Hydraulic Design Considerations

for

High-head Outlets

Gates and Valves

by

James W. Ball

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HIGH-HEAD RESERVOIR OUTLETS

High-head reservoir outlets are defined as conduits which release water from reservoirs under heads of 100 or more feet for flood control, irrigation, domestic supply, and power. These outlets may be divided into four general types: (1) those having no restriction or control device such as gates or valves within them; (2) those having a control or regulating device at the upstream end; (3) those having a control or regulator at some intermediate point, and (4) those having the control or regulator at the downstream end.

The first type is usually employed strictly for flood control, while the other three may serve to control or regulate flows for other purposes as well as for flood control.

There are four important hydraulic design considerations ~~problem areas~~ in outlets: (1) the entrance; (2) the control or regulator; (3) the main conduit, and (4) the exit. In general, these considerations ~~problems~~ apply to all four of the general types. The considerations ~~Problems~~ vary somewhat in the different types.

One of the first considerations in planning an outlet is to select the type best suited to the requirements. Hydraulic adequacy must be considered along with economics.

Once the most appropriate and economical type of outlet has been determined, the next important step is to ascertain the size needed. This can best be done by equating the total hydraulic losses to the design head, using the design discharge. One of the most convenient methods is to express the losses in terms of the velocity head ($\frac{V^2}{2g}$) using Darcy's equation; equating total losses to the design head, expressing velocity in terms of Q/A, (Q=AV); computing A (area of outlet) and determining diameter or dimensions for this area.

In this case, losses would be expressed thusly:

$H_L = K \frac{V^2}{2g}$, where K is the loss coefficient for the outlet component being considered. The losses may include: (1) Trashrack loss; (2) entrance loss (varies with shape); (3) friction loss; (4) shape loss (bends, junctions, expansions, contractions, etc); (5) control or regulator loss, and (6) exit loss.

The value of K for trashracks is small, about 8 times the velocity head at the trashrack. Trashrack velocities are usually between 1 and 2 feet per second, so omission of the loss in initial plans would not be significant.

The value of K for the entrance will vary with a sharpness of the entrance and will range from 0.04 for a well shaped bellmouth, 0.25 for a slightly rounded, 0.50 for a sharp edged, to 0.80 for an inward projecting entrance.

The value of K for friction loss will vary with velocity of flow, viscosity of fluid, diameter of conduit, length of conduit, and relative roughness of the flow boundary surfaces. The Darcy formula $H = f \frac{l}{d} \frac{V^2}{2g}$ is a convenient relationship to determine friction loss. The factor f is termed the friction factor and is dependent on the velocity of flow, diameter of conduit, kinematic viscosity of the fluid and the relative roughness of the conduit flow surface. The friction factor can be obtained by use of appropriate surface rugosity values, viscosity, and the well known Moody diagram. Values usually range from about 0.008 to 0.04, depending on the values of the parameters enumerated above. Data from many tests made throughout the world have been compiled in Bureau of Reclamation Monograph No. 7.

The values of K for special conduit shapes, such as bends, branches, junctions, enlargements, and contractions, vary with the shape. Values may be obtained from data gathered from many parts of the world.4/ 5/ 6/

The value of K for the control or regulating device (usually a gate or a valve) can be of particular importance because it varies widely for the different types of controls. The expression $K = (\frac{1}{C^2} - 1)$, where C is the

4/ (British publication)
5/ (translation)
6/

coefficient of discharge, can be used to determine K. The value of C for a particular control can be obtained from numerous experimental tables or curves. Some of the values for full ~~y~~ open controls and free discharge are given below:

Slide gate	0.93 to 0.97
Jet-flow gate	0.80
Hollow-jet valve	0.70
Fixed cone valve (Howell-Bunger)	0.85
Needle valve	0.45 to 0.60
Tube valve	0.50 to 0.55
Cylinder or ring gate	0.80 to 0.90
Butterfly valve	0.6 to .95
Plug valve	
Sphere valve	1.00
Gate valve	0.95
Globe valve	

The value of K for exit loss is usually taken as unity. With the control at the end of the system or discharging freely into atmosphere or adequately ~~united~~ aerated, the velocity in the conduit just upstream of the control is the basis for loss.

Summing up and equating losses to available head (H) as:

$$(K_1+K_2+K_3+K_4+K_5)\ \frac{V^2}{2g} = H$$

Expressing V in terms of Q and A:

$$\sum K \frac{Q^2}{2gA^2} = H$$

Select Q and solve for A (needed area). Compute conduit dimensions ~~to give~~ from A.

