Bascule bridges at the Berendrecht lock in the port of Antwerp, Belgium

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1 Introduction

The construction of the Berendrecht lock in the port of Antwerp started in 1983. After completion in 1988 this lock with a width of 68 m and a length of 500 m, will be the biggest lock in the world. Situated some hundred meters south of the Zandvliet lock, this complex of two locks will form the main access to the right bank of the port of Antwerp.

The older Zandvliet lock had a bascule bridge on the dock side, Zandvliet bridge, to allow road and railroad traffic to cross the lock. This bridge was put into operation in 1966.

During the construction of the Berendrecht lock the construction of three new bascule bridges was planned.

These bridges are:

- Frederik-Hendrik bridge across the Zandvliet lock on the river side
- Oudendijk bridge across the Berendrecht lock at the river side
- Berendrecht bridge across the Berendrecht lock on the dock side

The three bridges are basically the same. The main differences with the older Zandvliet bridge are:

- The greater weight of the new bridges due to more stringent requirements from road and railroad traffic
- The use of two-row self-aligning spherical roller bearings for the rotation points of the bridges. Zandvliet bridge was originally equipped with self-lubricating friction bearings which failed after a few months of operation and had to be replaced by grease lubricated bronze friction bearings.

The Frederik-Hendrik and Oudendijkbridge went into operation in 1984 and 1985 respectively. Berendrecht bridge is under construction and will be finished in 1988. The bridge deck of the Frederik-Hendrik bridge is 62.9 m long and 10.2 m wide. The Oudendijk and Berendrecht bridges are 74 m long and 10.2 m wide. All three bridges have a railway track embedded in the road.

This article gives a description of the main components of the hydromechanical equipment of the three new bridges.

2 Bascule mechanism

Figures 1 and 2 give a general survey of the bascule mechanism of the bridge. The bridge structure is supported by two bascule axes built-in a torsional tube connecting both main girders. Each bascule axis has one two-row roller bearing. The weight of the framework of the Frederik-Hendrik bridge amounts to 1,135 t and the Oudendijk and Berendrecht bridges to 1,189 t. The counterweights amount to 1,010 t and 1,283 t respectively.

Two almost vertically mounted hydraulic cylinders create the bascule movement. The bridge rotates 86 °. Each cylinder is mounted in a support, allowing rotations in two, mutually perpendicular axes *(see figure 3)*. The first rotation, which in fact is a pendular movement, is due to the rotation of the bridge. The second rotation is provided for to cope with possible misalignment of the axes of the cylinder with the axes of the bridge. The axes for the first rotation are mounted on two-row self-aligning spherical roller bearings. The axes for the second rotation are mounted in a friction bearing composed of a stainless steel shell shrink fit on the axis and a bronze friction material. The connection of the cylinder to the main girder of the bridge is made by screwing an eye-shaped end to the cylinder rod. A two-row spherical roller bearing is mounted in the eye-shaped end and an axis is put through it and built into the main girder. Roller, as well as frictional bearings, are lubricated with a MoS_2 grease. The equivalent static bearing load of roller bearings is calculated in accordance with ISO 76 standard. A safety factor of 1.5 is applied to obtain the allowable static load rating.

The mechanical elements of the bascule mechanism are designed in accordance with a serie of Belgian standards NBN E 52. These standards, dating from 1980 and originally intended to design cranes, give a detailed calculation method for the dimension of mechanical elements against rupture and fatigue. The Ministry of Public Works uses them for the design of mechanical elements not only in movable bridges but in all other fields such as locks, floodgates, and lifts as well as, of course, cranes.

3 Bolting mechanism for the open position of the bridge and hydraulic dampers

In open position the bridge is, at the lower end of the counterweight, blocked between the front wall of the cellar at one side and a bolting mechanism at the other. At the front wall of the cellar two hydraulic dampers are mounted.

They serve two purposes:

1 In a compressed position, they provide one of the supports for blocking the bridge

2 They are designed to dissipate the kinetic energy of the bridge when, due to technical failure, the bridge should not decelerate to its normal approach speed

The bolting mechanism is shown in *figure 4*. In open position the free movement measured at the lower end of the counterweight is only 5 mm. This limit is necessary to make sure that a varying wind load does not cause premature wear on the cylinder seals.

Whereas the bascule mechanism elements are calculated to overcome wind pressure of up to 600 N/m^2 bridge surface, the bolting mechanism parts have to withstand wind pressures of up to 1,500 N/m^2.

4 Bolting mechanism for the closed position and centre mechanism

Although in its closed position an unbalance of 1,000 kNm keeps the bridge closed, railway authorities wanted a mechanical device to lock the bridge. A solution was found by using a simple mechanism consisting of a steel cylinder mounted on the land side and a ring-shaped element on the bridge. When the bridge is closed small hydraulic cylinders push the steel cylinder into the ring shaped element on the bridge.

At the flap end of the bridge a cylinder is also fixed which, at the closing of the bridge, moves into a V-shaped construction on the land side as shown in *figure 5*. This centre mechanism makes sure that at each manoeuvre the bridge returns exactly to the same position. This is, of course, an absolute necessity for a railway bridge.

5 Hydraulic equipment

All mechanisms have hydraulic cylinders to drive them. The main characteristics of the hydraulic equipment is shown in *table 1*. Its design is based on standards specified by the Ministry of Public Works and based on thirty years of experience.

Some of the most significant specifications are:

1 The cylinder jacket is designed for a pressure of 1.5 times, the maximum working pressure. Lame's formula is used and the safety factor against rupture is 4.

2 Euler's formula is used to design the cylinder rod. The safety factor against buckling is 1.5.

3 Oil flow is limited to 3 m/s.

4 All important bearings are two-row, self-aligning spherical roller bearings.

5 Cylinder rod material is ASI 431 with a layer of at least 35 micron Cr to obtain a hardness HB 30 of 225-275, unless specific conditions require the use of other materials.

6 Connection of piping is done by making use of flange couplings with O-rings.

Particular specifications for this project were:

1 Four pump groups deliver the total oil flow. By doing so, the slow approach speed can be precisely controlled by shutting down three pumps and using the fourth. By doing so internal leakage flow into the pump is only a minor disturbance factor.

