EQUIPMENT FOR THE AKIBA NO. 1 AND NO. 2 POWER STATIONS

By

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I. INTRODUCTION

After more than 10 years following the end of the war, swift advances have been made in the development of energy resources which are the basis for progress in our daily living. As a result, marked progress was seen in the hydraulic power plant construction technique of our country. Through research and experience, the technique of manufacturing water turbines and generators is turning toward a new direction.

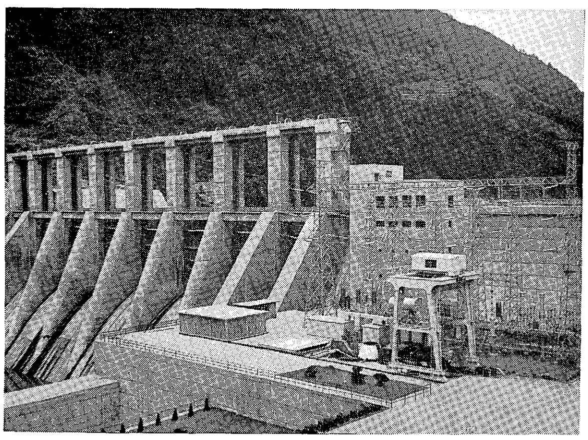

Fig. 1. Completed view of Akiba No. 2 P.S.

The water turbines and generators for the Akiba No. 1 and No. 2 Power Stations were manufactured by our Company. Three years were required from the time the order was received in April 1955 until operations were begun at the Akiba No. 2 Power Station. During these three years, numerous remarkable products were developed in the field of heavy electrical equipment in Japan. This was also the period when progress was made from the stage of highly reliable equipment to the stage of economical and commercially marketable products. One of the factors influencing this trend was the economic situation in our country. The equipment for the Akiba No. 1 and No. 2 Power Station were also influenced in this way from the planning stage until their completion. This should be borne in mind in reading the explanations contained hereunder.

The Akiba No. 1 and No. 2 Power Station are situated downstream from the epoch-making Sakuma Power Station (98MW × 4) on which various tests of great interest from the stand point of the history of hydraulic power development in Japan have been conducted. They were installed at Akiba Dam with the purpose of performing backwater adjustment, or in other words, to regulate the flow of water from the Sakuma Power Station. As shown in Fig. 2, the No. 1 Power Station is situated at a point 5km below the dam with an effective head of 47 m and its purpose is to allow the flow of a constant and considerable quantity of water at full load. The No. 2 Power Station is located directly below the dam with an effective head of 36 m and is to be used when the water flow exceeds the inflow to the No. 1 Power Station.

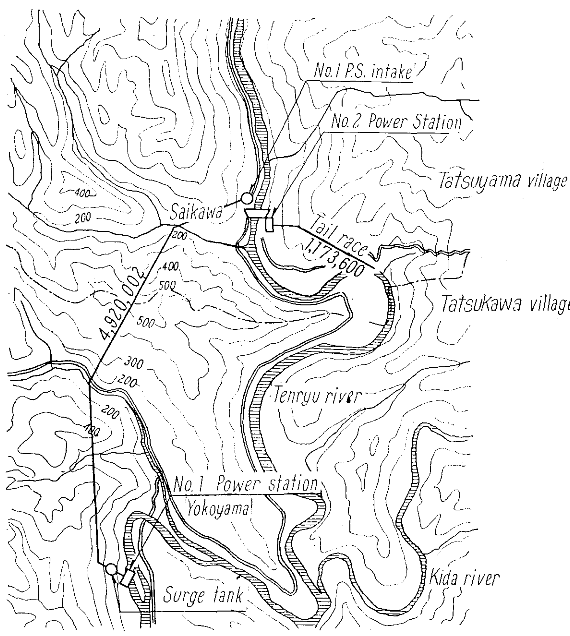

Fig. 2. No. 1 and 2 P.S. location sketch

With this is mind, two 26,300 kW Francis turbines have been installed at the No. 1 Power Station and one 38,000 kW Kaplan turbine, with the largest capacity in our country, was installed at the No. 2 Power Station. Operation is at 60 cycles throughout most of the year with occasional operation being conducted at 50 cycles. Since the end of the war,

Table 1. Table on Kaplan Turbine (Postwar)

No.	Customer	Name of P. S.	Generator No.	Output (kW)	Speed (rpm)	Head (m)	Quantity of water (m^3/S)	Runner diameter (mm)	No. of Vanes	Specific speed (m-kW)	Mfg. year
1	Tohoku Denki Seitetsu Co.	Ishibane	1	6,000	231	17.0	40.2	2,530	5	530	1953
2	Hokuriku Electric Power Co., Inc.	Jintsu-gawa No. 2	2	21,000	200	31.2	75	3,550	6	394	1953
3	Kansai Electric Power Co., Inc.	Tsunokawa First generator	1	13,000	300	36.5	40.3	2,530	7	390	1954
4	Tohoku Electric Power Co., Ltd.	Horyo	1	7,200	333	34.8	24.6	1,990	7	333	1954
5	Hokuriku Electric Power Co., Inc.	Jintsu-gawa No. 3 right bank	1	10,200	100	9.72	120	4,550	5	665	1954
6	Hokuriku Electric Power Co., Inc.	Jintsu-gawa No. 3 left bank	1	7,550	180	16	53	3,060	5	515	1955
7	Electric Power Development Co., Ltd.	Akiba No. 2.	1	3,500/38,000	150/180	36.6	110/121.8	4,071	7	387	1956
8	Kansai Electric Power Co., Inc.	Tsunokawa 2nd Generator	1	13,000	300	36.5	40.8	2,530	7	390	1957
9	Tohoku Electric Power Co., Inc.	Shinochiai	1	22,000	273	52 max. 62	47.8	2,780	8	290	1957
10	Hokuriku Electric Power Co., Inc.	Kabekura	2	13,900	300	37.7	41.8	2,530	7	378	1958
11	Hokuriku Electric Power Co., Inc.	Tomita	1	20,800	200	28.2	83.6	3,550	7	445	1958

our Company fulfielled orders for the manufacture of more than half of the Kaplan turbines in our country. Table 1 shows specifications for Kaplan turbines.

The total number of turbines manufactured by our Company since the end of the war is:

about 800,000 kW (51 units)

The total output of generators is:

about 900,000 kVA (53 units)

II. EQUIPMENT OF NO. 2 POWER STATION

1. Turbine

The turbine which boasts the largest capacity of any in our country, is a 38,000 kW Kaplan turbine.

Specifications

Effective head:

maximum	36.6 m	(when Q = 110 m^3/s)
normal	36.0 m	
minimum	32.6 m	(when Q = 110 m^3/s)

Water quantity:	60 c/s	50 c/s
at maximum effective head	119.2 m^3/s	110 m^3/s
at normal effective head	121.8 m^3/s	110 m^3/s
at minimum effective head	117.6 m^3/s	110 m^3/s
Output:		
maximum	38,000 kW	35,000 kW
normal	38,000 kW	34,500 kW
full open output at minimum effective head	32,800 kW	31,200 kW
Speed:	180 rpm	150 rpm

As mentioned above, this turbine is a Kaplan turbine with a maximum water quantity of 121.8m^3/s and specific speed of Ns = 387 m-kW. It is an enormous unit with the casing inner diameter being 4,800 mm and outer diameter of the runner being 4,071 mm.

