



**دانشنامه مرجع مهندسی ایران**

**Iran Engineering Reference Encyclopedia**

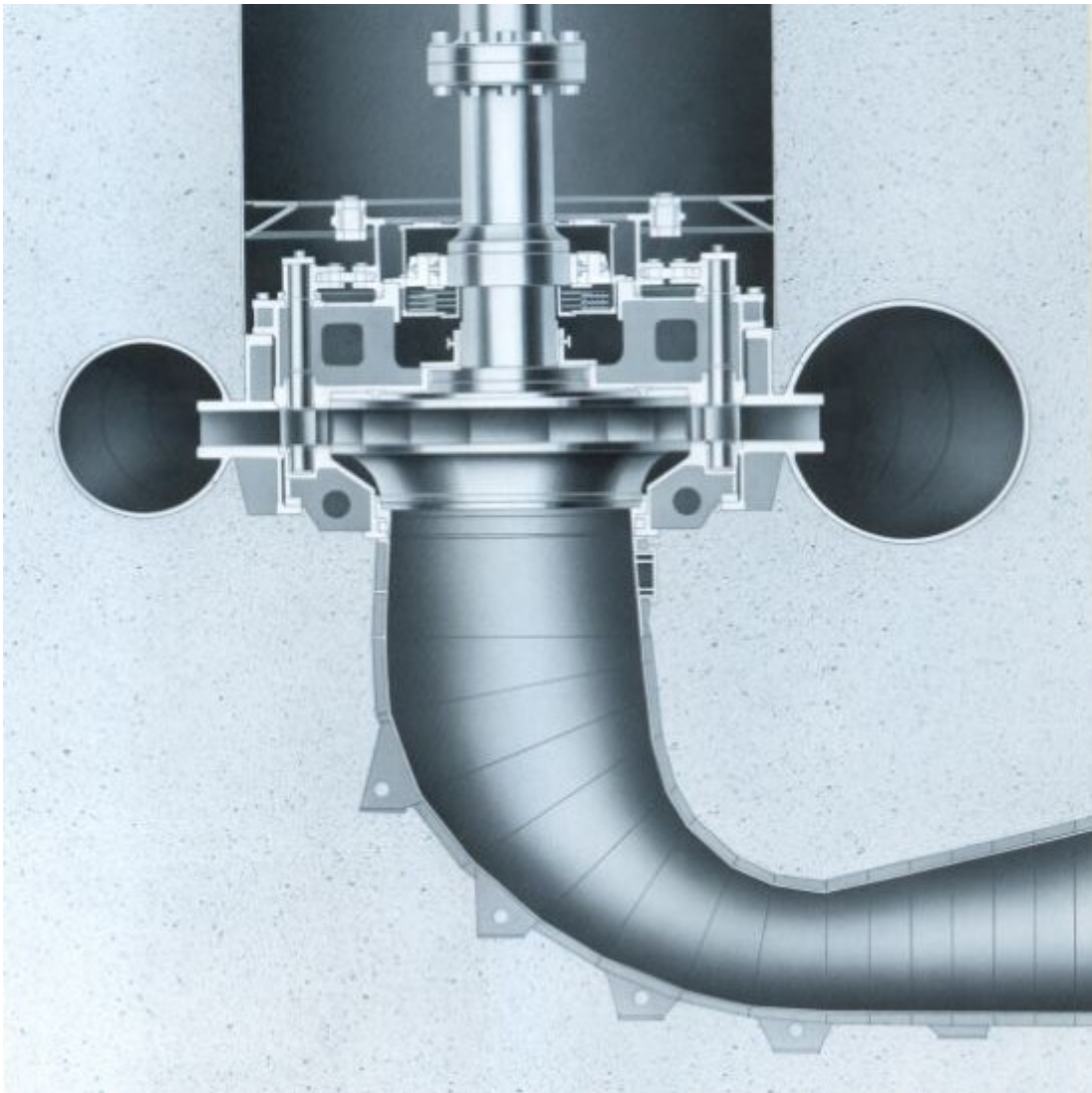
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## Hydraulic Turbines

### 1. FRANCIS TURBINE

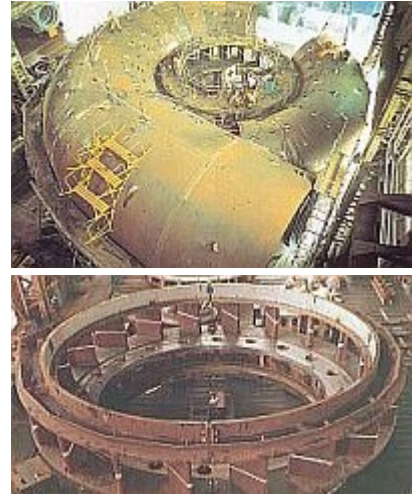
Francis turbines are most widely used among water turbines and the development of the Francis turbines in the last decade has opened up a large range of new application possibilities for this type. These advances, motivated by a search for maximum profitability, have become possible as the result of improved knowledge of the water flows in turbines and other hydraulic phenomena.

