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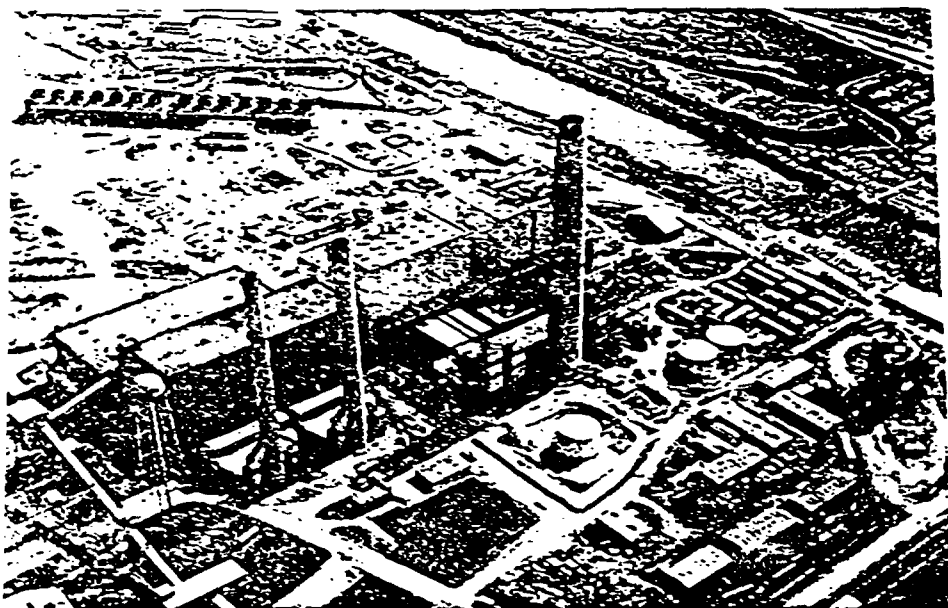
PLAINTIFF'S EXHIBIT

RS-267

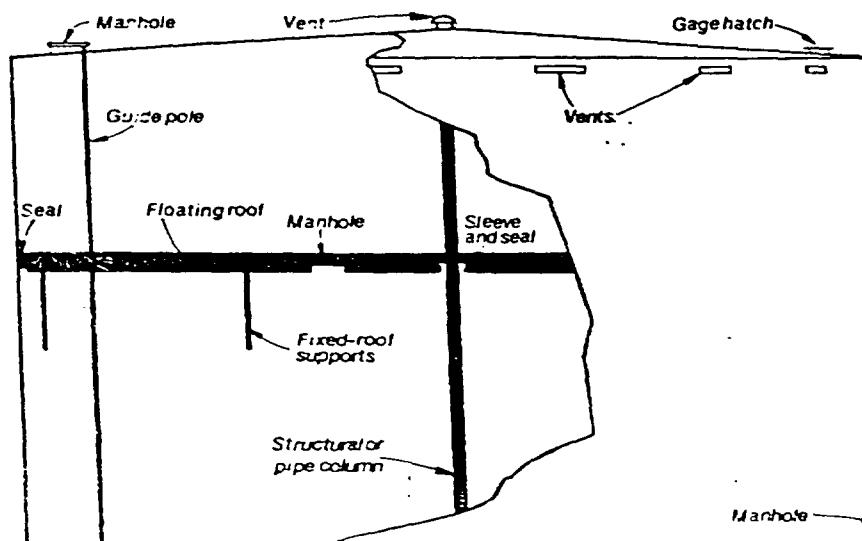
Pacemaker Plants/KARN

Designing crude-oil fuel systems

Two large cycling boilers for the Consumers Power system have the flexibility to switch from crude to resid without changeout of equipment. Safety is of primary consideration in system design and operation



Oil-fired Karn 3 and 4 (right) were built adjacent to two existing coal-fired units. Plant's location on Saginaw Bay makes it possible to deliver crude or resid by tanker



1. Oil received at the plant is stored in four 225,000-bbl. cone-roof tanks fitted with internal floating pans. The 18,000-bbl Karn day tank is of the same design

Several factors influenced Consumers Power Co.'s decision to add two 660-MW, crude-oil-fired cycling units at the Dan E. Karn Plant. Most important, perhaps, was that the company required a large block of intermediate-load-factor generating capability, and the Karn Plant, near Essexville, MI, is close to major industrial loads. Further, a pipeline direct from the Canadian oil fields passes within a few miles of the plant, and its cargo, low-sulfur crude, is an environmentally attractive fuel. The plant's location on Saginaw Bay also makes it possible to deliver oil by tanker.

