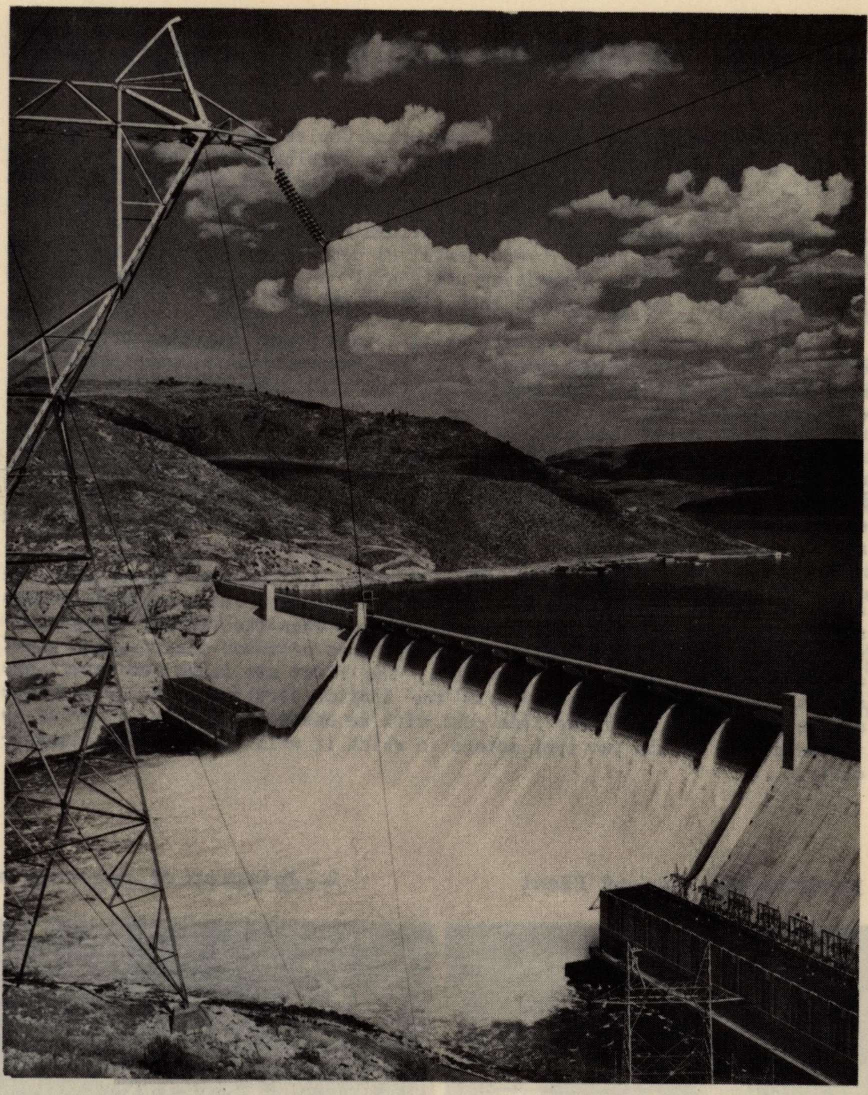


POWER

COLUMBIA BASIN PROJECT

UNITED STATES DEPARTMENT OF THE INTERIOR
J. A. KRUG, SECRETARY
BUREAU OF RECLAMATION MICHAEL W. STRAUS, COMMISSIONER

POWER PLANT AT GRAND COULEE DAM

The completed power plant at the Grand Coulee Dam will be the largest in the world, containing ultimately eighteen turbines of 150,000 hp, rated capacity, driving an equal number of 108,000-kw generators, and three 14,000-hp turbines driving 10,000-kw generators, a total rated capacity of 2,742,000 horsepower in turbines and 1,974,000 kilowatts in generators. In service, the generating units have proved themselves capable of carrying 125,000 to 130,000-kw. Nine large generating units will be installed in each of the two powerhouses, one located on each side of the spillway.

The 10,000-kw station-service units supply power for the operation of exciters, heaters, blowers, pumps, cranes, elevators, lights, and other equipment in the power plant and dam, and all electricity required in the Bureau's village, Coulee Dam.

The large units are to supply power for pumping water for irrigation, and will continue to furnish power for transmission to consumers on the Bonneville-Grand Coulee distributing system. The largest individual consumers are producers of aluminum, and other metals and alloys used in defense and peace-time industries.