A complete investigation and intensive research are carried out and efforts are put forth in the improvement of turbine performance, the selection of suitable materials, and the construction design in consideration of difficulties imposed by mechanical, manufacturing, and maintenance factors at the design stage.



### SPIRAL CASE and STAY RING

The hydraulic research of the water passage through the spiral case to stay vanes becomes very important in diminishing the losses of the flow and the angle and the shape of stay vane cascades are carefully designed. A new type of construction (parallel type) advantageous in structural design is applied to all the stay rings. The spiral case is made of steel plates for welded structures or high tensile strength steel plates. TOSHIBA has used 60 or 80 kg/mm<sup>2</sup> high tensile strength steel plates for spiral case shell plates of a big turbine or a high-head strength turbine. From the view point of field welding, the spiral case shells are accurately cut out by automatic gas-cutting machines, contributing to perfect field assembly even without a temporary shop assembly check.



### RUNNER

TOSHIBA is always making best efforts to design and manufacture highly efficient runners to meet all requirements or Specifications. The runner is designed in consideration of various parameters for computation by both theoretical analysis of internal flow and experimental investigation by model tests. The runner is usually made of carbon steel castings and overlay coating of stainless steel welding will be made on critical areas of cavitation if necessary. For higher head machines, the runner is made of stainless steel castings. Especially 13%a Chrome steel with enriched Nickel content becomes widely used for its excellent anti-cavitation corrosion characteristics and mechanical strength.

### MAIN SHAFT

The main shaft for the turbine is made of high grade forged carbon steel. The main shaft is connected to the generator shaft or the intermediate shaft by a flange coupling. The shaft surface passing through the shaft seal is protected with a stainless steel shaft sleeve to prevent the main shaft from wearing.