2 Piping from one pumping group is separated from the others. At the cylinder jacket the piping is interconnected. Safety reasons make such a solution advisable.

3 Auxiliary pumps bring the circuit pressure to 10 bar before the main pumps are started. Cavitation and an underpressure are thus eliminated. A simplified scheme of the hydraulic circuit is shown in *figure 7*.

4 The oil reservoir tank is made of stainless steel. No risks exist for the formation of corrosive products due to the contact with wet air entering the oil circuit.

6 Automatic control and regulation

The motion law of the bridge is shown in *figure 6*. Limit switches on the bascule axes detect the position of the bridge. Their information is collected by a programmable controller. This controller commands the flow-controlling mechanism of the pumping groups. The controller also changes and checks the traffic and shipping signs prior to a bridge manoeuvre.

		Frederik-Hendrik brige	Oudendijk bridge Berendrecht bridge
1	**Bascule mechanism**		
	a cylinder		
	number	2	2
	bore	630 mm	750 mm
	rod	315 mm	360 mm
	stroke	3,800 mm	3,800 mm
	working pressure	245 bar	245 bar
	disposition	vertical	vertical
	b hydraulic pump group		
	number	4	4
	type of pump	variable flow axial piston pump	variable flow axial piston pump
	driving electromotor power	75 kW	110 kW
2	**Bolting mechanism open position**		
	a cylinder		
	number	2 x 2	2 x 2
	bore	125 mm	125 mm
	rod	70 mm	70 mm
	stroke	230 mm	230 mm
	working pressure	204 bar	204 bar
	disposition	horizontal	horizontal
	b hydraulic pump group		
	number	2 x 2	2 x 2
	type of pump	fixed flow axial piston pump	fixed flow axial piston pump
	driving elctro motor power	7.5 kW	7.5 kW
3	**Bolting mechanism closed position**		
	a cylinder		
	number	2	2
	bore	50 mm	50 mm
	rod	28 mm	28 mm
	stroke	200 mm	200 mm
	working pressure	100 bar	100 bar
	disposition	horizontal	horizontal
	b hydraulic pump group		
	number	2	2
	type of pump	gear pump	gear pump
	driving electromotor power	1.1 kW	1.1 kW

