Annual inspection.-Check bearing clearances with dial indicators and by "jacking" the shaft or with feeler gauges. Any change in previous readings should be investigated. Calibrate temperature sensors and oil level indicators. Check operation of alternating-current and direct-current turbine guide bearing and thrust bearing high-pressure lubrication system oil pumps. Note operating pressure of high-pressure lubrication system and investigate if it is significantly different from previous readings. Check filters on high-pressure lubrication system and clean or replace as required. Check the generator thrust bearing and upper guide bearing insulation with an ohmmeter. If resistance is low, investigate cause immediately.

Not scheduled.-Remove bearings and check for any damage. Light scoring and minor damage from wiping can be removed by scraping babbitt bearings. If there is severe damage to the babbitt surface, the bearing should be rebabbitted. Remove cooling coils and clean out any deposits. Hydrostatic test coils for several hours to check for leaks before reinstalling. Check normally inaccessible portions of thrust bearing high-pressure lubrication system for leaks or broken hoses.

i. *Shaft and coupling.*-

Annual inspection.-Check shaft runout with dial indicator or with proximity probes and a strip chart recorder. At minimum, check runout at full load, and if possible, record the runout as the unit is loaded from speed-no-load to full-load. Make note of the maximum runout magnitude and the load at which it occurred. Investigate if runout is excessive or has changed significantly from previous readings.

j. *Generator or motor rotor.*-

Annual inspection.-Thoroughly inspect stress-carrying parts of rotor for cracks. Pay particular attention to welds on the rotor spider. Any cracks should be evaluated by engineering personnel and a repair procedure developed. Check bolted connections for tightness and any evidence of movement.

k. *Air coolers.*-

Annual inspection.-Clean exterior surfaces of coils check for leaks. Check interior of coils for excessive scale buildup. If scale is excessive, clean mechanically or with an approved chemical treatment.

l. *Unit brakes.*-

Annual inspection.-Measure brake shoe thickness and check condition of brake ring. Operate brake cylinders to check for any binding or sticking. If necessary disassemble brake cylinders, and repair.

m. *Inspection reports.*-

Annual inspection.-Inspection reports similar to the Hydroelectric Unit, Mechanical Inspection Report (figure 13) or the Large Pump Inspection Report (figure 14) should be filled out annually to record data obtained during the annual inspection.

Auxiliary pumps

n. *Pump impeller or rotor and casing.–*

*Annual inspection.–*If inspection ports are available, the pump impeller should be inspected annually. Check for leaks from casing at gasketed joints and tighten or replace gaskets as required. Take ammeter readings of pump motor with pump at full capacity. A decrease in amperage indicates a decrease in pump output, which suggests some maintenance is required.

*Not scheduled.–*Disassemble pump if there is a reduction in capacity or pressure, an increase in vibration, or other indication that a problem exists or at intervals determined by past maintenance experience. Check for worn parts and repair or replace as required.

o. *Shaft and coupling.–*

*Weekly inspection.–*Check shaft and coupling visually for excessive runout or vibration. Look for loose coupling bolts or other damaged coupling components.

*Annual inspection.–*Check shaft runout with dial indicator or with proximity probes. Check shaft alignment if runout is excessive.

p. *Packing.–*

*Weekly inspection.–*Check for excessive heat and for proper amount of leakage. Tighten packing as required.

*Not scheduled.–*Remove old packing and lantern ring and thoroughly clean packing box. Check packing sleeve for excessive wear and repair or replace as required. Install new packing, staggering adjacent rings so that joints do not coincide.

q. *Mechanical seals.–*

*Weekly inspection.–*Check for excessive leakage. Properly installed mechanical seals should require very little maintenance. When excessive leakage does occur it normally is an indication that new seals are required.

r. *Bearings.–*

*Weekly inspection.–*Check for vibration and for adequate lubrication. Prior to complete failure, vibration will increase and the bearing will usually become extremely noisy. As it is sometimes difficult to detect an increase in noise or vibration, some sort of vibration monitoring system can be helpful. If a bearing fails prematurely, determine cause and correct it before restarting the pump. Insufficient or excessive lubrication, contamination of the lubricant, and misalignment of the shaft or bearings are some possible causes of premature bearing failure.

s. *Pressure-relief valves.–*

Annual inspection.–All positive displacement pumps, such as in hydraulic systems, must have a pressure-relief valve installed in its discharge line ahead of any valve or obstruction that could restrict flow. In some pumps, the relief valve is an integral part of the pump. Test all relief valves for proper operation and setting.

t. *Eductors.–*

Not scheduled.–Disassemble and clean any scale or rust buildup from nozzle, eductor body, and piping. Repair or replace nozzle if damaged by corrosion or cavitation.

HYDROELECTRIC UNIT, MECHANICAL INSPECTION REPORT

PROJECT__________ POWERPLANT__________ UNIT NO.____ DATE__________

WICKET GATE CLEARANCES											
	CLEARANCES BETWEEN FACING PLATES AND WICKET GATES		CLEARANCE BETWEEN WICKET GATES, CLOSED POSITION, PRESSURE RELEASED				CLEARANCES BETWEEN FACING PLATES AND WICKET GATES		CLEARANCE BETWEEN WICKET GATES, CLOSED POSITION, PRESSURE RELEASED		
GATE	UPPER	LOWER	TOP	MIDDLE	BOTTOM	GATE	UPPER	LOWER	TOP	MIDDLE	BOTTOM
1						13					
2						14					
3						15					
4						16					
5						17					
6						18					
7						19					
8						20					
9						21					
10						22					
11						23					
12						24					

AIR GAP, BEARING, AND WEARING RING CLEARANCES				
READING	POSITION READING TAKEN			
	North	South	East	West
MAIN GENERATOR AIR GAP				
EXCITOR AIR GAP				
UPPER GENERATOR GUIDE BEARING				
LOWER GENERATOR GUIDE BEARING				
TURBINE GUIDE BEARING				
UPPER WEARING RING				
LOWER WEARING RING				

SHAFT RUNOUT				
BEARING	RUNOUT MAGNITUDE AT FULL LOAD		MAXIMUM RUNOUT MAGNITUDE	
	NORTH/SOUTH	EAST/WEST	MAGNITUDE	LOAD (MW)
UPPER GENERATOR GUIDE BEARING				
LOWER GENERATOR GUIDE BEARING				
TURBINE GUIDE BEARING				

Figure 13. - Hydroelectric unit, mechanical inspection report.

GENERAL INSPECTION

Note type of paint and condition of painted surfaces. Check unpainted surfaces for corrosion, wear, scoring or other damage. Check operation of pumps and other equipment. Document any repairs made as part of inspection. If not checked during this inspection, note date last inspected.

PENSTOCK

Interior______________________________

Exposed Exterior, Expansion Joints______________________________

SCROLL CASE______________________________

DRAFT TUBE______________________________

DRAFT TUBE AND SCROLL CASE ACCESS DOORS______________________________

TURBINE RUNNER

Type, Mfg., and Total No. of Pounds of Welding Rod or Wire Used______________________________

Approximate Area Repaired--____________Square Inches

WICKET GATES

Gate Body______________________________

Gate Stems, Bushings, and Packing______________________________

Wicket Gate Linkage, Shift Ring, Ect.______________________________

Squeeze on Wicket Gates Measured at Servomotors ---------- Right Servomotor____Inches, Left Servomotor____Inches

MAIN SHAFT PACKING OR MECHANICAL SEALS______________________________

LUBRICATION SYSTEMS

Name, Mfg., and Viscosity of Oil______________________________

Name, Mfg., and Grade of Grease______________________________

Laboratory Tests of Oil______________________________

AC and DC Turbine Bearing Oil Pumps______________________________

Thrust Bearing High Pressure Lubrication System______________________________

Oil Coolers______________________________

Wicket Gate Greasing System______________________________

UNIT BRAKES______________________________

GENERATOR ROTOR______________________________

GENERATOR AIR COOLERS______________________________

OTHER COMMENTS AND RECOMMENDATIONS______________________________

Inspection Made By______________________________

Figure 13 (Back)

LARGE PUMP INSPECTION REPORT

PROJECT__________________ PUMPING PLANT______________________ UNIT NO.____ DATE______________

AIR GAP, BEARING, AND WEARING RING CLEARANCES				
READING	POSITION READING TAKEN			
	North	South	East	West
MOTOR AIR GAP				
UPPER MOTOR GUIDE BEARING				
LOWER MOTOR GUIDE BEARING				
IMPELLER GUIDE BEARING				
UPPER WEARING RING				
LOWER WEARING RING				

SHAFT RUNOUT		
BEARING	RUNOUT MAGNITUDE AT RATED SPEED AND LOAD	
	NORTH/SOUTH	EAST/WEST
UPPER MOTOR GUIDE BEARING		
LOWER MOTOR GUIDE BEARING		
IMPELLER GUIDE BEARING		

GENERAL INSPECTION

Note type of paint and condition of painted surfaces. Check unpainted surfaces for corrosion, wear, scoring or other damage. Check operation of pumps and other equipment. Document any repairs made as part of inspection. If not checked during this inspection, note date last inspected.

DISCHARGE PIPE

Interior____

____

Exposed Exterior, Expansion Joints____________________________________

____

PUMP CASING____

____

PUMP SUCTION____

____

Figure 14. – Large pump inspection report.

PUMP CASING AND PUMP SUCTION ACCESS DOORS____________________

IMPELLER

Type, Mfg., and Total No. of Pounds of Welding Rod or Wire Used____________________

Approximate Area Repaired -- __________ Square Inches

MAIN SHAFT PACKING OR MECHANICAL SEALS____________________

LUBRICATION SYSTEMS

Name, Mfg., and Viscosity of Oil____________________

Name, Mfg., and Grade of Grease and Where Used____________________

Laboratory Tests of Oil____________________

AC and DC Impeller Bearing Oil Pumps____________________

Oil Coolers____________________

UNIT BRAKES____________________

MOTOR ROTOR____________________

MOTOR AIR COOLERS____________________

OTHER COMMENTS AND RECOMMENDATIONS____________________

Inspection Made By____________________

Figure 14 (Back)

CHAPTER 3 — PENSTOCKS, OUTLET PIPES, GATES, VALVES AND AUXILIARY PIPING SYSTEMS

1. Penstocks and Outlet Pipes

Penstocks and outlet pipes are steel; concrete; or, in some cases, wood stave water conduits. Penstocks and outlet pipes may be entirely or partially embedded in concrete, placed under ground, or carried on suitable supports above ground or in a tunnel. A penstock is conduit that conveys water from a reservoir, forebay, or other source to a hydraulic turbine in a hydroelectric powerplant. An outlet pipe is a conduit that conveys water from a reservoir for irrigation, run of the river, municipal or industrial water supply, or other purposes. Both penstocks and outlet pipes may have expansion joints, manholes, drain and fill lines, and other accessories which may require periodic maintenance.

2. Gates and Valves

General.-There are numerous types of gates and valves installed in Reclamation powerplants and dams. Figures 15, 16, and 17 illustrate some common gate and valve layouts. The primary purpose of a gate or valve is to regulate flow or to act as a secondary shutoff. A gate regulates flow of water through the use of a gate leaf or other closure member which is moved across the fluidway from an external position. A valve regulates the flow of water through the use of an internal closure member that is either rotated or moved longitudinally within the valve housing. Guard gates or valves are installed upstream from a regulating gate or valve to act as a secondary device for shutting off the flow of water in case the regulating device becomes inoperable. Except for emergencies, guard gates are operated under balanced-pressure, no-flow conditions. Regulating gates and valves operate to vary flow under full pressure and flow conditions.

Gates.-Closure or regulating devices meeting the above definition of "gates" appear in a variety of forms. The more common types are discussed in the following sections.

a. Radial or tainter gates.-Radial gates (figure 18), or tainter gates as they are also called, are used primarily as spillway crest gates but are also used in canals or other open channel applications. A radial gate basically consists of a skinplate, shaped like a cylindrical section, connected to radial arms which converge to a horizontal pivot pin. The gate usually is raised or lowered by a wire rope or chain and sprocket hoist.

b. Drum gates.-Drum gates (figure 19) are used as spillway crest gates. A drum gate consists of a long buoyant vessel or "drum" hinged to the spillway crest. A water chamber below the drum is filled or drained to raise or lower gate.

c. Slide gates.-Slide gates, in their various configurations, may be used as guard or regulating gates for closed, high-pressure conduits, such as penstocks and outlet works, or for open channel flow such as canals. The construction of a slide gate can vary a great deal. The cast iron slide gate consists of a flat or rectangular leaf that is moved within a frame over a circular or rectangular opening. The leaf is connected to a hoist by a stem which is supported by guides attached to the concrete above the opening. High-pressure gates and outlet gates are also slide gates. They consist of a leaf, a body and bonnet embedded in concrete, and a hoist for raising and lowering

