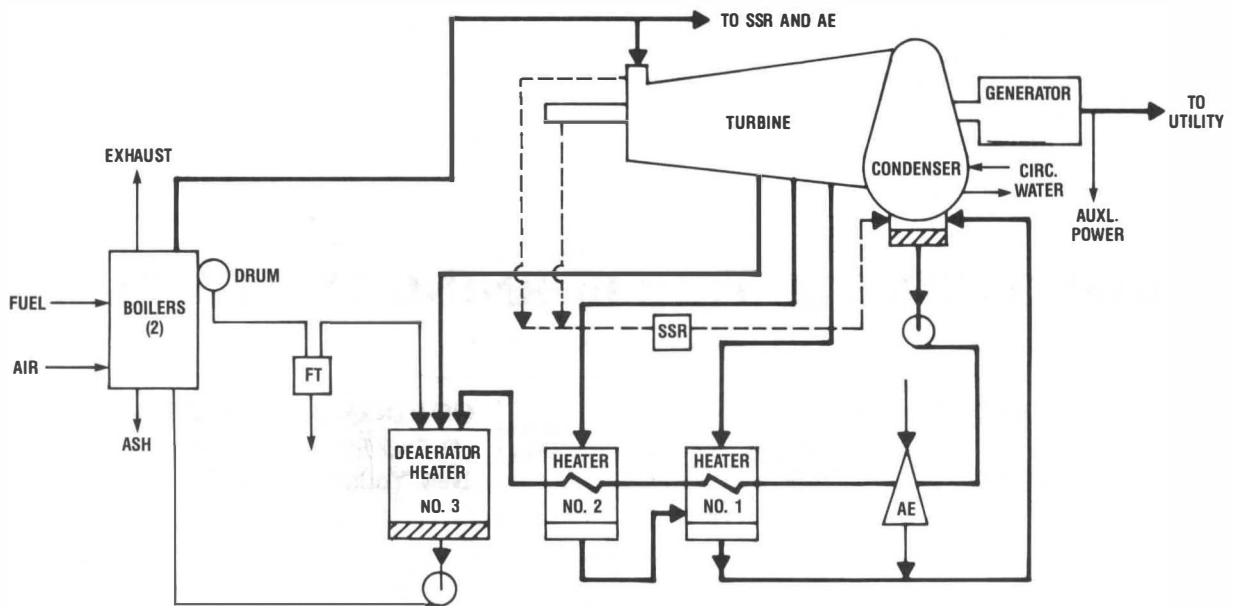


FIG. 1 MODESTO CYCLE SCHEMATIC

**PLANT DESCRIPTION**

The power plant has two (each at 50% of total steam) boiler/incinerator units each producing 65,800 lb/hr of steam, in which whole automobile and truck tires are fed through the tire feed system. The heat resulting from tire incineration is used to generate steam that in turn drives a single condensing steam turbine-generator. The steam cycle, including the steam turbine with three feedwater heaters is shown in Fig. 1. The plant design also includes a wet cooling tower and a zero liquid discharge system consisting of an evaporation pond and a spray pond. The tires are burned on a reciprocating metal grate in a refractory lined enclosure. The flue gases pass to a conventional boiler with a water wall furnace and convection pass, including superheater, steam generator and economizer surfaces. Two gas-fired burners are provided for each incinerator startup and also two auxiliary gas fired burners are used to maintain the rate of steam production in case the tire feed is interrupted.

The air pollution control equipment includes: combustion modifications built into the incinerator design; ammonia injection for NO<sub>x</sub> control; a baghouse for particulate control; and a wet scrubber for SO<sub>2</sub> control. Stack gases are reheated by a closed-loop water system heated by flue gases between the baghouse outlet and the wet scrubber inlet. Emissions of CO and hydro-

**TABLE 1 MODESTO PLANT PERFORMANCE**

Net Output	13,900 kW
Net Heat Rate	13,870 Btu/kWh, LHV
Stack Temperature	180°F

NOTE: The above performance is based on 60°F dry bulb ambient, 56°F wet bulb ambient and 14650 Btu/lb for lower heating value of fuel.

carbons are controlled by high efficiency combustion design. The two incinerators discharge to a single baghouse with dampers and two I.D. fans.

This power plant is designed for base load operation on whole tires with a performance shown in Table 1. No supplementary fuel, other than that required for startup or occasional combustion stabilization, is used. The plant is capable of operation with both or either boiler available. The plant will not be operated without the steam turbine available. Given below is a brief description of the major subsystems.

