RECLAMATION
Managing Water in the West

Design Standards No. 6

Hydraulic and Mechanical Equipment

Chapter 6: Bulkhead Gates and Stoploqs
Phase 4 Final

U.S. Department of the Interior
Bureau of Reclamation

January 2018

Mission Statements

The U.S. Department of the Interior protects America's natural resources and heritage, honors our cultures and tribal communities, and supplies the energy to power our future.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

Design Standards Signature Sheet

Design Standards No. 6

Hydraulic and Mechanical Equipment

DS-6(6): Phase 4 Final
January 2018

Chapter 6: Bulkhead Gates and Stoplogs

Foreword

Purpose

The Bureau of Reclamation (Reclamation) design standards present technical requirements and processes to enable design professionals to prepare design documents and reports necessary to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public. Compliance with these design standards assists in the development and improvement of Reclamation facilities in a way that protects the public's health, safety, and welfare; recognizes needs of all stakeholders; and achieves lasting value and functionality necessary for Reclamation facilities. Responsible designers accomplish this goal through compliance with these design standards and all other applicable technical codes, as well as incorporation of the stakeholders' vision and values, that are then reflected in the constructed facilities.

Application of Design Standards

Reclamation design activities, whether performed by Reclamation or by a non-Reclamation entity, must be performed in accordance with established Reclamation design criteria and standards, and approved national design standards, if applicable. Exceptions to this requirement shall be in accordance with provisions of *Reclamation Manual - Policy*, FAC P03, "Performing Design and Construction Activities."

In addition to these design standards, designers shall integrate sound engineering judgment, applicable national codes and design standards, site-specific technical considerations, and project-specific considerations to ensure suitable designs are produced that protect the public's investment and safety. Designers shall use the most current edition of national codes and design standards consistent with Reclamation design standards. Reclamation design standards may include exceptions to requirements of national codes and design standards.

Proposed Revisions

Reclamation designers should inform the Technical Service Center (TSC), via Reclamation's Design Standards Website notification procedure, of any recommended updates or changes to Reclamation design standards to meet current and/or improved design practices.

Chapter Signature Sheet
Bureau of Reclamation
Technical Service Center

Design Standards No. 6

Hydraulic and Mechanical Equipment

Chapter 6: Bulkhead Gates and Stoplogs

DS-6(6)[1]: Phase 4 Final
January 2018

Chapter 6 – Bulkhead Gates and Stoplogs is a new chapter within Design Standards No. 6. It revises and updates information on bulkhead gates, stoplogs, and lifting frames and beams, which were previously contained in chapter 1 of Design Standards No. 7 – Valves, Gates, and Steel Conduits (last updated in 1956). This new chapter contains the following general revisions:

- Updated bulkhead gate design process
- Updated stoplog design process
- Updated lifting frame and lifting beam design process

[1] DS-6(6) refers to Design Standards No. 6, chapter 6.

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Chapter 6

Bulkhead Gates and Stoplogs

6.1 General

Bulkhead gates and stoplogs are used at powerplants, diversion structures, pumping plants, and canals. They are used to isolate equipment or features for repairs or inspection but are not used to regulate flow. Bulkhead gates and stoplogs are also used at intakes, outlet works, spillways, check structures, and draft tubes. They can be designed for relatively low- to high-pressure head applications. One bulkhead gate or one set of stoplogs may be used to service several outlets or bays; on occasion, several sites may share bulkhead gates or stoplogs. When designed for use at multiple sites or locations, the largest load case should always be used for the design. Nameplates should be added to each bulkhead gate and stoplog, identifying its design parameters (i.e., maximum head, maximum span, dead weight, stacked position, etc.).

Bulkhead gates and stoplogs are both sliding-type gates (i.e., the operating member moves on sliding surfaces to engage with the sealing element). They should generally be lowered and raised under balanced pressure heads and no-flow conditions. Other gates or valves are used to shut off flow prior to installation or before removing bulkhead gates and stoplogs.

Stoplogs serve a function similar to bulkhead gates, but they are stacked on top of each other to reach the desired height. A stoplog may be considered for use when a design limitation (such as the maximum lifting weight, the high hook, or the total height of the opening) prevents the use of a bulkhead gate). The primary disadvantage to using stoplogs is their increased longitudinal (horizontal) sealing surfaces, which can potentially lead to more leakage.

Hereafter, for this chapter, the term “upstream” will refer to the nonsealing side of the bulkhead gates or stoplogs (the side towards the reservoir or tailwater), and the term “downstream” will refer to the sealing side (side towards the conduit or chamber to be unwatered).

Bulkhead gates and stoplogs are normally raised or lowered in place through the use of lifting beams, lifting frames, or lifting slings using a mobile crane or gantry-type crane. Dedicated fixed hoists or a monorail-type hoisting system have also been used.

For most bulkhead gate and stoplog installations, metal seats and guides are embedded in the face of the structure (see figure 6.1-1) or embedded in the structure walls (see figure 6.1-2) and floor to provide guiding and sealing surfaces.

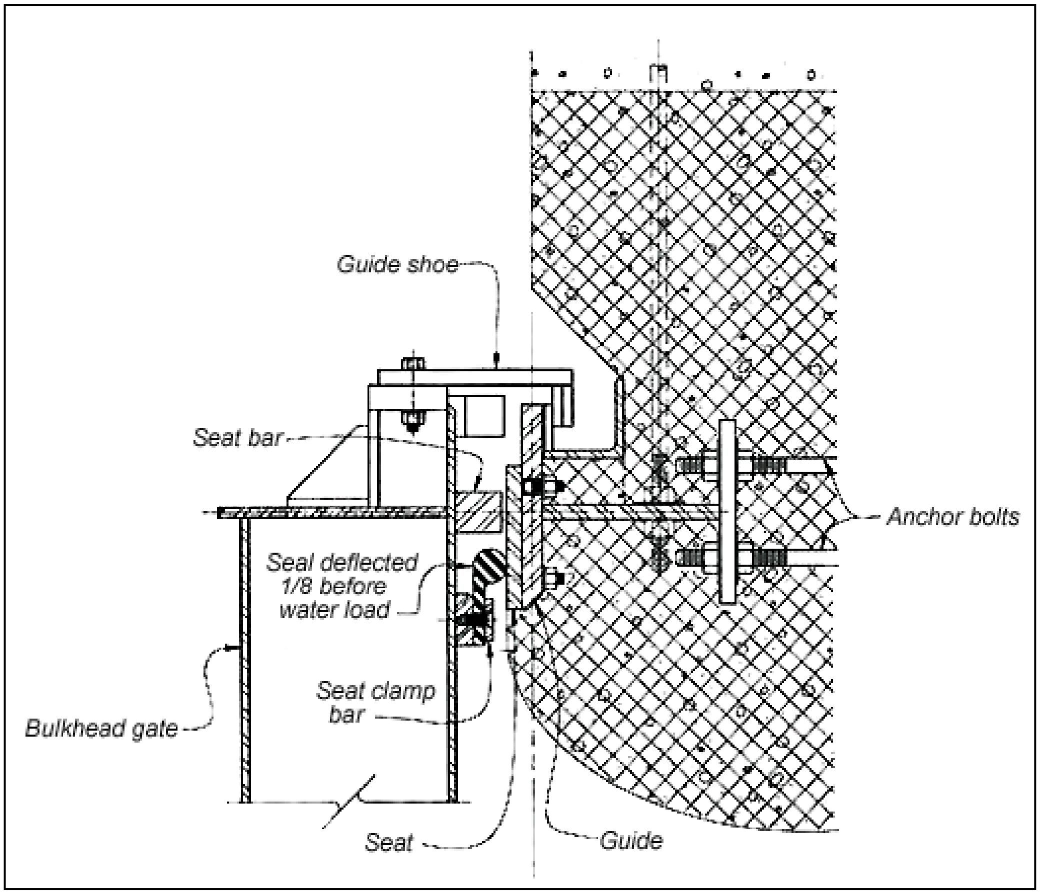

Figure 6.1-1. Section through bulkhead gate (or stoplogs), and seats and guides embedded in the face of the structure.

