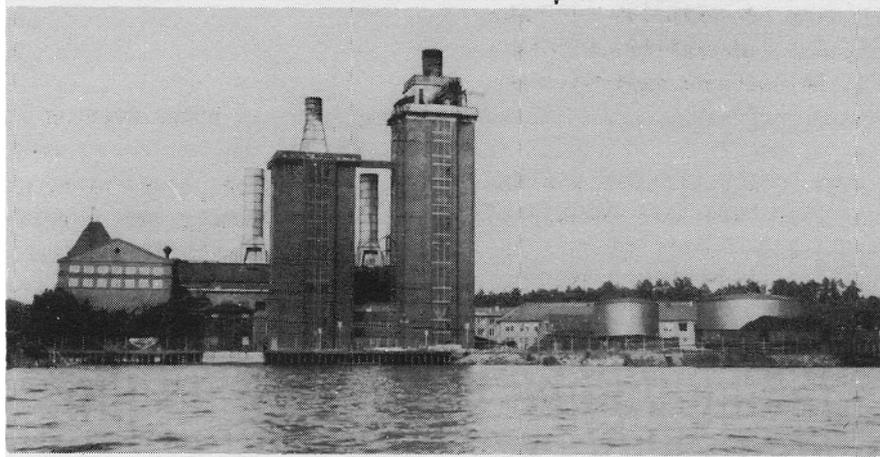


VÄSTERÅS

STEAM POWER PLANT, SWEDEN

063.022

Printed in Sweden Stockholm 1950
Kungl. Vattenfallsstyrelsen



THE SWEDISH POWER SYSTEM

The Vasteras Steam Power Station is a link in the chain of interconnected power stations in Sweden. As Sweden is a country rich in waterfalls, the bulk of the electricity needed is produced by water power. With the exception of some industrial plants, where large quantities of low-pressure steam are employed for heating purposes, and, therefore, electricity economically can be generated in back-pressure turbine plants, the steam power plants serve as peak-load and low water stand-bys.

Prior to the last war about 10 % of the total power was produced by steam. But during the war the shortage of fuel forced the country to reduce the output of steam power to 2.5 % of the total. This was made possible with the aid of extensive regulation of lakes and rivers.

The total power resources in the Swedish waterfalls are estimated at 50,000 million kilowatt hours per annum. About 85 % of these resources are located in the northern part of Sweden, where the power requirements are low. At present something like one-third of the available power has been harnessed.

The total generator power at present available amounts to 2,535,000 kW. Additional power plants now in course of construction will provide a further 465,000 kW. Projects are also

in hand for future plants which will augment this figure with 420,000 kW. Among the stations in course of construction maybe mentioned the one located at the Harspranget, which is north of the Arctic Circle. This will comprise three generator units, each with an output of 95,000 kW, totalling 285,000 kW for the station.

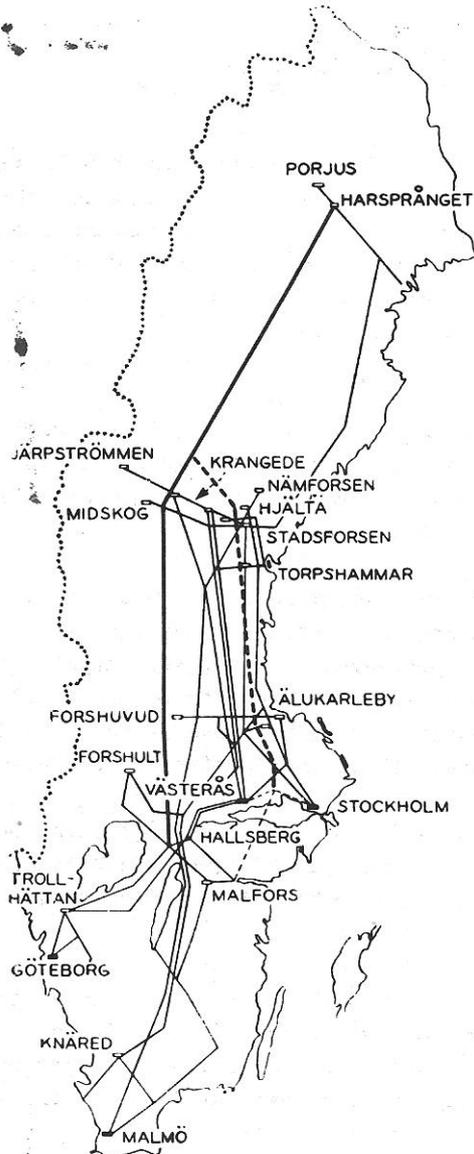
The power system is arranged as a grid which will interconnect all the power plants of any importance. The tension of the grid is 130 and 200 kV.

The power system is owned and run partly by the State, and partly by local governments or private concerns. The power output from the State-owned plants amounts to about 40 % of the whole. The other enterprises largely cooperate. Thus, the "Central Power Board" has been constituted during the war voluntarily by the larger power companies for the purpose of mutual exchange of power etc. This activity and cooperation has also continued since the war.

As the bulk of the power is consumed in the central and southern parts of Sweden, it is natural that the waterfalls in that part of the country have been utilized to their full extent. As the demand increased, it became necessary to utilize the resources in the far

north and transmit the power to the south. But there is also a tendency to establish large power-consuming plants, e.g. furnace plants and paper mills, in the northern part of Sweden.

It is anticipated that by the time the available waterpower resources have been fully exploited, something like 3 million kW must be transmitted from northern Sweden over an average distance of approximately 500 miles to southern Sweden. Since a 200 kV tension is uneconomical for this purpose, it has been decided to erect a north-south running 380 kV system, the first line of which will connect Harsprånget and Hallsberg and is scheduled to be taken into service in 1951.



VÄSTERÅS STEAM POWER STATION

The State-owned power plant at Västerås constitutes a standby and a peakload station. It is mainly intended to:

- Supplement the water power at periods of low-water, thus augmenting the supply of primary energy
- Ensure a certain supply of energy in the event of breakdowns on the lines or at the water power stations
- Assist in regulating the tension on the main system
- Supply peakload power even at high water

The power-plant as erected at first was ready for use in the year 1917. Since then it has been repeatedly extended and enlarged, and is at present equipped with machinery for 110 MW. When the work now in hand has been completed the output will have been raised to 230 MW.

Both investigation and actual experience go to show that while occasionally a vast output is required from the steam-power station, the length of time during which that output is needed is nevertheless comparatively short. It is unusual that the maximum capacity will be used for more than altogether 500 hours per annum. It should be noted specially, that the period during which full output is needed, is only from 50 to 100 hours per annum.

