

Dependency on Electricity

It takes a hurricane such as that which swept the Northeast Seaboard on November 25 to drive home to most people their widespread dependence upon electric energy for carrying on their normal everyday pursuits. Among the diverse inconveniences and hardships resulting from partial or complete suspension of electric service were stoppage or curtailment of electric railway service, both above and under ground, ferry service where docking facilities were dependent on electric power, telephones, street, shop and home lighting, heating with oil burners or stokers, electric hot-water heating, cooking by electricity, radio and television, not to mention a multitude of other electric appliances.

Had the storm occurred during the week, numerous business operations would also have suffered.

While many of the service stoppages were due to overhead distribution lines being down from fallen trees or poles, or cut off as a precautionary measure, underground distribution also suffered in some cases from inundation. The extent and periods of outage varied, of course, with the location of the affected area, ranging from a few hours to two or more days. Meanwhile, those affected were treated to a glimpse of living during the middle of the nineteenth century. For the most part the inconveniences were taken in their stride, as inevitable in an electric age where the annual per capita use of electricity reaches approximately 1650 kw/hr. However, one may wonder as to how many stopped to think of the heroic efforts of the utility service crews in striving, under adverse and often dangerous conditions, to restore normal services as quickly as possible. These are the men to whom major credit is due.

Troubles from Burning Residual Oils

One of the best attended and most timely sessions at the A.S.M.E. Annual Meeting, from the operating man's standpoint, was that dealing with the burning of residual fuel oils in steam boilers. With the marked increase in fuel oil consumption by central stations and the influx of foreign oils during the past few years, difficulties from corrosion and plugging have been encountered. These have initiated several studies and resulted in a number of published papers on the subject. In general, the vanadium content of certain oils was believed to be chiefly responsible, although its action and that of certain other constituents was not definitely established.

The survey presented at this session, and reported briefly elsewhere in these pages, was most exhaustive in that it brought together the operating experiences of practically all the oil-burning central stations, as well as the refineries, supplemented by the findings of several investigations. It would appear from this that the

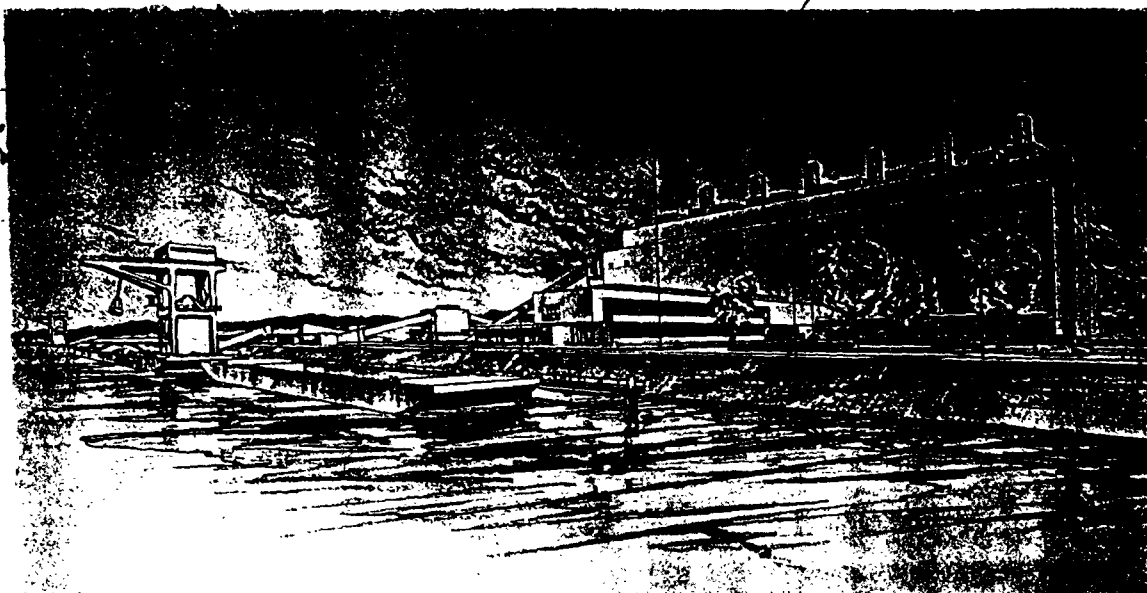
serious cases are not as widespread as might have been supposed; that other contents of the oil, notably sodium sulfate, are as responsible as vanadium pentoxide, and that trouble from plugging and hot-end corrosion is unlikely if tube temperatures are kept below 1100 F. Cold-end corrosion in the air heater may present a problem due to the sulfur, if the exit gas temperature is low. Here it is a matter of balancing a slight decrease in efficiency against the cost of washing and maintenance, as well as the residual oil price.