The first six large generators installed in the west powerhouse are arranged for connection to long-distance transmission lines or to 65,000-hp synchronous motors which will drive huge pumps when the irrigation phase of the project is developed. Since ordinary types of motor-starting equipment are not adapted to such large motors, the first six large generators are separately excited with energy from the station-service units, so that one of the generators, starting from rest with an energized field, can bring up to speed with it the two pump motors to which it will be connected electrically.

BUILDING WORLD'S LARGEST PLANT

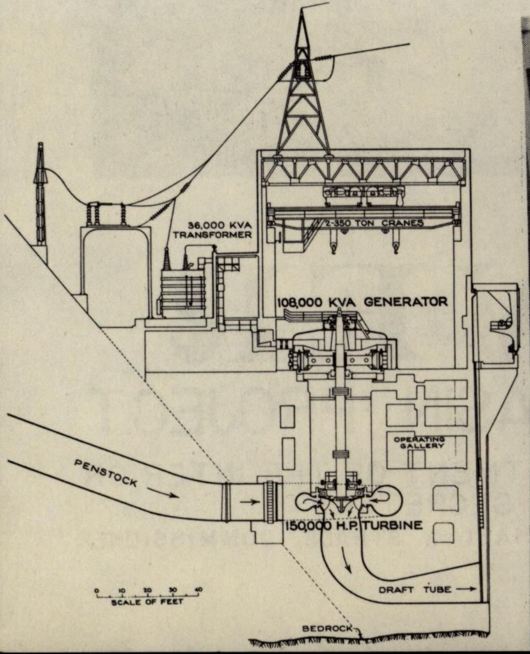
Each large generating unit at the Grand Coulee Dam includes a vertical-shaft turbine rated 150,000 hp, but actually capable of delivering 175,000 hp. Water from the reservoir is admitted to a turbine through an 18-foot steel penstock embedded in the dam, entering first the turbine scroll case (3), which is a spiral water passage around the cylindrical wheel chamber. The scroll case, 51 feet wide, and weighing 291 tons, was embedded in reinforced concrete while filled with water under a pressure of 145 pounds per square inch, so that it would have the same size, shape, and position as under normal operating conditions.

Power is derived from the turbine by the reaction of swiftly flowing water on the curved vanes of the 16-foot turbine wheel or runner (4), a single steel casting weighing about 60 tons, surrounded by the spiral scroll case. When the turbine carries its rated load, water passes through it at the rate of 141 tons a second, moving at velocities of about 12 miles per hour in the penstock, nearly 20 in the scroll case, and in excess of 50 as it leaves the scroll case through a 34-inch annular opening and enters the runner. Passing downward through the runner, the water enters the draft tube, and is discharged downstream at a velocity of less than five miles per hour.

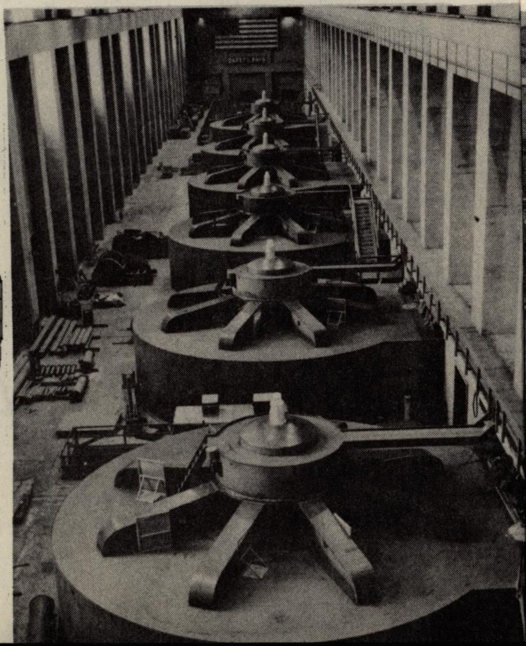
The turbines are set low, near the river's low-water level, so the turbine and draft tube are always under pressure. Generators are set on concrete piers over the turbines, above normal high-water levels.

Connecting a turbine and generator is a shaft 44 inches in diameter, more than 70 feet long, and weighing about 200 tons. (5) Its three sections are connected by means of 75-inch flanges, held together by 5.75-inch bolts, made oversize, and shrunk by chilling in dry ice before they can be put in place.