Cavitation Potential

One of the most important hydraulic considerations when designing an outlet is the cavitation potential of its various parts. Cavitation is a phenomenon that takes place when the pressure within the fluid reaches the vapor pressure of the fluid for the existing temperature. Vapor cavities form and then collapse as they pass suddenly into a higher pressure area, producing high unit forces which damage flow surfaces of any material when in contact with them. Cavitation may occur at the entrance, within the outlet, or at or within the control or regulator.

Conduit and Penstock Entrances

Entrances of penstocks and conduits are usually streamlined. The entrances for power penstocks are designed for a minimum of loss and this requires good streamlining. Conduits that carry high velocity flow (in excess of 50 feet per second) also require streamlined entrances. The streamlining in this case is needed to prevent regions of reduced pressure which might cause' cavitation. Streamlining in these areas ~~are~~ usually consist of surfaces forming to the shape of an ellipse. Suitable shapes for circular and rectangular entrances have been developed by laboratory investigations._/_/_/ General static pressures will influence the streamlining. Less streamlining is necessary when the static pressures (back pressures) are high.

Smoothness of flow surfaces

Where velocities are high and static pressures are low, it is important that flow surfaces not contain roughness or irregularities that would cause a local reduction in pressure that would induce cavitation. The cavitation potential of possible surface irrigularities should be investigated during the design stage. The potential of a given type of irregularity will vary with the size of the irregularity, the flow velocity, and the static pressure in the vicinity of the irregularity. Hydraulic tests have been made for several shapes. _/_/_/ Curves showing critical velocities and pressures for sharp curved offsets into the flow are shown on Figure ________. Partially open valves or gates in closed lines can be treated as irregularities in water passages. The cavitation potential of such arrangement has been studied by evaluating the cavitation index K in terms of the pressure, vapor pressure, and the velocity. The following relationship has been found useful in this respect.

$$K = \frac{H_2 - H_v}{H_t - H_2}$$

Where H_2 is pressure short distance downstream from the control, H_v is vapor pressure of water relative to atmosphere, and H_t is total head just upstreat from control. Results have shown that very mild cavitation occurs for $K \geq 1.0$, that there is no cavitation whatsoever for $K \geq 2.0$, and that cavitation intensity increases as K decreases below unity.

DRAFT JWBall:saj-s

Gates

Control gates may be classified generally as leaf gates, or gates in which a structural leaf is used to regulate or control the flow from closed conduits. Leaf gates may be classified further according to some particular feature or purpose, such as, slide gates, ring-follower gates, fixed-wheel gates, tractor gates, jet-flow gates, radial gates, and bulkhead gates. The physical and hydraulic characteristics of gates vary widely, thus each should be considered in the light of these characteristics and the purpose of the gates is to serve. The various gates, their characteristics and use, are discussed so that proper selection of the design can be made.

Slide Gates

A slide gate is one with a rectangular or square leaf, usually of cast iron or steel, contained in a cast iron or steel housing or body. The leaf slides on special sealing surfaces in side grooves in the body to shut off the flow. The leaf seats and seals on the flat bottom surface of the gate body. Guides, wheels, rolls or tracks are often used to reduce the sliding friction between leaf and body. Slide gates may be classified further depending on purpose to be served, or some hydraulic or physical characteristic. Some of these gates will be of particular interest.

Ring-follower gate.

This gate has a leaf that is solid at one end and has a hole in the other which is the same diameter as the conduit. The leaf slides in grooves in the gate body. The solid end shuts off the flow and the end with the hole in it forms a continous flow passage when the leaf is in the wide open position. The name of this gate originates from the fact that ring (end of leaf with hole) follows the shut-off portion of the leaf to form the continuous water passage for the fully-open position. The ring-follower gate offers essentially no resistance to flow and is therefore the most efficient of the many types of gates and hydraulic losses need not be considered. However, this gate is not to be used at partial openings for flow regulation at high heads. The sharp corners of the opening through the leaf and the body are conducive to cavitation and this would induce noise, vibration, and distructive pitting. These conditions are prevailent during the opening and closing cycle but the duration is so short that there are no serious problems. The opening in the gate leaf should coincide with the conduit to form continuous flow surfaces in the water passage when the gate is in the wide open position.

