Chapter 5
Vertical-Lift Gates

5-1. Vertical-Lift Gates

a. General description.

(1) Two types of vertical-lift gates may be used. One type, a double-leaf or triple-leaf, vertical-lift gate, referred to in this chapter as emergency gate, is located at the upper end of each lock chamber. The upstream leaf, consisting of horizontal girders and a skin plate, is designed for use as a movable sill. The downstream leaf, also consisting of horizontal girders and a skin plate, is designed for operation through flowing water. The downstream side of both leaves is provided with a grating screen to prevent drift and debris from lodging between the horizontal girders. A screen and bulkhead are provided above the ends of each leaf to prevent drift from entering the recess and to prevent damage to the recess from tows entering the locks. The hoist component at each side of a gate is mounted on a structural steel frame which is anchored to a concrete structure on the lock wall, the unpowered component for each lock being on the middle wall and the powered component on the opposite wall. The structure is of such height that the hoist machinery will be above high water. The hoist assembly is enclosed in a concrete housing with removable aluminum roof sections. For the normal open or stored position, the leaves are lowered into the sill. The emergency gate is used for lock closure in the event of accident or damage to the lock gates that otherwise would result in a loss of the navigation pool. The gate will also be used to skim ice and drift from the lock approaches, or for upstream lock closure during maintenance and repair operations in the lock chamber, and in connection with opening the lock gates to pass flood flows when necessary after navigation is suspended. (See Plate B-42.)

(2) The other type of vertical-lift gate is a single-leaf gate that can be used at either end of a lock and is frequently used as a tide or hurricane gate along the sea coast. This type of gate is raised when not in use, permitting normal traffic to pass underneath. This type is referred to as a “Tide” or “Hurricane” gate in this chapter (See Plate B-41).

b. Skin plate.

(1) The primary design method for skin plates of vertical-lift gate leaves supported by girders or trusses should be as described previously in paragraph 2-1*c* for horizontally framed miter gates. The skin plate may be designed by the method of Column Analogy, utilizing the thickness of the flange in conjunction with the skin plate to form a beam of variable section spanning from center to center of girder webs. The stress should be determined at the center line of girder webs, which is the end of the assumed beam, at the edge of the girder flange, and at the center of the beam, midway between girder webs. See Plate B-43 for additional information on this method of analysis.

(2) The skin plate of gate leaves with close girder spacing or without intercostals may be designed as continuous members.

c. Framing. Vertical-lift gates may be fabricated of plate girders or horizontal trusses, with economy normally indicating which system will be used. The basic framing of gates utilizing plate girders consists of the plate girders, downstream bracing, intercostals, diaphragms, and end girders. When horizontal trusses are used the main framing items are the horizontal trusses, vertical trusses acting as diaphragms, downstream bracing, and end girders. When gates are lifted above the locks for clearance, the lifting towers are included in the major framing.

(1) Plate girders. Plate girders are essentially the same as those for horizontally framed miter gates. Girder webs should be determined in accordance with current AISC Specifications, with the web depth-to-thickness ratio such that no reduction in the allowable stress for the compression flange is necessary. In the event longitudinal stiffeners are considered to be advantageous on girder webs for special conditions, the stiffeners should be placed and sized according to the American Association of State Highway and Transportation Officials Specifications.

(a) The girders should be designed by the moment of inertia method. The effective design length should be the full length from bearing. For buckling about the minor axis of the girder due to any applicable axial loads, the effective length may be the lesser of diaphragm spacing or panel spacing of vertical trusses formed by the downstream bracing.

(b) Girders should be designed to withstand water load and a combination of water and dead load and boat impact. Emergency loadings such as boat impact shall have a permissible increase of one-third in the allowable stresses. The water load should include wave pressure if applicable, with consideration given to the effects of breaking or nonbreaking waves, whichever is more appropriate. The downstream flanges of girders that act as the chord member of a vertical truss formed by the downstream bracing shall be designed for the combined loading of water and dead load. The force in the flange, from acting as the chord member of the vertical truss, should be determined from one-half the vertical load on the leaf, assuming the skin plate to carry the remaining one-half. The resulting axial force in the flange shall be considered as an eccentric column, with the stress being the normal P/A + MC/I. The allowable axial stress F_a shall be determined by using a value of the radius of gyration computed as shown in Plate B-43. The allowable bending F_y shall be the appropriate value as determined from EM 1110-2-2105 or from AISC as indicated in paragraph 1-6*b*.

(c) Girder webs should be investigated for shear and the requirement for transverse stiffeners as well as the effect of combined shear and tension, which may reduce the allowable tensile stress to less than $0.6F_y$. Web crippling should also be investigated for all uniform and concentrated forces applied to the girders.

(d) Deflection should be investigated for all girders, especially those of high strength steel.

(2) Horizontal trusses. Horizontal trusses serve the same function as plate girders, with the choice of plate girders or trusses being determined by economics and weight. Where trusses are used the diagonal members should be designed as tension members. Working lines of truss members should coincide with the centroidal axis of the members in order to minimize secondary stresses. Secondary stresses in truss members caused by stiffness, restrained joints, and excessive deflection due to truss depth limitation should also be investigated. Where beams are used as chord members the webs are normally placed horizontally, except the top frame where it may be more advantageous to place the webs vertically to support walkways and equipment. An operational loading equivalent to a minimum differential head of 6 ft applied to either side of the gate should be considered as acting on each truss. The reduction of negative moments for continuous members in the truss is not recommended. Deflection should be investigated for all horizontal trusses.