Great care has been exercised in the building of the boilers to enable quick starting and great flexibility under variable load conditions. Thus, it has been possible to get a 100,000 lbs/h boiler up to full pressure from cold in 6 minutes.

The largest boiler of 670,000 lbs/h can be brought to full pressure in 20 minutes.

The power station is located on the shore of Lake Mälaren. There is a harbour and also storage facilities for 150,000 metric tons of coal (330 million lbs). At present there are available also fuel tanks with a total capacity of 45,000 tons (100 million lbs).

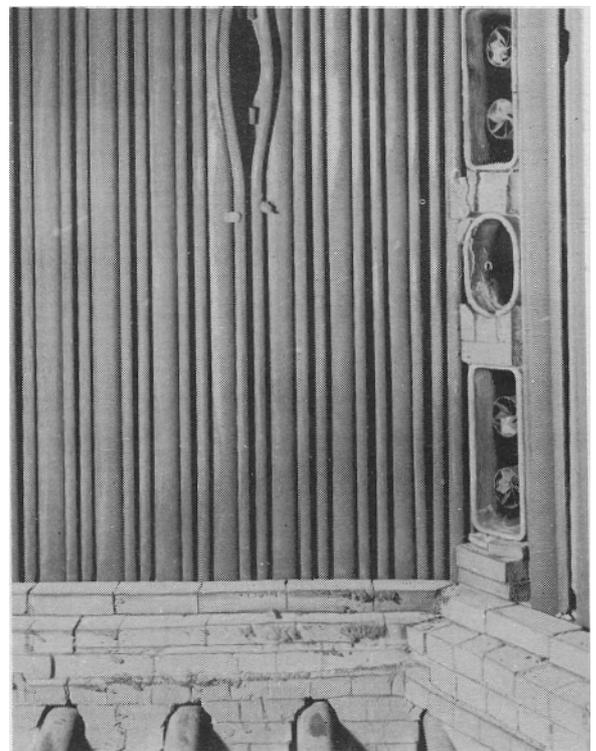
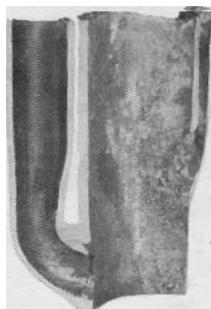
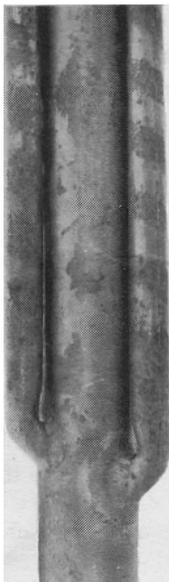
Boiler Plant

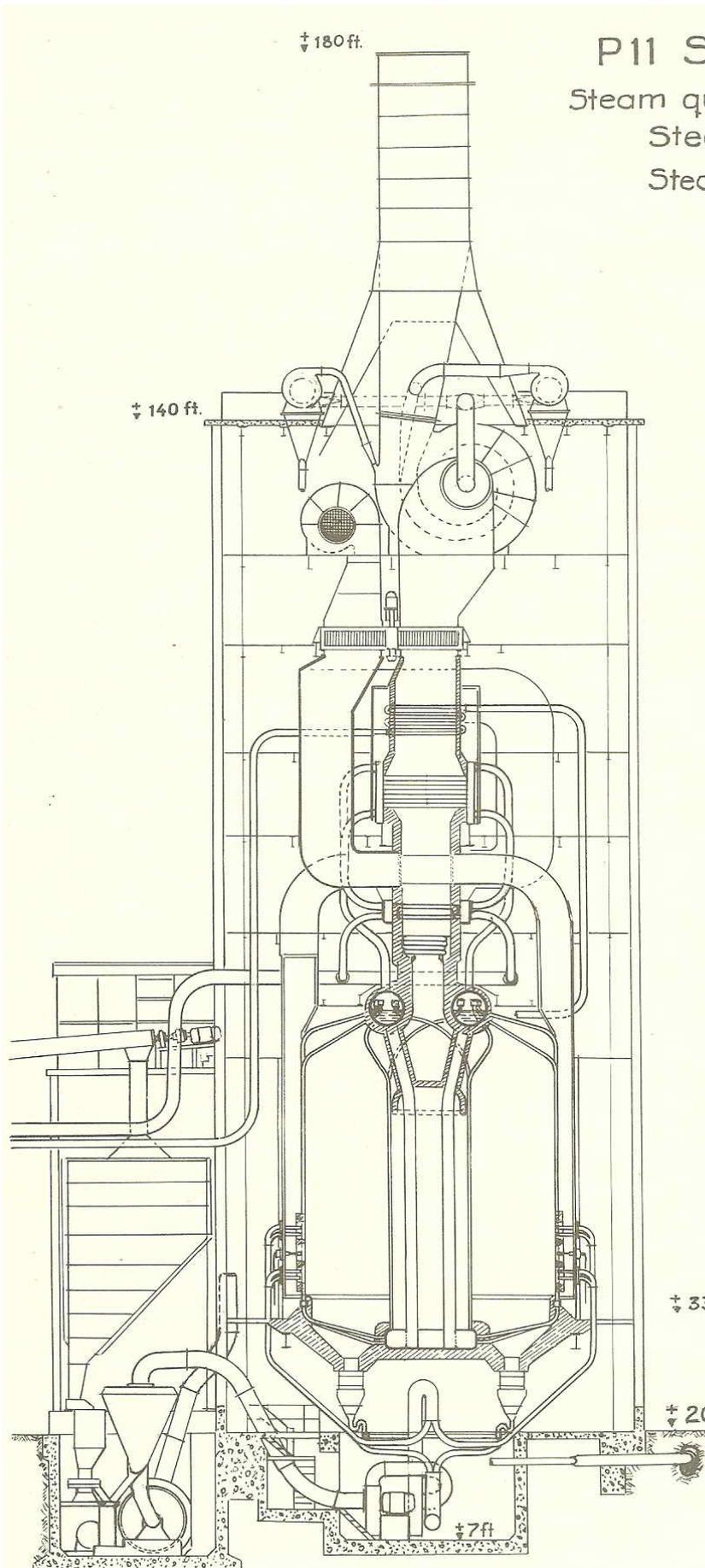
An older part of the steam generating equipment includes ten boilers, eight of which are of Babcock & Wilcox or similar types. These boilers, which have a combined heating surface of 50,000 square feet, are designed for coal firing, some of them being furthermore furnished with oil burners for forced duty. The remaining two boilers are radiation boilers, each with a heating surface of 2,400 sq. ft, both being designed for oil and pulverized coal firing. The normal steam generating capacity for this older boiler installation is at present 220 tons per hour (485,000 lbs/h), of which the two radiation boilers contribute 80 tons (176,000 lbs), The steam pressure is 20 ato (284 psig) and the steam temperature 350°C (660°F).

