CHAPTER 9

Bulb Turbines

Introduction

The Bulb turbine is a reaction turbine of Kaplan type which is used for the lowest heads. It is characterised by having the essential turbine components as well as the generator inside a bulb, from which the name is developed. A main difference from the Kaplan turbine is moreover that the water flows with a mixed axial-radial direction into the guide vane cascade and not through a scroll casing. The guide vane spindles are inclined (normally 60^o) in relation to the turbine shaft. Contrary to other turbine types this results in a conical guide vane cascade.

The Bulb turbine runner is of the same design as for the Kaplan turbine, and it may also have different numbers of blades depending on the head and water flow.

9.1 General arrangement

A general arrangement of a Bulb turbine plant[/1/] is shown in Fig. 9.1 by a vertical section through the unit. Fig. 9.2 shows the turbine design in more detail.

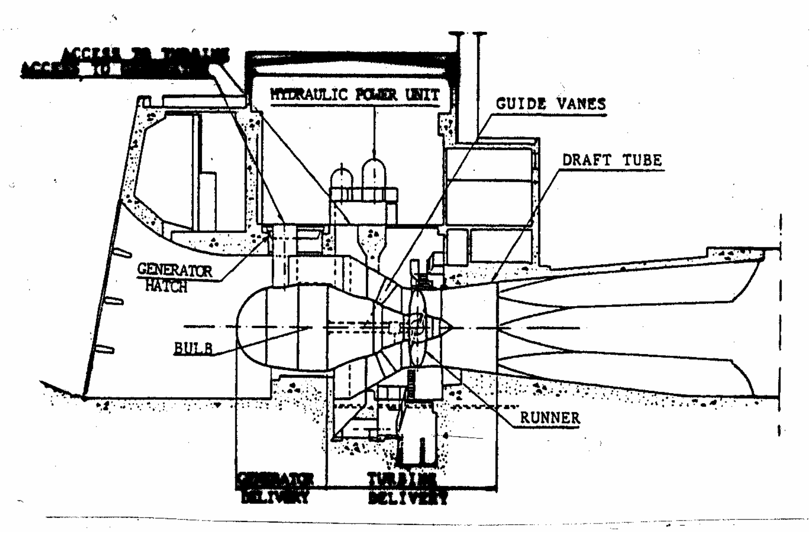


Fig. 9.1 Bulb turbine. General arrangement /1/

The water flows axially towards the unit in the centre of the water conduit and passes the generator, the main stays, the guide vanes, runner and draft tube into tale race channel.

9.2 Main components

The Bulb turbine consists of the following main components:

- stay cone
- runner chamber
- draft tube cone
- generator hatch
- stay shield
- rotating parts

- turbine bearing
- shaft seal box
- guide vane mechanism

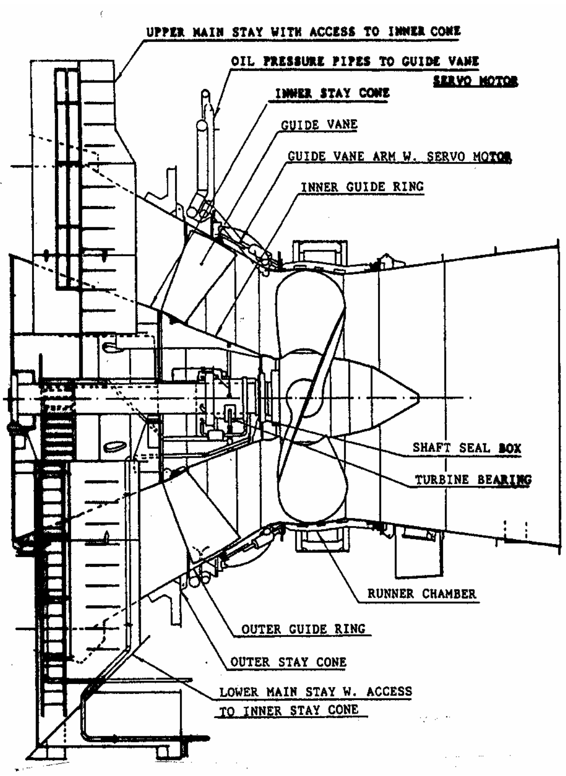


Fig. 9.2 Bulb turbine (Courtesy of Kværner Brug)

9.2.1 Stay cone

A longitudinal section through a stay cone structure and draft tube/1/ is shown in Fig.9.3. There are one lower (1) and one upper (5) main stay. An inner stay cone (3) and outer stay cone (6) are welded to the main stays. To the downstream end of the inner stay cone the inner guide ring is bolted as shown on Fig. 9.2.