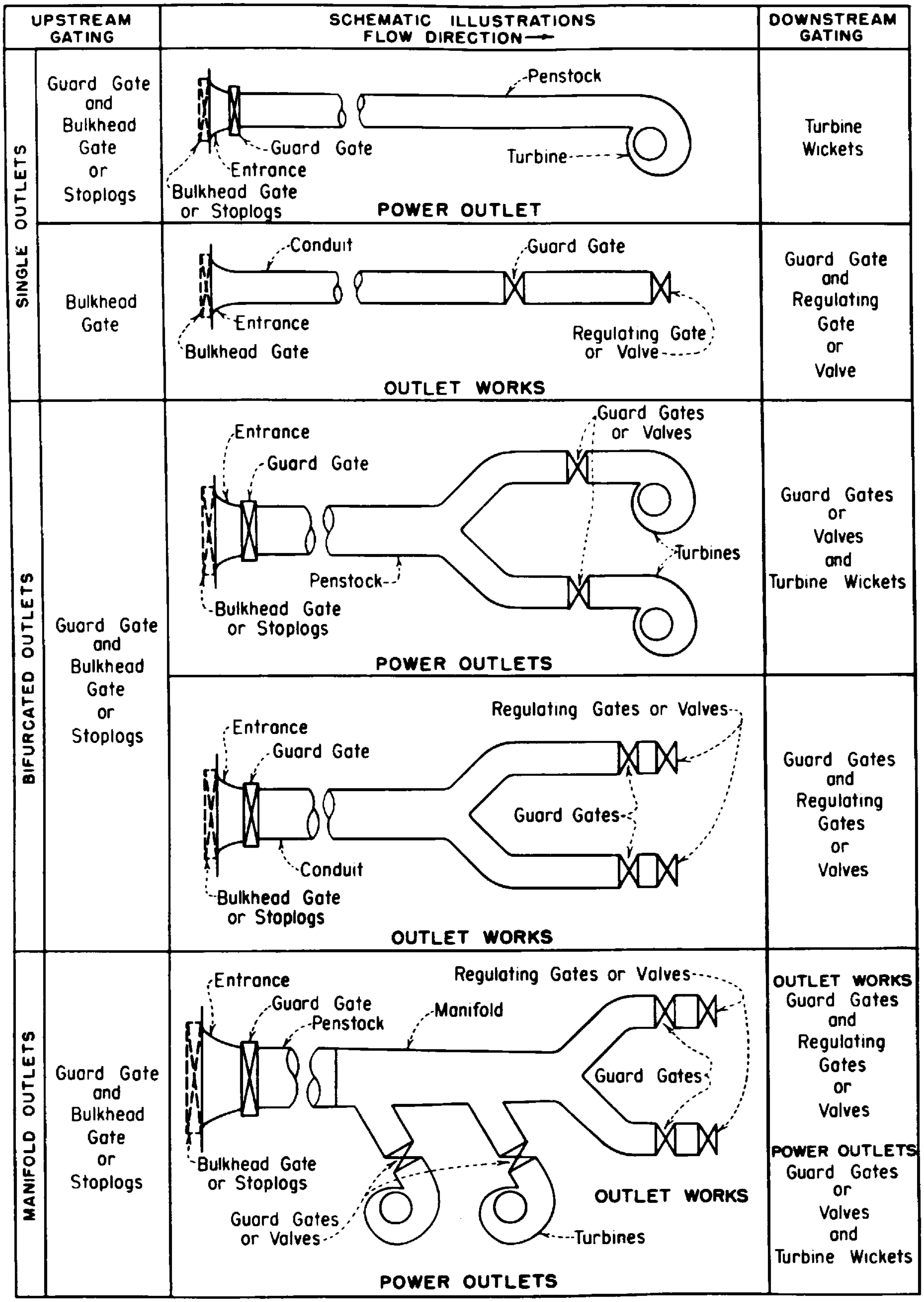
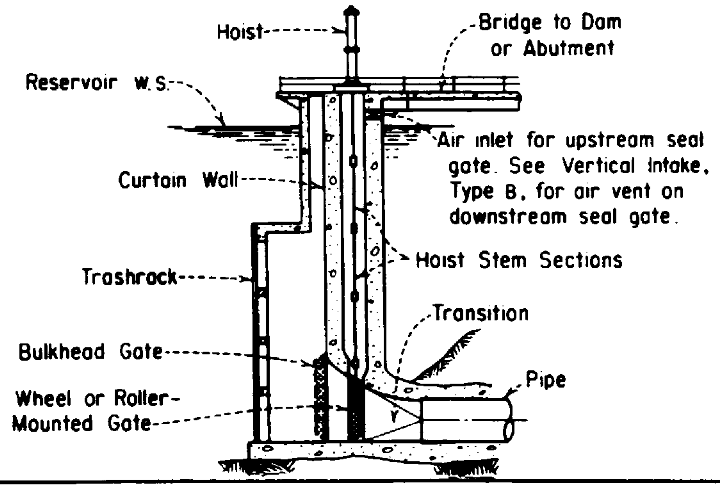
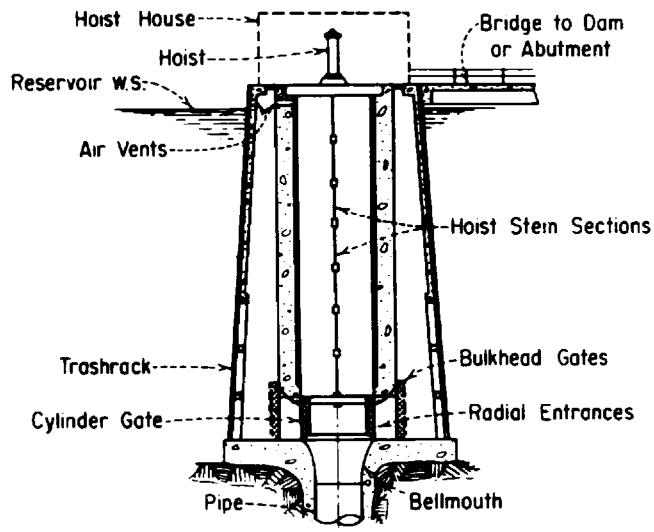
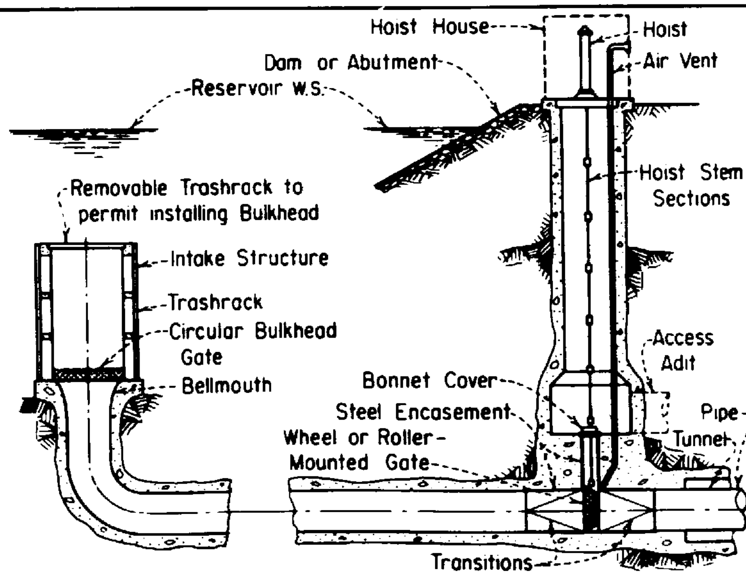


Figure 15. – Common gate and valve arrangements.

<table>
<tr><th>TYPE</th><th>SCHEMATIC ILLUSTRATION
FLOW DIRECTION ⟶</th><th>NOTES AND COMMENTS</th></tr>
<tr><td>TOWER INTAKE (RECTANGULAR GATE)</td><td>


</td><td>Tower intakes are used principally on earth dams where abutments are not suitable for intake structures. Also used for concrete dams where intakes must be located on abutments and other types are not suitable. Basic arrangement is similar to vertical abutment intake. Bridge is usually provided to dam or abutment.</td></tr>
<tr><td>TOWER INTAKE (CYLINDER GATE)</td><td>


</td><td>Tower intake used primarily where intake entrance is vertical. Other selection factors are similar to those stated above for vertical towers for rectangular gates.</td></tr>
<tr><td>SHAFT (SUBMERGED UPSTREAM INTAKE)</td><td>


</td><td>Intake arrangement used principally on earth dams. Shaft usually located near axis of dam, either in dam or abutment. Abutment location is preferrable to avoid joint between abutment rock and dam fill. Intake Bulkhead installation requires drawing reservoir down or placement from a barge and the employment of divers.</td></tr>
</table>

Figure 16. – Intake arrangements.

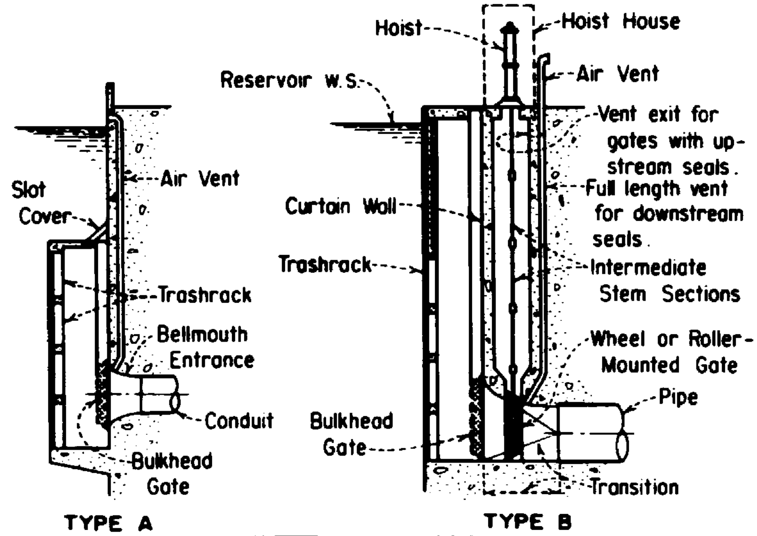
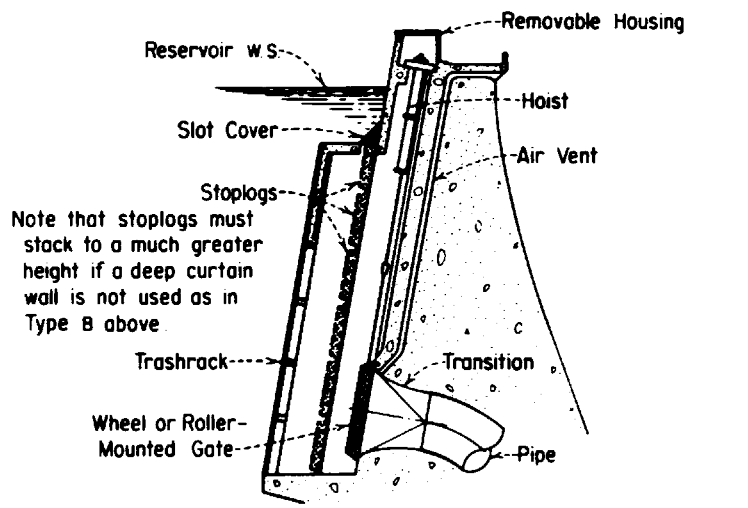
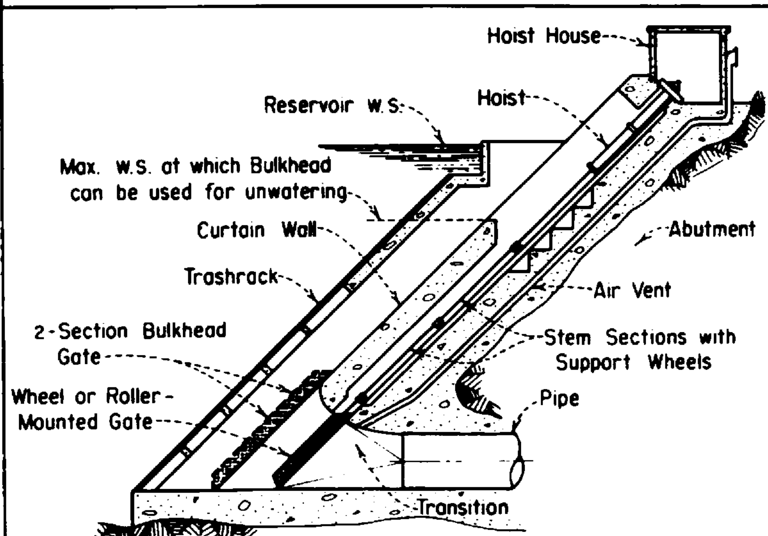
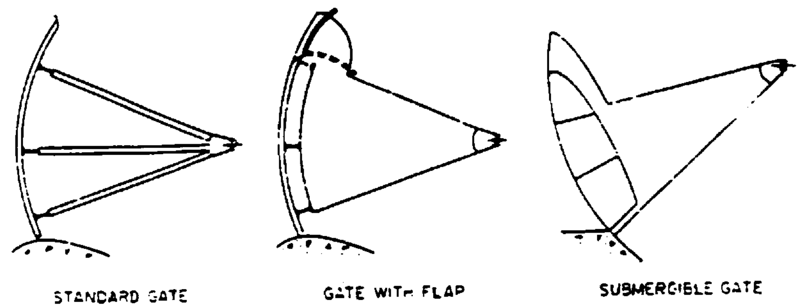
<table>
<tr><th>TYPE</th><th>SCHEMATIC ILLUSTRATION
FLOW DIRECTION ⟶</th><th>NOTES AND COMMENTS</th></tr>
<tr><td>VERTICAL INTAKE ON DAM OR ABUTMENT</td><td>
</td><td>Intake types used principally on concrete dams and on earth dams with abutment intakes. Type A used primarily for single line outlet works. Type B used for all types of power outlets and for branched and manifold type of outlet works.</td></tr>
<tr><td>SMALL SLOPE INTAKE ON DAM</td><td>
</td><td>Type of intake frequently used on thin-arch concrete dams. Used for all types of power outlets and for branched and manifold outlet works. Gantry crane is usually provided for handling gate and stoplogs for multiple outlet installations.</td></tr>
<tr><td>LARGE SLOPE INTAKE ON ABUTMENT</td><td>
</td><td>Intake used mainly for abutment intakes on earth dams. Hoist stems must be provided with support wheels. Reduction in effective weight for gravity closing may require the provision of closing thrust by the hoist, or the use of roller-mounted gates.</td></tr>
</table>

Figure 17. – Intake arrangements.



Types of Tainter gates.