The two new units, designated Karn-3 and -4, were built alongside Karn-1 and -2. The eight-unit John C. Weadock Plant is located on the same site. Karn-1 and -2 and two of the Weadock units (totaling approximately 850 MW) burn coal, but the remainder of the units at Weadock (about 300 MW) have been converted from coal to crude-oil firing.

Although this discussion primarily is related to Karn-3 and -4, reference to Weadock is made because the same crude-oil-storage and forwarding system supplies both plants. The Weadock conversion was completed about two years before Karn-3 went on-line in December 1974, and the operating experience gained was applied to the two new units as it became available. Karn-4, still under construction, is expected to start up later this year.

The cycle selected for each of the new cycling units provides 1800-psig steam at the turbine; superheat and reheat temperatures are 950 F. Extraction steam from the low-pressure turbine is used for the deaerator, two feedwater heaters, the airheater and the boiler feedpump.

Consumers Power and its architect/engineer on the Karn project. Commonwealth Associates Inc. expended considerable effort at the design stage (1) to ensure that the environmental impact of the new units would be minimal and (2) to solve any special problems in fuel storage, handling and combustion associated with the use of crude oil.

A major objective of Consumers' environmental-management program was to prevent thermal pollution of Saginaw Bay and the marsh lands surrounding the existing condenser-coolant discharge canal. This was accomplished by installing mechanical-draft cooling towers and closed circulating-water systems for the new units.

Stack emissions and crude-oil-firing procedures were studied in depth, and applicable experience of major utilities burning crude in the U.S., Canada and Japan was applied to the Karn design. As a result of these investigations, the company decided to use a single 450-ft stack for both units. Gas-duct design allows for the addition of precipitators and dust collectors if experience and future fuel conditions dictate their use. Boiler, gas duct and stack are designed for water washing of furnace and gas passages.

Fuel-handling, storage and combustion systems and equipment are designed with safety as a primary consideration. Designers also allowed for the possible change to residual oil as the economics of the fuel market dictate. All equipment can handle crude and resid with a minimum of retrofitting, and conversion to gas firing is also possible if gas should become an economical alternative.

Crude-oil handling

The Canadian crude burned at Karn is either a fluxed-pitch crude blend or a sweet mixed-crude blend (see table). The former is 90% crude, 8% pitch (similar to asphalt) and 2% flux ("hago," which is similar to light fuel oil). Oil is received by the utility at a tap site on the pipeline and is measured and stored in a 100,000-bbl gaging tank there. After delivery documentation is complete, oil is forwarded seven miles to the Karn/Weadock storage tanks. The 16-in.-diameter pipeline follows the

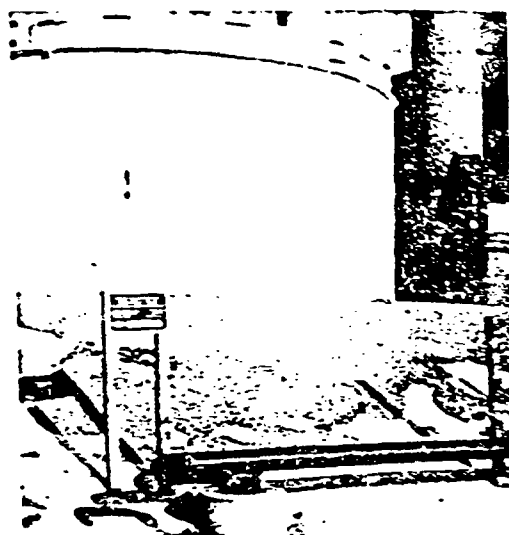
right-of-way of a company transmission line.