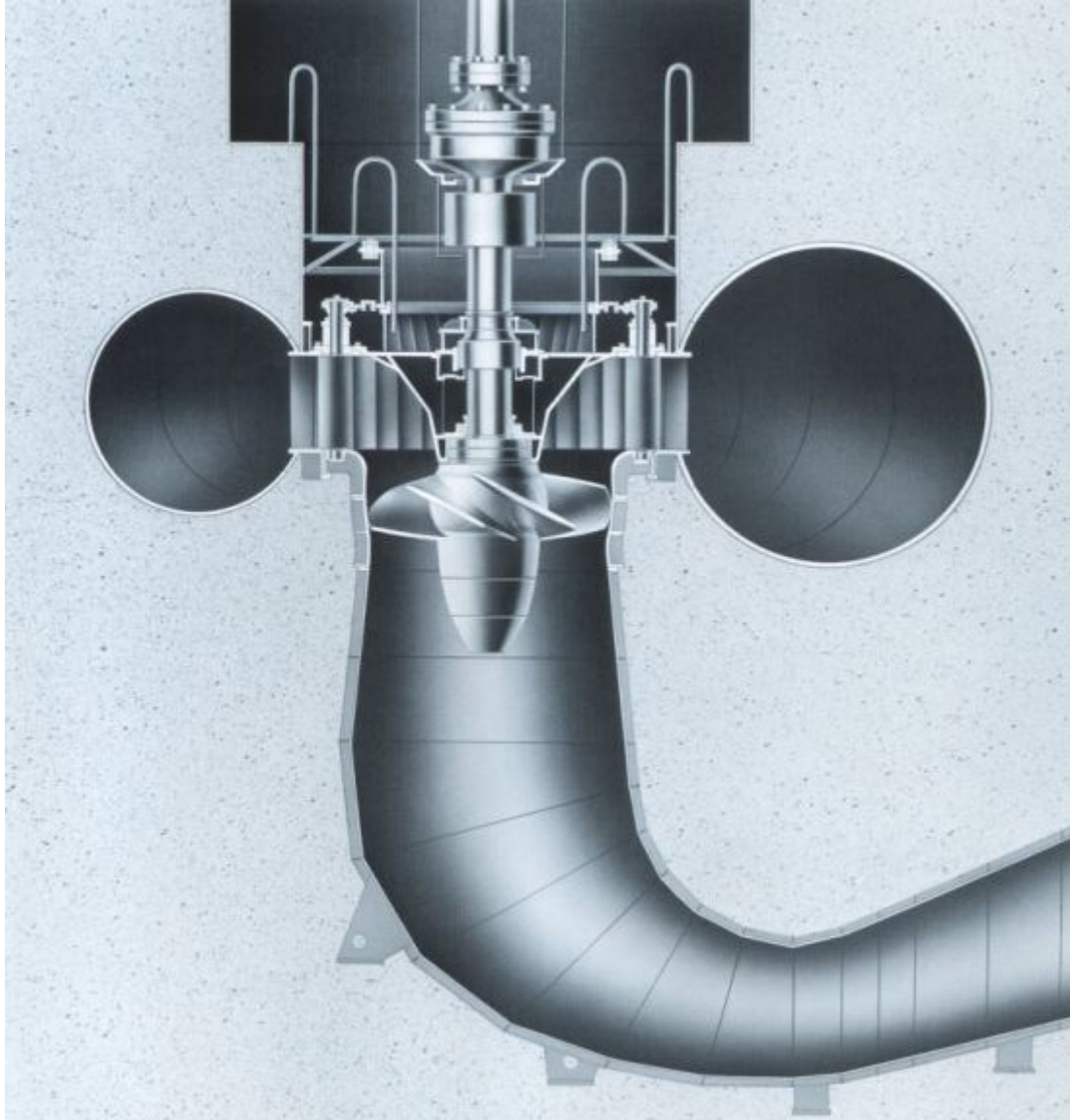


### DRAFT TUBE LINER

The most commonly employed draft tube is of elbow type, in a concrete structure, fixed with anchoring materials. Overall configuration of the draft tube is thoroughly checked at Toshiba Research Laboratory to ensure effective use of the head energy. The draft tube liner, of welded construction, is made of steel plate for general structure. If necessary due to theoretical and practical reasons, a special air admission system is provided with a draft tube liner to reduce water-pressure pulsation in the draft tube.

## 2. KAPLAN TURBINE

Kaplan turbine is most appropriate for operation with a low head and a large amount of discharge. Owing to adjustable runner blades it offers the significant advantage to give high efficiency even in the range of partial load, and there is little drop in efficiency due to head variation or load. As a result of recent advances, the range of Kaplan turbine applications has been greatly improved, which favors numerous undeveloped hydro sources previously discarded for economic or environmental reasons. As having adjustable runner blades, the construction of Kaplan turbine becomes naturally a bit complicated. The runner blade operating mechanism consists of a pressure oil head, a runner servomotor, and the blade operating rod inside the shaft etc.

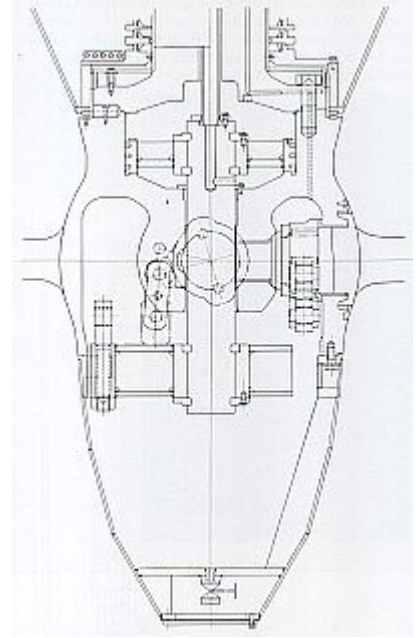


## RUNNER BLADES

The runner blades are operated to smoothly adjust their blade angles by a link mechanism. Their mechanism is installed inside the runner hub, containing the runner blade and stem, the link crosshead and so on. A high quality lubricating oil is filled inside the runner hub to lubricate the mechanism interior. The special packing are installed between the runner hub and blade stem to prevent both water intrusion from the outside of the runner hub and leakage of lubricant oil to the outside, as shown in the figure.

Drawing right: Construction of runner hub

Picture below: Oil head



## OIL HEAD

The pressure oil head supplies pressure oil for the blade servomotor and serves to feed back motion of the servomotor to the speed governor. It is usually installed on the top of the generator.

