Chapter 5
Layout and Design

5-1. General

This chapter provides guidance for the layout and design of navigation locks. Guidance and details are provided on the following features: lock dimensions, filling and emptying systems, lock walls, approach walls, miscellaneous walls, gate types and locations, lock operating systems, lock sills, lock wall operating requirements, lock closure, galleries and cable trenches, lock wall accessories, tow haulage unit and movable kevel, and ice and debris control.

5-2. Lock Dimensions

The overall layout of a lock and the dimensions of the lock chamber are determined by making a thorough study of all controlling factors (see paragraph 3-3) before a final decision is made. The determination of elevations for the top of all lock walls, elevations for service and closure gate sills, and the elevation for the floor of the lock chamber is extremely important, since sufficient clearances are required for efficient and economical construction and operational conditions to accommodate present and future situations.

a. Width and length. Adoption of specific barge sizes by the towing industry operators over the past years has led to the standardization of lock chamber widths at either 84 or 110 ft for most new projects, unless some overriding factors exist. The standard widths and lengths for locks are discussed in more detail in paragraph 3-3*c*. The layout of the usable width and length of a lock chamber is governed primarily by the width of barges and the length of tows, both existing and envisioned. Usually, an additional allowance of 3 to 5 ft is added to the assembled barge widths to enable tows to enter the lock chamber without damaging the barges and to avoid undue scraping on the walls. These allowances are reflected in the most commonly used lock widths of 56, 84, and 110 ft which were established to accommodate the tow widths composed of two or more of the common barge widths of 26, 35, and 48 ft. An allowance of 30 to 50 ft in length is also made to ensure that tows entering the chamber will not damage the service gates. This allowance, plus a tow length of 1,170 ft (six 195-ft barges), and space for a miter gate recess results in distance of 1,275 ft between pintles for a nominal 1,200-ft lock. The usable length is measured from the downstream side of the upper miter sill to the upstream point of the lower gate when it is in the recessed position. No lock feature should impinge on this space since it is for the exclusive use of waterway traffic.

b. Wall elevation. The top elevation for lock walls depends upon the characteristics of the waterway and the type of dam selected, as well as the type of lock structure. Also, to be considered are such factors as the balance between initial construction and maintenance cost and uninterrupted transportation during high stages, and other conditions peculiar to any given location.

(1) Nonnavigable dams. On important waterways with nonnavigable dams, locks should be designed so that they will be usable at all times except during large floods. The lock walls should be at least 7 ft above normal pool to properly guide high-riding empty barges along walls and thus prevent items atop the walls from being subjected to damage by an overhanging barge. The tops of the walls should be at least 2 ft above the maximum pool at which navigation is to be maintained. For important waterways where currents, floating debris, or other navigation hazards do not force suspension of river commerce at high stages, serious consideration should be given to providing lock walls of sufficient height to accomodate traffic in all but the most infrequent floods. Unless the walls are extended above high stages, the operation equipment for the movable structures will be submerged, or it will be necessary to remove the parts that are subject to water and debris damage each time the walls are likely to be overtopped. In addition to the cost and inconvenience of removing such equipment, a major cleanup job must be completed after the water has subsided, and there is always the chance of making the change too soon or too late, resulting in navigation delays or damage to machinery. It is usually wise to extend the lock walls above all stages that the economics of the project will allow.

(2) Navigable pass dams. When the characteristics of the river are such that a navigable pass dam can be incorporated, considerable savings in the initial cost of construction can be realized by using low lock walls with an operating system suitable for frequent lock submergence. Freeboard between the top of the lock wall and cessation of navigation through the lock should be 2 ft as previously discussed. In order to take advantage of this type of construction, the river must be navigable for considerable periods without the use of controlled pools, and the time intervals available for changeover from open river to controlled pool navigation or vice versa must be sufficient to allow for raising or lowering the dam. Planning of navigable dams is discussed in EM 1110-2-1605.

c. Lock sills. Lock sills are those elements of a lock forming the fixed portion of the damming surface under the service gates or temporary closures. The elevation of sill tops in relation to the water surfaces of the upper and lower pools dictates the draft of vessels which can use the lock. The effective depth of the lock (SD) is measured from the top of the sill to the water surface of the respective pool to which it connects as shown in Figure 5-1. This measurement allows for the "squat" which always occurs when a tow occupying a large proportion of the lock chamber cross section passes over a sill, even at very low speeds. Additional depth over the lower sill should be considered if there is any probability that the tailwater will have to be lowered because of changed downstream conditions. EM 1110-2-1604 provides specific guidance on sill depth.

(1) Elevation. Experience and research data indicate that the gate sill depths should be as great as practical to lessen tow entry and exit times and to lessen chamber surges during these maneuvers. A 2- or 3-ft-high gate sill (above chamber floor) or a local recess will provide space for the gate operation to clear debris. The lock floor areas immediately upstream and downstream of the gate sill should be paved so that maintenance crews and equipment can be readily accommodated during lock unwatering activities. For a lock with a gated navigable dam, determining the upper lock gate sill elevation requires simultaneous study of the navigable pass sill. The lock sill level must allow passage of tows during the time of change over from open river navigation to controlled pool operation. Therefore, the upper gate sill elevation should be slightly lower than the accompanying navigable pass sill level. If site conditions warrant, it may be advantageous to provide the same sill elevation upstream and downstream, since this arrangement permits the miter gates to be interchanged.

(2) Gate sills. In some cases, the sill is required to resist a portion of the gate load; however, this requirement is restricted to vertically framed miter gates, to wide tainter gates which have intermediate trunnion supports, and to rolling gates. All sills must resist the forces which consist of both earth and hydrostatic pressure extending from the bottom of the gates to the sill foundation. For U-frame locks, where the walls and sill are of integral construction, the sill is proportioned to distribute the wall lateral pressures. In some cases, the gate sill concrete can be used to form intake ports for culvert filling and emptying systems. Crossover galleries, containing the various utilities for the lock, are frequently included in the gate sill.

d. Lock floor. Depth in a lock chamber is governed by the depth of the sills and by requirements for the filling system cushion depth. For operation and maintenance purposes, the lock floor should have a recess for the operating gate to clear debris or be 2 or 3 ft lower than the lock sill. Figure 5-1 indicates the sill-floor relationship. The design must allow for proper clearance for any gate stops that are provided below the body of the gate. The chamber depth must be great enough to satisfy filling system design submergence requirements. The multiport system layout requires trenches in the floor adjacent to the lock walls. EM 1110-2-1604 provides specific guidance on this topic.

(1) Paved lock floor. The need for a a concrete lock floor is determined by the type of natural foundation involved and its resistance to soil-carrying seepage. Paved lock floors are usually subjected to downward pressures when the water in the lock is at an upper pool elevation and to upward pressures when the water is at lower pool elevation or during the unwatered period. The downward pressures cause no difficulty; but unless pressure-relief devices are installed, the floor must be designed to withstand uplift which is caused by the difference between saturation levels in the soil and the water level in the lock. This problem can be solved by using concrete block paving placed on a sand and gravel filter directly on the natural formation. The concrete blocks should be provided with weep holes and should be separated from each other by open joints. These blocks should not be integral with the lock walls. If anticipated drainage conditions warrant the expenditure, parallel trenches filled with filter stone, open-end tile pipe, or perforated drainpipe extending the length of the lock chamber and discharging below the lower sill can be used. Filter drains are subject to clogging by fine-grained material. However, if a properly graded filter material is used, and if the river water is not silt laden, it is unlikely that the outlets will become inoperative.