The more recent boiler installation consists of two separately built radiation boilers, the first one having a normal steam generating capacity of 130 tons per hour (285,000 lbs/h) with a maximum of 160 tons per hour (352,000 lbs/h) at a pressure of 24 ato (340 psig), and a steam temperature of 425°C (800°F). This boiler, which was put into service in 1932, the same as the two older radiation boilers, has been designed and built in the works of the Waterfalls Board, It is fired with oil or pulverized coal. The boiler is housed in a tower-shaped building with a ground-area of 50 x 50 square feet and a height of 118 ft. The cross-section drawing shows the mutual

relation of the various parts. The boiler consist of a combustion chamber with a vertical flue in which the superheater, air pre-heater and economiser are located. The air and flue-gas fans are located at the top of the tower. In designing this boiler special attention has been devoted to rapid starting and flexibility under varying load, as well as ease of operation and maintenance in service. The combustion space is octagonal, with a circular pillar in the centre. The walls, floor and ceiling consist of tubes, in which evaporation takes place, The combustion chamber, which is suspended from the two steam-drums, and therefore free, can expand downwards, the bottom being formed by a water-drum. The latter is connected with the at eam@drums by four descending tubes in the circular pillar in the centre of the combustion chamber.

The wall-tubes, which to start with were made as fin-tubes, have later been reconstructed with lateral side-tubes cf Swedish construction as shown by the illustrations. This construction, which has now been operating perfectly for over 10 years, has proved to be a much cheaper wall than can be obtained with closely placed tubes; and furthermore, a much simpler fastening of the tubes in the cases and drum can be obtained.





P11 STEAM PRODUCER

Steam quantity 290 000 lb per hour
 Steam pressure 350 lb
 Steam temperature 800°F

Draft fans

Air fans

Air preheater 22000 sq.ft.

Economiser 6700 sq.ft.

Superheater 4300 sq.ft.

Air preheater 4300 sq.ft.

Superheater 1300 sq.ft.

La Mont-system 1600 sq.ft.

Drums

Furnace chamber:
 heating surface 4500 sq.ft.
 Volume 22000 cub.ft.

Burners for coal and oil

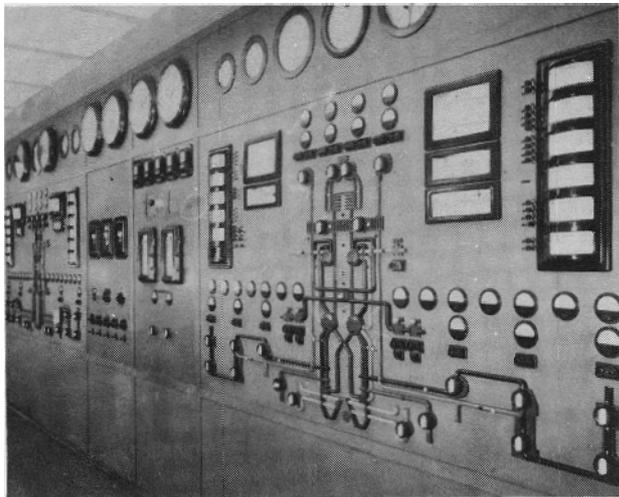
± 33 ft.

± 20 ft.

Coal Mills: 2 each of 28000 lb/h

± 7 ft.

In order to enable the characteristic qualities of rapid starting and rapid adaptation to variations of load to be fully exploited in service, all the operating gear and instruments have been collected on a control-panel on the same floor as that on which the coal and oil burners are located.



The other boiler in this more recent group has a capacity of 260 (570,000) to 300 t steam/h (660,000 lbs/h) with coal firing, which corresponds to 60 to 65 MW from turbine units now installed at the power-station. With all-firing, the output is 65 to 70 MW. This boiler, too, is of the radiation type, in principle of the same design and of the same appearance on the buildingblock as the immediately preceding turretboiler P 11. But it is taller - 52.5 m (175 ft) above the ground.

The operating results from the first boiler were, in fact, after some adjustments of the original construction had been made, so satisfactory that there was no doubt that the new boiler would be built on the same main lines. The costs for this turret-type, and for boilers of a more normal construction, were compared, but both the costs of erection and regard to other factors, as well as management, economy in operation and safety in operation for various types, spoke in favour of proceeding along the lines in which a start had been made, when the earlier radiation boilers were built.

The efficiency of the new boiler has been selected in such a way that the total annual costs will be reduced to a minimum. On the basis of some typical curves of duration of

