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SESSION
WORKSHOP NOTES

Session (4-1)
"Lock Systems and Lock Gates Systems",
Ernst Herz, Mannesmann Rexroth, Lohr,
Germany

WATERWAY LOCK SYSTEMS

by Ernst HERZ

Locks are installed in order to facilitate navigation by compensating for different water levels within a harbour, a regulated river course or a canal. Generally speaking they are of chamber design; the most common types are indicated in *Fig. 1*.

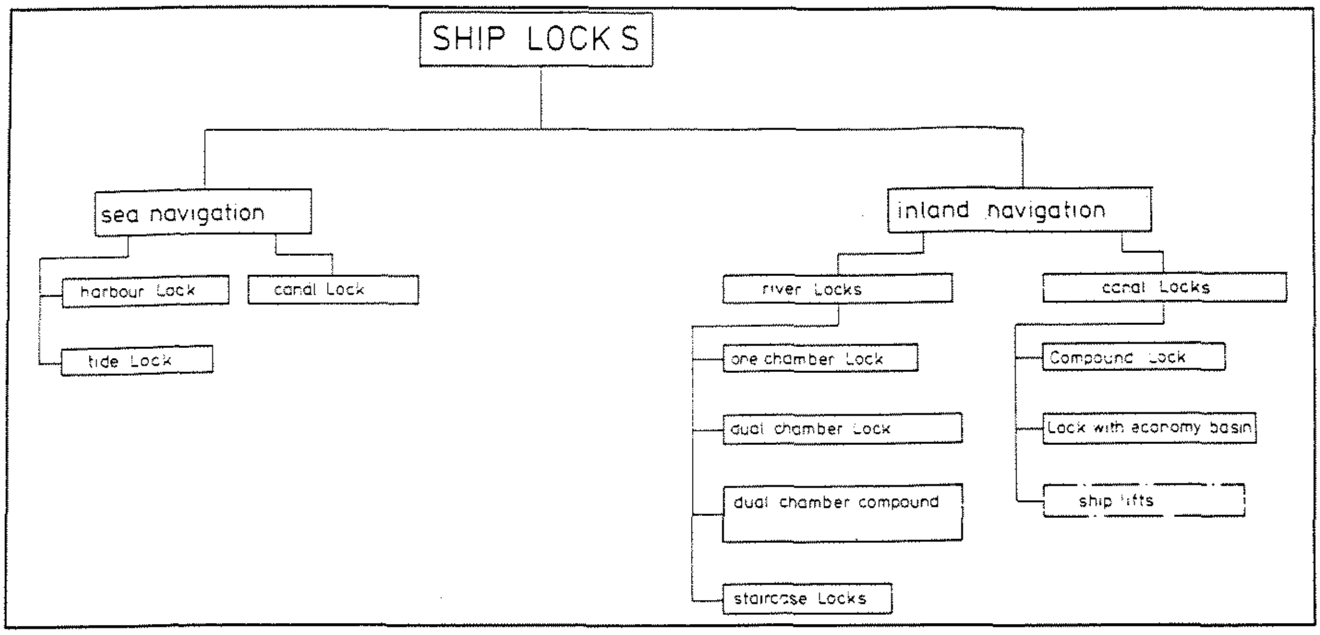

Fig. 1

1. Sea navigation

1.1 Locks for sea-going vessels

The lock type most frequently encountered for this application is the harbour lock, i.e. the harbour basin or dock systems are protected from the effects of the tide ebbing and flowing by means of a lock. In such systems, the water level in the dock or harbour may be either higher or lower than that of the outside sea, depending on the tide at the time.

1.2 Dock gates

Dock gates are systems in which the harbour basin is sealed off by a single gate system. Entry into and exit from the basin is only possible when the water levels either side of the gate are the same. *In many cases the gates remain open to allow the ebb and* flow to take their natural course, and are only closed in the event of extremely low or high (e.g. storm tide) water levels.

1.3 Canal locks

Canal locks serve to overcome height differences within the canal itself, and also as gateways between the canal and the sea. The same criteria apply to coastal canals as those relating to inland navigation waterways.

Locks at the canal outlet into the sea perform the same functions as dock canals as described under section 1.1 above (e.g. in the Panama Canal, the North Sea-Baltic Sea Canal).

1.4 Dimensions

The size of lock will depend on the type of traffic being handled. *Widths generally range between 12 m* (fishing boats) and 60 m (large sea-going vessels). The water level differentials vary between approx. 3 m and 6 m.

2. Inland navigation

A general distinction is made here between locks in flowing waterways, i.e. in regulated river courses, and locks installed in canals in which there is no natural inflow (dead water canals).

2.1 River locks

In rivers, weirs with adjacent locks regulate the water level in order to ensure that, even when water levels are low, a certain minimum depth is retained to allow navigation to continue.

The lock types employed in regulated rivers are as follows:

2.1.1 Single-chamber locks

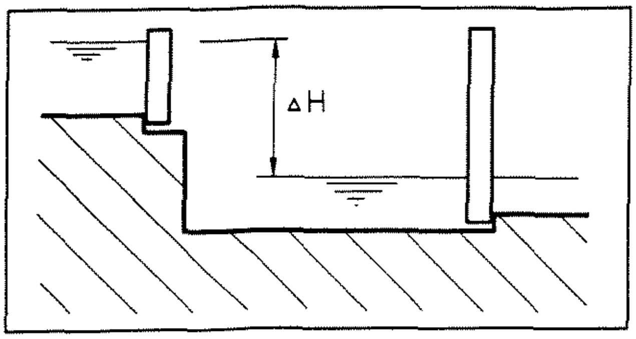

Fig. 2

2.1.2 Double-chamber locks

2.1.3 Parallel locks with linking culvert

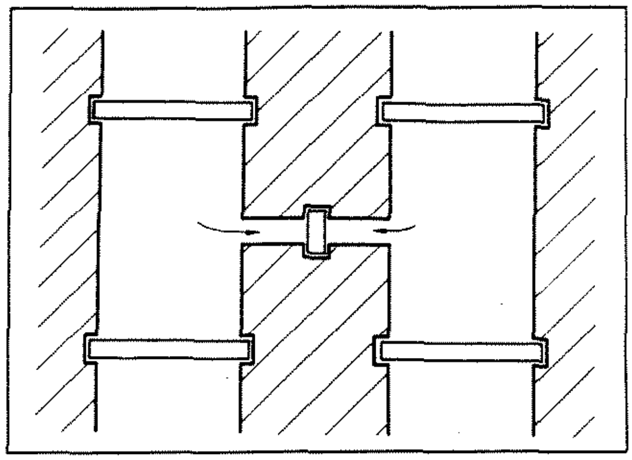

Fig. 3

2.1.4 Staircase locks for steep gradients

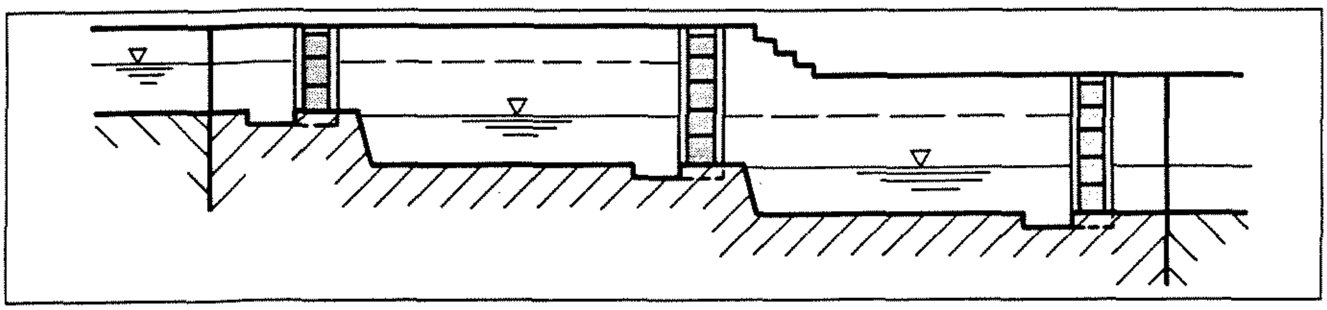

Fig. 4

2.2 Canal locks

Canal locks must be designed such that the water loss resulting from the locking operation is kept to a minimum.

Generally speaking locks in canals with no natural inflow are equipped with pumping stations which pump the water lost during locking back into the upstream channel. The lock types installed in canals are as follows:

2.2.1 Parallel locks with linking culvert

Culvert-linked parallel locks operate most effectively when vessels are being simultaneously transferred upstream and downstream, enabling the locking operation to be carried out with only minimal water loss. Consequently, the installation of such systems is only feasible in cases where regular and equal traffic flows in both directions can be expected to occur over long periods of time.

