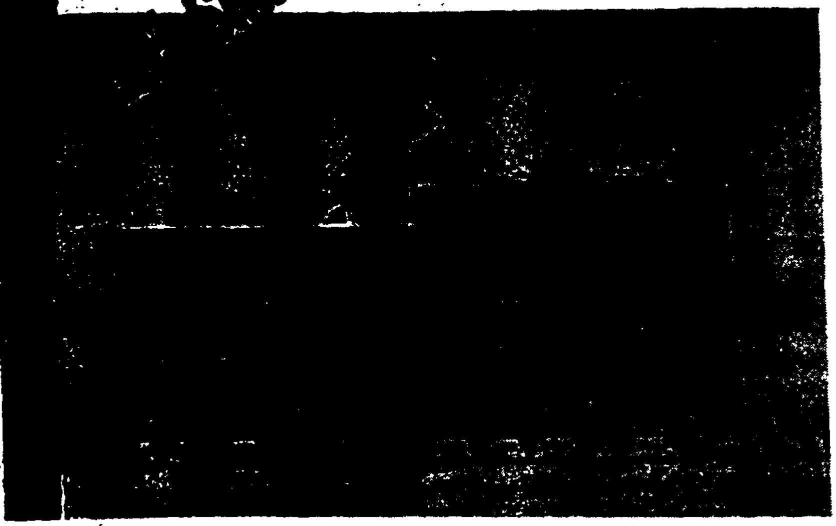
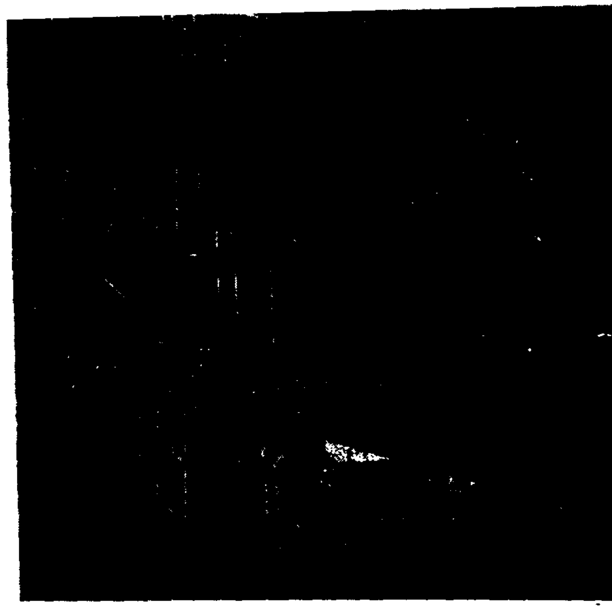


PLANT HAGOOD houses all equipment except deaerating heater and storage tank (on roof). Induced ventilating scheme draws air through first-floor windows and basement areaways, discharging through roof



NO WALL separates turbine-generator, right, and oil-fired boiler, center back. Control board of turbine backs onto that of boiler, centralizing supervision.