Oil received from the tap site is stored in four 225,000-bbl cone-roof tanks equipped with internal floating pans (Fig 1). These tanks provide approximately a 45-day supply of oil for both Weadock and Karn at projected use rates. The floating pans are essentially internal covers that float on the surface of the oil and are free to move up and down as the tank is filled and emptied. Seals around the edge of the pan and internal supports prevent exposure to atmosphere and the resulting evaporation and deterioration of the crude oil.

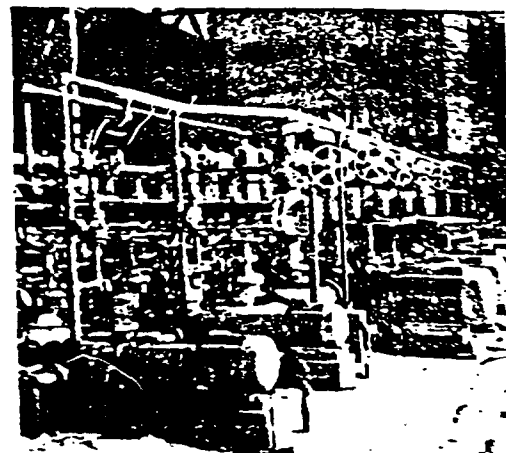
Each storage tank is located in a separate diked area. Sump pumps discharge accumulated rainwater to a drainage pond, where any oil is skimmed off before the water is discharged to the ash-settling pond. The tanks have foam fire-protection systems, which discharge foam at the inner periphery of the walls and direct the flow of foam down toward the seal between the floating pan and the tank wall. Foam is pumped into the system by a fire truck through a hose connection on the outside of the dike at each tank (Fig 2). Fire alarms are wired into the fuel-oil control-panel annunciator from each storage tank. The alarm also goes to the plant's fire-station alarm system.

Storage tanks are equipped with mixers that continuously agitate the oil to minimize (1) the formation of sludge on the bottom and (2) the precipitation of wax on the tank walls during cold weather. Provisions for a future change to residual oil include hangers for suspending the floating pan from the cone-roof support structure and blanked-off flanged connections for the installation of steam heaters. Steam heaters also may be installed for crude-oil storage if experience shows that problems result from wax deposits on the tank walls in cold weather. Oil-storage and day tanks were installed without insulation.

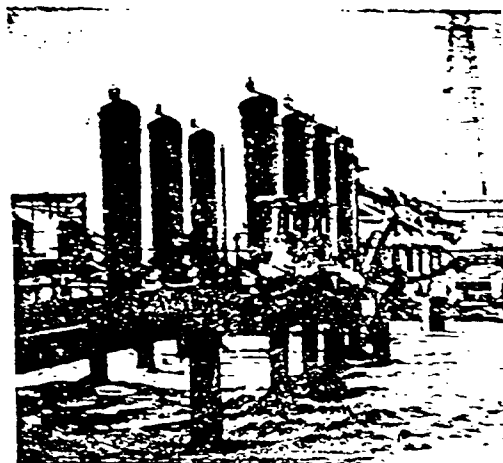
The fuel-forwarding pump station can handle the requirements of Karn and Weadock separately or simultaneously by pumping to the day tanks, which are similar in all design aspects to the oil-storage tanks—except for size. The Weadock