2.2.3 Side pond (economy basin) locks

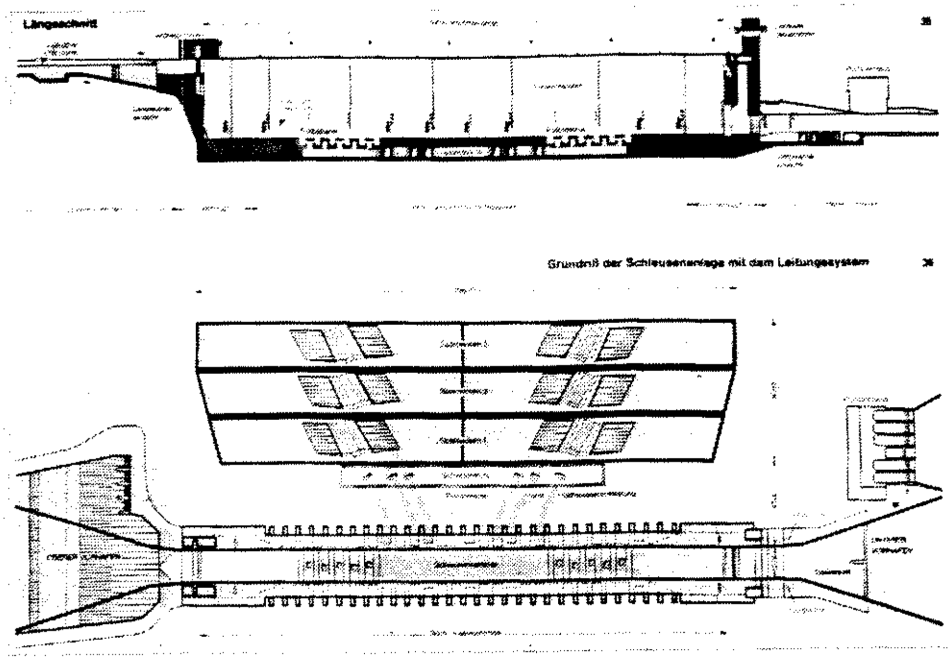

Fig. 5.1

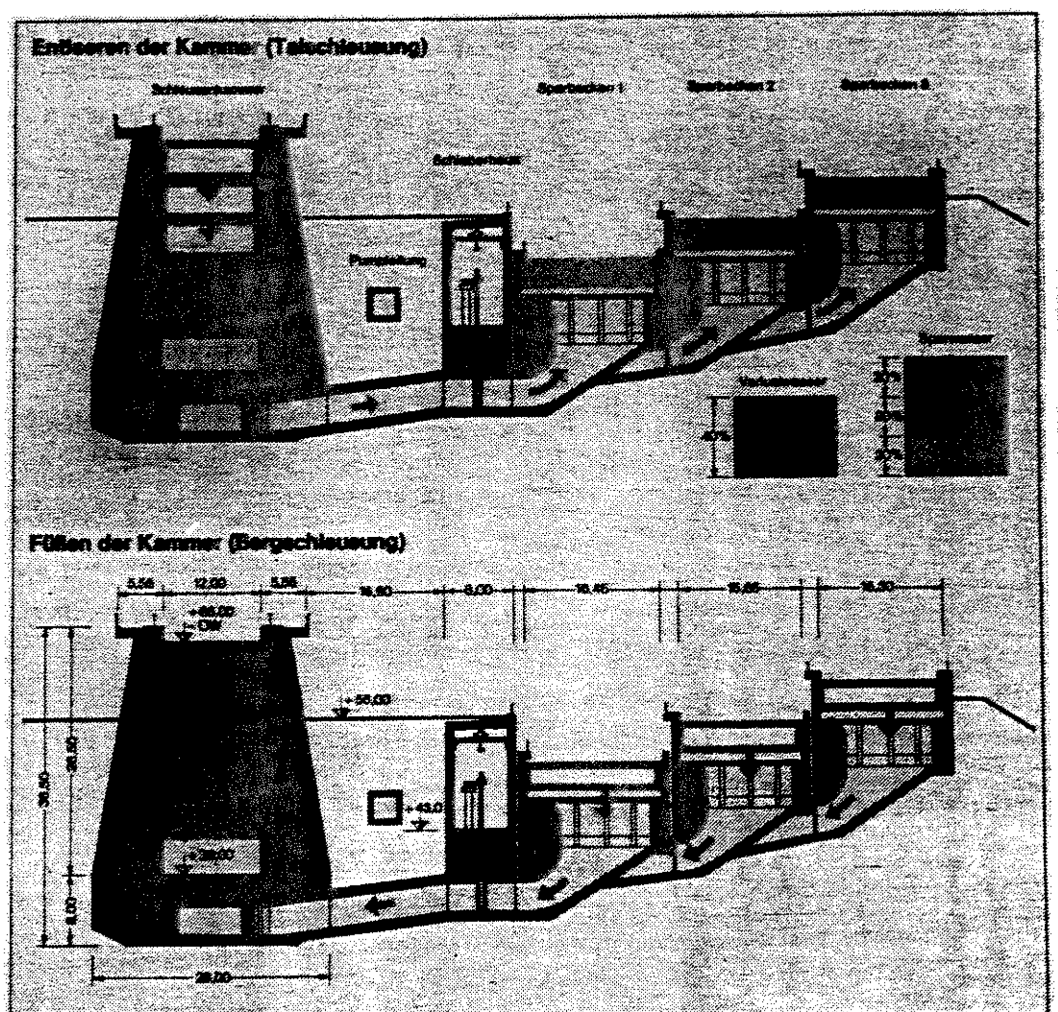

Fig. 5.2

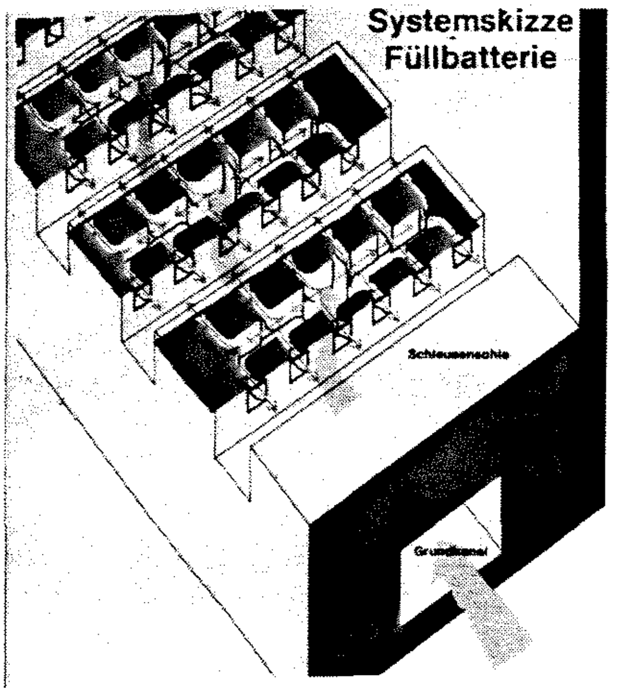

Fig. 5.3

Canals with no natural inflow are often equipped with locks combined with side ponds (also known as economy basins). These side ponds store a portion of the water outflow which occurs during downstream locking and feed it back in again during upstream locking operations.

2.4 Dimensions

The normal width dimensions for inland waterway locks in Germany are as follows:

12 m clear width
24 m clear width
34 m clear width

These clear width graduations correspond to multiples of the maximum width of 11 m which applies to inland vessels and pusher barges. The locks may be designed for level differentials of up to 24 m, or, in the case of staircase lock systems, up to 35 m.

3. Lock filling and emptying systems

Aside from the general designs described under sections 1 and 2, the locks may also differ in terms of the various filling and emptying systems and methods which may be employed. Indeed, it is the filling and emptying requirements which tend to govern which gate type is selected for a particular application. The various possible filling and emptying systems are as follows:

3.1 Filling and emptying through the gateways

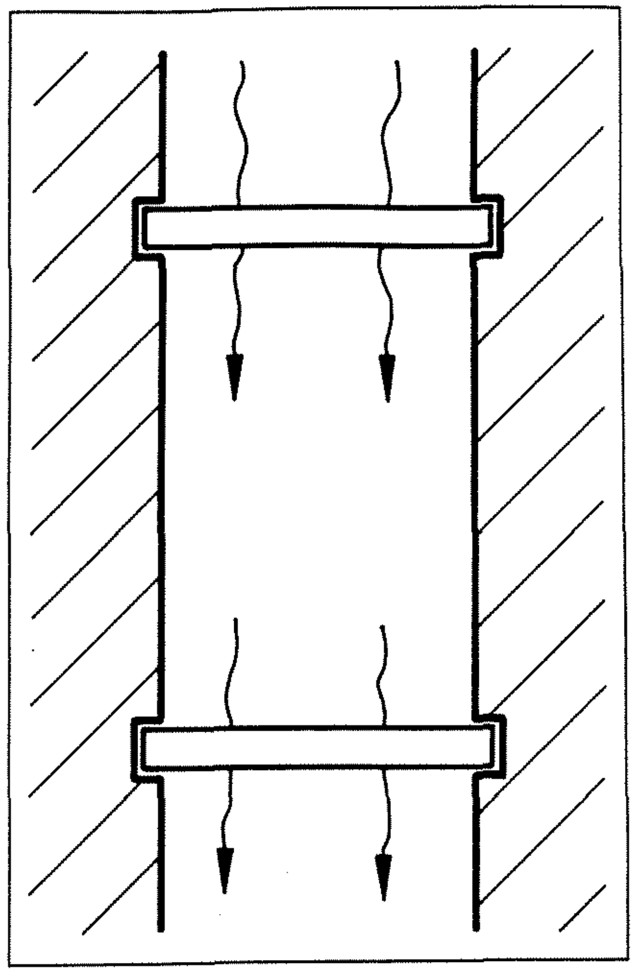

Fig. 6

Here the water inflow for upstream locking and the water outflow for downstream locking are provided by opening the appropriate gate. Generally speaking the gates are raised, although they may also be lowered. The filling operation may also be carried out by means of gate rotation, e.g.in the case of radial or flap type gates. All such operations result in a longitudinal water current developing in the lock.

3.2 Gates with integral filling and emptying devices

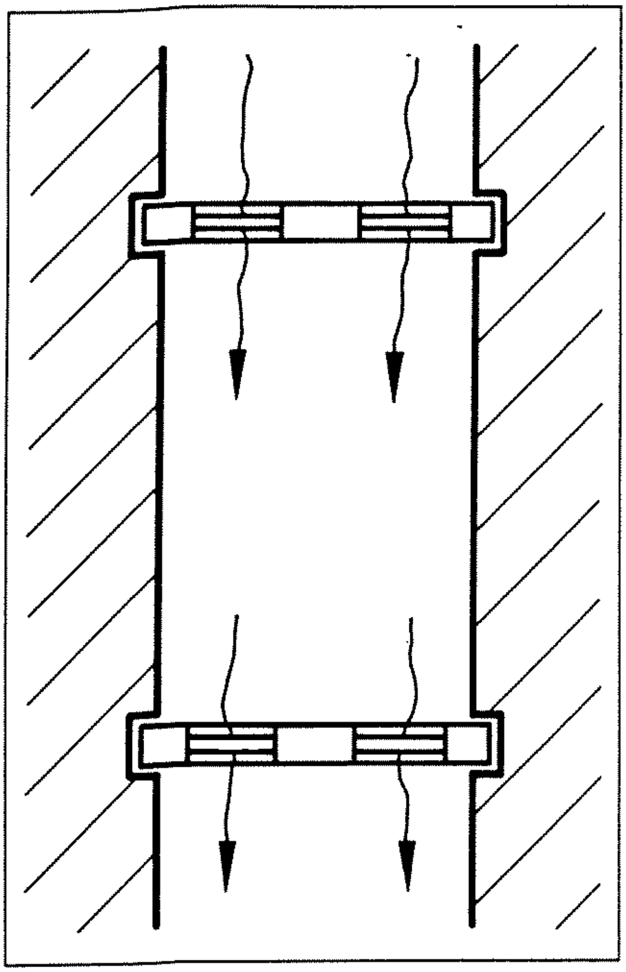

Fig. 7

In these systems the gates are equipped with additional devices which can be opened and closed in order to allow the water to flow into and out of the lock while the gate remains in its closed position.

3.3 Locks served by culverts

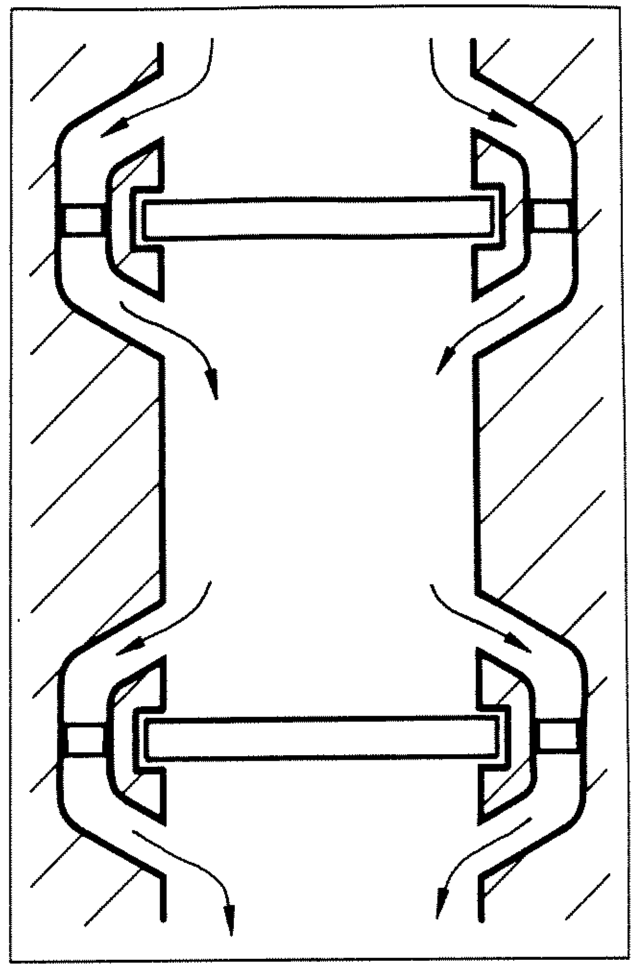

Fig. 8

Here the lockage water is fed into and let out of the lock by means of culverts. The culvert inlets are located just upstream of each gate, while the culvert outlets are located just downstream of each gate.

Here, as in the case of the systems described in sections 3.1 and 3.2, a longitudinal current develops in the lock.

3.4 Locks with parallel culverts

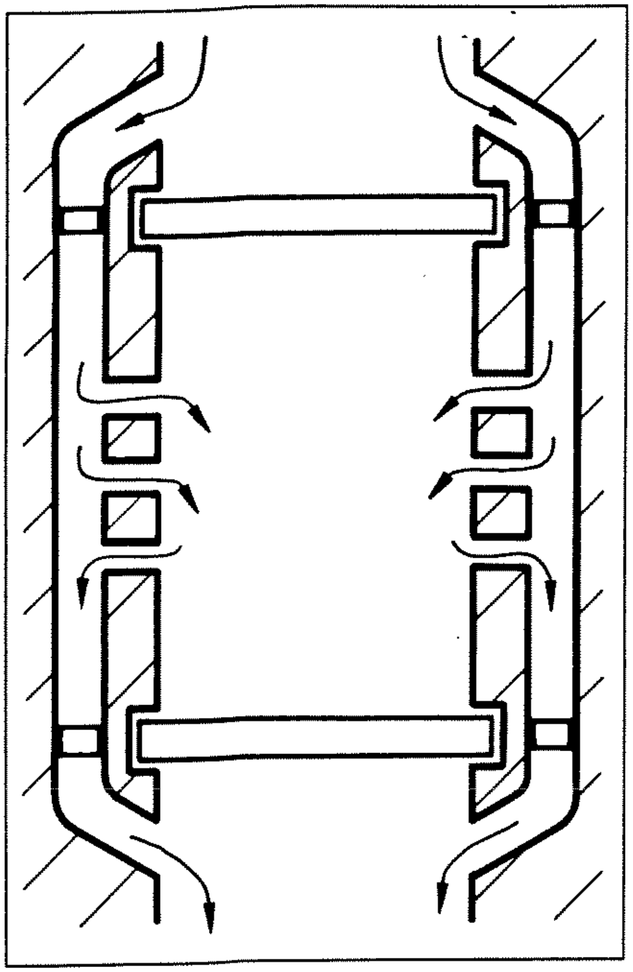

Fig. 9

Locks may also be designed with culverts which run parallel with the side walls for filling and emptying purposes. These are linked to the lock chamber via round or square section openings through which the lockage water flows in and out. This results in several relatively weak transverse currents rather than a single, strong longitudinal flow, so that the vessels being transferred remain largely unaffected by turbulence.