This outer stay cone forms a part of the outer water conduit contour and is embedded in concrete together with outer parts of the main stays. The generator bulb is bolted to the upstream end of the inner stay cone as indicated on Fig. 9.1. These parts are located in the centre of the water flow and forms the inner water conduit contour together with the runner hub.

Two side stays (4) and (7) on Fig. 9.4, are located on each side of the bulb upstream of the main stays for stiffening the bulb and avoid resonant vibrations.

The total weight and the hydraulic forces are transferred to the surrounding concrete through the stay cone via the two main stay vane structures. The dynamic as well as the static forces from the turbine and the generator are transferred through the structure to the building foundation.

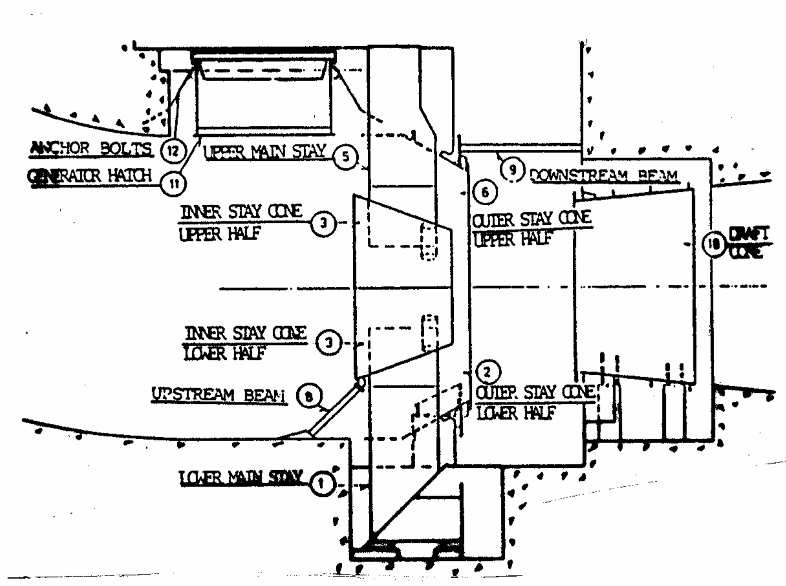


Fig. 9.3 Stay cone and draft tube. Vertical section(Courtesy of Kværner Brug)

9.2.2 Runner chamber and draft tube cone

The runner chamber is the connecting part between the outer stay cone and the draft tube cone, Fig. 9.2. The downstream end of the outer cone is provided with a flange to which the runner chamber is bolted.

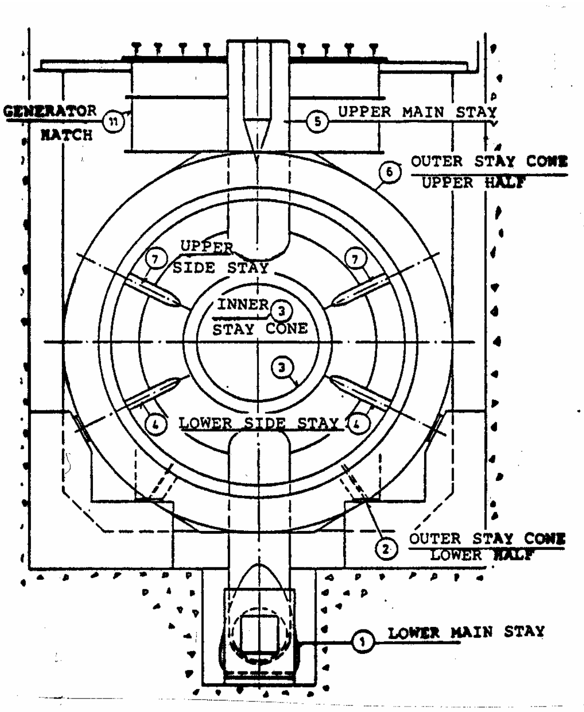


Fig. 9.4 Cross section of stay cone (Courtesy of Kværner Brug)