**TIRE FEED SYSTEM**

The tire feed system, shown in Fig. 2, consists of two (2) vibrating hoppers, weigh station, metal detec-

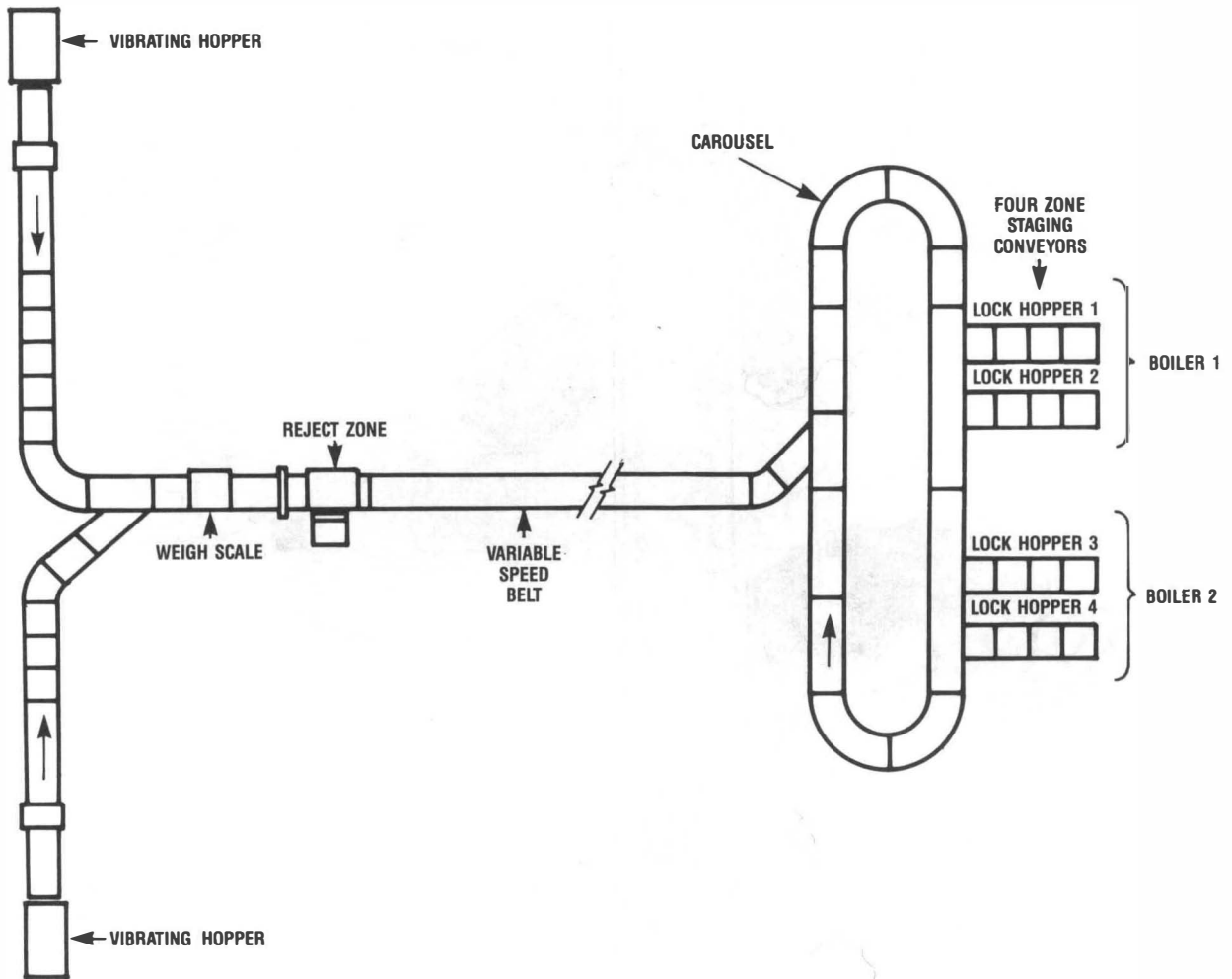


FIG. 2 MODESTO TIRE FEED SYSTEM

tor, conveyor systems, accumulator carousel, two lockhoppers on each of two boilers, and two control stations, one located near the vibrating hopper, and the other near the lockhoppers. This system is capable of providing continuous tire feed to the tire incinerators and reducing the tire feed rate if a boiler trips. Tires containing rims, and oversized tires that cannot fit through the boiler lockhopper, will not be permitted to enter the incinerator and are removed at the reject zone of the conveyor.

