Appendix D
Closure Gates

D-1. Purpose

The purpose of this appendix is to explain the procedure used in determining the size of gate closure, the stem size, the operator size, and loads to be carried by the structure at the gate location (Figures D-1, D-2, and D-3).

D-2. Gate Size

The size of gate required is determined using the maximum pumping capacity of the station and the number of pumps. The velocity through the gates at the maximum capacity should be limited to 2.0 feet per second (fps) to achieve the best flow conditions to the pump when used for sump closure. The maximum capacity of the station can be estimated at 33 percent above the design capacity.

Example: Station Capacity = 180 cfs
No. of Pumps = 3

$V = Q/A$

where

V = Velocity through gate = 2.0 fps

Q = Flow through a gate = Max. Cap./3
Max. Cap. = 180 × 1.33 = 240 cfs
therefore Q = 240/3 = 80 cfs

A = Gate area in ft^2

$2.0 = 80/A \quad => \quad A = 40\ ft^2$

$A = W \times H$

where

W = Gate opening width in feet.

H = Gate opening height in feet.

Note: The gate opening height and width are then determined using the area calculated, the sump floor elevation, sump width, and the minimum pumping elevation. The top of the gate opening should not be higher than the minimum pumping elevation. If this is not possible at a particular site, then the top of the gate opening should not be higher than the elevation at which all pumps are operating. For this example use:

$40 = H \times W \quad => \quad H = 5\ ft \text{ and } W = 8\ ft$

D-3. Type of Gate Operation

Slide gates can be used for seating and unseating operating head conditions. Seating head occurs when the level of the water is greater on the gate side of the wall. This type of head condition results in the best seal against leakage. Unseating head occurs when the level of the water inside the gate is greater than the water outside the gate. This type of head condition results in a lesser seal when compared with that achieved with the seating head condition.

D-4. Gate Operator Size

a. Required force. The size of the gate operator is determined by first calculating the force needed to open the gate with the maximum differential head acting on the gate. This will normally occur when the sump is dry and the maximum expected forebay water elevation is present.

(1) There are three terms used during the selection of a motorized gate operator: run torque, pullout torque, and stall torque. The definition of each of these terms is as follows:

(a) Pullout torque. This is the torque the operator develops to initially break the seal caused by the wedges on the sluice gate; operators are designed to develop this torque for only a short period of time.

(b) Run torque. This is the torque the operator develops to move the gate after the wedge seal is broken; operators should be designed to develop this torque continuously.

(c) Stall torque. This is the torque that is developed by the operator just as the motor stalls out; this is the maximum torque which will be exerted on the gate stem.

(2) Example: See Figure D-1:

Gate centerline - el 50.0

Maximum expected forebay water elev. - el 54.0

Gate height - 5.0 ft. Gate width - 8.0 ft.