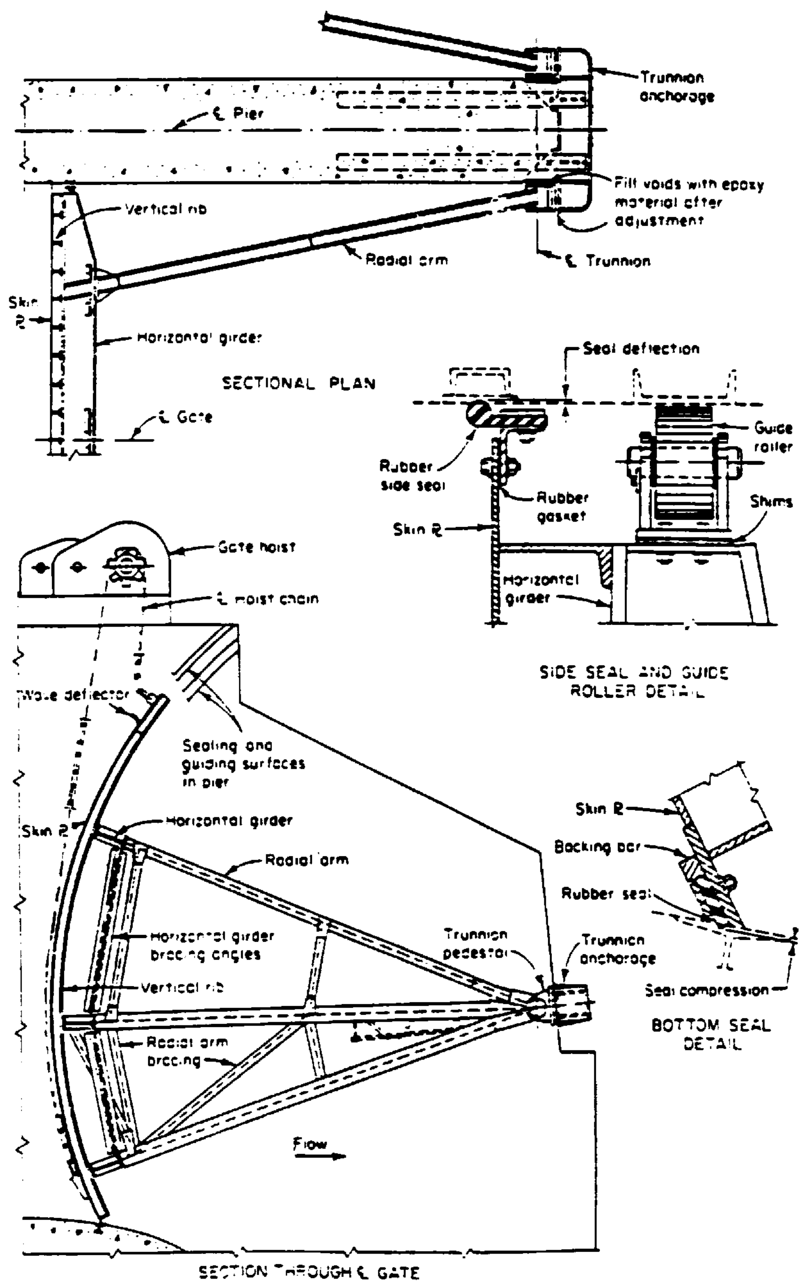
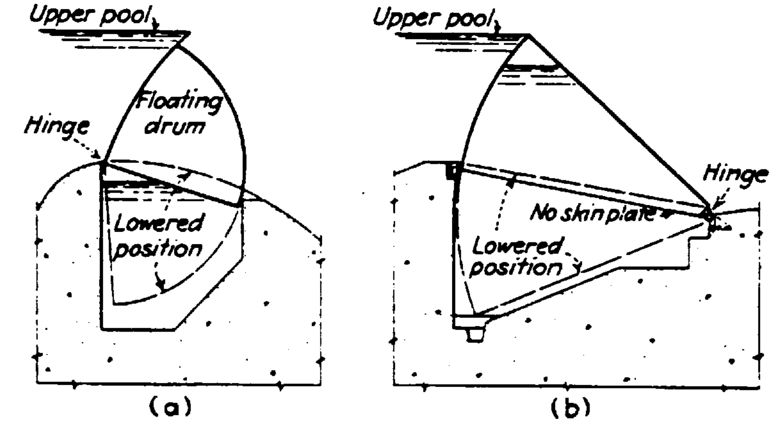


Figure 18. – Radial gate.



Drum gates.

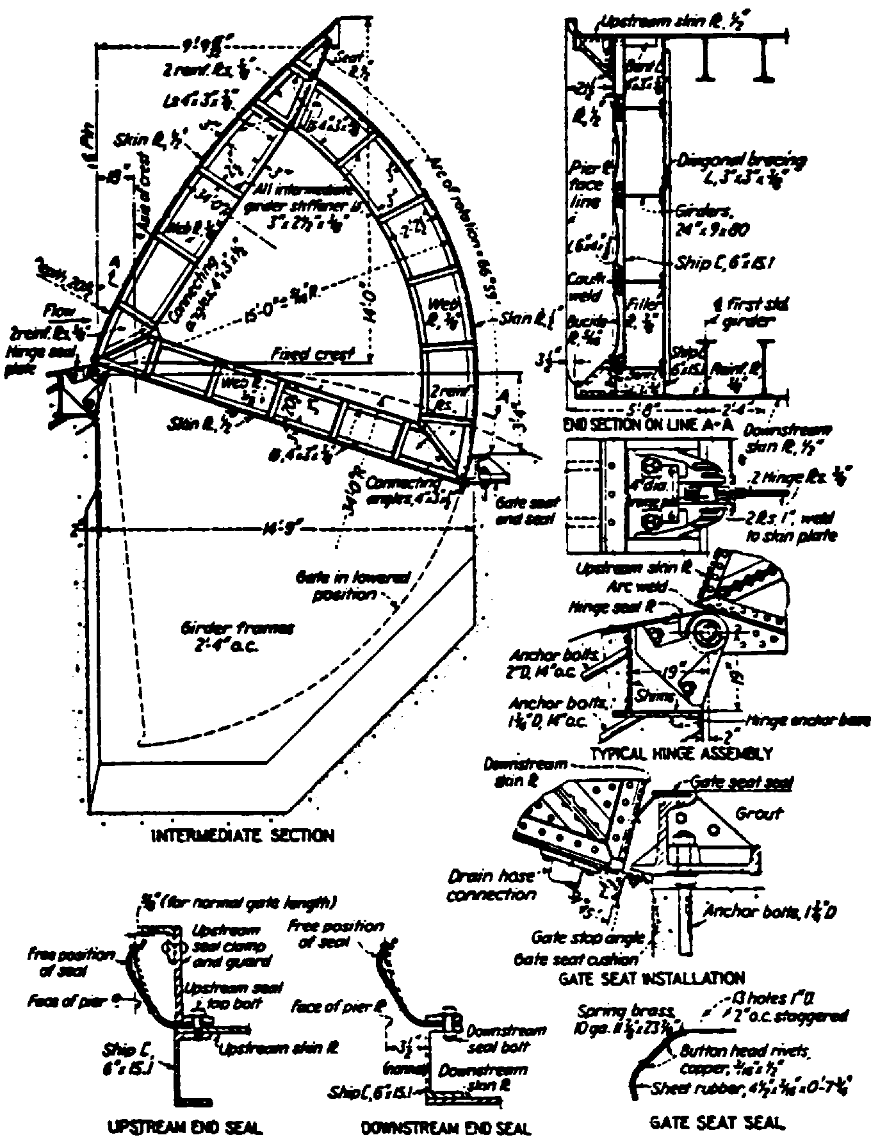


Figure 19. – Drum gate.

the leaf. Since slide gates usually seal downstream, the downstream mating surfaces between the leaf and the body act as bearing and sealing surfaces. Figure 20 shows an outlet works slide gate.

d. Roller- and wheel-mounted gates.–Roller-mounted (coaster) and wheel-mounted (fixed wheel) gates consist of a flat structural steel gate leaf with a roller system or a series of wheels fixed to the leaf to transfer the hydraulic load from the gate to tracks imbedded in concrete. These gates are used as spillway gates or as the primary guard gate for a penstock or outlet conduit. Depending on the application, the hoist for the gate may be a hydraulic cylinder or some type of a mechanical hoist. Figures 21 and 22 show typical installations.

e. Jet-flow gates.–Jet-flow gates are used strictly for water regulation through outlet conduits. A jet-flow gate is similar to a slide gate consisting of a leaf, a body, a bonnet, and a hoist to position the leaf. The outlet of the gate is circular in cross section, rather than square or rectangular as a slide gate, with a conical nozzle upstream of the gate. This nozzle produces a contracted, jet-type discharge that jumps over the gate leaf slot. Figure 23 shows a jet-flow gate.

f. Cylinder gates.–Cylinder gates are used on circular, vertical intake structures and can be used as a guard gate for penstocks or outlet conduits or to regulate flow. A cylinder gate consists of a cylindrical shell which is raised or lowered to open or close radial openings on the intake structure (figure 24). Mechanical or hydraulic hoists may be used to move the gates.

g. Ring-follower gates.–Ring-follower gates are used as guard gates for penstocks or outlet conduits and are not suitable for water regulation. A ring-follower gate is a slide gate with a leaf, body, bonnet, and a hoist, usually a hydraulic cylinder, to move the leaf. The ring-follower gate leaf consists of two parts, the bulkhead part which blocks the fluid flow in the closed position and the "ring" portion which has a circular opening matching the diameter of the penstock or conduit to provide an unobstructed water passage in the open position. A ring-follower gate is shown in figure 25.

h. Ring-Seal Gates.–Ring-seal gates are a type of ring-follower gate with a movable seal and a wheel- or roller-mounted gate leaf. The gate seal is hydraulically actuated by water pressure, either from the conduit or an external source, and may be located in the housing or the leaf. The hoist may be mechanical or a hydraulic cylinder. Ring-seal gates are shown in figures 26 and 27.

i. Bulkhead gates and stoplogs.–Bulkhead gates and stoplogs are installed under balanced, no-flow conditions, and are used to allow the unwatering of a waterway such as an outlet pipe, penstock, or turbine draft tube. In the case of outlet pipes and penstocks, they are placed as far upstream as possible to allow the complete unwatering of the waterway and provide access to gates or valves in the waterway. Bulkhead gates and modern stoplogs are both constructed of structural steel with rubber seals and are virtually identical in appearance. Stoplogs are differentiated from bulkhead gates in that they employ more than two sections and when all the sections are installed, extend above the reservoir surface. Bulkhead gates are made up of one or two sections and only cover the entrance to the waterway. Bulkhead gates and

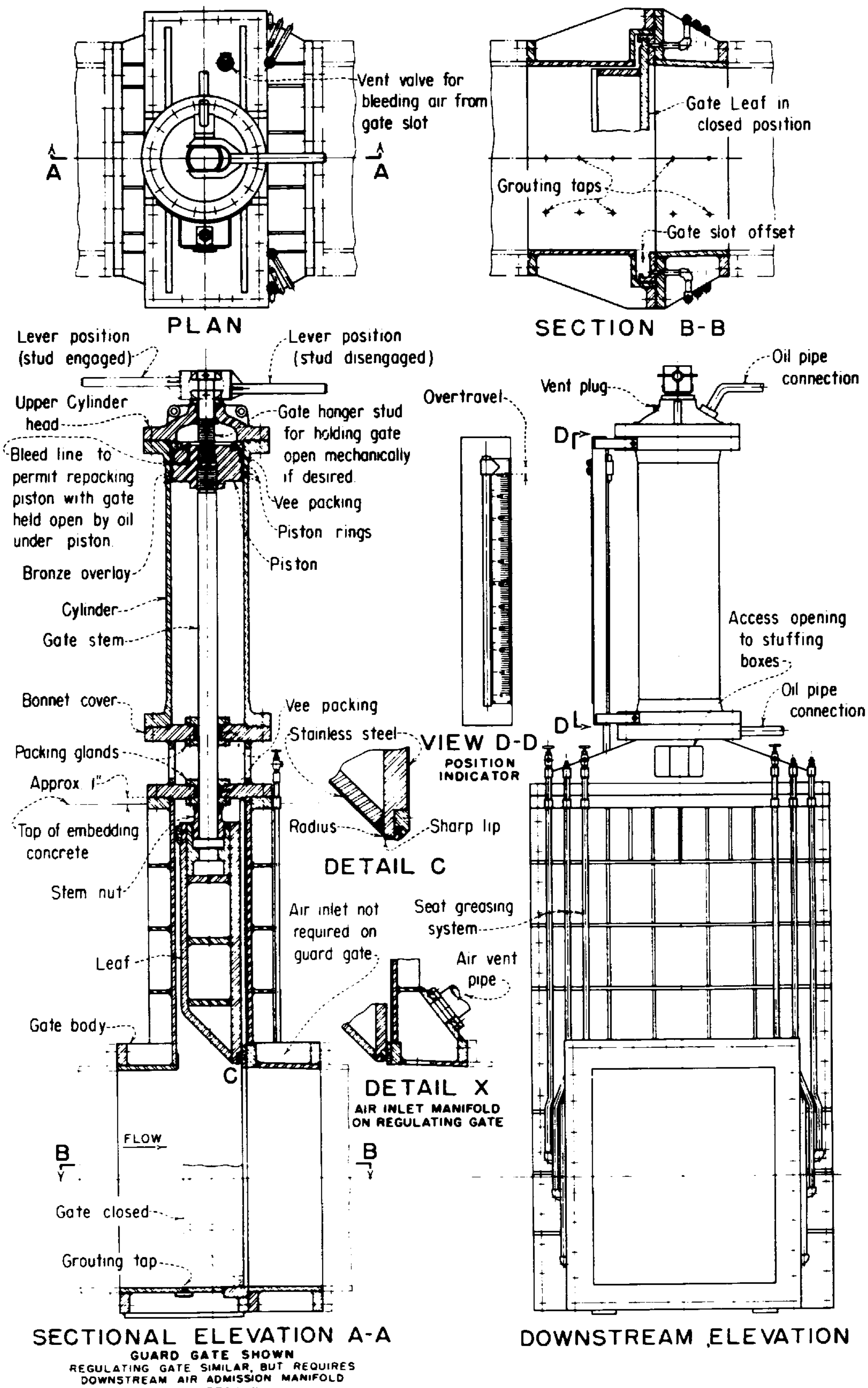


Figure 20. – Slide gate.