Engineering Manpower

One of the most important problems facing the engineering profession at the present time relates to the supply of engineering manpower. Several factors contribute to the anticipated shortage of engineers. Foremost is the international situation as reflected in military mobilization and defense production. But as far as continuing education of engineers is concerned, related factors are the pessimistic reports on the future need for engineers emanating from the Bureau of Labor Statistics and the fact that there are fewer persons now coming of college age because of the low birth rate during the depression of the 1930's. By implying that there will not be enough jobs for engineers and influencing school counselors to discourage high school students to enter engineering, one government agency is aggravating the engineering manpower problem at the same time that other government agencies—to say nothing of private industry—stand in need of more engineers.

The engineering profession through the Engineers Joint Council has been asked by the National Security Resources Board to suggest policies and methods which will insure the effective utilization of engineers for large-scale mobilization. An eighteen-man Engineering Manpower Commission composed of representatives of six engineering societies has been appointed with the responsibility of developing policies and procedures designed to secure the most effective use of engineering skills in industry and government during any future emergency and of taking necessary steps within the scope of the Engineers Joint Council to bring such policies and procedures into effect. The situation is complicated by the uncertainty of universal military training and expansion of R.O.T.C. in the colleges. Also, present policies of Selective Services have apparently led to much confusion concerning the future of engineering students.

The fundamental need is to use the limited reservoir of engineering manpower to its best advantage. It is to be hoped that the Engineering Manpower Commission will be able to set up and implement a policy which will forestall the waste of engineering skills that resulted from some of the induction procedures of World War II.



Architect's perspective of Johnsonville plant

Peterson Plants - V2a - T

Johnsonville Steam Plant of the TVA

By H. J. PETERSEN*

A discussion of the design features and some of the reasons why certain conditions and designs were selected. The plant is laid out for six 125,000-kw units with throttle conditions of 1450 psi, 1000 F. The first unit is scheduled for operation in October 1951 and the others at two-month intervals thereafter.

DURING the years following World War II the rapidly increasing demand for power in the Tennessee Valley area soon made it evident that an expansion program would have to be undertaken to prevent a critical shortage of power in the next few years. From July 1, 1948, to July 1, 1950, the average use of power jumped from 1,754,000 kw to 2,068,000 kw, an increase of 314,000 kw in two years. A study of this problem indicated that the quickest and most economical way to obtain this extra power was to firm up the Authority's secondary hydro power by erecting a steam power plant.

Accordingly, funds were requested from Congress for a steam plant of three units, each having a capability of 125,000 kw. These funds were approved in May 1949 and construction began immediately. In March 1950 one more unit of similar capacity was authorized, and during the fall of 1950 another two units were authorized, making the total installed capability 750,000 kw. The first unit is scheduled for operation in October 1951 with the remaining units following at approximately two-month intervals. When completed, the Johnsonville Steam

Plant will be the second largest steam-electric plant in the world and will make an important and substantial contribution to the national defense program.

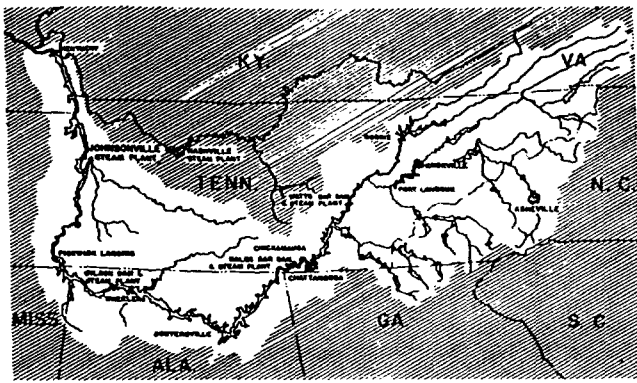
SITE SELECTION

The site selected for the plant was chosen because of the advantages it offered in the way of fuel availability and transportation, cooling water supply, relation to the system load center, topography, transmission facilities, and several other factors. When it is realized that the six units will burn more than 300 tons of coal per hour and will use more than 650,000 gallons of cooling water per minute when operating at rated load, the importance of such factors is evident. Therefore, the site chosen, as most nearly satisfying the requirements for this plant, is in Western Tennessee on U. S. Highway No. 70 where it crosses the Tennessee River. Coal can be delivered at this site by barge, rail or truck.

POWER HOUSE

An investigation was made regarding the merits of a semi-outdoor type of power house versus the conventional fully enclosed type. After considerable study it was decided that while it is recognized that the semi-outdoor type offers some saving in first cost, this could be minimized with a cheaper type of construction, and the operating conveniences of a closed power house need not be sacrificed. Accordingly, the superstructure walls are faced with aluminum siding, which has a very low erection cost, with a horizontal section of brick to relieve the monotony of the solid wall for architectural appearance.