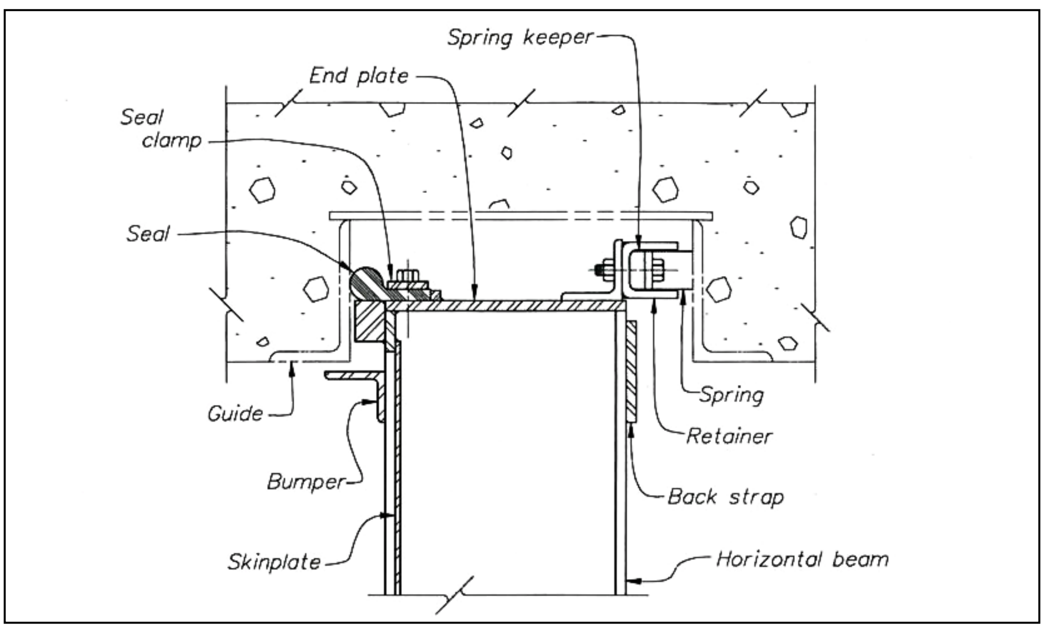

Figure 6.1-2. Section through bulkhead gate (or stoplogs) in guide slot embedded in structure walls.

Whenever new structures and facilities are designed, coordination should begin early between planners, operation and maintenance (O&M) personnel, structure and equipment designers, and the bulkhead gate/stoplog designers. Collaborative meetings should clearly identify the following project components:

- What equipment and/or features need to be isolated?
- Will the bulkhead gates or stoplogs be provided in the initial construction or in future construction?
- Will seats and guides be provided in the initial construction or in future construction? Designers should at least consider installing the seats and guides for bulkhead gates or stoplogs in the initial construction because retrofitting existing installations for seats and guides in the future could be difficult and expensive.
- How will the bulkhead gates/stoplogs be installed (including evaluating the availability, access, and placement of the cranes and/or hoists to accomplish installation and removal)?
- Where should the bulkhead gates/stoplogs be stored?

6.1.1 Codes and Standards

Stoplogs, bulkhead gates, lifting beams, and lifting frames should comply with the latest editions of American Institute of Steel Construction (AISC), ASTM International,[2] Aluminum Association (AA), and American Welding Society (AWS).

The latest editions of publications and standards listed here are intended as guidelines for design. They are mandatory only when specified in the text of this chapter or in applicable codes. The list is not meant to restrict the use of additional guides or standards. When discrepancies between requirements are encountered, Reclamation will determine the requirement. Codes and standards applicable to this chapter are listed below:

- AISC "Specification for Structural Steel Buildings – Allowable Stress Design and Plastic Design, with Commentary"
- ASTM International

[2] ASTM International was formerly called the American Society for Testing and Materials.

- AWS D1.1/D1.1M, Structural Welding Code – Steel
- AWS D1.6/D1.6M, Structural Welding Code – Stainless Steel
- AA Aluminum Design Manual

6.2 Bulkhead Gates and Stoplogs

6.2.1 Bulkhead Gates

The details and general construction of bulkhead gates vary with the service required, configuration of the structure to unwater, maximum depth of water, configuration of sealing surfaces, and the storage requirement when not in use. Bulkhead gates are used when sufficient hoist high hook and lifting capacity are available. The lack of horizontal joints makes sealing easier for one bulkhead gate than for several stoplogs.

Bulkhead gates may be used at the upstream and downstream ends of river outlet conduits, at the upstream end of penstocks, at pumping plant intakes, at canal intakes, at canal turnout structures, at check structures, at spillways, and at turbine draft tubes. Bulkhead gates generally fall into two categories: (1) intake bulkhead gates, and (2) draft-tube bulkhead gates. One bulkhead gate may be used to service several outlets. Two bulkhead gates may be required to allow isolation of equipment where water could remain on both sides (such as for a multi-bay canal intake). Bulkhead gates located at the upstream end of river outlet conduits and penstocks are usually subject to relatively high heads, whereas downstream gates are usually subject to lower heads. Bulkhead gates are typically rectangular shaped, one-piece gates that seal on four sides. For circular-shaped bulkhead gates, sealing occurs around the circular opening.

The size of the bulkhead gate is designated first by the width, and second by the height. The width and height of the bulkhead gate are defined by the dimensions of the opening at the plane of sealing. For bellmouth openings, this distance is from one point of tangency to the opposite point of tangency. Bulkhead gates are designed for full differential head on the gate, with the downstream side dry and at atmospheric pressure, and the upstream side at the pressure equal to the head at maximum water surface.

Bulkhead gates are usually constructed of structural steel shaped horizontal beams (rolled sections or flanges and webs welded together in built-up sections) welded to a skinplate (or series of skinplates), end plates, backing bars (sometimes called retainer bars), and seat bars (see figure 6.2.1-1 for section through rectangular shaped bulkhead gate). Bulkhead gates are usually equipped with guide shoes, bumpers, or guide lugs to help guide the gate during removal and installation.

Water pressure from the upstream side of the bulkhead gate acts against the skinplate and horizontal beams and is transmitted through the horizontal beams into the endplates and seat bars. The seat bars bear against the surfaces of the embedded seats carrying the load into the concrete structure.

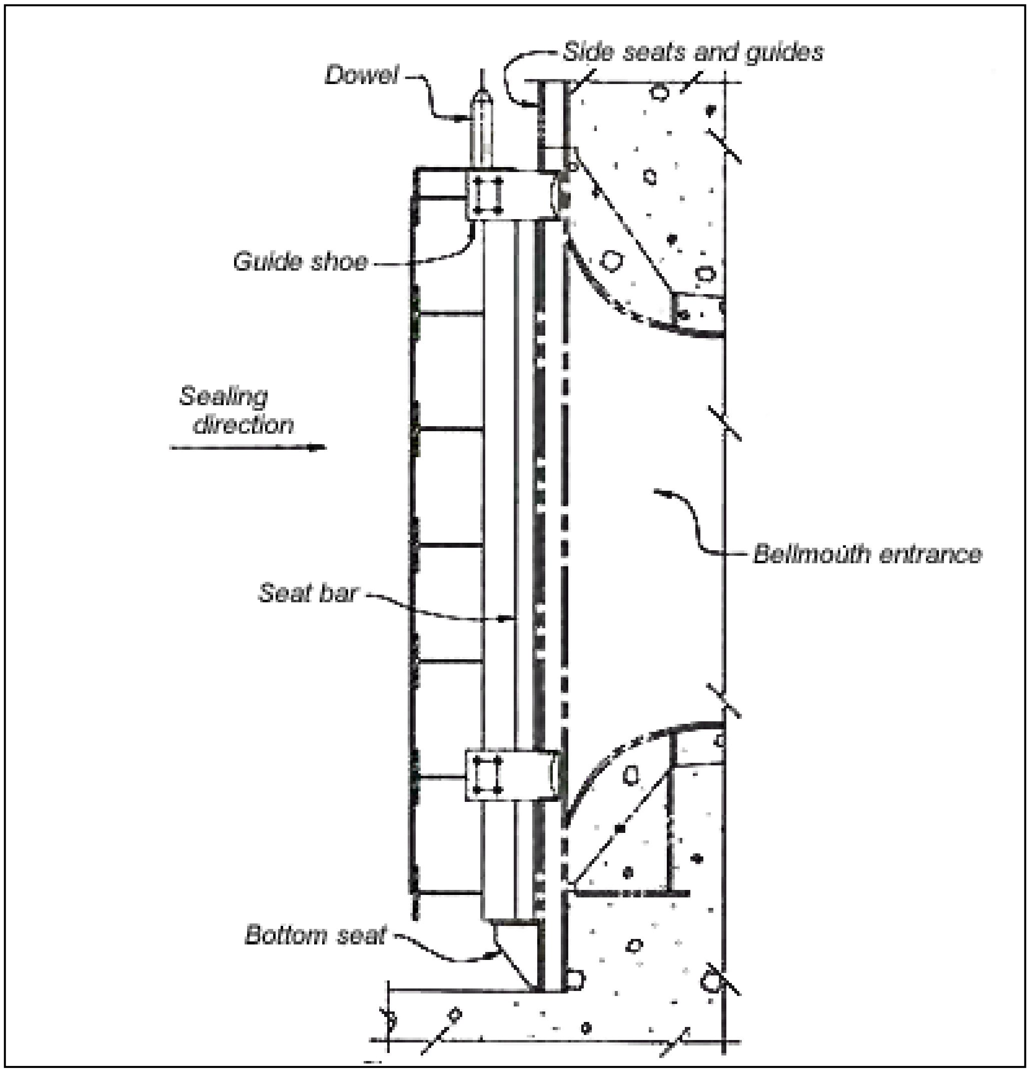

Figure 6.2.1-1. Bulkhead gate installed in outlet works entrance.