(3) Diaphragms. Diaphragms on vertical-lift gates where plate girders are utilized serve two main purposes, one being to distribute girder loads and the other to support the vertical loads applied to the leaf where the leaf is being used as a movable sill. The diaphragm should be sized according to AISC Specifications governing the width-to-thickness ratio of the vertical web. Vertical stiffeners should be utilized in accordance with the appropriate sections of AISC Specifications, with the stiffeners and effective section of the web being designed as a column, with each pair of stiffeners carrying a proportional part of the total vertical load on the diaphragm.

(a) The design shear load applied to the diaphragm will be the difference between the assumed load to cause equal deflection of the girders and the actual water load on each girder. The diaphragm should be checked for this shear and the requirement for transverse stiffeners to prevent buckling of the diaphragm due to this shear load. The vertical flange of the diaphragm should be designed as a column, consisting of the flange plate and the effective section of the diaphragm. The effective or unsupported width of flange and the effective section of the diaphragm should be determined according to the AISC Specifications. The load applied to the flange is the appropriate load from the vertical truss action of the downstream bracing.

(b) The extension of the diaphragm on the bottom of the gate leaf should have a bearing plate designed to resist both bearing and moment, with the forces created from the reaction between the plate and the concrete or steel pedestal. Stiffeners should also be provided on the extension of the diaphragm, acting as columns to transfer the load from the diaphragm through the bearing plate to the support pedestal.

(4) Vertical trusses. Vertical trusses, used in gates utilizing horizontal trusses instead of plate girders, perform the same function as the plate diaphragms discussed in the preceding paragraph. The vertical chord members should be designed as columns with the effective length equal to the horizontal truss spacing. The degree of fixity at the ends of the vertical chords, connecting them to the horizontal trusses, will determine the appropriate effective length factor K for design of the members as columns, with a minimum value of 0.65 being used for members considered completely fixed. The effect of the vertical chord acting as a chord of the downstream bracing should also be included in the design of the vertical truss. The deflection of the vertical trusses should be investigated, giving consideration to the effects of the deflection of horizontal trusses on the vertical trusses.

(5) Downstream bracing. The downstream bracing of a gate leaf, in conjunction with the appropriate girders or trusses, forms a vertical truss that supports the vertical

forces applied to the leaf, including the weight of the leaf. Normally the bracing carries one-half of the vertical load with the skin plate carrying the remaining one-half. The bracing should be placed so that the maximum number of members, while acting as truss members, will be designed for tension rather than compression. End connections of the bracing should be such that the forces in the member will be applied concentrically as far as practical. Any eccentricity of the connection from the gravity axis of the member should be considered in determining the stress in the member. The stress created in the girder or horizontal truss by the downstream bracing shall be combined with the bending from horizontal forces as indicated in preceding paragraphs on plate girders.

(6) Intercostals. Intercostals are essentially the same as discussed in the section on horizontally framed miter gates. The span of the intercostal is from center to center of horizontal girders or trusses, with the loading beginning at the edge of the flange or 6 in. from the center line of the girder web, whichever is the smaller dimension. The skin plate is assumed to be an effective part of the intercostal, with the effective width determined according to AISC Specifications. The most desirable shape for intercostals is an unequal leg angle, with the longer leg of the angle attached to the skin plate. This gives a much stronger member than a flat bar used as an intercostal. For additional information, see paragraph 2-1*c*(2).

(7) End girders. End girders, on vertical-lift gates used as upper gates where the gate is lowered into the sill or used as a movable sill, serve to distribute the vertical and horizontal reactions of the gate or gate leaf. These girders are designed as columns with a combined axial and bending load. The axial load is a combination of the dead weight of the gate in the dry plus silt and mud load. This force, normally applied through offset brackets attached to the outside of the end girder web, produces a bending moment in the end girder as well as a normal direct axial load. Usually the force on the end girder is divided between two brackets, with each bracket, along with its effective web and flanges, considered as an individual member, acting as a continuous beam fixed at the horizontal girder webs. Each member is subjected to a combination of bending and axial loading.

(a) The bracket on the outside edge of the end girder web, shown as bracket A in Plate B-44, makes up a vertical member in conjunction with the vertical plate that acts as a flange of the end girder, and the related flanges of the bracket itself.

(b) The bracket shown as bracket B in Plate B-44 makes up a vertical member consisting of the bracket and usually two standard rolled tees attached to the end girder web above the tapered segment of the bracket, forming a member with a haunched section on one end.

(c) The brackets are checked for shear in two directions, one being the vertical shear from direct loading and the other being horizontal shear caused by the moment resulting from the beam action of the member. See Plate B-44 for information on a typical effective column (or beam). Welds attaching the bracket to the web of the end girder are subjected to both direct shear and bending stress and should be sized accordingly.

(d) The end bracket is fitted with a base plate designed for bearing and bending. Where the loads are of such magnitude that the base plates would be excessively thick to prevent bending, stiffeners may be used to support the plate and thereby keep the thickness of the plate in a more desirable range. The stiffeners should be attached to the bracket web plate and be of sufficient length to transfer a proportional share of the force from the web to the base plate, acting as a short column.