Operating floor elevation - el. 65.0

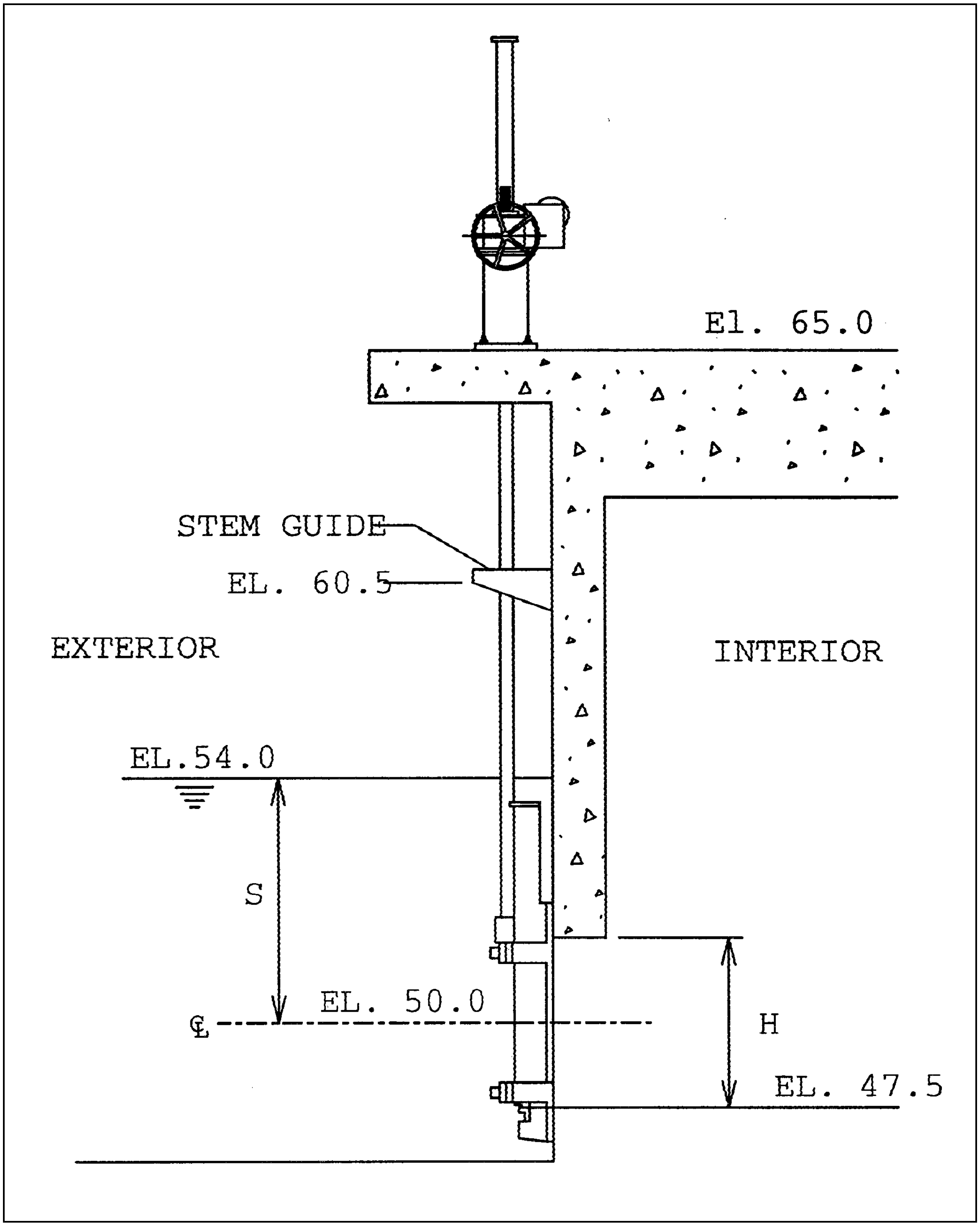


Figure D-1. Sluice gate and operator

$$F_u = 62.4 \times S \times A \times f_u + W_G + W_S \quad \text{(D-1)}$$

where

F_u = Maximum required gate unseating force, lbf

S = The distance from gate centerline to maximum forebay water elevation, ft

A = Gate opening area, ft^2

f_u = Friction factor for unseating (bronze seals)

W_G = Weight of the movable disk, lb (standard sluice gate catalog information)

W_S = Weight of stem, lb. Assume a 3-inch diameter stem that extends from the top of the disc to 4 feet above the operating platform elevation (standard sluice gate catalog information)

For this example:

S = el 54.0 - el 50.0 = 4 ft

A = 5 × 8 = 40 ft^2

f_u = 0.6

W_G = 4900 lb

W_S => Stem length - (el 65.0 + 4.0) - (el 50.0 + 5.0/2) = 16.5 ft

Weight = 16.5 ft × 24.03 lb/ft = 396.5 lb

Therefore,

$$F_u = 62.4 \times 4.0 \times 40.0 \times 0.6 + 4{,}900 + 396.5 = 11{,}287 \text{ lbf}$$

(b) Preliminary hoist and stem size. This force or thrust to unseat the gate is then compared with manufacturers of motorized gate operators' catalog information to determine a preliminary hoist and stem size.

b. Required torque. The required torque (ft-lb) is determined by multiplying the calculated thrust with the stem factor (provided by manufacturer). For this example the stem factor is 0.0204 with 3 threads per inch.