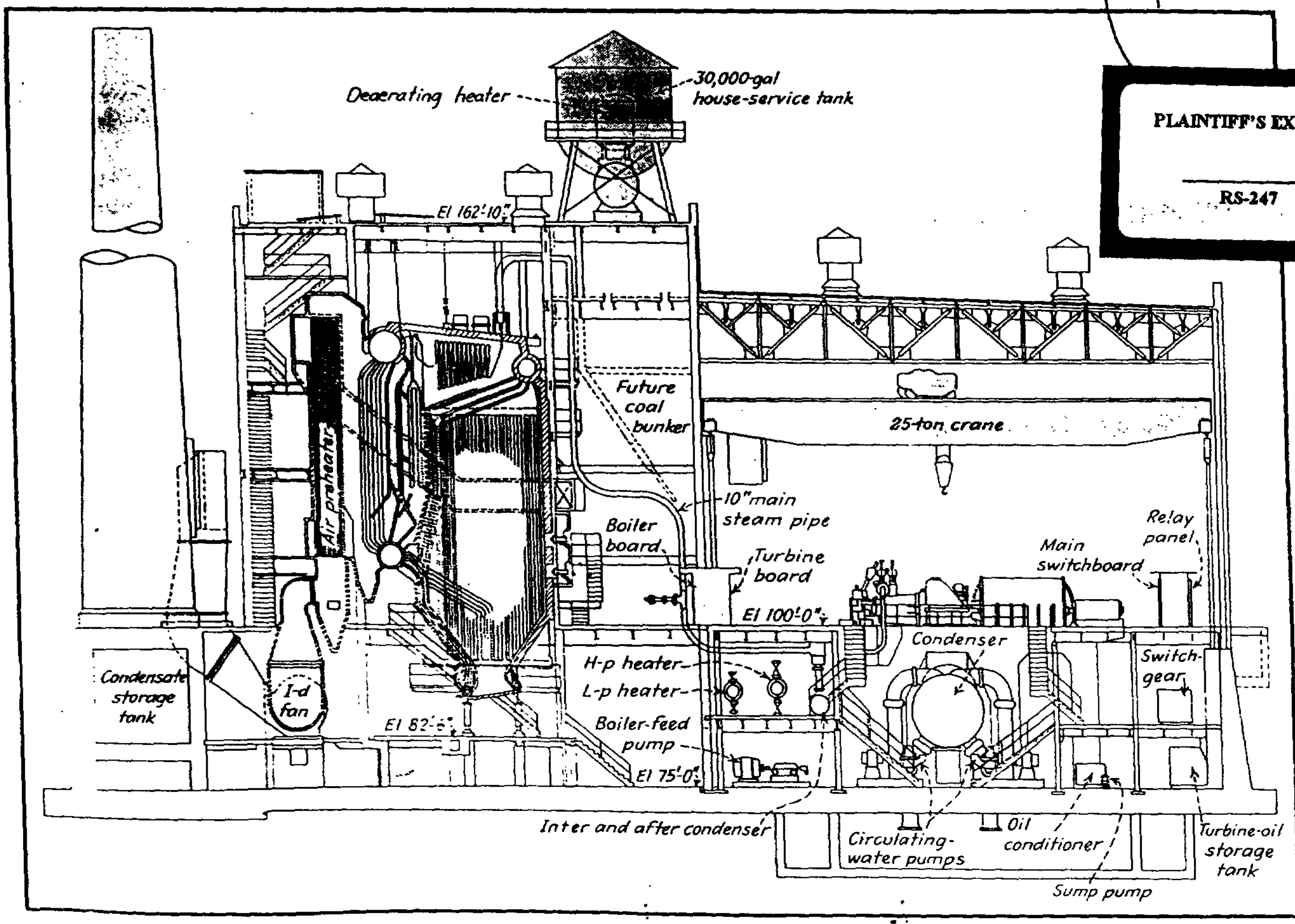
Plant Hagood Meets Growing

By D H DAVIS, *Superintendent of Production and Transmission, South Carolina Power Co*

(Riley)

PLAINTIFF'S EXHIBIT

RS-247



CROSS SECTION OF STATION shows simple arrangement of equipment. Oil-fired boiler can be quickly converted to gas. Note ample space provided for possible future coal-handling and firing equipment. Operators need not go above first floor

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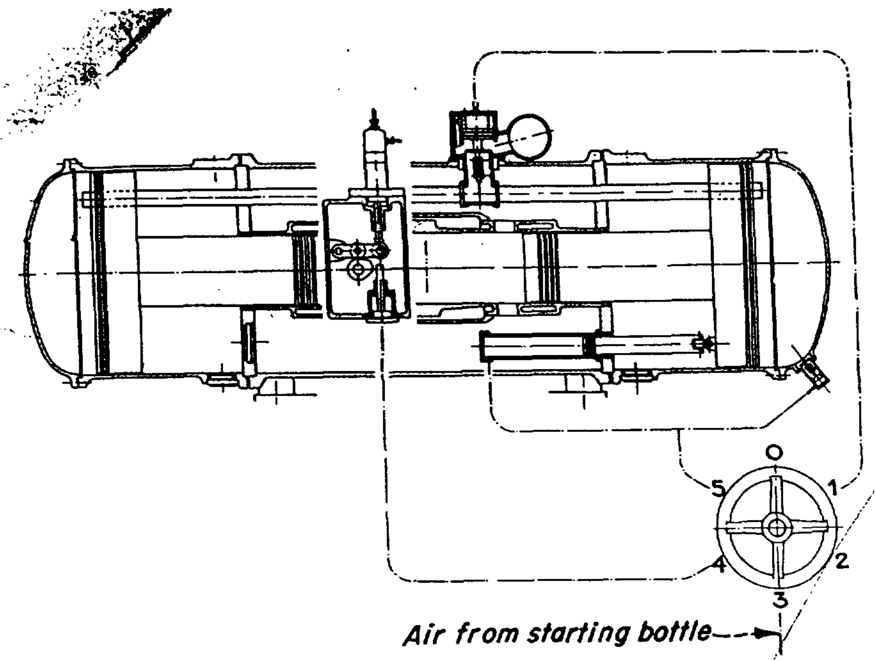
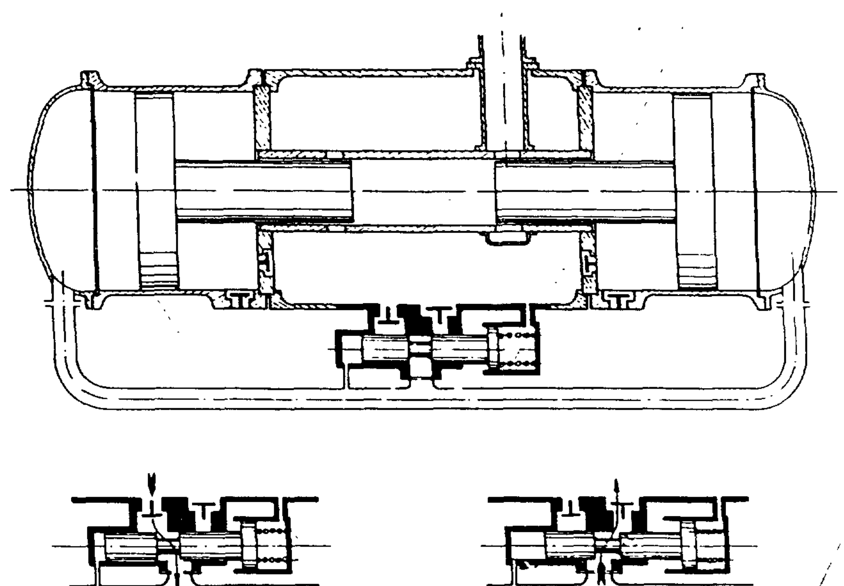


STARTING SYSTEM: Unit is started by introducing air under pressure to cushion chambers. Control insures simultaneous admission of right amount at proper pressure



STABILIZER: Backpressure valves and controlling slide valve coordinate mean pressure in air-cushion spaces with supercharging pressure at various engine loads

ing any rotational movement of the pistons. Arrangement for cooling the engine pistons requires only a single stuffing box at each end. The air-cushion space reaches deep into the interior of the engine piston.