(2) Other methods of lock-floor construction. To avoid thick concrete sections these methods include piles designed to resist tension, rock anchors, reinforced concrete floors, or paving on a sufficient depth of graded gravel and sand. Where sliding resistance is poor, reinforced concrete struts can be used to prevent horizontal movement of lock walls caused by lateral pressures. The monolith joints of the opposing walls should be at the same location so that the struts abut each opposing monolith. Provisions for short second placement concrete are usually made at each strut to compensate for shrinkage and thereby assure intimate strut contact to each wall. In

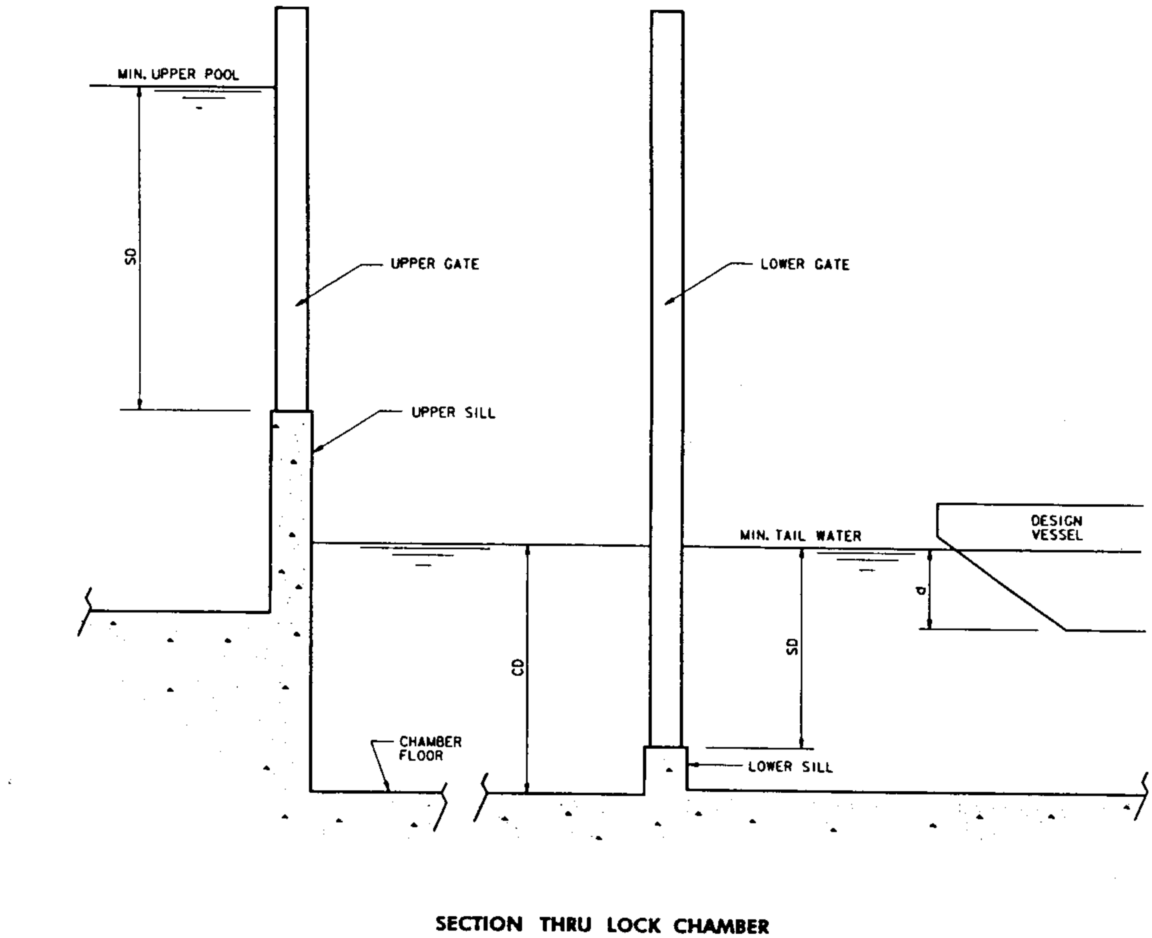

Figure 5-1. Definition sketch for lock sills

addition to being designed to resist the unbalanced horizontal force, the struts can also be designed with anchors or piling to resist uplift pressures especially during lock unwatering and other applicable stability design cases. Layout of the struts should be coordinated with the filling and emptying system layout in the lock chamber, particularly in instances of use of the bottom longitudinal and bottom lateral system. The joints in the continuous strut floor system must be water-stopped or other provisions made to take care of seepage. Struts are also provided between sheet pile walls where the foundation does not have sufficient passive resistance.

e. Approach wall. The top elevation of the upstream approach wall and upstream guard wall should be identical to the top elevation of the upper gate bay walls, even when the lock chamber walls are lower than the upper gate bay walls. Setting these upper walls at this elevation enables navigation traffic vessels to tie up to the wall at all times and offers additional safety by ensuring that the wall is visible at all reservoir pool levels. Also, the flow of water over the wall might have some undesirable consequences. The top elevation of the lower approach wall and lower guard wall should be set at least 2 ft above the maximum lower pool level or at the same elevation as the lock chamber walls if the project is subject to overtopping by flood waters. More information on these walls is contained in paragraph 5-5. Plates 21 through 26 depict typical layouts for approach walls.

5-3. Filling and Emptying Systems

When designing a lock, one of the first issues to consider is the type filling and emptying system to be used and the filling system cushion depth. The types of service gates, sills, walls, floors, and approaches often hinge on this decision. The filling and emptying system types that have been used in the lock chamber for previous lock projects include wall ports, laterals, bottom longitudinals, and multiple wall ports. Examples of these various types of filling and emptying systems are shown on Plates 30 through 33. Filling and emptying has been accomplished on some very low lifts by use of the following: sector gates, shutters in lock gates, and longitudinal flumes adjacent to the lock chamber with either vertical slide gates located in or adjacent to the gate bay monoliths. The filling and emptying system having the maximum effect on the structural design and layout of locks is one with culverts in the lock walls. Many types of valves have been used including vertical lift gates, butterfly valves, cylinder valves, and tainter valves, both direct and reversed. Plate 34 shows a layout of a reversed tainter valve. All recently built locks with wall culverts have used the reversed tainter valve. In the interest of economical construction and steel fabrication, all tainter valves for a lock should be identical and should be located in the lock walls close to the gate bay monoliths where the tops of the walls are wide. Valve pits should extend from the tops of the lock walls down to the culverts, thereby allowing the completely fabricated valve to be lowered through these pits for installation or removal. The filling and emptying control valves are critical components, and an outage can cause delay or disruption of barge traffic or even shutdown of the lock. Since the lower portion of the valve skin plate is subjected to negative pressure which could destroy protective coatings and cause cavitation damage, it should be made of corrosion-resistant steel. Cathodic protection of the sacrificial anode type should be provided. The shape of the valve body is extremely important and the latest recommended shape can be obtained from the Waterways Experiment Station. Reference is also made to EM 1110-2-1610 for layout and design details.

a. Design requirements. In the design of modern lock filling and emptying systems, the following conditions must be met:

(1) Filling and emptying operations should be performed as rapidly as possible without sacrificing safety, or incurring excessiveness costs.

(2) Disturbances caused by the flow of water during the operation should not endanger any craft that may be in the lock chamber or in its approaches. Localized turbulence can be generated by jets of water which the filling and emptying systems introduce into the lock chamber or lower approach. This disturbance may cause considerable damage to the individual components of a tow or smaller craft. An oscillatory, longitudinal surge can occur in the lock chamber during operation of the filling or emptying system. This disturbance is more serious since the possibilities of damaging both craft and structure are greater. To avoid damage to vessels and structures, it may be necessary to reduce the filling or emptying rate far below the design capacity. Because surging tends to cause a vessel to drift from one end of the lock chamber to the other, the vessel must be restrained by hawsers (lines) to keep it from striking the gates or damaging other parts of the structure. Vessel operators are responsible for providing the hawsers required to restrain their craft. The stress in the hawsers is essentially a function of the gross tonnage of the tow and the slope of the water surface in the lock. The frictional forces exerted upon the craft by flow in the chamber have only minor effects on the stress. To prevent the high hawser stresses caused by

surges, newer locks have incorporated an automatic control system for valve operation which prevents overfill and overempty of the lock chamber.

b. Features of commonly used systems. Detailed model studies of the filling and emptying systems most commonly used have been made by the Waterways Experiment Station. (Proposed systems that have not been model tested should be evaluated to ensure that design expectations can be met.) The studies plus followup prototype experience showed that the main features of a filling and emptying system must be constructed to very close tolerances. Those features requiring careful detailing and layout are the culvert intake manifolds, the culvert proper, the discharge manifolds, the chamber ports at the lock face or the structures in the lock chamber, the filling and emptying valves, and the bulkhead recesses just upstream and downstream of the valves. The following heights are applicable to the "lifts" mentioned in the following paragraphs: low lift under 30 ft, intermediate lift from 30 to 50 ft, and high lift over 50 ft.