(e) The lifting pin plates are generally attached to the end girder web where reaction wheels are not used. The transfer of the vertical force should be made through the welds attaching the pin plates to the end girder web. When reaction wheels are used the lifting connection is generally outside the end girder or reaction girder web. The vertical plate serving as the downstream flanges of the horizontal girders is extended past the reaction girder web and, with the appropriate stiffeners, serves as the vertical web for the lifting connection. The entire end of the gate is usually extended and boxed in by the extended vertical plate, skin plate, and an end plate attached to the ends of the horizontal girder webs.

(f) End girders on vertical lift gates used as lower gates, or where the gate is lifted above the sill for clearance, usually serve only to distribute the horizontal force applied to the gate, acting similar to the vertical plate diaphragm discussed in paragraph 5-1*c*(3), distributing the load so that all reaction wheels carry their appropriate part of the total force applied to the gate. The end girder for this type of gate consists of a solid end plate with an upstream and a downstream flange. The flanges may be of rolled members or of flat plate. The vertical load of the gate is transmitted through the vertical diaphragm or trusses through the bottom seal assemblies to the concrete sill.

(8) Towers. Where vertical-lift gates are used for the lower gate of locks, or where gates must be lifted above the sill for clearance, towers are usually required on top of the lock walls to lift the gate to the required vertical clearance. The towers should be designed for the vertical load of the gate, including 50 percent impact, applicable vertical bridge load, loading due to expansion or contraction of bridge, plus the wind load applied to the gate, bridge, and tower. Wind forces should be as indicated by TM 5-809-1, with a minimum force of 25 psf applied for all areas. The allowable stress can be increased by one-third for all loading conditions that include wind load, provided that the required section computed on this basis is not less than that required for the design dead load, live load, and impact, computed without the one-third stress increase. Consideration should be given to the effect of torsion on the tower, created by the wind load, reaction from the gate, and eccentric loading, as well as wind on the tower itself.

(a) Two basic types of towers used are steel framed or reinforced concrete, with economics normally determining the appropriate type. Hybrid towers of composite construction may in some cases be advantageous but normally are not the most economical. Steel towers should be designed on the basis of each face acting as a planar truss, with the diagonal members carrying tensile forces only. Horizontal cross-bracing should be provided at each panel point to resist shearing and torsional forces caused by the eccentricity of loading along the guide system as well as wind on the tower itself. Concrete towers should be designed with a minimum of 3,000-psi concrete, with the loading essentially the same as that for steel framed towers. Both types of towers should be designed as free-standing cantilevers, with the baseplates for steel towers attached to mass concrete with corrosion-resisting anchor bolts. Baseplates should be checked for bearing and bending from downward axial loads and also for bending due to uplift, with the connection of the baseplate to the tower leg being analyzed for maximum stress. For concrete towers the applied torque should be considered as resisted by pure flexure in the flanges at the cantilever fixed end and by pure torsional shear above the fixed end, with a transitional section between the two. The critical stress may be located in the transition with the shape of the tower influencing the length of transition and the stress concentrations.

(b) The gate guide system should be connected to steel framed towers only at panel points, so that gate wheel reactions will cause no lateral bending in tower legs. In the event it is not practical to avoid bending in some tower members these members shall be designed for the combined axial and bending loads. The guides should be designed as continuous members subject to moving loads from the gate reaction wheels. Where the guide system is attached to concrete towers, consideration should be given to the transfer of shear between the steel portion of the guide system and the tower proper, ensuring that suitable means of transfer are provided.

(c) If a bridge is used on top of the towers to support the vertical load of the gate, the bridge should be designed for the dead load plus impact and wind. The bridge should be connected to the top of the towers with fixed bearings, pinned to allow for deflection of the bridge and towers. The bearings should be designed in accordance with AASHTO Specifications, with the bridge framing meeting the requirements of EM 1110-2-2105 or AISC as indicated in paragraph 1-6*b*. Bracing shall be provided between girders to stabilize the bridge against lateral loads.

(d) When a bridge is not used, cantilevered gate supports must be used on top of the towers. This system causes more tower deflection under load and this should be considered when selecting the support system for the gate.

(e) Whichever support system is selected, cantilevered supports or a bridge, the tower deflection must be checked and the effect considered on the guide system of the gate. If necessary the towers may be cambered so that the gate guides and tower faces at channel-side will be in vertical alignment under the dead load of the gate.

(f) Access across the lock should be provided by way of the towers and the bridge as well as the normal walkway across the top of the gate.

(g) Consideration may be given to the use of counterweights to reduce the cost of electrical and mechanical equipment but the disadvantages of the counterweights, such as the additional load on the tower, the possibility of the need for the full weight of the gate to seat the gate, and the special adaptation of the tower wind bracing to provide clearance for the counterweights and their guide systems, must be compared with the advantages before a final decision can be reached.

d. End bearing. The end bearing of vertical-lift gates is essentially the same as that for a simple beam. There the upper gate is made of two leaves, the upstream leaf, depending on the intended use of the leaf, may be fitted with standard bearing plates designed for moment and bearing. The bearing surface of the plate should be made on a radius to act as a rocker to allow for deflection of the gate leaf. For the allowable stresses and dimensions related to the radius of the curved bearing the current AASHTO Specifications should be used. Where reaction wheels are used so that the gate may be operated under load, the wheels may be sized so that the requirements of AASHTO are met or other similar methods of analysis may be used. For additional information concerning reaction wheels see paragraph 5-2*b*(3)(f).