Tires are introduced into the system at the vibrator hopper units. These tires enter the vibrating conveyors singly at a controlled rate determined by the control system. Tires are transported, one at a time, to a scale where they are weighed and then sized. This data is

stored into a control system register for each individual tire. As a tire is processed, it is examined for excessive metal content and the data stored in the memory as a go or no-go bit. The discharge rate and the variable speed of the main belt conveyor allow the control system to control the pounds of rubber presented to the carousel prior to the lockhoppers. The carousel serves to distribute tires to the individual lockhoppers, and to store any excess tires arriving from the belt conveyor. The lockhoppers serve to isolate the high temperature boiler gases. During normal operation, tires are transported directly to staging conveyors prior to the infeed of each lockhopper as illustrated in Fig. 2. The four-zone staging conveyors upstream of each hopper are kept full at all times to ensure timely feed

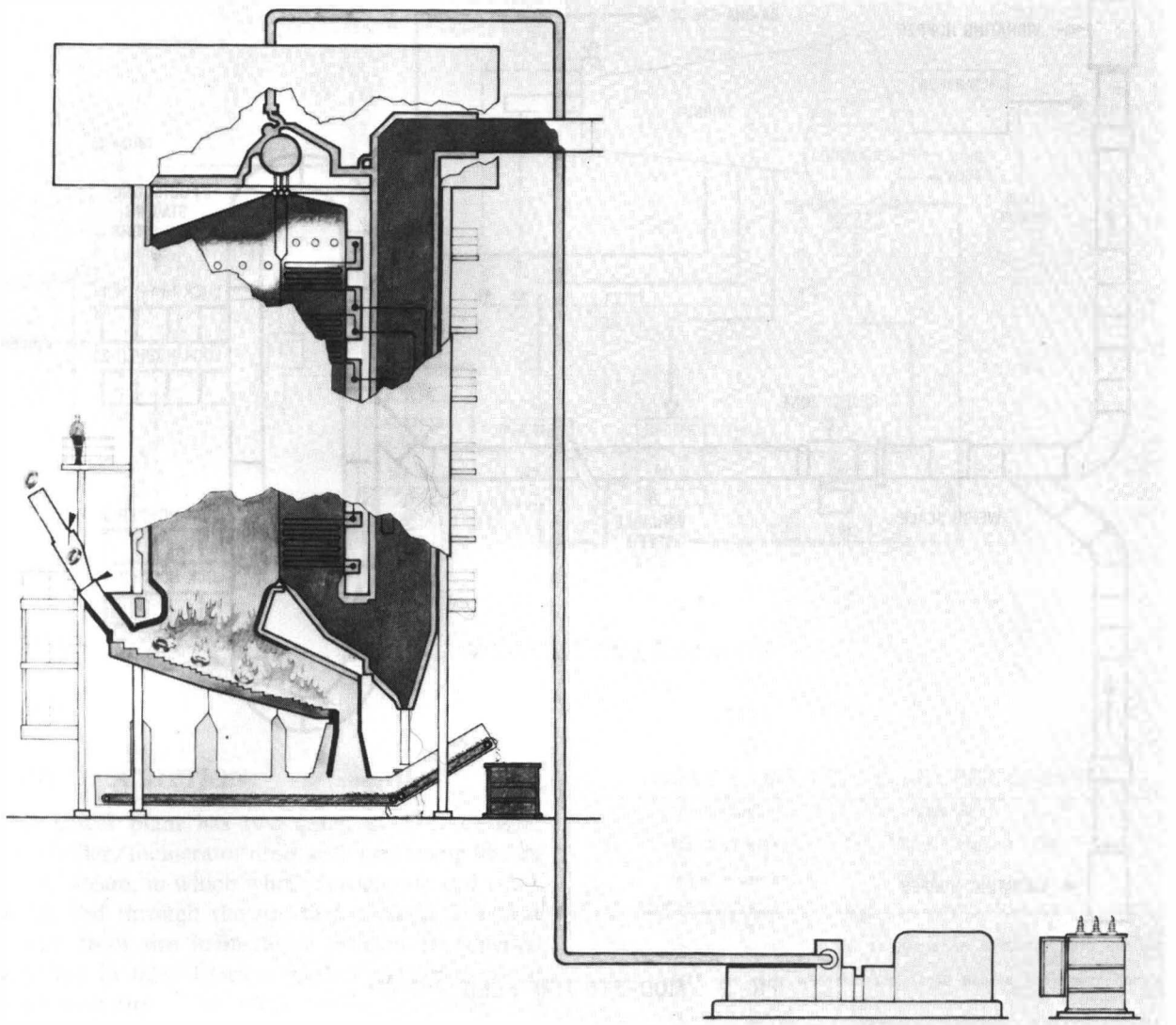


FIG. 3 BOILER/INCINERATOR

into the lockhoppers. Tires which cannot be immediately introduced into the staging conveyors at one of the lockhoppers are stored temporarily on the accumulator carousel.