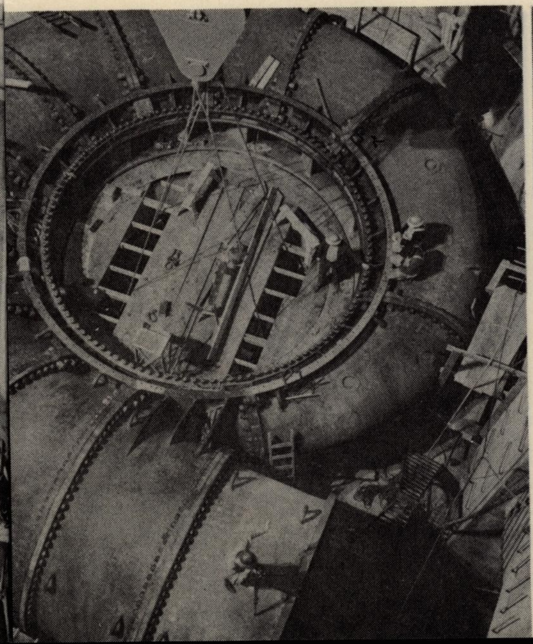
1 Cross Section of Plant



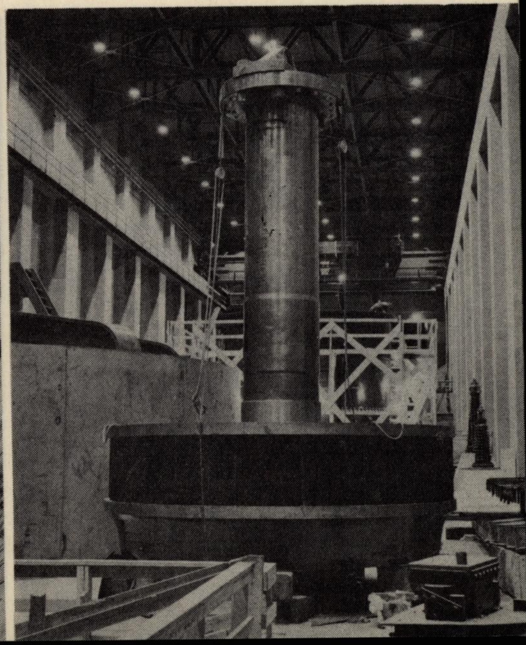
2 Interior of Powerhouse



3 Turbine Scroll Case



4 Turbine Water Wheel



Governors Maintain Precise Speed

The speed of modern generating units is regulated so closely that electric clocks, running in synchronism with them, are reliable timekeepers. As the load on a generator is increased, it tends to slow down; and it does, in fact, slow down briefly and very slightly before gates can be opened and more water can be passed through the turbine to carry the added load and to maintain the normal speed.

The flow of water through a turbine is controlled by adjusting the positions of a series of rectangular wicket gates inside the turbine casing, overlapping each other like the slats of a venetian blind, and set around the water wheel, in the gap through which water flows out of the scroll case to the runner.

A governing mechanism (6), driven in exact synchronism with the generator, includes a pair of revolving "flyballs", which droop if the generator slows down or swing outward if its speed is increased by a reduction in generator load. In so doing, they move a sensitive pilot valve, and cause oil under a pressure of 250 pounds per square inch to move the pistons in two large cylinders. Through them, the governor adjusts the openings between the wicket gates and admits more or less water to the turbine runner, as may be required to maintain the rated speed of 120 rpm.

The action of the governor can be made responsive to a change of one one-hundredth of one percent in the generator speed.

Generators are Built at the Dam

One of the two large essential parts of a generator is the stator (7), a cylindrical structure 37 feet in diameter and nearly 10 feet high. Each stator was shipped from the factory in four 68-ton sections. Here the sections were assembled, and coils were placed in slots in the magnet core. The coils are made of heavy copper bars, insulated with mica, asbestos, and glass tape.

Heaviest of the generator parts is the rotor (8), a 587-ton mass of steel and copper, which revolves inside the stator. In assembling it, the 31-foot section of shaft was set on end on an accurately leveled, finished casting, and the 60-ton cast steel spider, its hub expanded by heating, was lowered in place upon it.