Admitting pressure air to the cushion spaces throws the pistons from their outer position toward inner dead center. Because of the large piston area, air pressure need not be high. Starting system must, however, provide for supplying right amount of air, at proper pressure, to both chambers simultaneously. Starting-system diagram shows the connection from starting apparatus and previously mentioned guiding pipe between the two air-cushion chambers.

STARTING PROCEDURE. Putting the control wheel in first position delivers air at a preselected pressure to a small receiver, air pressure in the receiver holding a disk valve closed. At position 2, air pressure on top of a control plunger integral with the disk valve is released, admitting air from the receiver to the cushion chambers. Bringing control wheel to the third position closes the air-delivery pipe, pressure of air above the plunger closes the disk valve and the small receiver fills again.

At position 4, air pressure lifts the fuel-pump plunger and piston motion dies out. Bringing control wheel to fifth position causes a small air-pressure piston to return pistons to outer dead center and air is expelled from cushion chambers. After returning control wheel to position 0, starting operation may be repeated. It is possible to start and stop the unit in 20 seconds.

STABILIZER ACTION. An important function still remains: Mean pressure of air-cushion chambers must be adjusted in accordance with prevailing working pressure (supercharging pressure or pressure before the turbine). When working pressure changes, air-cushion mean pressure must be altered in the same proportion, to hold proper compression pressure in the engine cylinder. The *stabilizer* does this automatically.

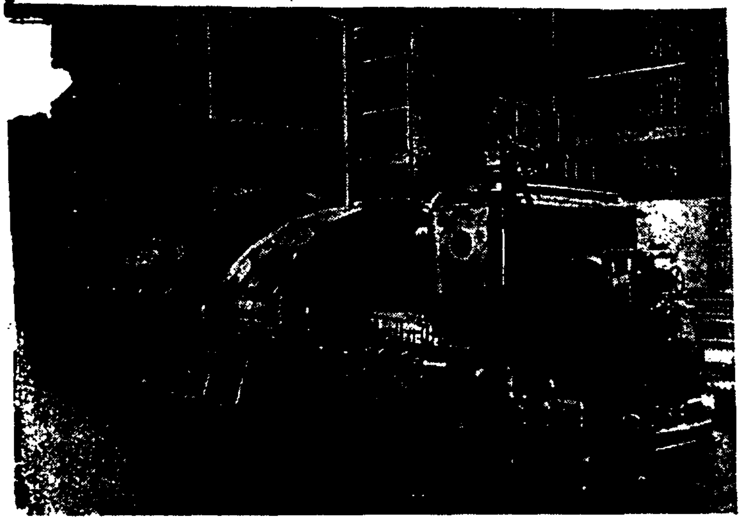
Mean pressure in the air cushions is automatically adjusted to pressure in the engine case, which is a function of engine load. But while pressure in the engine case, that is, of the scavenging air, may be assumed constant for any given load, air in the cushion cylinders is compressed at every stroke and allowed to expand again. Thus it is at times above engine-case pressure, and sometimes below.

Consequently, during one part of the stroke, air may flow from engine case to cushion space, with return flow during the other part of the stroke. For this purpose a passage is provided between the engine case and the pipe connecting the air-cushion chambers. By introducing a backpressure valve and a controlling slide valve, this passage may be kept open until desired pressure balance between engine case and air cushions is maintained. Stabilizer diagram shows this arrangement and position of slide valve during admission and expulsion periods.

Stabilizer may be built as a single backpressure valve incorporated in a movable slide valve. Most suitable backpressure valve is the type usually employed for compressors, with a cross section of ample dimensions. The valve is operated by a spring-loaded stepped plunger, by which any desired linear regulation of pressure from air-cushion level to engine-case level may be obtained.

FUEL INJECTION. In free-piston engines, fuel-injection must meet special conditions. Fuel must be injected during a period that includes the inner dead-center position of the pistons, when there is no motion. It thus becomes necessary to operate on a system of accumulation. Fuel must be metered

(*Continued on page 156*)

