Water In, Water Out
Flow Control Mechanisms
Design, Operation, Maintenance, and Repair

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Topics

1. Valve Types and Applications
2. Energy Dissipation
3. Monitoring, Inspections and Testing
4. Repairs and Overhauls
VALVE TYPES AND APPLICATIONS
Flow Regulation

- A flow regulation valve must be capable of holding in any position from fully closed to fully open.
- A flow regulation valve must be able to operate continuously in any position without cavitation or excessive vibration.
- The following valve types have been used for flow regulation:
  - Fixed Cone / Howell Bunger
  - Ring Jet
  - Hollow Jet
  - Plunger / Needle / Tube
  - Knife Gate
Pressure Regulating Valve (PRV)

- A PRV is used in parallel with a hydraulic turbine to operate during a load rejection and minimize pressure transients in the water conveyance.
- In order to operate as a PRV a valve must be capable of opening rapidly and closing slowly.
- Actuated by water from the penstock or spiral case, or by high pressure oil.
- The following valve types have been used as PRVs:
  - Fixed Cone / Howell Bunger
  - Plunger / Needle Jet
Turbine / Penstock Shutoff Valve (TSV / PSV)

- A TSV is used at the inlet of a hydraulic turbine.
- A PSV is used at the inlet of a penstock.
- A TSV/PSV is normally operated in a balanced condition with zero flow.
- Can close against flow for emergency shutdown, but not normally as primary protection.
- Actuated by water from the penstock or spiral case, by high pressure oil, or by electric motor.
- The following valve types have been used as TSVs/PSVs:
  - Gate (common until the 1930’s)
  - Butterfly (common from the 1940’s to present)
  - Spherical (common from the 1950’s to present)
## Matrix of Valve Applications

<table>
<thead>
<tr>
<th>Valve Type</th>
<th>Flow Regulation</th>
<th>External Dissipator</th>
<th>PRV</th>
<th>TSV / PSV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixed Cone / Howell-Bunger</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Ring Jet</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Hollow Jet</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Plunger / Needle / Tube</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Knife Gate / Jet Flow</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Gate Valve</td>
<td>No</td>
<td>-</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Butterfly</td>
<td>No*</td>
<td>-</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Spherical</td>
<td>No</td>
<td>-</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>
Fixed Cone / Howell-Bunger Valves

- Good for flow regulation and control.
- No energy dissipation - Requires separate dissipation chamber or structure.
- Installed in horizontal position.
- Can be installed above or below water surface
- Opened by moving gate ring with outer seat upstream.
- Actuation can be by hydraulic servomotors or Acme threads and gearboxes.
- Can be linked to turbine governor mechanism to operate as a PRV.
Fixed Cone / Howell-Bunger Valves
Ring Jet Valves

- Similar design to Fixed Cone Valve, but has hood mounted on gate ring.
- Hood creates hollow jet that can be discharged into open air to dissipate energy.
- Good for flow regulation and control.
- Installed in horizontal position.
- Opened by moving gate ring with outer seat upstream.
- Actuation can be by hydraulic servomotors or Acme threads and gearboxes.
Ring Jet Valves
Hollow Jet Valves

- Good for flow regulation and control.
- Creates hollow jet that can be discharged into open air to dissipate energy.
- Installed in horizontal position.
- Opened by moving plunger with inner seat downstream.
- Actuation by internal hydraulic servomotor.
Hollow Jet Valves
Plunger / Needle / Tube Valves

• Good for flow regulation and control.
• No energy dissipation - Requires separate dissipator chamber or structure.
• Installed in horizontal or vertical position.
• Opened by moving plunger/needle with inner seat upstream or downstream.
• Actuation by external hydraulic servomotor – direct acting or through mechanical linkage.
• Can be linked to turbine governor mechanism to operate as a pressure regulating valve (PRV).
Plunger / Needle / Tube Valves
Knife Gate / Jet Flow Valves

- Can be used for flow regulation and control.
- No energy dissipation - Requires separate dissipator chamber or structure.
- Installed in horizontal position.
- Opened by moving gate perpendicularly out of stream.
- Actuation can be by hydraulic servomotors or Acme threads and gearboxes.
Gate Valves

• Not good for flow regulation and control.
• Best for isolation and guard valve applications – Fully Open or Fully Closed.
• Require additional overhead clearance for actuator and valve bonnet.
• Installed in horizontal position.
• Opened by moving gate perpendicularly out of stream.
• Actuation can be by hydraulic servomotors or Acme threads and gearboxes.
• TSVs are often actuated by water from the penstock or spiral case.
• Commonly used as TSVs through the 1930’s.
Butterfly Valves

- Not good for flow regulation and control.
- Best for isolation and guard valve applications – Fully Open or Fully Closed.
- Less costly than spherical valves of same diameter.
- Installed in horizontal position.
- Opened by rotating disc with inner seat 90 degrees.
- Actuation can be by hydraulic servomotor and lever arm, or by electric motor and gearbox.
- TSVs and PSVs are sometimes actuated by water from the penstock or spiral case.
Butterfly Valves
Spherical Valves