3.5 Locks with underground culverts

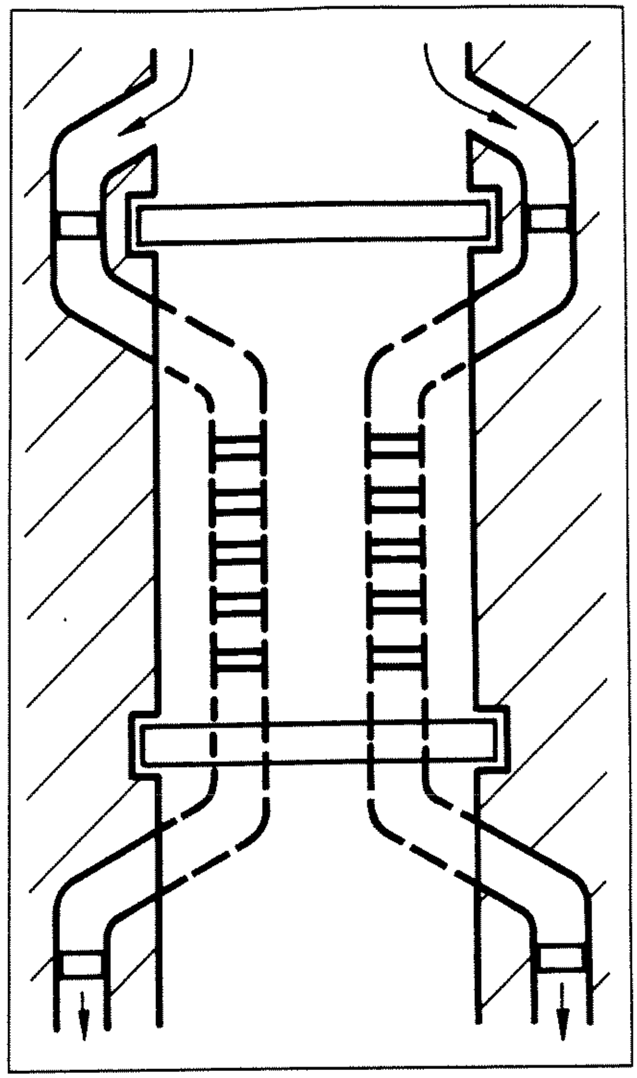

Fig. 10

As in the case of the system described in section 3.4. separate culverts are installed for the inflow and outflow of the lockage water. In this case, however, the culverts are located below the surface of the lock chamber bottom. The water therefore enters and leaves the chamber vertically through slits in its bottom, producing a uniform rate of level rise and fall without any currents occurring in the chamber. Such systems constitute an optimum solution for the filling and emptying of locks and are particularly preferred in applications

a) involving large-volume lock chambers, and
b) where extremely short lockage times are required.

3.6 Side pond locks

Locks with side ponds (economy basins) are usually equipped with underground culverts as described in section 3.5 for the filling and emptying operations. In this case, however, the feed/return culverts of the side ponds are also connected to the filling/emptying culverts of the lock.

4. Gate systems

The following is an overview of the gate systems most employed and installed in locks. In this case no destinction is made between gates for sea (coastal) locks and gates for inland waterways. Certain gate types are employed for both types of application, particularly those designed to withstand alternating head pressures applied from either side.

4.1 Gates for lock emptying and filling

4.1.1 Radial gates without a filling recess

- Installed in both sea locks and inland waterway locks.

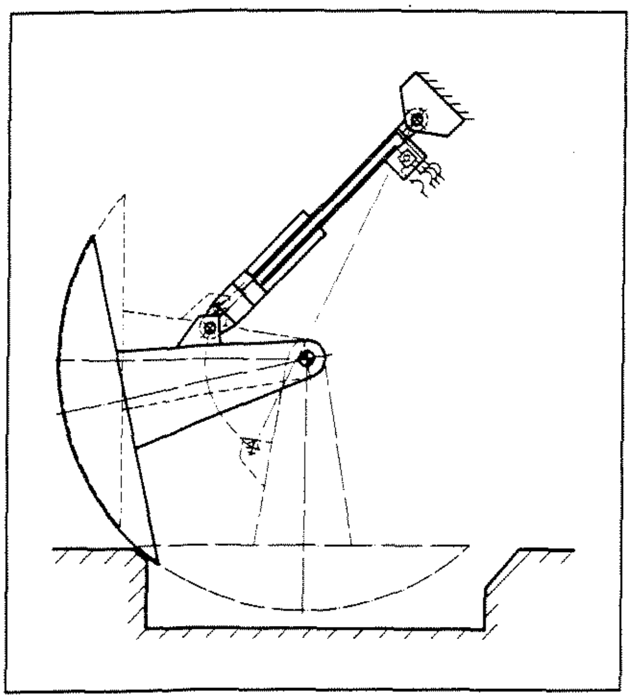

Fig. 11

Initially the radial gate is raised slightly to allow the lockage water to either enter or leave the chamber through the gap at the bottom. Owing to the limited degree to which the inflowing water can be decelerated, such gate systems tend only to be employed in locks which are subjected to minor head pressures.

4.1.2 Radial gates with a filling recess

- Installed in inland waterway locks

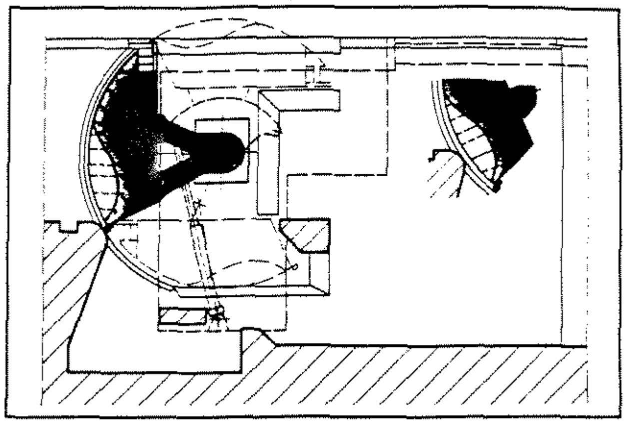

Fig. 12

For filling operations, the gate is initially lowered so that the water can enter the chamber through the filling recess in -the skin plate. The fast-flowing stream is decelerated by the deflector beams, thus preventing strong currents or vortex flows from developing inside the lock.

4.1.3 Lift/lower gates

- Installed in inland waterway locks

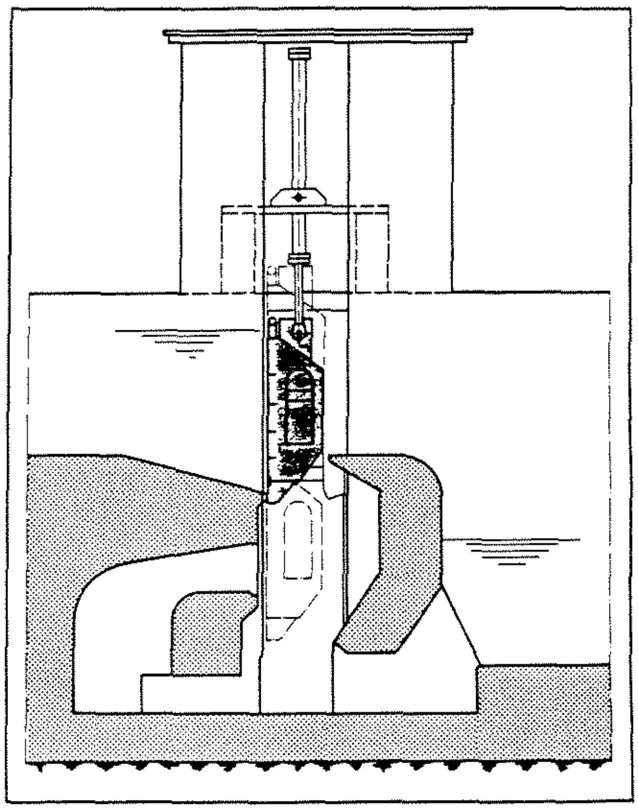

Fig. 13

The gate shown is predominantly employed for the upstream closure of locks subjected to high head pressures. To fill the lock, the gate is initially raised to allow the water to enter the chamber through a gap in the bottom. Once the chamber is full, the gate is lowered out of the way.

For maintenance purposes, the gate can also be raised above the water level by repositioning the hydraulic cylinder.