Table 1: *Main characteristics of the hydraulic equipment*

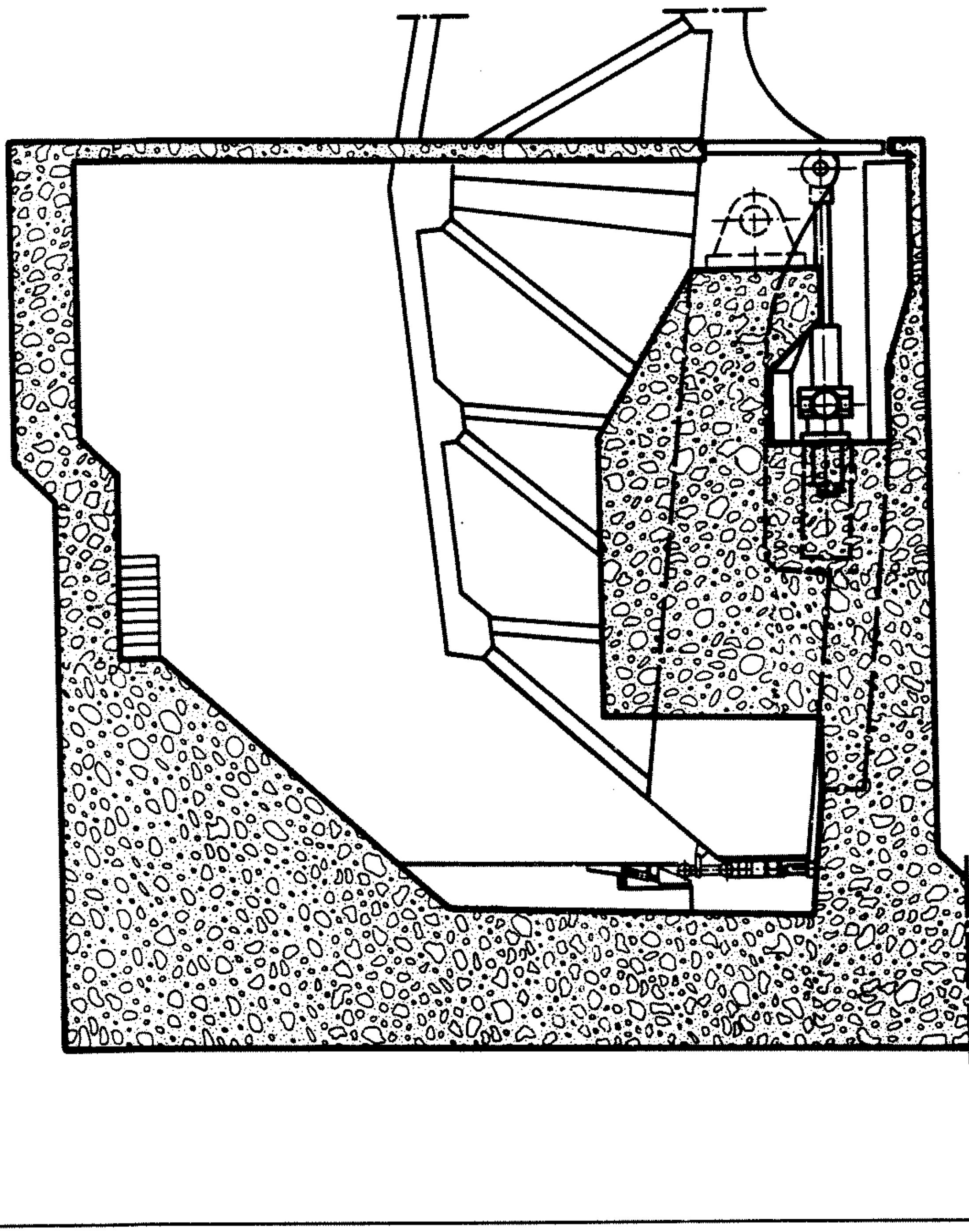

Fig. 1: *Frederick Hendrik bridge, side view*

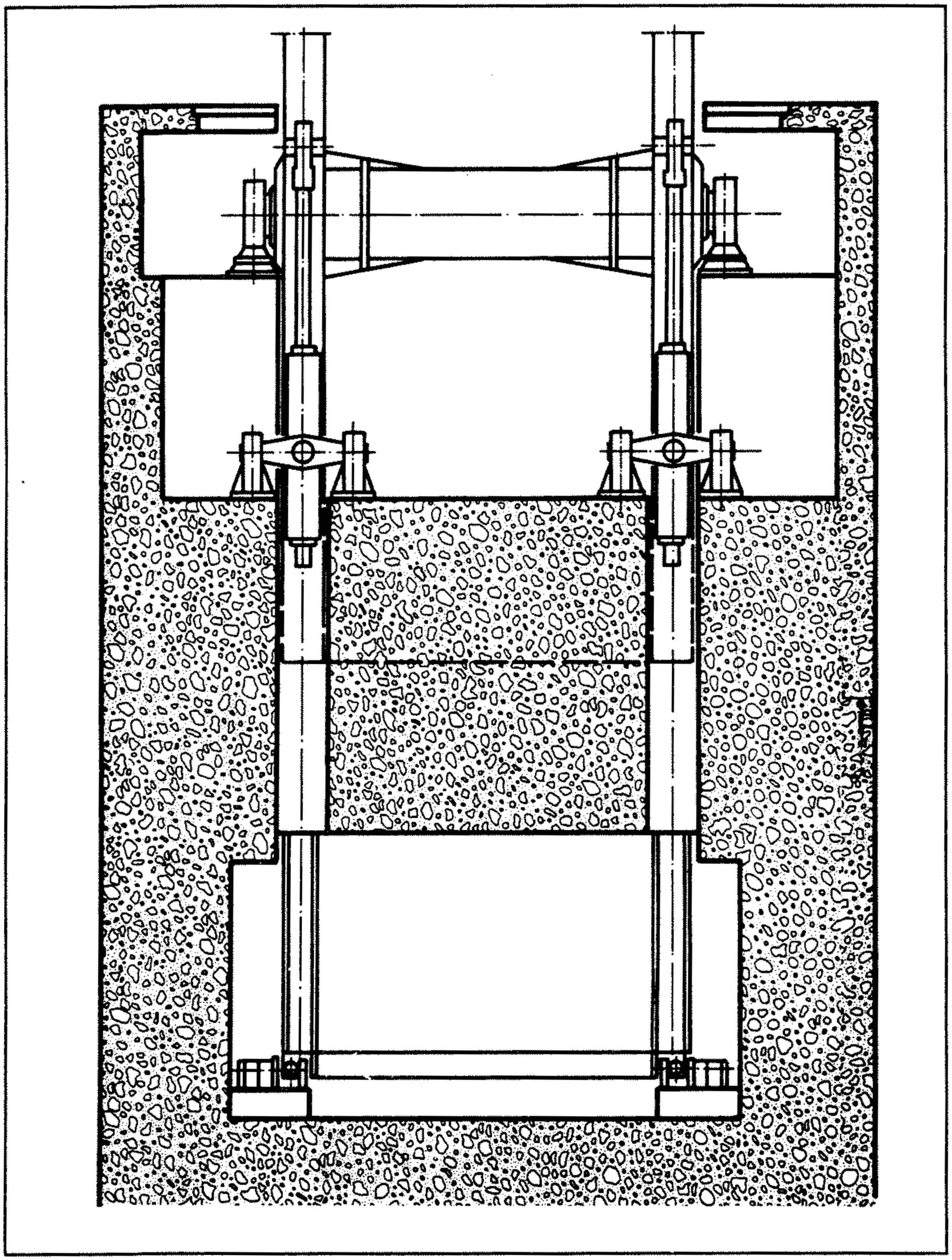

Fig. 2: *Frederick Hendrik bridge, front view*

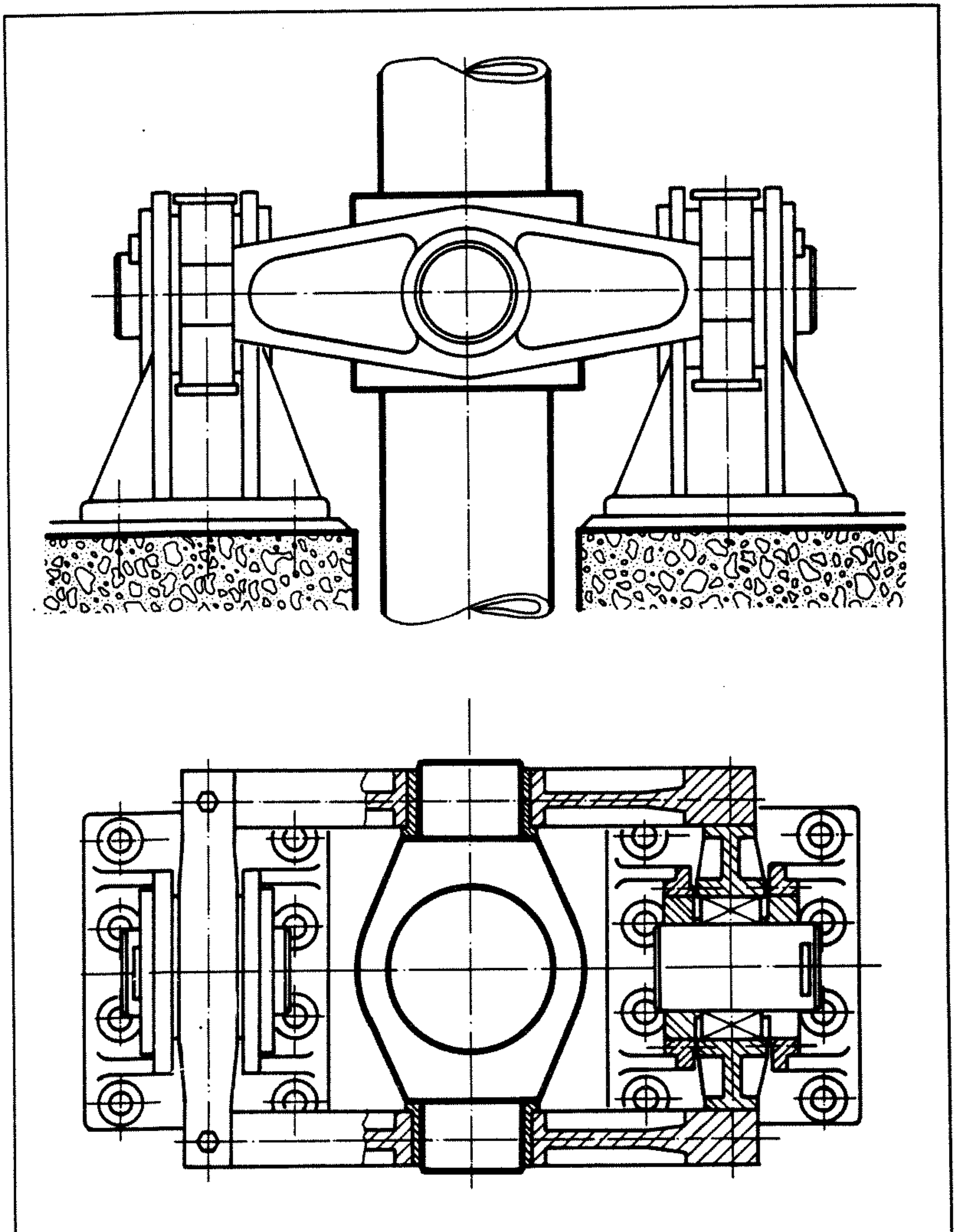