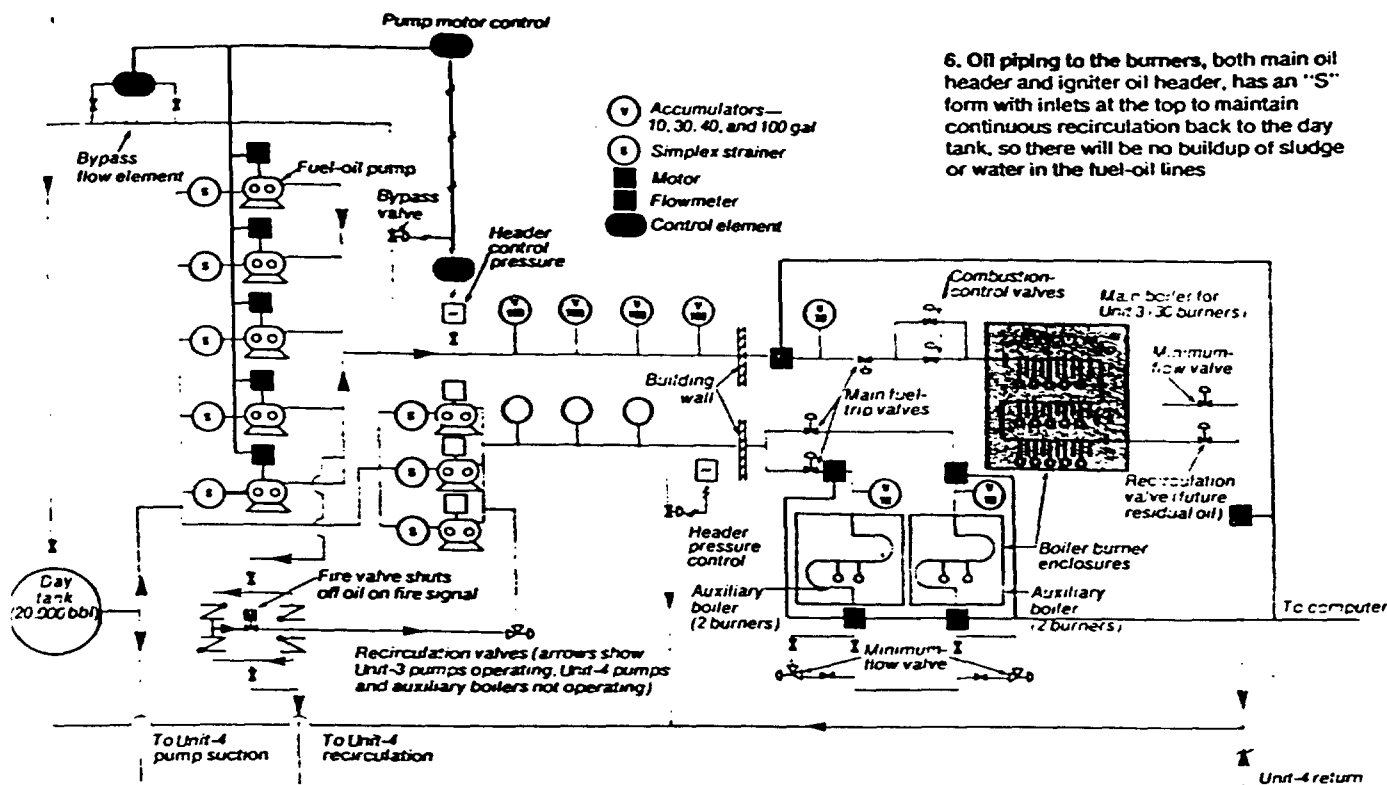
2. Foam is pumped into the fire-protection system by a fire truck through a hose connection located outside of the dike



3. Karn 3 and 4 each have five burner fuel-oil pumps—one is on standby—of the positive-displacement, screw type



4. Surge absorbers insure a constant fuel-oil pressure to the burners. Four 100-gal surge absorbers are provided per unit



tank holds 5000 bbl: the Karn tank, 18,000 bbl. These capacities represent about a six-hour supply for each plant at the maximum use rate.

Burner fuel pumps—there are five for each of the new units—are positive-displacement, screw-type (Fig 3), and each can provide 25% of boiler requirements. Hence, during normal operation, four pumps will be needed; the fifth will be on standby. The pumps, which are suitable for either crude or residual oil, are sized on the basis of the lower crude-oil pumping capability and powered for the higher residual requirements.

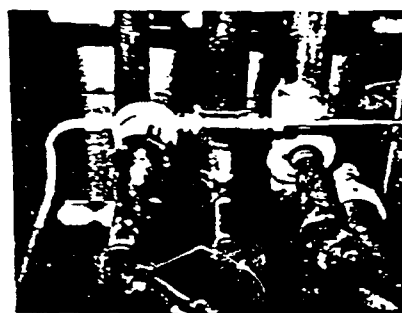
Strainer mesh is sized below the minimum orifice diameter of the burner nozzles. Single-basket strainers were selected because the standby pump can be used when the strainer on an operating pump must be cleaned. This way, strainers can be cleaned without reducing system capacity. All strainers are equipped with differential-pressure switches to alarm and warn operators of accumulations of dirt or wax in the baskets.

