CHAPTER 11

Valves

Introduction

The conduits in all water power plants except large low head plants, are ordinarily provided with shut off devices. Generally these components are valves. They exist in different types and design depending on function and requirements.

In any power plant valves for different purposes are usually needed. Normally it is a shut-off valve just in front of the turbine. In this way the turbine may be emptied without emptying the shaft or penstock. In addition the guide vane cascade is depresserised so that leakage flow is avoided.

With a long head race tunnel and surge chamber it is normal to have a shut off valve just downstream of the surge chamber. In this way the shaft or penstock may be emptied without emptying the tunnel.

To prevent large damage at an eventual rupture of the penstock, a pipe break valve is normally installed in the pipe just downstream of the shut off valve. This valve closes automatically when the water velocity exceeds a certain set value.

The most relevant types of valves are:

- spherical valves
- butterfly valves
- gate valves
- ring valves

11.1 Spherical valves

Spherical valves are applied mostly as shut off valves in front of high head water turbines. They are however, used as pipe brake valves as well. Spherical valves are presently covering a pressure range of 160 m to 1250 m water head.

The spherical valves consist of the valve housing with flanges, valve rotor, bearings and seals.

11.1.1 Valve housing and valve rotor

The valve housing has a spherical shape. It may either be axially split permanently in two halves and bolted together with heavy flanges, or these two halves may be welded together after the rotor has been installed.

The rotor inside the valve housing is principally shaped spherically as well. The circular passage through the rotor is equal to the size of the valve inlet and outlet. The length of the passage is dimensioned to fit almost close to the inner end faces at inlet and outlet of the valve housing. In this way the flow losses through the valve become about the same as in a corresponding pipe length.

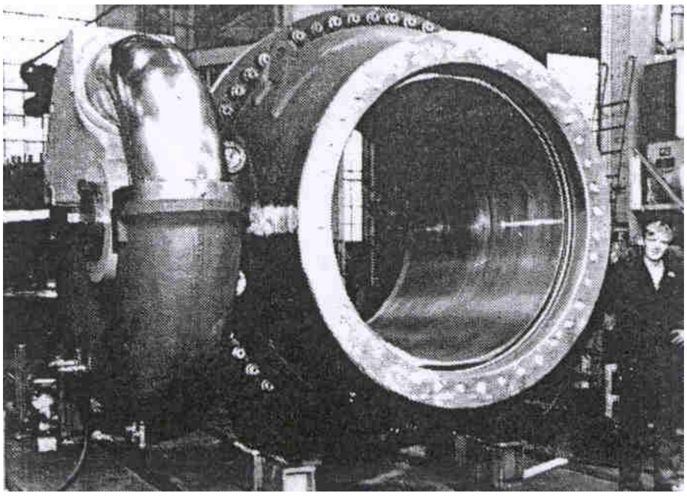

Fig. 11.1 Spherical valve in open position

Fig. 11.1 shows a picture of a complete spherical valve in open position, and Fig. 11.2 shows a picture of a spherical valve rotor.

11.1.2 Valve rotor trunnions and bearings

The trunnions on the valve rotor are horizontally supported in the valve housing. The rotor is turning on these trunnions by an angle 90^{o} from open to closed position.

The valve is normally designed to close under the worst possible conditions. This worst case is to close a valve upstream of the turbine when the guide vane cascade of the turbine is fully open.

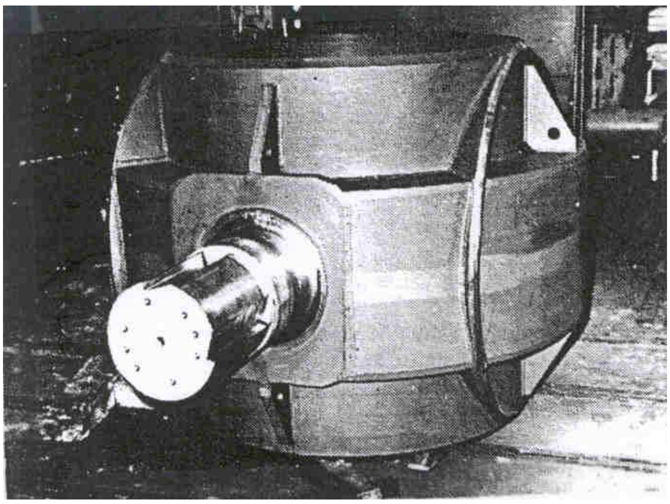

Fig. 11.2 Valve rotor (Courtesy of Kværner Brug)

The bearings are designed with bushings made of lead-bronze. The bushing is pressed into a bearing housing and provided with two sealings as shown on Fig. 11.3. The inner seal is an O-ring primarily for keeping the bearing free from sand and mud. If this seal after some time is not leak tight, the outer seal is a reserve. This seal is of U-seal type.