- Not good for flow regulation and control.
- Best for isolation and guard valve applications – Fully Open or Fully Closed.
- Better for higher head applications than butterfly valves.
- Full port for lower losses.
- Installed in horizontal position.
- Opened by rotating plug with inner seats 90 degrees.
- Actuation by hydraulic servomotor and lever arm.
- Larger spherical valves often have hydraulically operated body seats and require sequencing of operation to prevent damage to seats.
- TSVs and PSVs are sometimes actuated by water from the penstock or spiral case.
Spherical Valves
ENERGY DISSIPATION
Open Air Discharge

- When space is available, outlet valves that discharge controlled jets can be directed into open air to dissipate the energy of the water jet.
Submerged Discharge

- When space is limited or discharge flows are not directed the valve can be submerged to dissipate the water jet energy into a pool or chamber.
Submerged Discharge
Energy Dissipators

- Energy dissipators commonly consist of a heavy metal cone or frame placed directly in the path of a discharging water jet.
- The energy dissipator disperses or redirects the flow in order to reduce the energy and velocity of the water.
Energy Dissipators
Discharge Chambers

- Discharge chambers are typically concrete structures with steel plate liners on the surfaces where the discharging water will impact.
- The steel protects the concrete from erosion damage.
- The concrete supports the steel and absorbs some of the impact energy from the water.
- Discharge chambers often have bends or other discontinuities on the interior to redirect the flow and reduce the energy and velocity of the water.
Discharge Chambers
Discharge Chambers
MONITORING, INSPECTIONS AND TESTING
Monitoring

- Regular exercising of valves through at least one full open stroke and close stroke is a good way to verify full range of travel and smooth operation.
- During full stroke testing the travel timing should be recorded and compared to previous records.
- For electric motor actuated valves monitor the motor current during operation.
- For hydraulically actuated valves monitor the hydraulic pressures during operation.
- For water actuated valves monitor the discharge flow when the valve is fully open or fully closed.
- After a full travel cycle check the leakage of the fully closed valve.
Inspections

- Periodic inspection of valves in the dewatered state can allow for early detection of deterioration and other conditions that could affect valve performance.
- During inspections look for the following:
  - Material loss due to corrosion, erosion or cavitation.
  - Scoring or galling on surfaces of moving components and interfacing components.
  - Uneven wear on components.
- During subsequent inspections use photographs to identify changes in condition over time.
Valves

• During exercising look for the following:
  • Excessive play or lag in operating mechanism.
  • Changes in travel time in either direction.
  • Increase in leakage of fully closed valve.

• During inspections look for the following:
  • Corrosion, especially in locations where dissimilar metals are in contact or close proximity.
  • Erosion and cavitation on wetted surfaces and along the flow path.
  • Cavitation, scoring or galling damage on metal seats, and tears on resilient seats.
Governors

• During exercising look for the following:
  • Excessive play or lag in operating mechanism.
  • Changes in travel time in either direction – both normal travel and rapid shutdown.
  • Increase in leakage of wicket gates or needles following a shutdown.
• During inspections look for the following:
  • Scoring or galling damage on moving components of operating mechanism.
  • Accumulated dust or metal particles around pins, shafts, and joints.
Turbines

- During inspections look for the following:
  - Scoring or galling damage on moving components (wicket gates, needles, Kaplan runner blades).
  - Increased or out-of-tolerance clearances at runner seals and wicket gates vanes.
  - Erosion and cavitation on wetted surfaces and along the flow path.
  - Cavitation on runner blades or buckets.
  - Indications on runner blades or buckets (may require NDE to detect).
  - Voids and disbonding behind embedded components including spiral case and draft tube (detected by sounding with a hammer).
Energy Dissipators

• During inspections look for the following:
  • Erosion and cavitation on wetted surfaces and along the flow path.
  • Corrosion and deep pitting, especially at supports or bracing.
  • Cracking of welds in dissipator assembly or supports (may require NDE to detect).
Dissipation Chambers

• During inspections look for the following:
  • Erosion and cavitation on wetted surfaces and along the flow path.
  • Corrosion and deep pitting, especially on liner plates and anchors.
  • Cracking of welds or liner plates (may require NDE to detect).
  • Voids and disbonding behind liner plates (detected by sounding with a hammer).
REPAIRS AND OVERHAULS
Repairs and Overhauls

• Planning is essential to ensure project success within the constraints of schedule and budget.
• Aligning valve repairs with other major projects such as turbine overhauls and generator rewinds can minimize downtime.
• Manufacturing replacement components in advance can save time during the repair outage.
  • Stock material can be left on the new components for final machining after disassembly and dimension checks.
• When time permits it is often advantageous to refurbish or remanufacture an existing valve that has performed well.
QUESTIONS?