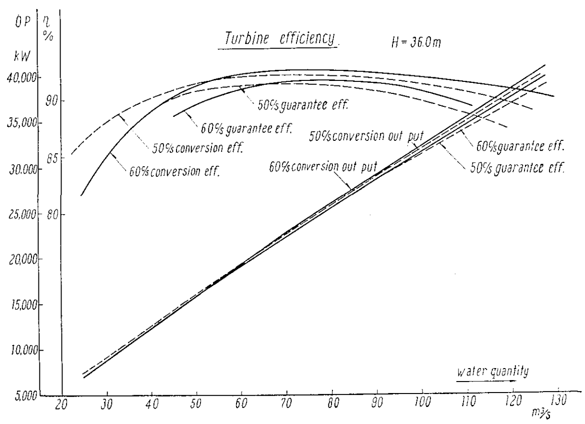

Fig. 3. Turbine efficiency curve

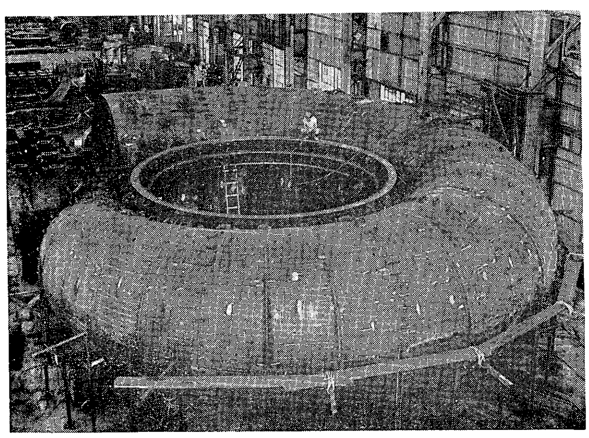

Fig. 4. Temporary plant assembly of casing

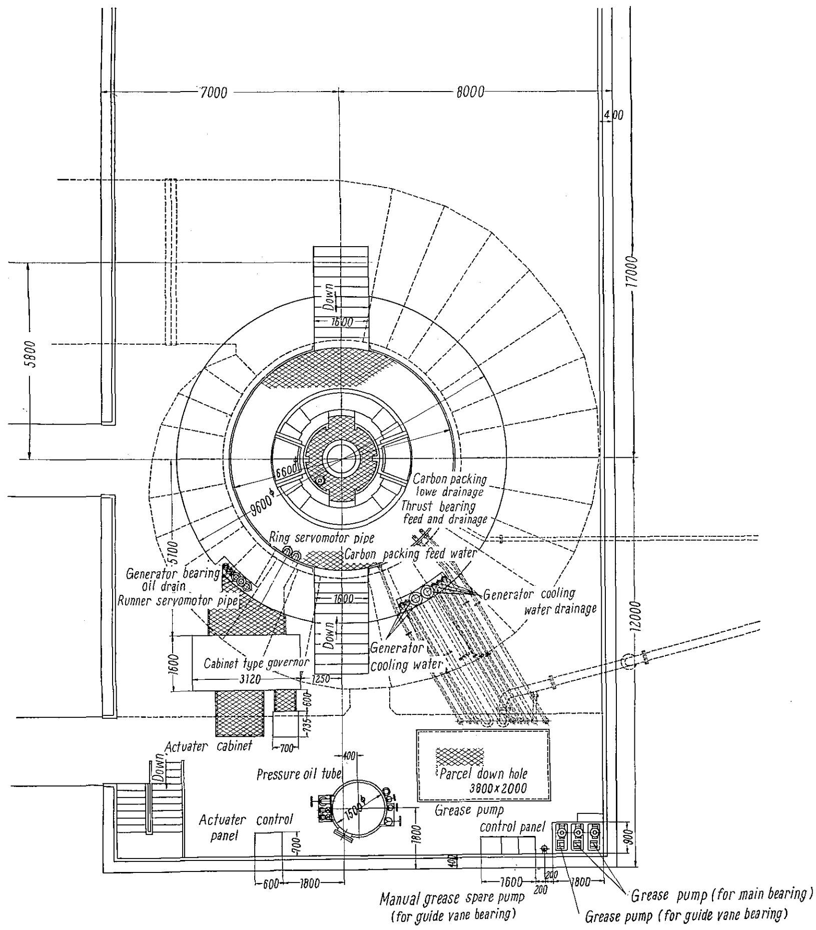

Fig. 5. Arrangement of Akiba No. 2 turbine room

As mentioned previously, it is operated when the water quantity flowing into No. 1 P.S. exceeds the scheduled limit. During an year's operation, it is run for longer periods at $50\sim30$ m^3/s. Fig. 3 represents an efficiency curve. The casing which is of steel plate welded construction, was first temporarily assembled and inspected, then transferred to the site and welded on the site. For this construction, SB 42B steel plates of 16, 19 and 22 mm thickness were used. Within our country in the past, it was thought that in such a construction as this, annealing to eliminate stress should be conducted after the welding. As the result of research tests conducted by our Company on the effects of residual stress on corrosion, the problem of brittleness, as well as various other tests, the conclusion was reached that annealing at the site is unnecessary. Through adoption of this method, satisfactory results were obtained. Fig. 6 shows a welding lines. By welding the portion shown by the thick line, distortion of the speed ring due to welding is prevented. Consideration was given to adequate preheating (100$\sim$150°C) and past-heating (200° C) at the time of welding, elimination of hydrogen from the seams, reduction of cooling of the deposited metal and its heat affected parts, improvement of toughness and elimination of bubble cracking by permitting dissolved hydrogen ejection, and prevention of extremely uneven distribution of stress. Using the low hydrogen or the illuminate electrode, we complemented for working condition of flat, over head, vertical or horizontal welding position. Loss due to gap-cavitation around the runner results in a severe loss in the discharge ring thus necessitating the use of stainless steel. Although it is customary for the discharge ring to be of single cast construction made from 13 per cent chromium stainless steel, our Company made this of welded steel construction with the interior lined with 18–8 stainless steel sheets. Since the shape of the discharge ring is easily transformable, the finished weld of the steel plates was first imbedded in concrete over which 18–8 stainless steel strips were welded and finished by grinding. As a means to prevent gap cavitation, a

Table 2. Rolled steel plates for boiler

Notation	Chemical composition (%)				
	C	Si	Mn	P	S
SB 42 B	under 0.24	0.15$\sim$ 0.30	under 0.80	under 0.035	under 0.040