Fig. 3: *Frederick Hendrik bridge, disposition of the hydraulic cylinder*

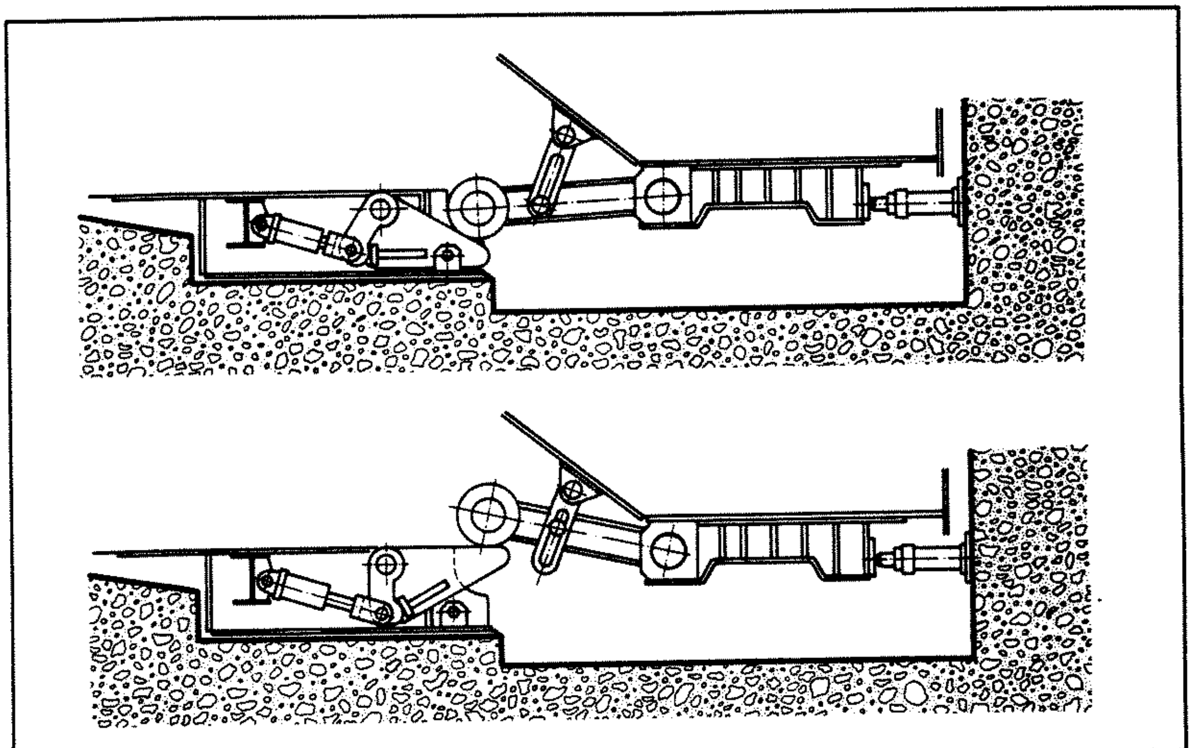

Fig. 4: *Bolting mechanism for the open position*

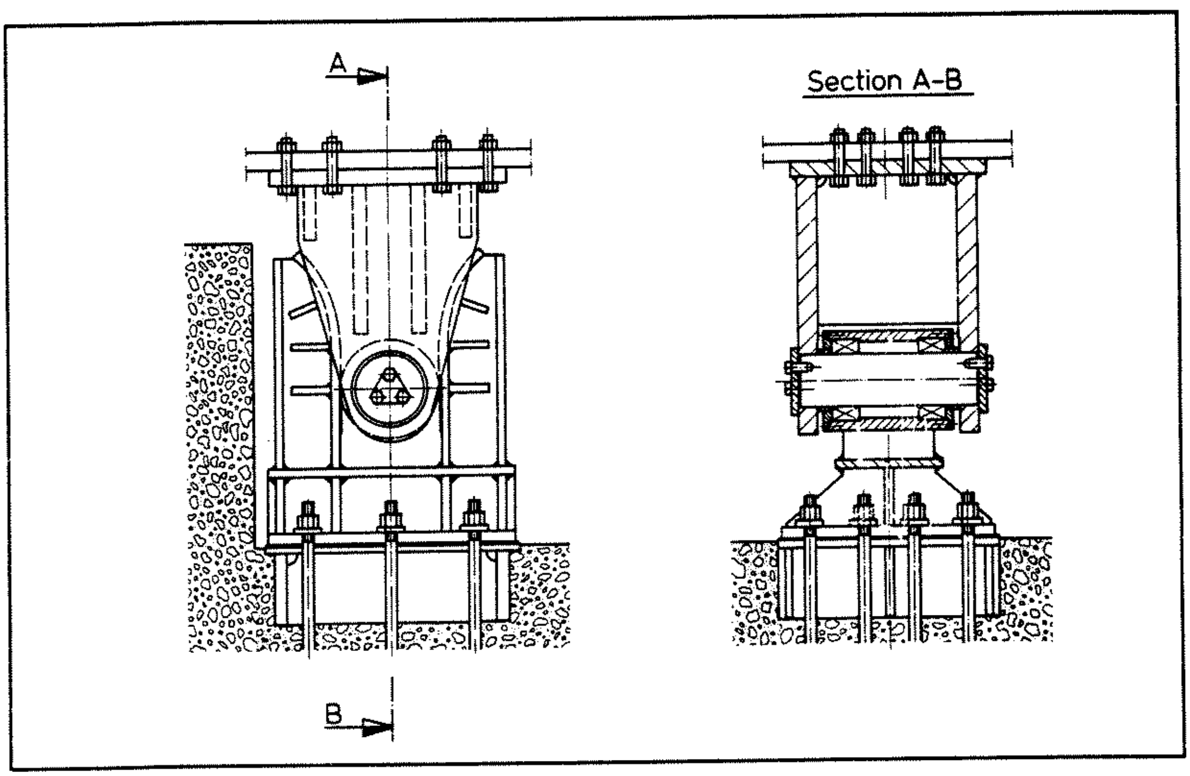

Fig. 5: *Centre mechanism*

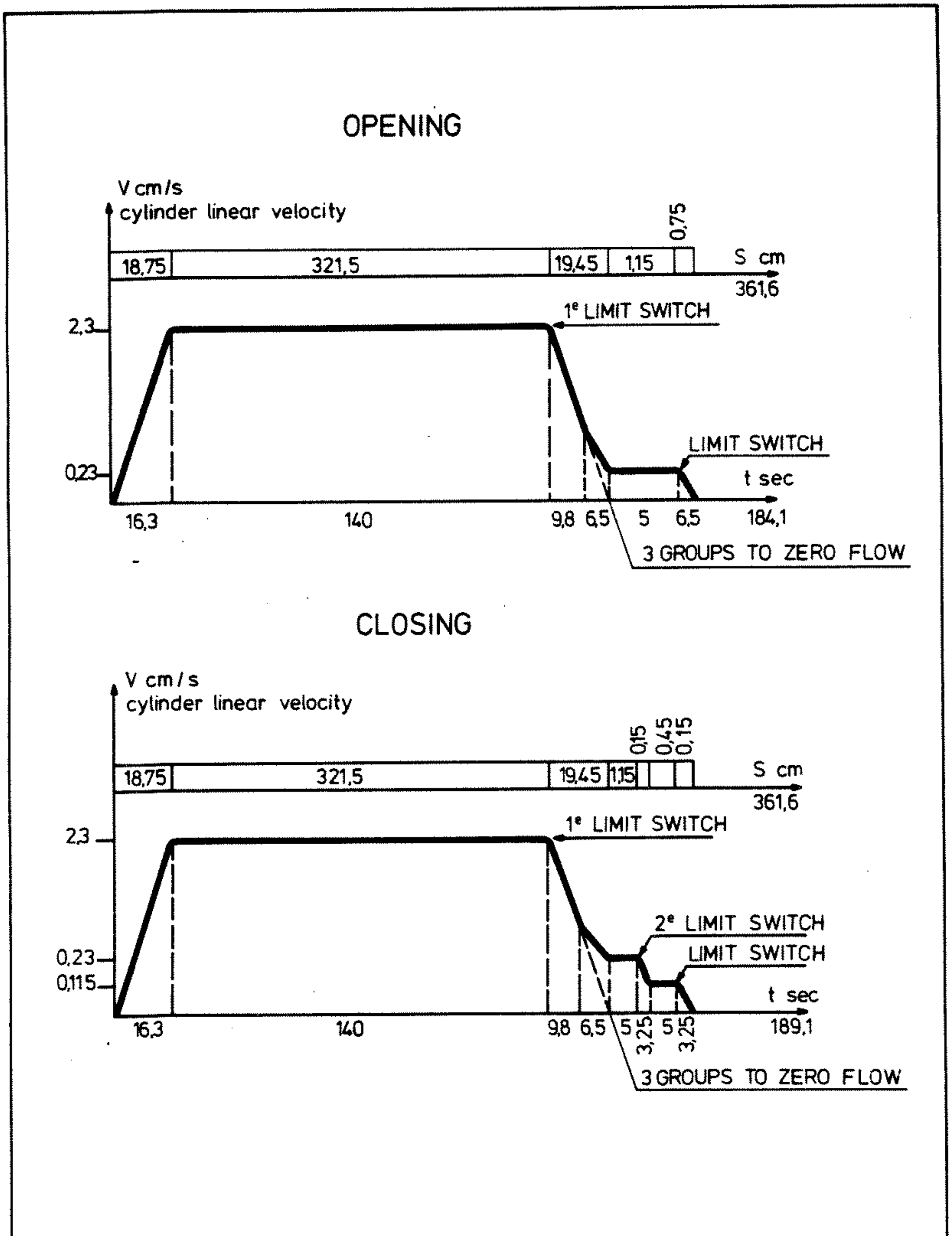
OPENING
V cm/s
cylinder linear velocity
18,75
321,5
19,45
1,15
0,75
S cm
361,6
1e LIMIT SWITCH
2,3
0,23
LIMIT SWITCH
t sec
16,3
140
9,8
6,5
5
6,5
184,1
3 GROUPS TO ZERO FLOW
CLOSING
V cm/s
cylinder linear velocity
18,75
321,5
19,45
1,15
0,15
0,45
0,15
S cm
361,6
1e LIMIT SWITCH
2,3
2e LIMIT SWITCH
LIMIT SWITCH
0,23
0,115
t sec
16,3
140
9,8
6,5
5
3,25
5
3,25
189,1
3 GROUPS TO ZERO FLOW