Burner pumps are located outside the boiler house between the day tank and the building. Some thought was given to putting the

pumps in a building, but after the ventilation requirements and necessary gas sensors and fire alarms were considered, it was decided that a restricted area surrounded by a fence was a better choice. Pump suction lines, suction valves, strainers and all instrument lines are heat traced to prevent the formation of wax deposits. The tracing is explosion-proof electric with thermostatic control and is covered with weather-resistant insulation.

Burners are arranged at three elevations on the front of the boiler. The burner-front enclosure is ventilated continuously and equipped with foam fire-protection devices (Fig 5) and a foam-drainage and -storage system. Cavities between the furnace hopper bottom and casing are purged, by ventilation fans before each boiler start to remove any gases that might have leaked through the furnace waterwall membrane. This purge is a permissive that must be satisfied before burner light-off. Gas samplers located in the burner-front enclosure warn of any accumulation of explosive vapors.

Oil piping to the burners, both main oil header and igniter oil header, is arranged in an "S" form



5. Burner-front enclosure is ventilated continuously and has foam fire protection

with inlets at the top (Fig 6). Reason: If continuous recirculation back to the day tank is maintained, there will be no accumulation of sludge or water in the oil lines.

Burner design

Burners are steam-atomized and have air-atomized crude-oil igniters (Fig 7). Provision for future resid firing has been made and requires only a supply of distillate oil to the igniter lines. Flexible metal hoses for oil and steam feature double-wall construction and are equipped with a pressure gage for monitoring leaks (Fig 8).

The hopper bottom is designed to

Design crude-oil fuel systems to these codes and standards

Basic design approach for a crude-oil fuel system is to avoid fuel leaks, spills and evaporation. If spills and evaporation occur, the effects are minimized by drainage and ventilation. Fire protection and safety are primary considerations, and fire-extinguishing and fire-detection equipment always should be installed. Further, strict adherence to laws and codes relating to fire protection must be practiced at all times. The following list of references is a basic library for the designer of a fuel-oil system.

Codes and regulations:

- NFPA 11—Standard for foam extinguishing systems
- NFPA 30—Flammable and combustible liquids code
- NFPA 31—Standard for installation of oil-burning equipment
- NFPA 51—Welding and cutting
- NFPA 51B—Welding processes
- NFPA 70—National electric code
- NFPA 77—Static electricity code
- NFPA 85D—Standard for prevention of furnace explosions in fuel-oil-fired multiple-burner boiler furnaces
- 49 CFR 180—Carriers by pipelines
- 49 CFR 195—Transportation of liquids by pipeline
- Flammable liquids regulations—Applicable local and state ordinances

Design standards:

- ANSI B31.1—Code for pressure piping: Power piping
- ANSI B31.4—Liquid petroleum transportation systems
- API Standard 5L—Specification for line pipe
- API Standard 5LX—Specification for high-test line pipe
- API Standard 6D—Specification for pipeline valves
- API Standard 610—Centrifugal pumps for general refinery services
- API Standard 650—Welded steel tanks for oil storage
- API Standard 1101—Measurement of petroleum liquid hydrocarbons by positive-displacement meter
- API Standard 2531—Mechanical displacement-meter provers
- API Standard 2545—Method of gaging petroleum and petroleum products
- API Standard 2550—Method for measurement and calibration of upright cylindrical tanks
- API RP500C—Recommended practice for classification of areas for electrical installations at petroleum- and gas-pipeline transportation facilities
- API RP540—Recommended practice for electrical installation in petroleum refineries
- API RP2003—Recommended practice for protection against ignitions arising out of static, lightning and stray currents
- API RP2533—Recommended practice for metering viscous hydrocarbons

NFPA—National Fire Protection Association, 470 Atlantic Ave., Boston, MA 02210
ANSI—American National Standards Institute, 1430 Broadway, New York, NY 10018
API—American Petroleum Institute, 1801 K St. NW, Washington, DC 20006
CFR—Code of Federal Regulations. Title 49 regulations available from Department of Transportation, 400 Seventh St. SW, Washington, DC 20590