4.1.4 Lifting tilting gates

- Installed in inland waterway locks

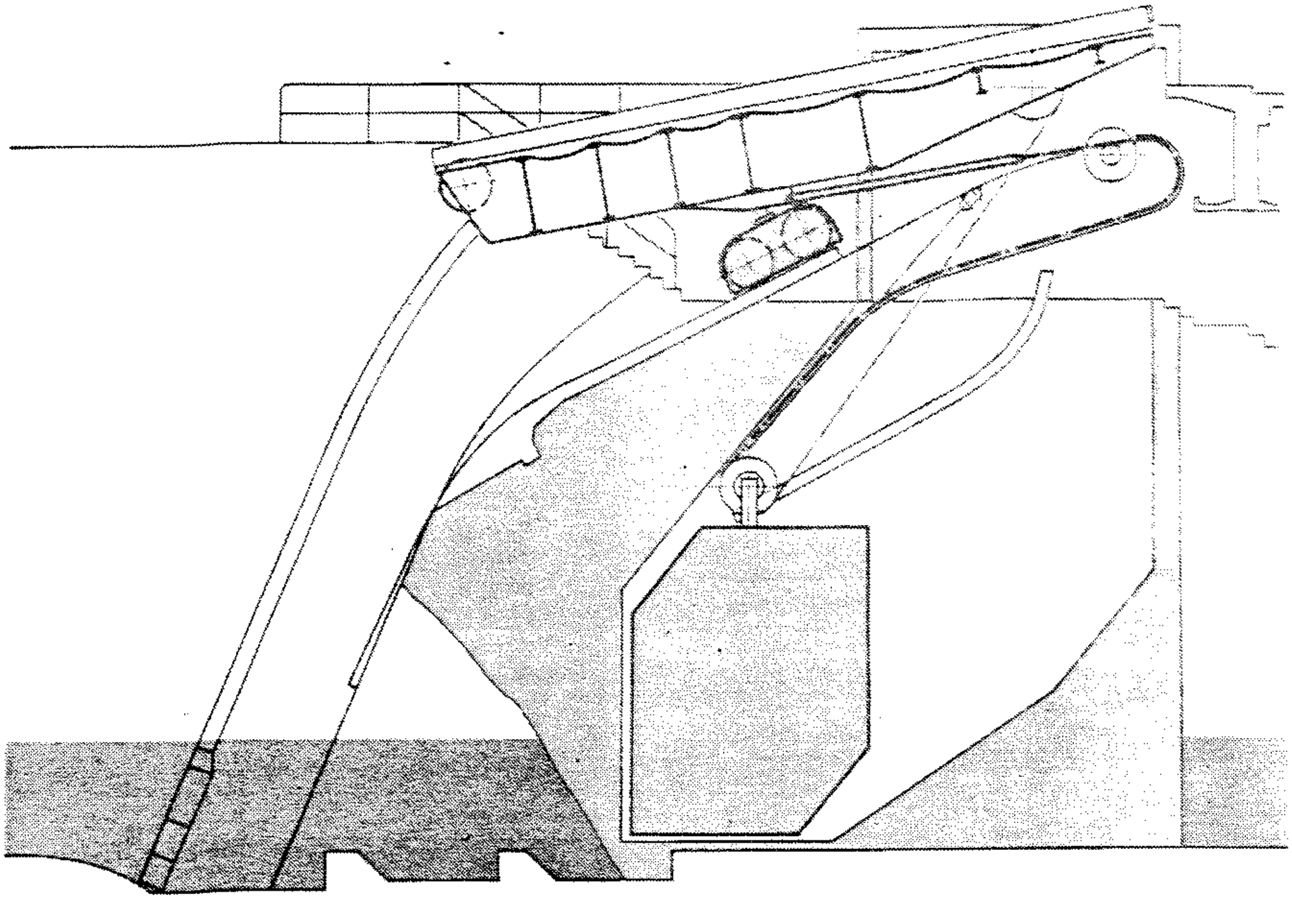

Fig. 14.1

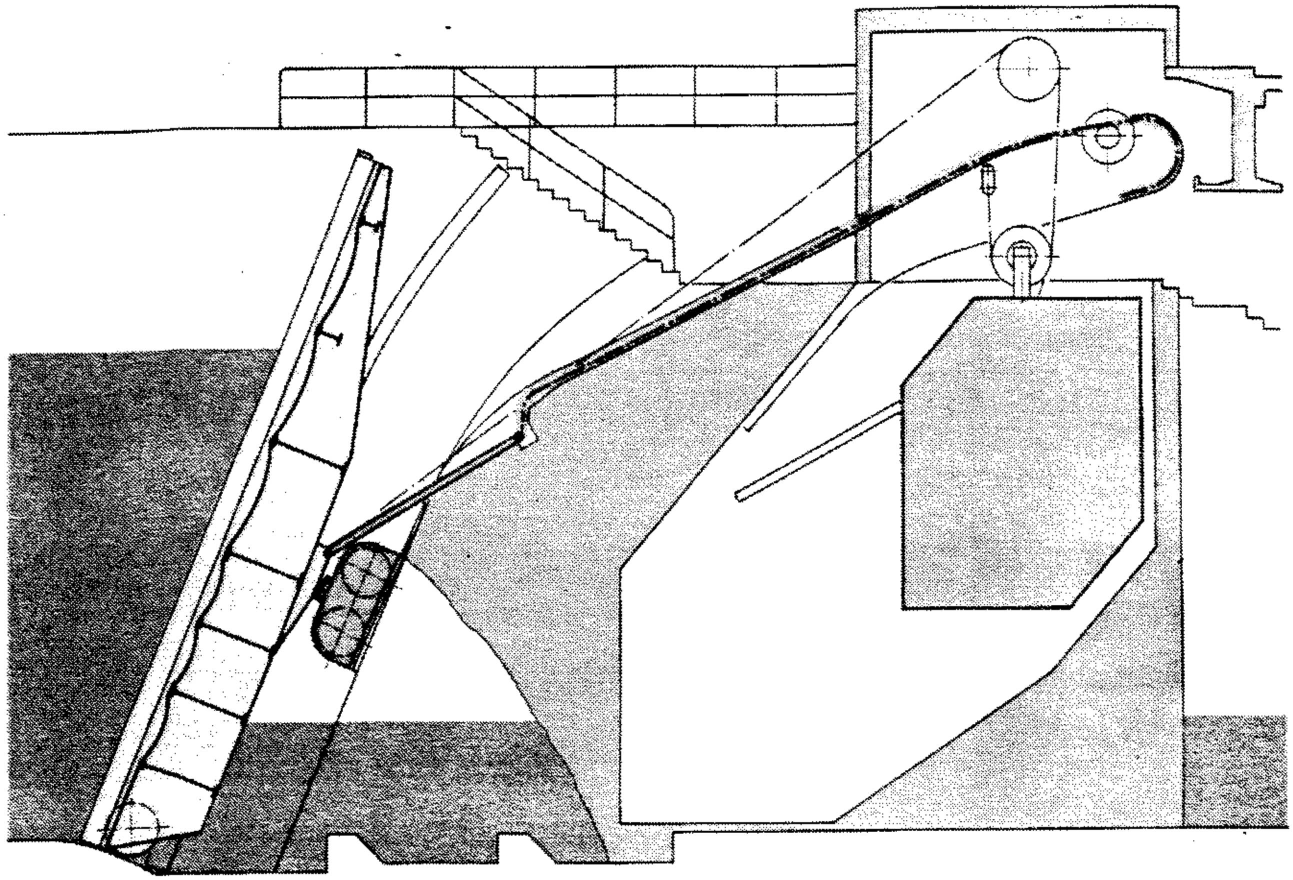

Fig. 14.2

This gate type is predominantly used as the downsteam closure for locks subjected to high head pressures.

To empty the lock, the gate is initially raised, allowing the water to flow out through the gap at the bottom.
Deflectors are arranged on the bed of the downstream side in order to decelerate the fast-flowing stream of water.

Once the lock chamber has been emptied, the gate is raised completely, whereby it assumes an almost horizontal position. The vessels then pass underneath the gate.

4.1.5 Flap type gates
- Installed in inland waterway locks

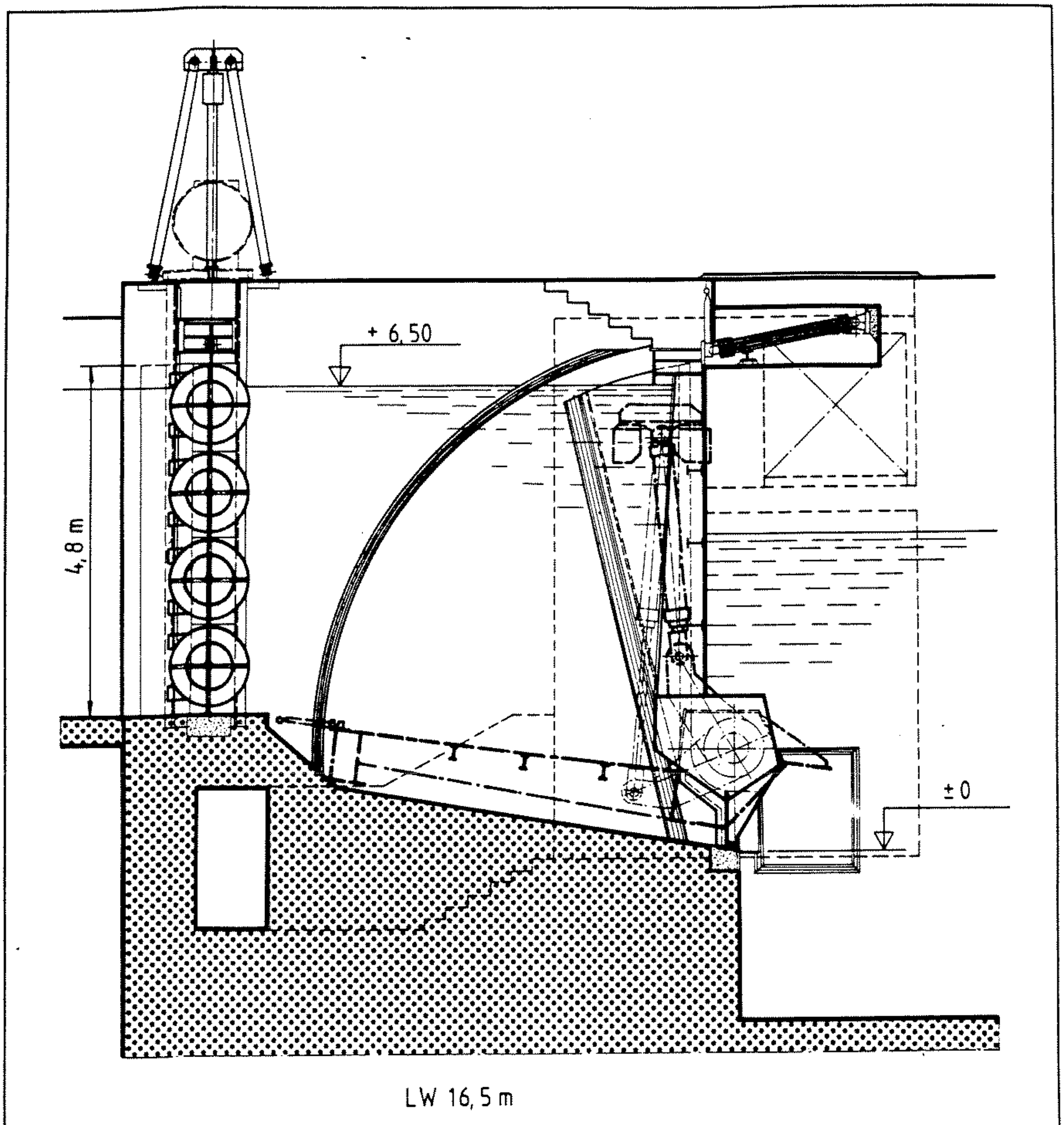

Fig. 15

Flap type gates are also predominantly installed on the upstream side of locks.

Gate rotation in the upstream direction produces an opening below the pivot line, allowing the lock chamber to fill up with water. Once the chamber is full, the gate is lowered down completely. Considerable drive power is required in order to initially open such gates against the head pressure of the upstream body of water for filling to commence.