Lubrication grease to the bearings is pressed through several borings into a section of grooves in the bearing surface.

11.1.3 Seals for closed valve

Spherical valves[/2/] usually have a main seal downstream and an auxiliary seal upstream of the passage of the rotor. The valve rotor is provided with two seal rings, one downstream and one upstream. These are made of stainless steel and fixed with screws to the rotor.

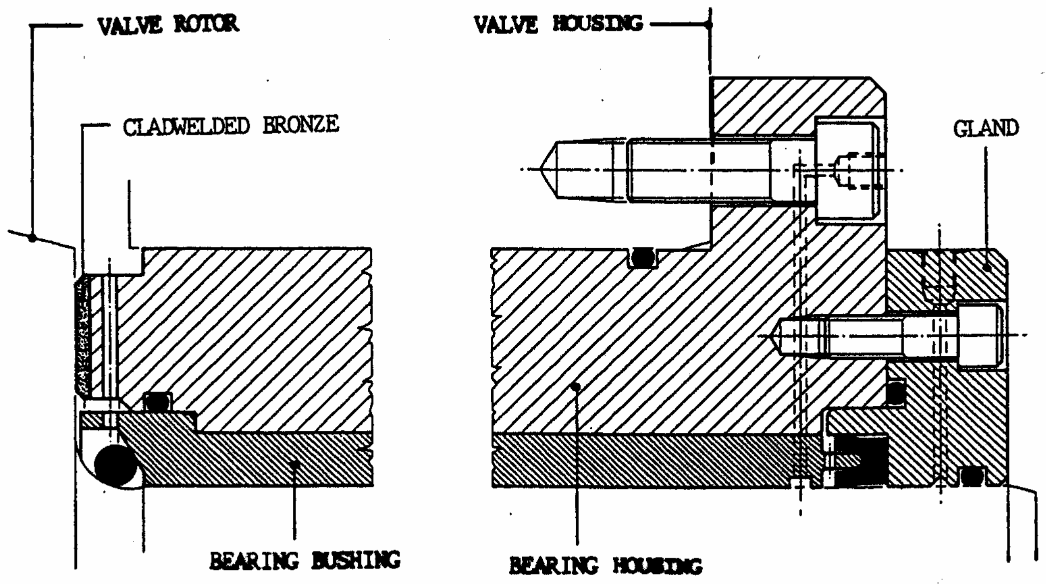

Fig. 11.3 Spherical valve bearing /2/

In closed position the circular passage of the rotor is turned 90° from the open position and the seals are then activated.

The main seal is shown on Fig. 11.4. This consists of a moveable rubber profile contained in a stainless steel seal housing which is bolted to the intermediate ring. The auxiliary seal located on the upstream side of the valve, is shown on Fig. 11.5. This consists of a moveable seal ring made of stainless steel and is operating as a differential piston.

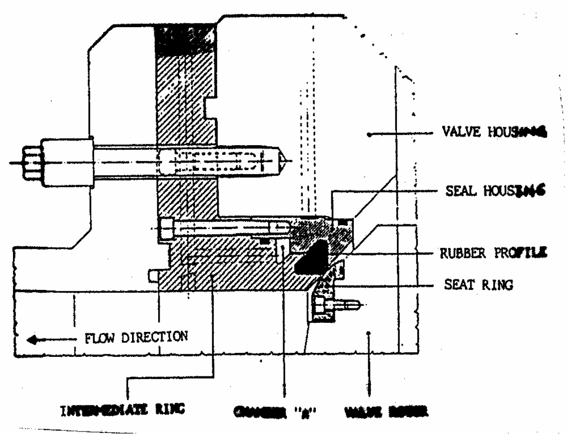

Fig.11.4 Main seal /2/

11.1.3.1 Main seal

The main seal activation is functioning as follows. If water pressure is equal from all sides, the rubber seal ring is resting in its groove as if no pressure was applied. The seal is pressed against the seat rings with a compression of 0.5 - 1 mm when external pressure on the seal is at atmospheric level.

When the valve rotor is in closed position, the rubber seal is pressed against the valve rotor seal surface by applying water pressure to the rear side “A” of the ring, shown on Fig. 11.4. If the downstream pipe in this case is empty and depressurised to atmospheric pressure, the valve is droptight.

To open the valve the downstream pipe is pressurised again through a bypass filling pipe and the rear side of the rubber seal is drained. Then the rubber ring profile is pushed back by the water pressure inside the valve. Thereby a gap between the profile and the seal surfaces is attained, and the valve rotor can rotate without touching the rubber seal profile.

