UDC 621. 224. 35

58,500 kW KAPLAN TURBINE FOR KANOSE NO. 2 POWER STATION, TOHOKU ELECTRIC POWER CO., INC.

Masahiko Tomimura
Electric Power Div.

I. INTRODUCTION

Fuji Electric has completed a 58,500 kW Kaplan turbine and its auxiliary equipments for Kanose No. 2 power station, Tohoku Electric Power Co., Inc. which have been in commercial operation since the successful inanguration in the end of 1972. Kanose No. 2 power station is located at the downstream of Agano River, Niigata Prefecture.

The existing Kanose power station is located on the opposite side of bank (left bank), and the existing dam is used commonly both for Kanose power station and the new Kanose No. 2 power station.

Agano River, having Tadami River on its tributary and the water sources of Ozenuma and Lake Inawa, has been in several stage developed into a most rich hydro-electric power source, which amounts now approximately 2,000,000 kW.

In the recent trends, that the sharp increase of power and the importance of hydraulic power station as the regulating power source is much more emphasized, the existing Kanose power station was utilizing only 270 m³/sec water as against 430 m³/sec of Kaminojiri power station located upstream of Kanose power station, hence this surplus water should have been effectively utilized and thus Kanose No. 2 power station has been constructed.

The followings are the brief explanation of Kanose No. 2 power station.

II. HYDRAULIC TURBINE

Fuji Electric had been supplying always the record-making Kaplan turbines, for example, 38,000 kW for Akiba No. 2 power station and 43,800 kW for Oyodogawa No. 1 power station. The Kaplan turbine of Kanose No. 2 power station is the largest capacity machine of 5-blades and the largest-dimension one in Japan.

In the design and manufacture of Kanose No. 2 Kaplan turbine, we have based on our rich experiences of designing and manufacturing many Kaplan turbines, and further introduced the latest developments and technology.

1. Some of Special Features are:

1) For the runner, we have newly developed the 5-blade model for high head range, which has superior characteristics of cavitation, and adopted it.
2) Though the water pressure is low due to low head, we have adopted the spiral casing of steel plate which has the strength of only pattern frame.

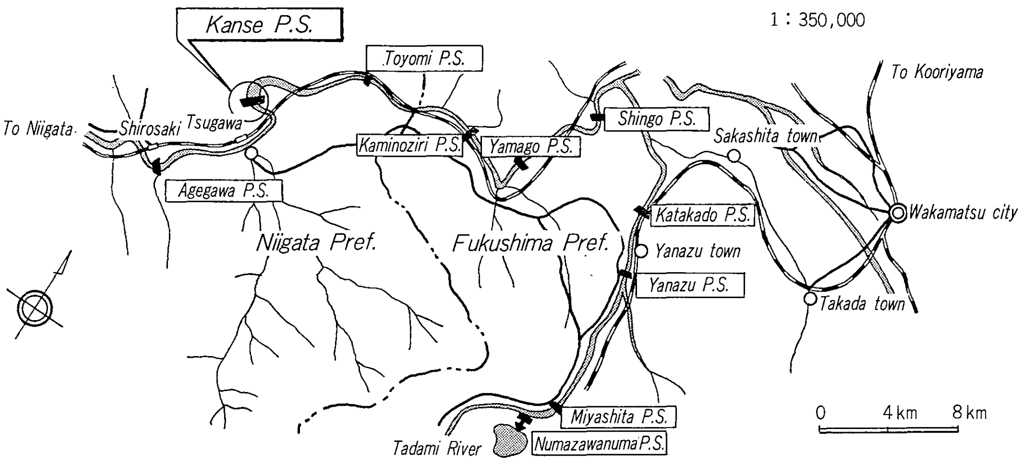

Fig. 1 Location of power stations

Thereby, the erection period was made shorter and the leakage water from the concrete was prevented.

The inlet diameter of spiral casing is 8,600 mm. It is the site-welded construction.

3) The runner servomotor was mounted in the runner boss.
4) The turbine shaft is of welded construction.
5) The guide vanes are of welded construction.
6) The weight of generator thrust bearing is supported on the turbine head cover.
7) The pressure oil is supplied at high pressure of 36 kg/cm².