4.2 Lock gates with integral filling and emptying devices

4.2.1 Mitre gates

- Installed in inland waterway locks

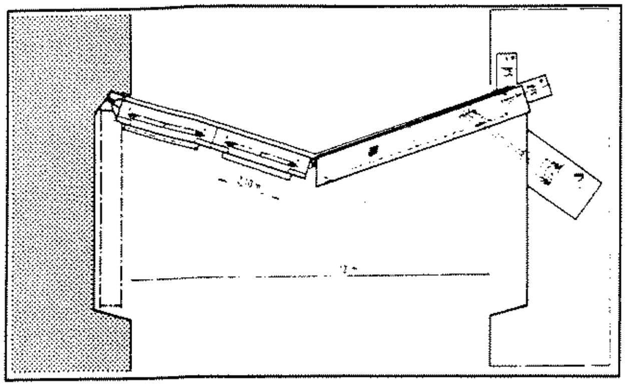

Fig. 16.1

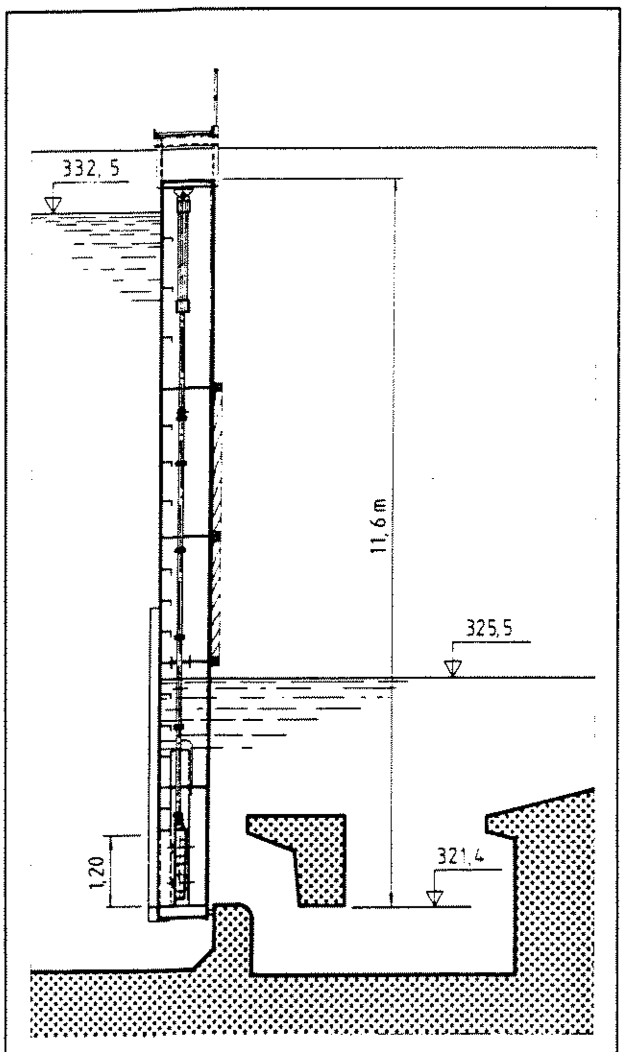

Fig. 16.2

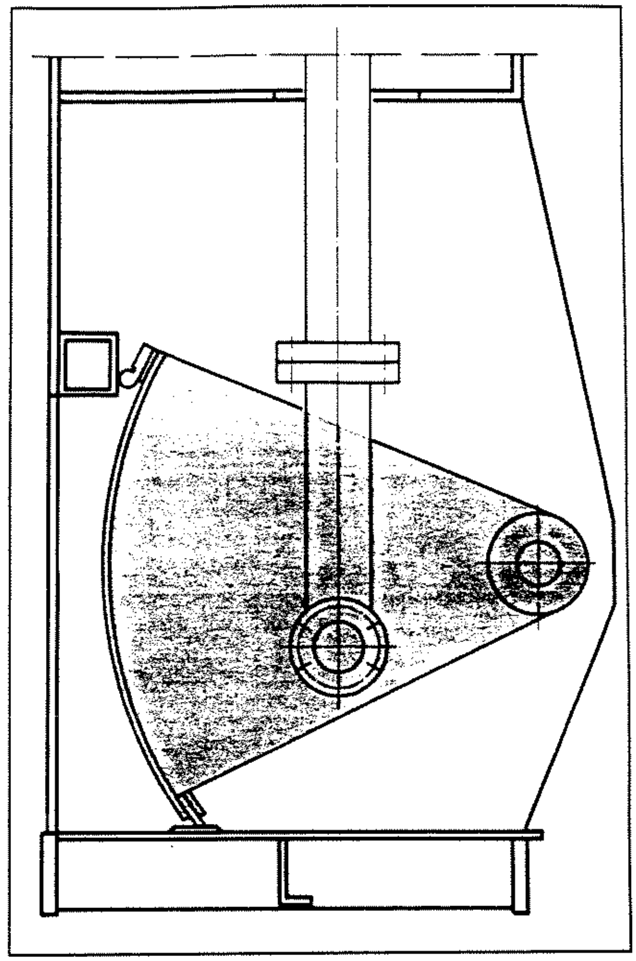

Fig. 16.3

The mitre gate is today the most widely used gate type for upstream lock sealing applications. This is even more the case with regard to the downstream sealing system.

Normally each gate leaf has at least two, and in the case of particularly wide systems, three ancillary gates in the lower section which are opened for lock filling and emptying.

The ancillary gates are either of the wheeled or radial type. If wheeled ancillary gates are employed, these can be arranged either within the main gate or upstream in front of the skin plate, as illustrated.

On the downstream side in front of the opening is a deflector beam which diverts the inflowing stream of water, thus preventing vortex development inside the lock chamber.

4.2.2 Sliding gates with filling and emptying devices

- Installed in sea locks and inland waterway locks

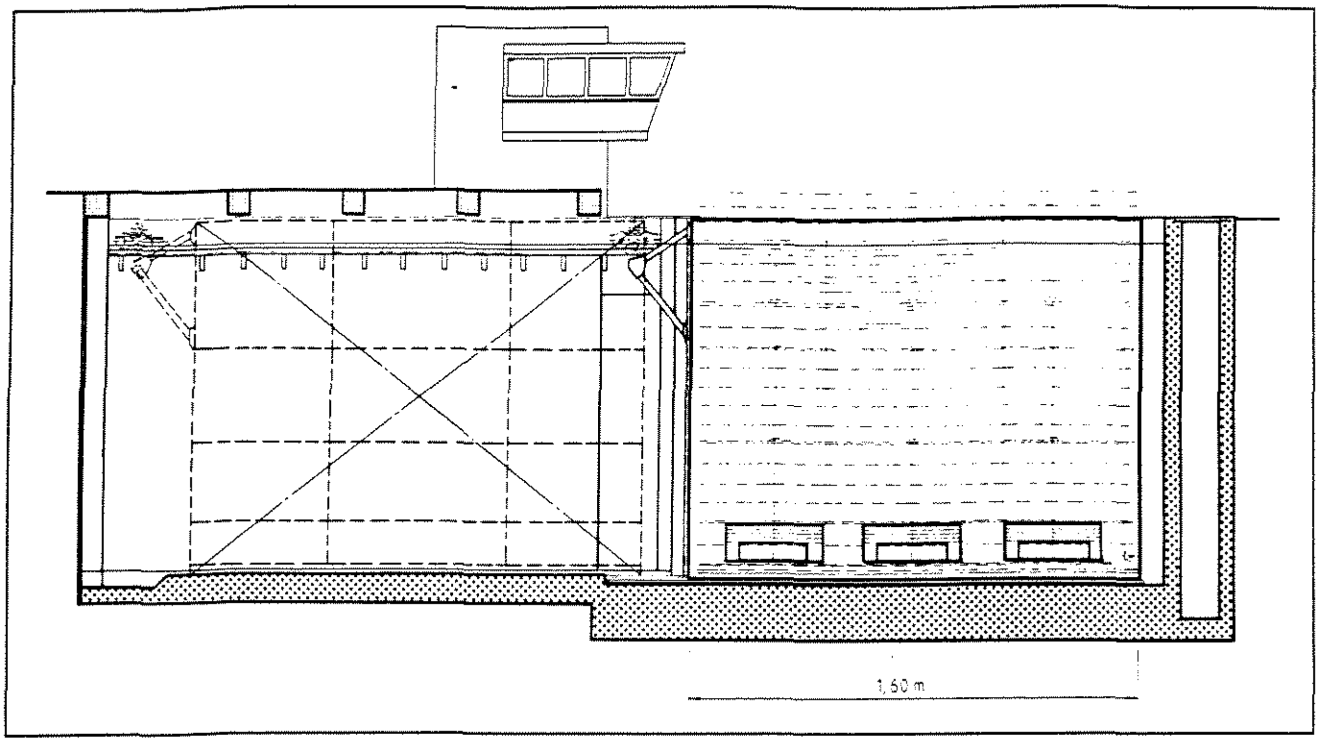

Fig. 17.1

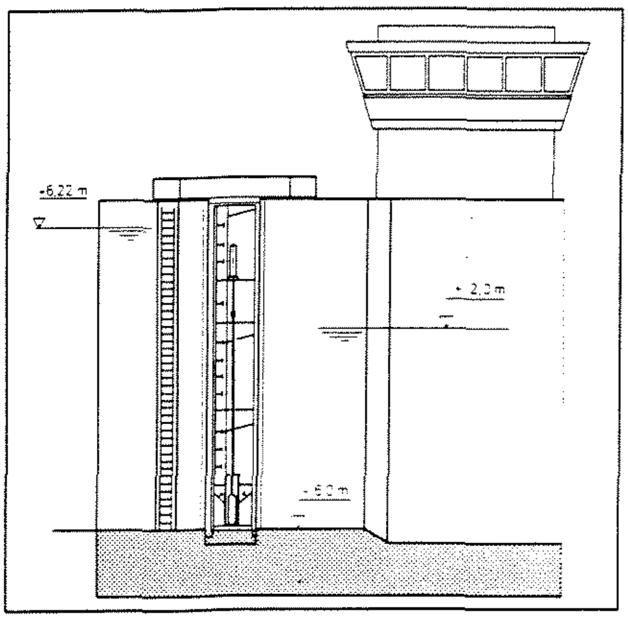

Fig. 17.2

Sliding gates are predominantly employed in sea locks. Designing these to withstand head pressures from both sides of the gate presents few difficulties - an advantage in applications involving ebbing and flowing tides.

Sliding gates too are equipped with filling and emptying devices, preferably in the form of wheeled ancillary gates which can likewise be designed for complete obturation irrespective of the high water side.

4.2.3 Lifting gates with filling and emptying devices

- Installed in inland waterway locks

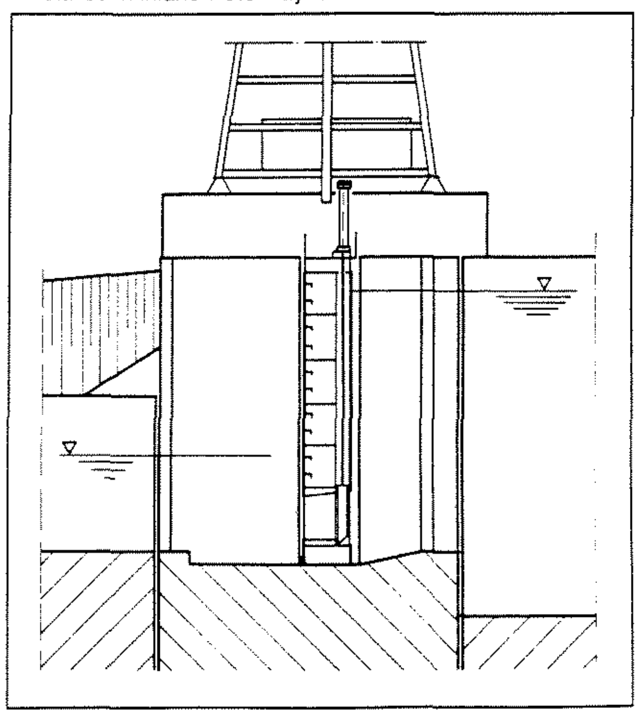

Fig. 18

Arranged at the bottom of these gates are wheeled or radial ancillary gates for filling and emptying the lock chamber. Once the water levels have balanced out, the main gate is raised to allow the vessels to pass underneath.

4.3 Gates for locks with filling and emptying culverts

4.3.1 Stop type swing gates

- Installed in inland waterway locks

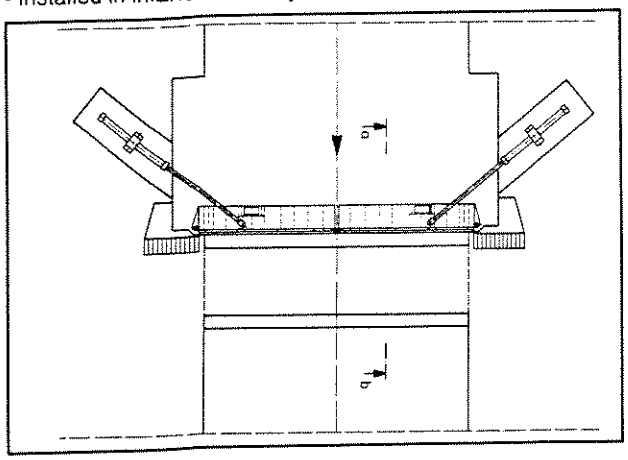

Fig. 19

Stop type swing gates are employed where the gates have to be particularly high, providing the possibility of support at a fixed stop at the top.

In their closed position, the gates are thus supported along three edges - by the sill at the bottom, by the lock chamber wall on one side and by a concrete structure at the top. The gate strength is derived from its vertical members, giving a particularly simple yet robust construction. Gates of this type have been built to heights of 20 m and more.