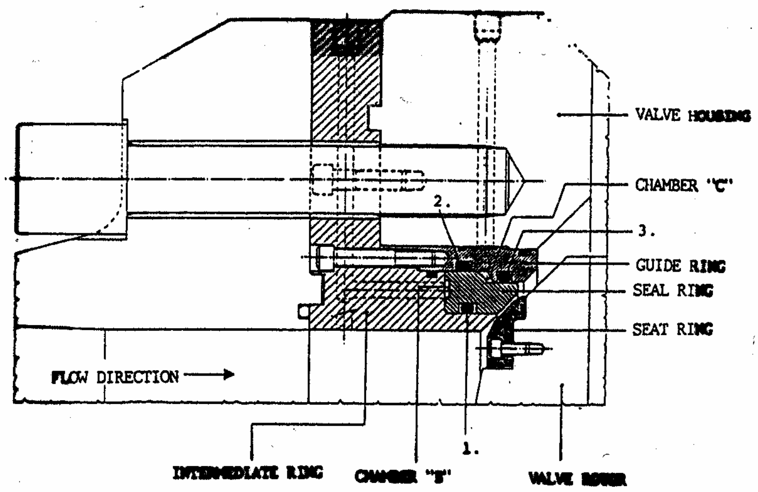

Fig. 11.5 Auxiliary seal /2/

11.1.3.2 Auxiliary seal

The auxiliary seal[/2/] is activated by supplying water pressure to chamber “B” in Fig. 11.5. The seal ring is then moved against the valve rotor seat ring. Chamber “C” is always connected to drain. The water pressure in the penstock and the spherical valve housing is pushing the seal ring back when chamber B is drained.

If the penstock has been drained with the auxiliary seal activated, the seal ring can be withdrawn by supplying water pressure to chamber C.

It is should be notified that the auxiliary seal must be activated only when the valve rotor is in closed position

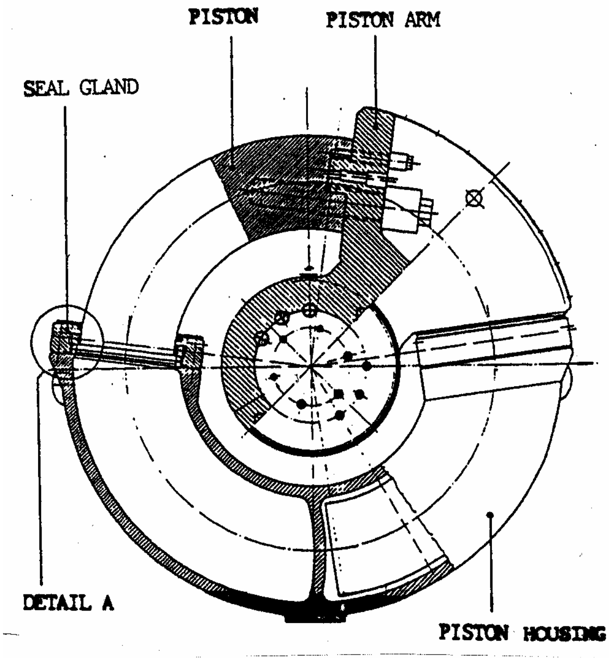

Fig. 11.6 Ring servomotor /2/

11.1.4 Operation mechanism

The opening and closing operation of the valve is carried out by one or two servomotors. Fig.11.6 shows the design of a ring servomotor[/2/] which is mounted solely on the valve housing.

Since the valve is designed to close against the flow at full turbine load, the valve rotor is subject to a large torque. This torque is transferred to the valve housing through the foundation of the servomotor. Therefore the total closing torque is absorbed by the pipe and the valve.

This design of the valve operation facilitates the foundation and dimensioning of flanges and connecting pipes.

The described operation mechanism design is the most applied in Norway.

Another type of the operation mechanism is to use a linear servomotor connected to an arm which is wedged to the valve rotor trunnions as shown on Fig. 11.7. In this case the servomotor and the valve housing have to be anchored to the surrounding foundations.

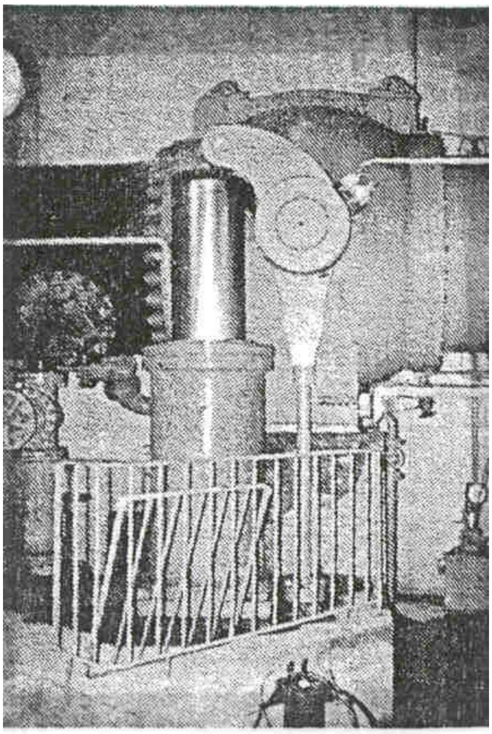

Fig. 11.7 Spherical valve operated by a

With this arrangement the adjoining pipes have to be dimensioned to withstand bending and torque forces in addition to the forces from the closed valve.