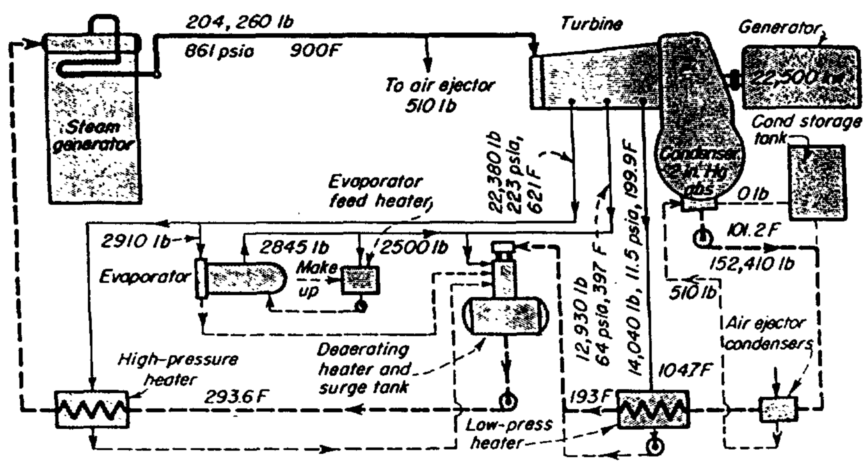


TURBINE-GENERATOR, 22,500 kw, uses 850-psig 900-F throttle steam, exhausts to condenser at 2-in. Hg abs backpress. Three bleed points supply one deaerating and two closed heaters

MAIN CONDENSER with 20,350 sq ft heat-transfer surface arranged in two passes is served by two 13,000-gpm circ-water pumps driven by 100-hp motors; takes water from Ashley River

Charleston's Electrical Demands

Extension of new plant is planned as first unit goes into service. Station will provide major part of energy formerly purchased from the neighboring utility systems through interconnected lines



STATION HEAT BALANCE uses three of four turbine bleed points. Steam generator has air preheater, no economizer. Gas bypass in boiler controls steam temperature

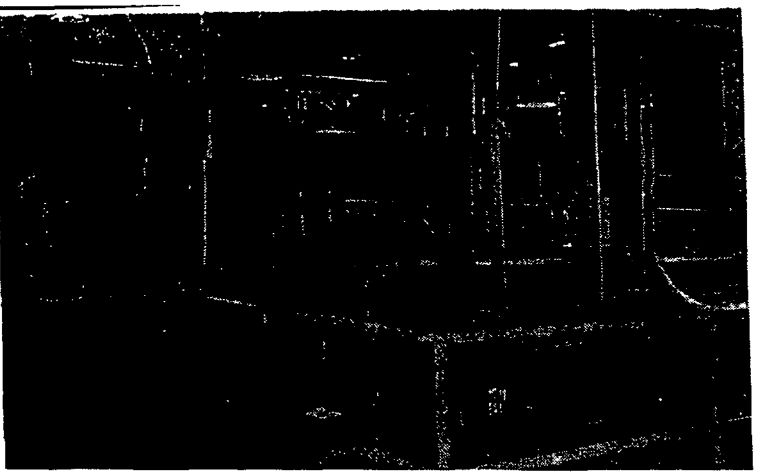
► BEFORE WORLD WAR II. electric load in the Charleston area was supplied from a 19,000-kw steam plant in the city and by transmission from South Carolina Power Co's hydro plant and neighboring utilities. The area's energy consumption grew from 89,000,000 kwhr in 1940 to 216,000,000 kwhr in 1944. Peak demand grew correspondingly from 21,000 to 46,000 kw.

An additional source of power was needed so a site for the new plant was acquired on the Ashley River, two miles north of the city. At this point there is access to deep-water navigation allowing fuel delivery by tanker or collier; also, there is an adequate supply of condenser cooling water.

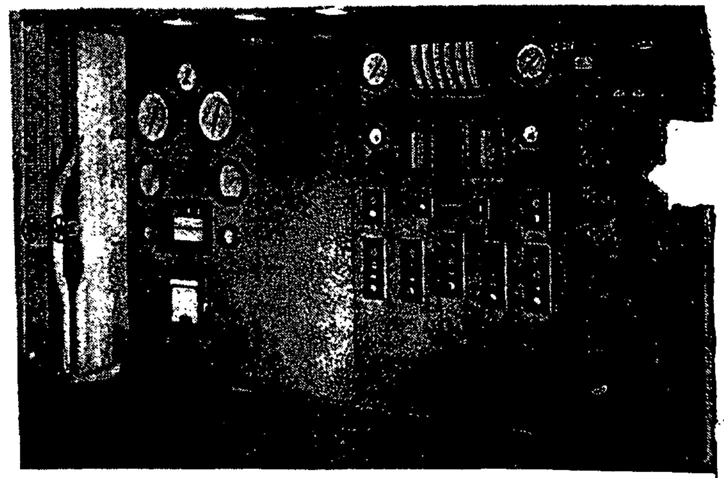
Construction of Plant Hagood began Dec 1, 1945, and its first power was produced on Nov 20, 1947. The plant, named for Benjamin A Hagood, first president of South Carolina Power Co. was dedicated on June 3, 1948. Plans are now being prepared for Unit No. 2. Construction is to begin early in 1949 and operation is scheduled for May 1950.

The station, designed by the engineering group of Commonwealth and Southern Corp, southern division, very closely duplicates several of its other plants in the Southeast. One of them, Plant Eaton, has been described in detail in POWER, Nov 1947, pp 90-4. Accordingly, only a brief outline of the highlights of Hagood will be given here, principally where they differ from Eaton.