Around the ends of the spider arms, a rim 20½ inches thick radially, and 79 inches high, was then built up of steel plates, 1/8 of an inch thick. Lugs on the plates engage rectangular slots in the ends of the spider arms, to transfer the turbine's driving force from the spider to the rim. Keys driven in the bottoms of these slots, after the massive rim had been expanded by electric heating, made the rim tight upon the spider, after cooling.

Sixty powerful electromagnets, each weighing two and a quarter tons, were then attached by dovetail joints to the outside surface of the rim. By shifting across the coils in the stator the powerful magnetic fields which this revolving group of magnets projects into the stator core, the power output of the turbine is expended in generating electricity in the stator windings.

Before a stator was moved from the assembly floor to its permanent location (9), an upper generator bracket, consisting of eight radiating cantilever beams attached to central steel rings, and weighing 160 tons, was set down upon it, and bolted in place to stiffen it. Then the two 350-ton bridge cranes let down their four large hooks, lifted the 430-ton combination from the assembly floor, and set it down on the base prepared for it.

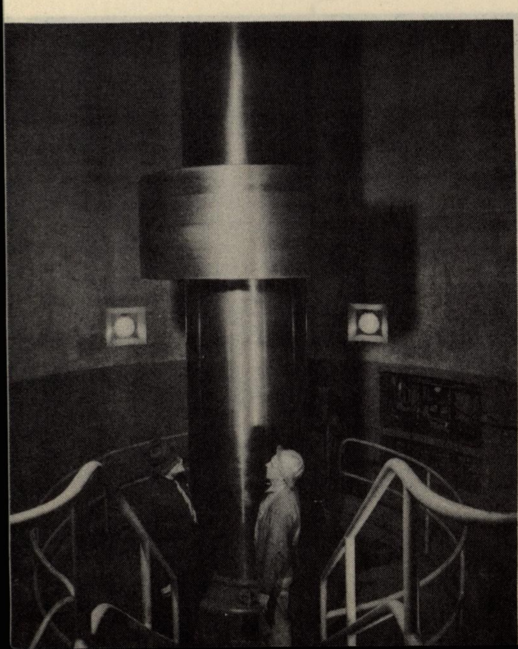
After a stator was shifted slightly, if necessary, to make it exactly concentric with the turbine shaft, and was secured in that position by dowels and bolts, a rotor (10) was moved into place by the two bridge cranes, using a 65-ton equalizer between the cranes and rotor, to distribute the 650-ton load evenly among the four crane hooks.

Thrust Bearing Carries Huge Load

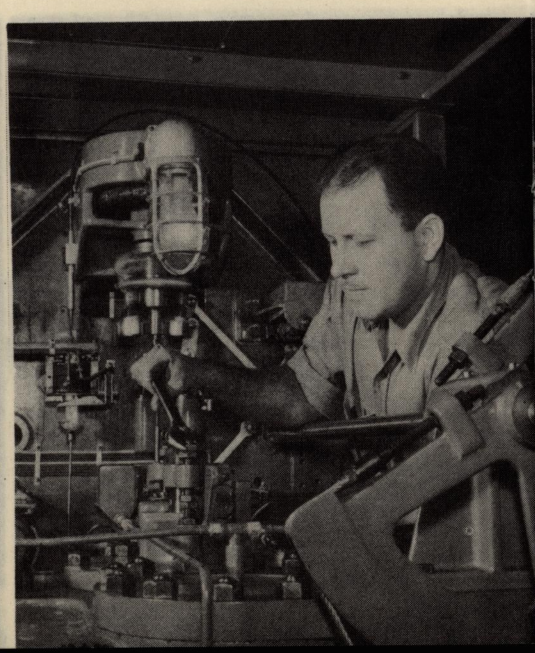
A heavy guide bearing, supported on the turbine casing, just above the runner, and two lighter guide bearings, one above and one below the rotor, restrain the shaft from lateral movement. They carry no vertical load.

All the rotating parts - rotor, shaft, and turbine runner - are suspended from a thrust bearing (11) on the top of the generator.