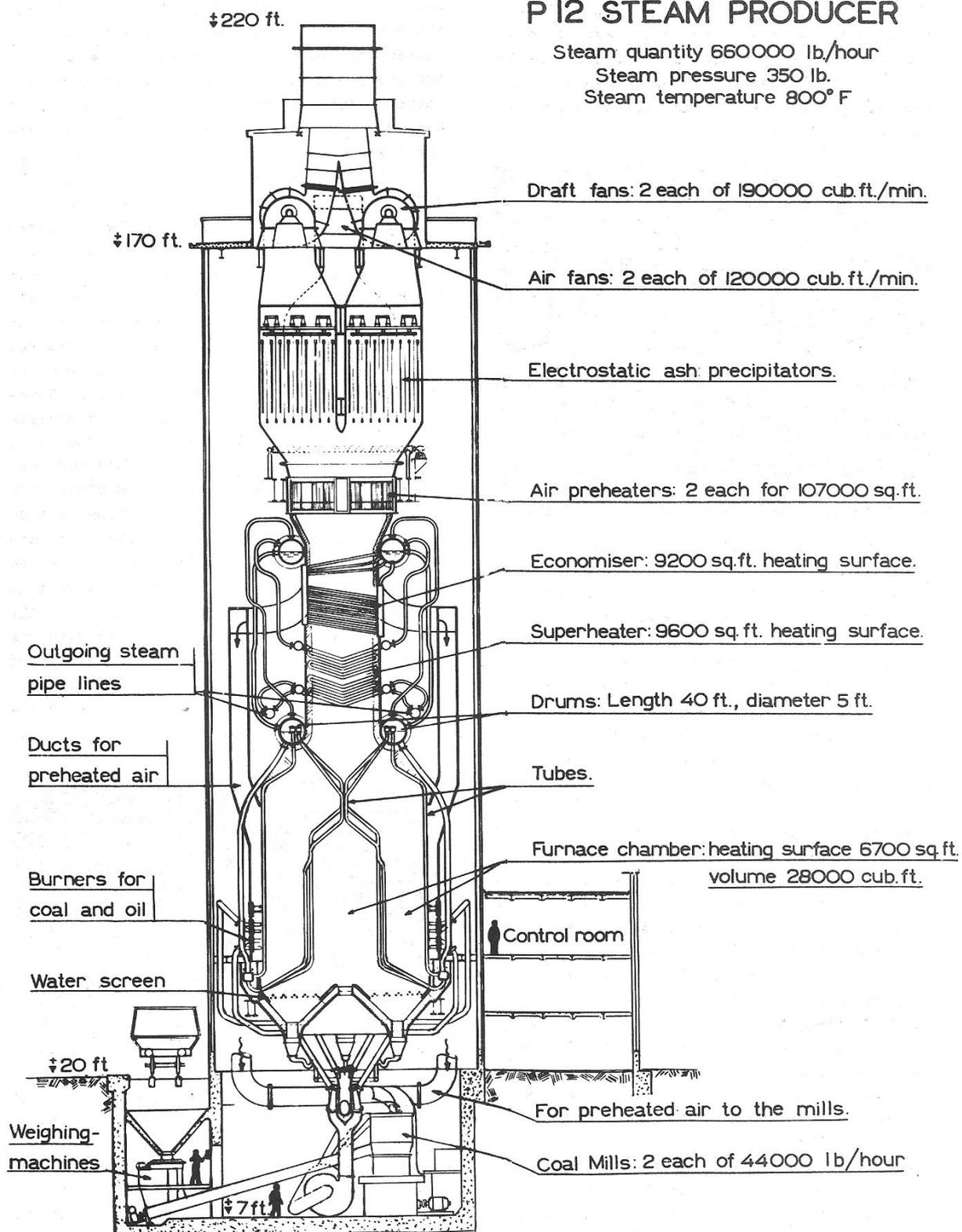
expected load there have been computed for various figures of boiler efficiency not only the costs of installation for all the pre-heating apparatus (superheaters, economiser and air pre-heater), fans and other parts, the costs of which vary with the efficiency of the boiler, but also the annual costs for fuel and for the operation of the auxiliary machinery (chiefly for the operation of the fans). The optimum of the total annual costs has been determined in such a way, and the results were that the boiler was designed and built for 90% efficiency. The boiler pressure has been selected in the same way as for the first boiler - 24 atS (340 psig) - since there was no reason to depart from this steam-pressure. But the boiler is, from a structural point of view, built for 30 atS (425 psig). The steam temperature is 815 °F. The superheat temperature is controlled by a spray-type attemperator. The fuel is pulverized coal or oil and the temperature of the air is 450° (840°F). The coal is fed into the plant by bottom-exhausting transport waggons to coal pockets beneath the ground-level, and is dried and ground to the fineness of dust in two mills for 20 tons coal/h (44,000 lbs/h) each, located in the basement, beneath the boiler. From here the pulverized coal is conveyed with special fans to the burners - two groups of eight burners each, located round the circumference of the furnace.



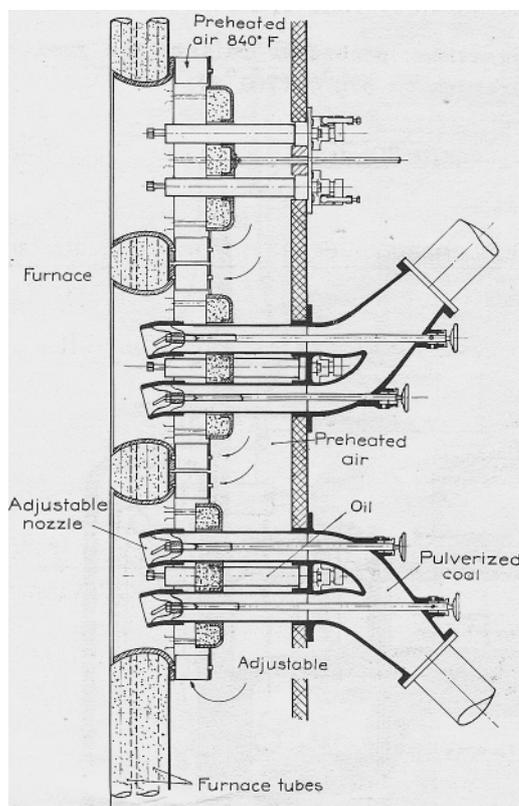
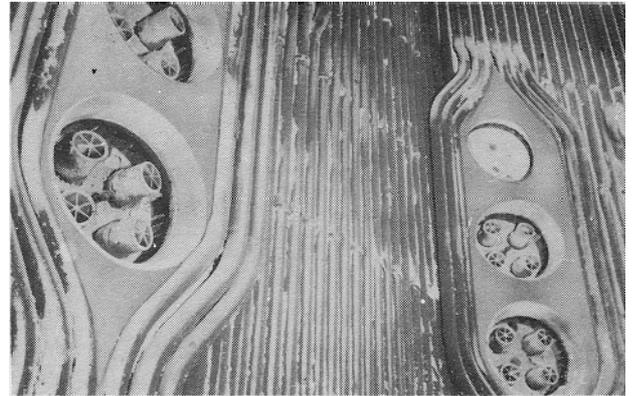
The furnace, which is an octagonal chamber of 46 ft height and 30 ft width, has all its walls covered with tubes. The latter are located closely together with only 1/2 inch spacing between them, and the furnace is outwardly delimited by a hot-air casing running round the same the wall between them being only of sheet