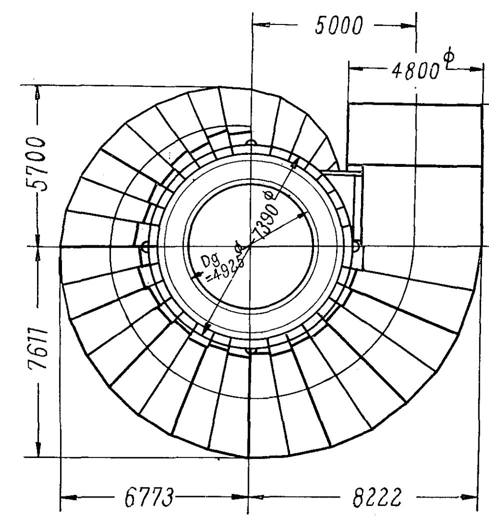

Fig. 6. Spiral casing field welding diagram

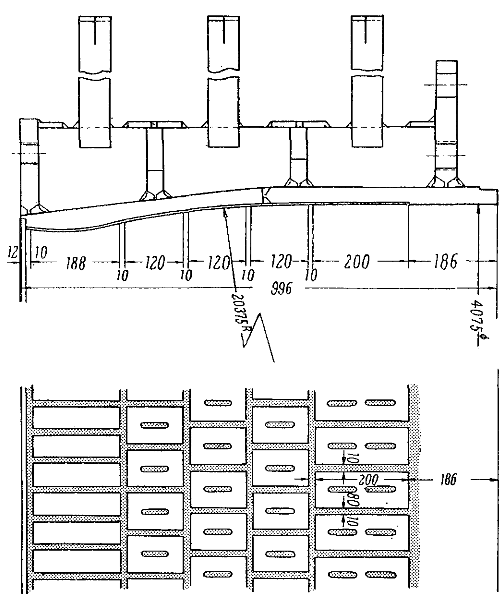

Fig. 7. Stainless steel plate liner on inner surface of discharge ring

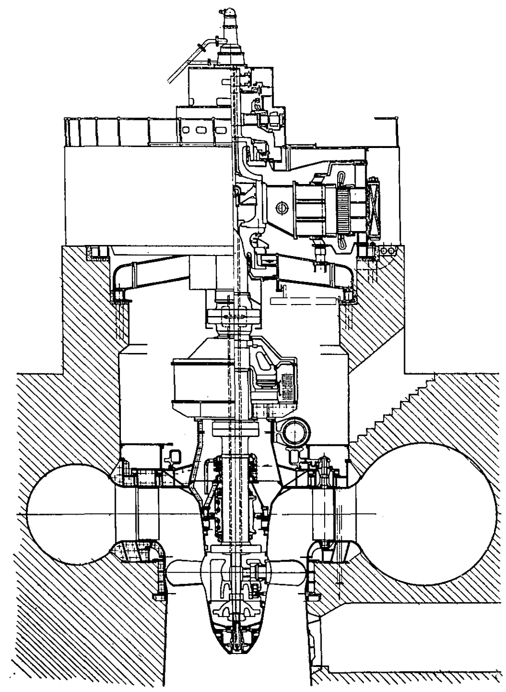

Fig. 9. Sectional diagram of turbine generator

cavitation protector was installed on the exterior of the runner. A hydraulic self-closing construction was adopted for the guide vane. In other words, closing force is applied to the guide vane by means of water pressure. Two types of closing systems are recently becoming popular in our country. Closing by means of a counterweight is being adopted for turbines with an effective head up to 80 m and having a main inlet valve. Since the counterweight must be heavy in the case of a turbine with an effective head above 80 m, either the hydraulic self-closing construction or the system employing a servomotor operated by water pressure for closing the main inlet valve is being adopted. The so-called ring servomotor is being used for the guide vane. The special feature of this system is the fact that it can be used with units equipped with runners that are more than about 2.5 m in diameter and it has not any relation to building in the erection. Because an a-c power