2. Specifications of Turbine

Type	Vertical Kaplan Turbine (VK-1RS)	
No. of unit	One (1)	
Net head	Max. 22.10 m	
	Rated 21.24 m	
	Min. 19.75 m	
Discnarge	At max. head:	297 m³/sec
	At rated head:	291 m³/sec
	At min. head:	282.5 m³/sec
Output	Max.	58,500 kW
	At rated head:	55,000 kW
	At min. head:	49,400 kW
Rated speed	107 rpm	
Specific speed	550 m-kW	
Runner diameter	6,400 mm	
Runaway speed	High runaway speed 290 rpm	
	Low runaway speed 250 rpm	
Suction head (at casing head)	−2.35 m	

3. Model Test

Kaplan model turbine of 5-blade, which is applicable for the head as high as up to 35 meters and of superior cavitation characteristics has been newly developed.

With this model, the efficiency, cavitation characteristics and runaway speed were tested and confirmed.

All these test results showed the higher figures than the guaranteed value.

1) Efficiency test

With model runner of 400 mm diameter, not only the runner but also the casing, guide vane, and draft tube were made perfectly similar to the prototype turbine.

The results of efficiency test are shown in *Fig. 2.*

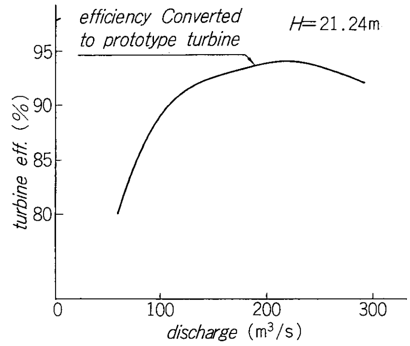

Fig. 2 Turbine efficiency curve

2) Cavitation test

The cavitation test was carried out with the same model turbine as for the efficiency test, at the net head of 14 meter.

Fig. 3 shows the critical cavitation coefficient (δ_c) and the plant cavitation coefficient (δ plant) versus discharge at the maximum net head of 22.1 m and at the minimum net head of 19.75 m.

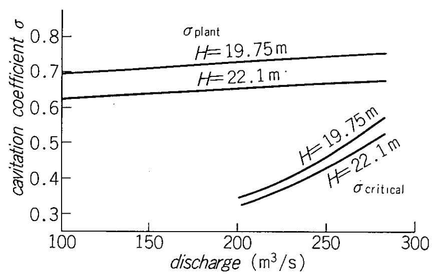

Fig. 3 Cavitation characteristics curves

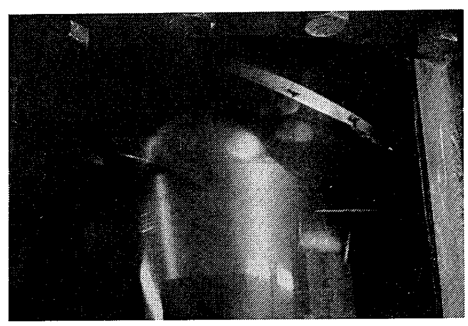

Fig. 4 Cavitation test

In the range of plant cavitation coefficient to correspond to the operation range of the prototype the cavitation was not observed on the surface of runner blade, assuring the enough safety and the superior characteristics.

Fig. 4 shows the cavitation test at the point of maximum net head and full load. A very slight cavitation was observed but on the surface of runner blade no cavitation appeared at all.

3) Runaway test

The factor to decide the runaway speed is the cavitation coefficient as well as the profile of runner blade.

On this model turbine, too, the runaway speed characteristics as against the cavitation characteristics have been measured by the cavitation test rig.

A part of the results of this measurements is shown in *Fig. 5.* During this model test result, the runaway speed of prototype turbine is calculated as 265 rpm (248% of the rated speed), which is enoughly safe value as compared to the guaranteed figure.

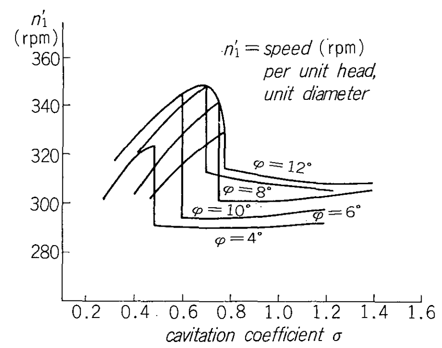

Fig. 5 Characteristic curves of runaway speed

4. Turbine Propoer

1) Outline

Kanose No. 2 turbine has the largest runner diameter (6,400 mm) so far manufactured in Japan. As shown in *Fig. 8* sectional view of water turbine, most of the parts are of welded construction.