P 12 STEAM PRODUCER

Steam quantity 660000 lb./hour
 Steam pressure 350 lb.
 Steam temperature 800° F

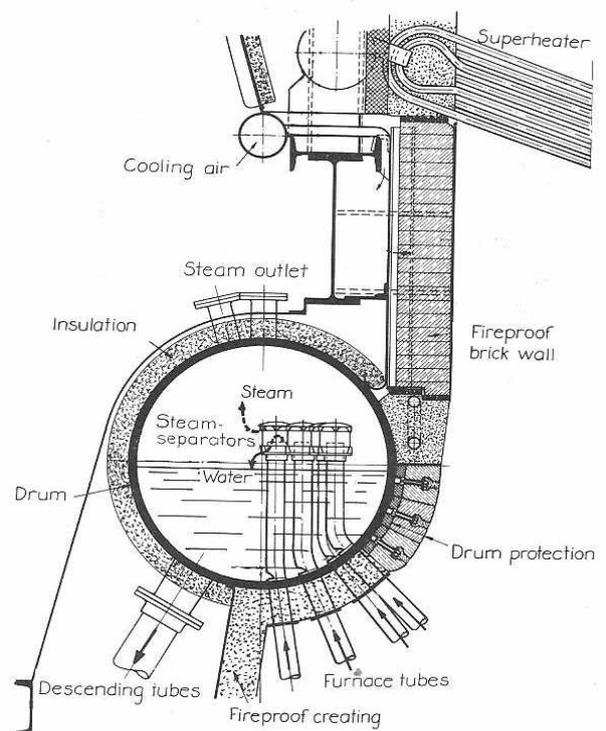


iron and a thin layer of heat-insulating casing. In the centre of the furnace is a circular palisade of steam-generating tubes, which, by reason of the double-sided radiation, exercises uncommonly high efficiency. The furnace has two drums of special steel lying along the entire width, with an inner diameter of 4,5 ft., a wall thickness of 2 inches, and a length of 30 ft. From these drums the water is conducted through 32 stout descending tubes outside the furnace wall down to distribution cases in the lower part of the furnace. From these cases there issue not only those tubes which constitute the walls of the furnace chamber, but also the tubes in the inner palisade. The pipes, which form part and parcel of the floor in the furnace, are also part of a special system with pump-circulation for the water (La Mont system) being fed from the economiser of the boiler.



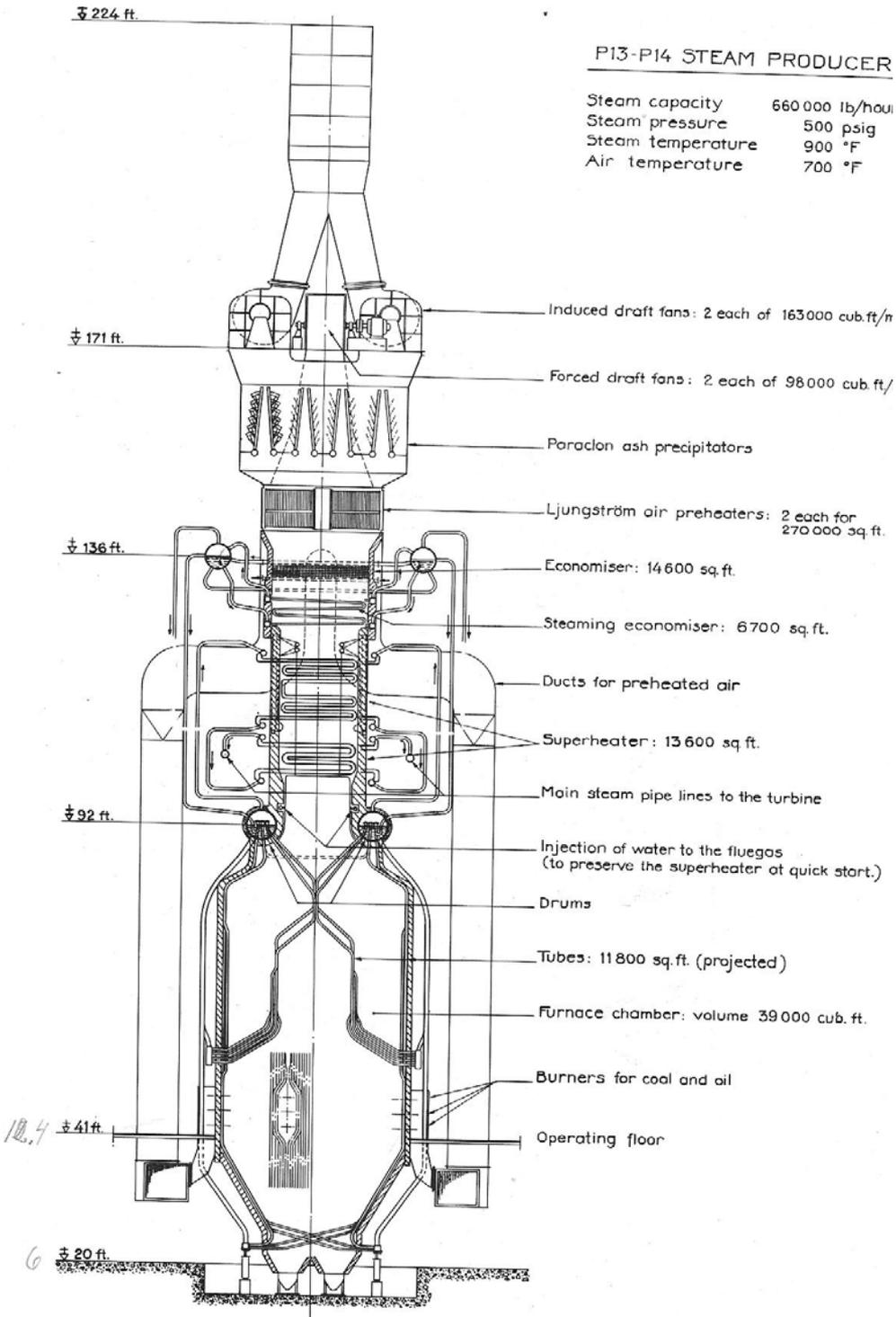
The fuel for the boiler is introduced together with the preheated air which is necessary for the combustion, through burners for pulverized coal and oil, which are located in each of the eight corners of the furnace. The 16 burners for pulverized coal, each one with four separate burner tubes, are whirlwind burners of

the plant's own design. Specially designed guidevane devices are incorporated for the supply of the combustion-air, and these have after tests carried out with models been given such regulation and shape, that an effective mixture of fuel and air is obtained. Furthermore, every separate burner tube is rotatable, so that means are provided for regulating the jet angle at varying load conditions in such a manner as to ensure the most effective combustion. The liberation of steam per unit area of the water surface in the drums is very high, approximately 10 t/hm² (2100 lbs per hour and sq. ft) and there have therefore been incorporated special steam separators on the ascending tubes, as is shown in the figure.



P13-P14 STEAM PRODUCER

Steam capacity	660 000 lb/hour
Steam pressure	500 psig
Steam temperature	900 °F
Air temperature	700 °F



With these separators a perfectly calm water-surface and dry steam are obtained.