The hydraulic downpull on the ring-follower gate is an important factor to be considered because the design of the operating equipment is dependent on the magnitude of this force. This downpull force can be controlled to some degree by providing adequate clearances between the leaf and portions of the gate body. The Paradox gate and ring-seal gates are variations of the ring-follower gate, in which the sealing devices differ materially. These gates are usually placed at some intermediate point in the conduit, either as a non-regulating control, or a guard gate. Adequate areation to prevent general areas of severe subatmospheric pressure with resultant objectionable noise and vibration, should be provided.

Jet-flow Gate

The jet-flow gate is one in which an orifice is built into the gate body joint upstream of the leaf to cause the flow to form a contracted ~~jetxflow~~ jet which passes through the gate body without contacting the gate grooves. The contraction facilitates aeration of the conduit downstream from the gate and because a contraction is present at all gate openings, the gate can be used as a flow regulator as well as a control. Also, the downstream conduit may be either circular, rectangular, horse-shoe or other shape without introducing difficulties. However, any transition from one shape to another downstream from the gates should be given careful consideration regarding surface irregularities and alignment. The diameter of the orifice should be equal to or less than that of the upstream pipe. The diameter of the pipe at the orifice should be about 1.2 times the diameter of the orifice. This deminsion may be obtained by an expansion or enlargement of the pipe section just upstream from the orifice or by using an ~~xupstream~~ upstream pipe 1.2 times the diameter of the orifice. For ~~1.2xtimesxthexdiameterxm~~ this setting and diameter relationships the coefficient of discharge is 0.80 based on the orifice diameter and the total head upstream from the gate. The pressure drop for would be about 0.56 $\frac{V^2}{2g}$, where V is the average velocity at gate orifice.

The smooth upstream force of the gate leaf remains in contact with the seal which is contained in the gate body on the downstream side of the orifice. This sealing at the upstream side of the leaf virtually eliminates the hydraulic downpull force which can be quite large for slide-gates.

Regulating Slide Gate

The early designs of the slide gate gave no consideration to the shape of the flow passage at the gate grooves or slots, or to the shape of the gate bottom. These early designs had a high cavitation potential for high heads and many incurred severe destructive pitting damage. Particular attention has been given to gate slot shape and size, shape of bottom surface and the contour of the upstream force of the gate leaf in designs developed in recent years. As a result there are now designs with very low cavitation potential (Figure). The gate slots in these gates have offset downstream corners and curves or flat converging surfaces connecting the corners to the downstream gate frame walls. The proper proportions for gate slots that minimize cavitation have been determined through research studies.[105] Many gate bottom shapes have been considered but the 45° slope with a flat sealing surface has proven most desirable. This shape is very effective in reducing hydraulic downpull.

In early designs the upstream face of the leaf was curved in the horizontal plane, making it quite thick at the center; at smaller openings this shape caused the flow ~~and~~ to concentrate in the center of the downstream channel and give very poor distribution of flow for stilling Basins. Gate leaves arenow made flatter and thinner. The roof of the frame just downstream from the gate leaf is usually offset upward to facilitate aeration. This regulating slide gate can now be used either within or at the end of a tunnel. The coefficient of discharge for this gate is about 0.95, but may vary from 0.92 to 0.97 depending on upstream conditions. The loss factor or pressure drop for the 0.95 discharge coefficient is about $0.11 \frac{V^2}{20}$, The design of the water passage upstream from these high capacity gates should be given careful consideration regarding surface irregularities and alignement in order that the system will have a low potential for cavitation, vibration, and noise.

DRAFT JWBALL:fhr-s
April 13, 1962

Bulkhead Gates

A bulkhead gate is one that is used for isolating the flow system or a part of it to permit inspection or repairs. The shapes of bulkhead gates may vary widely depending on where and how they are to be used. The bulkhead gates employed in unwatering outlet works conduits are usually rectangular in shape and are generally placed over the upstream ends of the conduits by using hoists and sliding them in guides on the upstream faces of the structures. They are generally known as coaster gates. A bulkhead gate is usually positioned under balanced pressurec conditions. However, in some cases where they serve also as guard gates or emergency closure gates they are subjected to unbalanced pressures and careful consideration must be given to their design and hydraulic characteristics. Cavitation potential and hydraulic downpull are two important considerations. Floatation and stability may need to be considered depending on how and where the gate is to be used and usually not where high heads are involved. Where bulkhead gates operate for emergency closure the downpull force can be quite large compared with the weight of the gate._/ There are so many factors of gate design that influence the downpull force that a general solution is not possible. The following items are typical of those to be considered: (1) head on gate, (2) gate width, (3) gate thickness, (4) shape of gate bottom surface, (5) type and shape of gate seal, (6) trashrack base position, (7) pressures in conduit, and (8) configuration of face of dam near conduit entrance. The influence of all but Item 4 and 8 can be adequately estimated. Sufficient data are available on certain gate bottom shapes to permit a reasonably accurate estimate of their influence. A recess in the face of the structure above and near the conduit entrance would be an example of Item 8. Hydraulic model tests may be needed to evaluate the influence of such characteristics. (Note: Figures in Hyd 130 may be useful).