4.3.2 Mitre gates

- Installed in sea locks and inland waterway locks

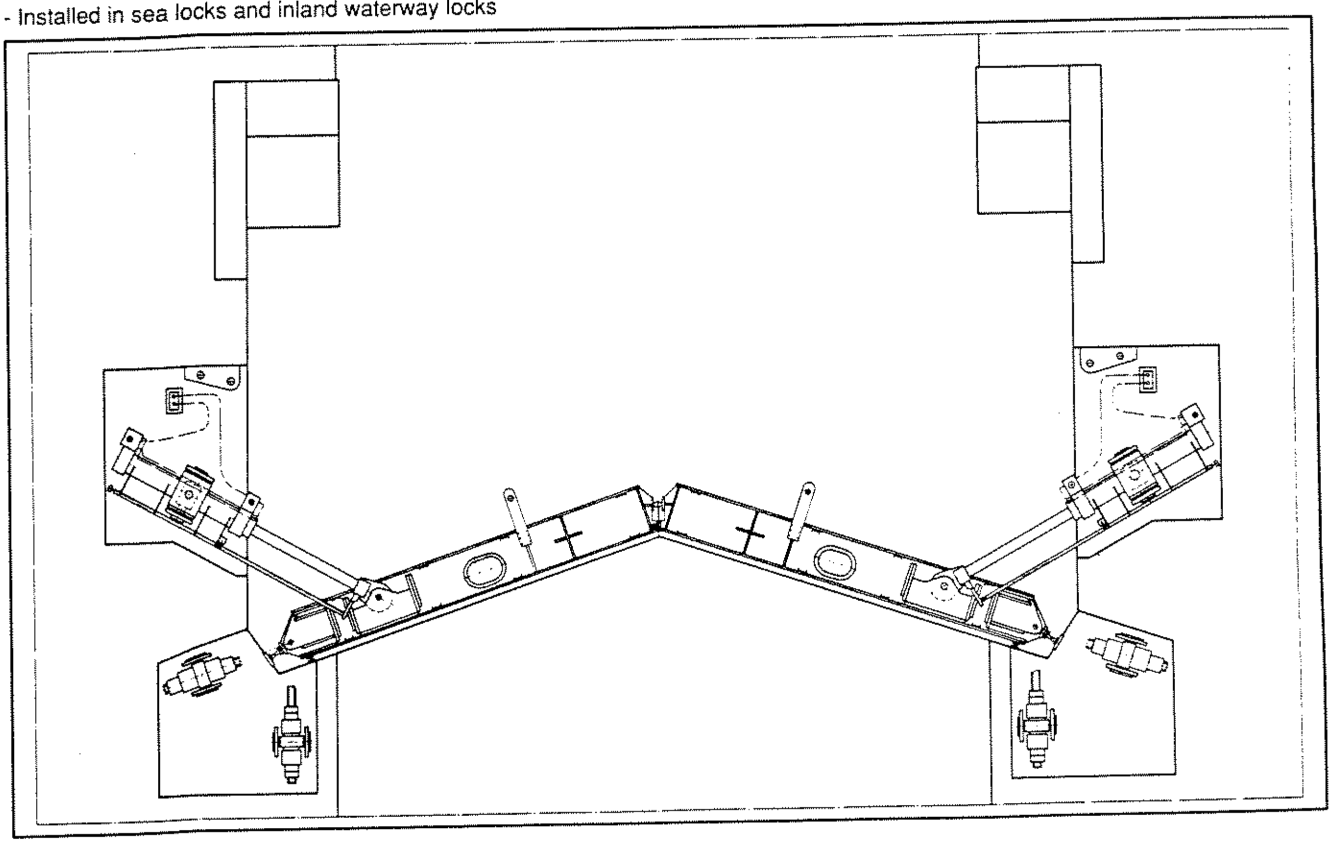

Fig. 20.1

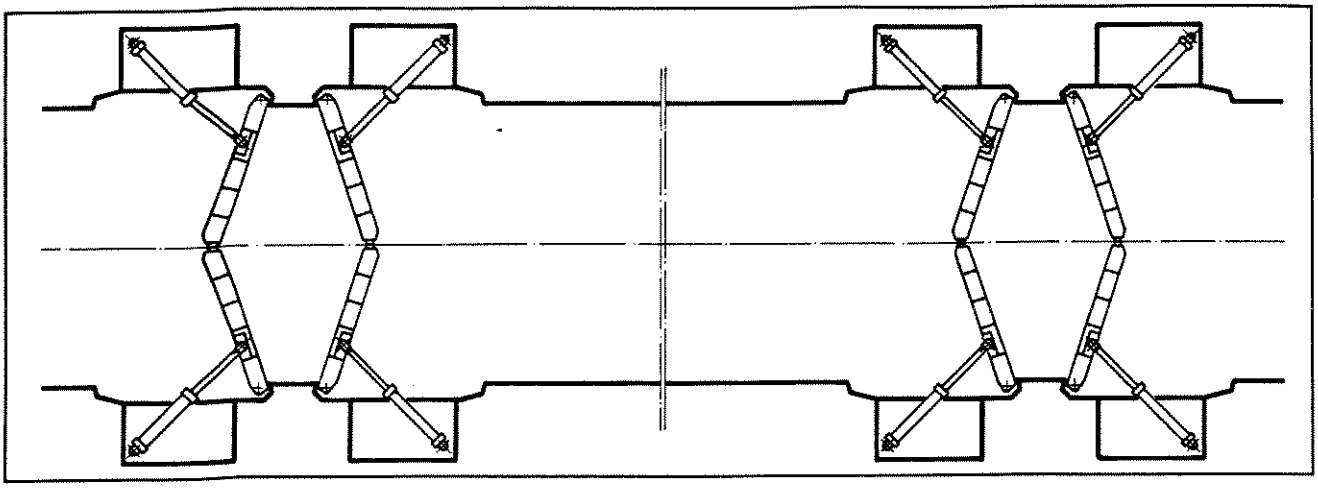

Fig. 20.2

As mentioned above, the mitre gate is the type most used nowadays for locks of all kinds. Owing to its ruggedness and simple design with few moving parts below the water line or in the water interchange zone, it has proven highly successful for both upstream and downstream lock gate applications.

Owing to their functional principle, mitre gates can only withstand head pressure for one side. Consequently, in harbour locks, 2 gate pairs have to be employed as indicated in Fig. 20 in order to cope with the alternating head. One gate is thus arranged to withstand the internal pressure from within the lock and the other to withstand the external pressure of the sea or harbour water.

4.3.3 Radial gates (horizontal axis)

- Installed in inland waterway locks

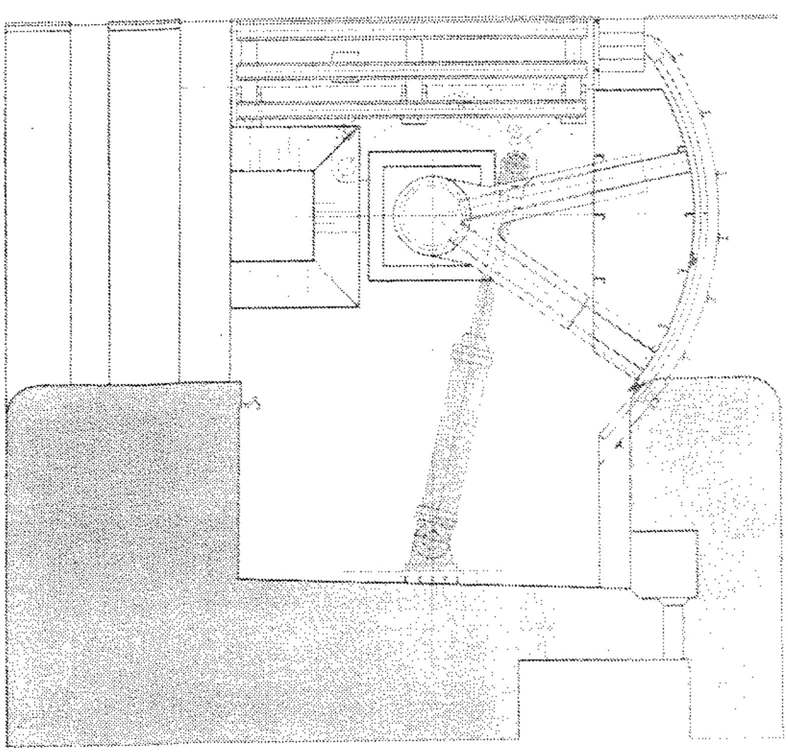

Fig. 21

Radial gates of the design indicated are predominantly employed for the upstream side of the lock. The gate is lowered to allow the vessel to pass. However, the gate can also be raised above the water line for maintenance purposes.