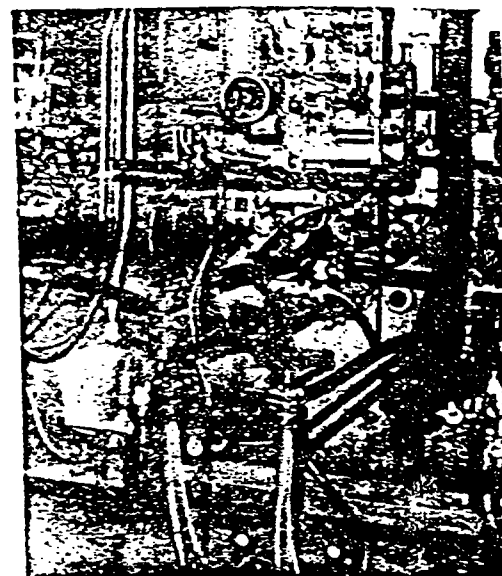
facilitate the collection of ash and water during boiler water-washing operations. Sootblower air piping has inlet connections for high-pressure water, as well as the necessary manual block and check valves. No modification of the sootblowing system, or controls, was necessary to provide water-washing capability.

Present plans call for periodic water washing of the stack and boiler on weekends after initial boiler cooling. Bear in mind that it is necessary to wash when internals are cool enough to avoid thermal-shock damage to refractory, but they must be warm enough to ensure rapid and complete drying. Water and ash

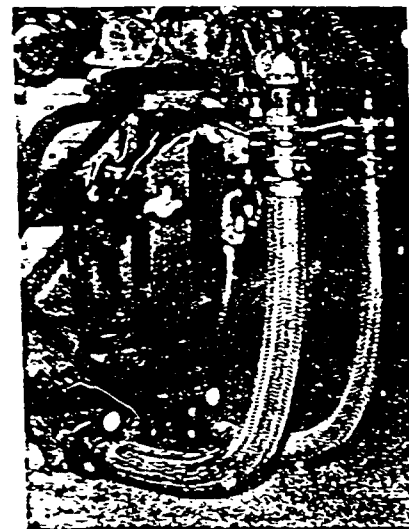
from the boiler washing system are collected in a storage tank and pumped to the ash-settling pond. Operating experience will determine the frequency of the boiler and stack washing sequence.

Control of the fuel-forwarding system is from a panel located in the Weadock Plant. An indicator on the Karn control panel indicates day-tank oil level.

Burner pumps are controlled from the boiler control rooms. The fuel system is either "on" or "off." In the "off" condition, no pumps are operating. In the "on" condition, one pump is always operating to provide a minimum recirculating flow



7, 8. Burners are steam-atomized (above). Flexible metal hoses for oil and steam have double-wall construction (bottom)



Analysis of typical Canadian crude oil

Parameter	Type of crude oil	
	Fluxed pitch	Sweet mixed
Specific gravity at 60 F	0.833	0.826
API gravity at 60 F	38.36	39.80
Density, lb./gal	6.945	6.886
Flash point, F	50	52
Fire point, F	51	53
Cloud point, F	-10	-20
Pour point, F	-15	-28
Viscosity, SSU at 100 F	39.3	36.8
Heating values		
Gross, Btu./lb	19,672	19,845
Net, Btu./lb	18,464	18,588
Gross, Btu./gal	136,622	136,652
Net, Btu./gal	123,232	127,997
Ash, wt %	0.0062	0.0061
Carbon, wt %	85.25	86.33
Hydrogen, wt %	13.29	13.14
Nitrogen, wt %	0.125	0.13
Sulfur, wt %	0.34	0.35
Hydrogen sulfide, wt %	Negligible	
Wax content, vol %	30	29

through the oil lines. Oil flow is controlled by sensing oil pressure and by-passing oil to the return line. On startup, a drop in pressure below burner requirements signals the start of another pump. When fuel requirements decrease, a pump is shut off by signals from a flow-measuring element in the return line after flow exceeds the capacity of one pump. Loss of a pump signals the start of the standby pump. A fire signal from the burner-front enclosure shuts off all oil pumps to the affected unit.