e. Seals. Rubber “J” seals are used to seal between the end of a single-leaf gate, or the downstream leaf of a divided gate, and the gate recess. Where the upper leaf is used as a temporary sill a rubber “J” seal is bolted to the upstream face of the leaf to provide a seal between the leaf and the existing concrete sill. A short section of rubber caisson seal is used to seal between the gate and the recess on the bearing-bar side of the leaf. One method of sealing between the two leaves at the lower edge of the skin plate of the downstream leaf is to use a tube member normally made of aluminum and in interchangeable lengths, held on top of the upstream leaf by guide brackets and forced into position against the skin plate of the downstream leaf by the force of the water. The seal tube is fabricated so that the water fills the tube after installation, with the tube and brackets installed in the dry and the upstream leaf lowered to a point where the tube is filled before lowering the leaf into its final position. The effect of the water load on the tube should be investigated.

(1) Where the gate is made of a single leaf, a solid block-type rubber seal is used on the bottom of the leaf, sealing against embedded metal in the floor of the lock.

(2) All seals should be fastened with corrosion-resisting bolts spaced approximately 6 in. on center. For additional information on seals, see Plates B-40 and B-41.

(3) Where corrosive elements are encountered, consideration should be given to using corrosion-resisting seal plates or the use of a plate or member with the exposed surface clad with corrosion-resisting metal.

f. Lifting arrangement. Vertical-lift gates are usually lifted by an arrangement of sheaves and cables. Where gates are used as upper gates, the hoist motor is normally fixed on the lock wall and through an assembly of sheaves attached to the gate, lifts the gate to the required heights.

(1) Similar systems are used for lower gates except that the hoist motor may be mounted on the gate or if a bridge is used between towers, the hoist motor is generally mounted on the bridge.

(2) For any system the supporting members used on the gate or for supporting the hoist drums or sheaves shall be designed for the actual load plus 100 percent impact. This should apply to all related pins, bolts, and anchor bolts.

g. Dogging arrangement. Support beams may be used for vertical-lift gates used as upper gates or where the gate is not lifted above the lock walls. These beams should be designed for shear and moment, using 50 percent impact for the applied loading. Stiffener plates should be used on each side of the support beam web under the support brackets of the gate and at the reaction points of the support beam.

(1) Where the gate is lifted above the lock wall on towers, dogging devices should be provided to allow the tension to be removed from the lifting cables under continuous loading. The preferred dogging device consists of a horizontal pin that moves into pin plates attached to the top of the gate. The pin should be so arranged that it can be operated from the control station of the gate, with instruments provided to show when the pin is fully engaged or fully released. (See Plate B-43 for suggested details.)

(2) The pin and pin plates on both the gate and support structure should be designed for the full gate load plus 100 percent impact.

(3) Limit switches should be installed so that when the cables become slack the gate drive motor stops and the brakes set. (See paragraph 5-2*d* for additional information.)

h. Tracks. Tracks for vertical-lift gates are usually incorporated into the guide system, with the track itself consisting of a corrosion-resisting plate where contact with salt or brackish water is a possibility. Where the corrosive elements of the water are minor, as with normal fresh water, the bearing plate or track may be of structural steel with a cladding of corrosion-resisting material on the exposed surface.

(1) Above the water line, consideration may be given to the use of structural carbon steel for the bearing or track plates with the determining factor being the economic comparison of maintenance and replacement against the higher cost of clad material.

(2) The bearing plate or track should be attached to a suitable support member, normally a standard rolled beam, with the support member embedded and anchored in the concrete wall or attached to the tower at tower panel points.

(3) The track plates are provided in pairs, one each on the upstream and downstream side of the recess or guide system.

i. Guides. The guide system for a vertical-lift gate consists of two bearing or track plates and an end guide plate. The bearing plates are so arranged that the wheels or bearing plates of the gate react against the bearing plates of the guide system. The system is arranged so that the gate may be loaded from either side and the bearing plates will remain effective.

(1) The end bearing plates are similar to the reaction bearing plates but are placed so that bumpers on the end of the gate will strike the end bearing plate and prevent excessive lateral movement of the gate in relation to the lock.

(2) The normal clearances should allow for not more than 1 in. total movement between gate and bearing plate and not more than 1/2 in. between gate and end bearing plate. See Plate B-41 for suggested details of a guide showing the recommended clearances.

(3) The end guide or bearing plate should be of the same material as the bearing or track plates, using the same criteria to determine the use of corrosion-resisting steel, clad steel, or standard structural steel.

(4) To minimize the effects of the guide system on the support towers the system should be connected to steel towers only at panel points of the structure.

j. Sill. The concrete sill for a vertical-lift gate may be of two types. One type, where the gate is lowered into a recess behind the sill, carries the weight of the gate on the lower segment of the sill on extended concrete pedestals or on steel pedestals bearing on an extension of the sill. The other type of sill, where the gate is lifted above the sill for clearance, carries the full weight of the gate on the top of the sill, with the weight of the gate being transferred through the seal assembly along the entire length of the gate. For this type of sill an embedded beam with corrosion-resisting seal plate attached is used in the top of the sill. The beam should be placed in second-pour concrete with anchor bolts, also used for adjustment, placed in first-pour concrete. The top of the corrosion-resisting seal plate should be flush with the concrete of the sill.

k. Walkway. Where gates are lifted above the sill for clearance and the top of the gate in the lowered position is at the same elevation as the lock wall, access across the lock should be provided by means of a walkway on top of the gate. The walkway should normally be the same overall width as the gate, with the walkway maintaining its width over the tapered ends of the gate. The minimum width of walkway shall be 4 ft 0 in. back-to-back of support angles. Where the gate width is more than 4 ft, the walkway may be made the minimum width if the additional width is not needed for the transfer of equipment. The support angles will also act as toe boards for the walkway, with a minimum vertical leg of 3-1/2 in. by 3/8 in. The vertical supports of the walkway should be designed as columns and located on the diaphragms and vertical members of the gate where practical.