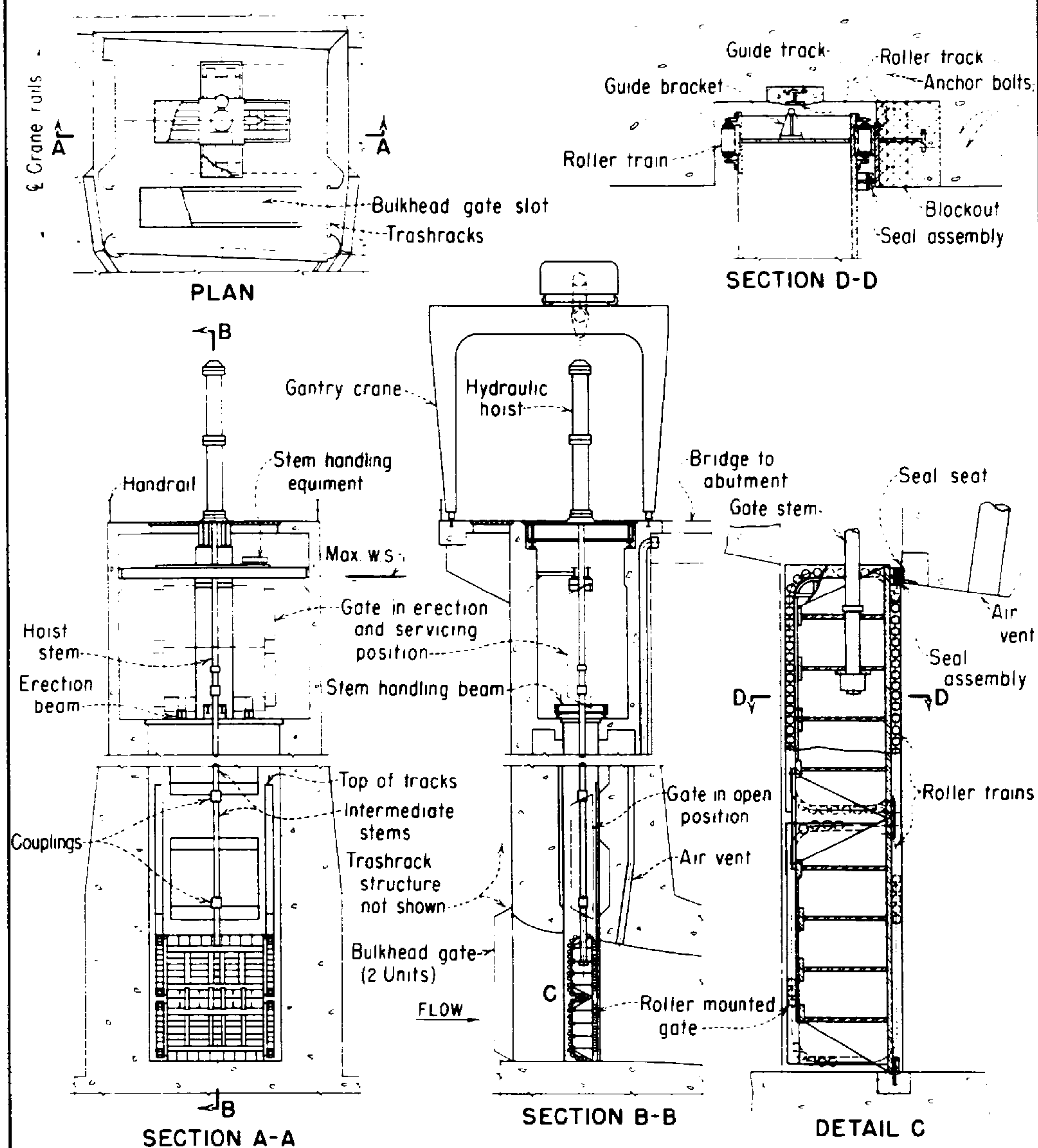


Figure 21. - Roller-mounted gate (coaster gate).

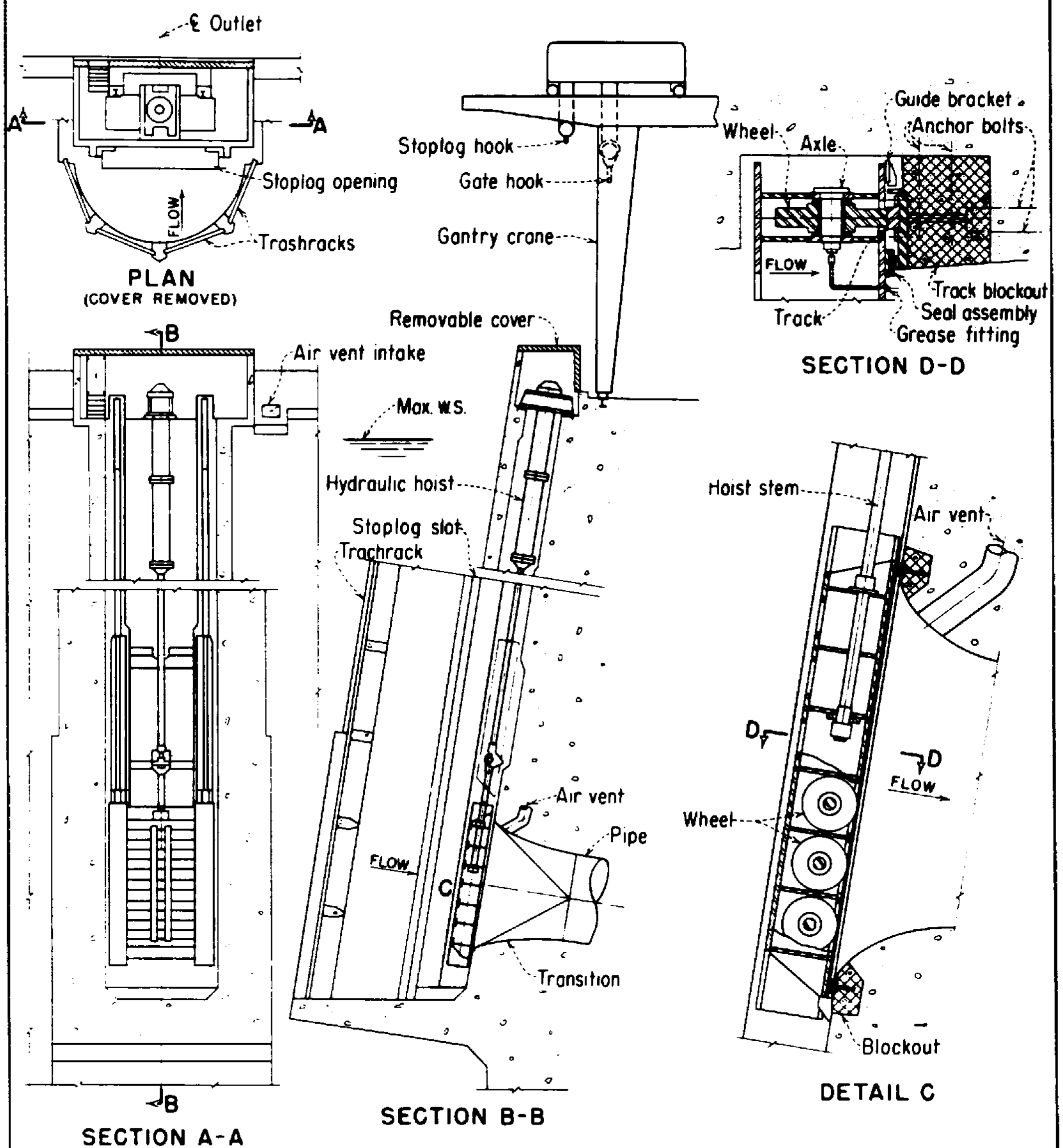


Figure 22. - Wheel-mounted gate (fixed wheel gate).

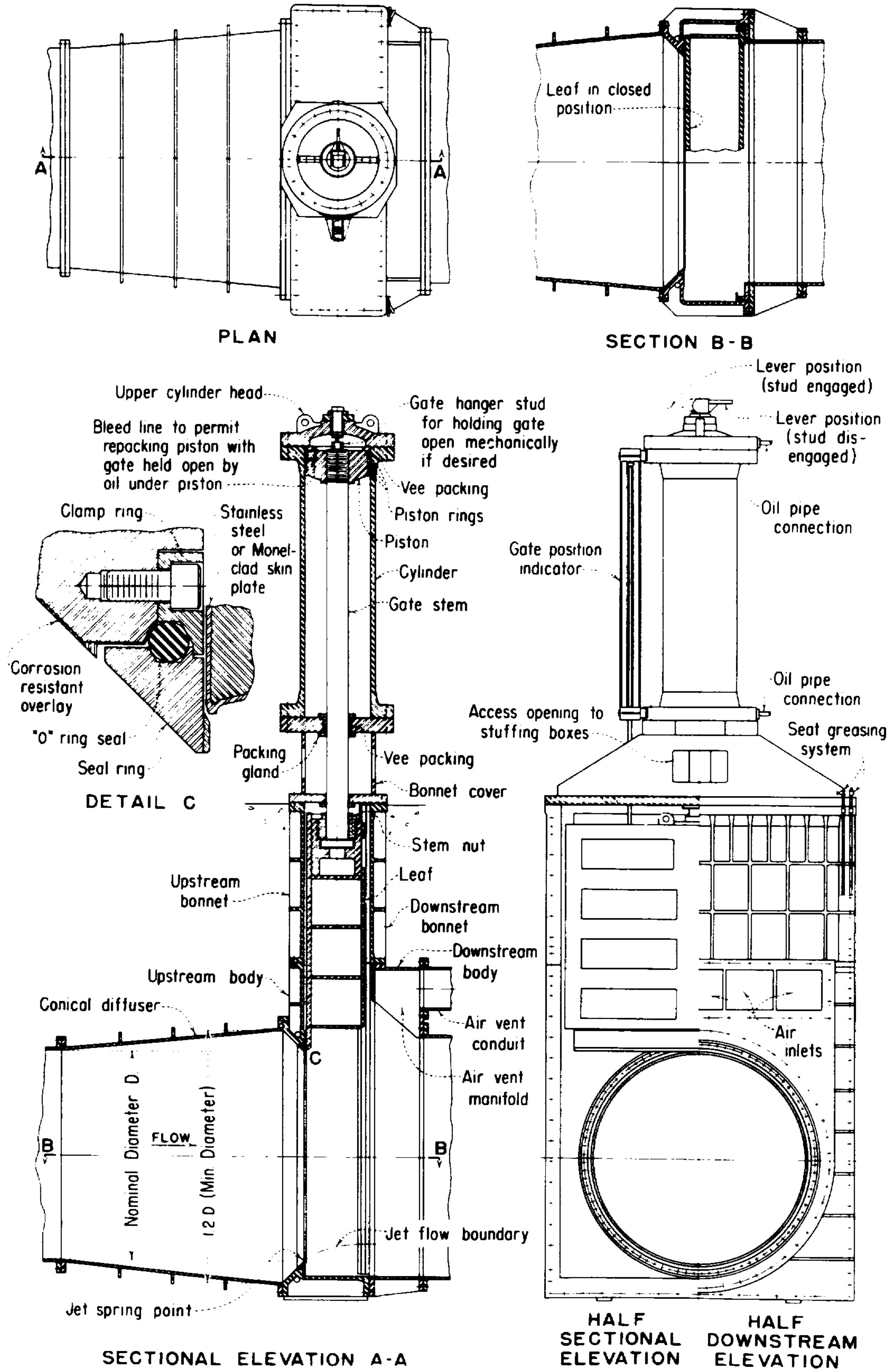


Figure 23. – Jet-flow gate.

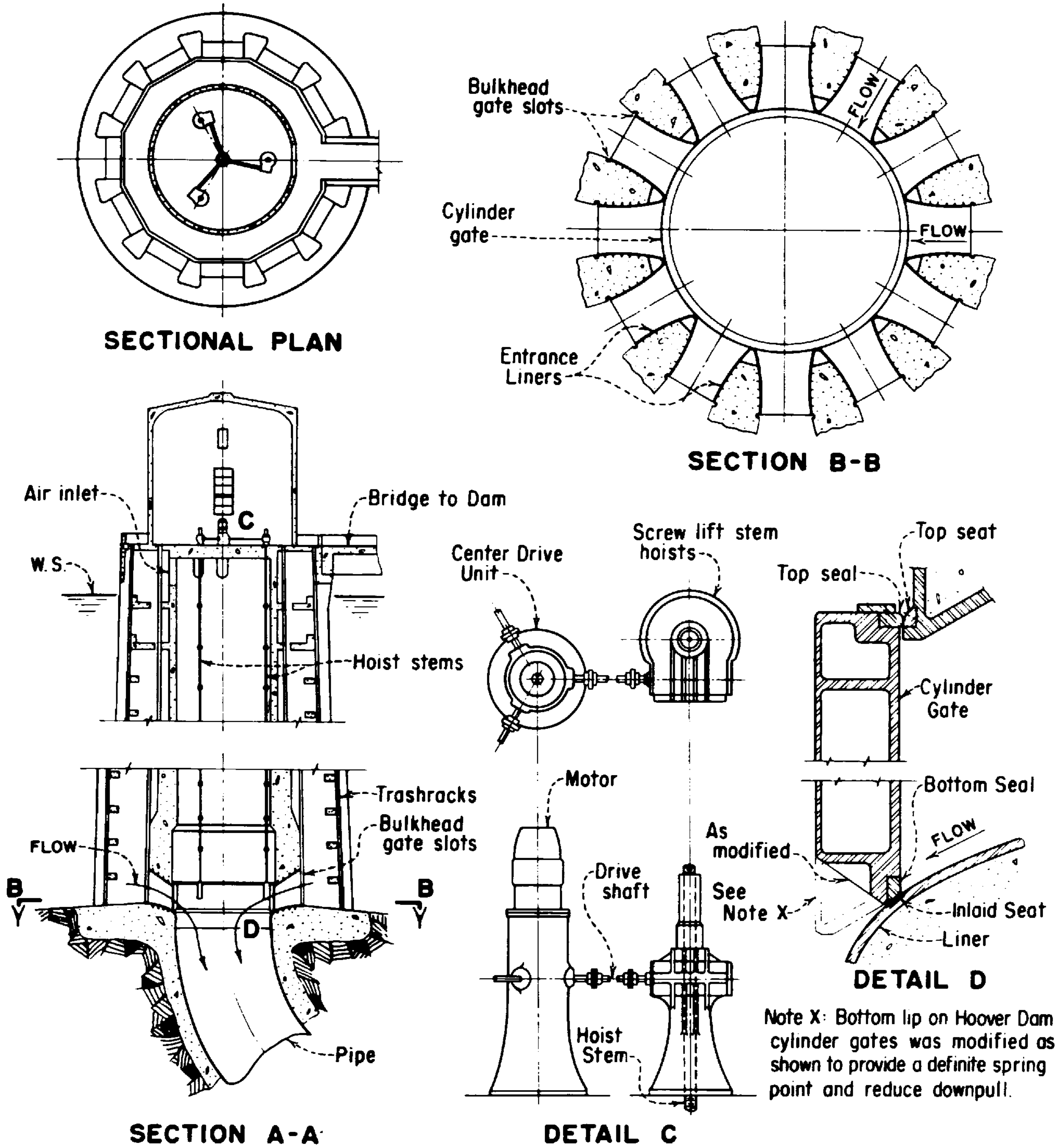


Figure 24. - Cylinder gate.