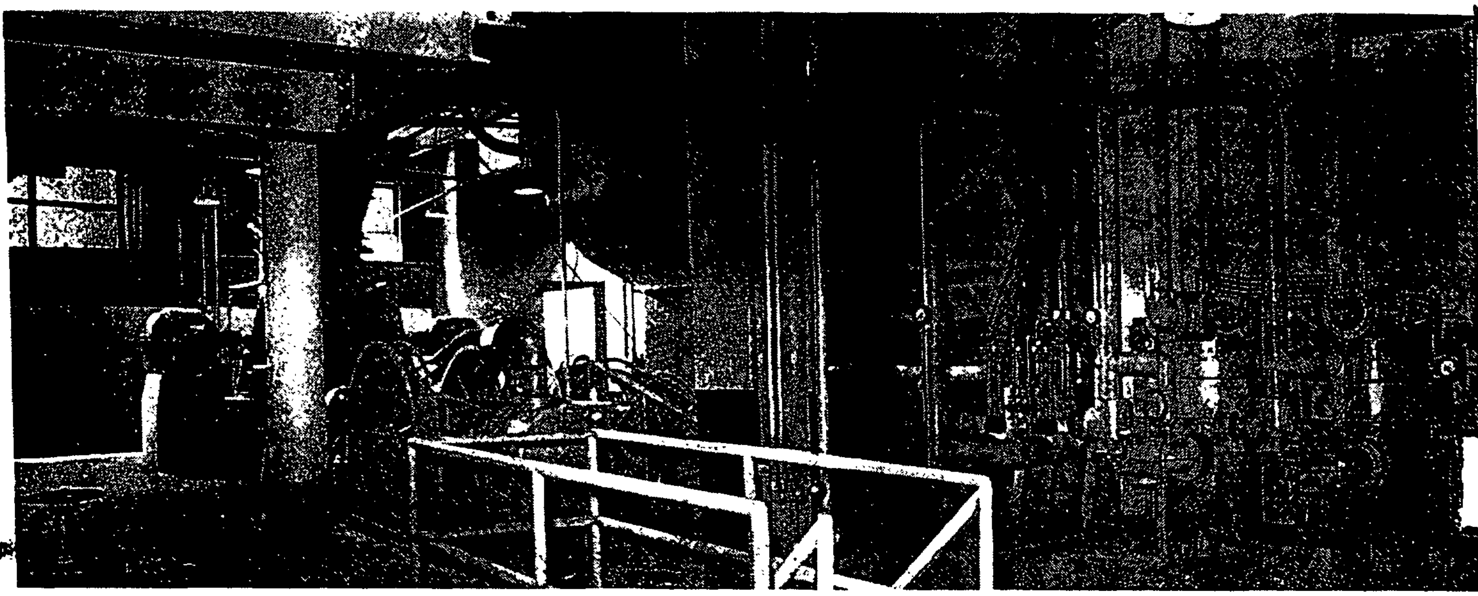
Plant Highlights. Planned to house four units ultimately, the station will operate on the unit system with one boiler feeding one turbine, and the generator connected to the system through one main transformer. First unit comprises one 230,000-lb-per-hr oil-fired boiler, feeding a 22,500-kw turbine at 850 psig and 900 F. Turbine exhausts at 2 in. Hg abs into a 20,350-sq-ft surface condenser. Heat-balance cycle is simple, using only three of the turbine's four bleed points. The end points feed closed high- and low-pressure heaters and the middle point feeds the deaerating heater and single effect evaporator of makeup water. No economizer is in-



HEATER FLOOR ACCOMMODATES the 4-pass low-pressure, 2-pass high-pressure heaters, evaporator and its feed heater



ALL CONTROLS AND INSTRUMENTS of steam generator centered on board facing boiler firing front for easy supervision

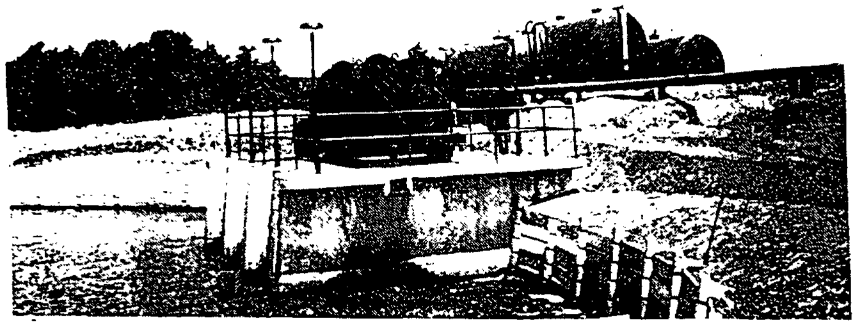


FAN-FLOOR VIEW shows, left to right, forced-draft fan driven by two motors, service- and control-air compressors, flue-gas ducts leading to induced-draft fan and fuel-oil heaters. Apparatus is below operating floor to rear of boiler

cluded in the steam generator although there is a tubular air heater.

Two factors were thoroughly investigated before starting construction: (1) subsurface exploration for foundation conditions (2) effect of river currents on cooling-water availability without causing recirculation.

Subsurface Exploration. Test borings showed sand and clay existed to elevation minus 40. Below that was a level layer of marl, over 200 ft thick. The marl consisted of very loose, fine particles, 76% passing through a 200-mesh sieve. It has a void ratio of 54% and specific gravity of 2.68, giving it a weight of 76.5 lb per cu ft. These data indicated the particles were in loose contact with one another and had not been subjected to much load.



