



LOCK & DOCK GATES

GUIDANCE ON TYPES, OPERATING FACTORS,
FAILURES AND MAINTENANCE

INTRODUCTION

Lock gates are an essential part of a navigational lock/dock system. They are the movable elements of the system that retain water for the rise and fall of the lock when closed, and allow vessels to pass when open. The two key functional requirements for lock gates are:

- the gates should move from a closed to an open position and provide unimpeded passage to vessels entering or leaving;
- the gates should move from an open to a closed position and be able to withstand the subsequent difference in water level (head);

Locks are used worldwide for commercial and recreational purposes. The US has around 25,000 miles of navigable inland waterways and 239 locks that form its water highway. The system is operated and maintained by the US Army Corps of Engineers, and most locks and dams on the system are well beyond their 50-year design life, which is a major maintenance issue and cause of vessel delays. Europe has an even more extensive system of navigable waterways with a total number of locks exceeding 340.

IN ADDITION, THERE ARE HUNDREDS OF PORTS AND SHIPYARDS WORLDWIDE WITH IMPOUNDED BASINS (I.E. WET DOCKS WHERE THE WATER IS KEPT AT HIGH-TIDE LEVEL) AND DRY DOCKS, WHICH RELY ON ENTRANCE GATES AND INTERMEDIATE DOCK GATES FOR THEIR OPERATION.

TYPES OF GATES

Several types of lock and dock gates are used, which are often classified as entrance or intermediate gates. These latter gates are typically used in large dry docks to subdivide the dock into two separate operational areas. Gates are further defined by whether they rotate on their vertical or horizontal axis or move horizontally or vertically. Many design aspects are considered in deciding the type of gate most suited to a particular situation. These include the frequency of operation, size of the entrance, lift (head), location, geology of the site, wave action, siltation conditions and whether vehicle access is required across the lock.

Dry Dock Entrance Gate Types	Dry Dock Intermediate Gate Types	Lock Gate Types
<ul style="list-style-type: none"> - Flap Gates: 'Box', Cantilever, Propped - Caisson Gates: Spanning, Gravity - Mitre Gates 	<ul style="list-style-type: none"> - Inverted "Y" - Lambda - Stop Beam 	<ul style="list-style-type: none"> - Ship Lock: Sliding, Rolling, Mitre - Marina Lock: Mitre, Double Sector, Single Sector, Delta, - Canal Locks: Lifting, Mitre

GATES THAT ROTATE ON A VERTICAL AXIS

Mitre gates

Mitre gates are perhaps the oldest and most frequently used gate in maritime locks, dock entrances, and port-impounding basins. Historically they were constructed in timber, but nowadays larger and modern examples are fabricated in steel. They comprise a pair of flat gates, which rotate about a vertical axis into side recesses (chambers), and when closed, lean against each other at an obtuse angle (mitre). They are typically operated with hydraulic rams.

Mitre gates require exact dimensions to form a seal and their operation can be affected by wave action. They are also known to vibrate (chatter) when there is only a small hydrostatic head holding the gates together. They are sensitive to drifting waste materials and ice and are at risk of collisions and being pushed open by a vessel colliding with the gates in the direction of the point.

Machinery maintenance is required, and structural maintenance can be difficult. Major repairs to mitre gates usually involve lifting out the gate(s), which requires navigation in the lock to be blocked. To keep this disruption as short as possible, spare gates should ideally be kept available in fully operational condition. Depending on the dimensions and weight of the gate, a mobile crane can be used to change out the gate, but if road access is unavailable or difficult, a floating crane will be required.