The resultant torque = 11,287 × 0.0204 = 230.3 ft-lb

c. Output rotation speed. The required output rotation speed of the operator (in rpm) is then determined. For this example, the desired gate travel speed is approximately 1 foot per minute.

Stem Nut Rotation Speed = (1 ft/min)(12 in/ft)(3 thrd/in) = 36 rpm

(1) The torque required of 230.3 ft-lb and speed of 36 rpm is used to select an operator.

(2) The electric data for this operator are then obtained from either the catalog or directly from the manufacturers. These data are used for preparing the electrical design of the station.

D-5. Maximum Loads on Stem

a. Calculation of maximum loads. The maximum loads which can be transferred to the stem and the structure are calculated. The design shall be such that the stem would fail before any supporting structural failure would occur. The maximum loads are based on 125 percent of the stall torque (taken from published catalog information) of the operator selected.

(1) For this example, the stall torque of the selected operator is 481 ft-lb (this figure should always be verified by the gate operator manufacturer).

Max. Thrust = (Stall Torque × 1.25)/Stem Factor

= (481 × 1.25)/0.0204 = 29,473 lbf

(2) The maximum thrust is an upward thrust of 30 kips and a downward thrust of 35 kips (this includes the dead weight of the gate itself).

(3) The required spacing of the stem guides is then determined. The Euler Column Formula is used:

$$F_{CR} = C\,^2EA/(L/r)^2 \quad \text{(D-2)}$$

where

F_{CR} = Maximum thrust, lbf

C = End condition factor

E = Modulus of elasticity, psi

A = Cross-sectional area of the stem, in^2

L = Maximum unsupported length of stem, in.

r = Radius of gyration, in.

(4) The L/r ratio shall not exceed 200.

(5) For this example:

C = 2 (for all slide gate computations)

E = 28,000,000 psi (for stainless steel)

A = for threaded portion = 2.14 in^2
for plain portion = 3.14 in^2

r = for threaded portion = 0.41 in.
for plain portion = 0.50 in.

(6) Using these numbers, the maximum unsupported lengths of the stems can be calculated:

$$L = r \ [(C \times E \times A)/F_{CR}]^{1/2} \qquad \text{(D-3)}$$

Maximum length of threaded stem (L_{MT}) = 82.2 in.

Maximum length of plain stem (L_{MS}) = 121.5 in.

(7) However, at an L/r ratio of 200

$L_{MT} = 200 \times 0.41 = 82$ in.

$L_{MS} = 200 \times 0.50 = 100$ in.