The skinplate allows the horizontal beams to be spaced sufficiently apart to facilitate welding and coating. Occasionally, where the bulkhead gate is to be used only once for a short time duration, the horizontal beams can be welded to each other, eliminating the need for a skinplate, and may also not require coating. The skinplate is usually located on the downstream side of the gate, but it can also be attached to the upstream side to move the center of gravity closer to the geometric center of the gate, allowing room for lifting lugs, filling valve, and alignment dowels or dowel pins. One disadvantage to upstream-mounted skinplate assemblies is that the water pressure loading will also occur on the webs of the top and bottom horizontal beams and on the end plates.

Bulkhead gates are usually handled by a crane using a lifting device (lifting beam or lifting frame) or lifting sling. If a lifting beam or lifting frame is used, dowel pins (may require dowel holes if the lifting device has the dowel pins) are typically required on the bulkhead gate to align the gate with the lifting device. The dowel pins ensure that the hook assembly on the lifting device aligns to attach to the bulkhead gate lifting lug.

Bulkhead gates should be installed or removed under a condition of balanced head and no flow. Occasionally, in cases where flow cannot be shut off completely, the bulkhead gate may be required to be lowered against a slightly unbalanced head. Wheels may then need to be provided to assist in lowering the bulkhead gate. The seals are more likely to be damaged during installation under this unbalanced load case, which could prevent good sealing of the gate, and may require replacement of the seals after a single use. Bulkhead gates located in turbine draft tubes may also experience significant turbulence in the tailwater during installation or removal due to operation of an adjacent power unit, spillway, or outlet discharge.

If filling lines are not provided in the structure, or a portable pump system (or other type of operator-controlled fill system) cannot be used to equalize the pressure across each side of the bulkhead gate, a filling valve is typically placed in the bulkhead gate to facilitate the pressure equalization required prior to removal of the bulkhead gate after work has been completed. The filling valve may be operated using tag lines, the hoisting mechanism with an extra leg on the sling, extra hooks on the lifting device, or by divers. If necessary, air vent/air supply line(s) can also be provided in the bulkhead gate to release air from the conduit during filling or to supply air to the conduit during unwatering. This is critical for two reasons: (1) to prevent air from being trapped in the conduit, which could unseat the installed bulkhead gate or damage the conduit; and (2) to prevent the conduit from collapsing due to a vacuum. A filling valve and air vent/supply line are typically required for horizontally installed, circular bulkhead gates.

Leaf springs are generally used to facilitate moving a bulkhead gate towards the sealing side within the guides. This can also be accomplished via jacking methods, by adding wedges to the guides, or by narrowing the guide slots once they have been lowered to the seating area. Wedges should also be considered when bulkhead gates are required to seal against low heads which may be insufficient to initiate sealing. When initially installed, the bulkhead gate's seals should press against the seats to form a mild seal. This configuration allows the work area to be unwatered via pumps or by using the downstream gate/valve drainage system. After the area is unwatered, the hydraulic load provides the necessary force to maintain a seal. Springs also help keep the bulkhead gate in a vertical position, so that the top does not lean away from the upper portion of the guides.

6.2.1.1 Intake Bulkhead Gates

Intake bulkhead gates are used at the upstream ends of penstocks or river outlet conduits, where other equipment is used to regulate and shut off flow, and can be subjected to relatively high heads. Intake bulkhead gates can also be used at the intake to pumping plants and canals. In either case, they are used to allow unwatering of the intakes for inspection, maintenance, and repair of the downstream equipment, penstocks, and conduits. Bulkhead gates can be stored within the upper portion of the guides below the deck (if favorable conditions exist) or be removed from the guides and stored at a separate location.

Horizontal structural shapes carry the load to the edge of the bulkhead gate, which then transmits the load through the end plates and seat bars to the embedded seats. All gates have a rubber sealing strip that extends continuously around the gate and seals against the face of the seats.

Intake bulkhead gates are usually rectangular shaped gates installed in a vertical position in the guides. If a bulkhead gate is installed in guides that are not vertically oriented, wheels and/or wear strips should be used to help reduce friction when the bulkhead gate is lowered into place. Seals are more susceptible to damage under this scenario; therefore, to reduce friction loads, the seals may require a low friction fluorocarbon (Teflon) coating applied to them.

A circular-shaped intake bulkhead gate is a special type of bulkhead gate that is used to close a horizontal opening at the upstream end of a conduit. The gates have horizontal beams lying in a flat plane and a skinplate welded to the top of the beams, an end plate around the circumference of the gate, and a seat bar under the gate along the circumference (see figure 6.2.1.1-1). Sealing occurs around the circular opening. Circular intake bulkhead gates are typically one-piece gates, but they can be two pieces for ease of installation. The intake structure configuration may require that the two halves of the bulkhead gate be installed separately then bolted together underwater by divers.

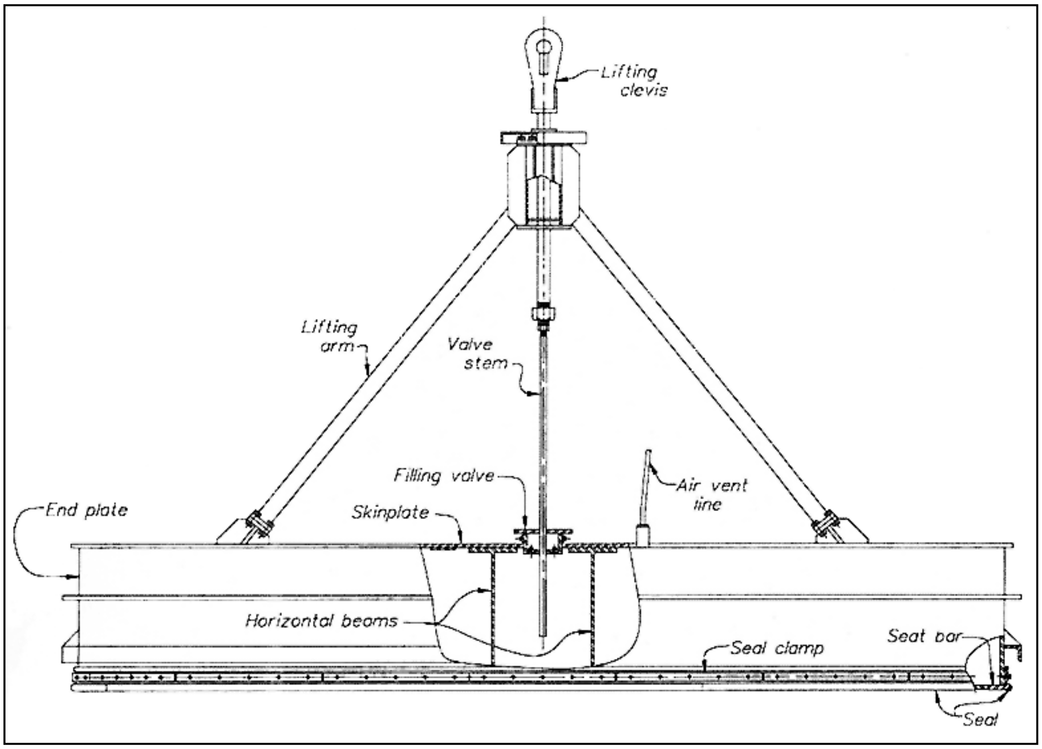

Figure 6.2.1.1-1. Circular bulkhead gate. Note: filling valve operated by the lifting device.

6.2.1.2 Draft-Tube Bulkhead Gates

Draft-tube bulkhead gates are used to isolate the draft tubes from the tailwater and permit unwatering of the draft tubes for inspection, maintenance, and repair of turbine parts and the draft tubes. The nominal size of the bulkhead gate is the width by the height of the draft-tube portal. These gates should be installed in vertical guides or slots in the draft-tube portal under no-flow conditions, although there may be considerable tailrace turbulence at the time. Bulkhead gates are preferable to stoplogs for draft-tube closures because fewer longitudinal joints are required, making it easier to obtain proper sealing on one bulkhead gate rather than several stoplogs. Due to the tailrace turbulence, draft-tube bulkhead gates should be guided the entire distance through which they are lowered.

Draft-tube bulkhead gates can be stored within the upper portion of the guides below the deck (if favorable conditions exist) or be removed from the guides and stored at a separate location.

The draft-tube bulkhead gate should be designed using the maximum tailwater surface on one side and the dry draft-tube on the other side. Horizontal structural shapes carry the load to the vertical sides of the bulkhead gate, which then transmit the load to the embedded side seats and into the concrete. All gates have seating surfaces on the two vertical sides, a top and bottom seal seat, and a rubber sealing strip that extends continuously around the gate.