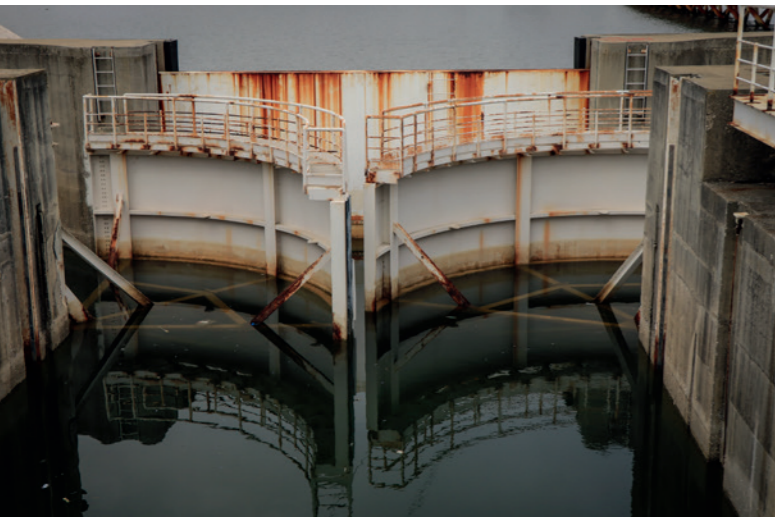
Mitre Gates – Adobe Stock



Steel mitre gate - Adobe Stock



Port of Immingham – www.ravestein.nl



A pound lock on the Keitele-Päijänne Canal, Finland - Adobe Stock



Chatham Docks Caisson Lock Gates - www.ravestein.nl

Single pivot leaf gate

The single pivot gate is a flat gate, which sits into a long shallow gate recess (chamber) in the lock wall. Its operation causes large water movement, which makes it particularly sensitive to drifting waste and ice, and it requires a powerful operating mechanism and strong rotation points. As with Mitre gates, machinery maintenance is required and structural maintenance can be difficult.

Sector gates

Sector gates have a curved outer skin supported on radial arms, which rotate around a vertical axis and are typically operated with hydraulic rams. They are widely used for sea locks at the entrance to harbours and marinas (e.g. St. Malo and St. Lawrence Seaway), where passage through the lock is required under extreme tidal ranges.

Their design requires high precision fabrication as pivot alignment is critical. Construction involves extensive and complex civil engineering works, and efficient sealing is often difficult.

Caisson gates

Floating caisson (watertight box) gates are often used in naval dock facilities, shipbuilding and repair docks, and in situations where a reverse hydrostatic head (i.e. water pressure from either side) needs to be supported. There are many designs for floating, rolling and sliding caisson gates. The gate's symmetry provides full reversibility, allowing the gate to be turned around enabling either side to be maintained or repaired whilst the gate remains in operation.

Designs usually include several watertight/ airtight compartments and pumping equipment, which require regular inspection and maintenance.

Sliding/rolling caisson gate design involves extensive civil engineering works and considerable mechanical maintenance, which can be difficult to perform.

GATES THAT ROTATE ON A HORIZONTAL AXIS

Flap/Tumble gates

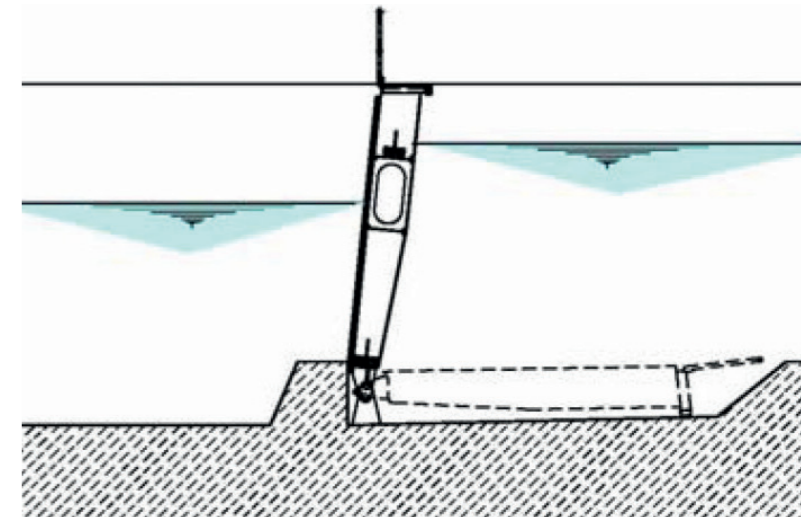
Flap or tumble gates rotate about hinges aligned horizontally in the bottom sill structure to an open position below sill level. They are typically operated using a winch(es) and wire rope(s), hydraulic ram(s), or compressed air. The gate is usually semi buoyant, and types include spanning box flap gates, propped flap gates and cantilever flap gates.

As the hinge points are below water they are sensitive to waste and silt, and the large water movement during opening and closing. Inspection is difficult, and they cannot be maintained in situ.