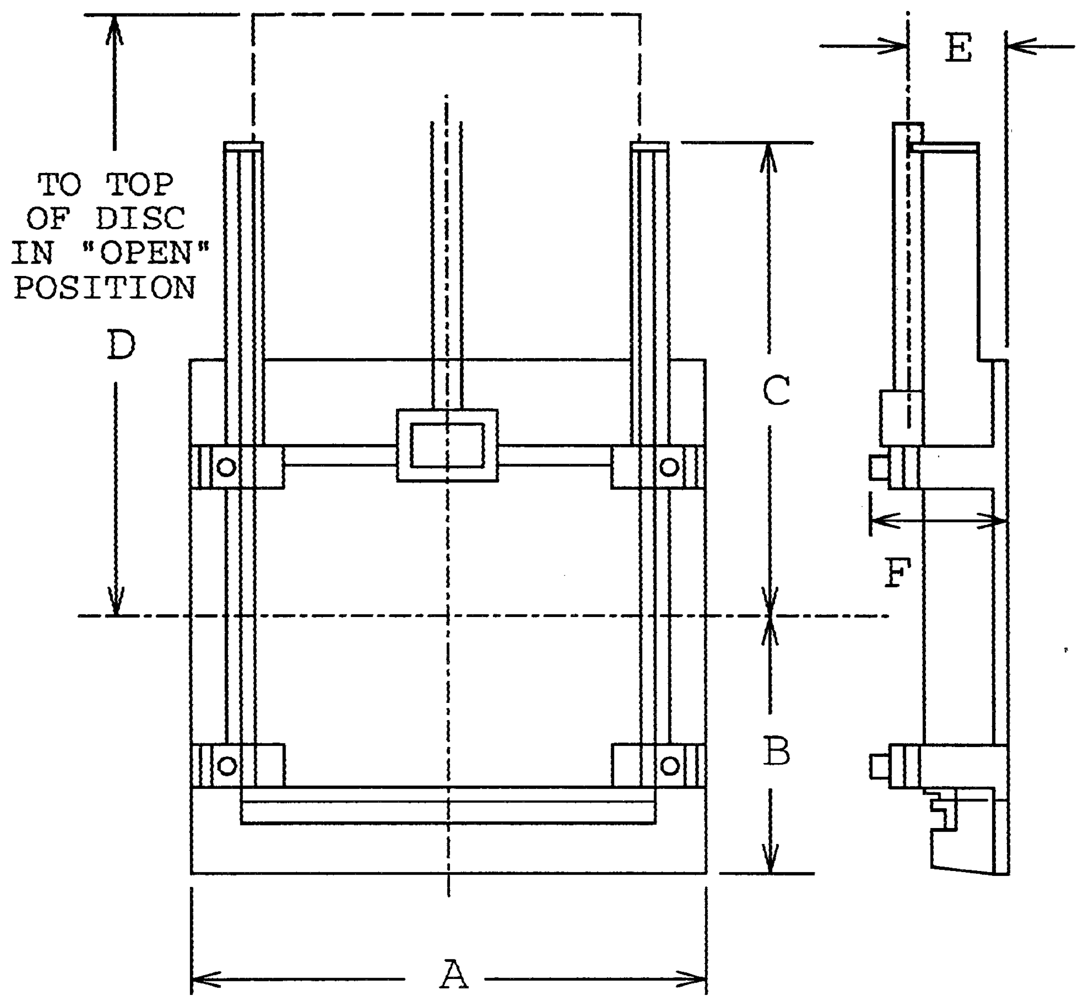
(8) Since both the L/r ratio < 200 and the Euler's Column Formula criteria have to be met, the criterion resulting in the shortest lengths is used. For this example, the L/r ratio < 200 criterion has resulted in the shortest lengths. Two stem guides are located to meet these calculated lengths. Figure D-1 shows that one stem guide was placed at el 60.5 or 96 inches (8.0 feet) above the top of the gate (this length of stem is solid; therefore the previously calculated 100-in. maximum length is applied). The other stem guide would be located at the bottom of the gate operator base. This location would result in a length between guides of 54 inches, which is less than the minimum for threaded stem (82 in.).

b. Position limit switches. All motorized gate operators shall be equipped with position limit switches in the open and closed positions. In addition, mechanical torque limit switches should be provided. These would provide backup in case the position limit switches fail or if debris jams the gate while opening or closing.

c. Roller gates. The same computations are done for roller gates to size the operators and structural design loads. The force required to open this type of gate is the sum of gate weight, stem weight, seal friction, and roller friction. The seal friction is a result of the deflection of the rubber J-seal attached to the top and sides of the gate. The roller friction is a result of the bearing friction in the roller and the roller-to-rail friction. The amount of seal and roller friction will vary depending on the types of materials used for the roller wheels, roller bearings, rails and seal plates.

(1) If the roller gate is extra wide or if the ratio of the width to the height is equal to or greater than 2:1, the gates are normally raised and lowered through the use of two stems placed near each side of the gate. Each stem passes through a geared operator. The geared operators are both connected to an electric or hydraulic operator located between the two stems. The loads incurred by raising the gate are equally distributed between the two stems.

(2) During the early design phases of a pump station, a roller gate manufacturer should be consulted to assist in determining the design loads, forces, and lifting arrangement.