(1) The walkway shall be designed for 100 psf with grating having a minimum depth of 1-1/4 in. The ends of all grating shall be banded with bars the same size as the bearing bars, with panels made in convenient size for installation and removal. Usually four standard clips per panel will be used to fasten each panel of grating. Grating shall normally be type II and hot-dipped galvanized after fabrication.

(2) Handrail should be made with 2-in. diameter extra strong pipe post and 2-in. standard pipe rail, or equivalent aluminum rail and post if economy dictates aluminum railing for the lock walls. Railing should be made removable and in convenient size panels for installation and removal. When standard and extra strong pipe is used handrail panels should be hot-dipped galvanized after fabrication. See paragraph 2-1*n*(5) for additional information.

l. Erection and testing.

(1) The procedures for vertical-lift gates are essentially the same as those for “miter gates.” Items that do not apply to vertical-lift gates are diagonals, pintle, anchorage links, and zinc or epoxy filler. The remaining discussion pertaining to trial operation, testing, and

workmanship should, in general, apply to vertical-lift gates. (See Chapter 2.)

(2) Towers for vertical-lift gates should be checked for deflection during the trial operations of the gate to determine if the guide system is in vertical alignment. The vertical alignment should be such that the guide and bearing plates of the guide system remain fully effective without binding on the gate and without excessive deflection or distortion of any member.

5-2. Operating Machinery

a. General description. Two types of vertical-lift gates may be used. One type is a double-leaf gate that normally is lowered into the sill. One leaf is located upstream from the other, and may be used as an upper lock gate or as an emergency gate in conjunction with a normal miter gate. This type of gate is referred to herein as an "Emergency Gate." The other type of vertical-lift gate, a single-leaf gate, can be used at either end of a lock and is frequently used as a tide or hurricane gate along the sea coast. This type of gate is raised when not in use, permitting normal water traffic to pass underneath. This type of gate is referred to herein as a "Tide" or "Hurricane" gate. On both types of gates, the leaves are raised by a cable hoist with the machinery mounted on the lock walls.

(1) Emergency gate machinery. The emergency-type gates generally consist of two leaves, one upstream and one just downstream of the other. The downstream gate is equipped with wheels and is designed to be raised in flowing water. The upstream gate is designed to be raised only in a balanced pool or when the swell head is 1 ft or less. The gates are used when failure of the lock miter gate occurs or when it is necessary to pass ice or debris with the miter gates open and latched in the recess. When operating the gates, the upstream leaf must be raised in steps behind the downstream leaf. Operating procedures for this type of gate are shown in Plate B-39.

(a) The hoist machinery used to raise the emergency gates consists of a double grooved rope drum driven by two stages of open spur gearing, a herringbone or helical gear reducer, and an electric-drive motor with spring set, magnet release holding brake. The rope drum has several layers of rope. One rope from the double drum attaches to one end of the gate through a multipart reeving. The other rope from the drum crosses the lock through a tunnel in the gate sill and passes through a multipart reeving which is attached to the other end of the gate. (See Plates B-56 and B-57.)

(b) The hoist components are generally mounted on a structural steel frame which is anchored in various ways to the lock wall or a concrete structure. Each leaf is raised by its individual hoist mounted side by side on the lock wall. The hoist structure is of such height that the machinery will be above high water. A typical hoist arrangement is shown in Plate B-58.

(2) Tide gate or hurricane gate machinery. The machine used for raising this type of gate consists of a dual drum cable hoist mounted adjacent to one of the lifting towers. The two drums are driven by a pinion gear located between the two drums. A triple reduction enclosed gear unit drives the pinion. The gear unit is driven by a two-speed electric motor with a double ended shaft. A magnet-type electric brake is provided between the motor and reducer. The motor shaft extension permits the connection of a hydraulic "emergency" lowering mechanism. The low speed of the motor is used when starting and stopping the gate. The gate is normally lowered by means of the electric motor; however, in the event of a power failure, the gate may be lowered by means of the hydraulic mechanism.

(a) The emergency lowering mechanism consists of a radial piston-type hydraulic pump connected to the electric motor shaft extension, a flow control valve, oil cooler, check valve, and necessary piping, all connected and mounted on an oil storage reservoir. When lowering without electric power, the weight of the gate, acting through cables and reduction gearing, turns the hydraulic pump. Oil from the pump is circulated through a flow control valve creating a transfer of energy to the oil in the form of heat. Excess heat in the oil is removed by a tubular-type oil cooler.

(b) The two drums wind both ends of a continuous cable which lifts the gate through a series of sheaves, the number of which are selected to give the mechanical advantage desired. Two of the sheaves mounted on the gate serve as equalizing sheaves to equalize the line pull in event one drum winds slightly more cable than the other. Each drum is precision grooved so that each winds the same amount of cable on each layer. Where the fleet angles of the cable approaching the drum exceed 1.5 deg, a fleet angle compensator must be provided.