During valve closing however, the valve rotor is subject to a closing torque caused by the flow and a bearing friction torque caused by the support forces acting in the opposite direction. The sum of these torques will act partly in the closing direction and partly in the opposite direction. Therefore the servomotor must be operative for action both as a brake and as a motor for the valve rotor.

11.1.5 Control system

The control system is in principle built up/2/ as shown on Fig. 11.8. It is made up by a pilot control system located in "Spherical Valve Control Desk" and a main control system located in the "Control Cabinet".

These two systems represent the automatic part of the control system. In addition the control system is provided with manually operated valves. By means of these valves it is possible to lock a closed spherical

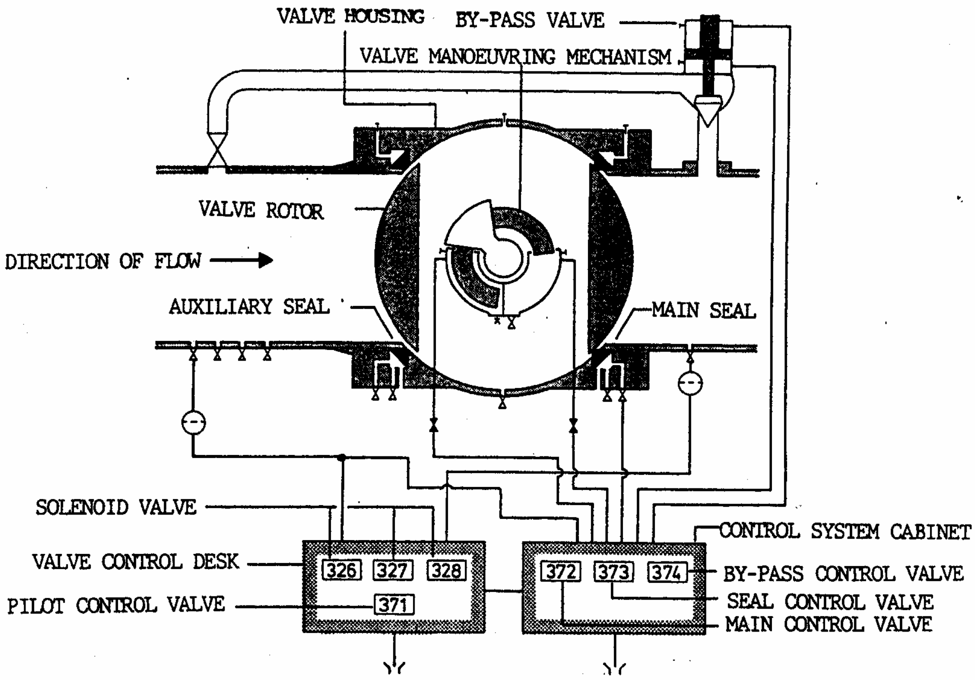

Fig. 11.8 Control system of a spherical valve /2/

valve and to shut off the automatic control system to operate the spherical valve manually.

The control system of a spherical valve is normally operated with the pressure water from the penstock. The water is carefully filtered and only rustproof materials are used in control and shut-off valves. This system of operation has proved to be convenient and reliable.

Alternatively the servomotor may be operated by means of oil hydraulics. This way of operation however, will be more complicated and expensive.

11.2 Butterfly valves

Butterfly valves are normally applied in front of low and medium head water turbines, i.e. heads up to 200 m. For high head power plants the butterfly valve is from time to time used as a closing device in inlet tunnels and alternatively as emergency closure valves.

Butterfly valves consist of mainly of a ring shaped housing, the valve disc, operating mechanism and counter weight.

11.2.1 Valve housing

The butterfly valve housing is a cylindrical ring with the same diameter as the connecting pipe. The housing is either not split or split axially. The valve ring with end flanges is mostly a welded design. In addition bosses for the disc trunnion supports are welded to both sides of the housing ring. Ribs are normally welded to the outer side of the housing ring in order to improve its stiffness.

It is favourable to cone the valve ring housing to a smaller diameter from the upstream to the downstream end. The effect of this cone is lower flow losses through the valve.