NOTE: A MINIMUM CLEARANCE OF 9 IN. SHALL BE PROVIDED ON EACH SIDE OF THE GATE

Figure D-2. Sluice gate layout

Typical Slide Gate Dimensions

Size Width × Height Inches	Design Head Ft. Seat	Design Head Ft. Unseat	Dimensions Inches A	B	C	D	E	F
36 × 18	88	40	46	14	20	33	6	8-1/2
36 × 24	88	30	46	17	26	42	6-1/4	8-1/2
36 × 30	60	36	46	20	32	51	6-1/2	9-1/2
36 × 36	60	30	46	23	38	60	6-1/4	9-1/2
36 × 42	76	43	47-1/2	26	44	69	6-1/4	9-1/2
36 × 48	65	30	47-1/2	29	50	78	6-1/2	10
42 × 24	90	21	53-1/2	17	26	42	6	8-1/2
42 × 30	88	25	53-1/2	20	32	51	6-1/4	9-1/4
42 × 36	88	24	53-1/2	23	38	60	6-1/4	9-1/2
42 × 42	87	23	53-1/2	26	44	69	6-1/4	9-1/2
42 × 48	80	23	53-1/2	29	50	78	6-1/4	10
48 × 24	58	21	59-1/2	17	26	42	6-1/4	8-1/2
48 × 30	60	32	59-1/2	20	32	51	6-1/4	9-1/4
48 × 36	62	27	59-1/2	23	38	60	6-1/4	9-1/2
48 × 42	65	32	59-1/2	26	44	69	6-1/4	9-1/2
48 × 48	69	16	59-1/2	29	50	78	6-1/4	10
54 × 48	130	45	67-1/2	30-3/4	51-1/2	81-1/2	9-1/2	15-1/4
54 × 54	130	45	67-1/2	33-3/4	57-1/2	90-1/2	9-1/2	15-1/4
54 × 60	130	45	67-1/2	36-3/4	63-1/2	99-1/2	9-1/2	16-1/2
54 × 72	130	45	67-1/2	42-3/4	75-1/2	117-1/2	9-1/2	16-1/2
54 × 84	130	45	67-1/2	48-3/4	87-1/2	135-1/2	9-1/2	17-3/4
54 × 96	130	45	67-1/2	54-3/4	99-1/2	153-1/2	9-1/2	17-3/4
60 × 36	80	25	71-1/2	23-3/4	39-1/4	61-1/2	8-3/4	13-1/4
60 × 48	80	25	71-1/2	29-3/4	51-1/4	79-1/2	8-3/4	13-1/4
60 × 54	80	25	71-1/2	32-3/4	57-1/4	88-1/2	8-3/4	13-1/4
60 × 60	80	25	71-1/2	35-3/4	63-1/4	97-1/2	8-3/4	14
60 × 72	80	25	71-1/2	41-3/4	75-1/4	115-1/2	8-3/4	14
60 × 84	80	25	71-1/2	47-3/4	87-1/4	133-1/2	8-3/4	14-3/4
60 × 96	80	25	71-1/2	53-3/4	99-1/4	151-1/2	8-3/4	14-3/4
72 × 36	60	20	83-1/2	23-3/4	39-1/4	61-1/2	8-3/4	13-1/4
72 × 48	60	20	83-1/2	29-3/4	51-1/4	79-1/2	8-3/4	13-1/4
72 × 54	60	20	83-1/2	32-3/4	57-1/4	88-1/2	8-3/4	13-1/4
72 × 60	60	20	83-1/2	35-3/4	63-1/4	97-1/2	8-3/4	14
72 × 72	60	20	83-1/2	41-3/4	75-1/4	115-1/2	8-3/4	14
72 × 84	60	20	83-1/2	47-3/4	87-1/4	133-1/2	8-3/4	14-3/4
72 × 96	60	20	83-1/2	53-3/4	99-1/4	151-1/2	8-3/4	14-3/4
72 × 108	108	36	85-1/2	60-3/4	114	171-1/2	9-1/2	19