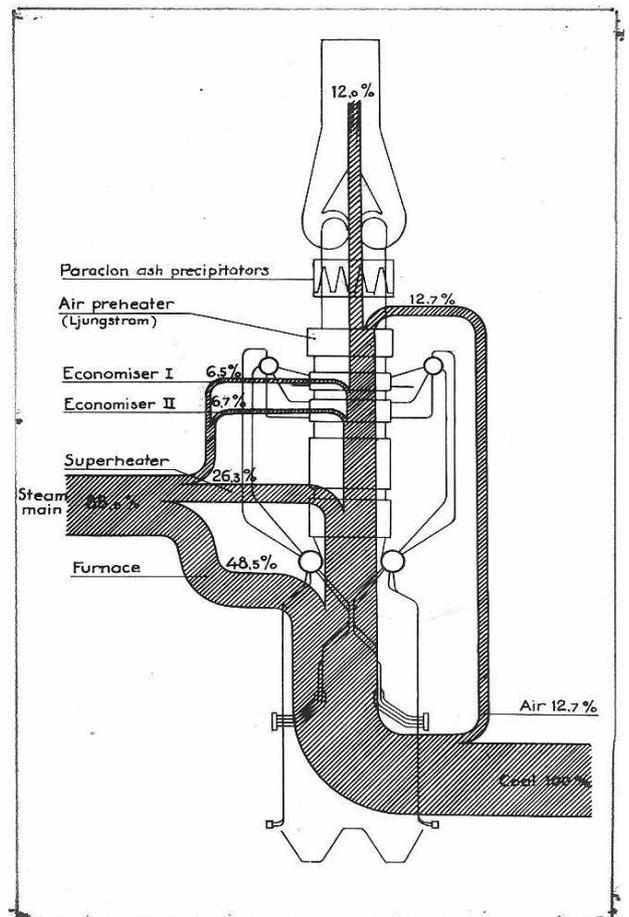
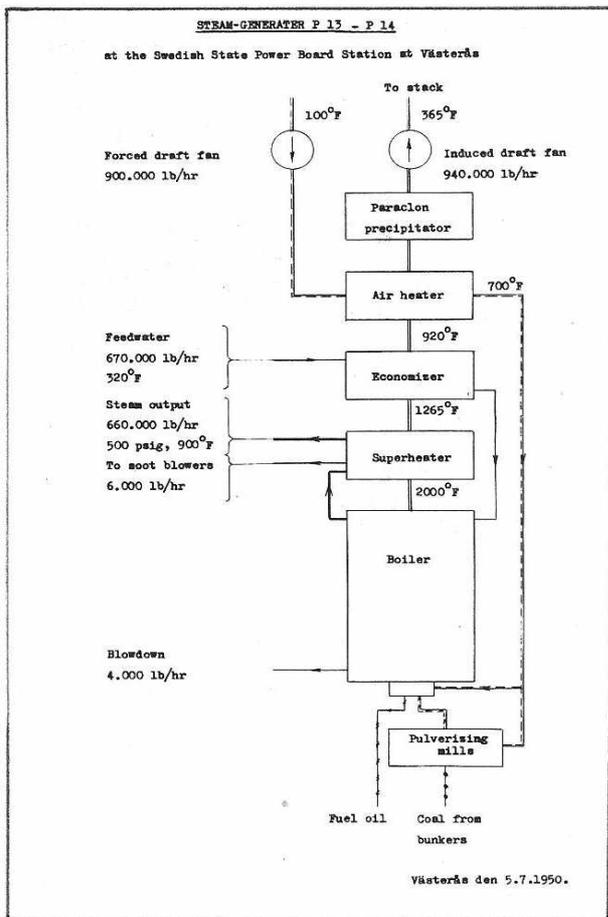
The volume of the furnace is 28,000 cu. Ft. Under a normal full load the furnace consumption is 32 tons of coal per hour at a calorific value of 11,000 B T U/lb.

Two similar boiler units, P 13 and P 14, are at present in course of construction, each with a max. capacity of 300 tons of steam per hour (660,000 lbs/h). The first of these is scheduled to be ready for service during the winter 1950-1951, and the second about a year later. Apart from certain improvements which have been incorporated as a result of operational experiences made with P 12, the two new boilers will be of similar design in all essentials. In view of the nature of the power plant, which is to provide standby and peak power, these boilers have been designed to give the same qualities of rapid starting and flexibility under varying load as P 12.

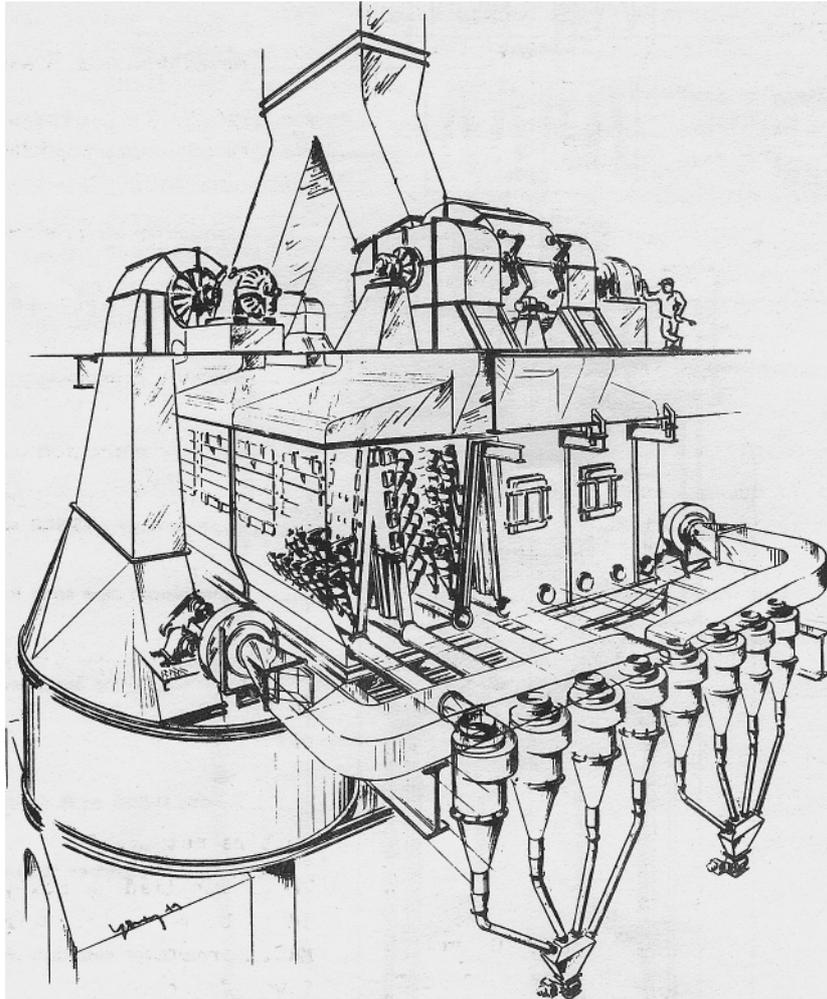
The steam pressure for the new boilers has been raised, compared with existing boilers, to 35 ato (500 psig), and they are to be tested to a pressure of 40 ato (570 psig). The superheat temperature has also been raised to 480°C (900°F) and superheating is effected in two stages, with interposed spray-type at-temperatör. In this way it will be possible to achieve full superheat temperature from 300 (660,000) down to 170 tons/h (375,000 lbs/h). The first superheater operates on the counterflow, and the second on the parallel flow principle. The superheater suspension consists of tubes connected to the boiler circulation system.