The draft tube cone consists of two or more straight welded steel cones and is embedded in concrete. The upstream end is connected to the runner chamber through a flexible telescope connection. This type of connection is necessary to allow for a certain axial movement of the runner chamber and the outer guide ring because of elongation/contraction due to temperature changes.

The length of the steel cone lining is determined by requirements to maximum water velocity at the exit and to avoid damage to the concrete.

9.2.3 Generator hatch

The generator hatch (11) on Fig. 9.4 is normally a part of the turbine delivery. It is located above the generator and provides access to the generator for assembly or dismantling tasks.

The hatch consists of a perforated part which forms the outer water conduit contour in the hatch opening. A cylindrical steel mantel with a flange on top is provided for the hatch cover and seal mounting. As the unit's bulb part will rise and lower with filling and draining of the turbine, the seal joint between mantel and hatch cover must allow for a vertical movement of the mantel.

9.2.4 Stay shield

The stay shields are located between the generator access shaft and the turbine main stay. They form an even wall for the water flow and the stay structure is streamlined at the upstream end to prevent undesired vortex formation. The shields are bolted to the bulb and connected to each other by screw stays for stiffness. They are freely supported against the access way and the main stay to allow for axial movements.

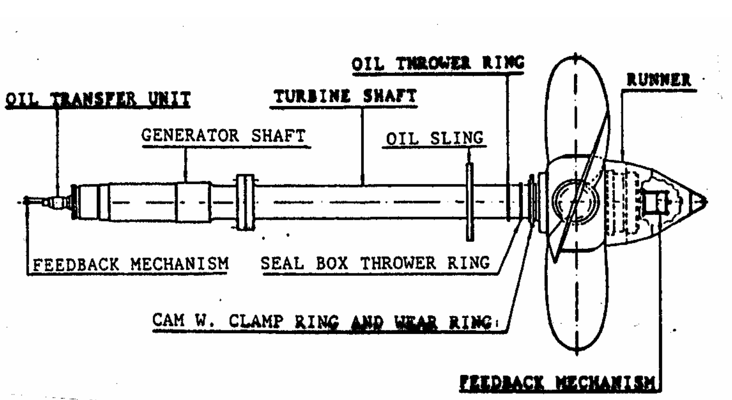


Fig. 9.5 Bulb turbine rotating parts (Courtesy of Kværner Brug)

The shields are provided with a manhole for inspection and possible maintenance of the space between them.

9.2.5 Rotating parts

The rotating parts are shown on Fig. 9.5 and consists of:

-runner
-turbine shaft

- shaft seal cam, clampring, wear ring and oil thrower ring
- turbine bearing oil thrower ring
- feedback mechanism and oil piping
- oil transfer unit from rotating to stationary parts