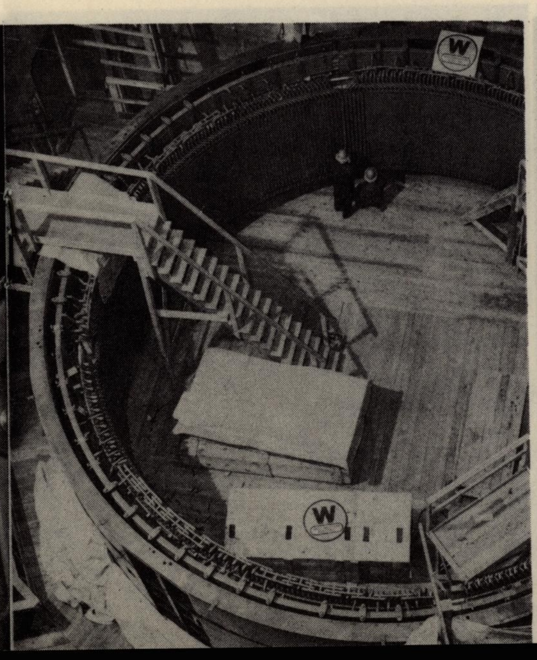
5 Shaft of Generating Unit



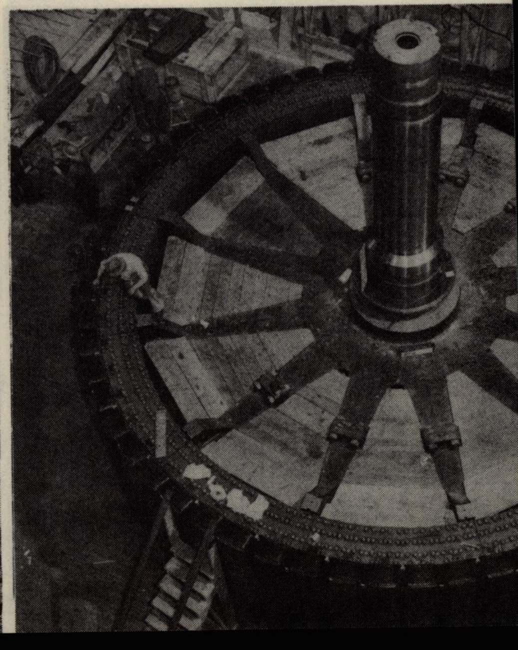
6 Speed Governing Device



7 Generator Stator



8 Generator Rotor



The thrust bearing consists of an 8-foot cast iron ring (the thrust runner) mounted on a cast steel thrust collar attached to the upper end of the rotor shaft, and eight stationary babbitt-faced steel thrust blocks, supported on pivots on the generator's upper bracket. The highly finished down-turned face of the cast iron thrust runner is carried on a thin film of oil between it and the upturned babbitted faces of the thrust blocks. The entire bearing is immersed in a bath of water-cooled oil.

Voltage Stepped Up for Transmission

Electrical energy, generated at 13,800 volts, is stepped up to 230,000 volts for long-distance transmission, in groups of three 36,000-kw transformers (12). Each transformer is 12 feet wide, 20 feet long, and 29 feet high over insulators, and each weighs 125 tons when charged with 14,500 gallons of insulating oil. They were too large and too heavy to be shipped in finished form.

At the dam, the two sections of the transformer case were assembled and welded together; braces used in shipping were removed; and after assembly was complete, a 28-inch vacuum was drawn on the case to remove air and moisture, 54 tons of filtered oil were put in, and nitrogen was added to fill the space above the oil.

High-tension lines from the transformers are carried on steel towers over the powerhouse and up the canyon walls to a switching yard, where facilities are provided for interconnecting generating units and transmission lines (14).

INSTRUMENTS CONTROL PRODUCTION

Power producers, unlike manufacturers of merchandise, cannot carry spare goods in stock to cover temporary underproduction or to meet a sudden demand; they must produce power to order, instantly, on the closing of a switch, and production must be reduced instantly when the demand is reduced. Electrical pressure (voltage) and the frequency in alternating-current circuits must be held very close to standard values. Intricate, sensitive, automatic regulating devices are required.