As the system receives a signal from a lockhopper, one or two tires will advance forward from the staging conveyor into the hopper. The number of tires entering the hopper is determined by size and weight. As a tire or tires enter, a signal is given to the control system indicating a new weight is available to be read. This weight is retained until the next batch of tires is ready for entry into the lockhopper.

## BOILERS

The incinerator has reciprocating grates, hydraulic grate drives, steel structure, lining, feeding chutes, wet slag removal plant, combustion and cooling air systems, two (2) startup fuel gas burners and two auxiliary fuel gas burners. The flue gas from each incinerator passes through a boiler to generate superheated steam. Each boiler can be operated continuously at a superheater steam flow not less than 65,800 lb/hr with feedwater entering a 305°F and with a superheater steam outlet pressure of 975 psig at 932°F with

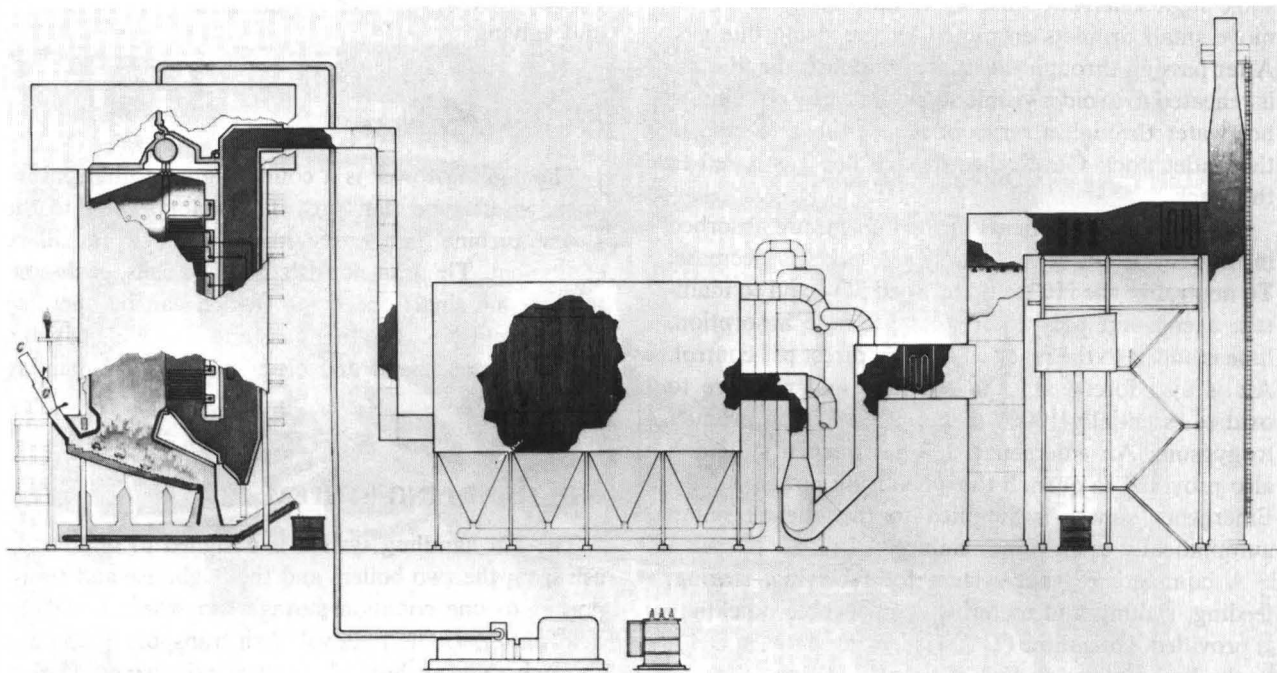


FIG. 4 MODESTO FLUE GAS CLEANUP SYSTEM

5% blowdown from the steam drum, 100% excess air, 77°F ambient temperature. A schematic of the boiler is shown in Fig. 3.