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Relation of Johnsonville to other plants of TVA

The walls of the turbine room and the office wing and service area are a combination of aluminum siding and brick and glass block.

By close supervision of the design, waste space in the power house was eliminated in so far as possible, thus further reducing the advantage of a semi-outdoor type. The final figure of 19.6 cu ft per kilowatt for the power house proper compares favorably with other modern stations of this size. If all the shops, offices, storage rooms, etc., are included, this figure increases only to 21.2 cu ft per kilowatt.

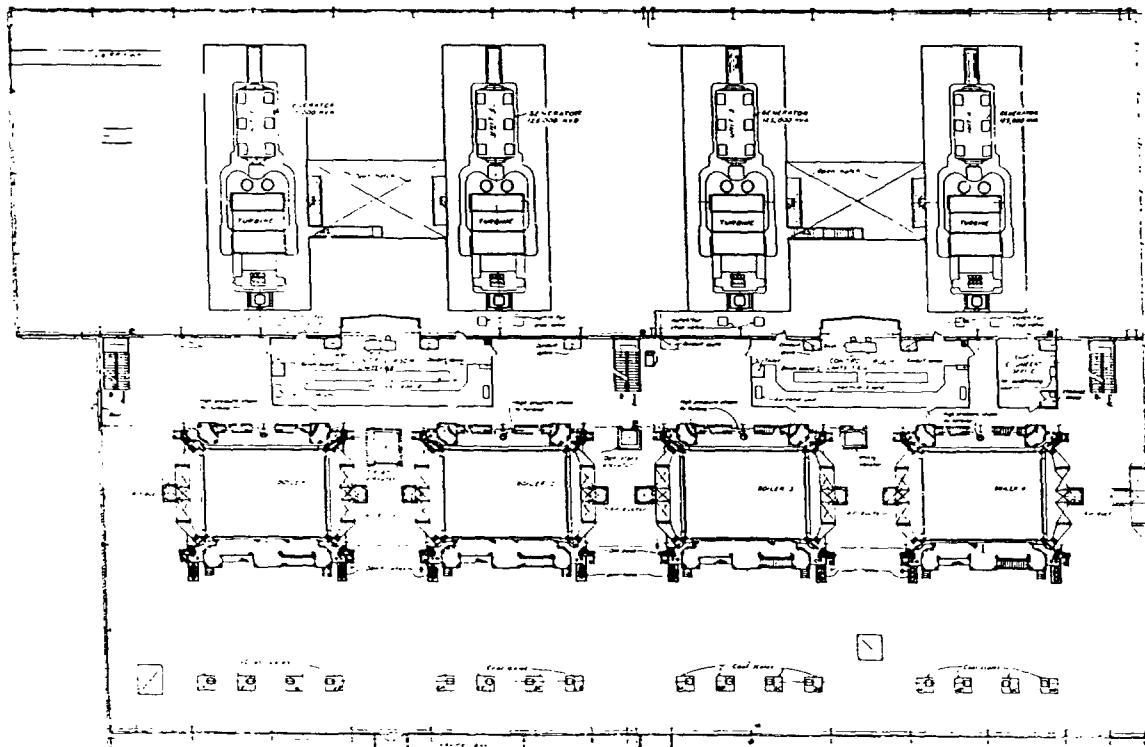
FLY-ASH DISPERSAL

The tremendous quantities of coal which will be burned at Johnsonville would result in a very large emission of fly ash from the stacks unless preventive measures were adapted. Although the location is not near any large centers of population, it was recognized that some steps

should be taken to eliminate as much of the fly ash nuisance as possible. The mechanical fly-ash collectors which are being installed to protect the induced-draft fans from excessive erosion will eliminate most of the fly ash. Also provision has been made in the power house design for the future installation of electrostatic precipitators should they prove necessary. The stacks rise 50 ft above the power house roof, which makes their height 171 ft above grade. They also are designed so that an additional 100 ft can be added at any future time, for better dispersal, if necessary. Wind direction and velocity instruments will be installed on the stacks to aid in the air pollution studies.

TURBINE-GENERATORS

The turbines have a capability rating of 125,000 kw with a terminal pressure of $2\frac{1}{2}$ in. Hg and the steam conditions at the throttle are 1450 psi and 1000 F. The first four generators will have a capability of 125,000 kva at 0.5 lb hydrogen pressure and 143,750 kva at 15 lb hydrogen pressure. The last two generators are designed for a capability rating of 156,250 kva at 30 lb hydrogen pressure. The first four units will be single-shaft tandem-compound double-flow units, operating at 1800 rpm with generator voltage of 13,800. The last two will be triple-flow units operating at 3600 rpm with generator voltage of 18,000. At the time the first four units were purchased they were among the largest units combining these limits of capacity, temperature and pressure. By the time the last two units were purchased the major turbine builders had developed designs for 3600-rpm machines of this size, which partially accounts for the change in speed. Another factor is that the 3600-rpm machines cost from \$400,000 to \$500,000 less per unit. The 1800-