(1) The most common system is the wall ports system. It consists essentially of a longitudinal culvert of constant size in each wall, each with suitable intakes from upper pool, a filling valve, a series of chamber ports, an emptying valve, and a discharge manifold into the lower pool. Chamber ports are usually rectangular in shape, spaced at intervals which are staggered in the two walls; however, several locks have been constructed using a multiple system of small circular ports arranged in two or three horizontal rows. For steel sheet pile locks or others having concrete gravity walls limited to the gate bays, a system of short loop culverts may be used. Two filling culverts extend from the upper pool around the upper gates into the lock chamber. A similar pair of culverts extend from the lock chamber around the lower gates and discharge into the lower pool. Other systems include filling around partially opened upper lock gates (when sector type service gates are used), or filling over or under the upper gates when tainter or vertical lift service gates are used.

(2) In the bottom lateral systems for high-lift locks, the simple wall ports used in low or intermediate lifts are replaced by laterals extending across the lock chamber below floor level. The flow is discharged into the lock chamber through a number of ports in each lateral. In early lock design which used the bottom lateral system, the individual ports were in the roof of each lateral. This design works satisfactorily with a deepwater cushion but may not be suitable for the shallower cushion available in barge locks. More effective energy dissipation can be obtained by locating the ports in the sides of each lateral, so that adjacent laterals will discharge into the common trench or box between them. If ports in adjacent laterals are staggered, an even better stilling action will result. The width of each lateral should decrease from its culvert connection to the opposite wall to produce a uniform flow through all ports. Two types of lateral systems have been used: the intermeshed type and the split type. In the intermeshed type, laterals from one culvert alternate with the laterals from the opposite culvert. The entire system is contained in about the middle third of the chamber and produces excellent results if the tow is placed symmetrically over the laterals. However, unsymmetrically placed tows will experience much higher hawser stresses during filling operations. The higher stress can be overcome by the split lateral system in which one culvert feeds a set of laterals in the upstream half of the lock chamber, while the second culvert feeds a similar set of laterals in the downstream half. Since each set of laterals receives the same amount of water, longitudinal currents in the lock chamber are held to a minimum, and hawser stresses will be almost identical regardless of the location of the tow. However, this split lateral system cannot be operated safely with one valve unless the filling and emptying time is greatly increased. A third type of bottom filling system, the bottom longitudinal system, has been developed and refined in the past 25 years. It uses longitudinals in the lock floor connected to the wall culvert. This system is the most sophisticated system developed to date for high-lift locks. This system is expensive for it requires a highly configured concrete structure in the lock chamber. In addition, its use could possibly cause lowering of the culvert monoliths to obtain the proper water depth over these chamber structures.

c. Intake manifolds. Culvert intake manifolds are usually located in the face of the lock wall just upstream of the upper sill. However, depending on individual situations, the intake may be on the other side of the lock, or in the upper sill, or taking water from both sides of the wall, or located away from the walls (in some rare cases). The ports at the face of the lock wall are of uniform shape and size. The area of the intake at the face of the lock wall should be considerably larger than the culvert area to reduce velocities and entrance head losses. This larger area also prevents damage to trash racks from impact of floating drift or ice, minimizes vortex formation, and lessens the tendency to draw air into the system. For structural reasons, several smaller intakes are preferable to one or two large ones. Intakes should be submerged below minimum pool a distance not less than the velocity head at the face of the wall to avoid vortices.

Since each successive port in the downstream direction is subject to increased pressure differential, each throat is made smaller to obtain approximately equal flow. The culvert converges between successive ports but expands abruptly immediately downstream from each port. This sudden expansion increases the pressure in the culvert to match the inflow from each succeeding port at its point of confluence and thus reduces impact losses.

d. Longitudinal culverts. These culverts usually measure the same size from the intake manifold end to the beginning of the discharge manifolds, and the valves usually have the same rectangular dimensions. However, in some designs, the valves and culverts may be different sizes, and the culverts may expand in height between the filling and emptying valves to obtain certain filling characteristics. The layout of the culverts in the lock wall should allow sufficient concrete thickness between the culvert and the lock face and between the bottom of the culvert and the foundation in order to satisfy all loading situations. The roof of the culvert should be at least 3 ft below minimum tailwater elevation to prevent air entrapment.

e. Discharge system. This system should be designed to achieve an efficient emptying operation and distribute the outflow from the lock at locations and velocities which will not imperil any craft in the immediate lock approach area. The system may be located either in the lock walls, as laterals in the lock approach floor, or at a location away from the lock appproch. Whenever practicable, the best type of discharge is one which diverts the entire flow outside of the lock approach. For such a layout, alternate designs could include crossover culverts with stilling basin and exterior side ports systems where sediment is a problem. Use of exterior discharge allows the planner to shorten the lock but requires a lengthening of the short approach walls and sediment collection problems may result. For this type of layout, each culvert discharge should be provided with a stilling basin to prevent high velocities from extending all the way across the lower pool and producing reflected eddy currents in the lower approach. If this type of emptying system results in a head differential between the lock chamber after emptying and the lower approach, the design of the lower gates and operating machinery may be affected. In extreme cases, it may be necessary to provide an auxiliary emptying valve to equalize the residual head differential.

f. Lock chamber wall ports. Side wall ports in the lock chamber are rectangular, usually venturi-shaped, with the larger area at the chamber face. They should have a rounded entrance at the culvert to increase efficiency in filling and a smaller radius at the wall face to improve entrance conditions during lock emptying. Dissipation of energy during filling is improved by staggering the ports in the two walls, so that the jets issuing from one wall pass between those from the opposite wall. Thus, the jets travel twice as far horizontally and are more diffused when deflected upward by the opposite wall. Spacing of ports on 28-ft centers in each wall of a 110-ft-wide lock will allow the jets to pass one another with only slight intermixing at their boundaries. Somewhat closer spacing may be used on narrower locks. Ports should be inclined downwards slightly for best results. With the 28-ft spacing, ports should be located approximately at the middle half of the lock chamber, symmetrically between the gates. Total area of ports at their smallest section should be about 0.95 times the culvert area. To avoid reverse flow from the chamber into the culvert, the hydraulic gradient in the culvert at the upstream port should be higher than the water level in the lock chamber. Placement of deflectors in front of the first few upstream ports helps to reduce surges in the lock chambers.

g. Lock chamber laterals. High-lift locks are usually equipped with floor laterals rather than wall ports. The two types of lateral systems that have been used are the intermeshed type and the split type (see Plates 6 and 31). Each lateral has pairs of rectangular ports discharging horizontally to either side of the lateral. Pairs are spaced about 12 to 14 ft apart on centers along the lateral. Ports in adjacent laterals are staggered to force their discharges to pass one another. The cross-sectional area of each lateral narrows from where it begins at the culvert to where it ends at the opposite lock wall to provide a uniform flow distribution. This narrowing occurs through a standard height and a width which either tapers steadily or narrows in successive steps between ports. A height to width ratio for ports of about two is recommended, and their length, exclusive of radii, should be no less than three times their width. If the lateral wall is not thick enough to obtain this length, port extensions should be provided. The clear space between each lateral, available for diffusion of discharges from the ports, should be no less than five times the port width. Intermeshed laterals should be located in the middle third of the lock chamber. In a split-lateral layout, each group of laterals should be located in the middle third of its respective half of the chamber. Lateral filling systems permit the lock chamber to fill more rapidly than wall ports. In all bottom lateral systems, the operation of the filling valves in each culvert must be synchronized to ensure equal discharges through each set of laterals. Unequal discharges will increase longitudinal surges in the lock chamber and produce higher hawser stresses.