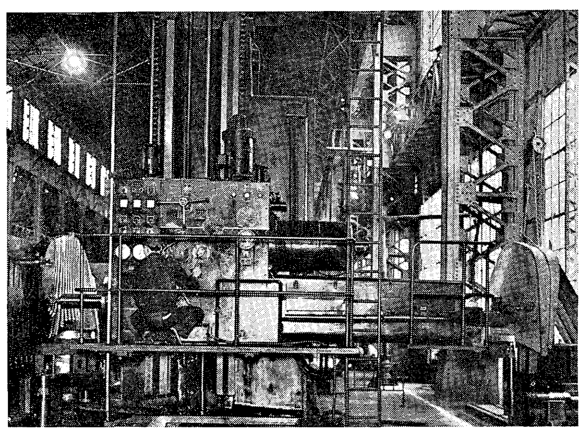

Fig. 10. Runner being profiled

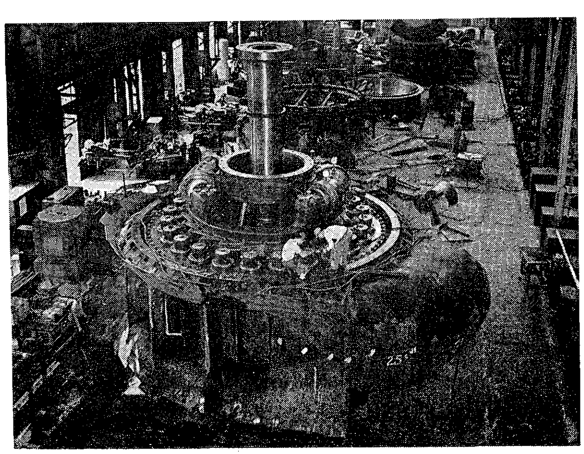

Fig. 8. Plant assembly of 38,000 kW kaplan turbine

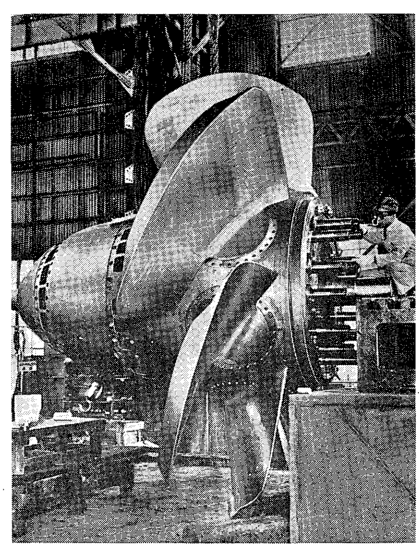

Fig. 11. Runner

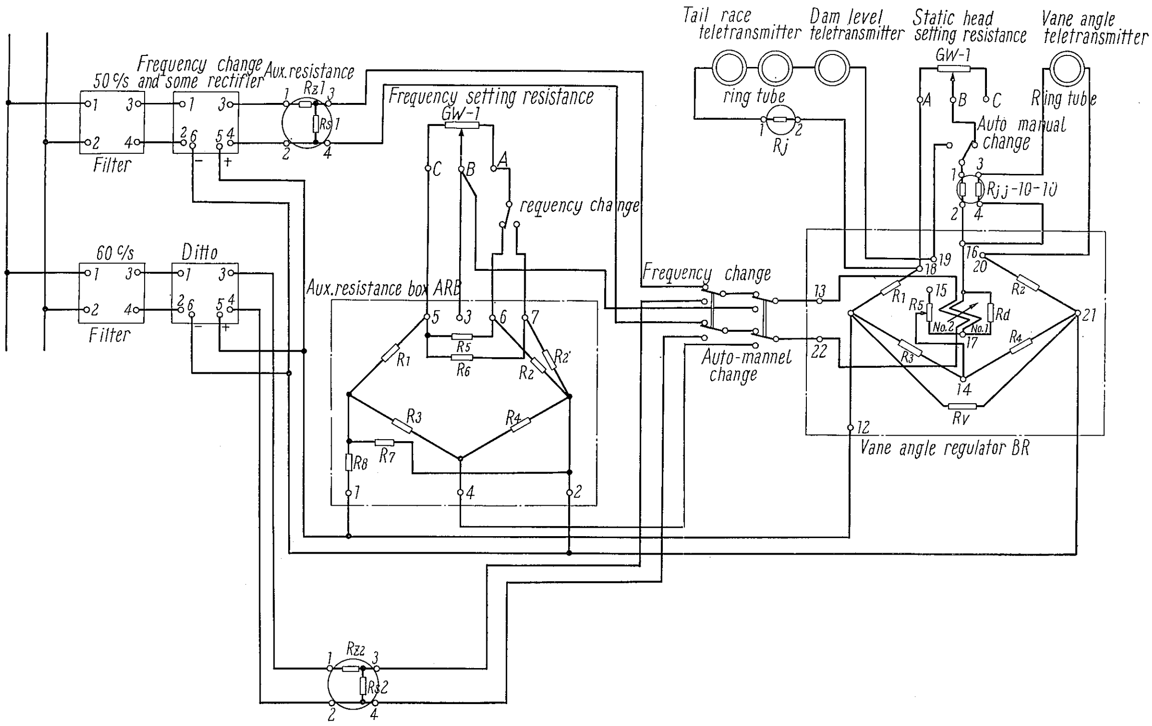

Fig. 12. Connection diagram for water-wheel high efficiency operation apparatus

source is always available, a regular and spare motor drive system was adopted for the oil pump. The runner was made of 13 % chromium cast iron. A device was installed to automatically maintain maximum efficiency at all times in the relationship between the runner vane and guide vane, i.e., between the fluctuations in the effective head and fluctuations in the frequency. Our Company refers to this as a turbine high efficiency operating apparatus. Details are shown in Fig. 12. The head cover and bottom ring are of welded construction. The hydraulic features were thoroughly examined by our Company centered around its hydraulics researching division. Improvement of efficiency and cavitation features and the determination of runner diameter and draft height are all closely related, so we feel that satisfactory

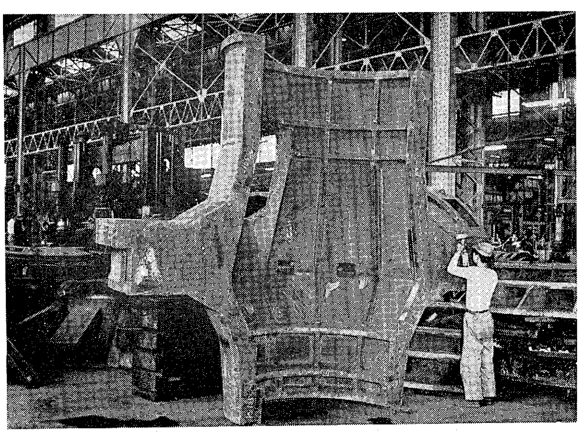

Fig. 13. Welded head cover for water turbine

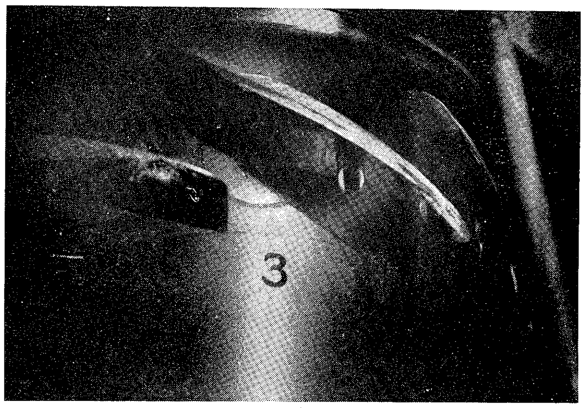

Fig. 14. Cavitation test at full load

results have been obtained in overall characteristics. Fig. 3 represents a scale model converted efficiency (converted on the basis of the moody multiply $^{1}/_{5}$ formula). Fig. 14 shows cavitation under actual operating conditions with no bubble formation.

In the structure of the guide vane self-closing apparatus, the shape of the vane itself posed a serious problem. The shape of the vane affects to some degree the full utilization of hydraulic energy. Tests were conducted with the utmost care. The same care was taken in the manufacture of the actual runner. A model of the runner was projected sectionally on paper by means of a special section projector with the purpose of comparing the vanes.

Another feature of this turbine is the fact that the thrust bearing is installed directly above the turbine's intermediate head cover, and load may be supported through the head cover and speed ring of extreme interest was the question of what values would be indicated by the change in the upper and lower gaps of the guide vanes at the time of at-the-site installation. After all, the guide vane gaps showed minus 0.3 mm as compared with at temporary assembly, but we considered that water pressure would rise the gaps about 0.2∼0.3 mm when the turbine in operation. Since the thrust bearing is located above the turbine body, there is no need to pay special attention to the barrel structure and installation and maintenance are simplified. This thrust bearing is of the self-circulating type. At the inlet and outlet above the bearing where there is formation of oil film, dial thermometers were installed to measure the temperatures.

The following method was employed in waterproof of the runner boss. Pressure oil taken from between the upper and lower piston rings of the runner servomotor was pressurized to 2 kg/cm^2 so that pressure would be applied to the lubrication oil within the runner. Consequently water was prevented from seeping through the boss. Oil having more about 0.02 specific gravity than pressure oil was used in the boss. With the increasing demand for electric power in our nation, there is an accompanying increase in the construction of new power stations. As a result, attention is being paid to the quality of the generated power and care is being directed to frequency control. Consequently electrical control governors were installed to regulate speed. The turbine efficiency test, the results of which are now being ready, was conducted by the Gibson method because the Pitot tube method and Current meter method could not be used due to the relationship between the installation diameter and position.

2. Generator

The generator is a vertical shaft totally enclosed self-cooling 3 phase a-c synchronous generator. It can be used for both 60 and 50 cycles. Its specifications are as follows:

Specifications

	60 c/s	50 c/s
Output	38,000 kVA	35,000 kVA
Voltage	11,000 V	11,000 V
Current	1,990 A	1,840 A
Power factor	0.90	1.00
Speed	180 rpm	150 rpm

The runner servomotor was installed at the rotor center. By referring to Fig. 9 one can see that this permits considerable reduction of the vertical height. The stator winding is of the wave winding, one coil, one turn system and no consideration need be given to the layer insulation. Transposition is carried out in the slot. This is the common design recently

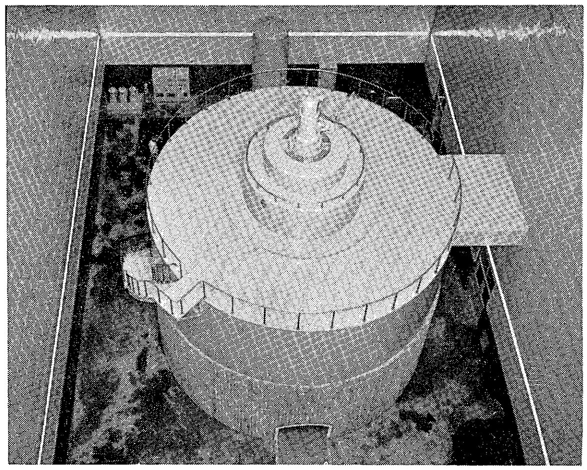

Fig. 15. 38,000 kVA generator

being used in our country for large type generators.