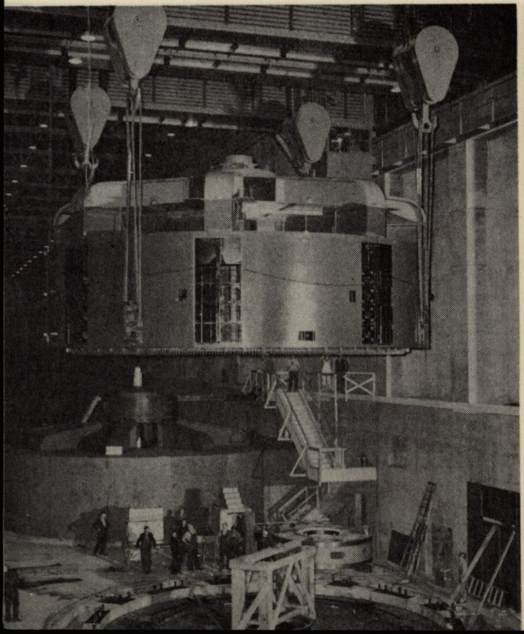
When many generators are supplying power to a network, it is the practice to set the governors of all but one or two of them so that each will supply power to the network at a uniform rate. Since the demand for power varies constantly, the governors on one or more of the generating units feeding the network are made highly sensitive to speed changes, and consequently to changes in load. Automatically, the governors regulate the flow of water to the corresponding turbines, increasing the water supply to the turbine runners as the load increases, and reducing it as the load diminishes, and so maintaining normal frequency and generator speed.

The generating unit that handles the fluctuations in the load performs another important function; it regulates the speed of all of the other generators in the network, and, incidentally, the speed of all of the electric clocks in the area served by it. Electric clocks are really not clocks at all; they have in them no time-measuring devices like the hair springs and balance wheels of watches or the pendulums of clocks; and they cannot keep time on their own resources. They are only electric motors running in step with the generators that drive them, and turning clock hands at a rate determined by the generator speed.

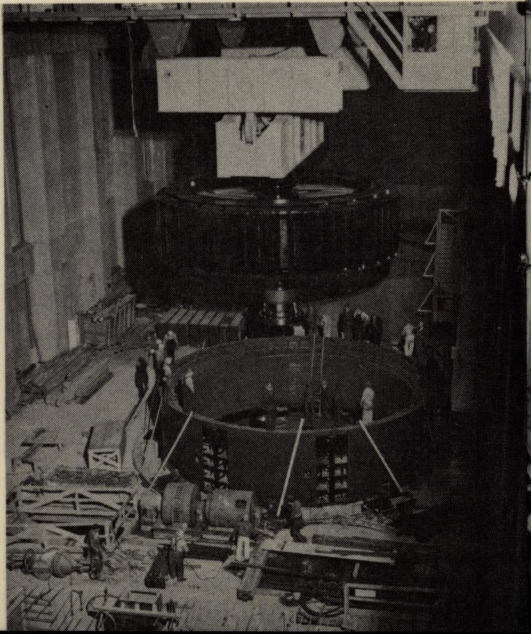
In order that the generators, and consequently the electric clocks in the area served, will turn at the right rate, the Grand Coulee power plant is provided with a master clock, which four times each day is compared with naval observatory time by means of short-wave radio time signal, and is corrected if necessary. The error is seldom more than a few tenths of a second, but correction for even such small errors can be made by turning dials on the control board.

The master clock is of unusual design. It contains the essentials of a clock - a source of power to make it go, a time-measuring device, and a mechanism to turn hands to indicate the passage of time - and to tell time if the clock is set correctly. But it differs in detail from ordinary clocks and watches - a storage battery takes the place of springs and weights as