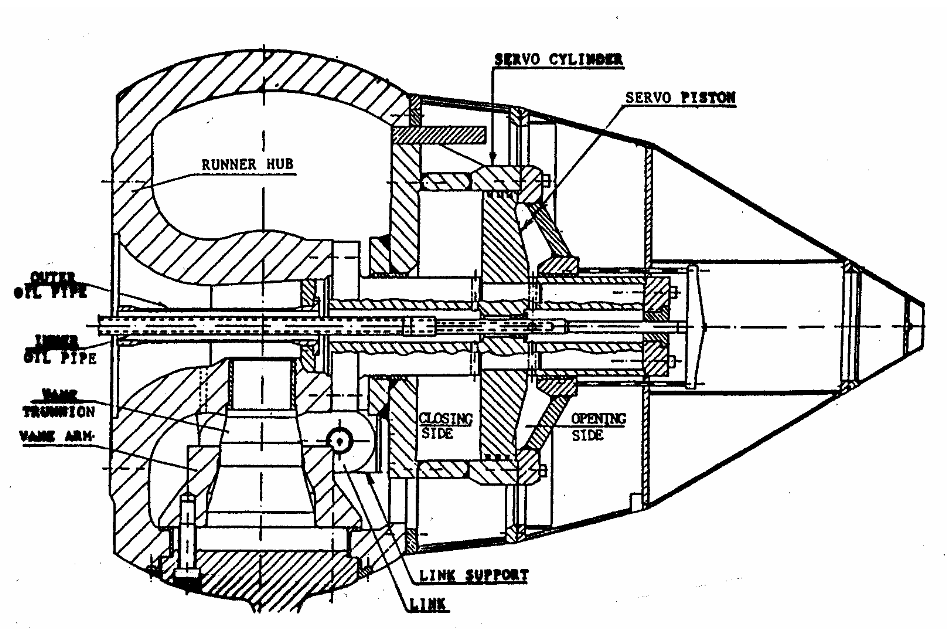


Fig. 9.6 Runner hub (Courtesy of Kværner Brug)

9.2.5.1 The runner

The runner[1] is similar to a Kaplan runner and has normally three to five blades made of stainless steel. The blades are designed with flanges and connected to trunnions and levers.

The servomotor for moving the blades is normally located inside the hub as shown on Fig. 9.6. The servomotor consists of a fixed piston and an axially moving cylinder and link supports, links and blade levers are located inside the hub.

A photo of a bulb turbine runner is shown on Fig. 9.7.

9.2.5.2 The turbine shaft

The turbine shaft is made of forged Siemens Martin steel and has flanges in both ends. One end is connected to the runner hub and the other to the generator shaft. These joints are pure friction joints.

9.2.6 Shaft seal box

Several types of shaft seal boxes are in use. One type as shown in Fig. 9.8 is however, especially for the Bulb turbines[1].

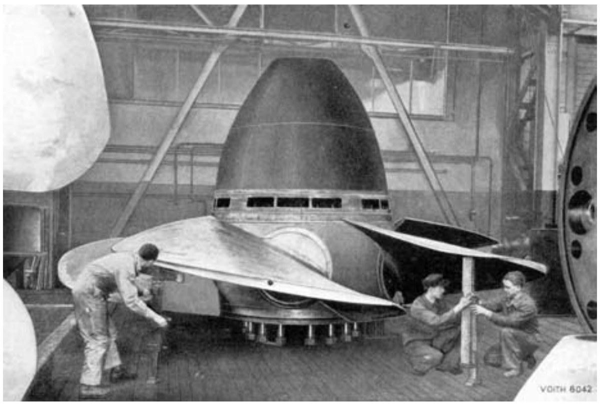


Fig.9.7 Runner assembly in the workshop

This box has radial seal surfaces consisting of a stainless hardened wear disk and two wear rings made of teflon type fibres. The wear disk is bolted to a cam fixed to the shaft. The wear rings are glued to the seal ring.This is movable and supported in the adjustment ring by means of a membrane.

The membrane allows the seal ring to move axially 5 - 6 mm. This is necessary for the shaft movement in the downstream direction when the unit is loaded. In addition allowance must be made for wear of the seal surfaces.

The adjustment ring is bolted to the support ring and may be axially adjusted by means of double acting jacking screws. According to the wear range of wear rings the adjustment range of the seal box should be 8 - 10 mm.

The auxiliary seal is located in the support ring. This may be pushed against/pulled away from the cam by means of push/pull jacking screws. When this ring is in contact with the cam the wear seal rings may be dismantled without draining the unit.

Possible water leakage into the seal box is drained through a pipe to the pump sump.

A thrower ring is mounted on the shaft to prevent water leakage along the shaft. A rubber ring is mounted on the upstream end of the shaft and seals against the seal box cover.

The seal box is provided with four springs which are pressing the wear seal rings against the seal surface to prevent leakage when the balance system is out of operation, e.g.,when filling the turbine.