The bearings are all of the oil-immersed self-circulation type. They are therefore less complex than the forced circulation type and their compactness simplifies maintenance and operation. This too is a new trend within our country and this system is being adopted in practically all of the turbine generators being manufactured in Japan. Painstaking effort was required in trying to prevent the leakage of oil from the reservoir and in the designing of the cooling system, but the basis of the design has already been established. Special mention should be made on its compactness and increased reliability. The supporting strength of the thrust bearing, including the water thrust, is 810 tons. This places the bearing in a fairly large size category. Needless to say, an upper thrust bearing is also available. Prevention of leakage of oil from the Kaplan device installed at the top of the generator to the lower slip ring and exciter have been fully considered. Furthermore, consideration has also been given to the distribution of the return rod of the runner blade. Ball bearing has been used for the rod bearing and the rod is of adequate diameter so that attention has

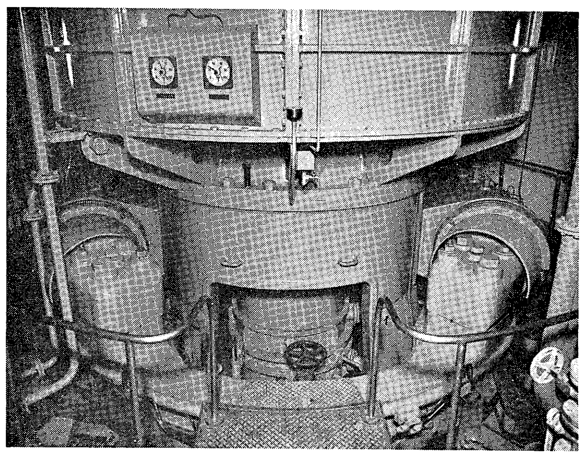

Fig. 16. Thrust bearing above the water-wheel head cover and turbine room

been paid to the improvement of control responsibility. As shown in the sectional diagram, the main shaft has been carefully designed and, through careful manufacture, satisfactory results were achieved at the time of installation in the field. Centering and Leveling of the bearings for the turbine and generator at the time of installation greatly affect the performance, stability and life of the apparatus. Therefore, particular care is paid in our country so that good results are being obtained. Careful adjustments are made for static and dynamic balance when the unit is assembled at the plant. The present trial run has resulted in an extremely noiseless operation.

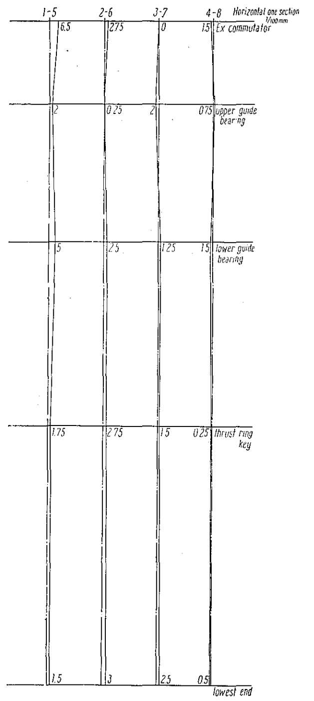

Fig. 17. Record of turbine generator shaft

In order to keep the generator winding in a dry state, in consideration of long stoppages, a moisture proof device has been installed. For ten hours after suspension of operation, relative humidity can be maintained at below 75%. The rotor is of 2.3 mm thickness plate laminated yoke construction. A 50% over speed test was conducted and the change in the stress of various parts was measured by means of strain meters. Conditions at runaway speed were also presumed.

It goes without saying that the exciter is of adequately large size in order to perform quick-response excitation. However, it possesses an Isthmus pole characteristic, and since quick response characteristic cannot be expected if there is a shunt winding in the exciter field system, a separately excited winding has been designed to obtain the quick response characteristic. This separately excited winding is regulated by the Amplitrans type AVR made by our Company, on which magnetic amplifier is applied. A permanent magnet generator acts as the power source for the governor, tachometer and relay. Series winding is employed and in order to eliminate high harmonics, V connections are used for the governor and a single phase system for the tachometer and relay. A CO_2 gas fire extinguisher is equipped on the generator.

3. Main transformer

One 38,000 kVA, 10.5 kV/154 kV–161 kV–147 kV 60/50 c/s outdoor use nitrogen-sealed oil-immersed forced air-cooled 3 phase transformer is used. In high and low voltage windings the initial potential distribution produced within the winding by the progressive impulse to the transformer is made as uniform as possible. In order to control the electric oscillation which follows, a perfectly oscillation-free winding system was employed. This system uses the cylinder type winding developed by our Company since the end of the war and which has gained a good reputation. Details on this winding will be omitted since it has been covered in a separate description. It can be said, however, that the 80 kV class reduced insulation was adopted as the neutral. The neutral is of the resistance grounded type. The wheel can be changed in a 90° direction. This transformer main body was temporarily covered and nitrogen-sealed before being transported. It was therefore possible to begin operation with the equipment in a highly reliable condition.

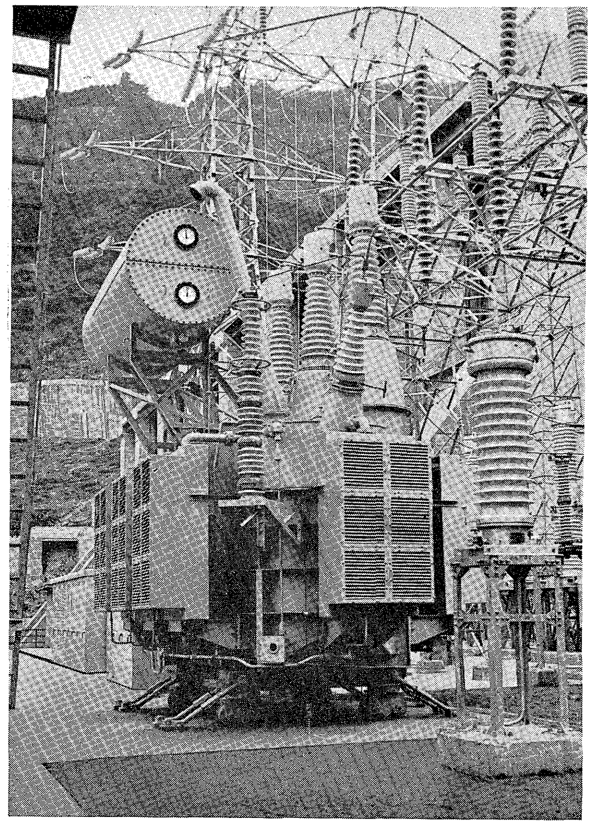

Fig. 18. 38,000 kVA main transformer

4. Control panels and control apparatus

The one man control system has been adopted. This system was designed on the basis of the system commonly in use in Japan following a reexamination of the control systems for power stations carried out in 1954 by power companies and equipment manufacturers. The master switch (# 1) has positions for " preparation," " start," " excitation," " parallel run-

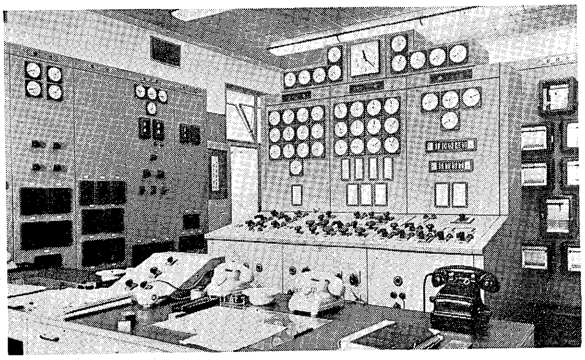

Fig. 19. Main control panel

ning," and "load." The turbine starts automatically by throwing a switch in the main control room and is controlled automatically. Consequently the operator need not remain in the turbine room. The protection system is divided into "normal stop," "emergency stop," "sudden stop," "no-load no-excitation operation," and "alarm." At "emergency stop," the occurrence of a failure causes the parallel running circuit breaker (♯52) to be switched off and, at the same time, the guide vane is closed. At "sudden stop," after the closing of the guide vane is completed, the circuit breaker (♯52) is switched off. The former is used when there is need for emergency stopping such as the generator differential relay etc. The latter is used for making emergency stops without increased revolution when oil pressure loss and a rise in the bearing temperature etc. are occurred. For the operation indicator (♯30S) and fault indicator (♯30 F), the target type was not adopted and the lamp type was adopted. The system employed in the lamp type is, 1) lamp is lit through action of the relay, 2) lamp flickers when the failure has been eliminated, 3) flicker goes out by throwing the flicker stop switch, and 4) lamp goes out by throwing the lamp stop switch. The breaker which has been tripped due to a fault, indicates this by a flickering of the lamp.