To protect the guides from damage when a draft-tube bulkhead gate is used, either an electrical lockout device must be provided to prevent turbine startup with the gate in the lowered position, or a special guide lug arrangement must be used. In the special guide lug arrangement (see figure 6.2.1.2-1), the top guide lugs are fixed to the gate, but the bottom guide lugs are fastened to the bulkhead gate with calibrated shear bolts. Each set of guide lugs moves in a separate slot, with the slot for the top lugs ending just below the position of the top guide lugs when the bulkhead gate is in the closed position. In the event high-pressure penstock water is admitted through the turbine and into the draft tube while the gate is closed, the calibrated shear bolts will shear, allowing the gate to swing out. The pressure within the draft tube is thereby relieved while protecting the embedded guides from damage.

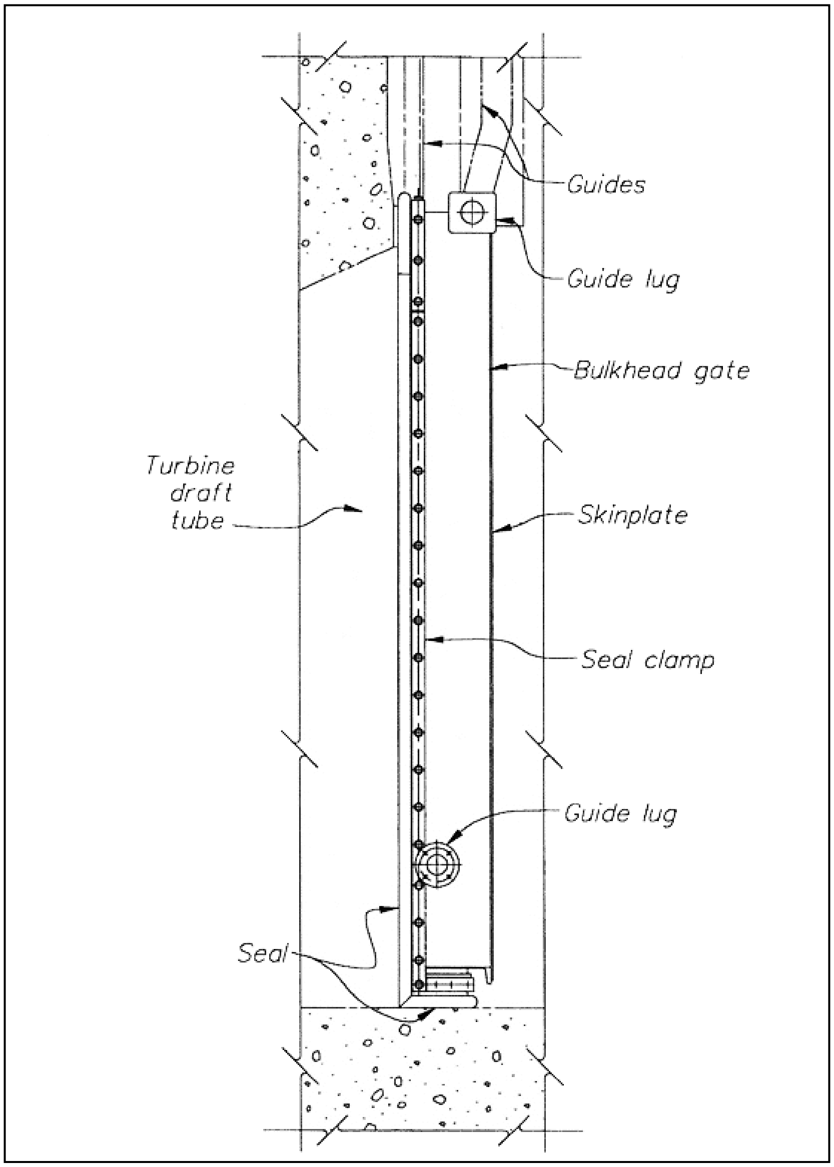

Figure 6.2.1.2-1. Draft-tube bulkhead gate installed.

A means for seating the bulkhead gate securely against the seats of the draft-tube portal should also be provided to counteract the forces caused by turbulence when the unwatering of the draft tube begins. Therefore, the draft-tube bulkhead gate should be provided with either an arrangement that uses leaf springs and guide angles or guide shoes, which act against wedges placed in the guides to initiate sealing contact. In many cases, seal contact does not begin until the bulkhead gate travels down the last 1 foot or so to minimize wear and reduce the likelihood that the gate will bind in the guides.

The pressure required to hold the gate securely against its seat, prior to unwatering the draft tube, is dependent upon the size of the gate and the degree of tailwater turbulence to be expected; thus, the total spring loading is considered as a constant loading per square foot (ft^2) of gate area. The degree of tailwater turbulence then becomes an index to the constant loading per square foot of gate. It should not be less than 10 pounds per square foot (lb/ft^2) of nominal gate area, which should suffice for turbulence caused by operation of an adjacent power unit. It should not be less than 25 lb/ft^2 of nominal gate area in cases where the draft-tube portal is adjacent to high-velocity spillway or outlet discharges.

Where the height of the gate permits, it is common to use four seal loading springs for the gate, with each spring supplying 25 percent of the total loading. The normal deflection of the spring is the deflection when the gate is completely seated. The guide angles against which the gate springs seat should be fastened securely to the pier, but the spring's retainer supports should be fastened to the gate by means of calibrated shear bolts. This configuration will allow the gate to be blown off its seat in case high-pressure penstock water is admitted to the turbine and draft tube while the bulkhead gate is in the closed position.

6.2.2 Stoplogs

The details and general construction of stoplogs vary with the service required, configuration of the structure to unwater, depth of water, configuration of sealing surfaces, and storage when not in use. Stoplogs are a type of bulkhead gate that, when used in sets, acts as a temporary closure for openings on various types of structures. Stoplogs are used in penstock intakes, canal check structures, spillways, and diversion intakes. Stoplogs can be made of wood, metal, or a combination of these, depending on the design span and head. Stoplogs are generally intended for short-term immersion in water. This is particularly true for aluminum stoplogs, which can show signs of corrosion rather quickly if left unprotected.

Stoplogs are used when the size of the gate is restricted by weight or high hook limitations, or when the opening is too large for one gate. The height of individual stoplogs in a set of stoplogs is determined by the height of the opening, and the weight and height of the stoplog, which can be conveniently handled.

Each stoplog is installed in vertical guides or slots, with each subsequent stoplog stacked on the previous stoplog (see figure 6.2.2-1). Each stoplog seals against the side guides/slots and the stoplog beneath it (the bottom stoplog seals against the bottom seat).