Fuel-oil control valve responds to the demands of the combustion-control system, maintaining oil flow to meet the requirements of throttle pressure, steam flow and combustion air.

The boiler is operated in the boiler-following [the turbine] mode by maintaining throttle pressure at the set point while the turbine is adjusting its control valves in response to generator load demands. Boiler controls automatically regulate drum level, furnace draft, steam temperatures, flue-gas oxygen and

main-steam header pressure. The process computer performs the functions of scanning and alarming, logging data, calculating performance, set-point control during unit startup, automatic turbine start and sequence monitoring during unit startup and shutdown. ■

Charles A. Horste, PE, of Commonwealth Associates Inc., who has had considerable experience in the design of fuel-oil and other utility fluid systems, was instrumental in the preparation of this article.

Unit 3 and 4, D E Kam Plant, Essexville, MI, Consumers Power Co

Turbine/generator and auxiliaries

Turbine/generator, 1 (Unit-3).....General Electric Co
605 MW, 1800 psig, 950/950 F, 3 in. Hg abs, 3500 rpm, tandem compound, four flow, 30-in. last-row blades, three phase, 60 Hz, 26 kV, 814 MVA (0.85 pf) at 60-psig H₂ pressure, 0.14 short-circuit ratio, shaft-driven AC exciter and silicon-diode rectifier

Turbine/generator, 1 (Unit-4).....Allis-Chalmers Power Systems Inc
626 MW, 1800 psig, 950/950 F, 3.5 in. Hg abs, 3500 rpm, tandem compound, four flow, 30.2-in. last-row blades, three phase, 60 Hz, 26 kV, 835 MVA (0.85 pf) at 75-psig H₂ pressure, 0.58 short-circuit ratio, shaft-driven AC exciter and silicon-diode rectifier

Main condenser, 1 per unit.....DeLaval Turbine Inc
Each single pass, 295,000-sq ft effective surface, single shell, dual pressure, 3,395,000-lb/hr steam flow, 281,000-gpm circulating-water flow at water temperature of 92 F, 70-ft effective tube length, 1-in.-diam tubes

Circulating-water pumps, 4 per unit.....Ingersoll-Rand Co
Each 68,250 gpm at 70-ft head, single stage, double suction, horizontally split pump casing; 3000-hp, 445-rpm motor drives two pumps at one time

Cooling towers, 1 per unit.....Marley Co
Crossflow, mechanical draft, 14 cells, treated Douglas fir construction, 28-ft manually adjustable-pitch fans driven by 200-hp, single-speed motors, capacity per cell, 21,000 gpm based on 116-F hot water and 92-F cold water at 74-F wet bulb

Turbine-oil conditioner, 1 per unit—400 gpm.....Fram Corp
Condenser vacuum pumps, 3 per unit.....Ingersoll-Rand Co
Each 15 scfm at 1 in. Hg abs condenser pressure

Condensate and feedwater system

Condensate pumps, 2 per unit.....Ingersoll-Rand Co
Each 4900 gpm, 1750-hp motor drive

Gland-steam condenser, 1 per unit.....General Electric Co
600-psig design, 900-sq ft surface

First low-pressure heater, 1 per unit.....Struthers Nuclear & Process Co
600-psig tube-side design, 100-psig vacuum shell-side design, 18,220-sq ft surface, 42,300-lb/hr steam flow at 7 psia/165 F (16th-stage extraction)

Second low pressure heater, 1 per unit.....Struthers Nuclear & Process Co
600-psig tube-side design, 100-psig vacuum shell-side design, 14,142-sq ft surface, 155,000-lb/hr steam flow at 16 psia/266 F (15th-stage extraction)

Deaerator, 1 per unit.....Graver Water Conditioning Co
4 030,000 lb/hr at 207-F inlet and 357-F outlet water temperatures, 63,000-gal capacity, 12 ft x 107 ft storage tank with 200-psig design, 593,000-lb/hr steam flow at 140 psig/696 F (11th-stage extraction)

Main boiler-feed pump, 1 per unit.....Dresser Industries Inc, Pacific Pumps Div
11,500 gpm at 189.4-psig suction and 2359-psig discharge