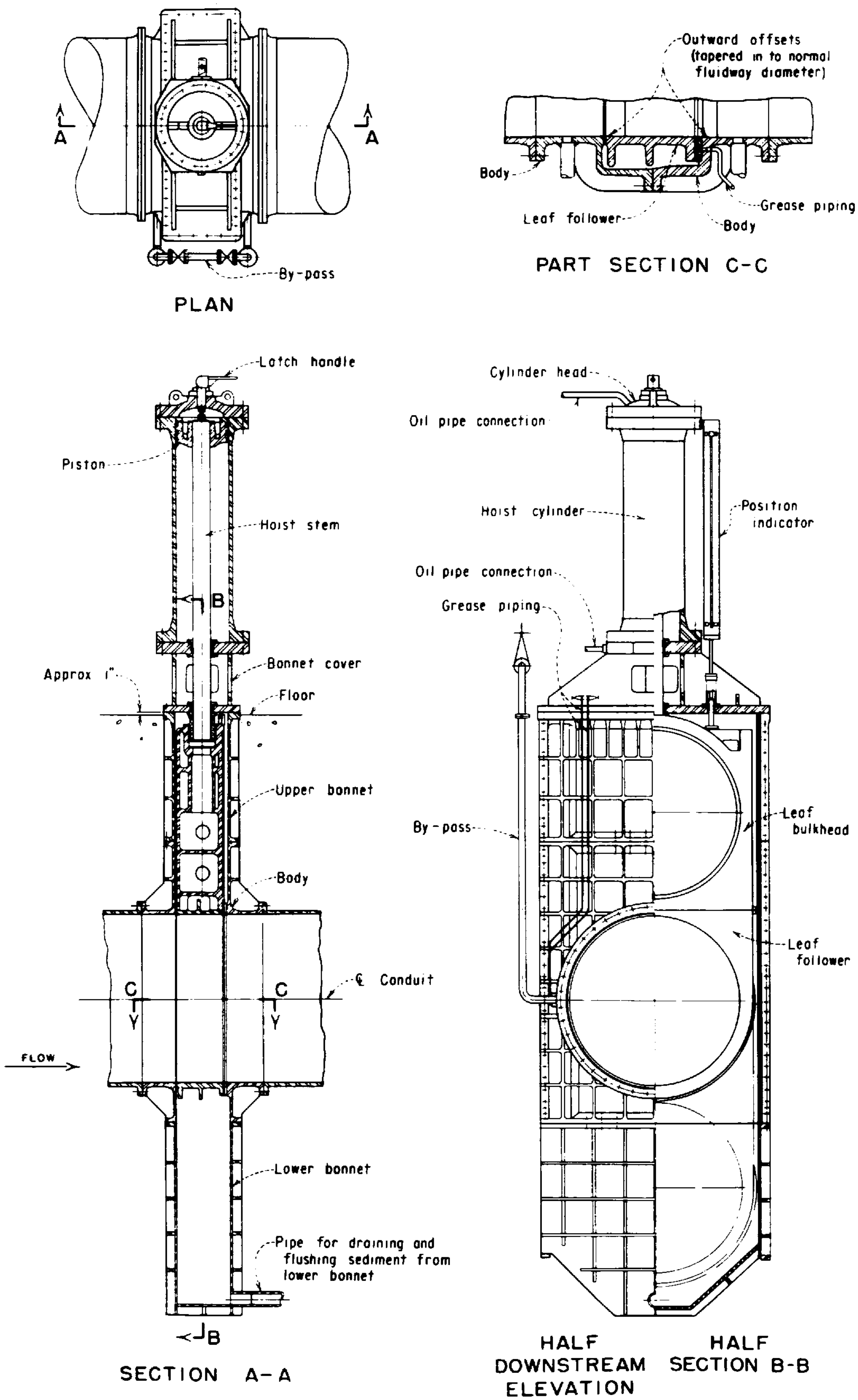


Figure 25. – Ring-follower gate.

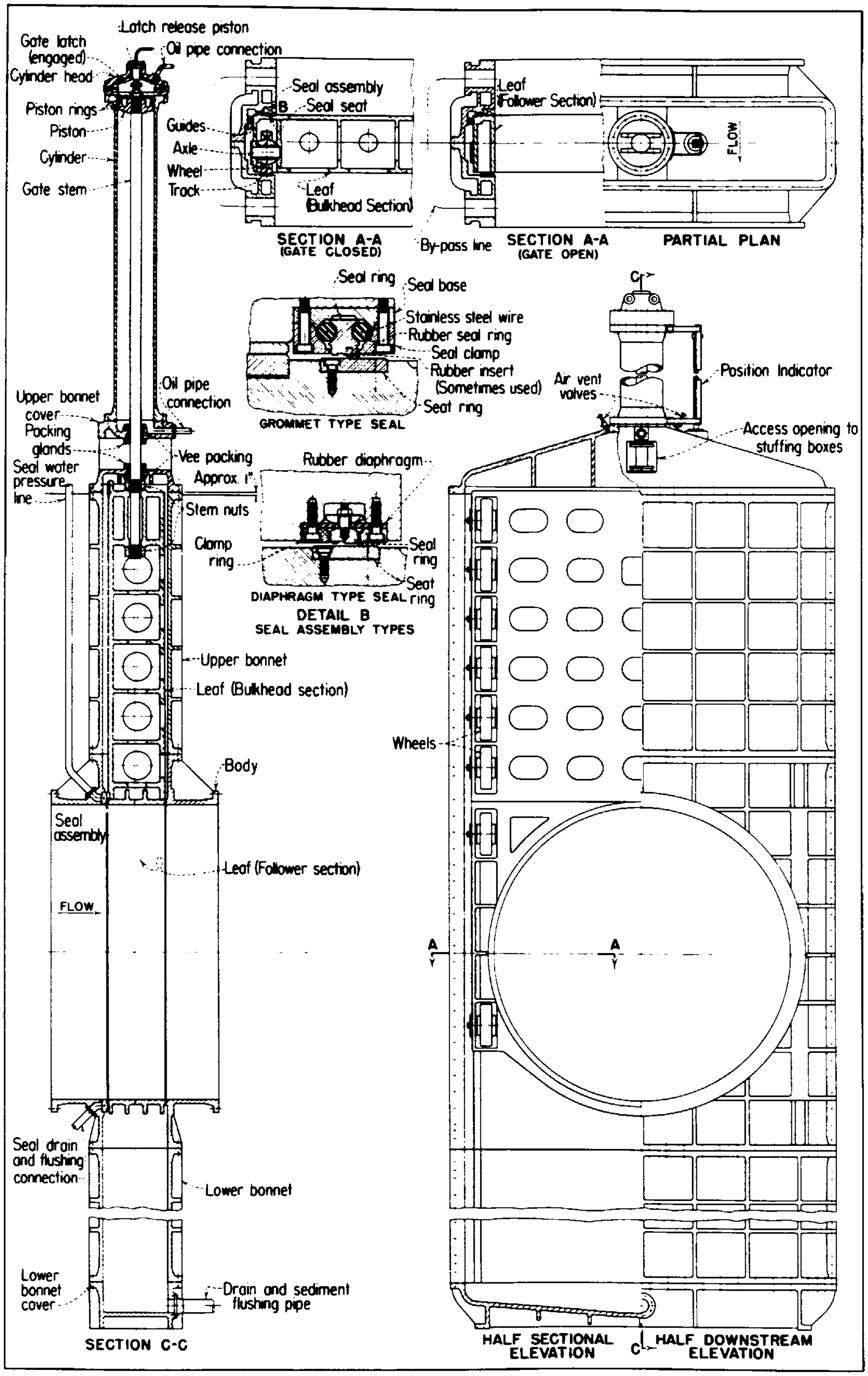


Figure 26. – Ring-seal gate (hydraulically operated).

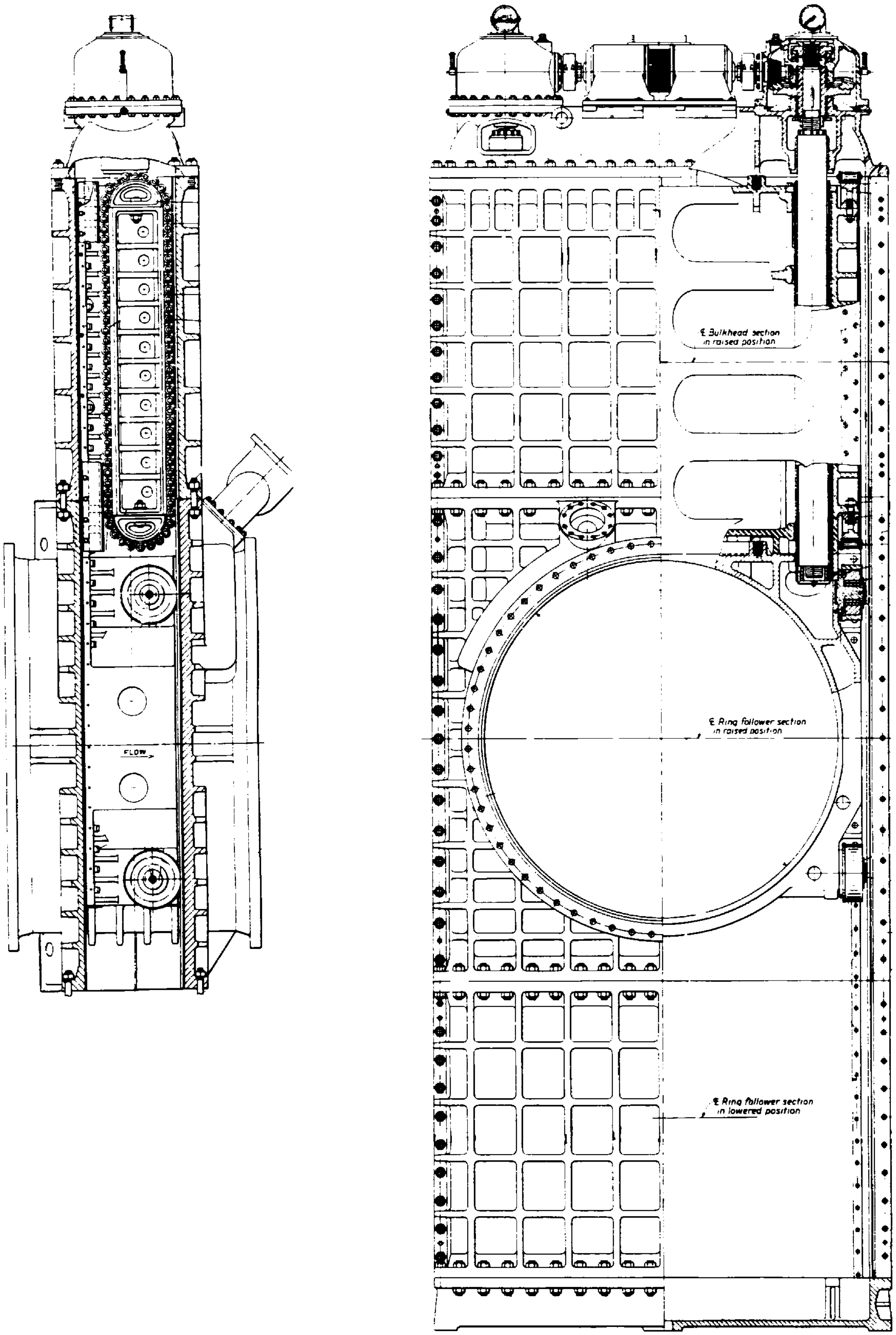


Figure 27. – Ring-seal gate (mechanically operated).

stoplogs are usually installed with a gantry or mobile crane. Figures 28 and 29 show typical bulkhead gate and stoplog installations.

Valves.–Valves, like gates, can regulate flow or act as guard valves to penstocks and outlet conduits. This section will describe the most common valve types in use in Reclamation facilities.

a. Tube valves.–Tube valves are used primarily as regulating valves in outlet conduits. The tube valve is essentially a needle valve with the downstream needle omitted to eliminate the cavitation damage experienced with normal needle valves. A hollow cylinder or tube is actuated by a mechanical operator to seal against a valve seat on the downstream end of the valve. Like a needle valve the fluidway converges at the outlet. A tube valve is shown in figure 30.

b. Hollow-jet valves.–Hollow-jet valves are used as regulating valves and are similar in construction to a tube valve. The closure member of the hollow-jet valve is the needle which moves upstream to seal against its valve seat. The fluid way is not converging so that the discharge is in the shape of a hollow jet. The hollow-jet valve can be operated either hydraulically or mechanically. Figures 31 and 32 are examples of hollow-jet valves.

c. Butterfly valves.–Butterfly valves are most commonly used as guard valves on penstocks and outlet conduits. They may be used for flow regulation only if the head differential across the leaf is small. The butterfly valve consists of a cylindrical or conical shaped body with a circular leaf, mounted on a horizontal or vertical shaft, perpendicular to the fluidway. An external actuator, usually hydraulic, rotates the leaf 90 degrees to fully open or close the valve. A butterfly valve is shown in figure 33.

Valve and Gate Operators.–

a. Threaded-stem hoist.–Basically, a threaded-stem-type hoist consists of a steel, acme-threaded stem mated to a bronze stem nut. Depending on the application, the stem or the stem nut may be rigidly attached to the gate. In a rising stem-type gate, the nut is rotated and the stem rises with the gate. In some cases the stem is rotated and the gate rises with the stem nut. In most cases, the hoist is electric motor driven through a system of gears. Ring-seal gates and some jet-flow gates use threaded-stem-type hoists with twin stems. Threaded-stem hoists are shown in figures 34 and 35.

b. Chain and sprocket hoist.–Chain and sprocket hoists are used to raise or lower large gates which are used infrequently. The hoists are powered by an electric motor which drives a reduction unit with two output shafts. The output shafts each drive a hoist unit with reduction gearing, drive sprocket, idler sprocket, and sprocket chain. One end of each chain is attached to the gate and the other to a counterweight. A typical chain and sprocket hoist is illustrated in figure 36.

c. Wire rope hoist.–Wire rope hoists are most commonly used with radial gates. Wire rope hoists normally use two drums driven by an electric motor through reduction gearing similar to the chain and sprocket hoist. A wire rope hoist is shown in figure 37.