All meters are of the wide angle type with non-reflecting glass. As a rule, the draw out type relays were used, the combination of the knife-blade switch and fuses was done away for the station's low tension circuits and the no-fuse breaker system was adopted. New handles designed by industrial designers were used for the control and change-over switchs. The feature of this handle is its shape and strength. The recorder is Fuji electronic tube automatic balancing type. The dam and tailrace water level indicator is a digital (numeral indicator type) water level measuring device manufactured by our Company. The indicator is at the right edge of the panel which appears in Fig. 19. It is a turning plate type indicator manufactured by the Fuji Tsushinki Seizo K.K. The indicating system is shown by the block diagram in Fig. 21. In this system, the water level teletransmitting mechanism is actuated at each one centimeter charge in water level. In other words, the combination of the wires of the multicore cable is checked and after the figure is confirmed it appears on the indicator. Consequently, it is essentially different from the pulse type and it is highly reliable. Operational results were satisfactory and we are convinced of the distinctiveness of this product, especially at this time when there is much concern over the progress being made with the digital system.

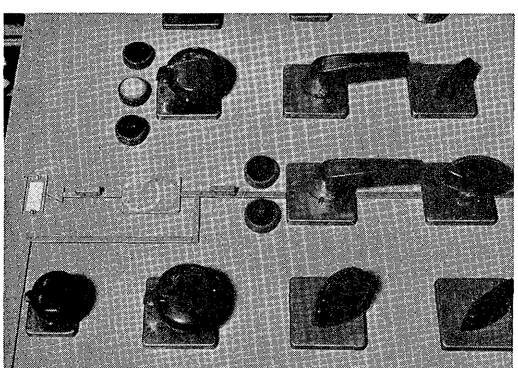

Fig. 20. Handle for new type switch

For indicating the guide vane opening and load limit position, the ring tube teletransmitting system has been used. The selsyn transmitting system is almost never used.

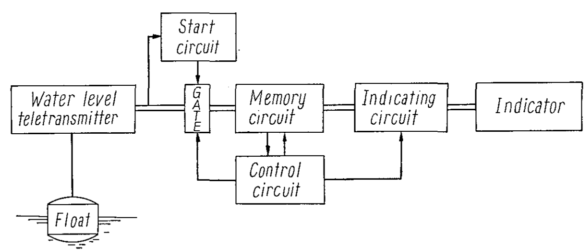

Fig. 21. Block diagram of water level indicator

A pulse type electric clock which guaranteries ± 3 sec. each days error is used. It is driven by a special torque motor operated by a battery. The torque is used to drive a temp-type mechanical clock, the pulse being generated by a transistor circuit. A music box with amplifying system has been installed for sounding the time.

A Fuji automatic induction voltage regulator with a voltage regulating sensitivity of 1.5% is used as the power source for the fluorescent lighting.

A magnetic amplifier type selenium rectifier with AVR is used as the battery charging rectifier. This model is manufactured by our Company as a standard type. Recently, the majority of the power stations in our country have adopted the float charging system. When the float charging system is used, the AVR rectifier is used with due consideration given to the special characteristics of the battery.

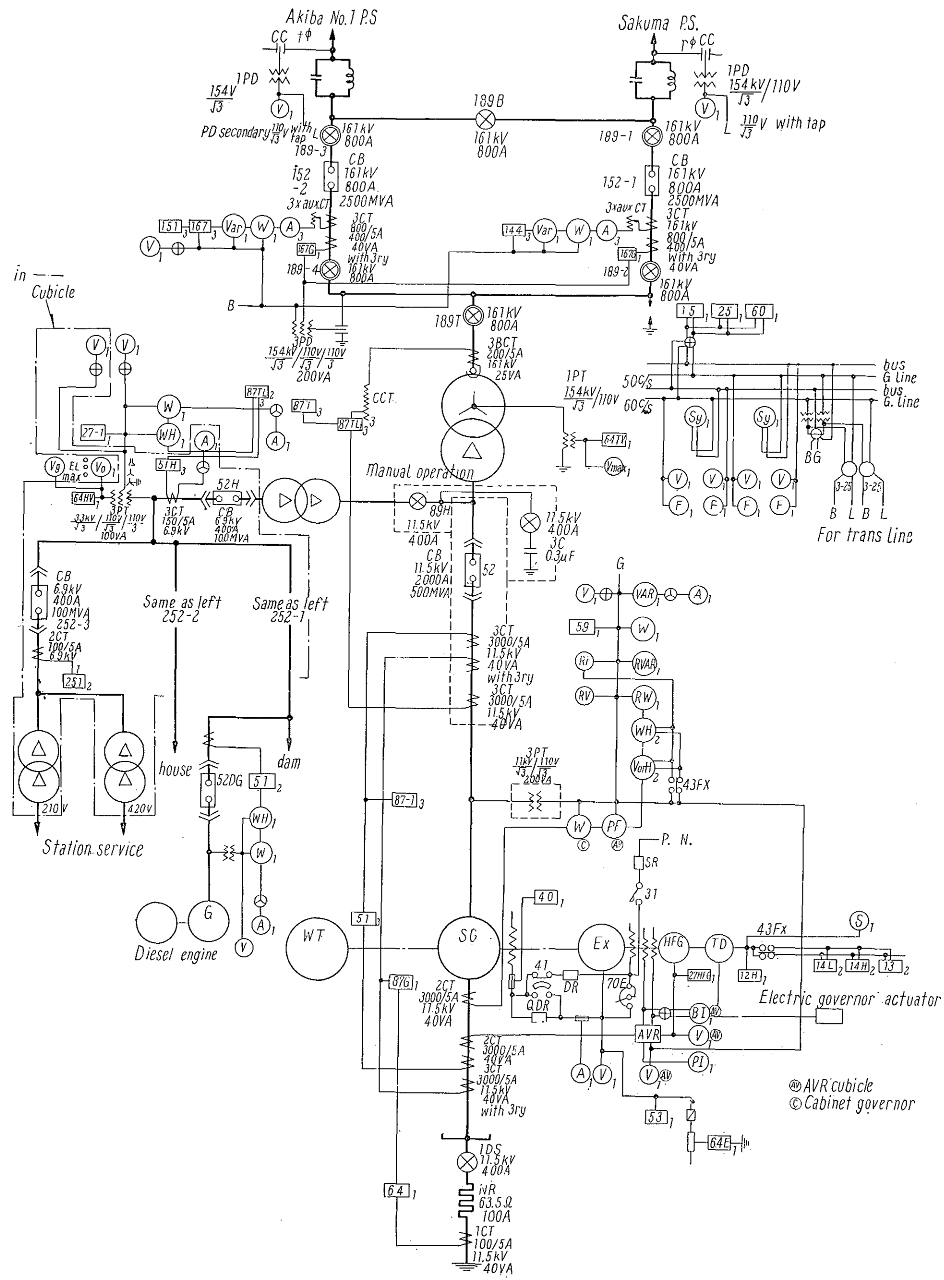

Fig. 22. Skeleton diagram of Akiba No. 2 P.S.