Fig. 6

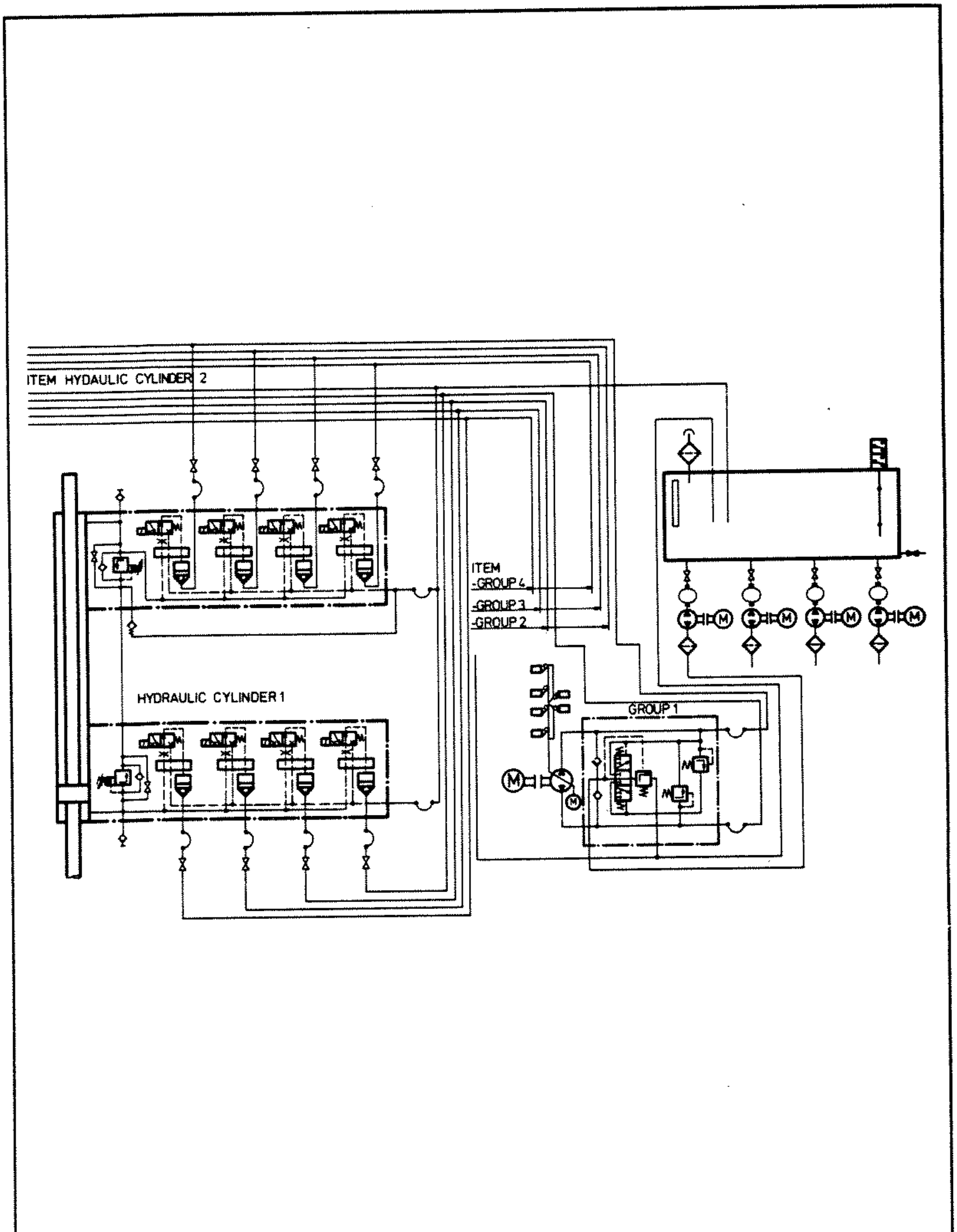

Fig. 7: *Hydraulic scheme*

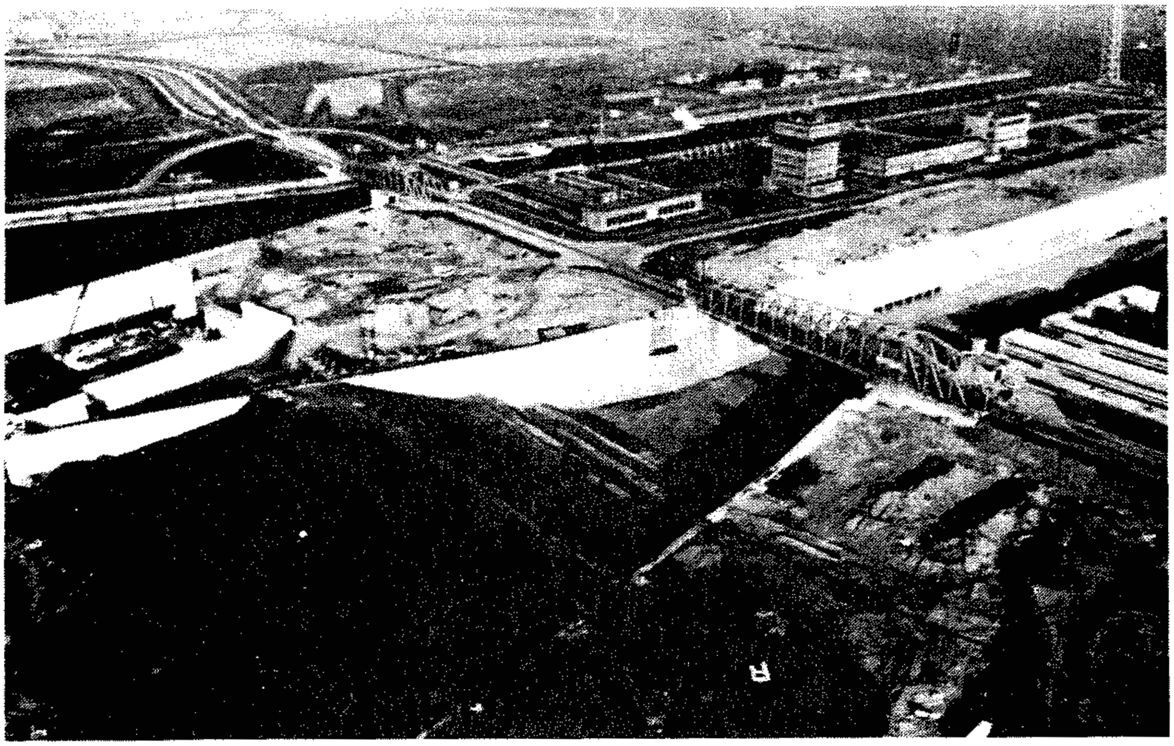

Fig. 8: Port of Antwerp: Foreground - construction of Berendrecht lock and Oudendijk bridge;
Background - Zandvliet lock, Zandvliet bridge (open position) and Frederik Hendrik bridge