In the manufacture, basing upon our rich experiences of large scale Kaplan turbine, we have further studied both on the performance and the economy of the turbine, and adopted several new construction. The following is mainly the description of the turbine proper.

2) Turbine proper

The speed ring is of steel-plate-welded, four (4) pieces split and flange-connection construction.

The vanes of speed ring consist of 12 pieces, which have straight line profile and are welded to the speed ring by means of electro slag welding.

The spiral casing, especially in a low head power stationlike this Kanose No. 2, is generally made of concrete. But, in respect of the shorter installation period and reduction of cost, the spiral casing of steel plate, which serves as pattern frame for concreting has been adopted. Hence, the spiral casing is of so large dimension as its inlet diameter is 8,600 mm.

In case of this spiral casing, though it could be of very small thickness in respect of its own strength because its purpose is only to serve as pattern frame for concreting and measure for water-tightness, the plate thickness of 16∼12 mm was adopted because of convenience for the manufacture and installation.

The water pressure is withstood by the concrete. *Fig. 9* shows the spiral casing under installation.

The spiral casing was transported to the site in 56 pieces-split state and pre-assembled in the site workshop into 28 blocks, then, finally assembled at the installation position by welding and jointed to the speed ring. The total length of site welding line reached as much as approximately 700 mm, which was subjected to X-ray and Ultra-sonic tests, but the water-tight test was deleted.

The speed ring was dispatched to site before the shop assembly of the turbine proper, hence the speed ring was not included in the shop assembly of turbine. This method is now rather a usual practice in respect of large dimension of machine, increased quantity of welding and minimized period of delivery time.

Fig. 10 shows the shop assembly of turbine proper.

The head cover was divided into the outer and inner pieces. The outer head cover is of 4 pieces split and flange-connected construction, and is so arranged that, except extremely special cases, it enable the overhaul work without being taken outside and it can be lifted down into the barrel by use of a special lifting lug.

And also it is so arranged that the guide vane packing provided on the outer head cover can be easily replaced from above without dismantling guide vane arm, guide vane bearing and etc.

The inner head cover is two-split into the upper and lower parts and provided with the air-type water sealing device so as to permit an easy maintenance of the main shaft water-sealing device and the turbine bearing.