h. Bottom longitudinals. Bottom longitudinal filling and emptying systems were developed to overcome the weakness of bottom lateral systems to nonsynchronous operation of the culvert filling valves. These systems are designed to admit water simultaneously through a number of ports, all of which are equidistant from the center of the lock in travel time. For this operation, the main culverts are directed to the center of the lock and through large laterals to two or more longitudinals, running upstream and downstream in the floor of the lock over most of its length. These longitudinals are equipped with pairs of side ports which are similar to those found in the bottom lateral system. The ports are arranged in a symmetrical pattern to obtain an even flow distribution throughout the chamber. Millers Ferry Lock on the Alabama River was one of the first projects in the country to incorporate bottom longitudinals. An improved system for a lock with a lift of 100 ft was developed for the Lower Granite Lock on the Snake River. In this project, the main culverts were increased in area by about 50 percent to improve pressures below the valves. One of the more recent projects which uses the bottom longitudinal system is the Bay Springs Lock on the Tennessee-Tombigbee Waterway. To maintain a constant velocity, the distributing laterals and longitudinal subculverts are sized in proportion to their discharge. Area of ports in each longitudinal is about 0.85 times that of the subculvert, and total area of ports is about 1.2 times the culvert area at the filling valves. The bottom longitudinal system has an important advantage in that the main lateral at the center of the lock is connected to both main culverts; thus the lock can be filled or emptied through one main culvert (assuming the other is inoperative due to culvert valve repair or other cause) while maintaining a balanced filling or emptying operation. Also, with both main culverts in use, the chamber can be filled more quickly without exceeding allowable hawser stresses.

i. Multiple wall ports. This system consists of a large number of small circular ports, 8 to 10 in. in diameter, at about 3 ft on centers, arranged in two or three horizontal rows. From 200 to 300 ports are used in each culvert, depending on the chamber size. They discharge below the lock chamber floor level into a longitudinal trench about 3 ft wide and 6 to 8 ft deep. Each port flares at both ends, and slopes down toward the trench at an angle of about 15 deg. Total area of ports for each culvert is about 0.95 times the culvert area at the filling and emptying valves. The ports are distributed over somewhat more than the middle half of the chamber. Culverts are generally enlarged throughout the port area by some 25 to 30 percent either by raising the culvert ceiling or by widening it. Model tests conducted by the Tennessee Valley Authority (TVA) on this type of system emphasized the utmost importance of forming a tight seal between the filling valves and the upstream ports to prevent entrance of air into the system. This type of filling system is suitable for use in a site where the lock wall foundations are considerably lower than the lock chamber floor. The trench can be either excavated in the rock or formed by concrete retaining walls. The TVA was successful in using this system on several locks on the Tennessee River with lifts up to 60 ft. It was also used on the Corps of Engineers Cordell Hull Lock on the Cumberland River as well. The major disadvantage of this system is that the culverts cannot be accessed from the lock floor.

j. Culvert valve layout. The reversed tainter type culvert valve (sometimes referred to as a segmental valve) has been used in most of the locks recently built in the United States, although vertical lift (stoney) valves, butterfly valves, and cylinder valves have been used in the past. Until the advent of high-lift locks, tainter valves were installed with the skin plate positioned upstream and the arms in compression. As the head increases, the pressure gradient just downstream of the valve drops below the top of the culvert and thus allows large volumes of air to be drawn into the system. The explosive release of air into the lock chamber during lock filling caused hazardous disturbances to small craft and decreased the efficiency of the system. The pressure below the valve was increased, and the air problem at the valve pit was eliminated by reversing the valve, so that the skin plate was downstream and the arms were in tension. This arrangement also converts the valve pit into a surge chamber, which relieves waterhammer stresses on the valve that might otherwise occur during a sudden closing due to structural or mechanical failure. A more detailed discussion of lock tainter valves is contained in EM 1110-2-1610. A short discussion on valves in other types of filling systems also appears in the same referenced work.

k. Culvert bulkhead recesses. Culvert bulkhead recesses are provided upstream and downstream from culvert valves to allow bulkheads to be lowered into place to close off the individual valve chamber to conduct valve repair. A lock of double culverts can function even when one culvert is closed since the lock can be filled and emptied through the other culvert at a reduced rate of speed. When the height of the walls is sufficient, hangers for storing the steel bulkheads in the recesses are often provided near the top of the walls for quick and easy access in case of valve problems. These culvert bulkheads are not designed to be lowered in flowing water. When only a slight amount of submergence can be obtained, the control valves and downstream bulkhead recesses are sealed. This type of system is provided through use of the reverse-type tainter valve which seals on the downstream face of the valve recess. Air is prevented from entering the culvert through the downstream bulkhead recesses through a removable water-seal diaphragm a few feet below the lower pool level. With such an arrangement, a passageway from the valve pit leading into the lower bulkhead recess keeps this recess to upper pool level to maintain a water load on the diaphragm at all times. A valve in the sealing diaphragm can be operated above upper pool to allow drainage of the recess to lower pool level and removal of the diaphragm when the bulkheads must be inserted.

5-4. Lock Walls

a. Chamber walls. The top widths of concrete land walls for lock chambers are usually 6 to 10 ft. In addition, the top widths of both the land and river walls may have to be sized to allow passage of a mobile rubber-tired crane or other utility vehicle. Other shape requirements are governed by galleries, conduits, and openings required for operating facilities and accessories, as well as by the general stability requirements for all loading conditions.

(1) Land walls are subject to horizontal loads from fill on the back of the wall. This fill may extend to the top of the wall on low or moderate lift locks, or it may end some distance below the top of the wall at high-lift locks.

(2) When the discharge through the dam is adjacent and parallel to the river wall, the river faces of the walls are often constructed to provide smooth flow conditions. If the riverbed is composed of erodible material, special construction will be required at the foundation level or at the river face of the wall to prevent undermining of the wall. Also, riprap and graded stone should be placed along the lock wall. The predominant load that river walls are subjected to are hydrostatic loads. The hydrostatic load combinations are due either to upper pool level in the lock chamber and lower pool level below the dam or to water outside the lock with the chamber unwatered for repairs or inspection. The hydrostatic forces involved in the river wall design will vary with respect to whether the section is above or below the dam, with the latter situation usually requiring the least volume of concrete in the wall. For economic reasons, therefore, the lock chamber should be located downstream of the dam unless some overriding factor exists.

(3) An intermediate wall for the lock chamber is required for dual, side-by-side lock construction or where provision is made for the installation of a second lock at a later date. The width of the top surface of the wall is determined by the width of the bottom of the wall. The two wall faces that form the sides of the two locks cannot be offset to obtain a narrower top width in the lock chamber, because the tows must rub against continuous straight surfaces as they pass through the lock. Smooth vertical surfaces are also needed for mooring during lockage. The volume of concrete can be minimized by leaving an earth-filled space in the center of the upper part of the wall. An alternative approach would be to leave a void in the middle of the structure, rather than inserting fill, to reduce the amount of concrete used and the load on the foundation. Also, the structure must be designed to prevent leakage from either of the lock chambers entering the other when the pools are not equalized. This type of structure can be accomplished by using waterstops in the monolith joints, by placing a steel sheet pile cutoff wall along the full length of the base of the walls when the foundation consists of pervious material, or by grouting the foundation when rock is the supporting medium.

b. Upper and lower gate bay walls. The top width of gate bay walls should be sufficient to house the operating mechanism, provide space for the gate anchorages, and enclose the valves. It should also allow the gates to be recessed flush with the faces of the walls (for miter and sector gates) and provide a sufficient thickness of concrete between the culverts and the gate recesses. These portions of the wall must resist the concentrated gate loads in addition to the lateral earth pressure or hydrostatic loads as do the lock chambers. The length of monolith must be adequate to safely distribute the gate loads. Also, the gate operating machinery is usually supported on the same monolith containing the miter gate support (pintle and top anchorage) to prevent any misalignment or relative movement between gate and machinery.

(1) Loaded miter and sector gates cause overturning moments in two directions on the lock walls. These loads must be accounted for in computing wall stability. Gate bay monoliths should be analyzed as three-dimensional units for stability and internal stresses with all forces calculated in both the transverse and longitudinal directions, and the resultant located with respect to the kern area of the base.

(2) Other types of gates transfer their loads parallel to the lock face; therefore maintaining wall stability is not as critical. However, the length and stability of such a monolith must still be carefully analyzed. The design of the downstream gate bay monoliths for high-lift locks requires two monoliths with monolith joints that are properly grouted to allow the two to act as a unit to satisfy stability requirements. If thin reinforced concrete sections are used, the walls should be analyzed for effects of twisting caused by the eccentric gate thrust. However, in gravity walls this type of load can usually be absorbed by the concrete in the supporting monolith.