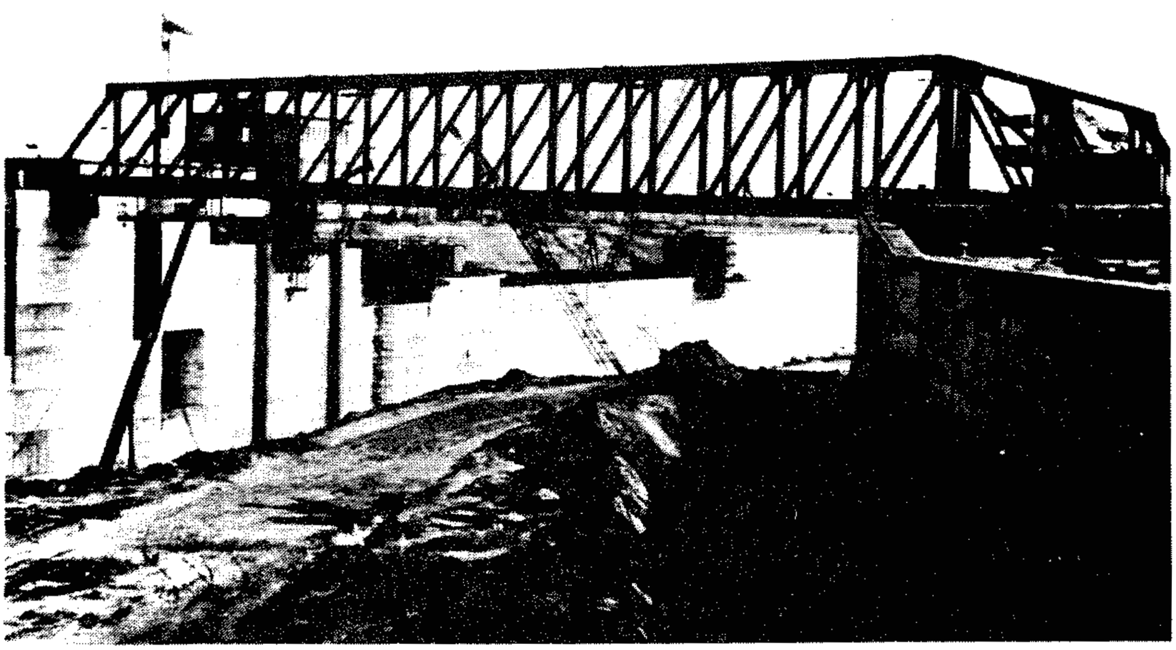

Fig. 9: *Oudendijk bridge during assembly*

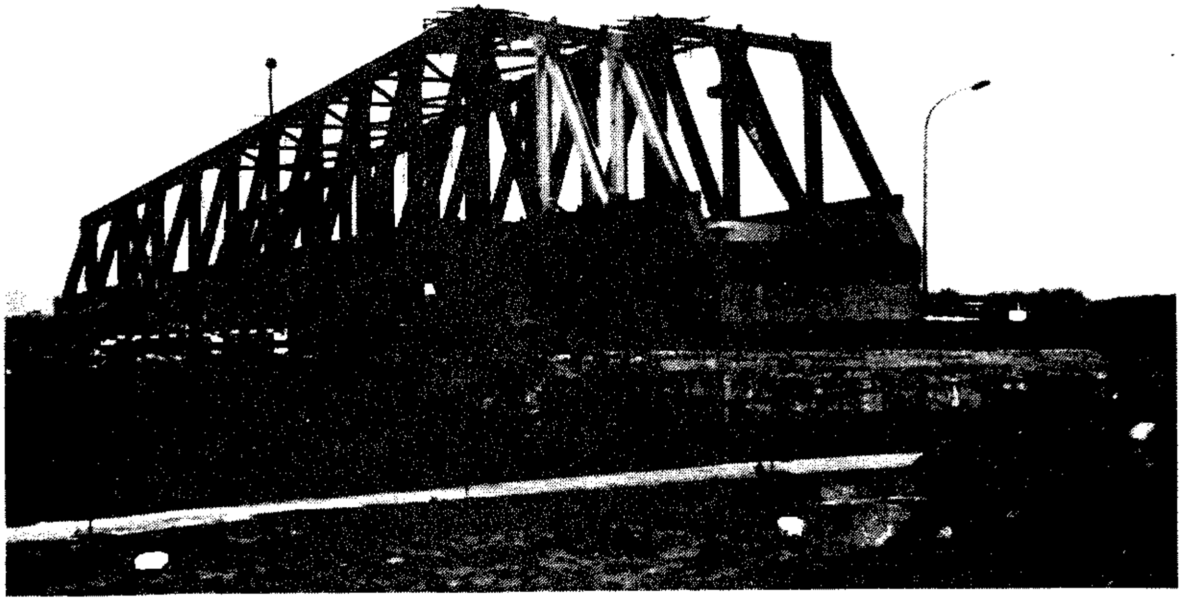

Fig. 10: *Frederik Hendrik bridge during assembly*

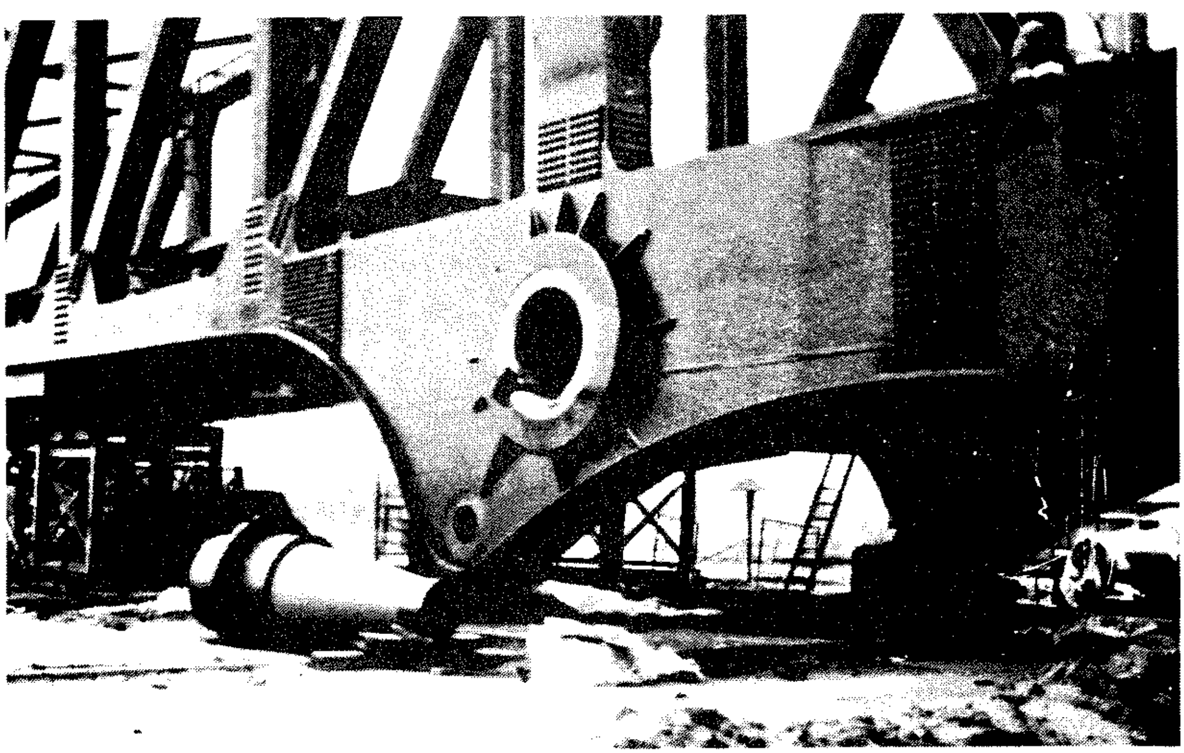

Fig. 11: *Frederik Hendrik bridge, bascule axis prior to assembly*