4.3.4 Radial gates (vertical axis)

- Installed in sea locks and inland waterway locks

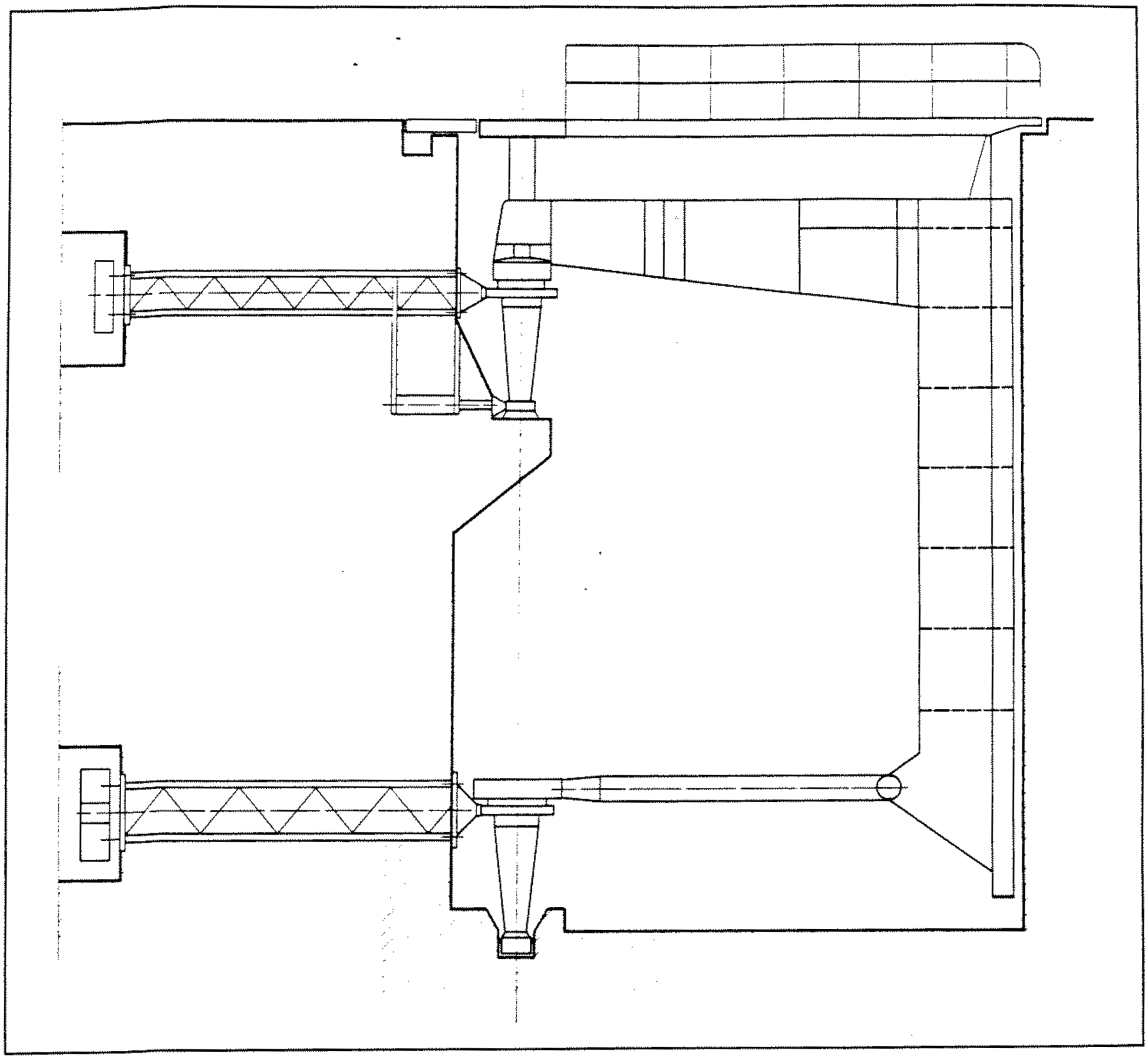

Fig. 22.1

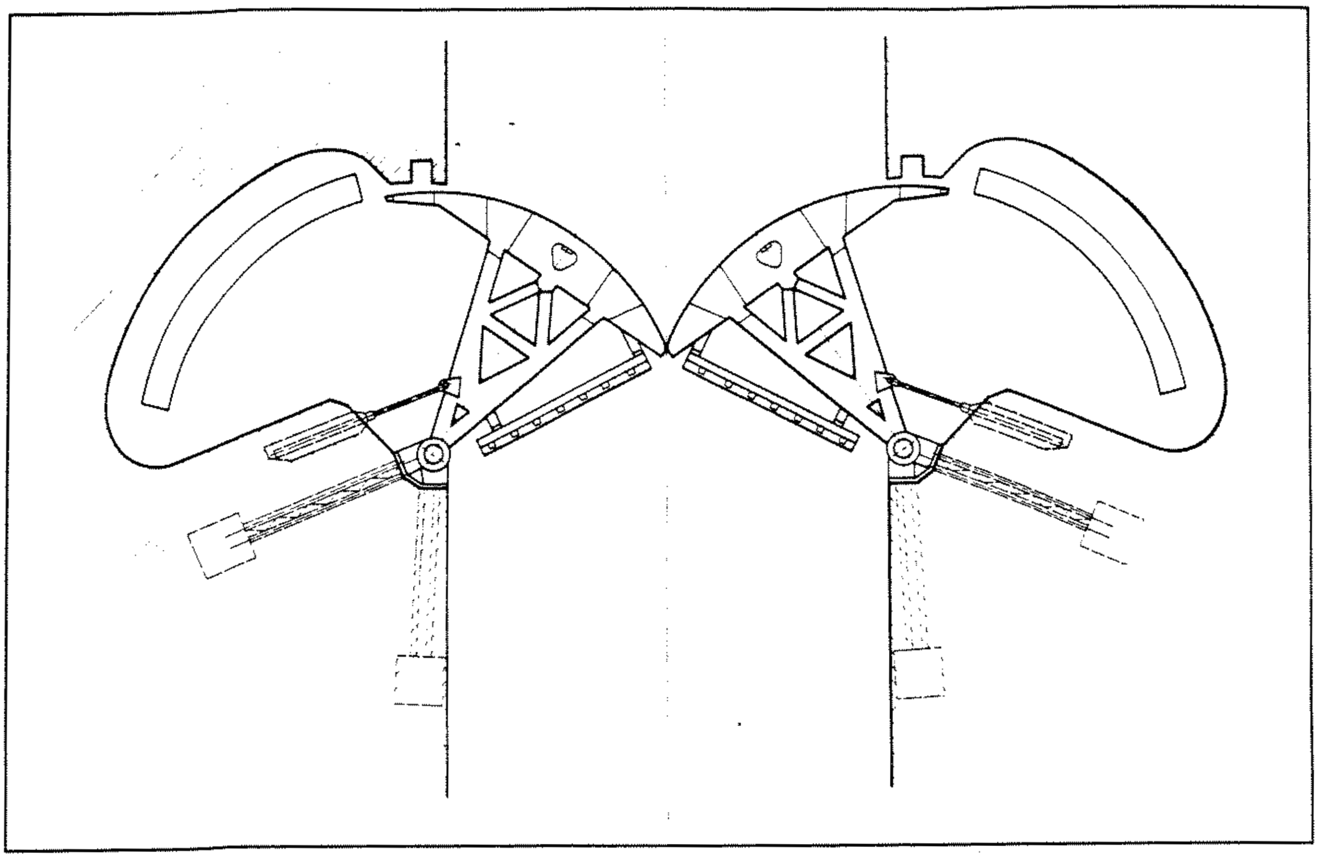

Fig. 22.2

As with radial gates of the vertical axis design, in radial gates with a vertical axis of rotation, the water pressures are absorbed by two pivot bearings. This design is particularly suited to sea locks as it can withstand head pressures from both sides, i.e. from both the sea/harbour water and the lockage water.

4.3.5 Lifting gates

- Installed in inland waterway locks

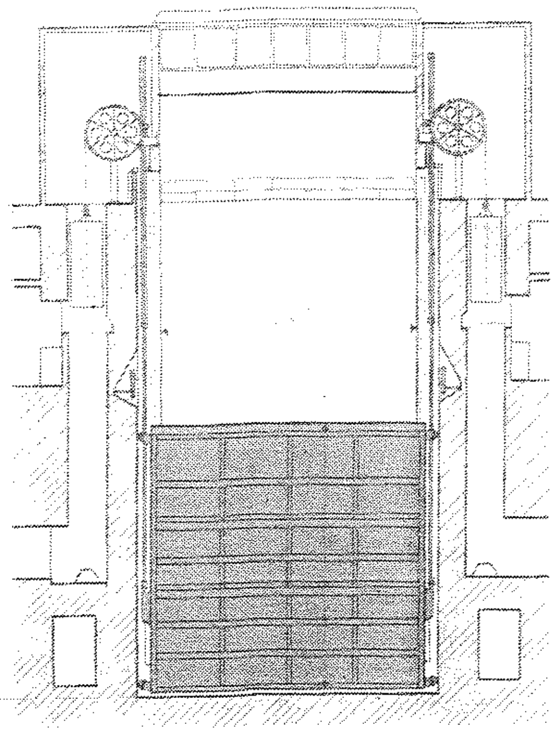

Fig. 23.1

Lifting gates are frequently used in applications involving high head pressures. They offer the advantage of being the shortest of all the options in the lock axis direction. Gate operation only takes place once the water levels have extensively balanced out.

The spring-mounted wheels are therefore only designed for a relatively low water pressure of 20 to 30 cm.

In its water-retaining position, the gate leaf structure is pushed against, and supported by, the guide rails.

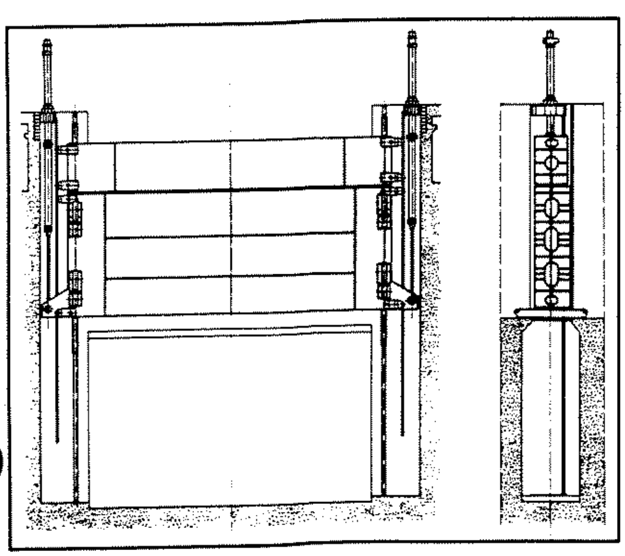

Fig. 24

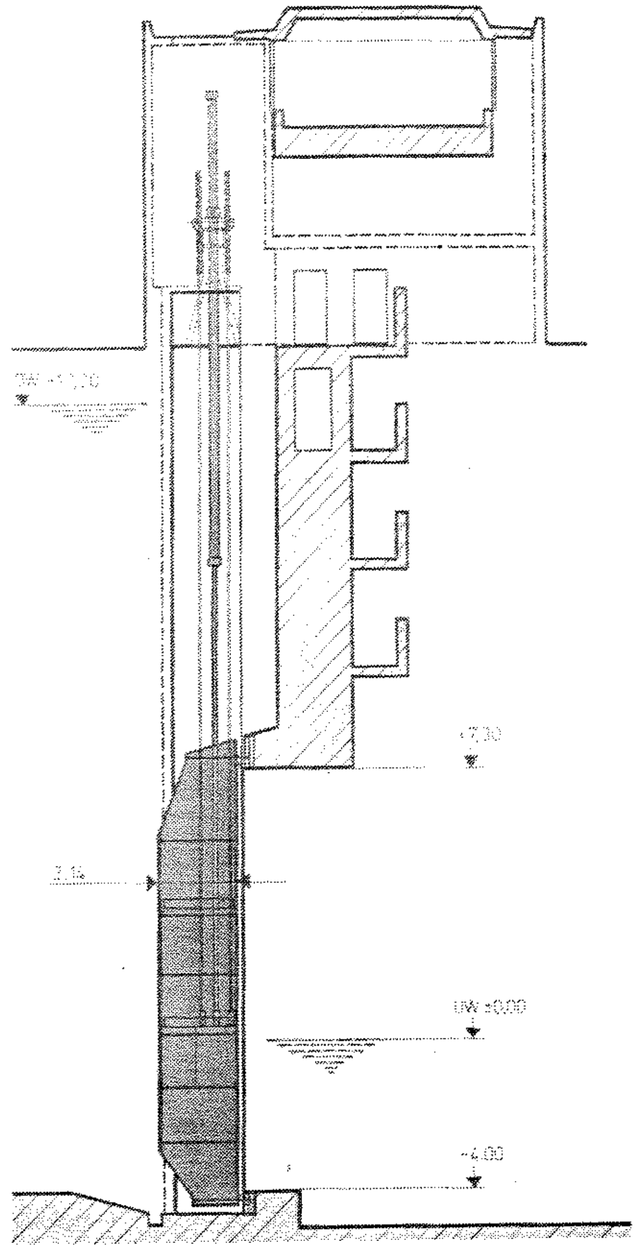

Fig. 23.2

4.3.6 Lowering gates

- Installed in inland waterway locks

Lowering gates are employed both as upstream lock sealing units and as middle chamber gates in staircase lock systems. The gates are lowered to allow the vessels to pass over the top.

4.3.7 Double hook gates

- Installed in inland waterway locks

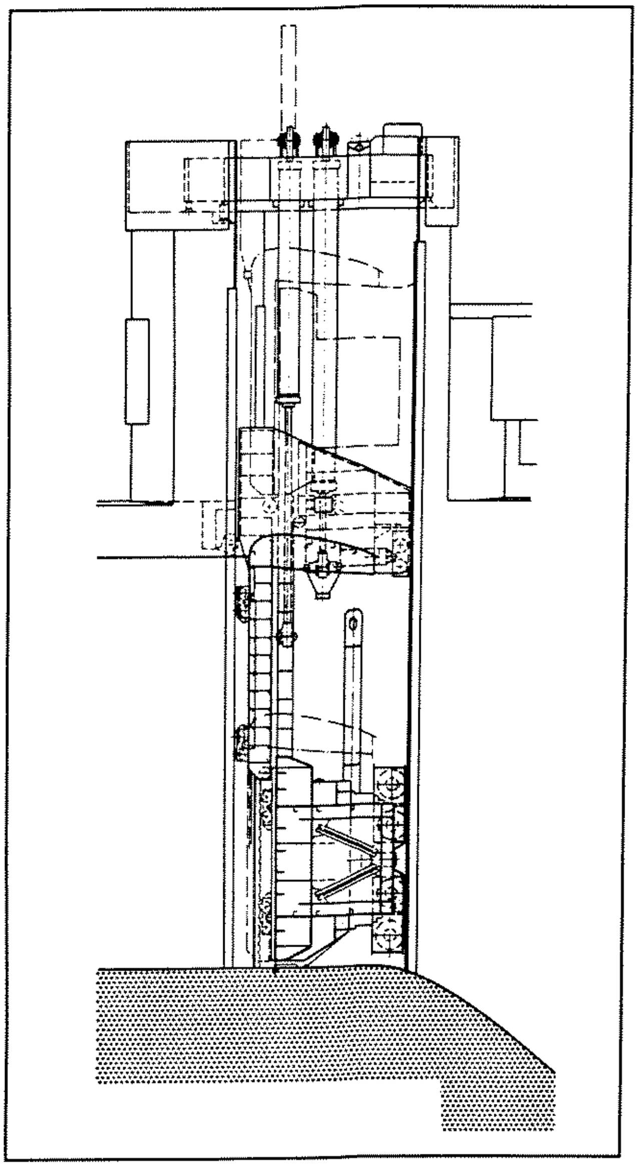

Fig. 25

Double hook gates are employed as the upstream sealing units in special applications such as in the case of regulated rivers. During the construction period or water accumulation phase, the shipping traffic passes under the raised gate. Then, after accumulation has been completed, the upper gate is lowered and the vessels pass over it.

It is also possible to remove drift ice over the lowered upper gate and to flush it out of the lock by utilizing the longitudinal current which is produced by the operation. If, in addition, high waters have to be removed through the lock, this can be effected by raising the lower gate.

In the case of both high water removal and drift ice removal, the bottom gates are locked in their open position.