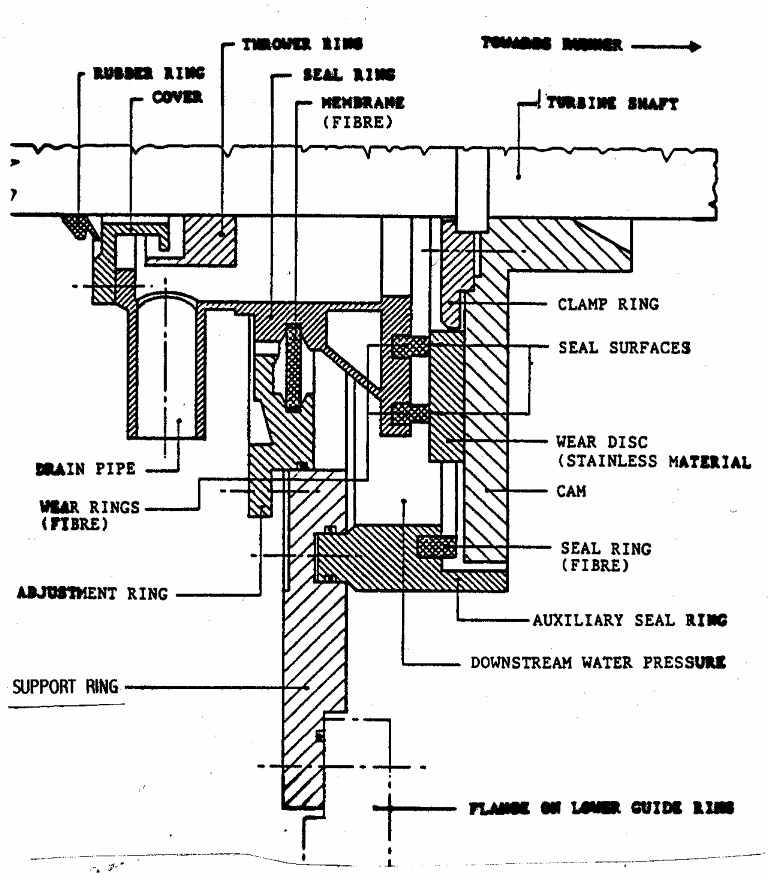
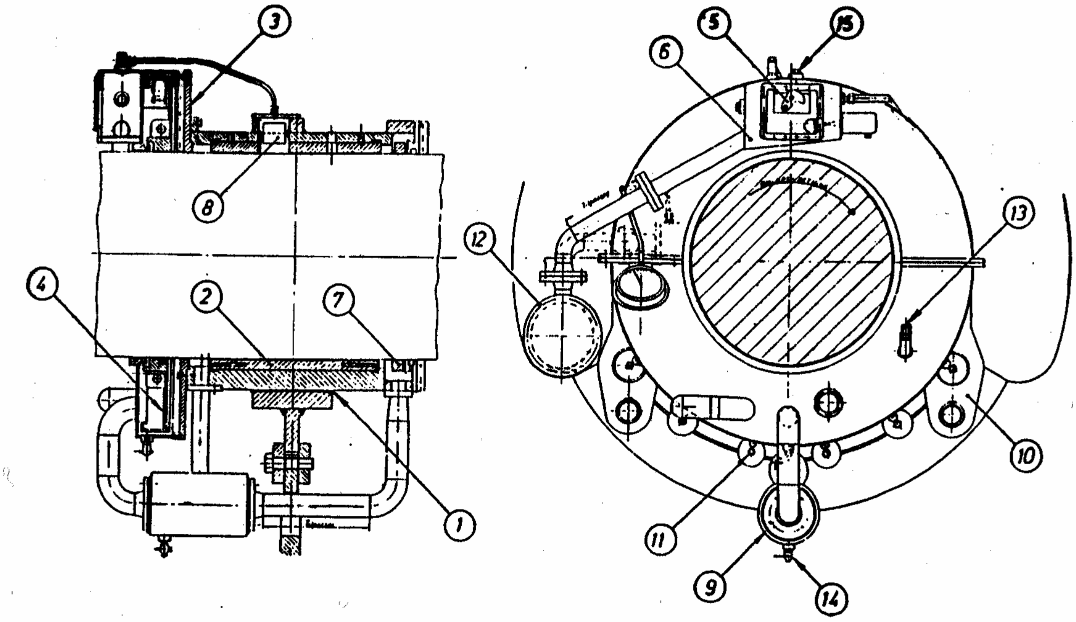