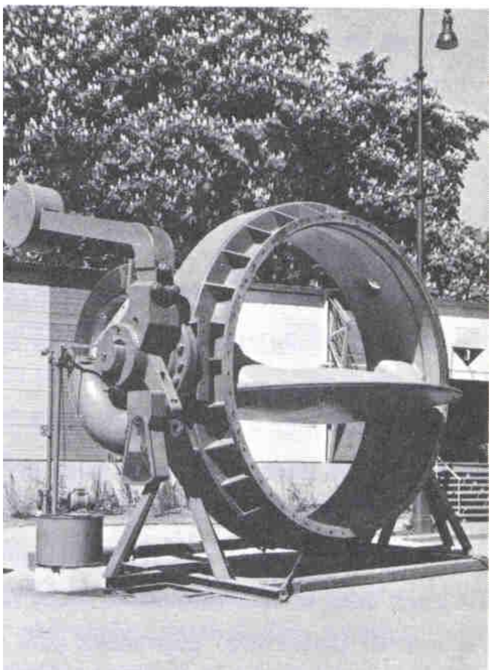

Fig. 11.9 ***Butterfly valve (Courtesy Kvæner Brug)***

11.2.2 Valve disc

Inside the valve ring housing a revolving circular disc with two trunnions, is supported in bearings in the ring housing. This valve disc is a plane with a packing around the cicumference. In the fully open valve the disc plane is parallel to the water flow. Fig. 11.9 shows a picture of a butterfly valve with the disc in open position.

A plane disc plate would however, in most cases be too weak to carry the load of the water pressure when the valve is closed. The disc therefore is often cast with a shape as a lens with internal ribs. For the larger sizes of these valves the disc may be made as a biplane structure to be sufficiently stiff and cause low flow losses. An example of a such design is shown in the butterfly valve on Fig. 11.10. In this case the disc is usually welded from plates with integrally welded boss with trunnions.

The trunnions are offset to the upstream side of the valve disc (considered in the closed position). In this way the seal between the disc and the valve housing ring may be a complete ring without joints at the trunnions. This facilitates the achievement of complete tightness.

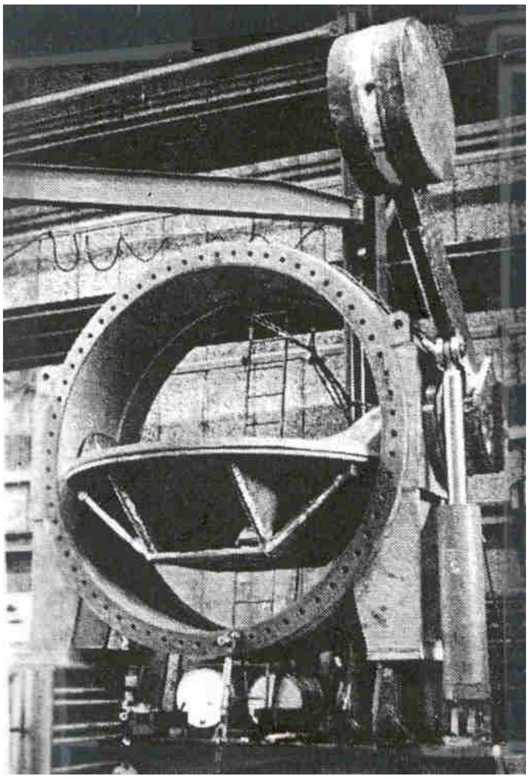

Fig. 11.10 Butterfly valve with a biplane disc (Courtesy of Kvæner Brug)

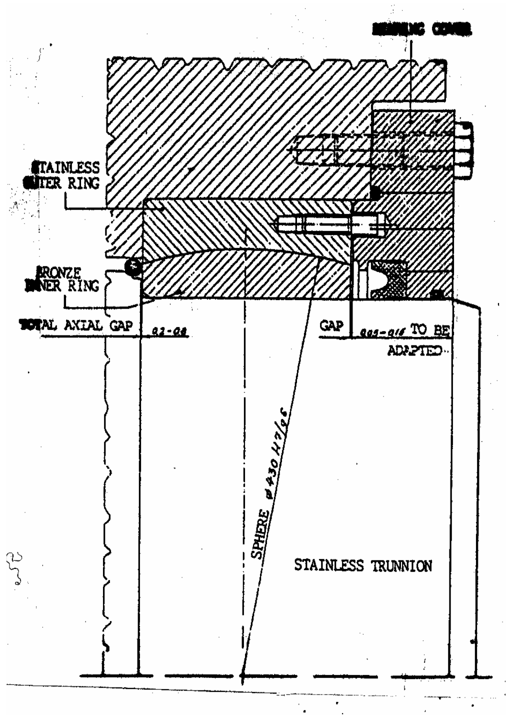

Fig.11.11 Butterfly valve bearing /2/

The disc trunnions are also offset somewhat either below or above the valve ring centre. This is called the butterfly valve's eccentricity.

11.2.3 Bearing

The valve disc has a bending tendency when it is in the closed position. Spherical bearings[/2/] are therefore normally used for the trunnions. They are rotating in a bronze bearing with spherical shape as shown on Fig. 11.11.

The bronze bearing is supported in a bearing ring made of steel or cast iron with internal spherical shape. The bronze bearing is lubricated by grease, and may also be designed on the base of self lubricating material.