DRAFT JWBall:awo-s
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Regulating Radial Gates

The radial gate receives its name from the fact that the leaf, or closure element, is a segment of a cylinder and rotates about the hinges which are on the framework arms that are radial to the closure element. Radial gates are used extensively for open channel regulation on spillway or canal structures, but are also being used to regulate closed conduit flow under moderate heads and where large discharges are required. In the wide open position, the radial gate offers essentially no resistance to the flow. The loss can be taken the same as an equivalent length of water passage. When this is done and there is no restriction due to seals or grooves the discharge coefficient can be considered to be unity. These gates are sometimes termed top-seal radial gates. These gates have been used successfully for heads of 110 feet. The seals on these gates are generally adequate but further improvement is desirable. Bottom seals may be troublesome by inducing vibration, depending on their nature and arrangement. The music note, or bulb seal does not always give good results and, in some cases, it has been necessary to replace this shape with a simple bar shape rubber seal. Special pressure actuated seals along the side and top have shown promise. The reaction of the hydraulic forces on the radial gates are always radial and through the trunion bearings of the gate arms.

Cylinder Gates

The designation "cylinder gate" is associated with gates having a cylindrical closure element. This closure element is usually in a vertical position and is raised and lowered from a circular seat to regulate the flow. There are two general types of cylinder gates, one in which the flow is outward from the conduit under the gate, and the other in which the flow is from outside the conduit, under the gate, and into the conduit. The magnitude, frequency, and direction of the hydraulic forces acting on the gate under various operating conditions are important factors as they may introduce vibration which might be damaging to the gate.

Seal and seat spacing and arrangement are important in order that damaging cavitation with the inherent noise and vibration can be avoided. Hydraulic downpull may or may not be a consideration, depending on the gate shape. The gate bottom shape and the seat ring configuration must be given careful consideration. Damping devices may be needed on long gate operating stems to prevent oscillation due to changing flows or fluctuating pressures which vary the elongation of the stems. The losses for an intake gate where water flows under the gate into the conduit can be considered negligible, while losses for and outlet gate controlling flow from the conduit is small. The coefficient of discharge for the intake gate can be taken as unity. That for the outlet condition is about 0.85 to 0.90. This value can vary with the ratio of gate diameter to gate travel.

DRAFT JWBall:btm-s
May 10, 1962

VALVES

Control valves may be classified generally as devices which use other than a structural leaf for regulating or controlling the flow from closed conduits. Valves may also be classified as general types, such as, needle, tube, fixed cone, hollow-jet, butterfly, and plug valves. Some of these types include several variations ~~tak~~ that will be discussed under the appropriate topics.

Valves are usually employed where regulation of flow varies from very small amounts to the full capacity of the system. They may be placed at the entrance, within, or at the end of conduits, but are usually placed at the end of conduits where they discharge freely into the stmosphere. The cavitation potential of the various valve designs differ widely depending on configuration of the water passages and under what conditions the valves are used. The hydraulic and structural characteristics of the various valves will be discussed to assist in the selection of these valves for the purpose intended. The common gate valve and the common globe valves will not be considered as controls for high head outlets. However, when use of these valves are contemplated,careful consideration should be given to their flow characteristics and their cavitation potential.

DRAFT JWBall:fhr-s
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Report

Needle Valve

A needle valve consists of an outer shell or body with a stationary cylinder supported within it on ribs or vanes and a closing or regulating element telescoping either inside or outside of the stationary cylinder. The needle valve is sometimes operated by regulating hydraulic pressure within compartments formed by the cylinder and closure element. The needle-like closure element moves downstream against a seating surface in the valve body to shut off the flow. This places the valve body under internal pressures equal to the reservoir head and requires that the body be of sufficient thickness to withstand these pressures. Because of this the needle valve is usually quite heavy.