The runner blade servomotor is installed between the main turbine shaft and the generator shaft or inside the runner hub as shown in the figure below. Suitable location of the servomotor is selected by duly considering mechanical and space factors.

## BEARING

The main guide bearing of Kaplan turbine is usually designed to have a construction with a grease lubricated system. In turbines with large dimensions or high revolving speeds, an oil-lubrication guide bearing system is adopted, with a cooling coil located inside the bearing oil reservoir for cooling the oil. Recently, to fulfill requirements for easy maintenance and low friction loss of the bearings, water-lubricating guide bearings are widely used as a sort of oil-less bearing.

Picture left: Water lubricating guide bearing

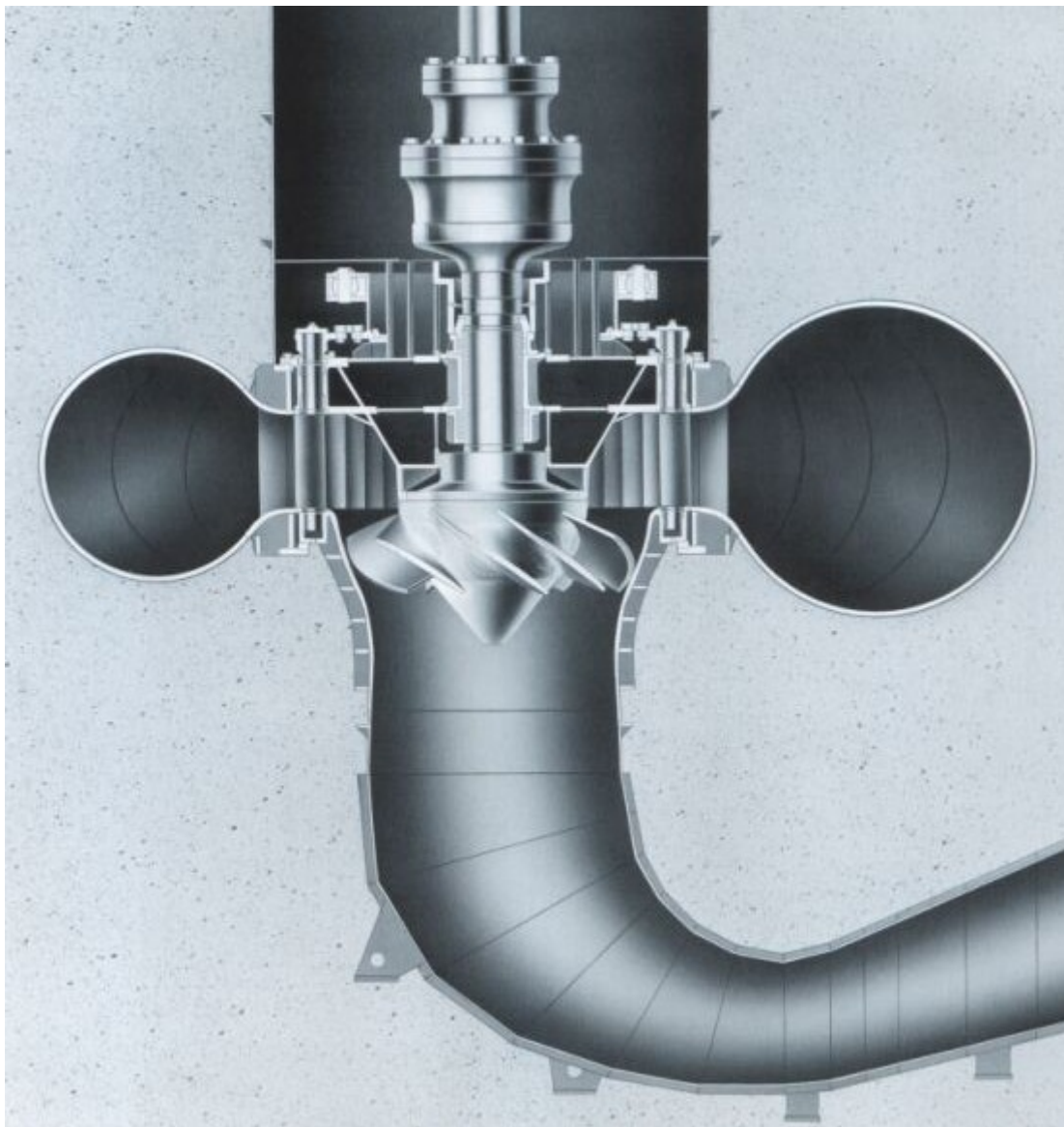
### 3. DIAGONAL FLOW TURBINE

The Diagonal flow turbine has the remarkable features that excel Kaplan turbine in the performance for high head, through the former's construction is very similar to that of Kaplan turbine in considering the adjustable runner blades.