As transmission line protective relays, the arc drop compensating (elliptical characteristic) high speed directional distance relay (♯DZ), high speed directional ground relay (♯DG) and high speed short circuit relay (♯DS) developed by our Company and now in service, have been adopted. Since their performance has been covered in another description, it will be omitted. However, protection for the transmission line was designed on the basis of the following points of view :

1) In two circuit transmission.
   (1) When a short-circuit and grounding occur simultaneously, the short-circuit will have priority
   (2) In the case of a two wire grounding in both circuits, the leading phase will have priority.
   (3) When there is a fault in both circuits at the same location, with one wire grounded in one circuit and two wires grounded in the other circuit, the circuit with two wires grounded will have priority.
2) In single circuit transmission.
   (1) When a short-circuit and grounding occur simultaneously within or outside of a section, the short-circuit will have priority.
   (2) When two wires are grounded within and outside a section, the leading phase will have priority.

5. Reserve power apparatus

A 450 HP Diesel engine manufactured by the Fuji Diesel Co., Ltd. and a 375 kVA synchronous generator manufactured by our Company were installed as reserve power equipment. The reserve power equipment is so set up that as soon as an a-c power loss occurs at the station, it immediately starts automatic operation, generates voltage and awaits the closing of the circuit breaker. After confirming the situation the breaker is manually closed. Special mention should be made of the fact that the exciter is separately excited by AVR output. This method was employed for quick-response excitation since an extremely large starting current is required for the dam gate motors. Operational results were extremely favorable.

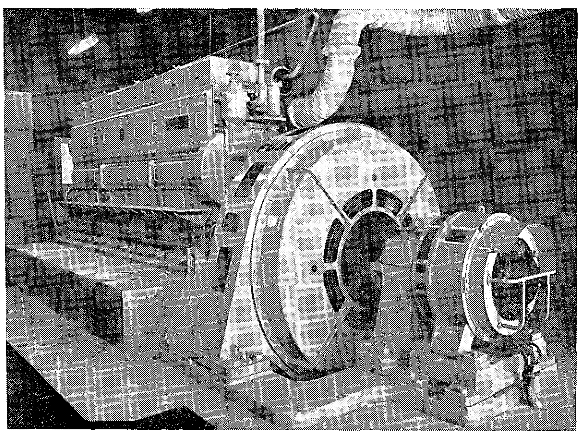

Fig. 23. Reserve Diesel generator

The following is a summary on the equipment of the No. 1 Power Station. Since many of the equipment are the same as the one installed at the No. 2 Power Station, only those that differ have been listed.

III. EQUIPMENT OF THE NO. 1 POWER STATION

1. Turbine

Two vertical shaft single wheel single flow Francis water turbines were used. Specifications are as follows :

Effective head :		
maximum	48.8 m	
normal	47.0 m	
minimum	44.8 m	
Water quantity	60 c/s	50 c/s
at maximum head	61.6 m^3/s	61.1 m^3/s
at normal head	60.6 m^3/s	60.2 m^3/s
at minimum head	59.6 m^3/s	58.9 m^3/s
Output		
maximum	26,300 kW	25,000 kW
normal	25,000 kW	24,000 kW
full open output at minimum head	23,400 kW	22,500 kW
Speed	200 rpm	167 rpm

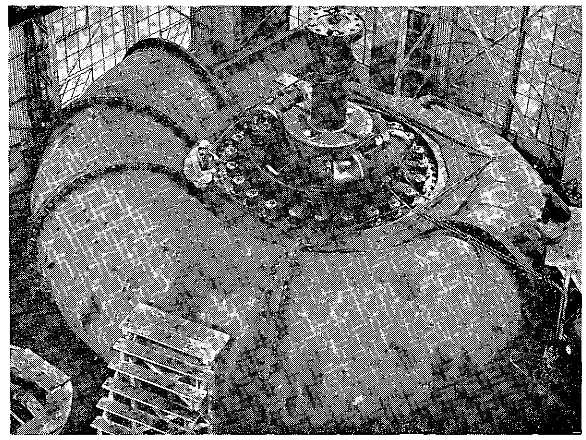

Fig. 24 Plant assembly of 26,300 kW Francis turbine

This is a Francis turbine with a specific speed of $n_s = 257$ m–kW as mentioned above. A Kaplan turbine could also be designed in the same manner. A Kaplan turbine built to the same specifications would become a turbine with a speed of 225/188 rpm.

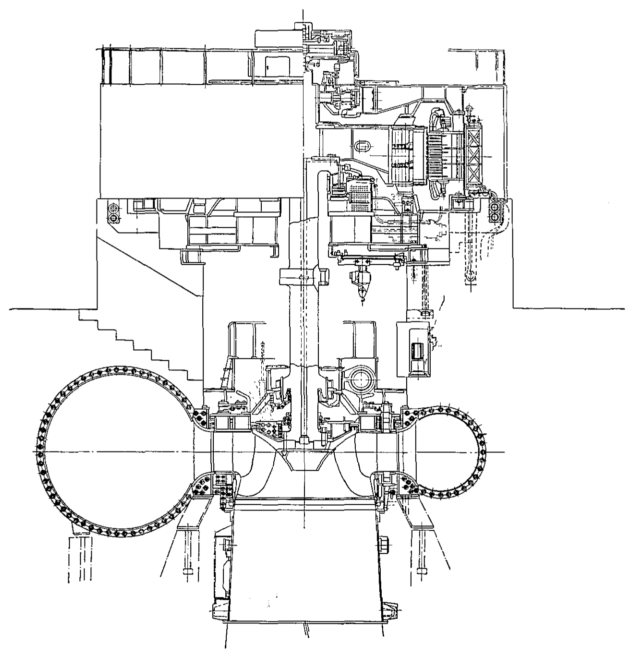

Fig. 25. Sectional diagram of water wheel generator

However, the Francis type was selected on the basis of its operation system and economy.

The runner is of cast steel construction with a welded padding of 18–8 stainless steel at the back surface of the vane outlet and at the inlet. Thorough study and tests were conducted on runner cavitation. The results were satisfactory.

The water wheel is a low head large water quantity Francis turbine. The maximum runner diameter is

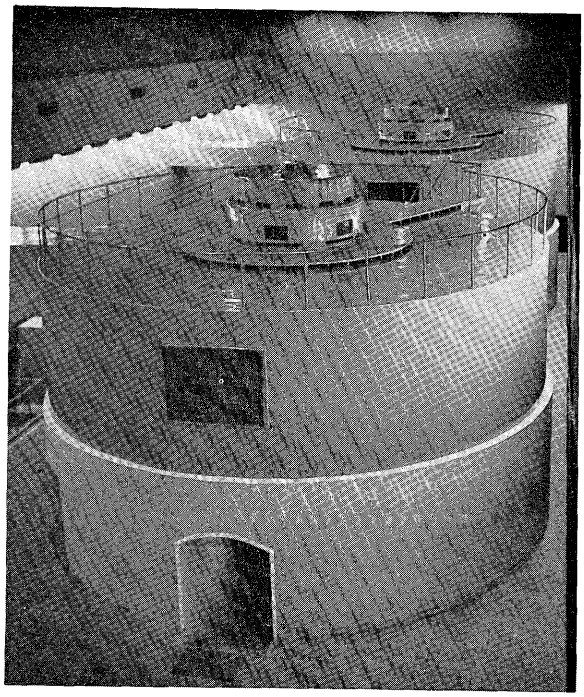

Fig. 26. Generator room

3,150 mm and the diameter of the casing inlet 3,600 mm. The casing is of welded steel plate flanged construction.

The forced circulation type of bearing was eliminated and replaced by a self circulation type using the pumping action between the shaft and metal.