There have been variations of the needle valve in past years. The Ensign valve, named for the prominent engineer who contributed to its development, was an early model. This valve was usually attached to the face of the structure over the conduit entrance and was quite inaccesible. The valve was not suitable for high heads and much difficulty ~~with~~ was experienced with cavitation when it was used under these conditions. Trouble was experienced with cavitation in soem of the early needle valves such as the Larner-Johnson type because of diverging water passages. This difficulty was overcome by making the walls of the passage between the body and needle parallel or slightly convergent.

The shaping of the water passage of the needle valve is quite importnat. The contour of the passage as well as the area of flow should never diverge because divergence will increase the cavitation potential. The body surface should recede suddenly from the water passage at the downstream end to provide complete separation and aeration of the jet.

The discharge coefficient of a cavitation-free needle valve design is about 0.59 when based on the area of the inlet and the total head just upstream. (In this case inlet diameter was 1.05 times exit diameter) There should be no difficulty with cavitation when the proportions are as shown in Figure ______. Hydraulic forces on the needle point for all operating conditions should be considered so that adequate actuating mechanism can be provided. The needle valve discharges a solid concentrated jet making special consideration necessary when the energy in the jet is to be dissipated in a stilling basin.

Tube Valve

The tube valve consists of an outer shell or body with a stationary cylinder supported within it on ribs or vanes and a closing or regulating tube-like element telescoping inside the cylinder. The regulating element is operated mechanically by a screw stem which passes through the transverse spider spanning the upstream end of the closure tube. The tube seats and seals of the downstream end of the valve body and the body is therefore subjected to full reservoir pressure when closed. The tubular closure element is actuated by level gearing driven through the shaft extension to a motor-reduction gear unit attached to the valve body. The tube valve has essentially no unbalanced hydraulic forces and therefore can be operated mechanically without difficulty. The cavitation potential of the tube valve is quite low because of the areas of the needle valve subjected to this action were not present. For a valve with an inlet diameter 1.1 times the outlet diameter, the discharge coefficient was 0.52 based on the total head and the area of the pipe just upstream from the valve. Flow from the valve at large openings is a steady concentrated jet similar to that for a needle valve.

The jet at small valve openings, below about 25 percent, pulsates and has a ragged appearance. It is not considered desirable to operate tube valves in this range for long periods of time.

DRAFT JWBall:wab-s
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Hollow-jet Valve

The hollow-jet valve is a needle type valve having a bell-shaped body with the larger bell-end directed downstream and the closure element or needle pointed upstream. The closure element moves upstream to shut off the flow as the needle seats against the body in the neck or smaller section of the bell. (Figure). The portion of the valve body beyond the seat is never under reservoir pressure, thus the valve is of relatively light weight construction. Water passes between the closure element and the body, and discharges from the downstream end of the short bell-shaped body in a tubular, or hollow jet, the outside diameter of which does not change with valve opening. There is very little dispersion of the jet regardless of opening; however, because of the tubular form of the jet the energy is distributed over a comparatively large area, facilitating the dissipation of energy and lessening the destructive action in the stilling basin. A special economical stilling basin for hollow-jet valves has been developed by hydraulic model studies. Hyd-446/

The proportions of the water passage through the valve are designed to prevent substmospheric pressures, thus assuring that cavitation damage will not occur when the flow surfaces are smooth and contain no objectionable irregularities. The pressures on the flow surfaces change with the movement of the closure element, decreasing as the travel or opening increases. The normal travel of $\frac{d}{3}$ was that determined by model studies to give definite positive pressures on the flow passage surfaces. The coefficient of discharge for this travel and based on the total head and area one diameter upstream from the valve is 0.70. The capacity of the valve can be increased some by increasing the travel of the closure element. A 3-1/2 percent increase in capacity can be obtained by a 5-1/2 percent increase in travel without introducing subatmospheric pressures in the flow passage. An extrapolation of the discharge coefficient and pressure curves indicates that the travel can be increased by 10 percent without introducing serious subatmospheric pressures. The coefficient of discharge for this increased travel would be about 0.75. The pressure intensity in various parts of the flow passage, and the coefficient of discharge variation with valve opening, expressed in percent of travel of the closure element, can be determined from graphs established through hydraulic model investigations (Figure). Proportions of the water passage and other parts of the valve can be obtained from a ratio chart prepared for this purpose (Figure). As in all cases where surfaces are subjected to high velocity flow there is danger of cavitation with damage, noise, and vibration unless these surfaces are kept smooth and free of troublesome irregularities. Hyd-448/

The pressure drop for this valve with a discharge coefficient of 0.70 is about $1.04 \frac{V^2}{2g}$ where V is average velocity at the valve entrance.