Station plan for first four units

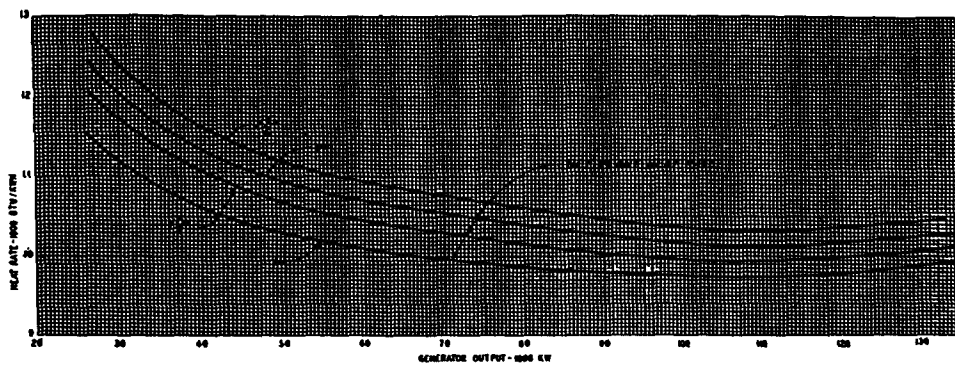
Single-casing versus tandem-compound double-flow turbines was investigated. It was found that the savings of the double-flow unit due to its higher efficiency at the scheduled loadings would more than offset the appreciably lower cost of the single-casing unit. This, plus the fact that no single-casing units of the required capacity had been built at the time these units were purchased led to the choice of the double-flow turbines.

The first four units (1800 rpm) will be equipped with moisture separators in the cross-over pipe to the low-pressure turbines. The turbine manufacturer guarantees that this device will remove 24,500 lb of moisture per hour at rated load from the steam at this point, resulting in a decrease in the turbine heat rate of 34 Btu at this load. This moisture will be drained from the separator to the lowest pressure heater, thus returning it to the heat



Use of 1050 F and some higher pressure than 1450 psi was also investigated, but not to the extent of running

The reheat cycle was investigated, especially for Units 5 and 6, but it was rejected because the low price of fuel (\$0.18/MBtu) did not offer enough financial advantage to overcome anticipated extra complexities of control.



Heat-rate curves

and maintenance. However, with fuel costs continuing to rise and with the added experience being gained in control and operation, the advantages of the reheat cycle continue to increase, and it is probable that the Authority will install reheat units in some future plants.

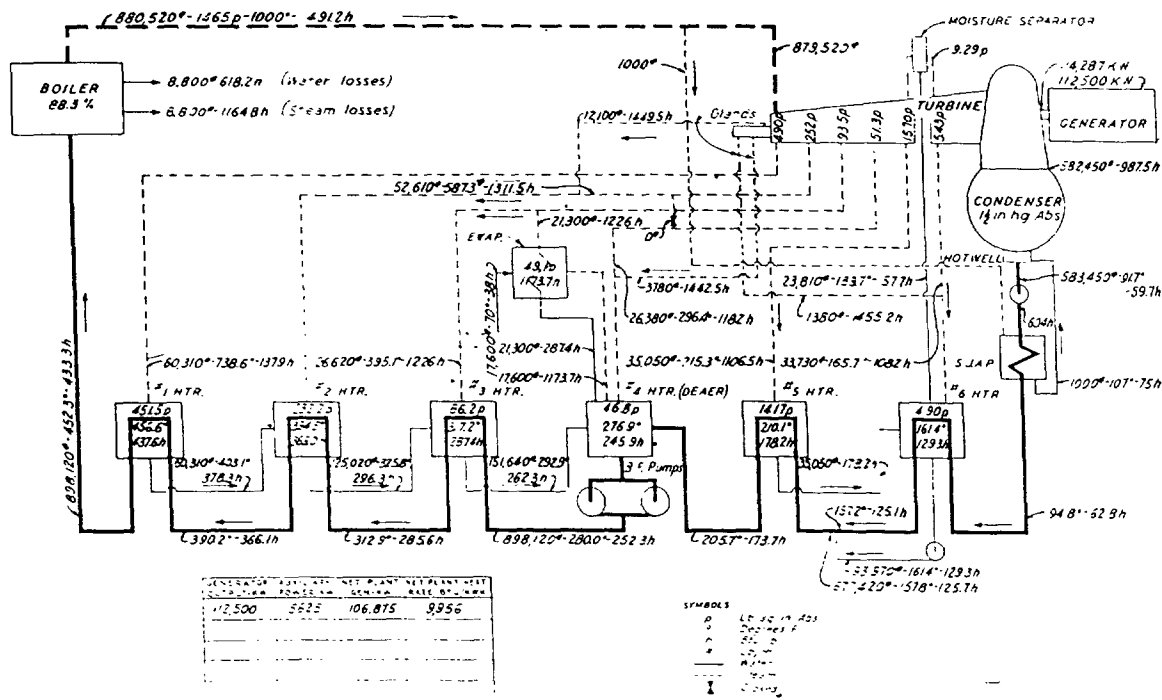
The maximum lift for the generator requires a 150-ton crane. However, two 80-ton cranes will be installed instead of one larger one, because it is felt that the slight extra cost of this arrangement is more than compensated for by the extra flexibility and availability of the two smaller cranes.