(3) Loads from vertically framed miter gates have less effect on lock wall stability than do loads from horizontally framed gates, because the vertically framed type transmits a considerable portion of its load to the miter sill while the horizontally framed type does not. However, the loads from these two gate types cause about the same overturning effect on the wall. The sill for the vertically framed gate must be designed to withstand part of the water load. The miter gate operating strut load has a negligible effect on the overall wall stability. However, local stresses are high at the anchorages for the struts. Strut loads of significant magnitude are caused by the resistance offered by the water to opening or closing the gate leaf.

c. Bulkhead monoliths. Bulkheads should be provided to unwater the lock chamber and gate bays. Providing bulkhead slots is recommended to ensure that individual lock gate bay monoliths can be unwatered. These bulkheads, slots, and sills can be placed either in the gate monoliths or in separate monoliths. In either case, these wall and sill monoliths should be analyzed for stability for the full unwatered condition.

d. Culvert valve monoliths. Valve pit design must consider the maximum differential hydrostatic loadings that can occur between the valve pit and the lock chamber under all possible operating conditions. Valve pit walls are often subject to combined axial tension and bending which increases steel reinforcing requirements and cracking potential.

e. Culvert intake and discharge monoliths.

(1) Intake walls which extend immediately upstream beyond the upper gate bays provide space for intake ports leading to the culverts. These wall extensions are often made with wide top surfaces for three reasons: (a) to support bulkhead handling machinery when temporary closure structures are used; (b) to provide bulkhead recesses, crossovers, risers, and gage wells; and (c) to leave space for other incidental equipment. These walls are usually as high as the lock walls. The bulkhead slots may be located upstream or downstream of the culvert intakes. For low-head lock projects, particularly canal locks, the upstream location is more adaptable. For higher head locks, the bulkhead is usually located downstream of the intakes, primarily because combining the bulkhead sill with the upper service gate sill is more economical. Unwatering of the intakes is not a critical function, since the only items needing maintenance are the intake trash racks. Special provisions for easy removal of the trash racks should be incorporated in the design.

(2) Discharge walls are located immediately downstream of the lower gate bay monoliths and extend far enough to allow the emptying culverts to exit the lock walls. The tops of discharge walls may be lower than the chamber walls, and they are usually at the same level as the adjacent lower approach walls. Maximum navigable tailwater governs the top level of these walls. Many different layouts and configurations are designed to diffuse and dampen the velocity of the water while the lock is being emptied. Model studies are usually conducted to determine how to accomplish this diffusing and dampening.

5-5. Approach Walls

Providing approach walls at each end of a lock facilitates lockages by reducing hazards and increasing the ease of the entrances and departures of tows. Because of the high cost of these features, the requirements for each project should be studied to ensure an economical solution. Plates 21 and 22 indicate the location of approach walls with respect to a lock. Loads that such walls may be expected to withstand are covered in Chapter 8.

a. Location. Historically, longer approach walls have been located on the landward side of a lock. This location facilitates operation close to the riverbanks when adverse currents make navigation difficult. This arrangement also confines lock operation activities to the landward wall which usually is more convenient. However, the location of approach wall must also account for other factors. For example, if the draw of water toward the dam on the upstream side causes crosscurrents in approaches, or if there is a slow upstream eddy in the lower approach, then it may be advisable to locate the longer approach walls on the riverward side. Additional concerns affecting location include prevailing winds, which may add to the tendency of the tow to move toward the dam, or the provision of tow haulage equipment. To determine the best arrangement of approach walls, model studies should be conducted covering a range of upper pool conditions coupled with a variety of spillway discharges. In some previous projects, model studies have shown the need for an upper approach wall that is longer than the lock chamber because of excessive draw caused by spillway discharges. Also, the same model studies have shown that rock dikes, which extend from the lower approach wall at an angle, are necessary to control adverse currents caused by spillway discharges. Unless site conditions dictate otherwise, locks should have the longer upstream and downstream approach walls on the same side of the lock. This rule applies particularly to walls containing tow haulage units and movable kevels, since with these two items the tow lockage can be continuous on the same wall. In canals, it may be advisable to locate the longer wall on the side toward which the prevailing wind blows. At locks used principally by ships, it may be desirable to locate the longer walls to port since most ships berth easier on the port side. If no valid navigational reasons exist for selecting one side over the other, the longer walls should be located on the side most convenient for lock operation.

b. Length. A general rule for the longer approach walls is that their length should equal the usable length of the lock chamber unless conditions dictate a longer wall. For example, if a majority of tows are longer than the chamber, then provisions should be made for a longer wall. In locations where the nature of the boats or the rockiness of the banks makes it impossible for tows or ships to nose safely into the natural banks during emergencies, the walls may need to be lengthened to provide mooring space for more than one ship or tow at a time. In these instances, consideration should be given to using mooring piers or sheet pile cells rather than longer walls. If an approach is located in an area that is protected from wind and has no adverse currents, the length of the approach wall may be reduced. Shorter approach walls often are built on the side of the approach opposite the longer walls. The requirements for shorter approach walls are always associated with specific local conditions. However, the shorter approach wall, or an approach wall supplemented with a cell, should be configured to prevent tows from hitting the lock gates or the ends of lock walls. Dual locks, separated locks, and side-by-side locks also have special site-specific needs for approach walls. In these cases model studies and conferences with tow operators and district operations personnel will provide valuable guidance for approach wall requirements.

c. Alignment. In general, the longer approach walls should be straight-line extensions of the lock walls. This requirement is especially important at locks dealing with tows. Shorter, opposite side walls (if used) are often flared for their entire length.

d. Types. In selecting the type guide and guard walls for a specific project, consideration should be given to designing walls that can be constructed in water without using a cofferdam. In past projects, this type of construction has proven to be cost-effective. However, the walls must be carefully designed and constructed since extensive and repetitive maintenance costs over the life of the structure could offset the original savings. Furthermore, traffic disruption or stoppage could be a major problem with added costs to the towing industry and shippers.

(1) Mass concrete or reinforced concrete walls. These walls are usually built within cofferdams and can be founded on rock, soil, or bearing piles. They are designed to meet all stability requirements for overturning and sliding with appropriate loads applied for barge impact, line pull, and earthquakes. These walls must be reinforced to resist all anticipated loadings. For ported walls, corbels (brackets) are usually provided on the sides of each pier to support the first concrete lift above the ports. This first placement contains reinforcement to support the additional lifts of the wall above.

(2) Cellular supported. Cellular supported guide walls can be built in water without a cofferdam. The supporting element of the wall is composed of steel sheet pile cells--either intermittent or continuous depending on requirements for the wall. An intermittent line of cells can be made into a continuous solid wall by driving a single line of steel sheet piling between cells. The cells can be filled either with granular material or with tremie concrete, with or without bearing piles depending on foundation conditions. In addition to stability requirements, the cells must be designed to withstand interlock tension stresses in the sheet piling. A granular filled, cellular supported wall usually has the end cell filled with tremie concrete since the wall supported by this cell will receive the greatest blows from incoming tows. Close control must be exercised during pile driving to assure that no “windows” exist in the piling which could cause loss of fill. If piling cannot be checked with confidence during pile driving, then a diver should check for “windows.” Concrete that has been put in the cells by tremie should also be carefully monitored during placement and each lift line thoroughly cleaned and checked, since coring of some tremie concrete on previous projects has revealed many voids. The concrete wall supported by the steel cells may be designed either as precast or

cast-in-place or as a combination of the two, depending on water levels.

(3) Prefabricated concrete beams. Prefabricated beams, either reinforced or prestressed, are usually used to make up the portions of the wall which are under water. The part of the wall above water may be cast-in-place. Since these beams span from cell to cell and since cells cannot be constructed in an exact location, engineers should precisely set the lengths of these beams and accurately position the bearing surfaces on the cells. Past experience also indicates that providing a tremie concrete "make-up" placement between the ends of adjacent beams compensates for unavoidable construction inaccuracies. The beams should have tongue and groove surfaces on the tops and bottoms plus installation and stacking guides, so that placing and positioning in the water is made easier and the faces of the wall will not be offset between beams. Casting of the beams on top of each other in the shop and numbering the beams to be in the same location in the wall will also help. The beams must be designed for transportation loadings, construction loadings, and typical guide wall loadings.