Moreover, in consideration of failure due to oil pressure loss, a counter weight closing type inlet valve was used. Therefore, automatic closing is possible whenever there is a loss in oil pressure.

In consideration of the power station operating system, a small turbine reserve operating system with electric motor was used as the pressure oil apparatus. Normal oil pressure is used 20 kg/cm^2 (24 kg/cm^2 at Akiba No. 2 Power Station).

Excluding the problem of leakage and manufacturing technique, it is more advantageous to maintain the oil pressure as high as possible. It is believed that this trend will be followed in our country in the future.

The method employed to drain the water leakage in the upper face of the water turbine was to drain it down through the stay vane.

The movable parts are lubricated by means of an automatic grease lubricating device. The compressed air generating apparatus is always operated automatically for braking purposes and can also be used for producing pressure oil. The cooling water is supplied through the penstock after passing through an automatic change-over type dust collecter.

2. Generator

The generator is a vertical shaft unbrella type totally enclosed self-cooling 3 phase a-c synchronous generator. It can be used for both 60 and 50 cycles. Its specifications are as follows:

Output:	27,000 kVA
Voltage:	11 kV
Current:	1417 A
Power factor:	0.85 (for 60 cycles)
	1.0 (for 50 cycles)
Speed:	200/167 rpm

Aside from its umbrella type, it has almost the same characteristics and make up as the generator at the No. 2 Akiba Power Station. In other words, the stator winding is of the wave type one turn coil with inner transposition. A 50% acceleration test was conducted on this generator.

3. Control panel and control apparatus

The control panel and apparatus are almost of the same specifications and composition as those for the No. 2 Akiba Power Station. The special characteristic of this control panel is that there is a switching station for switching to various places the electric power generated by the Electric Power Development Company so it is of considerably large scale. Fig. 27 is a skeleton diagram.

IV. CONCLUSION

Although this completes the introduction to the equipment for the No. 1 and No. 2 Power Stations, considerable difficulty was experienced in attempting to introduce, in a limited number of pages, the varied merits and charactors of the power plant equipment. We have therefore limited this introduction to a summary of our views on the principal equipment. We would be happy if the reader appreciates our intentions in manufacturing these equipment. It is a source of great joy to us to be able to report the success of our project with the equipment operating according to expectations. The 38,000 kW Kaplan high head turbine of No. 2 Power Station is the largest capacity water turbine in our country. It appears that the time has arrived when the high head Kaplan turbine will be put to practical use along with other 60 m class Kaplan turbines. Although we adopted the welded construction to a great extent, the results were favorable. These results probably will contribute toward the future construction of hydraulic power plants.

In conclusion, we wish to express our sincere thanks to the members of the Electric Power Development Company for the guidance accorded us from beginning to the end of our research.

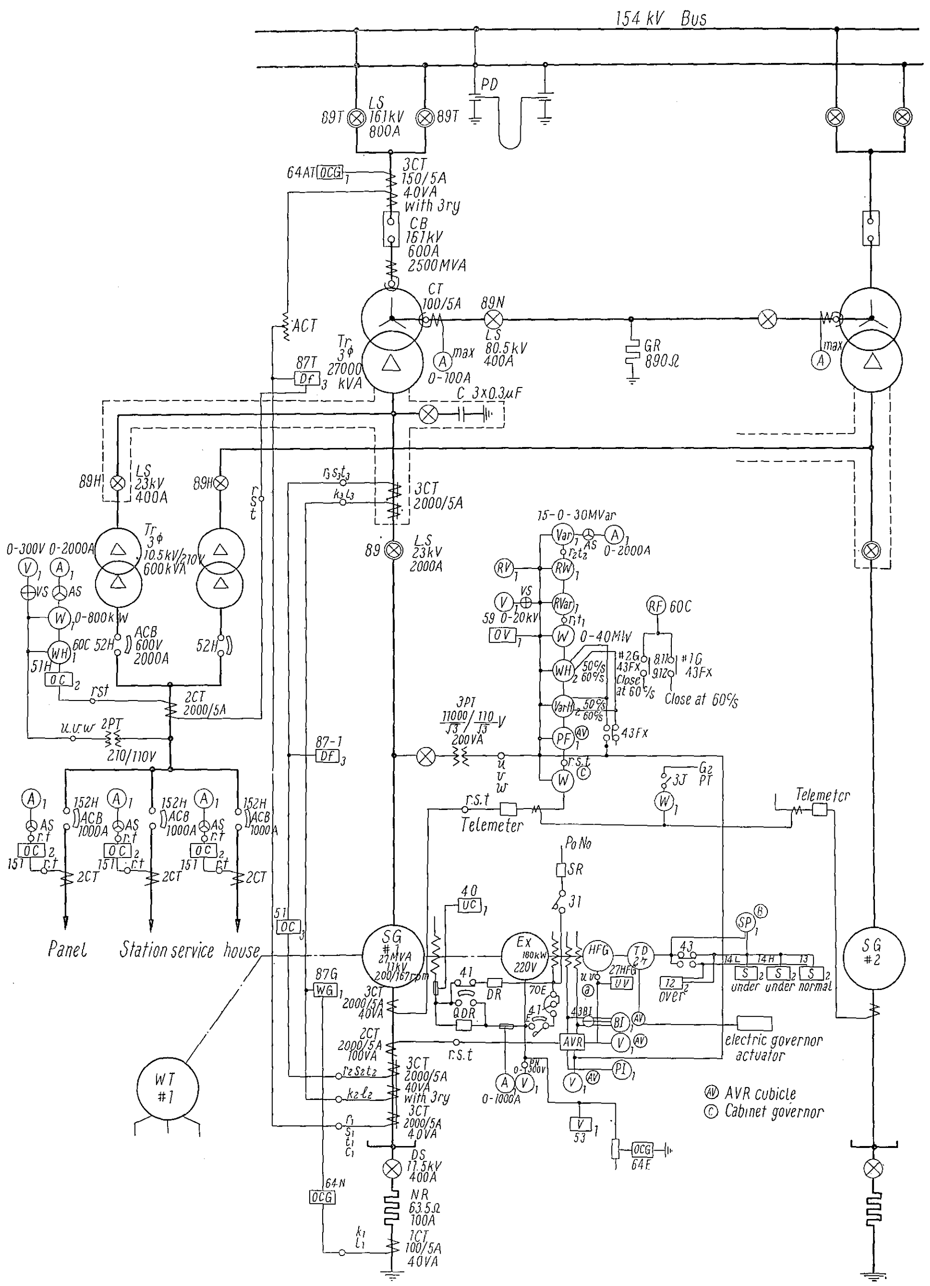

Fig. 27. Skeleton diagram of Akiba No. 1 P. S.

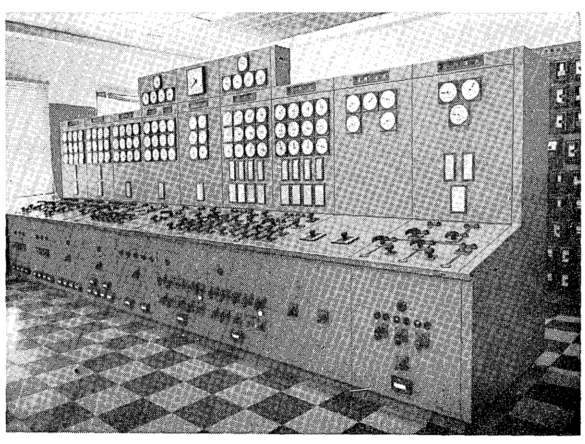

Fig. 28. Main control panel room