The seal around the trunnion is located in the bearing cover. The seal consists of an U-shaped rubber profile and an O-ring located outside this profile. Replacement of the bearing seals requires draining of the penstock.

11.2.4 Seal

The valve housing ring[/2/] contains a machined stainless seat. In a groove in the disc a rubber profile is inserted and kept in position by a clamp ring as shown on Fig. 11.12. With the disc in the closed position, the rubber is pressed outwards against the stainless seat by tightening the clamp ring

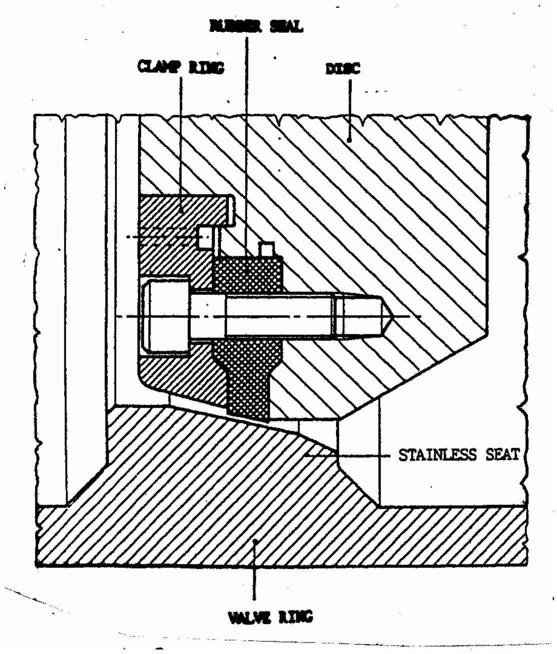

Fig. 11.12 Disc seal of the butterfly valve /2/

screws. In this way the butterfly valve will be completely tight. If the seal should leak, this may be stopped under full upstream water pressure, by tightening the screws in the leaking part of the circumference.

11.2.5 Operating mechanism

The butterfly valve shall be able to open and close under equalised water pressure on the disc sides as well as to close at full turbine discharge. In addition emergency closure valves shall close automatically in the case of penstock rupture.

The opening is done by means of one (or two) servomotors. This may be mounted on the side of the valve and is acting on the counterweight arm which is bolted to the trunnion. The servomotor may also be mounted on the top of the valve housing ring, and in this case the piston rod is acting directly on the valve disc.

The servomotor is operated by means of pressure oil from an external oil hydraulic unit.

The valve is kept in open position by oil pressure in the servomotor when the turbine is running. As the closing function is more important than the opening function, the valves are designed for closing at any conditions without supply oil pressure. The counterweight with the arm bolted to the trunnion, closes the valve when the flow is zero. The servomotor is then acting as a brake and ensures controlled closing.

11.4 Gate valves

Gate valves are also applied as shut off valves in front of turbines. The spherical valves however, have come more and more in use instead. The reason is that the spherical valves need smaller space and cause lower flow losses than the gate valves. Therefore the gate valves are produced merely with diameters up to 750 mm. They are mostly produced with cast housing. For lower heads however, some of these valves are produced with welded housings too.

An ordinary gate valve design with a double acting servocylinder is shown on Fig. 11.13. Common for gate valves is linear operated gate along a perpendicular to the longitudinal axis.

When the valve is fully open the gate is pulled away from the water canal. The movement of the gate is conducted by guides in the valve housing. When the valve is closed, the gate is pressed against the downstream stainless seal surface. The seal surface on the gate is also made of stainless material. In the closed position the water pressure acting on the gate is transferred directly to the valve seal. Increasing water pressure therefore results in increasing seal pressure.

The seal surface is inclined in relation to the gate closing direction. By closing movement the gate meets the seal surface just prior to fully closed position and slides against the seal surface the last part of the movement. To avoid bending between piston rod and the gate, the gate is mounted to the piston with a certain freedom of movement.