HEAT BALANCE

The diagram here reproduced shows the heat balance at rated load and $1\frac{1}{2}$ -in. Hg back pressure for the first four units. The calculated net plant heat rate of 9956 Btu per kw-hr which includes 5 per cent station power, 2 per cent makeup, and 1 per cent of the throttle flow each for steam and water losses in the boiler, will make the Johnsonville Steam Plant one of the most efficient steam plants in the world. Inasmuch as experience at other plants indicates a makeup of less than 1 per cent, the actual net plant heat rate will be somewhat lower.

The number of feedwater heaters was investigated and it was found that six heaters gave the best economy. As the diagram shows, condensate pumps will pump through two low-pressure heaters, one of which will be located in the condenser neck (two in the case of Units 5 and 6), then into the deaerating heater, from which the boiler feed pumps will force the water through three high-pressure heaters to the economizer in the boiler. The deaerating heater has an effective storage capacity of 200,000 lb of condensate, which is equivalent to approximately twelve minutes of operation.

Closed heaters were chosen over open heaters because of their simpler piping and pumping arrangement. On the first four units the three high-pressure heaters are designed with internal subcoolers to reduce the drain temperature to within 15 deg of the incoming feedwater. This was more than justified in the heat rate, and, in addition, reduces the flashing in the drain line, thereby eliminating to some extent a usually troublesome maintenance item. On the feedwater side, all closed heaters are designed for a 5 deg total temperature difference; but when Units 5 and 6 were purchased, further study indicated that a lower drain T.T.D. could be justified and



Heat-balance diagram

designed for a drain T.T.D. of 10 deg. In addition, a sub-cooling section is being added to the second low-pressure heater. This addition was primarily to reduce the high amount of drain flash, since the two low-pressure heaters are located in the condenser neck, and it is impossible to design the cascaded drain line such as to avoid entirely the erosion of fittings.

STEAM GENERATORS

The steam generators will be of the dry-bottom type each with a continuous rating of 1,000,000 lb per hr and a three-hour rating of 1,100,000 lb per hr based on using West Kentucky coal. They are completely water walled and steam conditions at the superheater outlet are 1475 psi and 1003 F. Because of the large capacity of these units, a study was made to determine whether one or two boilers should serve each turbine-generator. The unit system of one steam generator per turbine was finally adopted because of the proved reliability of steam generators of this size, and also because of the large savings in first cost, maintenance and operating costs of the unit system. To this end, the furnace, superheater, economizer and all other components of the steam generating units were specified to be designed liberally with respect to water-cooled heat-absorbing area, heat release in the furnace, tube sizing and spacing, gas velocities entering the superheater, etc., in order that the slagging be kept at a minimum and the unit availability be kept as high as possible. The heat release in the furnace was held to 15,100 Btu per cu ft per hr and the heat available in Btu per sq ft of water-cooled flat projected furnace envelope is 99,200, both at rated load. The temperature of the gas leaving the furnace at this load will be 1940 F which is below the fusion temperature of the coal. It is felt that with these safeguards the Authority will be able to burn any coal found in this area with a minimum of slagging.

Firing is by pulverized coal with provision for future burning of gas. Four pulverizers are provided per furnace with any three capable of carrying rated load with normal coal. There are four vertically adjustable, tangential coal burners, four ignitors, and one oil burning torch at each corner of the furnace. The oil-burning torches have a slightly greater capacity than the mini-

mum output from one coal pulverizer and will be used in starting up the boiler.