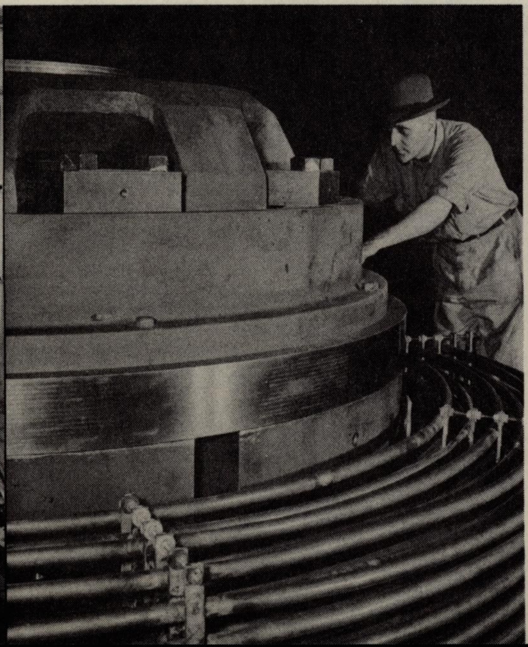
9 Placing the Stator



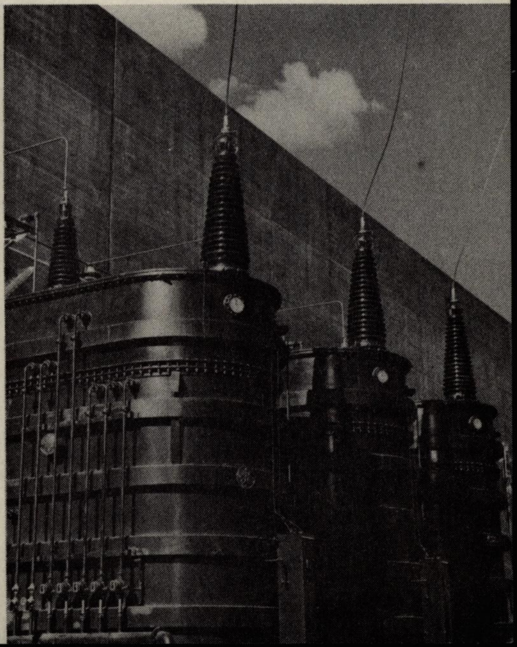
10 Placing the Rotor



11 The Thrust Bearing



12 Step-up Transformers



prime mover, a tuning fork vibrating sixty times a second measures time, and a small synchronous motor turns the clock hands at a rate fixed by the tuning fork vibrations. A feeble pulsating electric current generated by the vibrating fork is "amplified" by vacuum tubes like those in a radio set, that is, the vacuum tubes have the effect of releasing energy from the storage battery in pulsations timed by the tuning fork. Thus, the tuning fork times the clock motor.

As a means of keeping the generators running with actual clock-like regularity, electric impulses from the master clock are delivered to a "time-error indicator" on the control board, which also receives electric impulses from the "regulating" generator. If the generators run ahead of or lag behind the rate set by the clock, the electric impulses received from the generator and the clock cause the hand of the time-error indicator to show, in tenths of a second, how much the generators (and the power consumers' electric clocks) are fast or slow with respect to the master clock.

Whenever the time-error indicator shows the generators to be ahead of or behind the master clock, a second intricate instrument, the "load and frequency controller", actuated by the time-error indicator, adjusts the turbine governor, and admits more or less water to the turbine wheel, to change slightly the turbine speed and to bring the generators in the power plants and electric clocks on the power network back into correct time-relation with the master clock.

Enabling power purchasers to tell time by electric clocks (if the owners set them correctly) is really a minor function of the intricate and highly sensitive instruments in modern power plants. Their really important functions are the regulating and the protecting of numerous, and perhaps widely scattered, electrical generating units, with promptness and accuracy of which men are not capable, to the end that a continuous and dependable power supply may be available for industrial and domestic uses in times of peace, and for defense in times of war.

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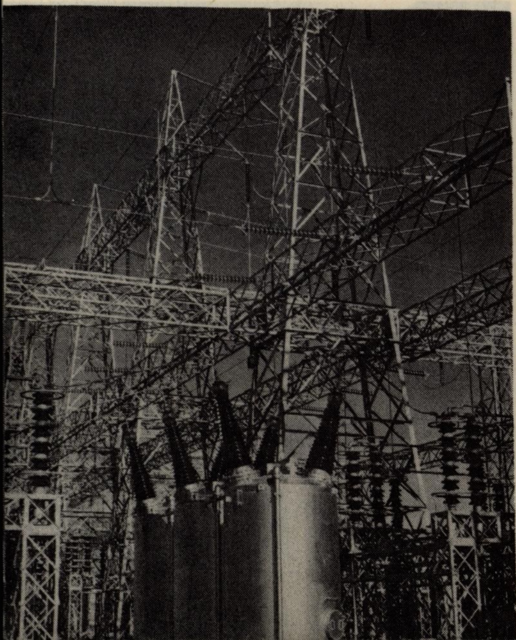
For additional information write F. A. Banks, District Manager, Bureau of Reclamation, Coulee Dam, Washington

13 230,000-volt Switchyard



14 Transmission Line Tower