(4) Caisson supported. Caisson-supported guide walls can be built in water where foundation and water flow situations preclude the use of steel pile cells for wall support. The only use of this type support by the Corps was the main lock (110 × 1,200 ft) upper guide wall at Melvin R. Price where six 6-ft-diameter steel caissons were used for each monolith. The caissons were driven to refusal at very hard material. Each caisson was cleaned out down to the beginning of the hard material and was then filled with concrete. The first caisson that was driven and filled with concrete was load tested for confirmation of the safety factor used for the design loading. The concrete wall on top of the caissons was cast-in-place and was designed somewhat similar to that for a cell-supported wall except that a heavy structural steel framework was provided for transfer of the wall loads to the caissons. The last upstream monolith was protected by a full height steel pile cell driven to 30 ft below streambed and filled with concrete. A steel sheet pile curtain wall was hung from the bottom of the wall on the dam side to attenuate the velocity of the water flowing under the wall. Also, stone protection was placed on the bed of the river and around the caissons to prevent erosion of material from around the caissons.

(5) Floating guide walls. In previous projects where upper pools are very deep, floating approach walls of concrete have been used successfully. The floating wall is composed of watertight cells with sealed inspection manholes surmounted by a vertical buttressed concrete or steel wall on the traffic side. The wall should be designed so that the concrete weight is distributed to make the wall float level at the proper submergence. The structure is a completely reinforced concrete design with the ability to resist impact from tows. However, heavy timbers must be provided on the traffic side to protect the concrete from barge rubbing and scraping and to distribute and dampen the impact forces from tows. These floating walls are hinged to the upper end of the main lock walls through a wheeled guide operating in a vertical recess, similar to a floating mooring bitt. A shock-absorbing device is also incorporated into the connection. The upstream end of the floating wall is anchored by adjustable cables fastened to dead men on the lake bottom. These adjustable cables allow the wall to be kept in proper alignment with the face of the main lock wall. An additional set of cables is provided as a safety backup in case the main cables fail.

(6) Sheet pile guide walls. Steel sheet piling in a double row, connected by diaphragms or tie-rods and filled with free draining material, has been used for guide walls with and without concrete on top. If the wall furnishes support for a concrete wall above, steel bearing piles can be used inside the piling enclosure. If site conditions are favorable, a single line of piling anchored into the material behind the wall with tie-rods can be used.

(7) Timber guide walls. Timber guide walls are used mostly on intracoastal waterway locks where the lifts are relatively low.

(8) Ported guide walls. Ported guide walls are designed primarily for upper approach walls adjacent to the dam spillway. The estimated size of the ports is determined from model tests. The ports should have adjustable features. When water is flowing over the spillway, flow through these ports can be regulated to prevent adverse navigation conditions for tows entering and leaving the lock chamber. The wall may be either a cellular supported wall or a reinforced concrete wall on piers. Steel sheet piling and precast concrete panels have been used to provide the adjustment capability for the ports.

5-6. Lock Sills

a. General. As discussed in Chapter 4, the sills may or may not be connected monolithically with the lock walls. Connecting the sill with the lock walls is usually beneficial in terms of the sill overturning or sliding in the upstream/downstream direction and may eliminate problems with inadequate bearing capacity of foundations under the adjacent lock walls since the vertical loads of the walls can be distributed to the sill foundation. If the sill is not connected to the lock walls or founded on rock, its stability may depend on use of bearing piles. The monolithic connection may be advantageous from an operational point of view in that it inhibits lateral movement of lock walls which could be detrimental to gate operation.

b. Navigation depths. Typically, the lock gate sill elevation is higher than the adjacent lock floor and other sills. It is set low enough to provide a cushion between the bottom of the vessel and the top of the sill. This cushion is required for hydraulic reasons and to allow for coatings of ice on the hulls of the vessels and for certain other contingency items. A description of the sill depth requirements for barge traffic is provided in EM 1110-2-1604. In some cases, there may be justifiable requirements for depths greater than that described in the reference, such as to allow limited navigation through the lock in the event of loss of upper pool. However, regulatory and legal requirements may preclude such variation.

c. Lock gate sills. Sometimes, the gate sill masonry can be utilized to form intake ports for culvert filling and emptying systems and for crossovers containing the various utilities. Some of the various types of gate sills are outlined below. For gravity locks, the sills are usually cast separately from the lock walls; however, with U-frame-type locks, the sill is cast monolithic with the lock walls.

d. Gate sill loadings. Sills must be designed for vertical and lateral water and earth pressures and for forces induced by uplift and foundation reactions. Generally, the lateral loadings occur between the elevations of the bottom of the gate and the foundation and act in the upstream/downstream direction. If the sill is monolithic with the lock walls or serves as a strut between the walls, the sill design must include the loads induced by the connection to the lock wall. The gate sill is required to resist a portion of the gate load when using vertically framed miter gates, or wide tainter gates havng intermediate trunnion supports, or rolling gates. Where the gate sill abuts adjacent sills or walls, the presence of waterstops may eliminate or cause the joint water pressure to be different from the pressure which would result from the joint being exposed to the adjacent pool. The design should consider joint pressures based on ruptured waterstops if such condition would be more critical than with the waterstops being fully effective.

(1) Horizontally framed miter gate. Sills for horizontally framed miter gates are used to provide a sealing arrangement and to form the damming surface below the gate. Horizontally framed miter gate sills are not required to resist any part of the gate thrust, since the entire thrust load is transferred to the lock walls. The gate gravity load is supported on pintles located adjacent to each lock wall. The pintle will generally be supported by a ledge extending from the lock wall; however, in the case of U-frame-type locks, the zone of influence of the pintle forces will extend into the lock sill.

(2) Vertically framed miter gate. Sills for vertically framed miter gates differ in design from sills for horizontally framed gates only in the method of load application from the gate. The horizontally framed gate load is taken as a thrust into the lock wall; whereas, a portion of the vertically framed gate load is taken by the sill. Miter gates with this type framing system will normally not be provided on modern locks.

(3) Lift gate. Lift gates do not transfer any water load to the sill. The sill provides a sealing surface, and in addition, the sill forms a spillway weir for passing discharges during flood stages where the lock is designed for such uses. In some conditions, the sill is required to support the full deadweight of the gate such as in the unwatered condition.

(4) Sector gate. Sills for sector gates are used to form the sealing surface for the gates and frequently to provide rolling tracks to carry a portion of the deadweight of the gates. However, supporting the gate on rolling tracks can present problems with keeping the rolling system operable and clear of obstruction. Water loads are distributed through the gates to rotating shafts located adjacent to the lock walls. The shafts in turn are supported by a hinge at the top of the lock wall and a pintle at the level of the sill, similar to miter gates. The sill also acts as a damming surface beneath the gates.

(5) Tainter gate. Tainter gate sills are of two distinct types from the standpoint of the loads which they are required to resist; however, for each case the hydrostatic and lateral earth pressures must be included in their design. The one type of sill merely provides a sealing surface for the gate and a top surface to fit the required spillway characteristics. This type of sill is practicable only for narrow lock chambers when the entire gate load is transferred to the lock walls through end trunnion arms. The other type of sill is one used for wide lock chambers

where end and intermediate trunnion arms transfer their loads to trunnion castings anchored to buttresses attached to the sill.

(6) Roller gate. A rolling gate sill consists of a straight concrete structure across the lock floor with embedded tracks upon which the gate rolls. Loads which the sill must resist are similar in nature to those of the vertically framed miter gate sill, the difference being in the determination of the total gate thrust and the dead-weight of the gate. Rolling gates in the United States were developed for use on wide locks with comparatively low lifts.

e. Emergency closure sills. Closure structures other than the service gates at each end of a lock are sometimes considered necessary in order that flow through the lock chamber can be stopped if the gates should become inoperable. These closure units are also used to close the lock chamber to permit unwatering for periodic inspections and repairs. In order for these structures to seal at the bottom and have a base for support, a sill is provided at, or a slight distance below, the elevation of the gate sills in many existing locks. Some recent installations have these closure sills outside the intake and discharge openings of the filling and emptying system in order that the latter elements may be conveniently inspected and repaired. For structures on pervious foundations, a row of steel sheet piling may be driven under the sill as a cutoff, and when on rock, pressure grouting may be utilized.

f. Bulkhead and temporary-closure sills. These sills are normally located both upstream and downstream of the lock gate sills and provide both bottom support and a sealing edge for bulkheads, stoplogs, etc. The top elevations for these sills will be lower than the adjacent gate sills and, in some cases, may be approximately the same level as the adjacent lock floor elevations. In some cases, these sills also serve as the lock floor and may be cast separately or monolithically with the lock walls similarly to the gate sills.