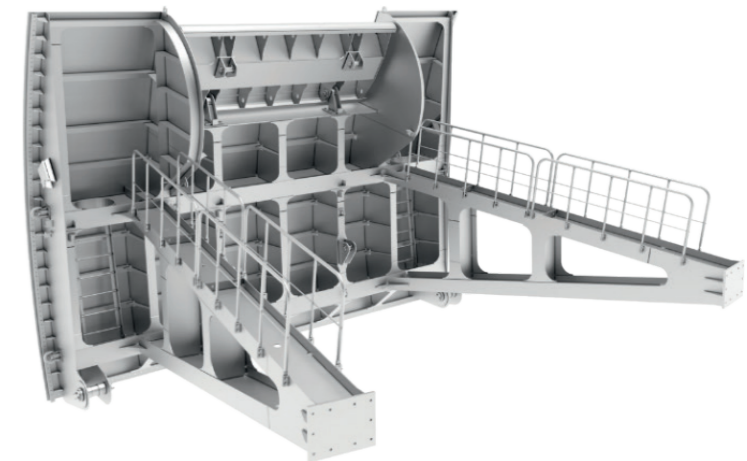
For larger gates a hinged strut is sometimes used to support the gate, which requires additional civil engineering works and can be prone to damage. An alternative is the cantilever flap gate, but again maintenance cannot be carried out in situ and removal can be very difficult.

Radial/Tainter/Rising Sector gates

Radial, Tainter or Rising Sector gates are similar in design to Sector gates but with their axis of rotation horizontal. They can be designed with or without counterweights, and the drum gates on the Thames barrier are a design variant. The design requires extensive civil engineering works and is sensitive to debris and silt in the gate recess. If counterweights are incorporated in the design there can be considerable forces acting on the pivot points, which can lead to ongoing maintenance issues.



Floor-mounted flap gate - Pinc



Radial Gate - Pinc

GATES WITH HORIZONTAL MOVEMENT

Rolling gate

The rolling gate usually rests on two roller carriages, each fitted with four wheels. The gate is guided along rails with sliding guides, and horizontal guiding wheels at the top keep the gate vertical during movement. The gate sits into a deep gate chamber in the lock wall when the gate is opened, which requires extensive civil engineering construction works. The gate is usually equipped with float control chambers to provide a lighter operating mechanism that reduces the load on the roller carriages. However, this requires more mechanical maintenance, which can be difficult to perform.

GATES WITH VERTICAL MOVEMENT



Vertical lift gate guides in Krimpen a/d IJssel - Adobe Stock

Lift gate

These gates lift vertically out of position on static towers using winches and wire rope(s) or hydraulic cylinders. The gate is usually balanced by means of counterweights. Variations include the double lift gate, which consists of two gate sections positioned either next to each other or one above the other. The gates have complicated gate guide systems, operating mechanisms, and an expensive support structure, which require regular inspection and maintenance.

Drop gates

A drop gate is a flat gate that drops into a shaft in the bottom of the chamber and has clear advantages over the lift gate, but the bottom seal is sensitive to waste and silt, and can be problematic with difficult access for inspection and maintenance.

OPERATING FEATURES

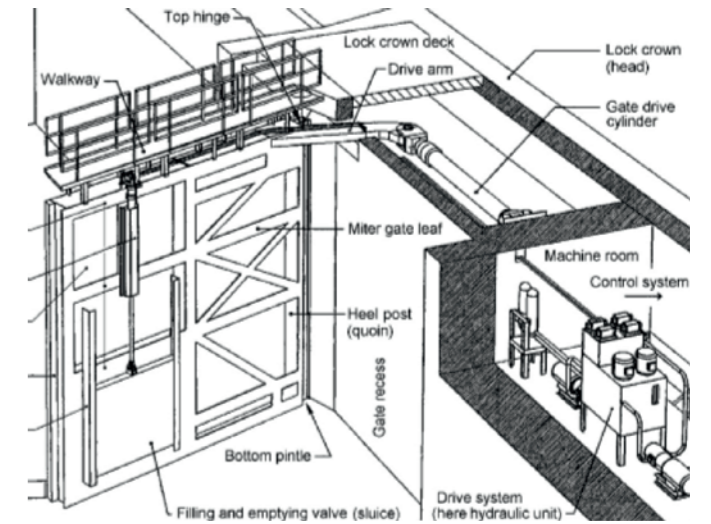
The opening and closing movement of a lock gate can be achieved by direct mechanical linkage, hydraulic cylinder, rope or chain. The operating equipment can come in many forms to suit the wide range of gate type and size. These include manual operation by handwheels, cranks, balance beams (mitre gate); electric motor driving mechanisms, such as winch drums; and electric motors for hydraulic power required for linear or rotational motion.