The Diagonal flow turbine, as a result of using adjustable runner blades, offering excellent advantages:

(1) it becomes possible to operate smoothly and to display high efficiency over a wide range of head and load, so that this type turbine is suitable for a power station with wide variation of head or large variation of discharge,

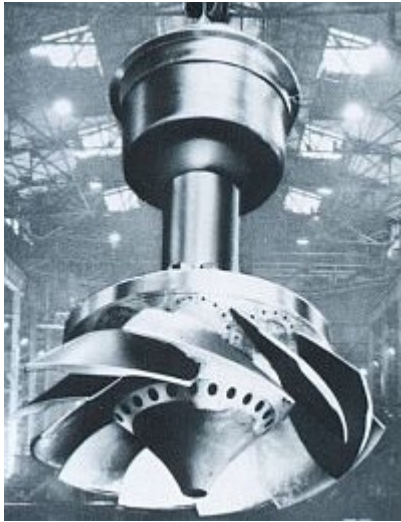
(2) it is available to select a higher revolving speed for given hydraulic conditions, compared with Francis turbine.



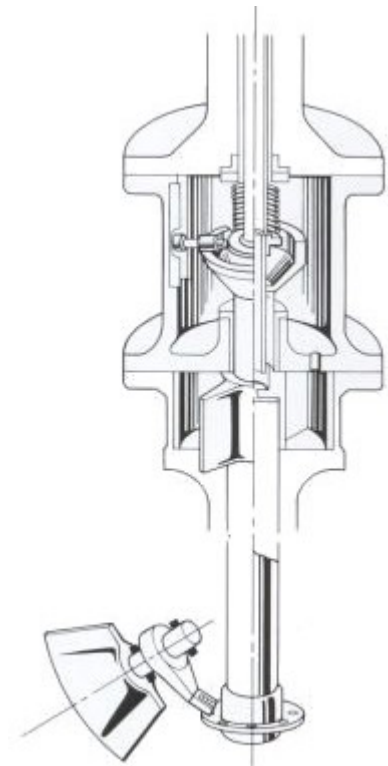
## RUNNER and BLADES

The Diagonal flow turbine has runner blade stems constructed at a certain diagonal angle to the vertical center line of the machine. Therefore, construction of the operating mechanism tends to be more complexity in a smaller space than that of Kaplan turbine. For these reasons, TOSHIBA Diagonal flow turbine employs compact, efficient arrangement for the runner blade operating mechanism, as shown in the figure. The runner blade servomotor is normally of rotary type, not like the type of Kaplan turbine, located inside the turbine shaft or the runner hub.

Rotating movement of the servomotor piston is transmitted to the spider inside the runner hub through the piston rod. Slide block is provided for each connection of the spider and the blade arm, and it conveys the rotating motion of the spider to the runner blade stem.