Fig. 9.8 Shaft seal box (Courtesy of Kværner Brug)

9.2.7 Turbine bearing

An example of a bearing design[1] is shown in Fig. 9.9. The bearing is sturdy and simple in operation. Maintenance will normally consist of oil change only.

The bearing housing (1) is supported in the inner guide ring Fig.9.2, by means of two yokes and two support stays and rests normally on six wedges. By moving these wedges axially the bearing housing may be vertically adjusted. The bearing housing is split horizontally.



1. **Bearing housing**	5. Oil scoop	9. Sediment collector	13. Filling opening
2. **Bearing pad**	6. Float box.	10. **Fork**	14. Drain valve
3. Oil housing	7. **Oil thrower ring**	11. **Wedge**	15. **Inspection filling plug**
4. **Rotating oil reservoir**	8. **Autom. start-lubrication unit**	12. Oil tank	

Fig. 9.9 Turbine bearing (Courtesy of Kværner Brug)

The bearing pad shell (2), Fig. 9.9, consists of an upper and a lower part. These are "floating" in the bearing housing where a radial locking pin in the upper part prevents the shells from rotation. The surface of the lower supporting shell and a surface in each end of the upper bearing shell are lined with babbit metal.

The oil housing (3) is bolted to the upstream end of the bearing housing. The oil reservoir (4) is fixed to the shaft. The oil scoop (5) and the box (6) are also located inside the oil housing. The float box is provided with a window for observation of the oil circulation while the turbine is running.

An oil thrower ring (7) is fixed to the shaft to prevent oil from seeping out of the bearing along the shaft in the downstream end.

The automatic start lubrication unit (8) is mounted on the top of the bearing housing. This consists of a container which is filled with oil when the turbine is running. When the shaft stops the oil content is kept in the container by a support device held by the shaft. As soon as the shaft resumes rotation the support is removed and the content is tilted. The oil in the container is then distributed on the bearing surface.

When the shaft and oil reservoir starts to rotate, the reservoir draws oil from the lower half of the oil housing. As soon as the oil layer is sufficiently thick, the oil scoop picks up oil and delivers it to the float box, then to the oil tank and the bearing pad. The rotating shaft transports this oil further to the bearing surface.

Normally more oil than required for lubrication is circulating through the oil tank. Therefore a bypass is provided for taking the excess oil back to the oil housing top. This bypass flow is controlled by a float switch inside the float box (6).

To increase the oil volume to more than the volume of the oil housing, an oil tank (12) is located beside the bearing.

The sediment collector (9) is located below the bearing housing. All dirt particles which are trapped in the oil during circulation in the bearing, shall be separated before the oil returns to the oil housing.

The bearing is provided with miscellaneous filling openings, oil level indicators, level float and temperature sensors as well.

9.2.8 The feedback mechanism and oil piping

The feedback mechanism and oil transfer piping are located in the shaft centre. The transfer piping consists of an inner and an outer concentric oil pipe running through the whole shaft length. The inner pipe continues through the oil transfer unit at the upstream end, and it is supported in the outer pipe and connected to the runner servomotor cylinder via an yoke.

The inner pipe is axially movable and follows the servomotor movement. A pointer mounted to the upstream end is moving along a measurement ruler showing mechanically the servomotor position at any time. The outer oil pipe is mounted by means of flange connections to the runner hub, turbine shaft and generator shaft respectively.

9.2.8.1 The oil transfer unit

The oil transfer unit is located at the upstream end of the generator shaft and has one fixed and one rotating part consisting of a distribution sleeve and distribution trunnion respectively.