Hinges

Hinges are a critical component of the gate and replacing a hinge is a costly and time-consuming task. For this reason, the selection of materials, durability, position, method of installation, maintenance and replacement need careful consideration at the design stage.

Seals

Seals are required for the efficient operation of a gate and will generally be made from rubber or wood. Sealing arrangements need to be robust and durable to reduce future maintenance requirements. Each gate type will have its own unique sealing arrangement and their selection, design and method of installation is important for achieving an effective sealing system and preventing water loss.



Diagrammatic view of hydraulic mitre gate operation - Pianc

MAIN MECHANICAL COMPONENTS

FUNCTIONS	ELEMENTS
Gate operation and power supply (transmission of a force to the mobile structure)	<ul style="list-style-type: none"> - actuators - drives (cylinders, electro-mechanical drives...) - motors - chain, cables
Guiding (rotation, translation) & Hinges	<ul style="list-style-type: none"> - rails - wheels and rollers - pivot, articulation
Bearing and contacts (sliding, rolling or static), transmission of forces to the foundation of the lock	<ul style="list-style-type: none"> - rails - wheels and rollers - pivot, articulation - Sealing - seals
Sealing	<ul style="list-style-type: none"> - seals
Maintenance	<ul style="list-style-type: none"> - accessibility - capacity to remove and change elements

GATE FAILURES

Ship collision is reportedly the most common cause of failure and damage to a lock or dock gate, although mechanical failure and fatigue cracking in the support structure of a gate is also a common cause of failure. Gate components such as the gudgeon (hinge socket), anchor arms and pintle (hinge pin) castings are subject to cyclic loading and fatigue cracking and are therefore a known cause of failure.



Shock absorber beam in front of mitre gates - Google

Mechanical Failure

There are numerous experiences of lock gate mechanical failures. Two major reasons broadly attributed to gate mechanical failures are:

- non-timely operation of gates and failure on behalf of operators to understand their design working parameters
- structural failure due to ineffective maintenance and omissions or negligence in carrying out simple but critical inspection tasks

It is therefore imperative that lock operators understand and are familiar with the design and operating parameters for the gates and their regular maintenance requirements.

Collision protection

A lock/dock will be unable to function if its gate is damaged and therefore preventative measures should be taken to decrease risk of collision or limit the duration of the repairs should an incident occur. These measures include:

- good design of approach jetties
- positioning the support structure of moveable access bridges outside and clear of the outer walls of the lock
- inclusion of anti-collision structures in front of the gates
- protection of operating mechanism
- availability of spare gates and parts
- wooden fenders on the outside faces of mitre gates

In special cases, and if possible to do so, energy-absorption devices such as cable nets, friction drums, collapsible buffers or shock absorbers should be installed.

ASSET MANAGEMENT

The main structure of a lock or dock will typically be constructed with a design life of 100 years. However, lock gates and their operating equipment will have a much shorter design life, often in the region of 25 to 30 years. Therefore, an asset management programme, which should include inspection, maintenance and monitoring procedures, should be implemented. To ensure reliable performance of lock gates and their operating equipment, periodic preventive maintenance is essential. Properly executed preventive maintenance will ensure efficient operation, improved performance and increased life.

All gate installations should have preventive maintenance schedules recommended by their respective manufacturers but if this is not available a system should be put into place in accordance with the National Standard (BSI ISO 55000).



The ISO 55000 series provides terminology, requirements and guidance for implementing, maintaining and improving an effective asset management system.

Preventive maintenance procedures have been developed to include predictive and proactive maintenance techniques to identify and eliminate the root cause of failures. Relevant equipment includes sensors and gauges strategically placed to measure stresses and strains, record pressures, temperatures and vibrations of critical components, to enable trend analyses and condition/health monitoring.

Condition monitoring should include fatigue monitoring of visually inaccessible parts of the system and fracture-critical components such as lock gate anchor rods.

The Engineer Research and Development Centre (ERDC) of the US Army Corps of Engineers (USACE) have developed a monitoring and reporting tool for the structural monitoring and analysis in real time of lock gates. Known as SMART Gate, the system was developed to provide an automatic structural health monitoring and reporting tool for ensuring the operational safety and effective maintenance of lock gates.