Figure D-3. Typical slide gate dimensions **(Continued)**

Typical Slide Gate Dimensions

Size Width × Height Inches	Design Head Ft. Seat	Design Head Ft. Unseat	Dimensions Inches A	B	C	D	E	F
84 × 36	54	17	95-1/2	23-3/4	39-1/4	61-1/2	8-3/4	13-1/4
84 × 48	54	17	95-1/2	29-3/4	51-1/4	79-1/2	8-3/4	13-1/4
84 × 54	54	17	95-1/2	32-3/4	57-1/4	88-1/2	8-3/4	13-1/4
84 × 60	54	17	95-1/2	35-3/4	63-1/4	97-1/2	8-3/4	14
84 × 72	54	17	95-1/2	41-3/4	75-1/4	115-1/2	8-3/4	14
84 × 84	54	17	95-1/2	47-3/4	87-1/4	133-1/2	8-3/4	14-3/4
84 × 96	54	17	95-1/2	53-3/4	99-1/4	151-1/2	8-3/4	14-3/4
84 × 108	80	30	97-1/2	60-3/4	114	171-1/2	9-1/2	19
84 × 120	80	30	97-1/2	66-3/4	126	189-1/2	9-1/2	19
96 × 36	52	14	107-1/2	23-3/4	39-1/4	61-1/2	8-3/4	13-1/4
96 × 48	52	14	107-1/2	29-3/4	51-1/4	79-1/2	8-3/4	13-1/4
96 × 54	52	14	107-1/2	32-3/4	57-1/4	88-1/2	8-3/4	13-1/4
96 × 60	52	14	107-1/2	35-3/4	63-1/4	97-1/2	8-3/4	14
96 × 72	52	14	107-1/2	41-3/4	75-1/4	115-1/2	8-3/4	14
96 × 84	52	14	107-1/2	47-3/4	87-1/4	133-1/2	8-3/4	14-3/4
96 × 96	52	14	107-1/2	53-3/4	99-1/4	155-1/2	8-3/4	14-3/4
96 × 108	65	25	109-1/2	60-3/4	114	171-1/2	9-1/2	19
96 × 120	65	25	109-1/2	66-3/4	126	189-1/2	9-1/2	19
108 × 48	55	23	121-1/2	30-3/4	51-1/2	81-1/2	9-1/2	15-1/4
108 × 54	55	23	121-1/2	33-3/4	57-1/2	90-1/2	9-1/2	15-1/4
108 × 60	55	23	121-1/2	36-3/4	63-1/2	99-1/2	9-1/2	16-1/2
108 × 72	55	23	121-1/2	42-3/4	75-1/2	117-1/2	9-1/2	16-1/2
108 × 84	55	23	121-1/2	48-3/4	87-1/2	135-1/2	9-1/2	17-3/4
108 × 96	55	23	121-1/2	54-3/4	99-1/2	153-1/2	9-1/2	17-3/4
108 × 108	55	23	121-1/2	60-3/4	114-1/2	171-1/2	9-1/2	19
108 × 120	55	23	121-1/2	66-3/4	126-1/2	189-1/2	9-1/2	19
120 × 48	50	20	133-1/2	30-3/4	81-1/2	81-1/2	9-1/2	15-1/4
120 × 54	50	20	133-1/2	33-3/4	90-1/2	90-1/2	9-1/2	15-1/4
120 × 60	50	20	133-1/2	36-3/4	99-1/2	99-1/2	9-1/2	16-1/2
120 × 72	50	20	133-1/2	42-3/4	117-1/2	117-1/2	9-1/2	16-1/2
120 × 84	50	20	133-1/2	48-3/4	135-1/2	135-1/2	9-1/2	17-3/4
120 × 96	50	20	133-1/2	54-3/4	153-1/2	153-1/2	9-1/2	17-3/4
120 × 108	50	20	133-1/2	60-3/4	171-1/2	171-1/2	9-1/2	19
120 × 120	50	20	133-1/2	66-3/4	189-1/2	189-1/2	9-1/2	19

Figure D-3. (Concluded)