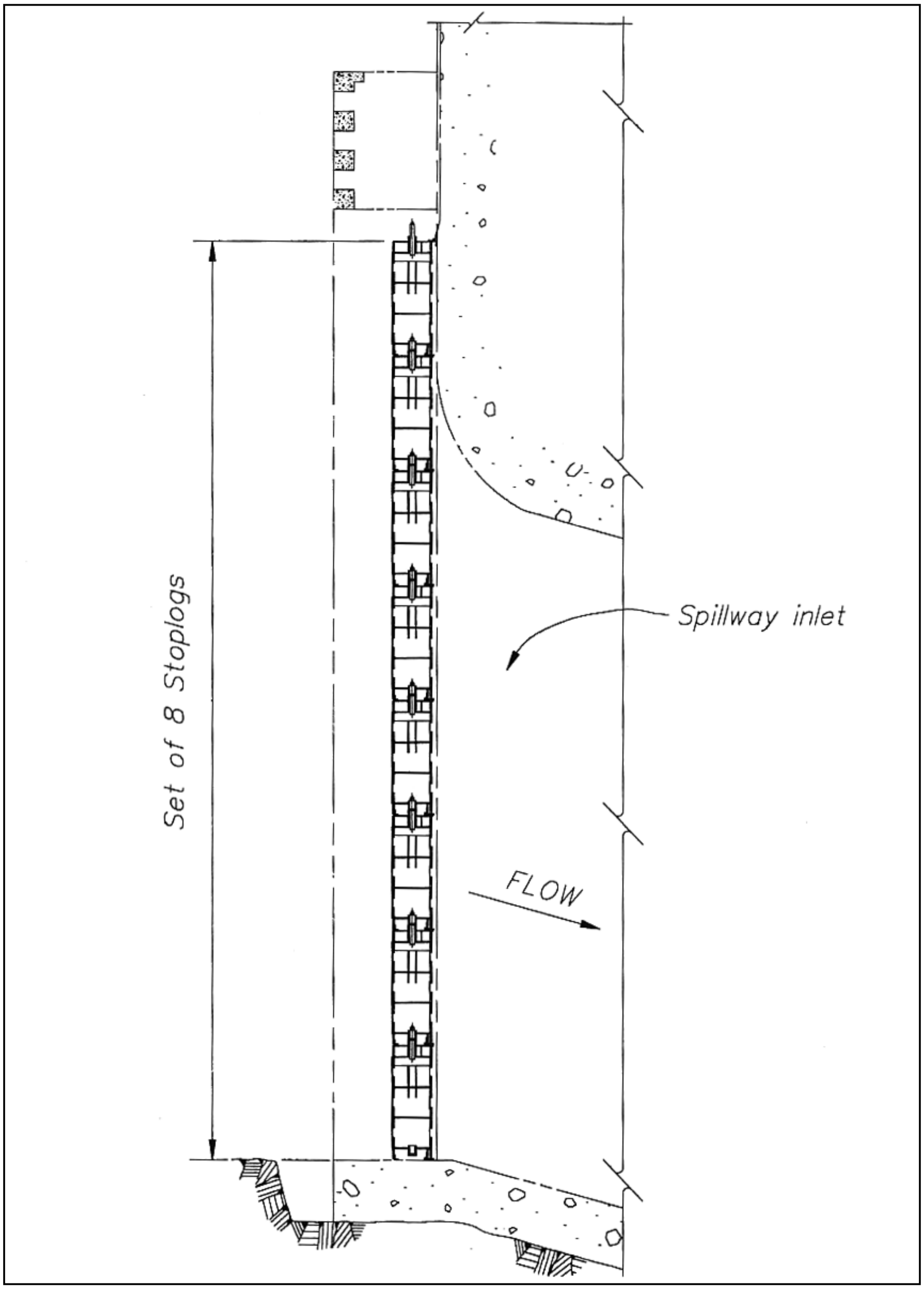

Figure 6.2.2-1. Stoplogs stacked on face of dam.

Stoplogs should be installed or removed under balanced head conditions and no flow. Where flow cannot be shut off completely, it may be necessary to install the stoplogs against slightly unbalanced head conditions. Under this scenario, it may be necessary to add wheels, sliding wear strips (brass, ultra-high molecular weight polyethylene, or other low friction member), or seals with a low friction fluorocarbon (Teflon) coating to the stoplogs to reduce the friction loads and facilitate lowering them.

6.2.2.1 Wooden Stoplogs

Wooden stoplogs consist of timbers that span an opening and are generally used for low-span and low-head applications. Wooden stoplogs are sometimes referred to as stop-planks.

Structural steel angles embedded in the stoplog slots are generally provided for the wood to bear against, while protecting the concrete corners in the stoplog slots, but they are not essential.

An effective seal can be made for the horizontal joints between the wooden stoplogs by caulking the beveled joints or by placing a rubber sheet along the upstream face of the stoplogs. If necessary, to overcome the buoyancy of individual logs, concrete weights may be used, or the logs can be drawn together with tie rods into a single bulkhead and held down by wedging or with additional tie anchors.

When designing wooden stoplogs, timbers greater than 14 inches thick should not be considered. Allowable stresses in the timbers vary, depending on the type of wood used and the region of the country where the wood was obtained. Therefore, prior to designing wooden stoplogs, determine the type of wood to be used, the region of origin, and the latest allowable stresses (allowable bending stress, allowable horizontal/longitudinal shear stress, and allowable bearing stress perpendicular to the grain on the wood) for that type of wood. Typical wood considered in the past include Douglas fir, Redwood, pine, and spruce.

6.2.2.2 Metal Stoplogs

Metal stoplogs, made of steel or aluminum, are used where large heads and/or spans preclude the use of wooden stoplogs. They consist of horizontal structural shape members with a skinplate (or series of skinplates), end plates, backing bars, and seat bars welded to the structural beam members (see figure 6.2.2.2-1). Water pressure from the upstream side of the stoplog acts against the skinplate and horizontal beams and is transmitted through the horizontal beams into the endplates, then into the seat bars (which bear against the seating surfaces) and into the concrete structure. Using a skinplate, the horizontal beams can be spaced to allow welding and coating of the stoplog’s interior. The skinplate is sometimes placed on the upstream face to move the center of gravity closer to the geometric center of the stoplog, which allows room for lifting lugs, a filling valve, dowel pins, and dowel holes.

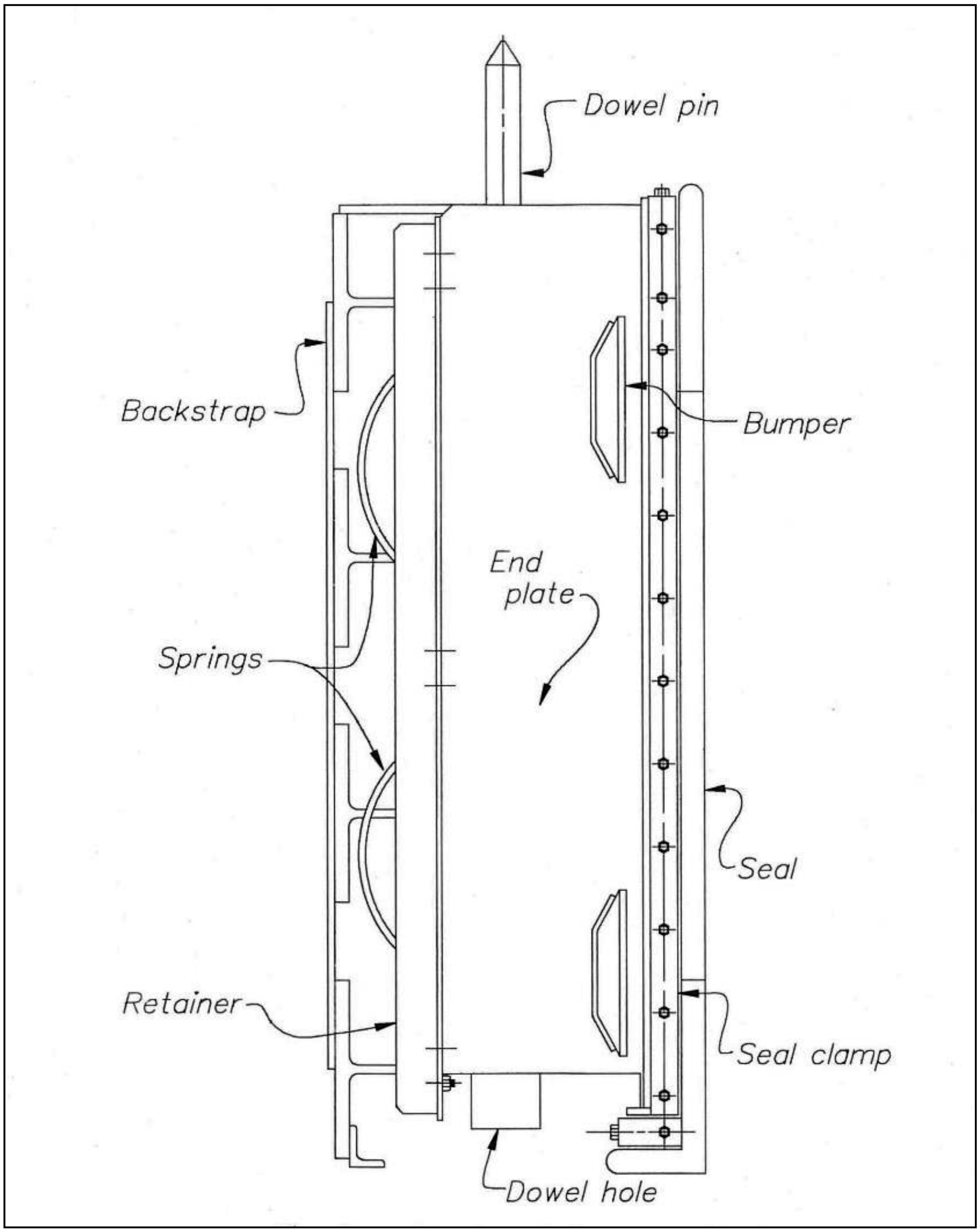

Figure 6.2.2.2-1. Fully assembled stoplog.

Dowel pins and dowel holes are provided to align each stoplog with the stoplog beneath it to prevent damage to the bottom seal and ensure seal contact at each end of the stoplog. Dowel pins also align the stoplog with the lifting device, which allows the lifting device hook assembly to attach to the stoplog lifting lug. If the skinplate is on the upstream side, the dowel holes need to be built to allow insertion of the dowel pins, while remaining sealed from water leakage through the stoplog.

If filling lines are not provided in the structure, or a portable pump system (or other type of operator-controlled fill system) cannot be used to equalize the pressure across the stoplogs, a filling valve may be placed in one of the lower stacked stoplogs. This will allow the pressure to be equalized on both sides of the stoplogs after work has been completed and prior to stoplog removal. If necessary, air supply/vent line(s) can also be provided to supply air during conduit unwatering or to release air from the conduit during filling.