CIRCULATING-WATER INTAKE draws water from Ashley River bottom to assure ample cooling supply. Day tank, condensate drain tank, starting oil tank (in back)

Some settlement was expected but the question was raised of whether this marl would flow under load the same as clay that was as fine and loose as the marl. Test pilings were driven into the marl and loaded with 12 times the design load to answer this question. No settlement over a week's period was observed, and hence no trouble of this nature is anticipated.

Effect of River Current. Predicting recirculation of condenser cooling water presented a new problem. So far as we know no plants in this part of the country use tidal water in the quantities Hagood will utimately require, 25,000 gpm per unit. Plants investigated were either on streams that flow uniformly to the sea or had much cooler

PRINCIPAL POWER-PLANT EQUIPMENT

Plant Hagood, Unit No. 1, north of Charleston, S. C., South Carolina Power Co

TURBINE-GENERATOR:

Turbine-generator .... General Electric Co
850-psig, 900-F, throttle steam, 2-in. Hg abs exhaust, 4 bleed points, 22,500-kw, 0.9-pf, 13,800-v, 3-phase, 60-cycle, 3600-rpm, 100-kw direct-connected main exciter, 4-kw direct-connected pilot exciter, hydrogen cooled.
Oil filter, 540 gph .... Bowser, Inc
Condenser .... C H Wheeler Manufacturing Co
20,350 sq ft surface, two passes, divided waterbox
Circulating pumps, 2 .... C H Wheeler Manufacturing Co
Single-stage, 13,000-gpm, 430-rpm, 2300-v, 100-hp motor drive
Condensate pumps, 2 .... C H Wheeler Manufacturing Co
3-stage, 400-gpm, 1150-rpm, double-suction, 575-v, 75-hp motor
Air ejectors, 2-stage .... C H Wheeler Manufacturing Co
Priming ejectors .... C H Wheeler Manufacturing Co

STEAM-GENERATING EQUIPMENT:

Boiler .... Riley Stoker Corp
975-psig design, 875-psig operating, 230,000 lb per hr, 11,700 sq ft convection surface, 7855 sq ft waterwall surface, 13,400 cu ft oil-fired furnace
Superheater .... Riley Stoker Corp
Convection, inter-bank, 9550 sq ft surface
Air preheater .... Riley Stoker Corp
Tubular, 31,500 sq ft surface
Forced-draft fan .... American Blower Corp
77,500 cfm at 1180 rpm, 57,500 cfm at 875 rpm, 2-motor drive—200-hp 2300-v, and 75-hp 2300-v
Induced-draft fan .... American Blower Corp
140,000 cfm at 705 rpm, 99,000 cfm at 500 rpm, 2-motor drive—450-hp 2300-v, and 150-hp 2300-v
Blowoff valves .... Yarnall-Waring Co
Water columns, 2 .... Diamond Power Specialty Corp; Reliance Gauge Column Co
Safety valves .... Manning, Maxwell & Moore, Inc
Soot blowers .... Diamond Power Specialty Corp

FUEL-HANDLING AND BURNING EQUIPMENT:

Unloading pumps, 2, 250 gpm against 120 psig .... Quimby Pump Co
Booster pump, 50 gpm against 120 psi, motor drive . Quimby Pump Co
Booster pump .... Worthington Pump & Machinery Corp
50 gpm against 120 psig, duplex reciprocating steam drive
Starting pump, 15 gpm against 300 psig, motor dr ... Quimby Pump Co
Burner pumps, 2, 50 gpm against 300 psig, motor drive
Quimby Pump Co
Burners, 6, horizontal-flare type .... Riley Stoker Corp
Oil guns, 6, mechanical atomizing .... The Engineer Co
Combustion control, oil and air operated ... Republic Flow Meters Co
Storage tanks, 2, 20,000 bbl each ...... Chicago Bridge & Iron Works
Duct work .... Birmingham Fabricating Co

FEEDWATER EQUIPMENT:

Boiler feed pumps, 2 .... Ingersoll-Rand Co
8-stage, single-suction, diffuser type, 550 gpm at 2490 ft total dynamic head, 3550 rpm, 2300-v, 450-hp motor drive
Feedwater heater, 7th stage .... Foster-Wheeler Corp
880 sq ft, 2-pass, 1400-psig water, 350-psig steam
Feedwater heater, 12th stage .... Elliott Co
Vertical deaerating type, 225,000 lb per hr, 50,000-lb tank
Feedwater heater, 16th stage .... Elliott Co
Horizontal, 4-pass, 765 sq ft, 250-psig water, 50-psig steam
Evaporator .... Griscom-Russell Co
7500 lb per hr, single effect, bent tube, 350-psig steam, 100-psig vapor
Evaporator feed heater .... Elliott Co
Vertical deaerating type, 7500 lb per hr, 15 psig
Feedwater regulator, oil operated .... Republic Flow Meters Co
Heater drain pump .... Worthington Pump & Machinery Corp
2-stage, condensate-type, 40-gpm, 300-ft, 3480-rpm, 575-v, 15-hp motor drive
Evaporator feed pumps, 2 .... Ingersoll-Rand Co
2-stage, end-suction, 20-gpm, 255-ft head, 3450-rpm, 575-v, 5-hp motor drive
Heater drainers and controllers .... Fisher Governor Co

Combustion-control oil pumps, 2 ... Worthington Pump & Machy Corp
Rotary-gear, 38-gpm, 100-psi, 1150 rpm, 575-v, 5-hp motor drive

PIPING, VALVES AND INSULATION:

General piping contractor .... Grinnell Company, Inc
Insulation contractor .... Phillip Carey Manufacturing Co
Gate and globe valves ..... The Chapman Valve Manufacturing Co; Lunkenheimer Co
Small high-pressure globe valves .... Manning, Maxwell & Moore, Inc
Check valves .... The Chapman Valve Manufacturing Co
Stop-check valves .... Lunkenheimer Co
Miscellaneous valves .. Atwood & Morrill Co, Crane Co, Fisher-Governor Co, Hagan Corp, Merco-Nordstrom Valve Co, Henry Vogt Machine Co
Steam traps .... Armstrong Machine Works

INSTRUMENTS:

Draft Gages .... Republic Flow Meters Co
Flowmeters .... Republic Flow Meters Co
Indicating-pressure gages .... Manning, Maxwell & Moore Inc
Recording-pressure gages .... Republic Flow Meters Co
Indicating thermometers .... Taylor Instrument Co's
Recording thermocouples .... Leeds & Northrup Co
Conductivity recorders .... Leeds & Northrup Co
Water-level recorder .... Republic Flow Meters Co
CO_2 recorder .... Leeds & Northrup Co
Liquid-level indicators .... Foxboro Co
Instrument boards .... Clement Industrial Electric Co

ELECTRICAL EQUIPMENT:

Main transformer .... Westinghouse Electric Corp
18,000-kva, self-cooled, 24,000-30,000 kva, forced-air cooled 13,800-v delta/44,000-v wye, 3-phase
Station-service transformer .... Westinghouse Electric Corp
2000-kva, self-cooled, 2500-kva forced-air cooled, 13,800-v delta-2300-v wye, 575-v wye, 3 phase
Standby station-service transformer ...... Westinghouse Electric Corp
2000-kva, self-cooled, 2500-kva forced-air cooled, 44,000-v wye, 2300-v wye, 575-v delta, 3-phase
Oil circuit breakers, 46-kv .... Westinghouse Electric Corp
Disconnecting switches, 15-kv ... Railway & Industrial Engineering Co
Disconnecting switches, 46-kv .... Johnson Manufacturing Co
Switchyard structures .... Lehigh Structural Steel Co
Power and control cables .... Okonite Co
Station-service switchgear .... General Electric Co
2300-v metalclad, 2500-v 600-amp breakers with 50,000-kva interrupting rating
Station-service switchgear, 575-v .... ITE Circuit Breaker Co
Station-service switchgear, 208-v .... Westinghouse Electric Corp
Motors .... General Electric Co
Generator neutral reactor .... General Electric Co
Main control switchboard .... Clement Industrial Electric Co
Lighting equipment .... Westinghouse Electric Corp
Storage battery .... Electric Storage Battery Co

MISCELLANEOUS EQUIPMENT:

Water screens, 2, traveling .... Chain Belt Co
Turbine-room crane, 25-ton .... Whiting Corp
Boiler-room hoist .... Robbins & Myers, Inc
Service tanks .... R D Cole Manufacturing Co
House-service pumps, 2 .... Ingersoll-Rand Co
Cooling-water pump .... Ingersoll-Rand Co
Sump pumps, 2 .... Yeomans Brothers Co
Chemical feed pump .... Worthington Pump & Machinery Corp
Service-air compressor .... Chicago Pneumatic Tool Co
Control-air compressor .... Chicago Pneumatic Tool Co
Radial brick chimney .... Alphons Custodis Chimney Construction Co

BUILDING CONSTRUCTION:

Excavation, piling, substructure and superstructure
Standard Construction Co
Building steel work .... Steel Construction Co
Design engineers .... Commonwealth & Southern Corp

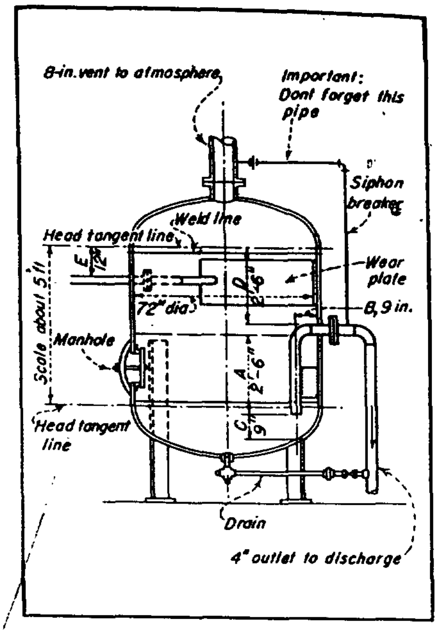
water during the critical load period.

To determine water movement between tides a number of sticks were placed in the river at the plant site at high tide. Stick movements were charted with the changing tides. Samples of water were simultaneously taken from top and bottom at various tide stages and temperature density measured. As expected, the bottom water is cooler and denser. These data—together with calculated dispersion and the fact that condenser-discharge water is hotter than river-surface water during August and hence would remain on top—led us to conclude that three units could be supplied without recirculation. Some slight difficulties might occur with the 4th unit. This was taken care of in the design by placing the intake at —30, the bottom of the river, and discharging cooling water into a creek about 1200 ft from the intake. No difficulties are expected under adverse conditions.