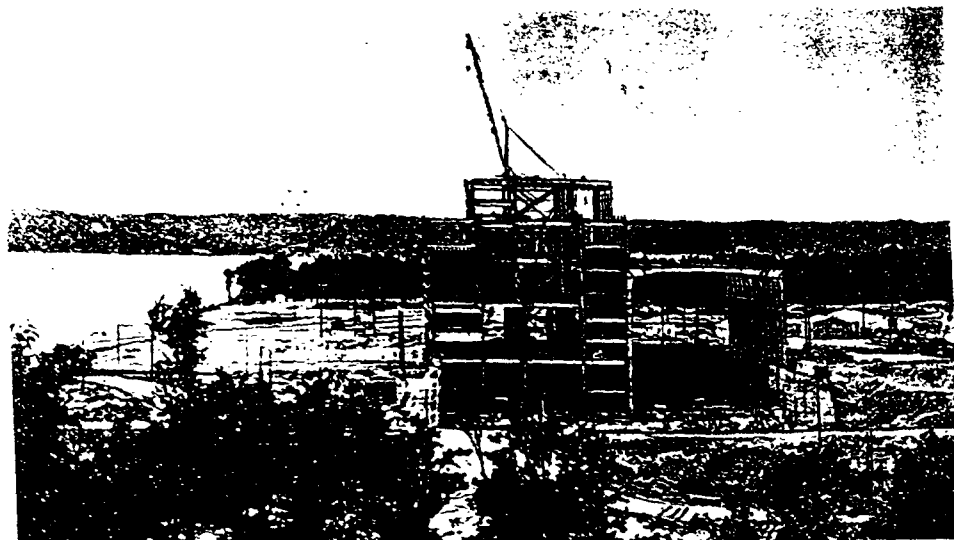
The economics of steam versus air soot blowers was investigated. The steam generators purchased have only three soot blowers on each side of the furnace at the entrance to the superheater section. This low consumption of soot-blowing medium would not justify the investment required of compressors, tanks, and piping for air soot blowing so a steam system was chosen. Provision is made in the economizer section and in the furnace for future soot blowers, if they should prove necessary. All soot blowing will be by the so-called automatic-sequential system where the pushing of one button automatically operates all soot blowers in their proper sequence.

Because of the height of the boiler drum it was found impractical to mirror drum level to the centralized control room. Accordingly, this level will be brought to the control room by a "Utiliscope," which is wired television. Furnace flame indication will be brought into the control room by mirroring glass cat's-eyes which are to be installed in the furnace doors.

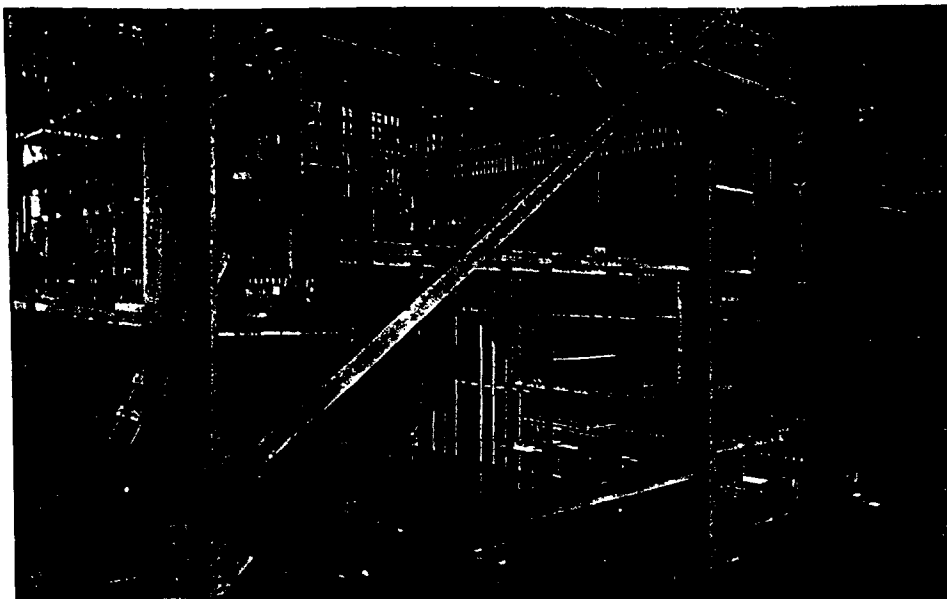
Provision has been made in the circulating parts of the steam generator for acid cleaning.

The superheated steam will be maintained at constant temperature (1003 F) down to one-half load. The control of this temperature will be by automatic tilting of the burners and by desuperheating.

Regenerative-type basketed air preheaters will be used and the exit gas temperature (uncorrected for leakage) will be 307 F. Lower exit temperatures were considered, but were discarded because of the possibility that exists of fouling the air preheater elements when the lower temperatures approach the dew point of the exit gases. However, provision has been made in the heaters so that additional elements may be inserted in the future, if they prove desirable. These additional elements will lower the exit gas temperatures approximately 20 deg, gaining approximately one-half per cent in boiler efficiency. Provision also has been made for manually bypassing the air preheater during starting up and low-load operation to prevent slagging of the heater elements at these relatively low temperatures. If operation proves it necessary, this bypass can be converted to automatic control.