### FLUE GAS CLEANING SYSTEM

The flue gas cleaning system removes particulates, hydrogen chloride and sulfur dioxide from the flue gas. The major subsystems are particulate removal, gas absorption, reheat, reagent storage and preparation and dewatering subsystems, as shown in Fig. 4.  $\text{NO}_x$  is controlled by injecting air/ammonia mixture into the boiler at one or more of the four injection nozzle zones located at different elevations on the sidewalls of the boiler. Ammonia concentrations are controlled by a thermal  $\text{DeNO}_x$  system.

The particulate removal system consists of a single reverse-air fabric filter to remove particulates. The fabric filter consists of eight isolatable compartments, each with 315 8-in. diameter filter bags. Particulates are collected on the inside of the bags as the flue gas passes through the bag. The fabric filter is designed to handle maximum flue gas flow with one compartment off-line for cleaning and one compartment off-line for maintenance. A single reverse air fan is provided. The fabric filter is supplied with a 100% flue gas flow bypass

plenum.  $\text{SO}_3$  in the flue gas will react with excess ammonia in the flue gas and form ammonium sulfate and bisulfate. If this reaction occurs after the fabric filter, additional  $\text{SO}_3$ -based particulates may be emitted from the system. If the reaction occurs before the fabric filter, the additional  $\text{SO}_3$ -based particulates will be collected in the fabric filter. Location of the reaction occurrence is largely determined by the ratio of ammonia to  $\text{SO}_3$  in the flue gas and the temperature of the flue gas. A water spray system is provided to cool the flue gas as required to achieve adequate  $\text{NH}_3/\text{SO}_3$  reaction ahead of the fabric filter.

Flue gas from the fabric filter passes through the two I.D. fans and is processed in a spray tower absorber where  $\text{SO}_2$  and  $\text{HCl}$  are removed using slaked lime as the chemisorbent. The reaction products formed are calcium sulfate (gypsum) as a solid and calcium chloride as a soluble salt. The flue gas enters the spray tower absorber and flows upward, countercurrent to a descending spray of recycle slurry droplets containing sufficient alkali to react with the  $\text{HCl}$  and  $\text{SO}_2$  in the entering flue gas. Intimate contact of the flue gas with the recycle slurry occurs in three staged spray zones resulting in the removal of greater than 97% of the  $\text{SO}_2$  and  $\text{HCl}$  in the entering flue gas. The treated flue gas leaves the uppermost spray zone and enters the absorber outlet duct which is equipped with a two-

stage high efficiency mist eliminator designed to remove small droplets entrained by the rising flue gas. After passing through the mist eliminator, the flue gas is reheated to avoid a visible stack plume by circulating hot water through a series of reheat tubes located in the outlet duct. Once reheated, the flue gas is fed to the stack.

As the acid components in the flue gas are absorbed in the recycle slurry, the slurry pH tends to decrease. To neutralize the HCl and absorbed SO<sub>2</sub>, and to maintain a constant pH required to promote absorption, lime is added to the reaction tank on direct pH control. Air is also forced at sufficient flow and pressure to oxidize essentially 100% of the SO<sub>2</sub> reaction product to gypsum. An emergency flue gas quench system is also provided to quench the gas during power outage. Emergency power is supplied to the quench pump automatically upon power failure.

A complete reagent system for receiving, storing, feeding, slaking and metering ¾ in. pebble quicklime is provided. Quicklime (CaO) is hydrated to Ca(OH)<sub>2</sub> in the lime slaking system. This milk of lime is stored in an agitated tank and fed to the absorber recycle tank, on demand, to maintain the required pH. The removal of gypsum and calcium chloride is accomplished by bleeding a small stream of recirculating slurry from the recycle pump to a hydro-cyclone system for dewatering.

## STEAM TURBINE GENERATOR

The steam turbine generator system has a condensing steam turbine, a reduction gear, a totally enclosed water to air cooled synchronous generator, a brushless excitation system, gland seal system, lube oil system with dual coolers and pumps and a vibration detection system consisting of probes, proximeters, cables, junction box, power supply and relays. The steam turbine instrumentation includes a low exhaust vacuum alarm and a high exhaust temperature alarm. Generator controls include an insert panel, governor, servo amplifier, turbine protective relays, interposing relay for trip solenoid, and emergency trip pushbutton. The steam turbine generator is shown in Fig. 5.

## CONDENSER

The condenser is a shell and tube, two pass surface condensing heat exchanger, and has a hot well located below the condenser shell. A steam driven air ejector package is supplied to maintain vacuum pressure in the condenser. The system includes first and second stage holding jet, integral inter- and after-surface con-

denser, suction manifold, hogging ejector, accessories and valving.