Detail design for No. 2 unit, duplicating original installation and preliminary design for No. 3 has begun. The Gilbert Associates, Inc of Reading, Pa. have been retained to handle this engineering. Construction on No. 2 is scheduled to begin early in 1949. The unit is expected to be in operation in the early summer of 1950.

Design Points You Need To Build a Blowoff Tank

Actual steps in laying out an adequate-sized boiler blowoff tank can get lost in a maze of codes and regulations. To help understand the problem, Stanley H Sye, mechanical engineer, Ford, Bacon & Davis, designs working tank step by step



1 Blowoff tank sketched to scale helps in determining the dimensions needed

► **Boiler blowoff tanks** are widely known power-plant equipment. Yet because of the many codes, some conflicting, that govern tank installation, construction, size, vent and discharge lines, the design elements drop out of sight.

But before we talk design let's review the function of a blowoff tank. It is primarily a safety device put in service to stop the practice of discharging a high-pressure boiler direct to atmosphere. In plants where blowoff lines from such high-pressure boilers can be sealed by river, lake, or other large body of water, the blowoff tank may not be needed.

How does the blowoff tank perform its service? It provides the necessary space for blowdown steam and water to lose pressure and temperature before discharge to atmosphere or sewer.

A recent and valuable paper* is the basis for the graph in Fig. 2. This graph, in turn, forms the basis for the following method of blowoff-tank design.

Tank Example. Let's assume a steam generator with a capacity of 460,000 lb per hr at 900 psig and 900 F at the superheater outlet. Pressure drop across the superheater at this steaming rate amounts to 75 psi. Steam pressure in the drum is 975 psig, or 990 psia.

The blowoff tank's vent pipe is arbitrarily picked to give maximum pressure drop of 10 psi between tank and atmosphere. This sets the blowoff-tank pressure during blowdown at 25 psia. From the steam tables we find.

Enthalpy liquid at 990 psia—540.85
Enthalpy sat steam at 25 psia—1160.6
Enthalpy liquid at 25 psia—208.42

*Flow of a Flashing Mixture, Benjamin & Miller, Transactions ASME, Vol 64, No. 7, pp 657-669

With this information as a starter, we can arrive at the pounds of steam flashed to atmosphere per lb of blowdown. We can figure amount of steam per blowdown by equating the enthalpy of liquid at 990 psia to the product of enthalpy of saturated steam at 25 psia, and pounds of steam flashed to atmosphere per lb of blowdown, plus the enthalpy of liquid at 25 psia, less amount of this liquid in steam flashed. Or stated in an algebraic equation: $540.85 = 1160.6\ (X) + 208.42\ (1\text{-}X)$. X figures out 0.35 lb of steam per lb blowdown.

So for every pound of water blown down from the boiler, 0.35 lb flash to atmosphere, and 0.65 must go to the holding volume of the blowoff tank. In normal operation this 0.65 lb displaces an equal amount of cool water to the sewer or other point of disposal.

Blowdown Weight. Steam drum of our 460,000-lb-per-hr generator measures 60 in. dia by 36 ft long inside heads. Our blowdown, a customary 4½ in. in the gage glass, can be translated to volume. This volume is 5 ft dia x 36 ft long x 4.5 in. ÷ 12 in. per ft, or 68 cu ft of a liquid at 990 psia with a specific volume of 0.02155 cu ft per lb. Weight of water per blowdown becomes 68 cu ft ÷ 0.02155 cu ft per lb, or 3108 lb. Of this, 0.65 × 3108 goes to the holding volume of the blowoff tanks—total of 2020 lb.

Now let's translate this 2020 lb to its volume in cu ft. Specific volume of liquid at 25 psia is 0.01692 cu ft per lb. So the volume is 2020 × 0.01692, or 34 cu ft going to the holding volume of the blowoff tank.

By *holding volume* we mean the volume contained between the bottom of the internal pipe and the bottom of the outlet connection as indicated by dimension A, Fig. 1. This volume should be at least twice the volume of the water entering it per blowdown. It is 68 cu ft minimum here—a 460,000-lb-per-hr boiler, 5-ft drum.

Tank Dimensions. We can now start on the blowoff-tank dimensions. Let's pick one 6 ft in dia. Its cross-sectional area is 28.27 sq ft. With this tank dimension, A figures out 68 ÷ 28.27, or about 2 ft, 6 in.

Our next step is to size a vent pipe. From plant layout drawings we can estimate closely the equivalent length of blowoff pipe between boiler and tank, allowing for valves, fittings and bends. For our tank example it comes out as 300 ft of 2-in. schedule-80 pipe. And the equivalent length of vent pipe is 100 ft: The diameter of 2-in. schedule-80 pipe is 1.94 in.

With this background we can compute the factor $0.144\ L\ (\text{ft}) \div d\ (\text{in.})$, the abscissa of Fig. 2, or 0.144 × 300 ÷ 1.94, and get 22.27 factor for the blowoff pipe.

Our chart, Fig. 2, published by Tube Turns, Inc, enables us to pick off the flow rate for a boiler pressure of 975 psig and a factor of 22.27. This shows on the chart as 49,000 lb per hr per sq in. of cross-sectional area. So total blowdown flow rate for a 2-in. schedule-80 pipe of 2.95 in. in cross section is 49,000 × 2.95, and equals 145,000 lb per hr.

Flow Rate. We established, above, that for every pound of water blown down from the boiler, 0.35 flashed to