The distribution sleeve is fixed to the capsule around the generator shaft end and is provided with pipe connections for oil supply and return as well as leakage oil. The distribution sleeve is provided with a bracket having a measurement scale where the runner servomotor position may be read.

9.2.9 The guide vane mechanism

Two different systems have been used for operating the guide vanes. Kværner Brug has designed a system where each particular vane has its own servomotor as shown in Fig. 9.10.

By means of a link ring a simultaneous movement of the pilot valves for the guide vane servomotors is achieved. The movement is governed by the valves controlling the opening/closing of the guide vanes.

How the servomotors are supplied with or drained for oil is shown in section A - A on Fig. 9.10.

The high pressure hoses are connected to the oil pressure system of the unit.

The advantages of this system is that even if one guide vane is stuck, the remaining vanes can be moved without any damage. The same will apply if a foreign object is caught and jammed between two vanes during closing, the remaining vanes can be closed without any damage. If required,

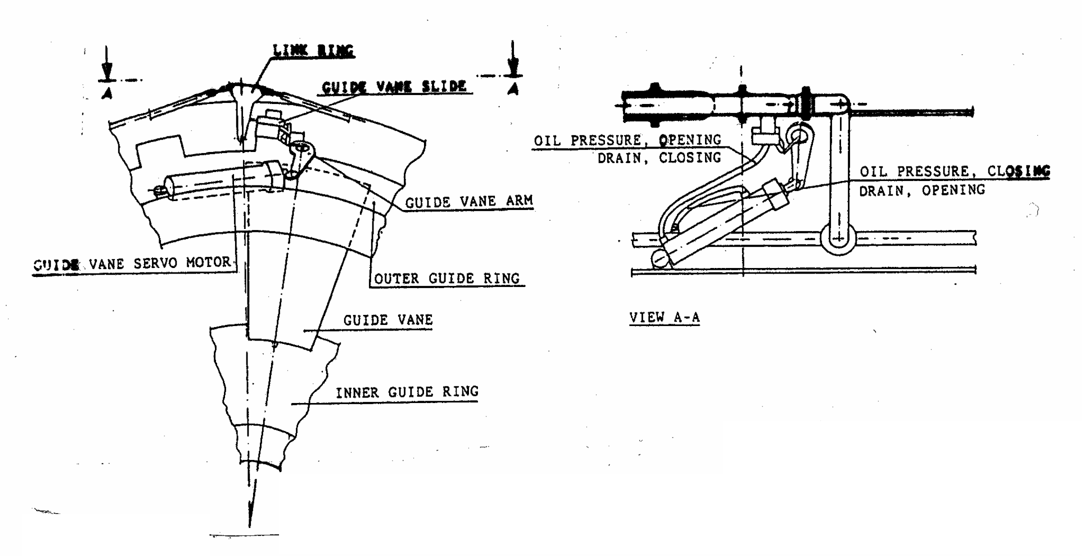


Fig. 9.10 Guide vane mechanism with single servomotors (Courtesy of Kværner Brug)

single vanes may be operated separately and thus jammed object may easily be flushed out of the guide vane system.

The disadvantages of this system are the assembly and extensive adjustment work. However, the total price will approximately be the same as for the regulating ring system which is the other method for moving the guide vanes.

The regulating ring system with links and levers is of the same type as for Francis turbines. A regulating ring with three main servomotors is shown on Fig. 9.11. Due to the conical arrangement of the guide vanes the lever link system must have spherical bearings with large angle movement.

The connection between the levers and the vanes is designed as friction joints. This is done to avoid damage to parts if one or several vanes are stuck or if foreign objects are caught between vanes. The friction joint makes it possible for the vane lever to move with the remaining parts of the guide vanes connected to the regulating ring even if the adjacent vane is stuck.

A disadvantage may be that large weight of the regulating ring and possible slack in bearings can make the governing inaccurate.