(c) The hoist machine should be located adjacent to the gate and in line with the hoisting sheaves. The hoist should be enclosed in a small protective building. A hydraulically operated dogging device should be provided to secure the gate in the raised position. A typical hoist arrangement is shown in Plate B-59.

b. Design considerations and criteria.

(1) Emergency gate machinery. The design of vertical-lift gate machinery should be determined by the combination of all loads applicable to the type and design of gate used. For two-leaf emergency gates, the upstream leaf or movable sill should be raised only under balanced head conditions or when lower pool is no more than 1 ft below the upper pool (the swell head when control of the river is lost). For design purposes a “swell head” of 1 ft should be used. Since horizontal force on this gate is light, gate rollers may not be required and the gate should be designed to slide against friction plates in the gate recesses.

(a) The downstream leaf will normally be raised in flowing water, thereby creating an additional horizontal and vertical force. The horizontal force usually will be great enough to require the use of reaction rollers on each end of the gate. Gate lifting speed for both leaves should be approximately 1 ft/min to 5 ft/min adjusted to suit the speed of the nearest standard speed motor.

(b) When this type of gate is used as an operating lock gate it would normally be operated under balanced head conditions and not through flowing water. Gate speed should be approximately 5 ft/min to 10 ft/min.

(2) Tide gate machinery. Criteria for the design of tide gate machinery are the same as those for the emergency gate machinery except that the gate must be capable of being raised or lowered against a differential head, plus against a force created by wind on the exposed section of the gate. In order to clear traffic passing under the gate, the gate must be raised a greater distance than either of the emergency-type gate leaves; therefore, the lifting speed should be approximately 5 ft/min to 10 ft/min or a speed sufficient to permit opening the gate in approximately 10 min. Wind load on the exposed section of the gate should be assumed to be 20 psf (for machinery design). (See Plate B-59.)

(3) Machinery components.

(a) General criteria. General criteria applicable to all types of operating machinery covered in this manual are presented in paragraph 1-11.

(b) Hoist motor selection. The required torque of the downstream vertical-lift gate hoist motor should be the root mean square value of torque vs. time curve for operation of the gate with the motor selected having a 1.15 service factor. The peak torque required should not exceed 125 percent of the rated full load motor torque. The normal hoist load for the downstream leaf will be the loads resulting from the required torque of the motor. The hoist motor should have torque characteristics conforming to Guide Specification CW-14615. A desirable feature to be considered is variable speed (AC or DC) hoist motors with a ramping function adjustable through the drive controllers.

(c) Hoist load division. The normal hoist load shall be considered as equally divided between the two drives of the hoist. For nonequalizing hoist arrangements, the loads resulting from the maximum torque of the motor will be divided between the two drives of the hoist by assuming that only one side of the gate is jammed. The load on the jammed side will be the loading resulting from the maximum torque of the motor minus the loads taken by the free side. Both drives of the hoist will be designed to withstand the jammed loads. For equalizing hoist arrangements the stalled torque of the motor will be considered as equally divided between the two drives of the hoist. For emergency-type gate machinery, force control switches may be used to limit the rope pull under stalled conditions and thus reduce the loads on the machinery components.

(d) Wire rope. Wire rope for these types of hoists should be 6 × 37, preformed, lang lay, independent wire rope core, 18-8 chrome-nickel corrosion-resisting steel. Wire rope shall be designed for a factor of safety of 5 based on normal load. A factor of safety of 3 should be provided for peak loads occurring during normal operation and a minimum factor of safety of 1.5 based on the maximum stalled rope load. Where multilayer hoist drum-winding is necessary, 6 × 30 Type G, lang lay, independent wire rope core, flattened strand wire rope should be used.

(e) Sheaves. Sheaves should be aluminum bronze bushed or antifriction bearing type as dictated by the conditions involved. Sheaves should be of standard dimensions with grooves clad with stainless steel. Published ratings of sheaves should be used in determining the factor of safety. The diameter of the sheaves may be as small as 24 times the rope diameter when used with 6 × 37 strand wire rope for an emergency-type gate. When used with a lock operating gate, sheave diameter should be 30 times the rope diameter.

(f) Gate wheels. Wheels for the underwater gates are a critical item and should be designed for the individual conditions encountered. A gate being raised with a considerable horizontal load caused by flowing water would have considerable deflection at ends. To avoid point contact of the wheels on the flat plate track caused by gate deflection, the wheels should be constructed with a crowned, hardened tread. A method for designing a wheel subject to gate deflection is shown in Plates B-90. This method was developed utilizing formulas from Roark and Young (1975). (The formulas in the fifth edition may also be used. However, the formulas for computing maximum compressive stress are in error.) Formulas give the maximum compressive stresses, which occur at the center of the surface of contact, but not the maximum shear stresses, which occur in the interiors of the compressed parts, nor the maximum tensile stress, which occurs at the boundary of the contact area and is normal thereto. Due to the flexure in the gate, it is difficult to determine accurately the distribution of load on the gate wheels; however, it is considered satisfactory to design the wheel tread for a maximum compressive stress of from 2.0 to 2.5 times the yield strength of the material involved based on the maximum wheel load from the gate. A slight misalignment of the track surfaces will prevent a wheel of the gate from bearing on the track for short distances of travel, causing an overload on some of the adjacent wheels. This condition should be taken into consideration when determining maximum wheel load. An option to the crowned wheel to compensate for gate deflection at the ends would be to use flat wheels with self-lubricating, self-aligning, spherical bushings. These are available in many bearing and lubricant combinations to suit a variety of applications. Self-lubricating, self-aligning, spherical bushings have been used successfully in nuclear offshore, industrial, structural, and dam applications.