Runner with main shaft

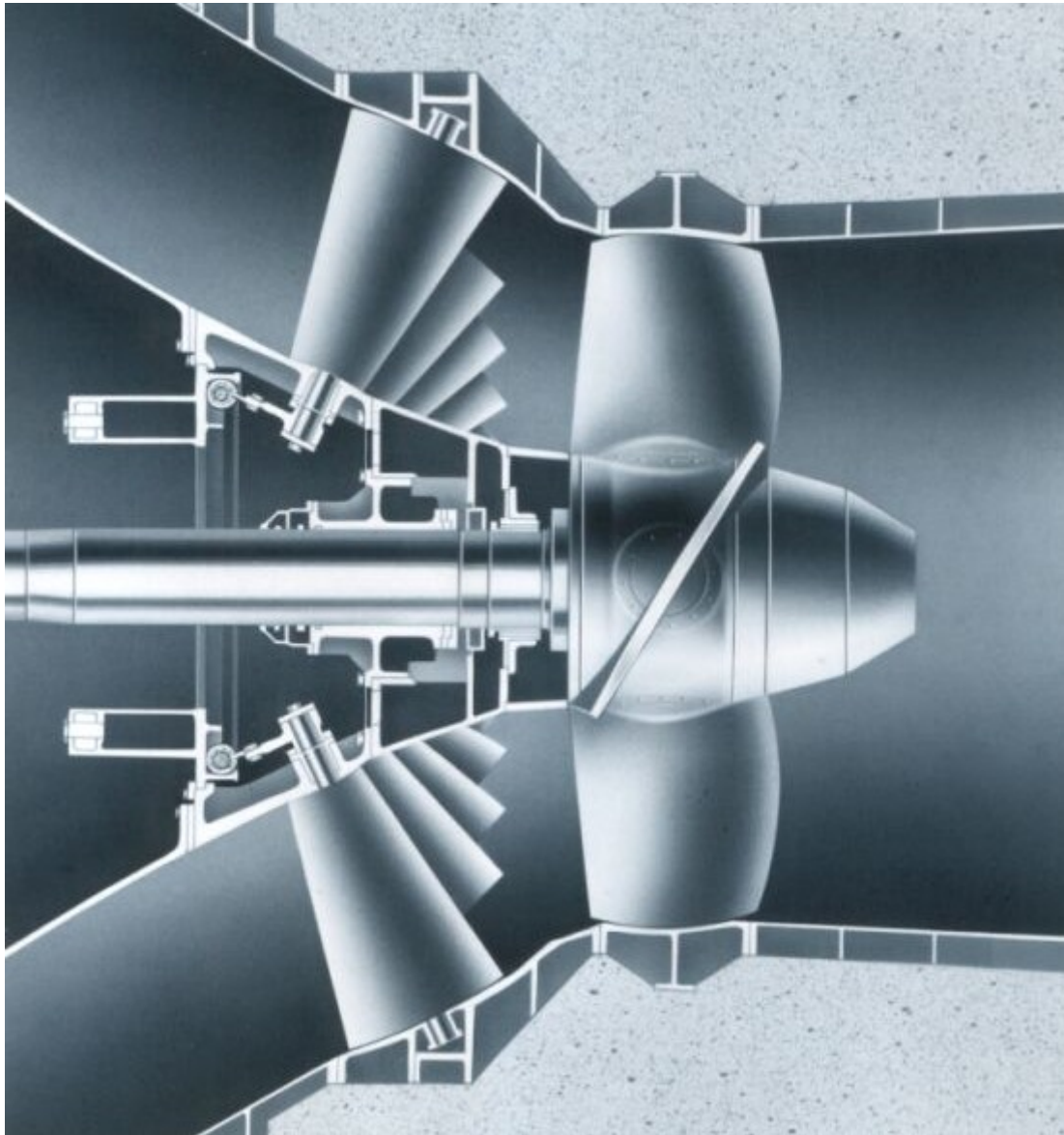


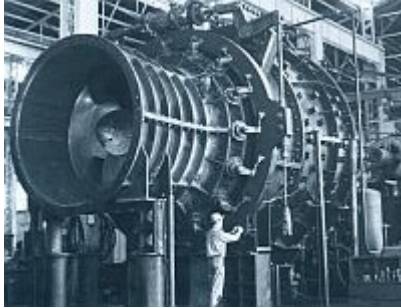
Runner blade operating mechanism

#### 4. TUBULAR TURBINE

Tubular turbine, gaining increasing interest throughout the world, is often selected in place of Kaplan turbine as a machine especially suitable for low-head development. Since the tubular type requires less space than other turbines, a saving in civil costs is realized due to a smaller powerhouse and shallow requirements for the draft tube. There are two types for this turbine, the pit type and the bulb type.

The tubular turbine is equipped with adjustable wicket gates and adjustable runner blades. This arrangement provides the greatest possible flexibility in adapting to changing net head and changing demands for power output, because the gates and blades can be adjusted to their optimum openings.