4.4 Gate types for culverts

4.4.1 Wheeled gates

Installed in sea locks and inland waterway locks

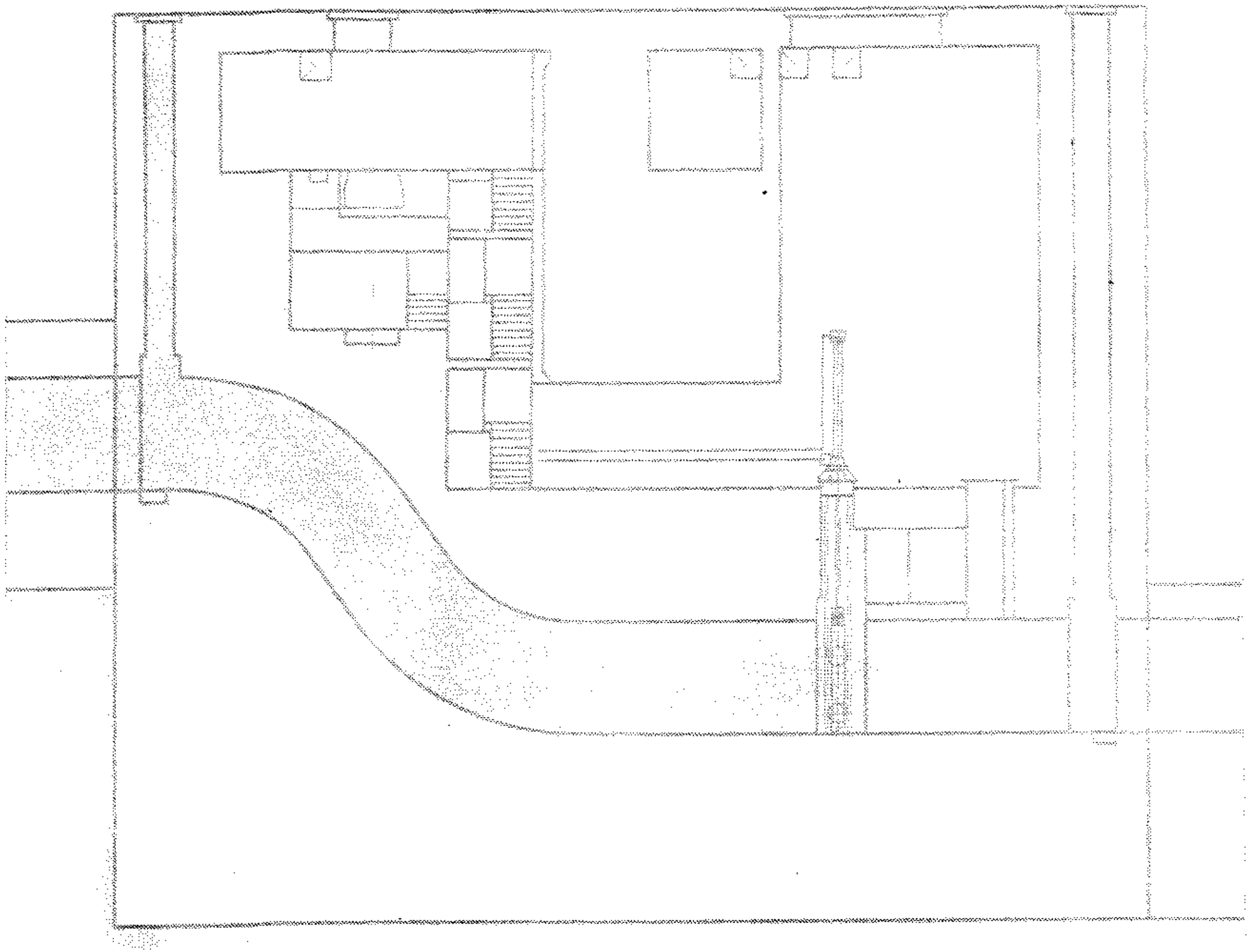

Fig. 26

The wheeled gate is the type most used for culverts, and is invariably hydraulically driven. Depending on the requirements of the application, the gate operates either in a shaft with a freely variable water level or in a closed shaft with a pressure cover on which the hydraulic cylinder is mounted.
Nowadays these gates are controlled by proportional valves in order to vary the gate opening speeds so that the rise and fall rate of the water level in the lock can be optimized.

4.4.2 Radial gates
- Installed in sea locks and inland waterway locks

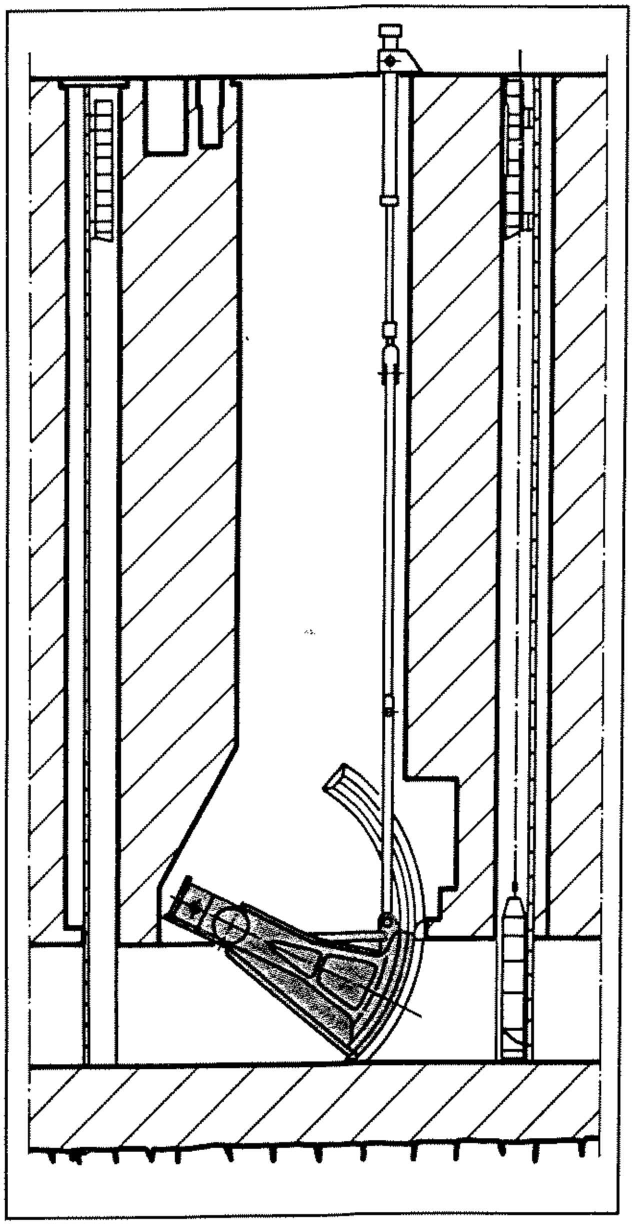

Fig. 27

Radial locks are predominantly used for relatively large filling and emptying culvert cross sections as they require substantially less drive power than is the case with wheeled gates. The gate arrangement is normally such that the head pressure acts in the compression direction on the gate arm assembly. However, there are systems in service in which the arms are in tension. As regards the gate controls, the same criteria apply as indicated in section 4.4.1.

4.4.3 Cylindrical gates
- Installed in inland waterway locks

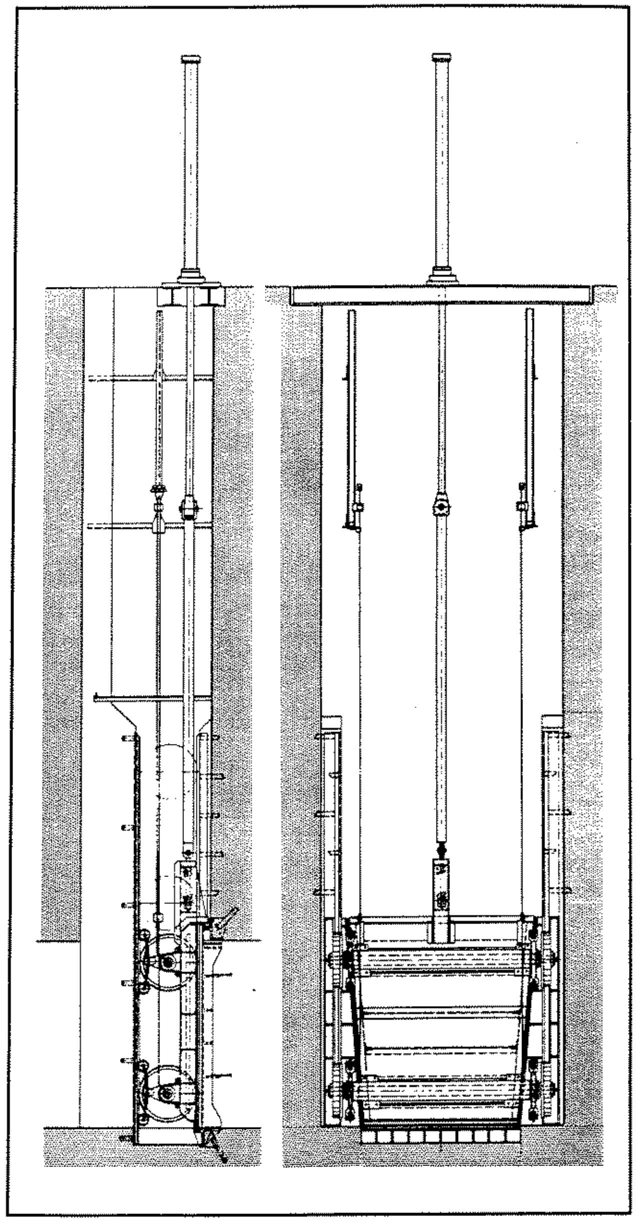

Fig. 28

Cylindrical gates are often found in older lock systems, and particularly upstream as the filling gates. Their advantages lie in their simple, robust construction and low drive power requirement.

4.4.4 Wedge type wheeled gates

- Installed in inland waterway locks

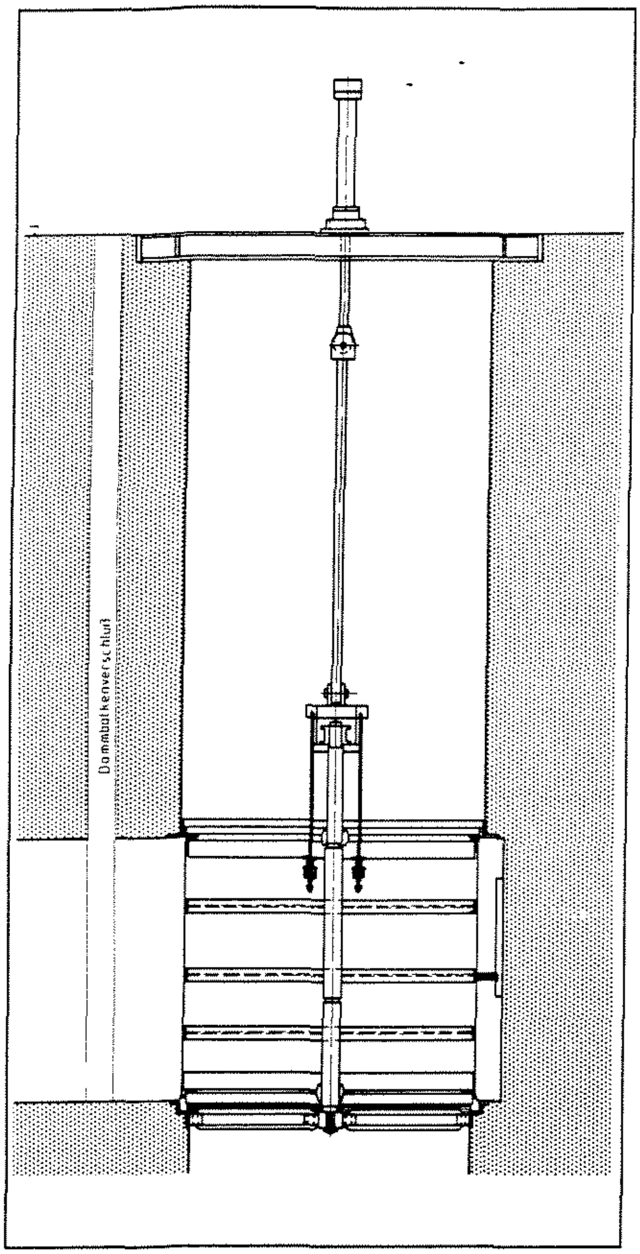

Fig. 29

The wedge type wheeled gates is a special modification of the wheeled gate described in section 4.4.1. This gate type is still frequently found in the older systems. The cross section is trapezoidal in shape and in their original condition these gates were equipped with metallic seals.

General remarks:

The current state of the art is to equip all the above-described gates with hydraulic drives, with the lock gates being controlled either by proportional valves or variable displacement pumps with proportional control.

This ensures that, in the case of particularly heavy moving masses, the requisite long acceleration and deceleration times are achieved together with the necessarily variable lifting and lowering speeds for the filling and emptying operations.

Experience has shown that adapting the acceleration and deceleration times to the gate operating conditions considerably increases the service life of the wheels, bearings, guideways, etc.

The gate and its moving parts are reliably protected against the occurrence of shock loads. Moreover, the hydraulic drive can also be designed for optimum overload protection, which if necessary can be graduated over the length of the stroke.