9.3 Condition control

The general principles for condition control are the same as for the Francis turbines. Further

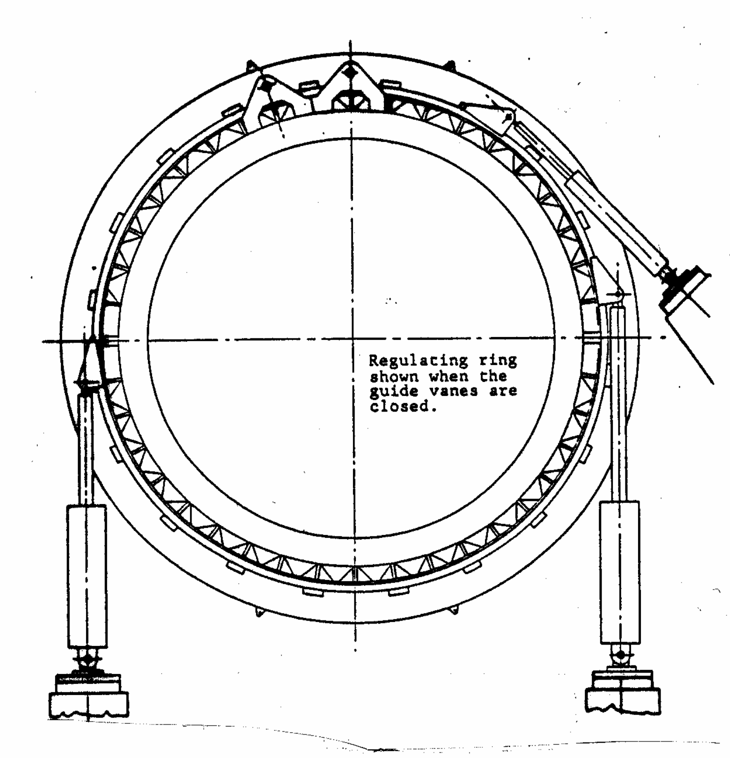


Fig. 9.11 Regulating ring /1/

considerations are therefore connected only to a few specific details.

9.3.1 Runner

The runner should be inspected both from above and below. Particular attention should be given to possible cavitation erosion and scratches on the blades as well as leaks around the blade flange against the hub.

9.3.2 Runner chamber

The narrow gap between runner and the runner chamber should be checked if foreign objects may have passed the gap and made scratches in the chamber.

9.3.3 Guide vane mechanism

For guide vane mechanism with individual vane servomotors on bulb turbines it should be checked that the vanes have an identical movement.

9.3.4 Shaft seal box

For Bulb turbines at standstill it should be checked that the water does not flow out of the box along the shaft into the turbine bearing.

9.3.5 Generally for Bulb turbines

Special attention should be paid to changes in the sound when the unit is in operation.

9.4 Monitoring instruments

The turbine is normally equipped with the following instrumentation:

- A manometer connected to the upstream end of the generator bulb
- A vacuummeter connected to the runner chamber downstream of the runner
- A contact manometer for reading of the pressure in the shaft seal box water pressure pipe, which triggers alarm or alternatively stop signal at too low pressure
- A contact manometer giving alarm:
  Pressurised water in the shaft seal box upon start of the unit
- A float switch for alarm for high water level due to too large leak in the shaft seal box
- A contact thermometer for reading of oil temperature in the bearing housing. The thermometer has two adjustable contacts, one for alarm at high temperature and one for disconnection for the unit on further temperature rise

- A remote indication thermometer with two temperature sensors for reading of temperature in lower bearing pad
- A level float for alarm on low oil level

9.5 Assembly and dismantling

Among the large main parts of the bulb turbine it is only the runner which is normally needed to dismantle. The runner chamber is split axially horizontal in two halves. By removing the upper half access to the runner is obtained.

The guide vanes cannot be dismantled without extensive work. Repairs of these and the guide surfaces should be performed at the plant.

Bearing and seal box can easily be dismantled. By applying the overhaul seal the seal box may be removed without draining the water canal. Then necessary stairs and floors around the guide vane and the runner chamber may be erected.

The stay shields are adapted against bulb and outer water conduit contour. The shields are mounted as soon as the generator bulb and penstock are completed.

Finally the generator hatch dome plate and cover are installed.

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