## COOLING TOWER

The cooling tower is a counterflow, mechanical induced draft type that provides cooling water to the steam turbine condenser and additional auxiliary equipment. The unit consists of three cells, each containing one single speed fan, which can be operated independently of the other cells and is capable of being repaired, maintained and cleaned with all remaining cells in service.

## ASH HANDLING SYSTEM

The ash handling system is designed to remove fly ash from the two boilers and the baghouse and transport it to one common storage silo where it will be held until periodic removal. Ash transport is attained through two mechanical vacuum exhausters. The fly ash contains a significant concentration of zinc oxide, and is a saleable byproduct to resmelters for recovering zinc.

Bottom ash and slag from the two boilers is collected in a conventional wet drag-chain conveyor. This material comprises mostly steel slag with some short pieces of wire beads and belting material. Carbon content in the bottom slag is less than about 0.2%.

## ELECTRICAL SYSTEM

The steam turbine generator is connected to the 13.8–115 kV main stepup transformer through a 1200 A generator breaker. The high voltage side of the stepup transformer is connected to the 115 kV utility system through a 1200 A oil circuit breaker and oil filled metering units. Two station auxiliary power transformers, 13,800–480 V, are connected to the 13.8 kV bus between the steam turbine generator breaker and the main step-up transformer. Auxiliary power may also be supplied from a diesel generator during emergency or black start.

## CONTROL SYSTEM

The plant utilizes a microprocessor based distributed control system (DCS) and programmable logic controller (PLC) for the control, protection, sequencing and on-line monitoring of selected plant equipment from the central control room as shown in Fig. 6. This