Construction view as of late September



Progress on boilers by mid-October

CONDENSERS

The condensers are horizontal single-pass units, and each will condense 690,000 lb of steam per hour at 2 in. Hg with 79-F circulating water. They each have 70,000 sq ft of surface, are directly connected to the turbine exhaust, and are supported by springs which are anchored to the turbine foundation. A twin-element steam jet ejector will remove all non-condensable vapors.

The use of two-pass condensers was rejected because of excessive pumping costs and also because we shall have an unlimited supply of cooling water which is required for the single-pass design. No chlorination of condensing water will be provided for at present, but provision has been made for this feature in the future should it be required. Moreover, no reverse flow of circulating water for trash removal is provided because past experiences with plants on the Tennessee River have indicated that it was not needed. Racks and traveling screens are deemed sufficient to keep the condensers from clogging.

Each condenser will be served by two vertical mixed-flow circulating water pumps, each rated at 56,000 gpm at 21-ft head. They are located in the pumping station at the river's edge and pump through 78-in. diameter concrete pipes to the condensers. Under emergency conditions, one pump will operate the system with 85-F cooling water to produce 3 in. Hg back pressure at a throttle steam flow of 1,100,000 lb per hour. At this rating one unit will pump 74,000 gpm at 10-ft head due to the reduced friction loss in the circulating system at this lesser flow. All necessary valves and pumps will be controlled from a central control room in the pumping station.

PIPING AND VALVES

All 1000-F main steam piping is forged and bored and conforms to the requirements of A.S.T.M. Specification A182-48T, except that the chemical composition will be in accordance with A.S.T.M. Specification A213-46, Symbol T-22, containing 2 $\frac{1}{2}$ per cent chromium and 1 per cent molybdenum, except that the carbon will be limited to 0.10 per cent maximum. Steel is specified to be silicon killed to minimize graphitization.

A scale model test was performed on the main steam piping. There are no loops in this piping and our calculations indicated that the stresses were close to the allowable limit. A model test confirmed this by indicating the maximum stress to be less than 300 lb per sq in. under the allowable limit. Thus, the use of the model test permitted us to eliminate loops in this heavy expensive piping. It is estimated that the savings because of the elimination of these loops amounts to \$18,000 per unit.

There are no valves on the main steam line between the superheater outlet and the turbine stop valve. Venturi valves will be used in the boiler feed discharge lines. A cost analysis indicated that the extra pressure loss for this type valve was far outweighed by the saving in first cost. All 1500-lb valves have pressure-sealed bonnets.

CONTROL ROOM

Throughout the whole design of this plant an effort was made to reduce the number of operators required. This is especially evident in the design of the control room where all the principal mechanical and electrical control functions (except switching) are centralized in one room. For example, each unit will be provided with an 80-point temperature indicator-recorder scanning device to record the temperatures of all main turbine-generator, draft fan, boiler feed pump and pulverizer bearings.

Each control room will serve two generating units. This arrangement called for some ingenuity of design because of the multiplicity of control piping and conduit concentrated at one point; however, it is felt that the result is worth the effort. Some investigation of a single control room for each boiler-generator combination was made, particularly with a view toward reducing the length of the control boards. It is probable that as the development of miniature instruments becomes more advanced that they may be used in future plants, thus reducing the size and length of the control boards.

AUXILIARIES

No steam-driven auxiliaries will be used except the steam jet air pumps for the condensers. The numerous

incoming sources of power supply dictated the use of motor drives for all auxiliary equipment.

Calculations indicated that fluid drives were economical for the boiler feed pumps, but not for the mechanical draft fans. One of the major factors influencing fluid drives for the pumps was that we omitted the boiler feed-water regulating valve in the pump discharge line, thus eliminating pumping against the high-pressure drop across the regulating valve. The speed of the pump which regulates the feedwater flow is controlled by the fluid drive.

Three boiler feed pumps are provided for each boiler with any two capable of handling the rated load. These pumps are barrel-casing type and are rated 1209 gpm at 4770-ft head with 290-F water. They each have a shut-off head of 5505 ft, and the impellers are designed with a rising pressure characteristic which will prevent hunting with its consequent surging at the part-load operation. They operate under a net positive suction head of 66 feet.

The test block requirements of the forced-draft fans are 160,000 cu ft of air per minute against 12.5 in. water pressure and of the induced-draft fans are 250,000 cfm of gas against 14.75 in. water pressure. There are two of each per boiler, and the ratings established are such that a continuous output of approximately 600,000 lb per hr may be obtained from the boiler with only one forced-draft and one induced-draft fan operating. Speeds were limited to 900 rpm for the forced-draft fans and 600 rpm for the induced-draft fans. All fans are direct-connected and volume regulation is by means of inlet vanes and inlet dampers.