(g) Hydraulic lowering brake. A vertical tide gate is normally lowered by an electric-drive motor on the hoist, with a diesel electric generator set standing by in the event of power failure. In some cases, it may be desirable to use a second standby means of lowering the gate. This can be done by coupling a hydraulic motor to the shaft extension of the electric-drive motor. This fluid motor is connected in an oil circuit which permits free flow of the oil in the raise position but restricts flow in the lowering position. A typical circuit required for this operation is shown in Figure 5-1. The flow control valve used in this circuit should be designed and adjusted in the field to limit the speed of the electric motor to about 140 percent of its synchronous speed in order not to damage its windings or rotor. The flow control valve and fluid motor shall be sized so that the pressure of the oil leaving the motor shall not exceed the normal working pressure rating of the fluid motor. When lowering the gate, approximately 10 min may be required and during this time braking energy will be transformed into heat in the oil as it passes through the flow control valve. A shell-and-tube-type heat exchanger must be provided in the circuit to prevent the temperature of the oil in the tank from exceeding 120 deg F. Since this system is used so seldom, cool clean potable water or raw water may be used in the heat exchanger then exhausted to drain. A thermostatically controlled valve may be used to automatically control the flow of water through the heat exchanger.

c. Determination of machinery loads.

(1) Since this type of gate is required to be closed in flowing water, considerable difficulty was originally encountered in the design of the crest for the downstream leaf. The original gate, in laboratory tests, was found to bounce violently during certain tailwater conditions. In order to obtain a gate which would perform satisfactorily, WES was requested to perform a series of tests on gate crests for this type of gate. Eight alternate gate designs were investigated, incorporating the following modifications: triangular-shaped crest with slope on downstream side; crests with the apex offset from upstream gate face by a horizontal or sloped surface; vented girders; crest skin plate; various girder locations; truss-type gates; and combinations of the preceding modifications.

(2) The design recommended for prototype construction is a triangular-crest with a IV on 3H sloping upstream offset and has the flanges of the gate girders turned downward. This design was found stable for all conditions investigated and required no aeration of the crest. Maximum downpull on the gate was about 220,000 lb and maximum uplift was about 50,000 lb. A curve showing uplift or downpull plotted against gate position above sill is shown in Plate B-89, Sheet 10. Loads taken from these curves should be used in the design of vertical-lift gate machinery where the gate is of similar proportions. The complete results of the above tests may be found in Report 2-527 (USAEWES l959).

(3) In designing the downstream leaf of a vertical-lift emergency gate hoist, the following loads should be considered and used to determine cable pull.

(a) The weight of the gate leaf, trash screens, and recess protection in air. There should be no buoyant effect since the normal tailwater is generally too low to keep the gate submerged when it is lifted a few feet.