When feasible, springs should be added to metal stoplogs to ensure the seals contact the sealing side of the guides/slots to enable easier unwatering. On taller designs, the springs also help prevent the top of the stoplog(s) from rocking away from the sealing side of the guides/slots.

6.3 Design

6.3.1 Design Decisions or Assumptions

Final selection of the type and sizing of stoplogs, bulkhead gates, and associated equipment should be made based on project conditions. Maintenance, reliability, and equipment life should also be major considerations.

Bulkhead gates and stoplogs are used to temporarily isolate equipment and features for inspection and maintenance; therefore, their design and use constitute a life safety issue. The water pressure loading should always use the maximum water surface that could occur at the site (this load might be the future maximum water level if the bulkhead gate or stoplogs could still be used at that time). When stacked stoplogs are used, it is typical to design each of the stoplogs using the maximum loads to allow the stoplogs to be interchangeable and prevent improper stacking during the installation. If different designs and member sizes are used for the stacked stoplogs, each stoplog should be provided with a readable nameplate that clearly identifies its stacked position.

Ice loading will need to be evaluated and included in the designs if the project site has the potential for ice formation during times the bulkhead gate or stoplogs would be in use. Ice can induce much greater loads than would normally be expected, due to the expansion and contraction of the ice as temperatures change. An example of an ice load that was used for designing stoplogs at a Reclamation facility assumed a 3-foot-thick ice sheet and a design ice loading of approximately 35 pounds per square inch (lb/in^2).

To prevent ice from accumulating within the structural members of the bulkhead gate or stoplogs, the skinplate would typically be located on the upstream side of the bulkhead gate or stoplogs, and drain holes would be provided within the support beams. Other measures to consider during project design include adding a heating system to the metal guides or guide slots (to keep ice from freezing to the guides) and a bubbler system (to ensure open water at the guide/slot area) to allow installation and removal of the bulkhead gate or stoplogs. The bulkhead gate or stoplogs should never be forced through the ice and down the guides.

Seismic loads should also be evaluated and may become a part of the designs for the bulkhead gate/stoplogs, particularly where longer-term use (versus temporary, short-term use) of the stoplogs or bulkhead gate is anticipated.

For many structures, the designer must consider additional parameters besides the design loads and allowable stresses. For example, when sizing members of a bulkhead gate or stoplog, the designer must also consider corrosion, ease of fabrication and welding, economics, stresses due to shipping and handling, operation, etc. When selecting member sizes, storage of bulkhead gates or stoplogs must be considered. Bulkhead gates and individual stoplogs may be stored in the upper portion of the guides in which they are used. This can cause high levels of material loss if this location exposes members to partially submerged conditions over long periods of time.

Special consideration is necessary when divers will be used to operate the filling valve. Filling valves are usually small (6 inches or less), and high head conditions create a high differential pressure at the valve. The pressure can be high enough, and the valve opening small enough, that a diver can be pulled to the valve and create a seal with their body if they get too close to the opening. A pipe or barrier screen must be used to protect the diver. A pipe can be used to increase the length between the valve and the water intake. This distance must be long enough to enable the diver to operate the valve and then swim away from the bulkhead. If a barrier screen is used, the velocity through the screen must be low enough to enable the diver to swim away if positioned next to it. In addition, the barrier screen area must be large to prevent a diver from inadvertently blocking the opening. When practicable, it may be preferable to use tag lines to operate valves, rather than divers.

Unwatering can create a vacuum in penstocks, conduits, or draft tubes if the supply of air is insufficient. If air supply lines are not provided in the structure, they may need to be added to the bulkhead gate (or, on a rare occasion, to the stoplogs) to ensure sufficient air can be introduced during unwatering. Air lines need to be strong enough to withstand collapsing, due to head pressure, and they need to extend above the water surface. The air supply lines can also be used as an air vent, when refilling the unwatered area, to equalize the pressure across the bulkhead gate or stoplogs. For both unwatering and refilling conditions, the amount of water being removed during the unwatering process, or added during the refilling process, needs to be controlled to limit air velocity in the supply/vent lines.

Water delivery requirements may dictate that the bulkhead gate or stoplogs be designed to allow some passage of water downstream (see figure 6.3.1-1). This may require valves to be operated while underwater. If divers are used to operate the valves, the same restrictions apply to them as they do to divers who operate filling valves. When practicable, it may be preferable to use tag lines to operate valves.

Figure 6.3.1-1. Two-piece, circular bulkhead gate being installed from a barge. Note the downstream water delivery lines extending from bottom of bulkhead gate.

Other important considerations include installation and removal of the bulkhead gate or stoplogs. Bulkhead gate installation may require a lifting beam, lifting frame, lifting sling, or direct connection between the bulkhead gate and the crane. Stoplog installation and removal will typically require use of a lifting beam or lifting frame between the stoplog and the crane. Site access and the crane's lift/reach capacity needs to be investigated. On occasion, a crane or hoist on a barge may be required (see figure 6.3.1-1).

Installing a circular intake bulkhead gate may require that two separate pieces be installed and then bolted together underwater prior to operation; for example, when a submerged concrete intake structure contains trashrack bays not wide enough to allow one-piece installation. In a case like this, horizontal movement may also be required, as well as the use of multiple cranes. If the bulkhead gate is installed in two pieces and assembled underwater, bolts should be a minimum of ¾ inch. Larger sized bolts and nuts are recommended because they are easier for divers to handle while underwater.

6.3.2 Design Stresses and Codes

No codes directly relate to bulkhead gates and stoplogs. Bulkhead gates and metal stoplogs can essentially be designed, detailed, and fabricated according to AISC and AWS D1.1. Aluminum stoplogs should be designed and fabricated according to AA.

6.3.3 Design for Bulkhead Gate and Stoplogs

To design a bulkhead gate or stoplogs, the working design loads (maximum water load, ice load, seismic load, etc.) must first be determined. Bulkhead gates and stoplogs must be designed to support forces applied by the maximum water pressure. Stresses should always include the dead weight (dry) of the bulkhead gate or stoplogs. Stoplogs should also be designed for the column loading due to the full weight of all the stacked stoplogs when installed. Knowing the loads, the working stresses can be determined and compared with acceptable allowable loads.

Horizontal members for bulkhead gates and stoplogs are designed as simply supported members with a uniform, distributed load over each beam. To calculate beam bending stresses, the properties of the beam section are determined using the rolled beam section (or flange and web of a built-up section) plus the effective skinplate width. The centerline to centerline spacing of the support beams should typically not be greater than 2 times the depth of the beams. For structural steel, the effective skinplate width is considered to be 30 times the skinplate thickness, plus the width of the beam flange for intermediate beams, and 15 times the skinplate thickness plus the width of the beam flange for top and bottom beams.

The safe working stress, when referring to a bulkhead gate or stoplog, should not exceed the following value:

$$S_S = 0.6F_Y \qquad (1)$$

Where:

S_S = safe working stress in kips per square inch (kips/in^2)
F_Y = minimum yield stress of material in kips/in^2

Lateral support for the compression flanges of the horizontal beams is provided at intervals given by the following equation:

$$L=76b_f/(F_Y)^{1/2} \qquad (2)$$

Where:

L= interval in inches
b_f = flange width in inches
F_Y = minimum yield stress of material in kips/in^2

If a skinplate is provided on the compression side of the beam, the beam is considered to be laterally supported along its entire length. In this case, the lateral support length should still be used as the maximum spacing between the backing bars.

The required skinplate thickness is controlled by a combined stress analysis involving beam bending and skinplate bending. The skinplate bending moment is determined by analyzing a 1-inch-wide vertical strip of skinplate. The design loading on the strip of the skinplate is the water pressure corresponding to the design head acting uniformly over the entire length of the strip.

The stress due to skinplate bending is perpendicular to the stress due to beam bending. The stresses can be combined using the "maximum shear-strain theory."

The web of the horizontal beam directly under the seat bar, through which the water load is transmitted, is subject to web crippling. Vertical and horizontal shear stresses in this section are calculated. The need for web stiffeners is determined in accordance with the AISC specifications. Stresses due to loading on the webs for the top and bottom horizontal beams are included on stoplogs and bulkhead gates with upstream skinplates.

The horizontal beam spacing, width and thickness of the seat bars, and the embedded seats should be designed so that the loads carried into the concrete structure are sufficiently distributed to not exceed 1,050 lb/in^2 for 3,000-lb/in^2 compressive strength of concrete (1,400 lb/in^2 for 4,000-lb/in^2 compressive strength of concrete).

When designing for aluminum stoplogs, the strength after welding is a primary concern. Aluminum loses significant amounts of strength during the welding process. Aluminum stoplogs should be heat treated to regain the strength lost during the welding process, or reduced allowable stresses should be used.