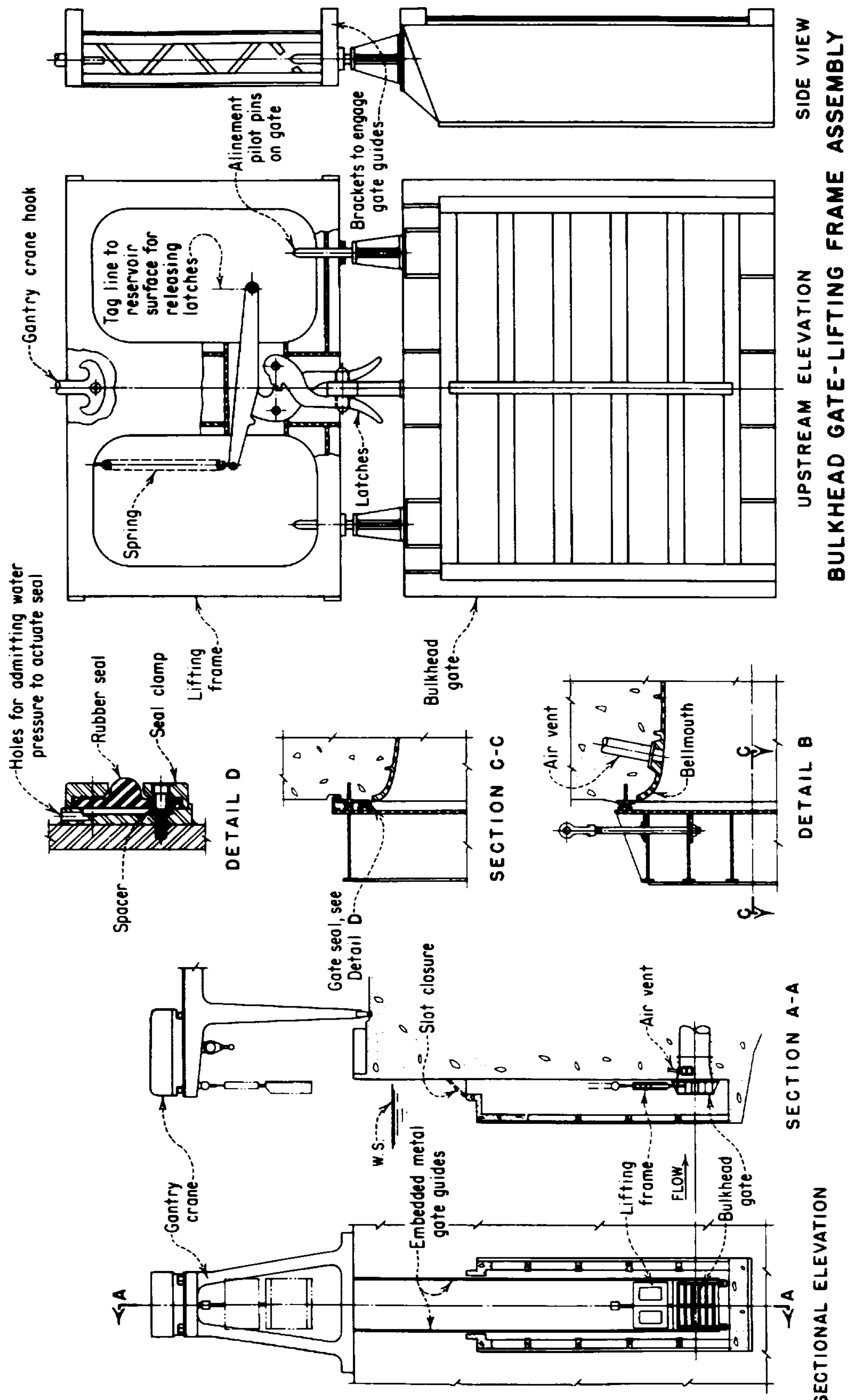


Figure 28. - Bulkhead gate.

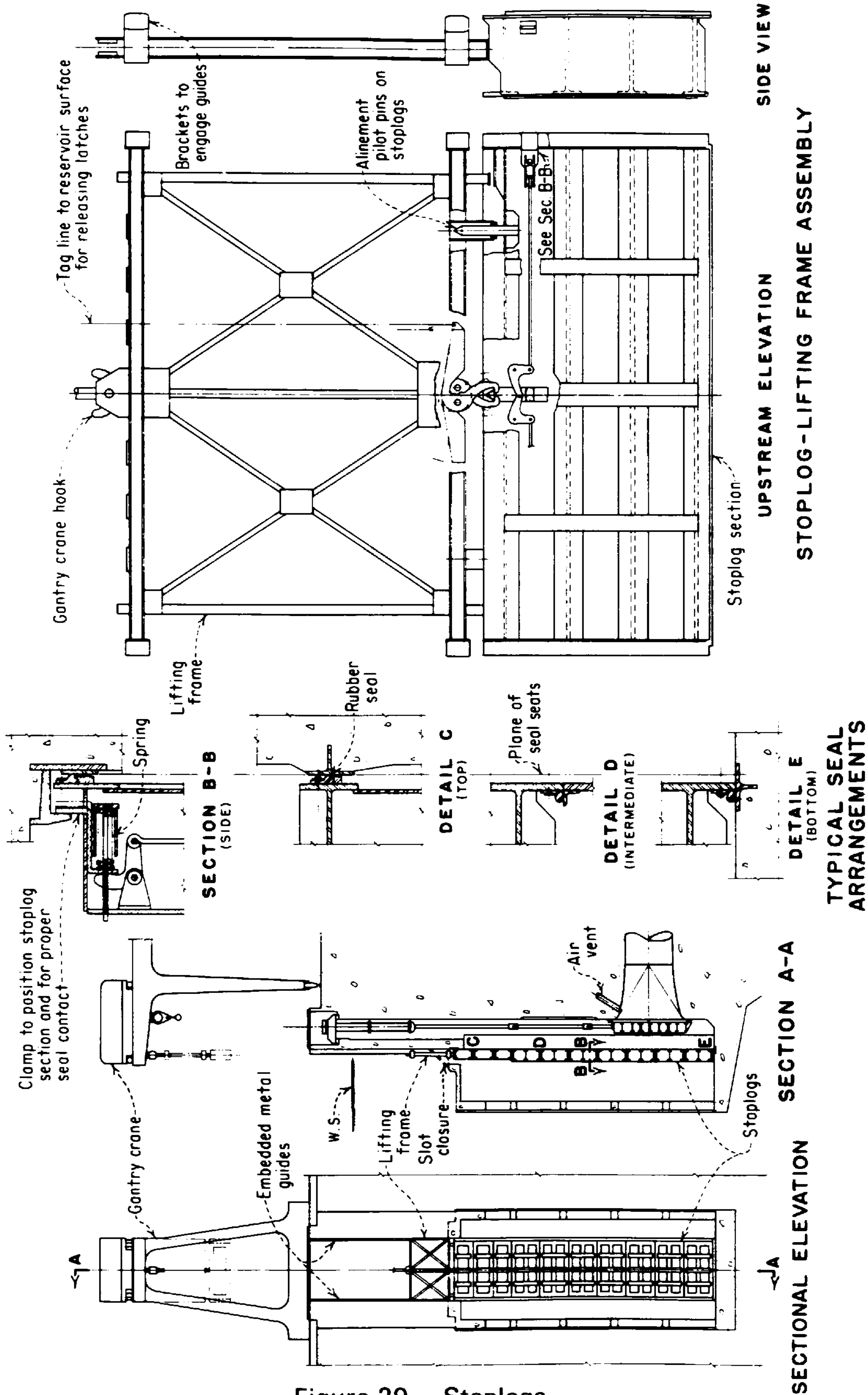


Figure 29. - Stoplogs.

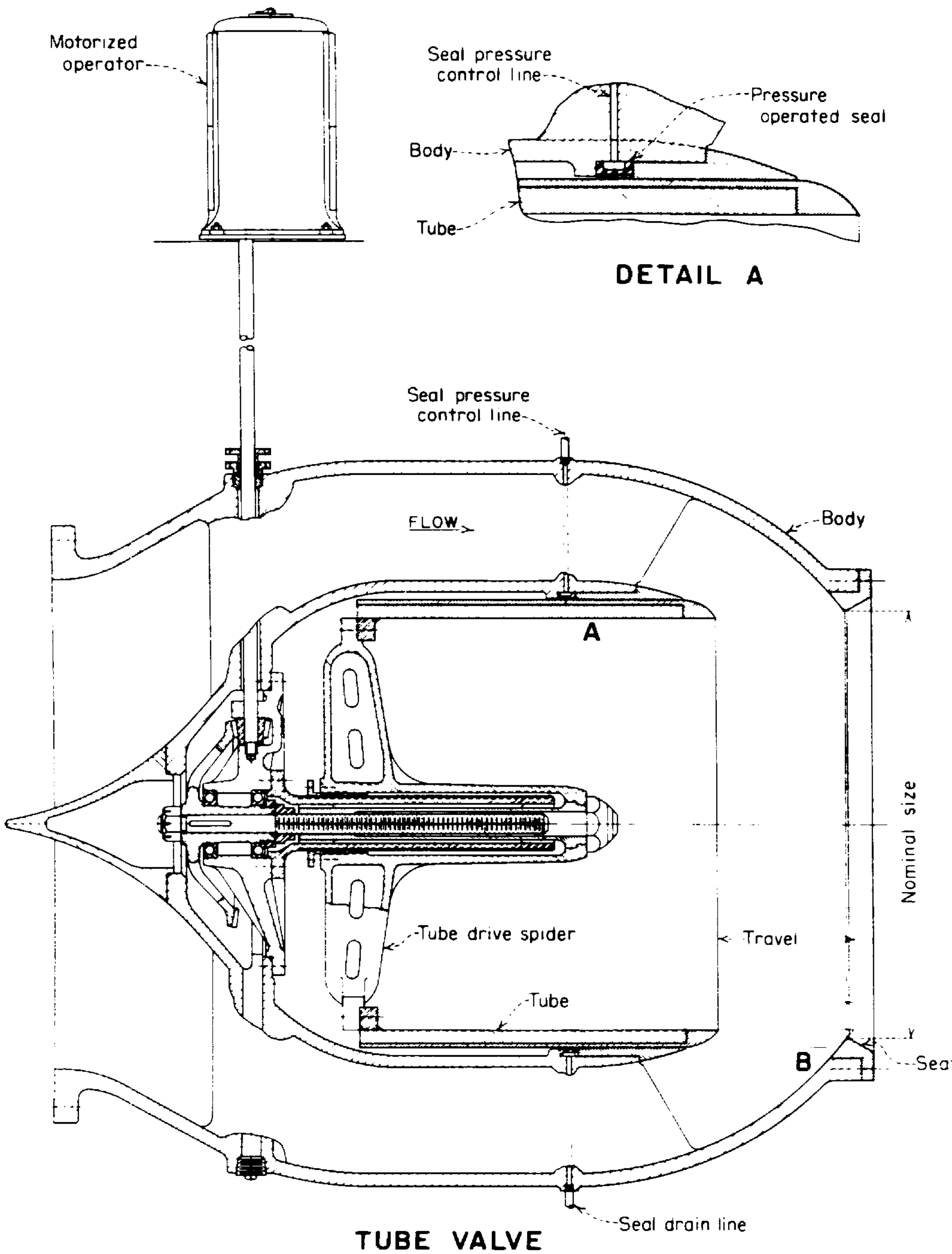
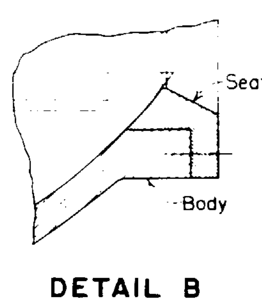


Figure 30. - Tube valve.



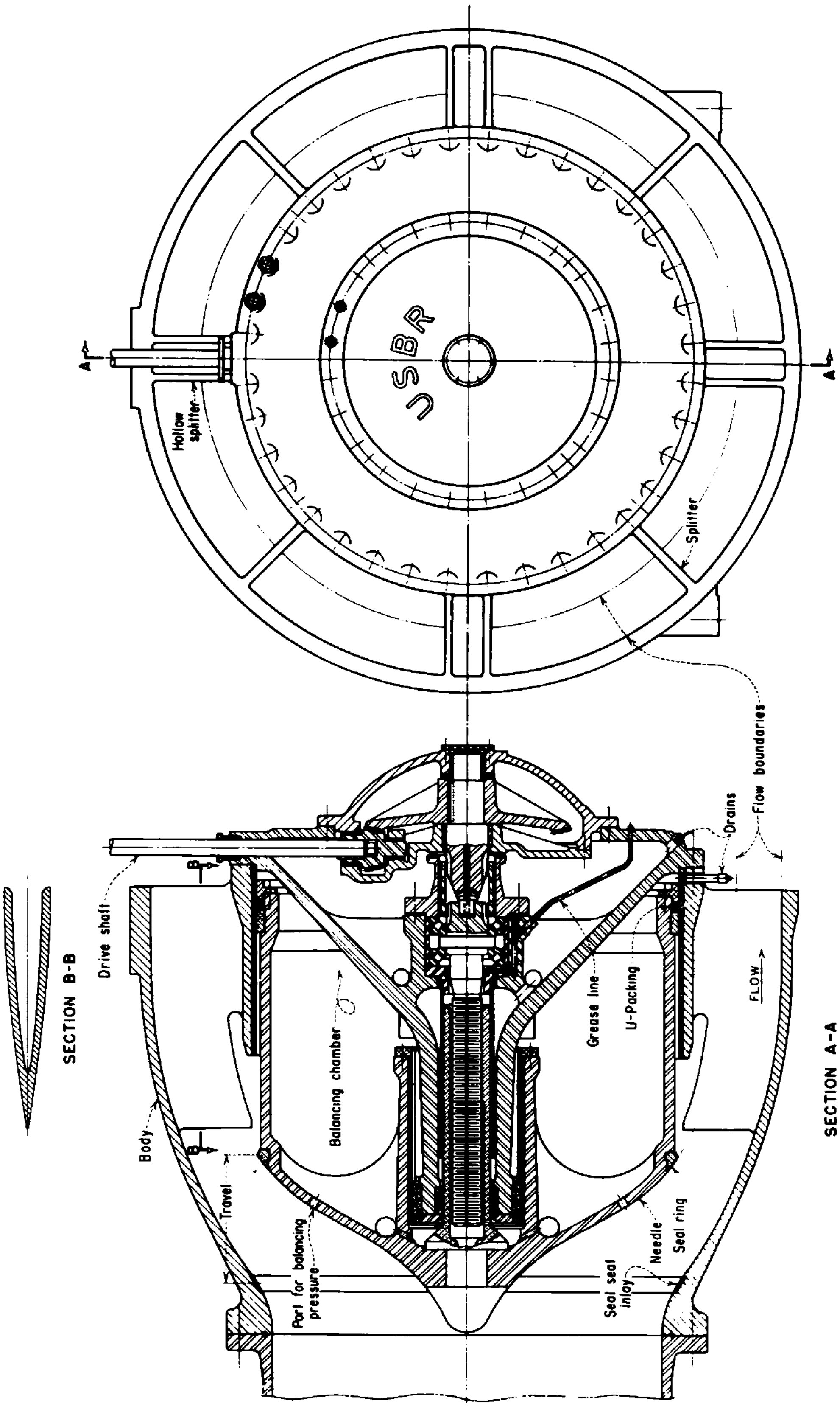


Figure 31. - Hollow-jet valve (mechanically operated).