For facilitating mechanical operation, the valve is provided with an internal chamber which is connected to the flow surface by equalizing ports. The use of these ports permits hydraulic forces on the closure element to be balanced within plus or minus 13 percent regardless of opening (Figure). This balancing reduced to a minimum the mechanical forces needed for operation.

Hydraulic operation of the hollow-jet valve is now used extensively. The balancing ports are of course omitted when hydraulic operation is used.

Butterfly Valves

The butterfly valve consists of a short metal cylindrical or globular body enclosing a circular leaf mounted on diametrically opposed pivot shafts one of which extends through the body wall to a pivot arm that rotates and regulates the position of the circular leaf.

Butterfly valves are used mainly as guard valves or emergency closure valves in pipelines upstream from regulating valves or turbines. They are usually provided with a by pass to fill the pipe downstream and equalize pressures for easy opening. However, some butterfly valves have been used in special settings for free discharge.

The shape of the leaf may be conducive to subatmospheric pressures and cavitation when operated at low pressures and high velocities. The leaf position is also conducive to low pressures, cavitation, turbulence and vibration during the closing and opening cycles (at partial openings). Therefore, they are not good regulators in closed systems. Also,much dispersion and spray are present when valves are used for free flow at partial openings.

The discharge coefficients for butterfly valves may vary widely depending on whether valve is contained in a closed conduit system, discharges freely into the atmosphere, has a body with diameter same as pipe, has a blobular body or has a thick or thin leaf. The hydraulic losses may vary widely also, depending on these factors. The discharge coefficient for a valve having a pipe-size body and a rather thick leaf is about 0.60, while one with a globular body and streamlined leaf may exceed 0.90. Valves with globular badies are generally used as guard valves ahead of turbines to minimize the hydraulic losses. Cylindrical bodies are used where free discharge is concerned or where losses are not an important consideration.

Operating torque induced by hydraulic pressures is quite high at partial openings and changes with opening.

Fixed-Dispersion Cone Valves

The body of the vixed-dispersion cone valve consists of a cylindrical section with a deflecter cone connected to the downstream end by a spider of vanes. The closure or regulating element is a cylindrical sleeve section which telescopes over the cylindrical body and the vanes to seat against the cone. The sleeve is retracted over the valve body by screws and a system of gears to change its position and vary the opening of the valve. This valve might be considered a special type of cylinder gate.

The flow, as it leaves the deflector cone, is directed outward, being dispersed in a cone-shaped jet. There is very little hydraulic force exerted endwise on the closure sleeve,thus the operating power needed is that required to overcome this force and the frictional resistance of the sleeve and gearing and the total is quite small. The valve is therefore considered to be of the balanced type.

Sometimes a hood, either attached or detached, is used to confine the flow and direct it downstream. In such cases reaction forces on the hood or deflector should be given careful consideration as should the pressure conditions on various parts of the valve. The valve seat must be properly shaped to prevent cavitation pressures. This characteristic should be given particular consideration if the valve is to be operated submerged. This type of valve is particular suited to submerged operation in a vertical stilling well when all its characteristics have been taken into a consideration.

A detached hood or confinement can be used very effectively with this type of valve.

The discharge coefficient for valves of this type range from about 0.85 to0.90 depending on the ratio of sleeve trowel to pipe diameter. Air requirements will vary with type and extent of jet confinement and may vary from a small percentage of the water flow in guantity to many times the valve discharge. Venting should be given special attention when these valves are to be confined, in fact, model studies of individual cases are desirable.

Plug Valves and Sphere Valves

Plug valves or sphere valves have globular or spherical bodies with a plug-like or spherical rotating closure elements. They are used mainly in the wide open or closed positions and are especially adopted to 3-way or 4-way branches in flow systems. These valves usually have a high cavitation potential under high heads and partial openings so are not used under these conditions for extended periods. Some special valves of this type are used for free flow discharge. The coefficient of discharge is usually high, approaching unity in most cases. Irregularities in the flow passages at partial openings must be considered, and their cavitation potential evaluated. Operating torque due to hydraulic characteristics varies with design but usually is comparatively high.