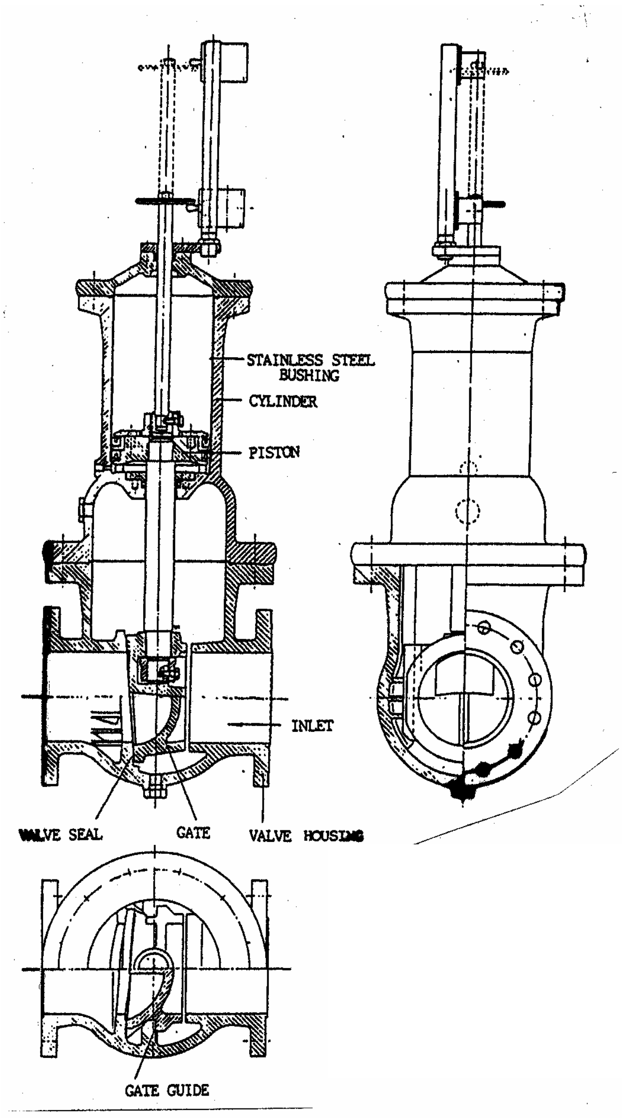

Fig. 11.13 Gate valve with double acting hydraulic cylinder

For opening and closing of the valve the operating mechanism may be hydraulic, electrical or manual. On larger valves it is natural to use hydraulic control due to the large forces involved. For the hydraulic operation water pressure from the penstock or oil pressure from a hydraulic power unit is used.

If water pressure from the penstock is used, the cylinder wall has an inner layer of rustproof material. In this case the piston normally has a leather gasket against the cylinder wall. The water must pass a filter and be carefully cleaned before entering the cylinder. For smaller remote controlled valves electrical operation is an alternative.

11.5 Ring valves

Ring valves have been used in many types of hydro power applications. In pump storage plants they are the most applied valve for closing the outlet of the pumps. However, they are applied also as pipe break valves, drain valves and safety valves.

An example of the design of a ring valve[/2/] is shown in Fig. 11.14. This has a piston shaped closing device which is moved axially when opening and closing. The valve housing is partly conical and partly cylindrical, and together with the closing device it forms a ring shaped flow cross section. The closing device is supported in the housing by ribs.

The closing device consists of a piston with piston rod connected to a cylindrical member. This member has a seal ring fastened to the dowstream end of it. The seal ring is made of stainless steel and designed to adapt to the housing seal ring in the closed position. The piston and piston rod are centered by a bushing at each end.

The design shown on Fig. 11.14 is operated by water pressure from the penstock through the connection A and B, and there is also a connection for emergency closing C. Some ring valves are using oil as operating fluid. For this operation a hydraulic power unit is needed.

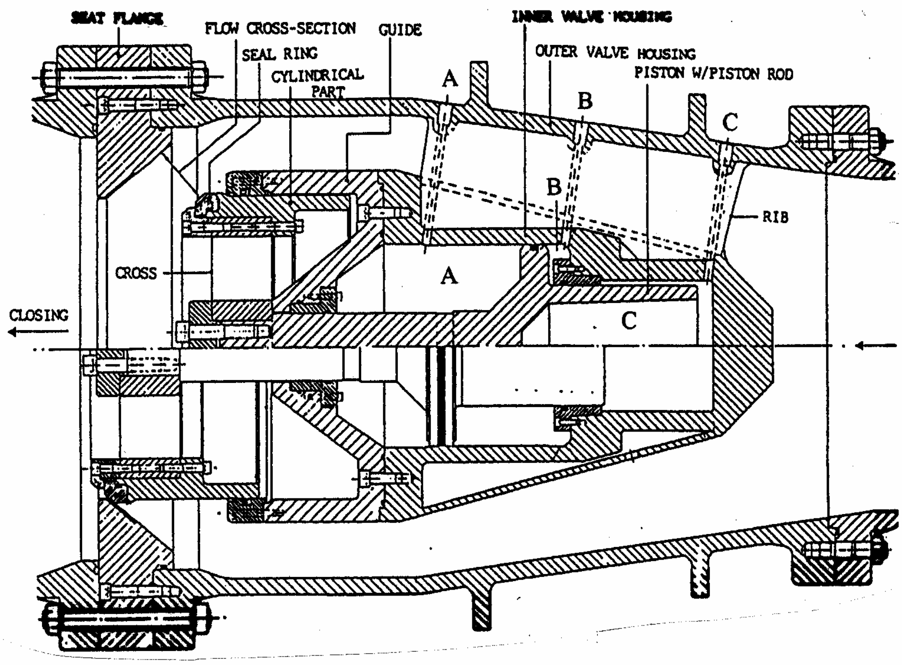

Fig. 11.14 Ring valve section /2/

Ring valves installed in drain conduits[/2/] are equipped with an auxiliary valve upstream and a pressure reducing device downstream of the ring valve. The pressure reducing device is an energy dissipator connected with the downstream end of the ring valve as shown in Fig. 11.15.