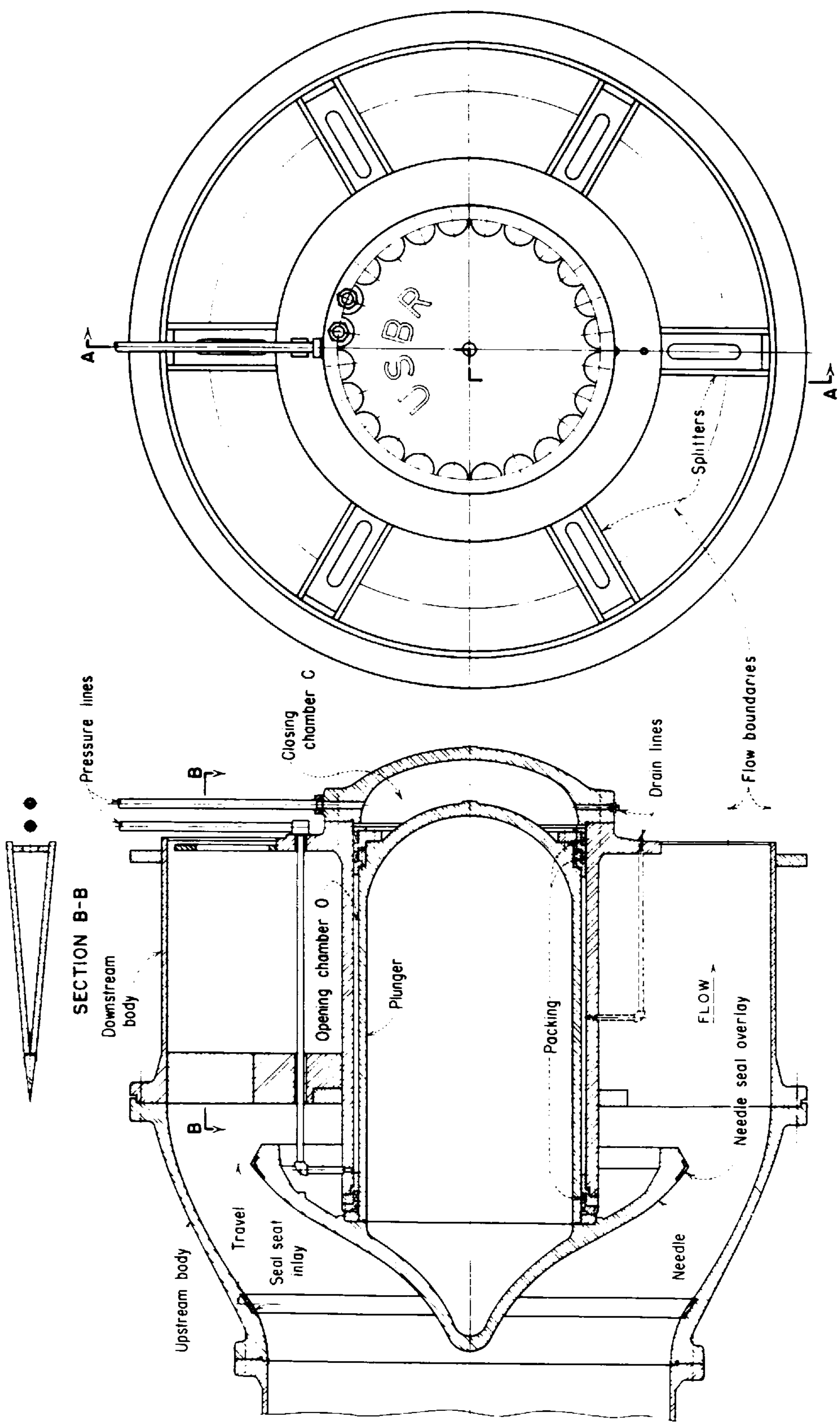


Figure 32. – Hollow-jet valve (hydraulically operated).

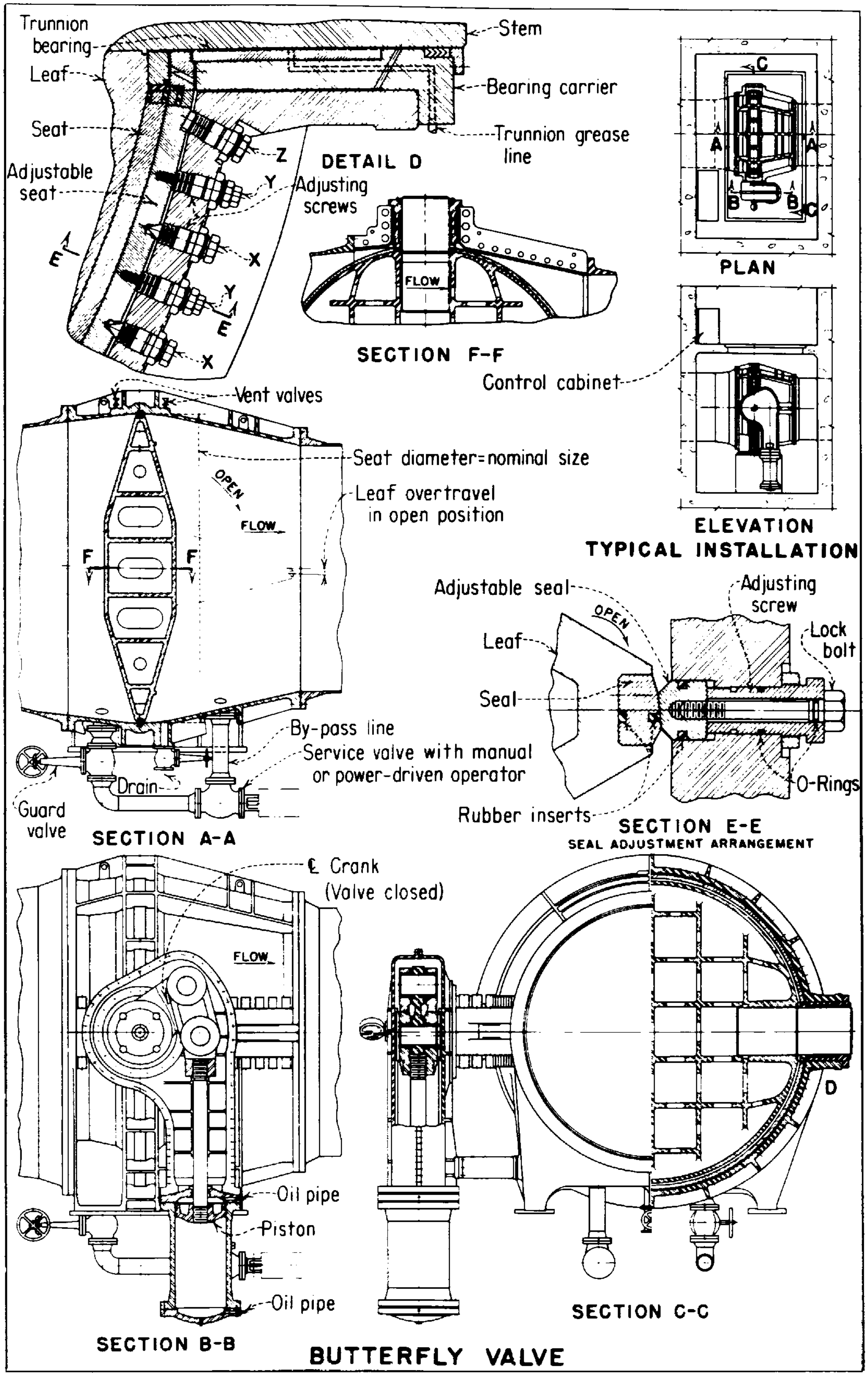


Figure 33. – Butterfly valve.

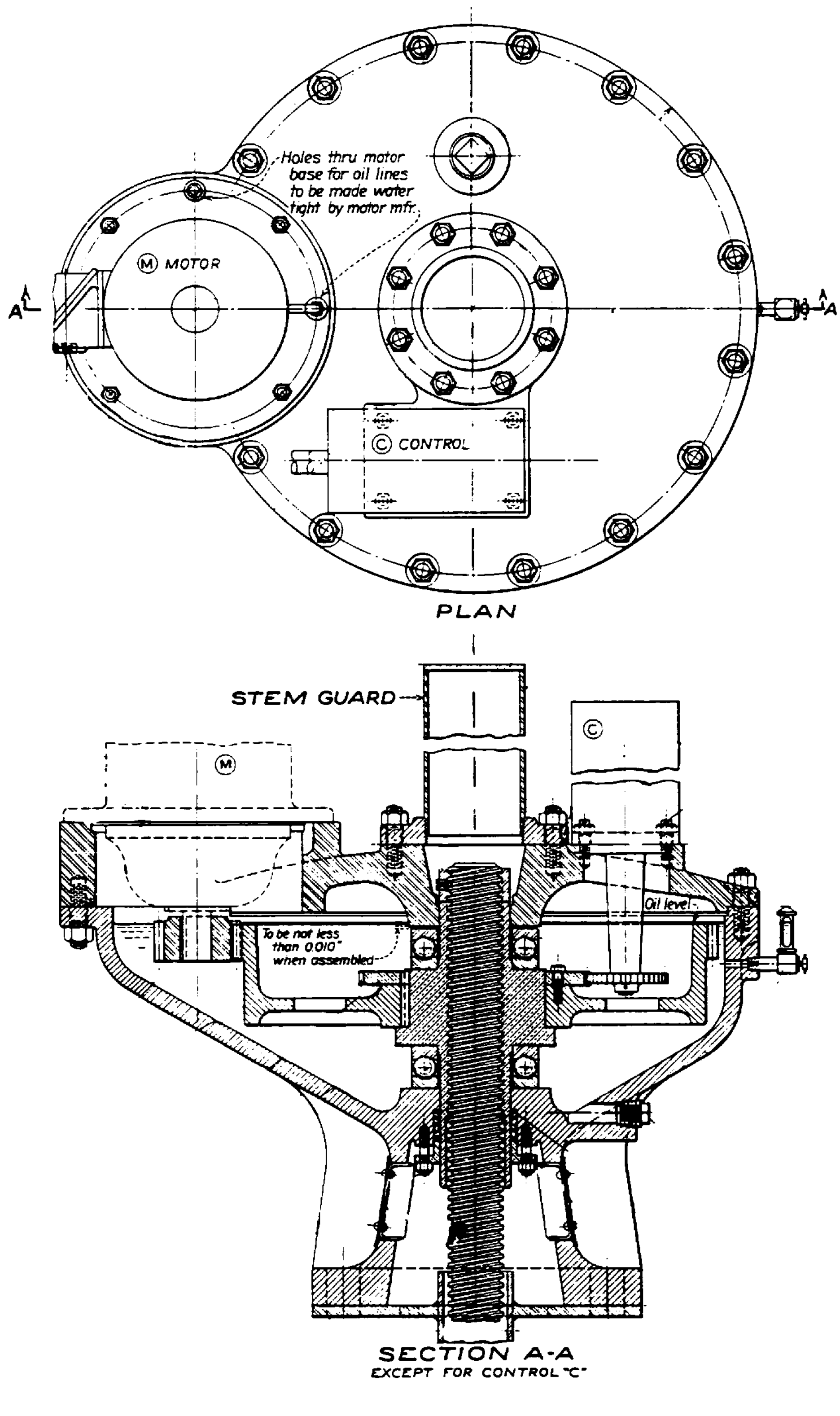


Figure 34. – Rising stem gate hoist.

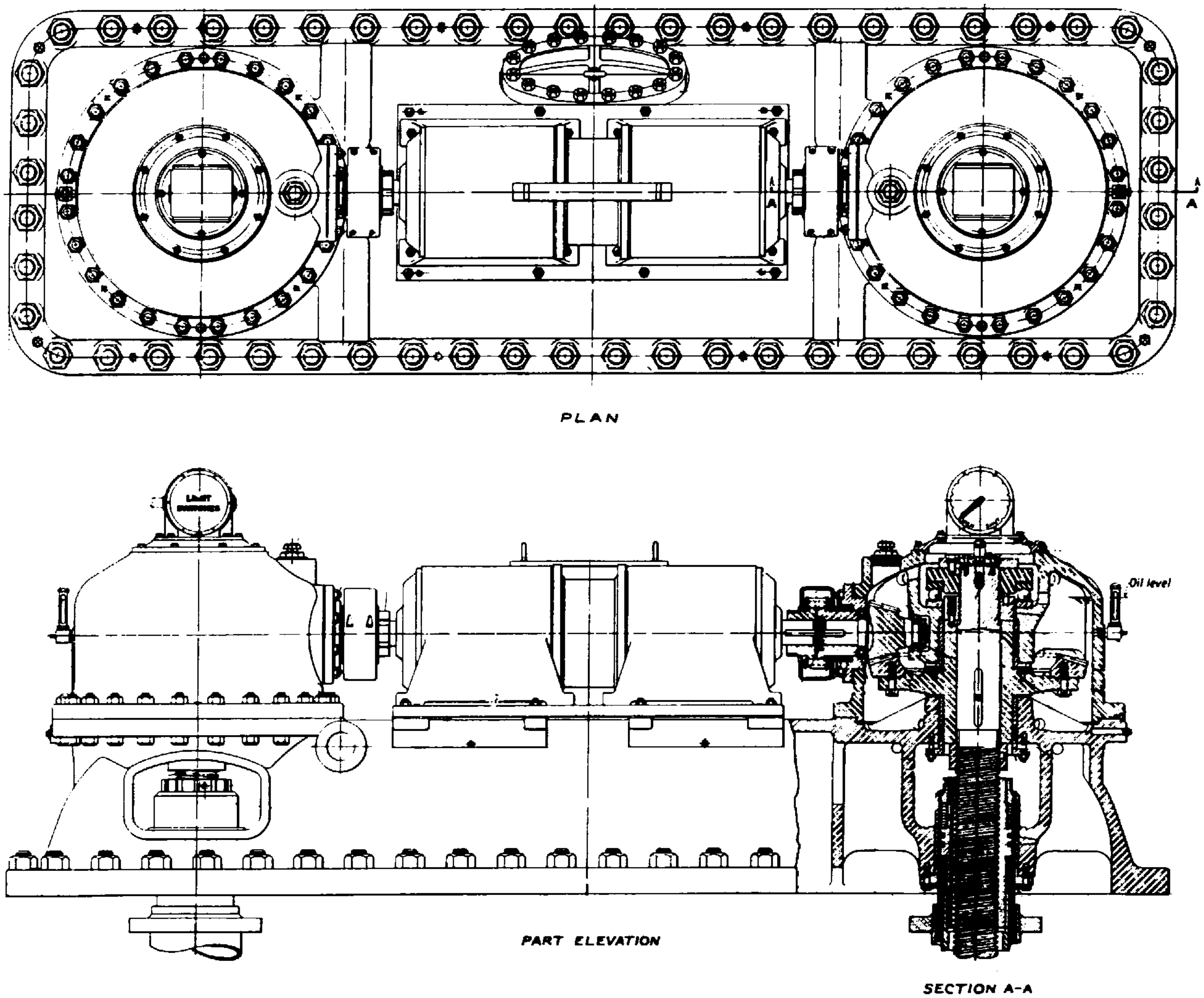


Figure 35. - Twin threaded stem gate hoist (non-rising stem).