If used, leaf springs are typically fabricated from spring steel and sized to provide a force equal to 5 to 10 lb/ft^2 of bulkhead gate area (width multiplied by height) or the individual stoplog area at the normal spring deflection. (Note: Draft-tube bulkhead gates may require higher spring loadings due to turbulence in the tailwater; see Section 6.2.1.2, "Draft-Tube Bulkhead Gates.") In many cases, the normal spring deflection chosen is 3/4 inch. Exceeding 10 lb/ft^2 may risk damage to the seals during installation or removal. Where possible, four springs should be provided, each supplying 25 percent of the force. Springs are required not to take a permanent set at the maximum spring deflection, which, in many cases, equals 1.5 inches. For design purposes, spring stresses due to bending shall not exceed 115,000 lb/in^2 at the maximum spring deflection.

6.3.4 Design for Lifting Beams and Lifting Frames

Lifting beams and lifting frames are used as grappling devices for placing or removing bulkhead gates and stoplogs. They are designed to operate below the water surface using the guides or slots provided for the equipment being handled. In some cases, such as a one-piece stoplog or a bulkhead gate, a two-legged wire rope sling may be used, eliminating the need for a lifting device.

Wherever possible, when using a lifting beam or lifting frame, large stoplogs and bulkhead gates should be picked up from a single point, with a single hook assembly. Where two hook locations are used, the possibility exists for only one hook to engage, which could potentially result in a dropped load. When designing either a lifting beam or lifting frame, it is desirable to provide pilot rods or dowel pins to guide the hook into proper position for engaging, as well as to prevent rotation of the bulkhead gate or stoplog when raised above the guides.

Lifting beams are designed as simply supported beams with concentrated load at the hook points (see figure 6.3.4-1). The unsupported length is equal to the distance between the lifting lugs (sling or hoisting ropes attachment points). Lifting beams and lifting frames should be designed for two times the deadweight of the bulkhead gate or stoplog to account for friction during removal.

The total height of the lifting beam should be at least 0.4 times its length. Lifting beams may require vertical end plates with stiffeners to meet this requirement. Rollers and/or wear strips can also be added to these end plates, which reduces the lifting beam's ability to rack in the guides when the bulkhead gate or stoplogs need to be removed. To provide greater stability, lifting beams should be equipped with two hoisting ropes or a suitable lifting sling.

Figure 6.3.4-1. Lifting beam stored on concrete pad in yard. Note the stored stoplogs behind the lifting beam.

Lifting frames serve the same function as lifting beams, but they are configured differently. Lifting beams generally consist of two structural members aligned on a horizontal plane, while a lifting frame has multiple structural members that create a box or truss type frame. To reduce the possibility of binding in the guides, the height of the lifting frame should be at least 0.6 times its length, in which case a single-rope connection from the lifting frame to the hoist or crane is considered sufficient. A lifting frame should be considered if the depth of submergence renders any jamming of the lifting device unacceptable, or if the weight and span of the stoplog makes a lifting beam impractical.

The safe working stress, when referring to a lifting beam or lifting frame, should not exceed the following value:

$$S_S = 0.6F_Y \tag{3}$$

Where:

S_S = safe working stress in kips/in^2

F_Y = minimum yield stress of material in kips/in^2

6.3.5 Corrosion Protection

Corrosion is a design concern for bulkhead gates and metal stoplogs. The thickness of metal to be used in bulkhead gates and stoplogs is dependent upon the site conditions, water quality, coating protection, the installation, storage and operational requirements, and the maintenance upkeep. Even with coating protection, the design of bulkhead gates and stoplogs should allow for some deterioration without sacrificing structural integrity. The typical minimum thickness used for skinplates is 5/16 inch, the minimum support beam web thickness is 1/4 inch, and the minimum support beam flange thickness is 3/8 inch. However; if intended for long-term submergence, structural members may be increased in thickness by 1/16 inch or more for each wetted surface to allow for corrosion.

Drain holes should be provided in the support beams to allow water drainage when the bulkhead gate/stoplogs are removed from the guides, as well as to prevent water retention during storage. These drain holes are typically located within the webs of the intermittent and bottom support beams, but the location may vary in the bottom beam, depending on the location of the skinplate and the seals.

Welds are especially vulnerable to corrosion. When determining weld size, it should be recognized that the allowance for corrosion of the weld is of equal importance as the strength of the weld. Welds that are highly stressed or in pure shear are usually oversized by 1/16 inch for corrosion.

It is recommended that bulkhead gates and stoplogs be painted with a protective coating. Current practice, based on past performance, is to recoat bulkhead gates and stoplogs as necessary during their usable life. On some installations, cathodic protection systems have been used for protection; however, at this time, only a few systems have been installed. Cathodic protection is generally only needed when bulkhead gates or stoplogs are stored in the guides where they are to be used under partially submerged conditions. If possible, bulkhead gates and stoplogs should not be stored where partial submergence regularly occurs. Selecting the type of protective coating for the bulkhead gates and stoplogs may also require accounting for whether marine growth, such as zebra and/or quagga mussels, are in the area. Galvanizing bulkhead gates and stoplogs is not an acceptable method of protection for normal water conditions, but may be considered for one-time-use installations where submergence is short term (uncoated bulkhead gates or uncoated stoplogs may also be considered in this case). During shipping and installation, care should be taken not to damage the protective coating. If the coating does get scratched or chipped, it should be properly repaired.

6.3.6 Seats and Guides

6.3.6.1 Seats and Guides for Bulkhead Gates

Steel guides and a frame consisting of side, top, and bottom seats are embedded in concrete in the structure. Blockouts are often provided with anchor bolts to allow precise adjustment of the seats and guides before the blockout concrete is placed. On occasion, seats and guides have been placed in the primary concrete. The seats and guides should be sufficiently strong to withstand the placement of blockout concrete without appreciable deflection. In some cases, consideration should be given to using a corrosion-resisting material for the embedded seats.

For bulkhead gates which are only installed occasionally, guides may not extend up to the water surface. In this case, divers may be required to help position the bulkhead gate into the guides.

For a circular bulkhead gate, a circular seat is embedded in the concrete around the horizontal opening.

6.3.6.2 Seats and Guides for Stoplogs

Steel guides and a bottom seat are typically embedded in concrete in stoplog slots and the floor of the structure. A top seat is provided in the headwall of the structure when a top seal is required for metal stoplogs. Blockouts are often provided with anchor bolts to allow precise adjustment of the seats and guides before the blockout concrete is placed. On occasion, seats and guides have been placed in the primary concrete. The seats and guides should be sufficiently strong to withstand the placement of blockout concrete without appreciable deflection.

Due to the small loads, wooden stoplogs may not require a full set of metal guides and bottom seat. If not provided, however, leakage may increase between the stoplogs and the concrete guide slot/floor. If full metal guides are not provided as part of the wooden stoplogs, it is typical to embed an angle to protect the corner of the concrete guide slots that will be loaded by the stoplogs. In some cases, consideration should be given to using a corrosion-resisting material for the embedded seats and guides.

6.3.7 Sealing

6.3.7.1 Seals for Bulkhead Gates

An elastomer sealing strip extends continuously along the two vertical sides (see figure 6.3.7.1-1) and the top and bottom of the bulkhead gate. On circular bulkhead gates, the sealing strip extends continuously around the circumference of the gate. Music-note-shaped seals are generally used, although double-stem seals and flap seals have been used occasionally.

On some bulkhead gates (particularly those subject to turbulence, such as draft-tube bulkhead gates), an initial 1/8-inch interference between the seal and seats is provided by wedging to ensure a positive seal before the draft tube is unwatered. If necessary, seal friction is reduced by using a seal with a fluorocarbon (Teflon) coating on its surface to contact the seat.

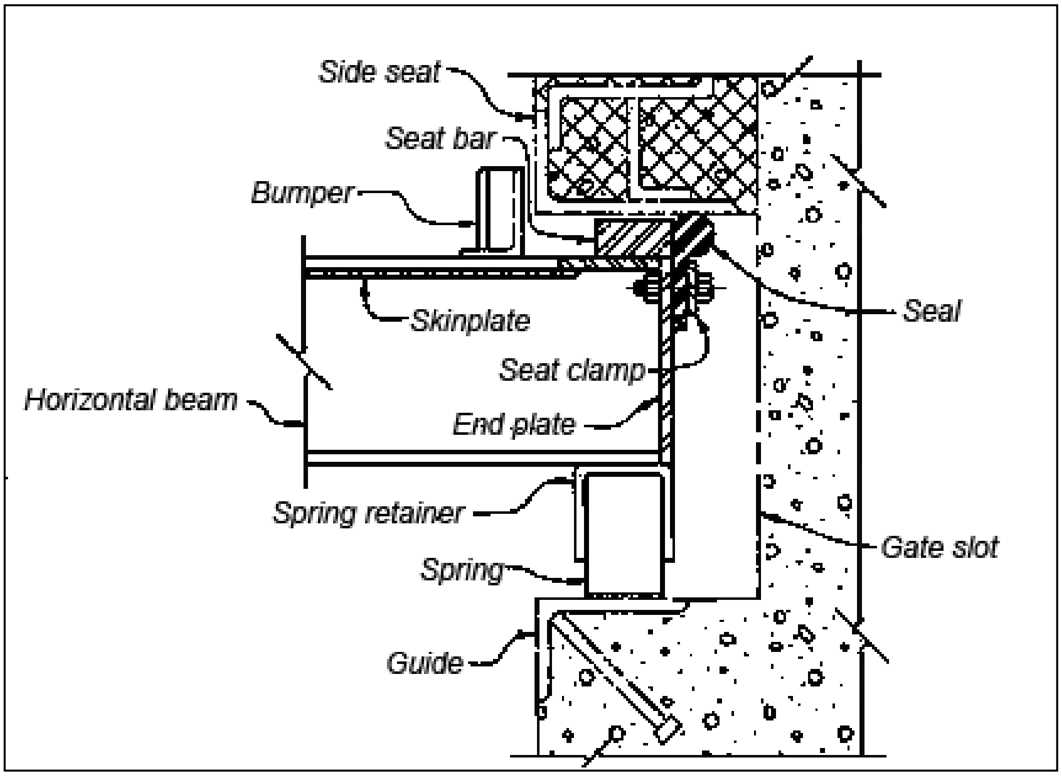

Figure 6.3.7.1-1. Section through bulkhead gate in slot.