DRAFT JWBall:fbe-s
June 21, 1962

Report

HIGH-HEAD OUTLETS, VALVES AND GATES

POSSIBLE FIGURES AND REFERENCES

<u>High-Head Reservoir OUtlets</u>

Figure: ~~Drainage typed~~ Drawings of Typical outlets of the four types

<u>Hydraulic Losses</u>

Reference: Trashrock losses(~~Red~~ Reclamation. Manual)

Friction losses--(Monograph 7)

Entrance losses--(Corps of Engineers reports on rectangular bellmouth entrances)

Bureau of Reclamation Reports on circular bellmouth entrance Hyd-66)

Also there is a reference on slightly rounded circular entrance which I cannot remember. AB

Shape losses--(bends, junctions, expansions, contractions etc.)

English publications--

Bureau translation--

Bureau Reports, Expansions, HYD-365, Branches, Hyd-350

<u>Regulator or Controls Losses</u>

(Use of coefficient curves)

Exit Loss

(Any Hydraulics textbook)

Smoothness of Flow Surfaces

Figure: May wish to include curves for abrupt offsets into flow, and changes in alignment of flow surfaces. (Figures in ~~above~~ paper)

Reference: Hyd-473

Hyd-448

Paper "Close Construction Tolerances and High Velocity Flow," to be published in either the Construction Division Journal or Hydraulics Division Journal in the near future.

GATES

Slide Gate

Figure: Dwg of slide gate, curve on downpull?

Coefficient curve for slide gate

Jet Flow Gate

Figure: Dwg of gate
Coefficient curves

Reference: Report Hyd-201 (Shasta gates)

Regulating Slide Gate

Figure: Dwg of gate (Palisades type)

Gate slots (curves)

Coefficient curve

Stilling basins for gates?

Reference: Paper "Hydraulic Charateristics of Gate Slots,"

Hyd Div ASCE October 1959, PAP-105)

Report Hyd-387 (Palisades Gate)

Bulkhead Gate

Figure DWG of Bulkhead Gate

Downpull curve

Reference: Hyd=130 (Downpull for gates)

Paper by ~~Womack &~~ Warnock and Pound (Civil Engr)

Papers by Simmons and Colgate,

Hyd Journal, also, PAP-104 and PAP-102

Regulating Radial Gate

Figure: Dwg of radial gate

Coefficient curve

Reference: Hyd-171 (Davis Dam Gates)

Hyd-463 (Twin Buttes OW)

Paper by T. J. Rhone, PAP-103, also Hyds Journal

Cylinder Gate

Figure: Dwg of cylinder gate

Coefficient curve

Seals and seal spacings

Reference: Hyd-454 (Sherbourne Lakes OW)?

Paper, PAP-93 Ball and Schuster IAHR

Paper, PAP-124, Ball, IAHR

VALVES

Needle Valve

Figure: Dwg of needle valve

(Photograph should be considered)

Coefficient curve with unit dimensions

Reference: Paper by Ball and Herbert IAHR (Hyd-240)

Hyd-98 (early tests, by Noonan)

(There are other references)

Hollow-jet Valve

Figure: Dwg of Valve

(Photograph if available)

Coefficient curve with unit dimensions

Stilling Basin(s) for Valves

Reference: Paper, Ball and Herbert, IAHR (Hyd-240)

Paper, PAP-101, Lancaster-Dexter (ASCE)

Hyd-446 (Stilling Basins for ~~H. J.~~ Hollow-Jet Valves

Hyd-148, Hyd-189 (Anderson Rouch H. J. Valve)

Butterfly Valves

Figure: Dwg Butterfly Valve (two types)

Coefficient curve

(photograph if available)

Reference: Paper, Ball, Herbert IAHR (Hyd-240)

Outside ref on torque, capacity, proportions, cavitation potential ~~poluted~~)

Hyd-191 (Losses)

Fixed Dispersion Cone Valves (Howell-Bunger)

Figure: Dwg of valve

(photograph if available)

Coefficient curve

Reference: Paper, Ball, Herbert IAHR (Hyd-240)

Paper- ASCE by M. L. Dickinson, 1957 or 1958

Plug, and Sphere Valves

Figure: Dwg of valves

(Coefficient curves if available)

Reference: ?