The energy dissipator consists of consentric plates with a large number of small axial holes. By this arrangement the pressure drop at any point is kept below a level where cavitation may occur. For lower heads than 75 meters ring valves are delivered without pressure reduction device.

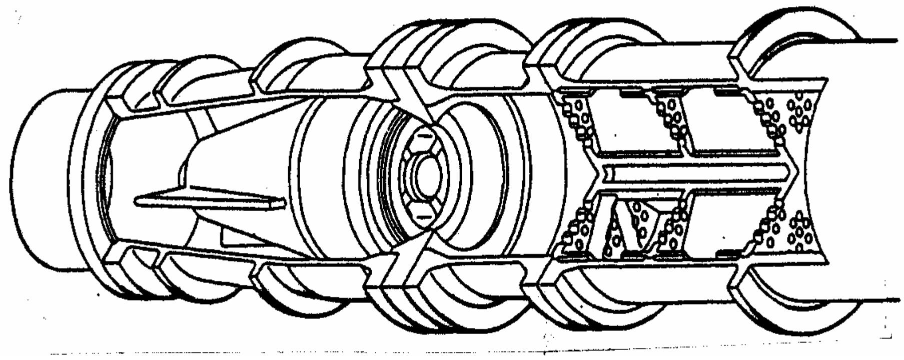

Fig.11.15 Ring valve with energy dissipator /2/

11.6 The bypass valve

A bypass valve is the opening/closing device in a pipe connecting the upstream and downstream side of the valve in the main conduit. The arrangement of a bypass valve is schematically shown in Fig. 11.8. This bypass is used to equalize the pressure on the two sides of the main valve to relieve the valve from large loads during normal opening and closing. The bypass is also used to fill the scroll casing of Francis turbines and the distribution pipe of Pelton turbines

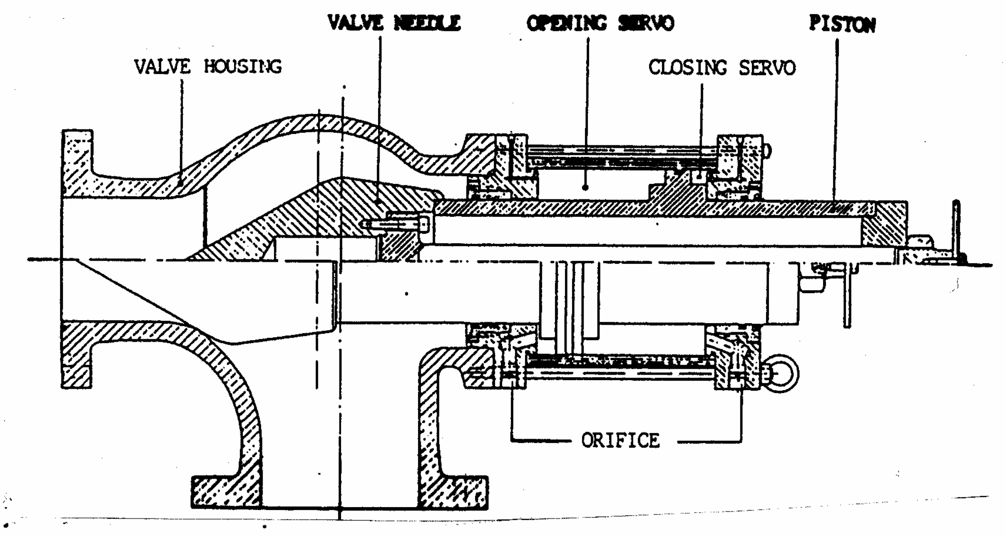

Fig. 11.16 Bypass needle valve /2/

An example of the design of a hydraulically operated bypass valve[/2/] is shown on Fig. 11.16. The valve needle is operated by a double acting servomotor. Opening and closing times are determined by orifices in the supply pipes to the servomotor.

11.7 Guidelines for inspection of valves

On valves and the connecting pipe ends the usual damages to be found are:

- normal wear
- mechanical damages

The valve housing and the closing body as well must be inspected. The access to the upstream side may be difficult to achive, and the time interval between inspections must be determined on the base of the choice of materials, shape, probability of cavitation, vibrations or mechanical wear from sand and so on.

Spherical valves, butterfly valves and gate valves have different properties and patterns of damages. They consist however, of the same main components: valve housing, closing body and operating mechanism. The operating mechanism is normally a hydraulic servomotor operated either by water pressure or oil pressure.

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