The economiser comprises a preheater unit in the form of a normal cast-iron economiser and a steam generating unit, the latter being connected to the economiser drums and designed for automatic circulation.

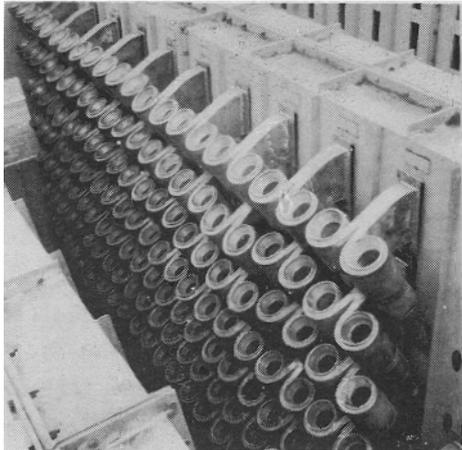
A hjungstrom preheater raises the fuel air temperature to 370°C (700°F).



Blank page



The ash precipitator is of entirely new design consisting of 880 paraclone units which operate in parallel. The small size of this precipitators which is designed to handle a gas flow rate of 560,000 m³/h(3330 cu.ft./min.) is indicated by the following dimensions: Height 3.6 m (11,8 ft;), width 8 m (26.3 ft.) and length 8 m (26.3 ft.). Consequently it has been possible to incorporate the ash precipitator in the body of the boiler and the vertical pas shaft.



Because of the possibility of being obliged in the future to use lower grade coals with high ash content and heavier fuel oils with inferior combustion properties, the height of the new combustion chamber has been increased by 3 m (10 ft.) compared with the P 12 unit. In consequence the heat rate per unit volume of the furnace is lower and to avoid excessive cooling of the burner flames at low load the inner palisade tubes are not extended so far down as in P 12,

The Generating Machinery

The generating plant includes 5 steam turbo-generators for 6,300,- 7,000 volts, 50 cycles, The turbines are built for a steam pressure of 14-20 at o (200-280 psig), 350-400°C(660-750°F)

The following aggregates are installed:

Turbine set No. 1.

Built 1916 by Stal, Finspong.
Max. generator output 8,750 kVA,
Power-factor 0.8,

Max. turbine output 7,000 kW,
Speed 3,000 r.p.m.

Turbine set No. 2.

Built 1933 by Stal, Finspong, Max.
generator output 30,000 kVA,
Power-factor 0.9,

Max. turbine output 27,000 kW.

Turbine set No. 3.

Built 1919 by Stal, Finspong. Max.
generator output 15,000 kVA.
Power-factor 0.93.

Max. turbine output 14,000 kW.

Turbine set No. 4.

Built 1921 by the de Laval's Angturbin, Stockholm.

Max. generator output 17,500 WA.
Power-factor 0.8.
Max. turbine output 14,000 kW,

Turbine set No. 5.

Built 1932 by Stal, Finspong, Max.
generator output 50,000 kVA,
Power-factor 1.

Max. turbine output 50,000 kW.

Turbine set No. 6.

Built 1949 by Stal, Finspong. Max.
generator output 72,000 WA. Power-
factor 0.9.

Max. turbine output 65,000 kW.

Turbine set No. 7.

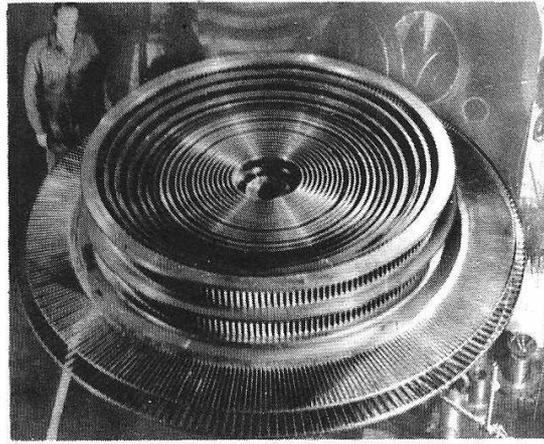
To be supplied by Stal, Finspong, and scheduled to be taken into service in 1951,

Max. generator output 72,000 kVA,
Power-factor 0.9.

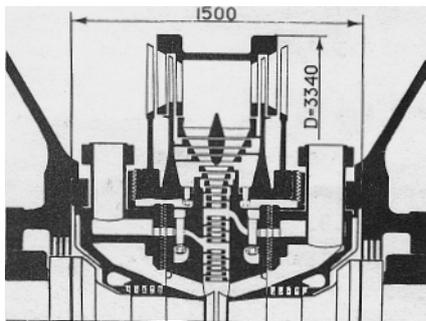
Max. turbine output 65.000 kW.

The de Laval turbine installed is of the axial flow impulse type with two cylinders. The high pressure cylinder has 9 velocity-stages, and the low pressure cylinder is arranged for quadruple flow exhaust with 4 x 3 wheels, The generator of this set is also manufactured by de haval's Angturbin.

The Stal turbines are contra-rotating, radial flow turbines, working on the reaction principle. The blades are dove-tailed into steel rings which are fixed alternately to two rotating wheels. The blade-systems fixed to one wheel rotate between the blade-system of the other wheel. The two systems rotating in opposite directions. There are thus no stationary guide blades with this type of radial turbine, but the blades of one wheel serve as guide-blades for those of the other. The relative speed between the blades and the guide-blades thus becomes twice as high as if stationary guide-blades had been adopted. As a result the quality factor becomes four times greater than if only one wheel had been rotating, and of about the same value as, or even higher than, that for multicylinder axial flow turbines



The length of the blades is adapted to the volume of steam, as shown in the figure.