(1) Bulkhead sills. Bulkhead sills are not required to resist any part of the bulkhead lateral load. Thus, the sill structure needs be designed to support only the weight of the bulkheads and to resist the hydrostatic pressures below the bottom unit. An advantage of the bulkhead type of closure unit, if properly designed, is that a positive seal can be effected without the services of a diver during installation. However, lowering carriages or special hoist cars are usually needed to assure installation in flowing water as it is possible that a single (or unballasted) bulkhead will not sink in flowing water.

(2) Poiree-dam sills. Poiree-dam sills differ from bulkhead sills in that they resist the full hydrostatic load on the closure. The lock walls form the sealing surface at the ends. The sill contains the structural anchorage to which the A-frames are attached to support the needed damming surface. Because of the complications of attaching the frames to the sill anchorages, the services of a diver will be needed during installation of the frames.

(3) Needle-dam sills. Needle dam sills are generally used on narrow or shallow draft locks. A horizontal girder is placed in recesses in the lock walls, and the needles rest against it at the top and against a recess in the sill at the bottom. The sill resists about two thirds of the horizontal load on the needles and the total hydrostatic and earth pressure thrusts below the damming surface.

(4) Other closure methods. Other types of closure methods are possible and have been used such as float-in bulkheads. Loadings and the corresponding sill would be similar to those required for conventional bulkheads. The principal difference would be the method of bulkhead installation. For shallow draft locks, an earthen embankment could possibly be used on the downstream end of the lock. In any event, the logistics of closure including methods, costs, time constraints, and availability of closure handling equipment should be considered in selecting the types of closure systems to be used.

5-7. Gate Types and Locations

The type of lock gates must be determined early in the design since this can have significant impacts on the overall lock layout. Various types of gates are discussed in Chapter 7.

5-8. Lock Closure

a. Maintenance closure. A maintenance closure system for use in unwatering the lock should be provided in case it becomes necessary to repair the lock gates or other underwater items. When practical, locks should be designed to allow for full unwatering of the lock chamber by using the uppermost and lowermost bulkhead recesses in the lock walls. The most common type of maintenance closure consists of lock bulkheads installed by floating crane. However, allowable downtimes, traffic, and economics may dictate the use of more rapid system with permanent onsite equipment readily available for closure. A typical bulkhead closure system is shown in Figure 5-2.

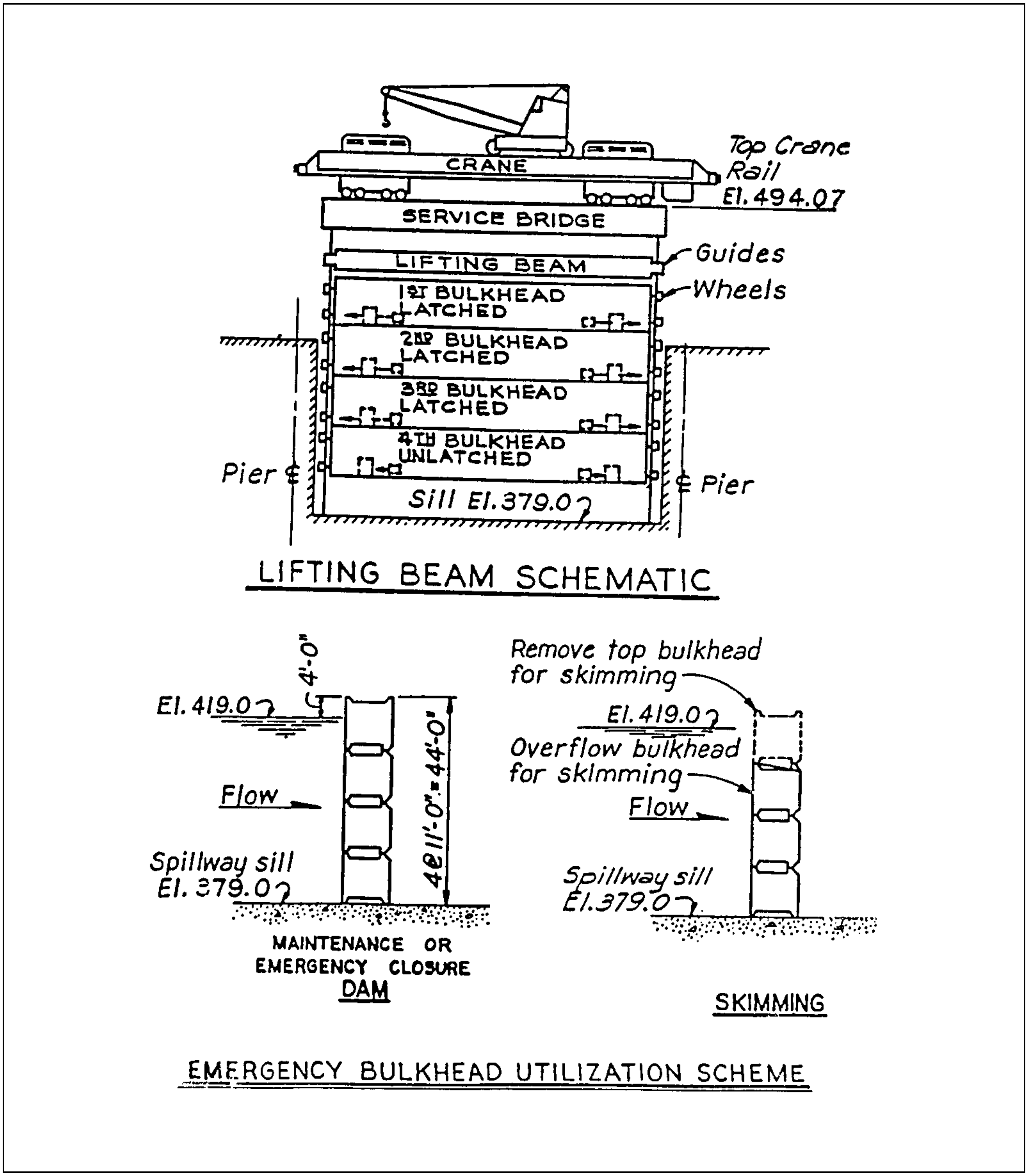

Figure 5-2. Typical bulkhead closure systems

b. Emergency closure. Sometimes it may be necessary to build emergency closure structures in addition to service gates to ensure that flow through the lock chamber can be stopped if the gates become inoperable. The decision to install emergency closure system is made on a project by project basis and depends on such factors as the likelihood of pool loss, extent of damage which could be caused by pool loss, amount of traffic, remoteness of site, and the cost of the emergency closure system. Such closures typically consist of a structure system stored immediately adjacent to the lock (such as bulkheads) and an onsite lifting system such as a pedestal crane, gantry crane, or stiff-leg derrick located on or adjacent to the lock wall. The system is designed and arranged to minimize time required to install the closure. Operating personnel must be able to install these structures in flowing water, and therefore the system requires special attention. If bulkheads are used, typically a lowering carriage will be installed in the bulkhead slot which allows the bulkhead stack to be lowered slowly. With this closure procedure, the flowing water does not pass over the bulkheads. Other emergency closures that have been used consist of the following:

(1) Hoist car traveling on overhead service bridge and handling the emergency bulkheads which are also used for the dam spillways.

(2) Submerged vertical lift gates with permanent operating machinery in the lock walls.

(3) Bulkheads or a single-leaf gate and operating machinery permanently located upstream of the upper service gate--mounted high enough to allow upper pool traffic to have proper overhead clearance.