SMART Gate instrumentation uses an array of strain gauges, tilt inclinometers and other sensors, which are strategically mounted on the structure and are interfaced to dataloggers. The data is seamlessly transmitted from the structure to a database for post processing. Preselected critical-parameters are then analysed using purpose developed software to provide advanced warning of deteriorating gate performance before serious damage or failure occurs. A system of automatic alerts when gate loads exceed predetermined maximum load levels can be incorporated into the software.

A computerised maintenance management system (CMMS) should also be used to keep a record of past shutdowns, repairs and trends as well as listing work instructions for each job to create a knowledge base, which will improve repair quality and reduce costs.

Maintenance Requirements

A maintenance strategy related to the safety of the retaining structure and the availability requirements of the lock should be considered.

An assessment should be carried out to determine the need for spare gates and equipment. If the acceptable time for operational interruption is much shorter than the time required for regularly recurring maintenance or emergency repairs, preparations should be made to store spare lock gates, valves and critical components in case of accidental damage. Spare gates and equipment should be stored in an area which is easily accessible for exchange, and is equipped with the necessary means (lifting, etc.) to enable maintenance work and gate replacement to be carried out.

Maintenance Schedule

The planned preventive maintenance programme for gates and their operating systems should involve monthly, quarterly and annual inspections and maintenance tasks that include:

- regular marine growth and waste removal, greasing of moving parts, tightening bolts, checking and adjusting collar and anchorage bars and linkages, painting, cleaning, jetting.
- replacement of those parts which incur normal wear and tear – see above “Scheduled Replacement Parts”.

Spare Parts

Depending upon the type of gate, the requirement to stock spare parts can typically be split into the following two categories:

Emergency Parts

Where replacement cannot be foreseen and therefore cannot be scheduled; these include anchorage bars and linkages, pintles, gudgeon pins, diagonal bars, and operating strut arms.

Scheduled Replacement Parts

Those parts that need to be replaced due to normal wear and tear, such as pintle bushings, gudgeon pin bushings, anchorage bushings, gate actuator parts and sensors, fenders and seals.

Annual Inspection should be used to assess the rates of change of defects, allocate condition factors, and amend condition grades to be used as benchmarks for future inspections. They should also flag if detailed inspections are required by third party inspectors/engineers to determine potential failure risks and whether major interventions are required.

Some simple but critical checks are listed in the table below. If these are not carried out in a proper and timely fashion they can lead to the disruptive operation of the lock and structural damage.

TYPICAL MAINTENANCE SCHEDULE

Monthly:

- Check and clear obstructions to gate movement
- Visible seals and seal seating inspected for leakages
 - Locations of excessive leakages recorded, and remedial action taken
 - Excessive and wide-spread leakages to be recorded and reported to Engineer
- Visually inspect hinge and drive assembly, remove dirt, grit, etc., and lubricate moving parts with water-resistant grease
- Visual inspection of critical structural components and welds

Quarterly:

The following checks and maintenance shall be carried out in addition to checks mentioned under monthly maintenance.

- All accessible nuts and bolts checked, tightened and replaced as required
- All accessible welds visually inspected and repaired. Non Destructive Testing (NDT) if required
- All accessible drain holes cleaned
- Check upstream face of skin plate for pitting and corrosion. Record findings for future planned maintenance and carry out emergency/temporary repairs
- Clean & lubricate mechanical components
- Check seals for leakage and damage and schedule replacement as necessary
- Guides, wheels and seal assemblies to be cleaned of dirt and grit, etc.
- Check condition of wire ropes and rope sockets. Grease wire ropes

Annually: (with divers)

The following checks or maintenance shall be carried out in addition to checks mentioned under quarterly maintenance.

- All nuts and bolts checked and tightened
- All welds visually inspected and repaired. NDT if required
- All the embedded parts checked for defects/damage and repaired as required
- Exposed parts cleaned and painted
- Sill beam and guides cleared of grit, sand etc.
- Wire ropes checked for equal tension. If broken strands are noticed, wire rope shall be replaced. Fixing of rope sockets to be checked. Grease wire rope
- Check guide roller pins for rotation and lubricate

References:

Some of the contents of the paper and diagrams have been used from the references.

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