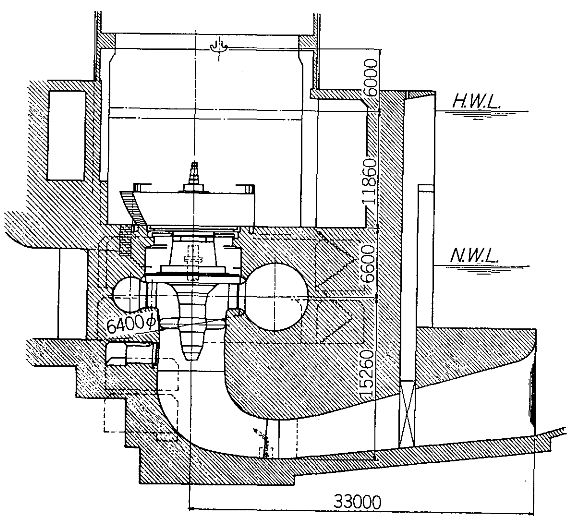

Fig. 6 Sectional view of the power station

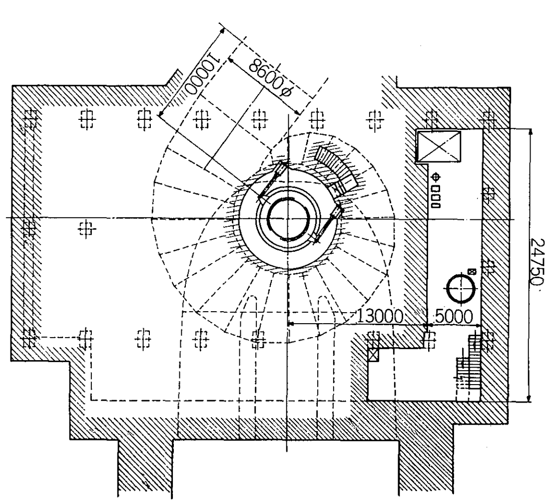

Fig. 7 Plan of turbine floor

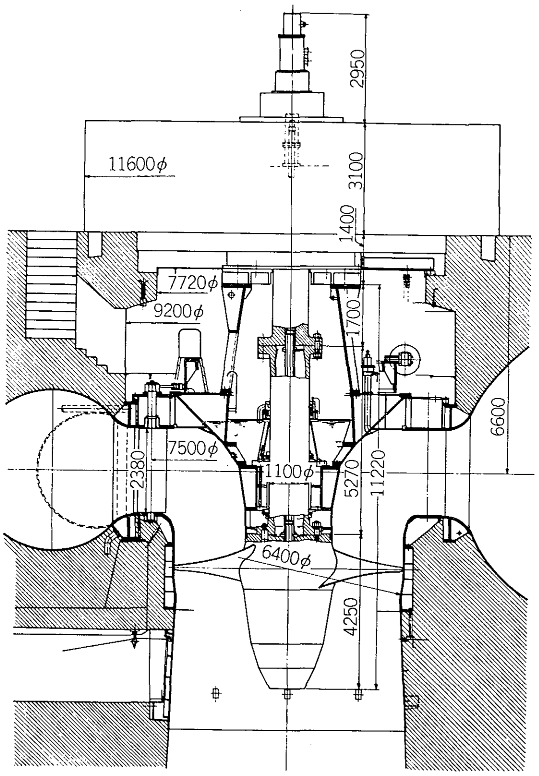

Fig. 8 Sectional view of water turbine

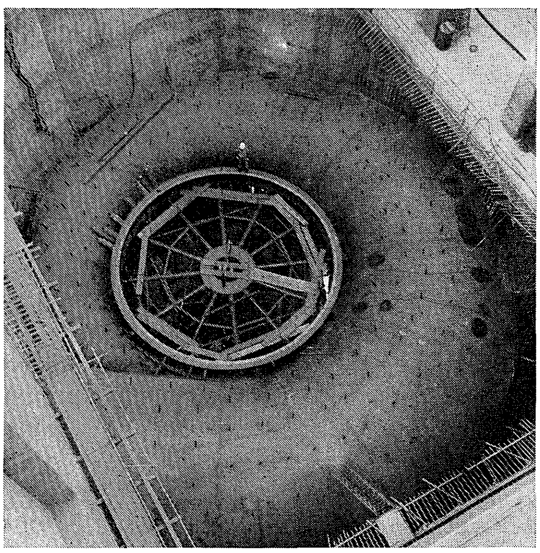

Fig. 9 Installation of spiral casing at site

And also a vaccum valve for prevention of the reverse thrust at the time of load rejection and the vibration detection device for detecting the abnormal vibration at the time of any foreign material clogged on the runner are provided.

In such a large dimension machine like Kanose No. 2 turbine, important point in the structural design is the flexion rather than stress.

Therefore, we have fully applied the Finite Element Method of calculation and analysis for the design of the head cover and other parts.

The bottom ring together with the bolt-connected discharge ring was placed and embedded on the lower foundation.

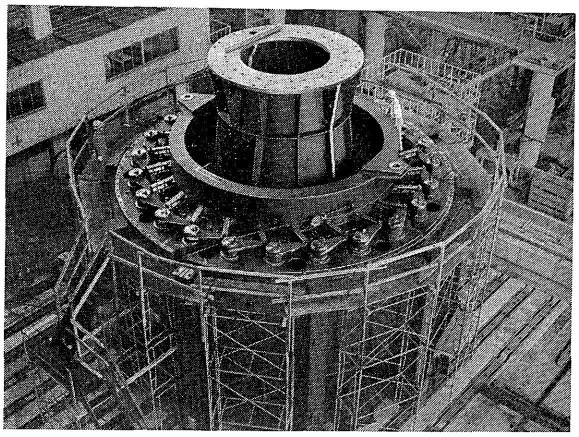

Fig. 10 Shop assembly of water turbine

The water-tightness with the speed ring was done not by packing but by the weld-sealing method. This welding was carried out after concreting. The head cover and bottom ring are provided with replaceable guide vane sheet liner of steel plate.

As *Fig. 8* shows the section of turbine, the weight of generator thrust bearing is supported by the head cover of turbine and transmitted to the bottom foundation through the stay vanes. The discharge ring is of 4 split, semi-sphere and welded construction.

The important part consists of the base metal of general use steel plate with stainless steel lining, and the surfaces to contact with water are applied with errosion resistant materials.