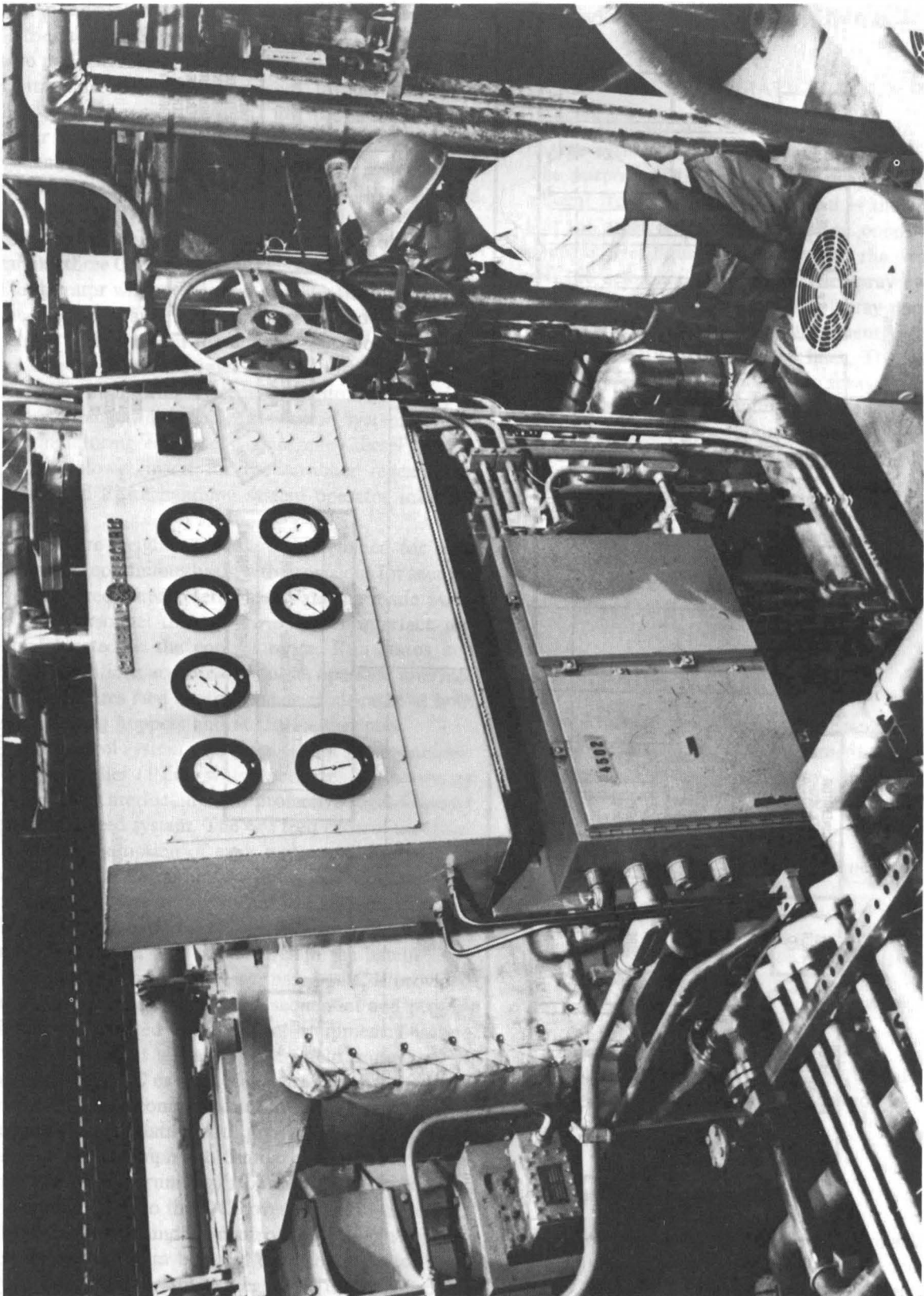


FIG. 5 MODESTO STEAM TURBINE GENERATOR

- FUEL
- CONDENSER
- HOTWELL
- DEAERATOR
- FSH
- BFP
- COND. PUMP
- ETC.
- COOLING WATER
- CIRC. WATER
- COOLING TOWER
- DEMINERALIZER
- STEAM/WATER SAMPLING
- INSTR. AIR
- EMISSION MONITORING
- ETC.