Main boiler-feed pump turbine drive, 1 per unit.....Westinghouse Electric Corp
17,025 hp at 5600 rpm with 40-psig inlet steam and 3 in. Hg abs exhaust, electrohydraulic variable-speed control, exhaust steam condensed in main condenser

Standby boiler-feed pump, 1 per unit.....Dresser Industries Inc, Pacific Pumps Div
186.5-psig suction, 2024-psig discharge, five stages

Demineralizer.....Crane Co, Cochran Div
500-gpm primary-treatment train with chlorinator, cold-amine soft-

ener and carbon filters feeds two parallel trains of demineralizer equipment each rated at 200 gpm and consisting of a primary cation exchanger, vacuum degasifier, primary anion unit and mixed-bed polishing demineralizer

Steam-generation equipment

Boiler, 1 per unit.....Riley Stoker Corp
4 650,000 lb/hr at 1980 psig and 995/995 F, oil fired, balanced-draft, front-fired furnace, natural circulation, gas recirculation, 240,000-cu ft furnace volume, 51,660-sq ft boiler and waterwall surface, 532,000-sq ft economizer surface

Burners, 30 per unit.....Forney Engineering Corp
Steam-atomized type with air-atomized igniters

Burner management system, 1 per unit.....Forney Engineering Corp
Furnace cameras, 4 per unit.....General Television Corp

Air heaters, 2 per unit.....Yuba Industries Inc, Yuba Heat Transfer Div
Each 570,000 cfm at 4-F inlet and 259-F outlet temperatures, three coil banks per heater, 360,000-lb/hr steam at 86 psia/570 F (14th-stage extraction)

Forced-draft fans, 2 per unit.....Westinghouse Electric Corp, Sturtevant Div
Each airfoil type, inlet-vane and outlet-damper flow control, 825,000 cfm at 20.2 in. H₂O static pressure and 125-F inlet air, 3000-hp, 505-rpm motor drive

Induced-draft fans, 2 per unit.....Westinghouse Electric Corp, Sturtevant Div
Each airfoil type, inlet-vane and outlet-damper flow control, 1,650,000 cfm at 26 in. H₂O static pressure and 525-F inlet flue gas, 7000-hp, 705-rpm motor drive

Gas recirculation fan, 1 per unit.....Westinghouse Electric Corp, Sturtevant Div
Airfoil type, inlet-vane and outlet-damper flow control, 228,000 cfm at 20.6 in. H₂O static pressure and 500-F inlet flue gas, 1000-hp, 1180-rpm motor drive

Scrubbers, 20.....Diamond Power Specialty Corp
16-long-retractable and four half-retractable air blowers with electrically operated sequenced controls. Scrubbers can be used for water washing without modification

Auxiliary boilers, 2.....Combustion Engineering Inc
Each shop-assembled, 225,000 lb/hr at 250 psig/525 F

Boiler and stack water-wash system.....Goulds Pumps Inc
Two pumps rated 400 gpm each at 400-psig discharge pressure

Fuel-oil system

Oil storage tanks, 4.....Chicago Bridge & Iron Co
Each cylindrical, uninsulated, fixed-cone roof with internal floating pan, 200 ft diam x 40 ft high, 225,000-bbl capacity

Fuel-oil day tank, 1.....Graver Tank & Manufacturing Co
Cylindrical, fixed-cone roof with internal floating pan, 60 ft diam x 38 ft high, 18,000-bbl capacity

Fuel-oil transfer pumps, 4.....Goulds Pumps Inc
Each vertical orientation, centrifugal type, 1100 gpm, 50-hp motor drive. Note: These pumps are designed for crude oil only

Fuel-oil pumps, 5 per unit.....Gibbarco Inc, Ser-Bath Pump Div
Each screw type, 275 gpm at 400 psig, 200-hp, motor drive

Auxiliary boiler fuel-oil pumps, 3.....Gibbarco Inc, Ser-Bath Pump Div
Each 40 gpm at 250 psig, one pump per boiler with one standby unit, 25-hp, 1800-rpm motor drive

Surge absorbers.....Greer Hydraulics Inc, Greer Oiler Products Div
Four 100-gal surge absorbers per unit, three 40-gal surge absorbers for auxiliary boilers