24 pieces of guide vanes are welded construction of SS41P and S25C plates (general plate and structural carbon steel plate), and their blade position is hollow. The guide vane operating mechanism is provided with the alarm device for the break of shear pin, and the adjustment of guide vane blade was done by the eccentric pin.

The turbine bearing is lubricated by grease and located in the water. On both ends of bearing, the labyrinth is provided to feed clear water.

The turbine shaft is 1,100 mm in diameter and 5,270 mm in total length, and is welded construction steel plate (SM 50 B) at shaft portion and of forged steel (SF 50) at flange portion.

The shaft portion is made by bending one sheet plate of 140 mm thickness, and its welding line is one line on/axial direction. The grease-lubricated bearing is much more simplified construction that the oil-content type bearing, hence it was very convenient to adopt the welded construction of turbine shaft.

The water sealing device of the turbine shaft is adopted with both-ends type carbon sealing, which is our standard type and has been used in rich supply records. And as this water sealing device is located above the water level on the head cover, the maintenance is quite easy.

The runner is 6,400 mm in diameter and of 5 blades. The runner boss contains the runner servo-

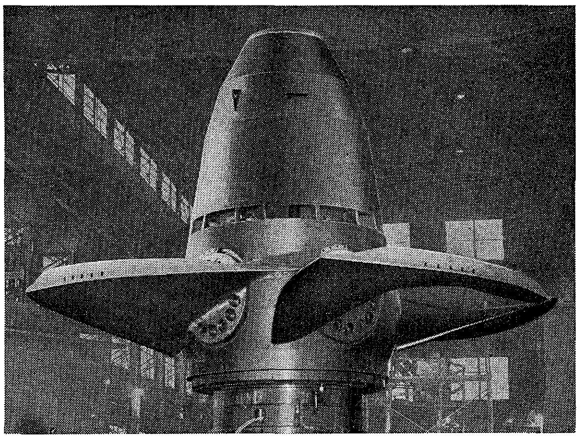

Fig. 11 Runner

motor, in which the piston is fixed and the cylinder is movable. The runner blades are made of stainless steel (SCS 1) and the shaft of runner blade shaft is of forged steel (SF 55).

The runner blade and the shaft are bolt-connected from the outside of runner boss.

By making separate construction of blade and shaft, as above, each can be made of different materials, and the runner, once preassembled in the factory, can be transported, as it is, to the site only without blades, enabling the reduction of man-hours of assembly and disassembly. On the circumference of runner blades, the erosion liner is provided to prevent the pitting by gap cavitation.

The vertical position balancing method was adopted for balance test of runner.

Fig. 11 shows the runner being installed.

The lubrication oil in the runner boss varies its oil quantity in response to the movement of runner servomotor. To keep the oil pressure constant, many methods have been applied. However, this turbine is adopted the method, which eliminated the change of volume and keeps it constant. This method does not require any special device at all, hence the stable performance and the simplified maintenance are assured.

The runner vane packing can be replaced without dismantling the blades.

The oil head is provided on the generator and two coaxially placed oil feed pipes connects between the oil head and the runner servomotor. One of above two pipes serves also as the return rod of runner servomotor.

5. Auxiliary Equipments

1) Governor and oil pressure equipments

The governor is our standard TRANSIDYN type electric governor, and the Kaplan cam is a conventional cam. As Kanose No. 2 power station has the head whose variation is rather small, we have confirmed in the model test that the adoption of the conventional cam does not make any substantial difference of efficiency in comparison with the three-dimensional cam.

The oil pressure equipment is M-M type and, under the recent trend of making compact the equipment by applying higher oil pressure, the control oil pressure is adopted a high pressure of 34∼37 kg/cm^2.

The compressed air to the pressure tank is automatically done by air compressor, that is, on the conditions given by the oil level switch, unloader and oil pressure relay, the compresses air is automatically supplied when air quantity is short and oil level is high.

The greasing device is provided with the bulk tank which has capacity good for approximately 6 months and feeds to respective grease tank, permitting a simplified maintenance.

2) Water feed equipment

The cooling water to the main equipment is taken from the casing and fed, via an automatic strainer, directly to the main equipment. When the quantity of cooling water comes down, the standby strainer is automatically switched in.

The water to the sealing water device of shaft and the bearing labyrinth is taken from the dam and stored once in the intermediate tank by being pumped up by the specially provided water feed equipment.

As standby, this water can be also taken from the spiral casing and is, after pressurized by the pump, supplied.