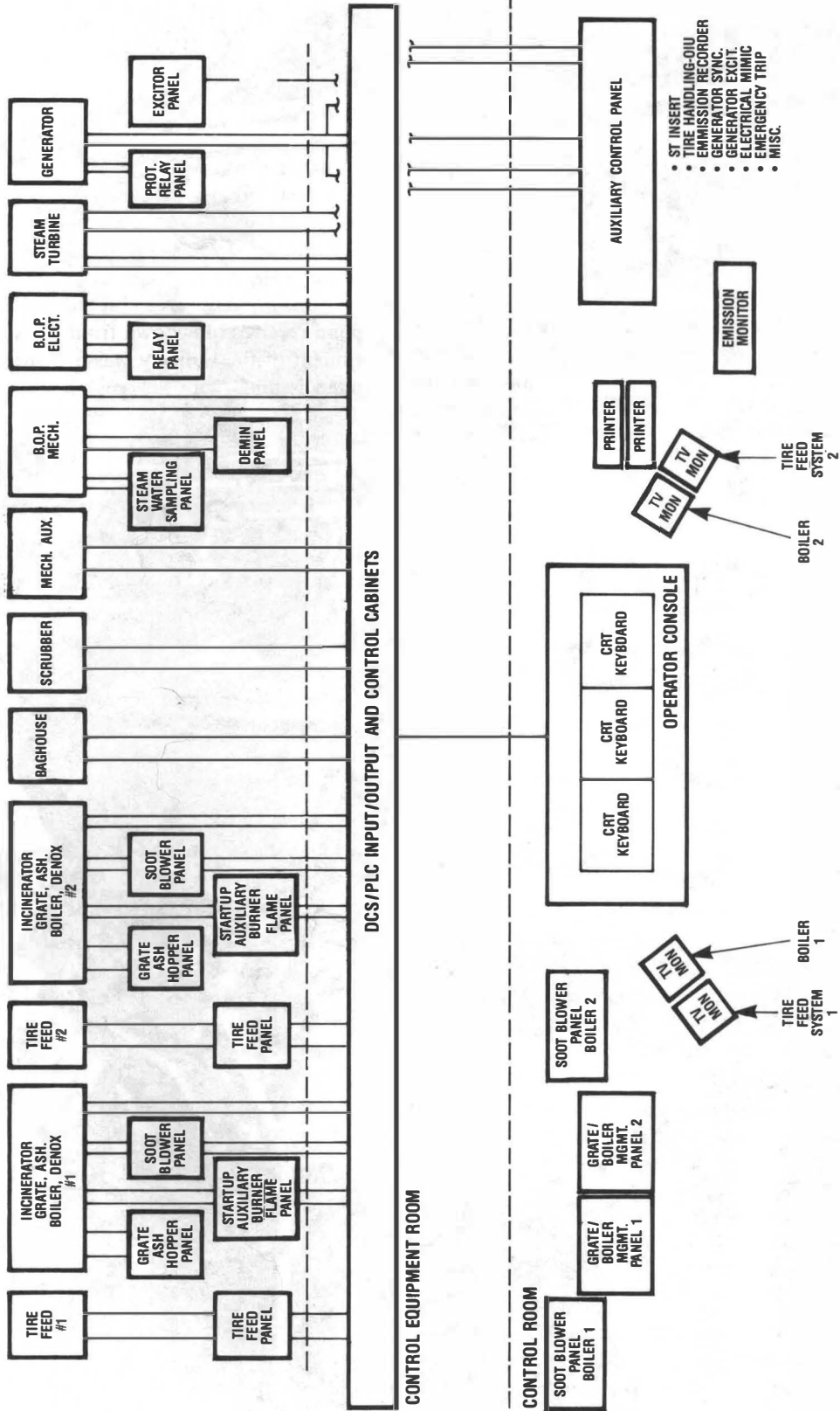


FIG. 6 MODESTO PLANT CONTROL SYSTEM



equipment includes the necessary sensors, control equipment cabinets, final control elements and operator interface units for incinerator/boiler, plant auxiliaries and balance of plant. In addition the DCS will also perform selected monitoring, and/or supervisory control functions for the steam turbine generator, burner management system, fire protection system, water treatment system, instrument and service air system, chemical injection, incinerator grate, chlorination system, ash handling system and tire handling systems. The DCS operator interface units in the central control room consist of an operator console containing three CRTs and three keyboards through which the operator will control and monitor the operation of the plant. An auxiliary panel is also provided in the central control room for an emission monitoring recorder, steam turbine inlet control, turbine-generator vibration monitoring system, generator synchronization equipment, electrical distribution system control and monitoring equipment, emergency diesel generator, sootblower insert for the scrubber regenerative heater and a tire handling system operator interface unit.

Total tire weight and count are retained for each boiler on a continuous basis with provisions for secured manually requested reset. These data are made available to personnel through an operator interface terminal located in the control room. Run status and alarm conditions are directed to the operator interface terminal. Tires feed control panels are located at both the vibrating hoppers and at the lockhoppers.

The control system uses a redundant programmable logic controller (PLC) which performs the necessary sequencing, interlocking and protective logic required by the tire feed system. The tire feed control monitors the tire consumption of each boiler and controls the tire feed to the carousel to maintain the tire inventory in balance. A tire batch weight signal is provided by the tire feed system to the boiler fuel feed control based upon the number and size of tires in the batch.

A redundant microprocessor based PLC is provided to implement the interlocking, sequential and protective logic associated with the plant equipment. Discrete input and output signal to/from field equipment is wired to the PLC cabinet. Operator command signals to the PLC are communicated from the DCS over a redundant serial data link to permit the starting/stopping of plant equipment. Similarly equipment status information, e.g., running/stopped, open/closed, etc., is communicated to the DCS over the serial data link. The DCS has redundant controllers, power supplies, communication data bus and operator interface controls. The plant control strategy is to utilize a turbine follow mode of control during normal plant operation.

This mode of control utilizes the steam turbine inlet control valve to regulate steam pressure and the boiler fuel and air flow controls to regulate steam flow.

## SPRAY AND EVAPORATION POND SYSTEM

The Modesto site requires a zero waste water discharge system. Two ponds are provided at the site. The purpose of the ponds is to evaporate the liquid effluent from the plant. One pond is the spray pond and the other is a solar evaporation pond. The spray pond receives liquid discharges from the wet scrubber and the demineralizer system. The spray evaporation pond receives blowdown from the spray pond and the effluent of the sanitary waste treatment system. Each pond is lined with a Hypalon liner. The spray pond uses low pressure spray nozzles to spray water droplets into contact with surrounding air, thereby causing the droplets to partially evaporate and the air to absorb heat energy from the water droplets, resulting in a temperature drop of the water. To increase the evaporation rate, the spray pond design includes the spray pumps and heat exchangers which continuously add heat from the auxiliary cooling system to the water to maintain the water temperature well above the wet bulb temperature.

## ENVIRONMENTAL EMISSIONS

The Modesto plant, located in Stanislaus County, California, has stringent environmental emission requirements. The air permit states the following pollutant emission levels shall not be exceeded.

<u>Pollutant</u>	<u>lb-/day</u>
NO <sub>x</sub>	500
CO	346.4
Particulates	113.0
SO <sub>x</sub>	250
HC	148.4

Preliminary startup tests performed to date indicate that the plant has environmental emission levels within above requirements.

## ACKNOWLEDGMENTS

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