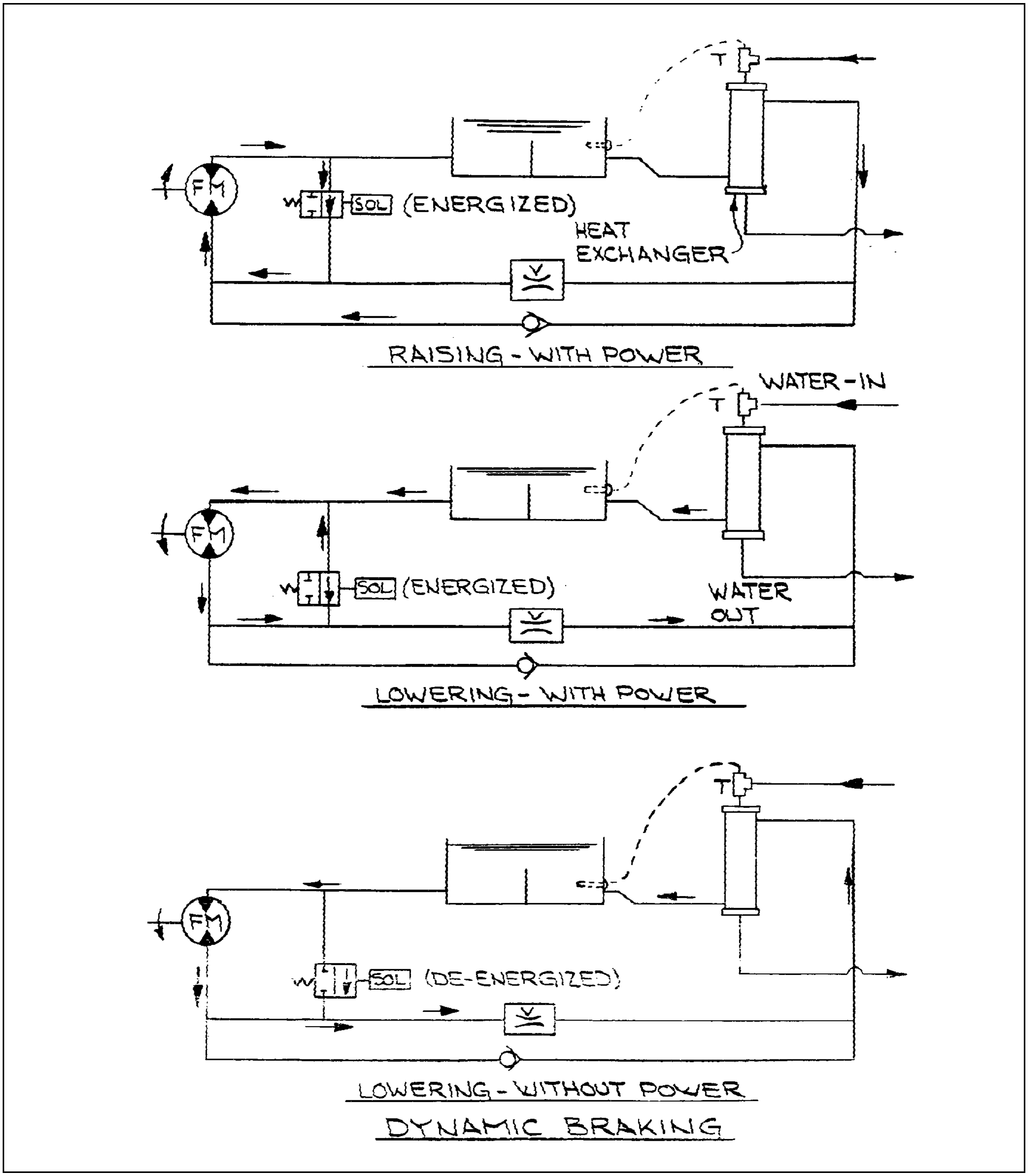

Figure 5-1. Typical circuit requirements for raising and lowering a vertical tide gate

(b) Silt at 125 pounds per cubic foot (pcf) which may be trapped above the web of the girders to the height of the downstream flange.

(c) Side seal friction. Load caused by sliding friction using coefficient of rubber on steel of 1.0.

(d) Roller friction. The total friction due to the gate reaction rollers running against steel tracks and the friction of the bearings in the reaction rollers shall be taken as 5 percent of the load normal to the gate leaf.

(e) Downward hydrodynamic force. This force on the gate nappe when the gate is raised through flowing water may be obtained from the curve showing results of studies by WES. (See curve in Plate B-89, Sheet 10.)

(4) The upstream leaf normally will not be equipped with reaction rollers or buoyancy tanks. It should be lifted only under balanced head conditions or when lower pool is 1 ft or less below upper pool (the swell head when control of the river is lost). The hoist design load will be the dead weight of the gate leaf in air, side seal preset force, weight of trash screens, weight of silt load (when raised to maintenance position), or the summation of the following, whichever is larger:

(a) Weight of gate leaf minus weight of water displaced.

(b) Silt load amount trapped by flanges less weight of water displaced.

(c) Sliding friction due to horizontal force caused by 1.0 ft swell head. The coefficient of friction for this condition should be assumed as 0.40 for steel on steel.

(d) Downward hydrostatic load due to 1.0-ft swell head.

(e) Weight of recess protection and trash screen minus weight of water displaced.

(f) Side seal friction based on a differential head of 1.0 ft plus preset force for approximately 3/4-in. deflection. The friction coefficient for rubber on steel is assumed to be 1.0.

(5) Typical calculations for determining loads for design of emergency gates are shown in Plate B-88 for the upstream leaf and in Plate B-89 for the downstream leaf.

(6) Loads used for design of vertical-tide gates are similar to the loads used for vertical-emergency gates except that the wind load is a more critical factor. The gate is hoisted high above the structure permitting barge traffic to pass underneath. This exposes the gate to a considerable wind load which must be included. To find the hoist capacity, the following two conditions should be considered and the condition creating the greater load should be used for design of the hoist.

(a) Condition I. Weight of gate leaf in water consisting of the skin plate, framing, sheaves and brackets, wheels, etc., and the weight of silt (125 pcf) trapped by the flanges of the gate girders less the weight of water displaced. Rolling friction of 5 percent of the horizontal load on the gate caused by the largest combination of differential head when the gate is lowered into position plus the wind load, at 20 psf, for the exposed portion of the gate.

(b) Condition II. Weight of the gate leaf in air consisting of the skin plate, framing, sheaves and brackets, wheels, etc., and the weight of silt (125 pcf) trapped by the flanges of the gate girders. Rolling friction of 5 percent of the horizontal load on the gate caused by the wind load, at 20 psf, for the exposed surface of the gate.

d. Operating machinery control. Control stations for vertical-lift gates are usually located adjacent to the gate along with the hoist machinery. The control equipment consists of the combination of full voltage magnetic controllers, limit switches, and control switches arranged to produce the desired operating sequence. The limit switches used in previous designs were usually of the traveling-nut type in the National Electric Manufacturers Association's four enclosures. Due to the unavailability of traveling-nut limit switches, cam-operated switches are being used. Slack cable limit switches and skew control and indication should be used on vertical-lift gates to prevent them from becoming stuck. Gate leaf control can be performed as indicated on the typical electrical schematic diagram for an emergency gate hoist (Plate B-73) or by using electronic devices such as position encoders, and position and speed tachometers.