The general scheme of ventilation is for the incoming air to be blown in at the lower levels in both the boiler room and the turbine room. Additional outside air will be blown in at the heater area level to make these hot spots more comfortable. The floor areas and gratings are designed to make the inlet air for the forced-draft fans pass from the lower power house levels to the fan floor up along the walls of the boiler. In this way the air will pick up a good deal of heat from the radiation from the boiler thereby increasing its temperature before it reaches the forced-draft fan inlet. Since each 38 deg rise in this air increases the efficiency of the boiler approximately one per cent, the advantage of this arrangement becomes obvious. The whole power house is under a slight positive pressure from the supply fans, which helps prevent infiltration of dust and dirt.

All the main auxiliaries which will have a direct influence on the plant output, such as draft fans, feedwater pumps, condensate pumps, condenser circulating water pumps and pulverizers, were investigated as to their capacities during times of reduced frequency and/or voltage. It was found that each generating unit will be able to maintain an output of 125,000 kw with frequency reduced to 55.2 cycles at 100 per cent voltage, or with a frequency of 56.3 cycles at 83 per cent voltage.

The capacity of the coal bunkers was fixed at 2200 tons per unit. This capacity was decided upon because it is enough coal to run the units at rated capacity over a week end, thus eliminating any coal handling activities over that period. The coal yard has sufficient area to store 1,000,000 tons of coal. Because of the large size of the storage area, mobile coal-handling equipment will be used.

The furnace ash, fly ash and pyrites will be removed by a jet system, rather than by pumping. This method of handling the ash was selected because the Authority believes it involves less maintenance and operation. The fly-ash system will be controlled by an automatic sequential arrangement whereby each hopper is automatically unloaded in its proper sequence.

Plant service air will be obtained from three 660-cfm, two-stage, air compressors operating at 100 psi. Air for the various control instruments will be obtained from a separate system of two single-stage compressors, each rated 440 cfm at 100 psi. These latter machines will have non-lubricated carbon rings in the cylinders to prevent oil leakage past the pistons where it might reach the instruments.

A completely automatic sodium-zeolite system is being provided for treating the makeup water delivered to the evaporator, and a secondary chemical system will be provided for feeding sulfite, phosphate and caustic soda to the feedwater as required.

All engineering and construction work on this plant is under the direction of C. E. Blee, chief engineer; R. A. Monroe, chief design engineer; G. K. Leonard, chief construction engineer; and J. S. Bowman, chief water control planning engineer. All mechanical design is under the supervision of the writer.

JOHNSONVILLE STEAM PLANT—PRINCIPAL EQUIPMENT FOR SIX GENERATING UNITS

ITEMS	CONTRACTORS
Turbine-generators (Units 1, 2, 3 and 4)	General Electric Co.
Turbine-generators (Units 5 and 6)	Westinghouse Electric Corp.
Steam generators	Combustion Engineering-Superheater, Inc.
Soot blowers	Diamond Power Specialty Corp.
Condensers	Ingersoll-Rand Co.
Feedwater heaters	The Lummus Co.
Deaerating heaters	Elliott Co.
Evaporators	Foster Wheeler Corp.
Boiler feedwater pumps	Worthington Pump and Machinery Corp.
Condenser circulating water pumps	Ingersoll-Rand Co.
Combustion controls and control boards	Bailey Meter Co.
Piping contract	National Valve and Mfg. Co.
Ash-handling system	United Conveyor Corp.
Draft Fans	American Blower Corp.
Fly-ash collectors	Western Precipitation Corp.
Boiler room coal scales	Richardson Scale Co.
Coal valves	Columbus Conveyor Co.
Zeolite softeners	Hungerford and Terry, Inc.
Secondary chemical feed equipment	Proportioners, Inc.
Station service air compressors	Pennsylvania Pump and Compressor Co.
Control air compressors	Bury Compressor Co.
Valves—high pressure	Chapman Valve Mfg. Co.
Safety valves	Foster Engineering Co.
Butterfly valves	Henry Pratt Co.
Condenser water conduits (78-in. diameter)	Lock-Joint Pipe Co.
Turbine room cranes	Judson Pacific Murphys Corp.
Traveling water screens	Chain Belt Co.
Coal-handling equipment	Link-Belt Co.
Powerhouse structural steel	Ingalls Iron Works
Stacks	Birmingham Tank Co.
Aluminum siding and steel roof decking	H. H. Robertson Co.
Main Transformers	Westinghouse Electric Corp. and General Electric Co.
Main switchboard	Allis-Chalmers Mfg. Co.
Auxiliary switchboard	Westinghouse Electric Corp.
Auxiliary switchboard	I T E Circuit Breaker Co.
Station service transformers	Westinghouse Electric Corp. and General Electric Co.
Oil circuit-breakers	Westinghouse Electric Corp.