The seat configuration used depends on the shape of the opening. One type of seal configuration is a "picture frame," which is a continuous seal around the downstream face of the gate, where the sealing surfaces of the seals are all in the same plane. The picture frame seal configuration is used where seats perpendicular to the flow can be provided all around the opening, such as on bellmouth openings. Another configuration, where the sealing surfaces are not all in the same plane, has a bottom seal and is used where it is necessary to seal against a surface which is parallel or at an angle to the flow, such as the flat or sloping floor of a structure.

The sealing strip and seat bar on each side of the bulkhead gate contact the side seats, and the sealing strips along the top and bottom of the bulkhead gate will contact the top and bottom seats. For bulkhead gates with springs, the top and side sealing strips project at least 1/4 inch beyond the face of the seat bars, and the bottom sealing strip projects at least 1/4 inch below the bottom surface, or 1/4 inch beyond the face of the seat bar, depending on the seal configuration. For bulkhead gates with guide shoes and wedges, which provide an initial interference between the seals and the seats, the seal projection is increased accordingly.

The seat bar and elastomer strip on a circular bulkhead gate contact a circular seat embedded in the concrete around the horizontal opening.

6.3.7.2 Seals for Metal Stoplogs

A music-note-shaped elastomer sealing strip is typically used for sealing, although flap type and rectangular seals have also been used. The elastomer sealing strip extends continuously along the two vertical sides and the bottom of each stoplog. If the stoplogs are to seal across the top of the opening, the sealing strip then also extends continuously across the top of the uppermost stoplog. The sealing strip and seat bar on each side of the stoplog contact the guide/seat surface, and the sealing strip along the bottom of a stoplog will contact the surface of the top angle of the stoplog below it (see figure 6.3.7.2-1) or, if it is the bottom stoplog, the bottom sealing strip will contact the bottom seat. If provided, the top sealing strip will contact the top seat. The top and side sealing strips project at least 1/4 inch beyond the face of the seat bars, and the bottom sealing strip projects at least 1/4 inch below the bottom surface.

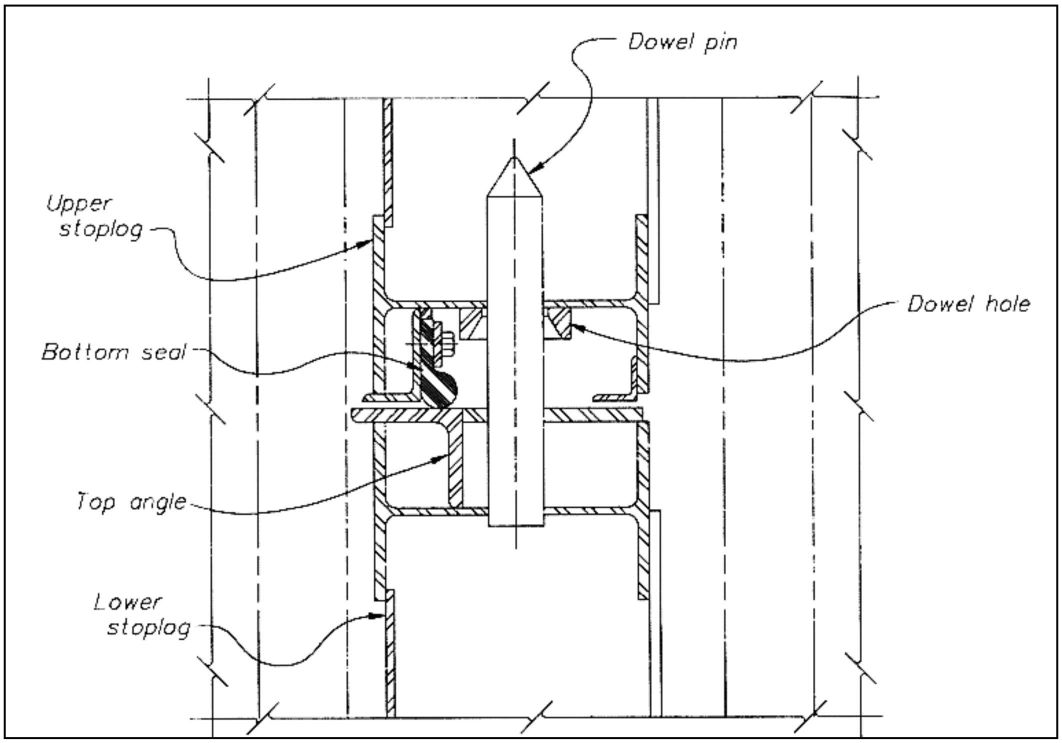

Figure 6.3.7.2-1. Section through stacked stoplogs at installation.

6.3.8 Storage

Where possible, bulkhead gates are stored in the upper portion of the gate guides, above the water passage and maximum water elevation, and below the surface of the deck. The bulkhead gates can be suspended from latches mounted on the guides and recessed sufficiently for grating to be placed over the gates when in the stored position, or the gates can be built with extendable arms, which can be extended to sit on a ledge near the top of the guides. Bulkhead gates may also be stored in a specially designed pit or in a yard. Bulkhead gates stored prone in the yard should have the skinplate facing up to shed water. In addition, they should be blocked by using timbers having wood cut away in the area of the seals to prevent compression of the seals during storage.

Stoplogs may be stored in a specially designed pit or on a concrete pad. Vertical pipes or posts resembling the guides are sometimes embedded in the concrete pad to prevent the stoplogs from falling over (see figure 6.3.8-1). Sometimes, stoplogs are stored in a prone position in a yard. Stoplogs stored in a prone position should have the skinplate facing up to shed water. In all cases, stoplogs should be blocked by using timbers having wood cut away in the area of the seals to prevent compression of the seals during storage.

Figure 6.3.8-1. Stoplogs stored in the storage yard in vertical supports resembling the guides that are embedded in a concrete pad.

For long-term storage, removing the seals and storing them separately to ensure their protection from the sun and weather, thus increasing the life of the seals.

6.4 Checklist for Bulkhead Gates and Stoplogs

6.4.1 Bulkhead Gates and Stoplogs

1. Have the maximum water surface and water load been determined?
2. Have icing and seismic conditions been identified?
3. What will the bulkhead gates/stoplogs be used to isolate?
4. Are they part of a new facility or a modification to existing facilities?
5. Are there maximum height (high hook) limitations?
6. Are there maximum weight considerations for installation?
7. Has the required span (width) been determined?
8. How will the bulkhead gate/stoplogs be installed, and will they need a separate lifting device?
9. Are there site restrictions that would affect crane access and use? (This may also apply to boat or barge access and use.)
10. Will the bulkhead gate or set of stoplogs be installed in a submerged environment, requiring divers to assist the installation, operation, and removal?
11. Are there existing seats and guides? If not, will embedded seats and embedded guides or concrete slots be required, and can they be extended to above the water surface?
12. What is the required seating direction or directions?
13. How many bulkhead gates or sets of stoplogs need to be provided to allow isolation of the desired equipment and features at the site?
14. Will the bulkhead gate/stoplogs be used at multiple bays or locations?

15. Will the bulkhead gate/stoplog installation be for a one-time use, for a temporary/short-term use, or for a long-term use?

16. How/where will the bulkhead gate/stoplogs be stored?

17. Will a filling valve system be required as part of the bulkhead gates and stoplogs?

18. Will an air supply/vent line be required at part of the bulkhead gate or set of stoplogs?

19. Are there water delivery requirements that could affect the design of the bulkhead gate/stoplogs?

20. If necessary, how will water delivery requirements be met?

6.5 References

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