5-9. Galleries and Cable Trenches

Galleries are sometimes used in lock structures to provide passage for mechanical and electrical lines across the lock or down the lock chamber walls to the lower gates. Typically, galleries crossing the lock are located in the upper gate bay sill if sill thicknesses will allow. This type of gallery can also provide emergency access to the river wall in the event access across the upper gates is lost. Where a gallery is not feasible, mechanical and electrical lines can pass along lock walls in cable trenches located in the top of the walls. These trenches are easy to reach and relatively easy to maintain and permit quick access to lines for maintenance as well. However, if the lock walls can be overtopped, cleanup could be a problem. These trenches are sized in accordance with the mechanical and electrical design of each individual lock. The trenches should be covered with either open grating or steel plating and should allow for easy lifting or removal of the covers.

5-10. Lock Wall Accessories

a. Floating mooring bitts.

(1) Purpose. When tows have entered the lock chamber, some method is required to keep the barges under control and relatively stationary while the lock chamber is being filled or emptied. Floating mooring bitts attached by lines to the vessels will meet this requirement. Many improvements have been made in filling and emptying system designs in recent years, i.e., reduction of turbulence in the lock chamber and elimination of overfill and overempty situations by timely culvert valve operation. However, it is still necessary to use floating mooring bitts to keep barges and pleasure craft from drifting into the lock gates and bumping each other and to compensate for any human error in the filling and emptying process. It may also be necessary to use only one culvert for lock filling and emptying, in which case the turbulence in the lock chamber could result in greater forces on the vessels than that normally experienced.

(2) Locations. Four to eight floating mooring bitts are usually provided in each chamber wall, depending on the length of the lock chamber, with a variable spacing to fit tows of different size barges. Plate 38 shows suggested spacing for floating mooring bitts, as well as spacing for other lock accessories, for a 600-ft lock chamber. Generally, floating mooring bitts should be no closer than 30 ft from the upper gate or 75 ft from the lower gate in the mitered position, to help protect the gates from barge overtravel.

(3) Description. Floating mooring bitts with mooring posts consist of a watertight floating tank which rises and falls as the lock chamber water level raises and lowers. This floating tank is mounted with wheels which ride inside steel guides in the mooring bitt recesses. It is desirable to provide two mooring posts on each tank, spaced at levels to accommodate the height above water level of either loaded or empty barges. Usually a vertical spacing of about 6 to 8 ft for the two posts will be required. See paragraph 10-2 for design of floating mooring bitt components.

b. Line hooks. Line hooks are placed in the face of the lock chamber and approach walls whether or not floating mooring bitts are provided. These hooks are usually placed in a series, one directly above the other about 5 ft apart, starting a short distance above lower pool level and ending near the top of wall or above maximum upper pool level. The spacing of the hooks along the lock walls is for the use of small boats or short tows when it is considered unnecessary for such vessels to pass lines to the top of walls for mooring. The boat operator in this case transfers the line to the next hook as the boat is raised or lowered. Although not directly related to floating mooring bitts, a vertical row of heavy line hooks for checking tows (to discourage checking on the bitts) should be provided at each bitt and at about 150-ft intervals outside the local chamber.

c. Ladders. Vertical ladders are necessary for access to and from the lock chamber. These ladders shall be placed at strategic locations for use in gaining access to the floating plant, as an aid in the rescue of accident victims, and for access to the lock floor during construction and maintenance operations. At least one ladder that leads directly to the lock floor should be located on each wall, and to provide access to both the upper and lower sills inside the unwatering closure structures. Ladders should be provided to low-water surfaces on both the upper and lower approach walls. Wall ladders should be spaced to ensure that a person falling into the water would not have to swim over 200 ft to a ladder. It is recommended that ladders be mounted in offset recesses.

d. Guardrail and parapets. Guardrails must be provided on both sides of gate and bridge walkways and for lock and approach walls when the backfill is a sufficient distance below the top. All waterside faces of walls shall have either guardrails or parapets for their entire length. Parapets about 2 ft high with indentations at each of the check posts may be provided in areas where snow and ice do not pose hazards. Removable guardrails consisting of posts and chain may be provided in cold climates. In addition, all stair wells, ladder recesses, and other openings at the top of walls and at other locations not protected with covers shall have guardrails or other protective equipment on all sides. Guardrail and other protective devices shall conform with the safety requirements contained in EM 385-1-1.

e. Safety jib crane. Fully rotating (360 deg) electrically operated jib cranes must be provided to store and efficiently handle the safety skiffs (16-ft boat) required by safety regulations. The skiffs should be located upstream on the upper approach wall and on the downstream guard wall. Cranes and associated appurtenances should be located to provide easy access to the skiff by means of permanent ladders or stairs, regardless of whether it is in the water or stored on the lock wall. Each of the two lifeboat locations should be equipped with half-ton jib crane, a 16-ft aluminum lifeboat, and a 10-hp outboard motor. The specifications for jib cranes should include weatherproof motors and a hoist of industrial design, mounted on a suitable trolley which will allow travel up to 12 ft to permit precise spotting of boat. The entire jib crane should be constructed to allow one man to conduct complete operation and skiff launching procedures.

f. Distance markers and sill markers. Distance markers should be provided along the lock approach walls and lock chamber walls to provide tow operators with means to estimate their distance from the lock gates and gate sills. For the upstream approach walls, distance markers should begin with zero immediately upstream of the upper gate recess and should consist of a number indicating the distance in feet to zero. The numbers should be white on a green background. In the lock chamber, the markers should be located on each chamber wall. The left descending wall should contain distances to the upper gate sill marked every 100 ft. The lower approach wall marking should be similar to the upper wall, with distances measured from the lower gate.

5-11. Tow Haulage Unit and Movable Kevel

When a tow is longer than the lock chamber, it must be split and locked through in two sections with the towboat remaining with the second section. Some means must be provided to pull the first section out of the chamber so that the chamber can be prepared to lock the second section through. A number of types of haulage units have been used, and the type selected for a particular project will depend on the amount of use expected.

a. Types of tow haulage units.

(1) The simplest installation of a tow haulage unit is a pair of single-drum hoists, either electric or air-driven. One hoist is located on the top of the lock wall upstream from the upper gate bay, and the other similarly mounted downstream from the lower gate bay. The free end of the line is paid off the drum and fastened to a bitt on the back barge of the first section. The barges are then pulled out of the chamber and snubbed to check posts or line hooks until the second section is locked through. The tow haulage unit should always be on the guide wall side, and upstream and downstream approach walls (guide walls) must be located on the same side of the lock in order for the tow haulage unit to function properly.

(2) Another type unit consists of a single reversible hoist located at about the center of the lock and an endless cable running along the face of the lock wall and

around sheaves near the gate recesses. The single-hoist layout should always be used since the double-hoist arrangement with a single line is extremely dangerous to operating personnel. This cable (wire rope) is provided with a flexible fiber line long enough to reach pool level and is fastened to the back barge either directly or with an intermediate hawser. Barges are pulled out as described above. The hoist drum is designed so that as the cable (wire rope) is paid out at one end at bottom of the grooved drum, it returns onto the top of the drum at the same end. The length of the cable on the drum equals total travel plus two wraps. The most sophisticated system uses a reversible hoist and endless cable which pulls a wheeled towing bitt on the top of the wall between the gate bays. The bitt may travel in a recess provided for it, or it may be mounted on a rail fastened to the concrete. The latter is used for locks already constructed or in cold climates where snow and ice would clog the recessed type. A hawser (line) furnished by the tow is slipped over the traveling bitt and fastened to the back barge as before. It is very important that the lock operator be able to see the barges that are being pulled during the entire operation. Therefore, the lock operator should operate the tow haulage unit from the lock wall opposite the tow haulage unit.

b. Movable (traveling) kevels. All tow haulage units should be furnished with two unpowered, movable kevels. One of these kevels should be located on the upstream guide wall, and one should be located on the downstream guide wall, just outside the main lock gates. The minimum length of travel of each of these kevels should be equal to the travel of the tow haulage unit. The length of travel for the tow haulage unit should be equal to the clear inside length of the lock chamber--the distance between downstream miter gate recess and upstream miter sill. The purpose of these unpowered traveling kevels is to hold the head of the tow into the guide walls as the haulage unit pulls the tow out of the lock chamber. An unpowered, power retrieved kevel can be provided to prevent a lockman from having to walk the length of the guide wall and return (retrieve) the kevel manually.