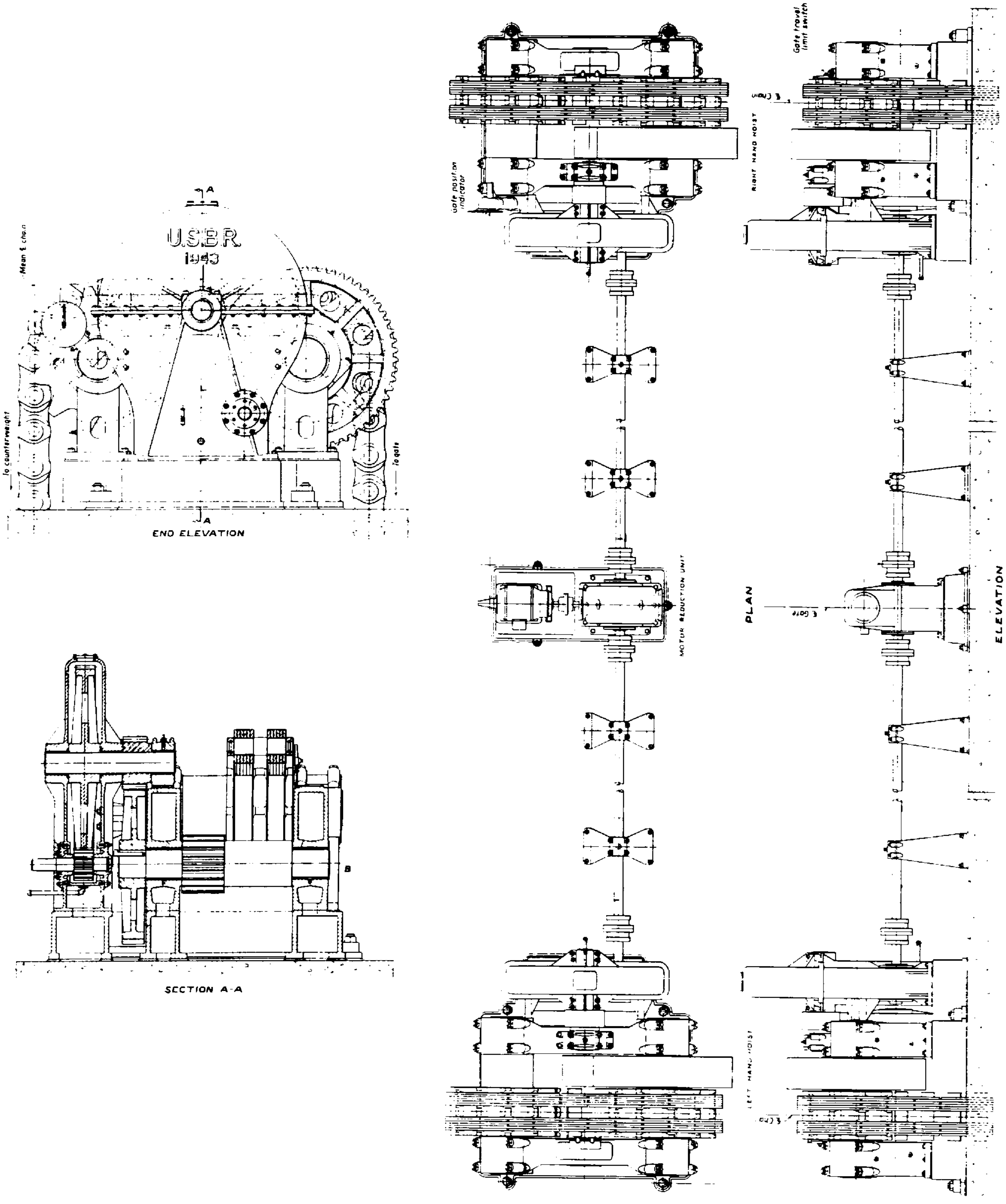


Figure 36. - Chain and sprocket hoist.

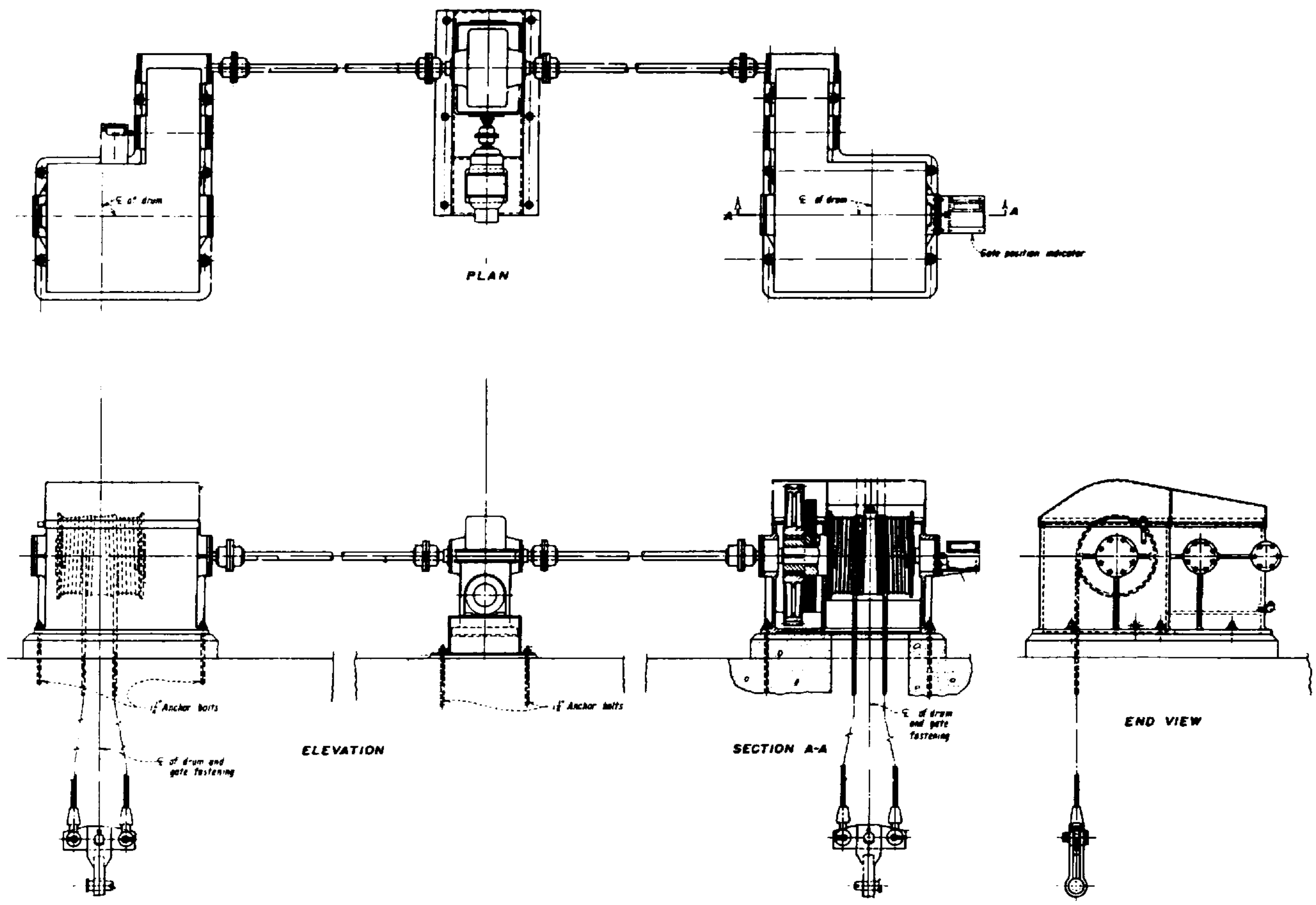


Figure 37. - Wire rope hoist.

d. Hydraulic operators.-Hydraulic operators are used for a variety of gates and valves. Basically a hydraulic system consists of an oil reservoir; electric-motor-driven pump; directional, relief, check, flow control, and shutoff valves; filters; and the operator itself, usually a hydraulic cylinder. Many systems use two pumps in parallel to provide a backup should one fail. The operator may be driven in both directions or it may be powered open and allowed to close by gravity. Examples of hydraulic systems are shown in figures 38 and 39 and a hydraulic cylinder is shown in figure 40.

3. Power Penstock Guard Gate and Valve Closure Tests

Closure tests of all power penstock guard gates and valves are required periodically to verify gate and valve dependability and determine maintenance requirements. While some gates and valves can only be tested under balanced conditions, most should be given a simulated emergency closure test under maximum-flow, full-load conditions.

The purpose of these tests is to ensure that the gates will operate as intended under severe, but controlled, conditions. If the gates fail to operate as intended during these tests, the wicket gates are still available to stop the flow. In an actual emergency situation, such as a ruptured penstock, multiple shear pin breakage, or loss of governor control, the guard gate would be the only means of stopping flow.

The gates requiring simulated emergency closure tests are designed to close under full-flow conditions with no damage, but it is essential that the correct test procedure be followed exactly. Such factors as penstock air venting and gate closure rate must be considered. If there is any doubt about the validity of the test procedure or if a written procedure for a particular gate or valve is not available, contact the appropriate engineering personnel immediately.

The gate closure tests should be scheduled to fit into the regular maintenance schedule at the plant. The tests many times can be set up to correspond with preventive maintenance on the gate, with the gate taken out of service for maintenance immediately after the test. The schedule for these tests should be convenient, but the scheduled interval between tests for an individual gate should not exceed 10 years.

4. Auxiliary Piping Systems

Auxiliary piping systems include domestic, fire protection, and cooling water systems; hydraulic and lubricating oil systems; and service air systems. In most cases, oil systems require little maintenance other than repair of an occasional leak. Due to corrosion, most water systems do require maintenance and, eventually, replacement. The life of a water system will depend a great deal on the corrosiveness and mineral content of the water it carries.

Since determining the internal condition of water piping is very difficult, the first indication of a problem may be a leak or the failure of a valve or other component. Although a leak or valve failure may just be an isolated event, frequently it may be an indication of the condition of the entire system. By monitoring the condition of a piping system, maintenance and replacement can be scheduled, preventing an unscheduled outage. Partial disassembly of the piping can provide a good indication of the condition of the system but it may damage the piping and valves. Nondestructive tests, such as radiographs

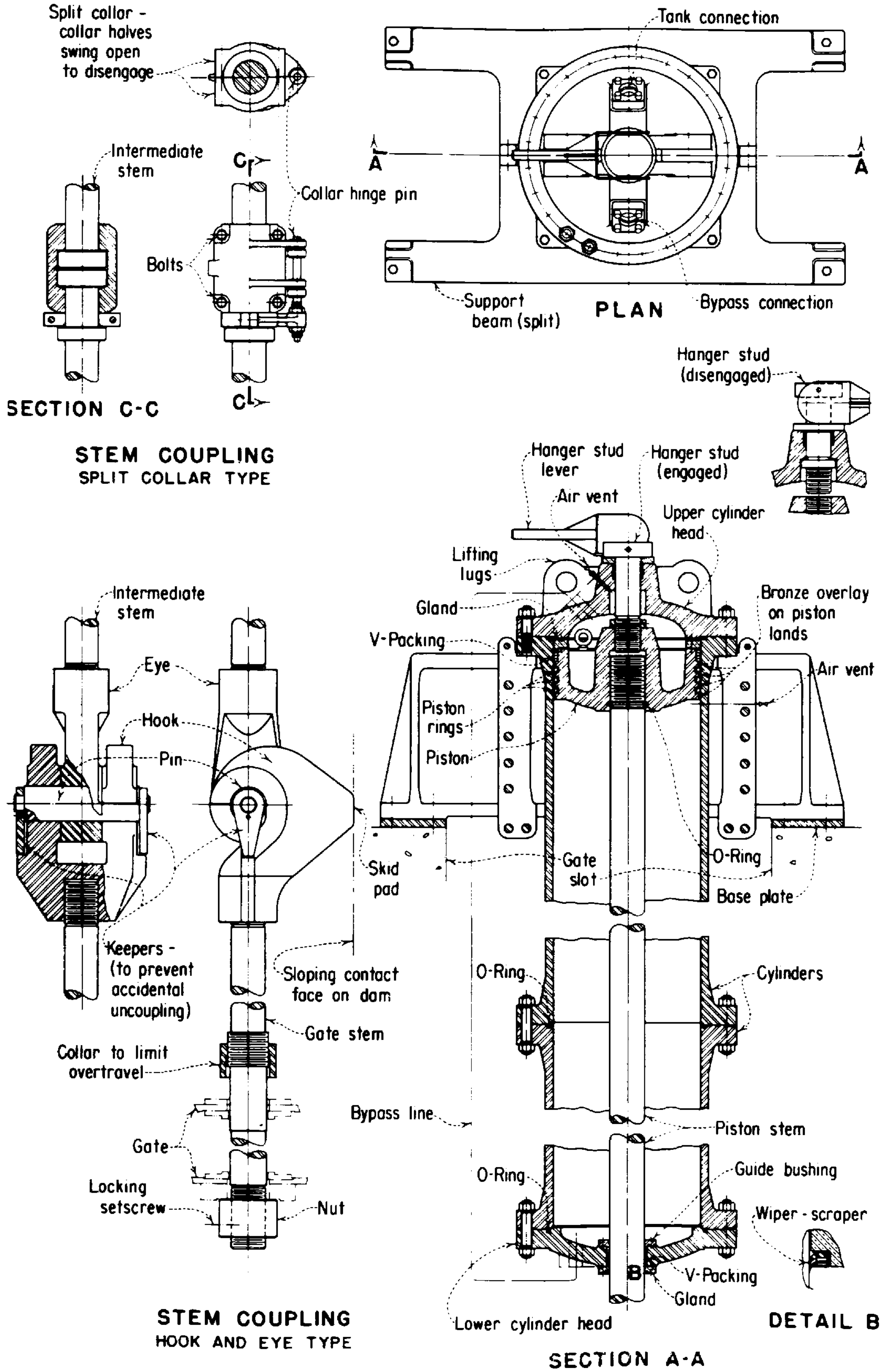


Figure 38. – Typical hydraulic hoist system.