Tubular turbine: shop assembly



Wicket gates

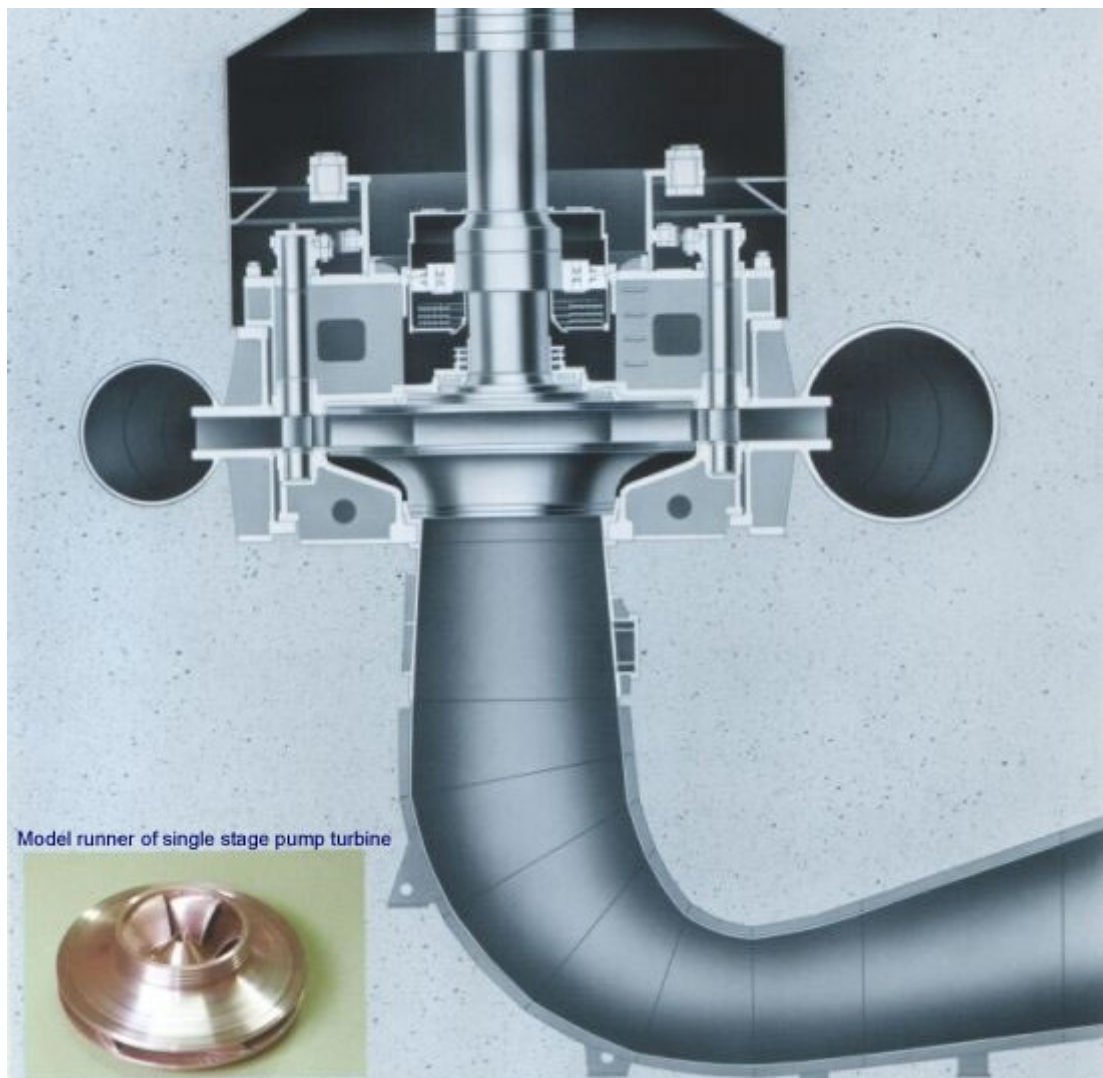
The **wicket gate** operating mechanism is installed inside the inner casing or outside the outer casing; and in both cases, spherical bearings are used to ensure highly smooth operation. The runner blade servomotor is contained in the runner hub, and the pressure oil for it is supplied from the oil head at the upstream end of the generator shaft. While, the runner hub is filled with lubricant oil fed from a gravity tank, which is located on the upper floor of the power house.

As the turbine shaft seal, a mechanical seal or a labyrinth-type seal is adopted for easy maintenance. An opening in the concrete structure is provided around the discharge ring and the runner is installed or dismantled through that opening.

## 5. PUMP TURBINE

Since pumped storage power plants were constructed as a powerful and economical measure for the storage of electric power, various efforts have been undertaken to improve the economy and the reliability of these plants. Recent technology concerning single-stage pump turbines has been explored and developed toward realization of higher head and larger capacity machines.