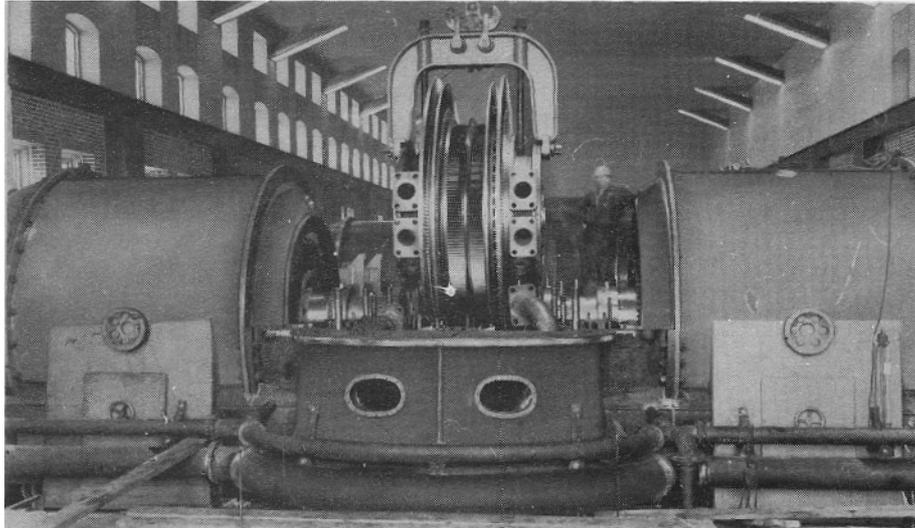


For large units, where the volume of the steam in the final stage becomes very large, each turbine wheel is further provided with one or two rows of radial blades for the last expansion-step. These blades work together with the stationary blades fixed to the turbine casing. Owing to this design, an exhaust area is obtained which is equal to that of an axial flow turbine with double outlet.

An A.C. generator is direct-coupled to each one of the rotating wheels, the generators work in parallel, the output of each corresponding to half the turbine output.

Turbine set No. 6 is one of the largest contra-rotating turbines built hitherto. At the final acceptance tests a thermo-dynamic efficiency of 90.3 % was obtained. The turbo-generator rests on the condensor, thus making the foundations for Stal-sets very simple and cheap, as compared with axial flow turbines. The condensor is designed as two parallel-connected standard condensers, and all the auxiliary machinery is duplicated in order to increase stand-by facilities, and enhance reliability. Steam is bled off from the blade systems for preheating the feed-water in three steps up to 150°C (300°F)

The set is arranged to give the quickest possible start. All auxiliaries are, therefore, driven by squirrel-cage motors in order to simplify starting-up. The cooling-water pumps are of the vertical propeller type, with the impeller below the water-level. They take up the water instantaneously, and as there are no valves whatsoever in the piping, the water begins to circulate immediately the motors are started up.



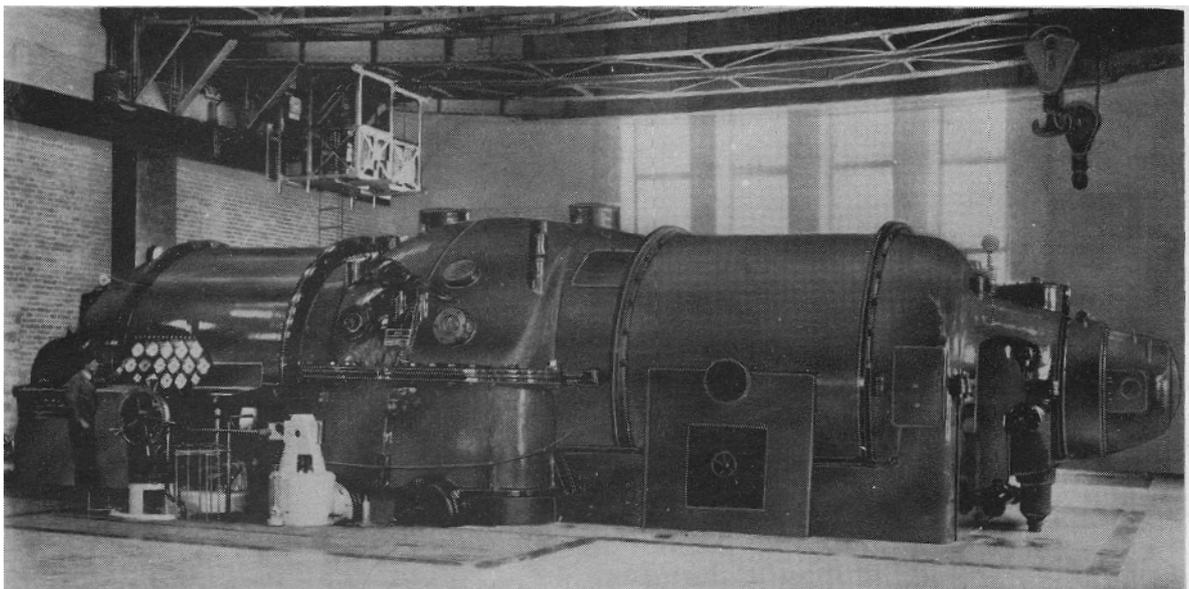
In order to attain the necessary vacuum, a special starting ejector is fitted, which produces a vacuum of 80 % in 2 minutes. The starting time reckoned from cold turbine until the set is ready for synchronising and supplying load, is less than 5 minutes,

The generators are manufactured by the ASEA Company. The field coils are connected in series and fed from a common exciter at 440 volts. The exciter is overhung on the shaft of one of the generators. The generator rotors are of the cylindrical type, built up of a

number of steel blocks clamped between two flanges by means of four bolts. The rotor-winding is a concentric coil-winding, embedded in open radial slots.

A gear wheel pump, driven by a worm-gear from one of the generators, supplies the necessary lubricating oil for the bearing. The oil is cooled in two oil coolers by means of the condensate.

The new turbine set No. 7 is essentially similar to the preceding one, No. 6.



The heating schema of the plant is shown in the drawing. The deaeration of the feed-water takes place at 1.3 ata (18 psia) pressure and 105°C (220°F) in 4 deaerators located directly on 2 feed-water tanks with a volume of 150 m³ (4250 cub. ft) each.