Figure in next page shows TOSHIBA remarkable trends of single stage pump-turbines towards higher heads since the 1960's; 545m in Ohira Power Station is the worlds highest pumping head in operation as of 1981 and it reached 621 m as represented by an installation at Bajina Basta Power Station. Based on these achievements, TOSHIBA is presently manufacturing 216MW pump-turbines with 701 m head for Chaira Power Station in Bulgaria. The trend will continue further and will expectedly reach 800m or even 900m within the next decade.

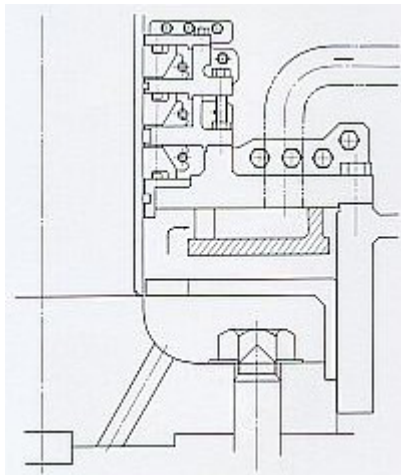




256MW / 545m head Pump-turbine

### Higher head pump-turbines

To cope with further needs for higher head pump-turbines, extensive developmental work has been undertaken at the TOSHIBA hydraulic laboratory and the design department. In case of a head exceeding the limit for single-stage pump-turbines, multistage pump-turbines are adopted. To provide load regulation capability, developmental study is under way on multistage pump-turbines with movable wicket gates.

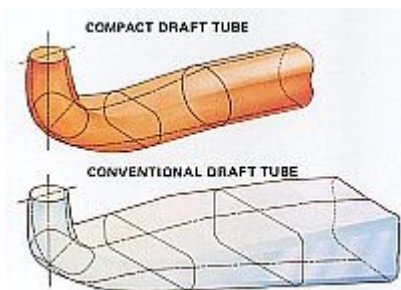


Air Release system

TOSHIBA has recently developed a model of a 2-stage pump-turbine with movable wicket gates for a head of 1,250m, and furthermore, the model characteristics under a real head were satisfactorily verified by using a "Real-head High-power Test Rig" which is capable of testing up to 2,000m in head for a multistage model. Based upon the model test results, the structural design and control methods of the prototype have also been established.

Special attentions, in TOSHIBA design criteria, are given to the air release system after dewatering in pump start, the wicket gate sealing, compact type draft tube and so on.

A partition wall is provided near the air release pipes and it was proven to be greatly effective to prevent the choking of the air release pipes with water; consequently this construction contributes to the quick startup of pump operation.



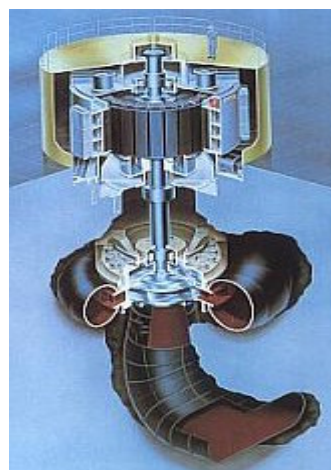
Comparison of Draft tube

A special seal ring around the wicket gate stem is fitted for high head machines, in addition to seal packing installed between wicket gates and facing plates. When the impeller-runner is rotating in air, the seal ring displays very satisfactory results for minimizing the power loss to about one-third of the value of a design without such a seal.

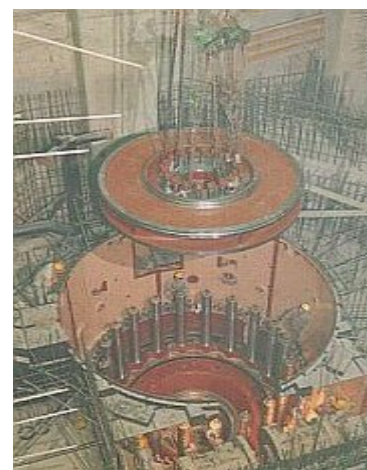
TOSHIBA has developed "the compact draft tube" which is appropriate for an underground power station. It has shorter vertical height and there is less area at each section than those of the conventional draft tube. This draft tube contributes greatly to a saving in the capital cost for excavation and reinforcement around the draft tube.



Compact draft tube



115.8MW/182.2m head Pump-turbine



207MW/539m head Pump-turbine

#### Reference

Web site: [http://www.atals.com/newtic/hyd\\_tbfr.htm](http://www.atals.com/newtic/hyd_tbfr.htm) <http://smsm.ir>