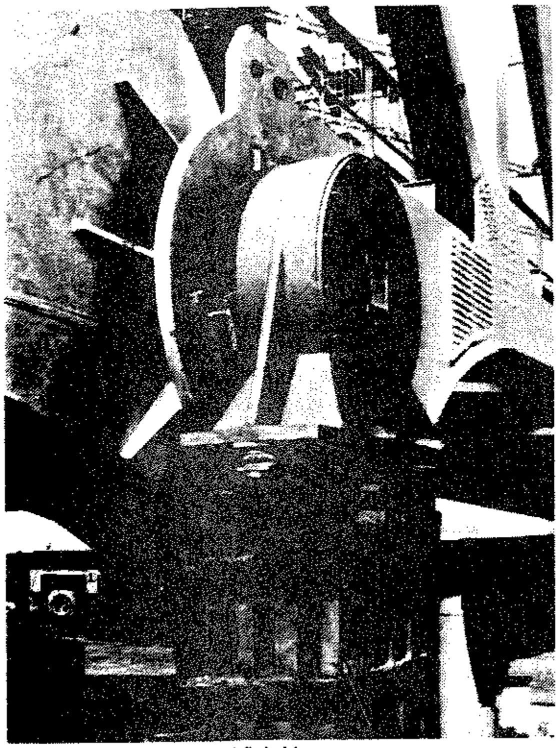

Fig. 12: *Frederik Hendrik bridge bascule axis, bearing and bearing house*

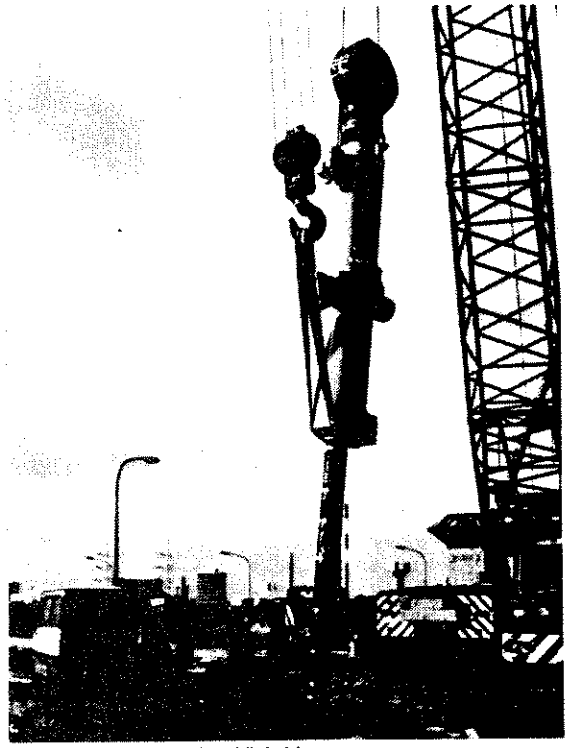

Fig. 13: *Frederik Hendrik bridge bascule mechanism cylinder*

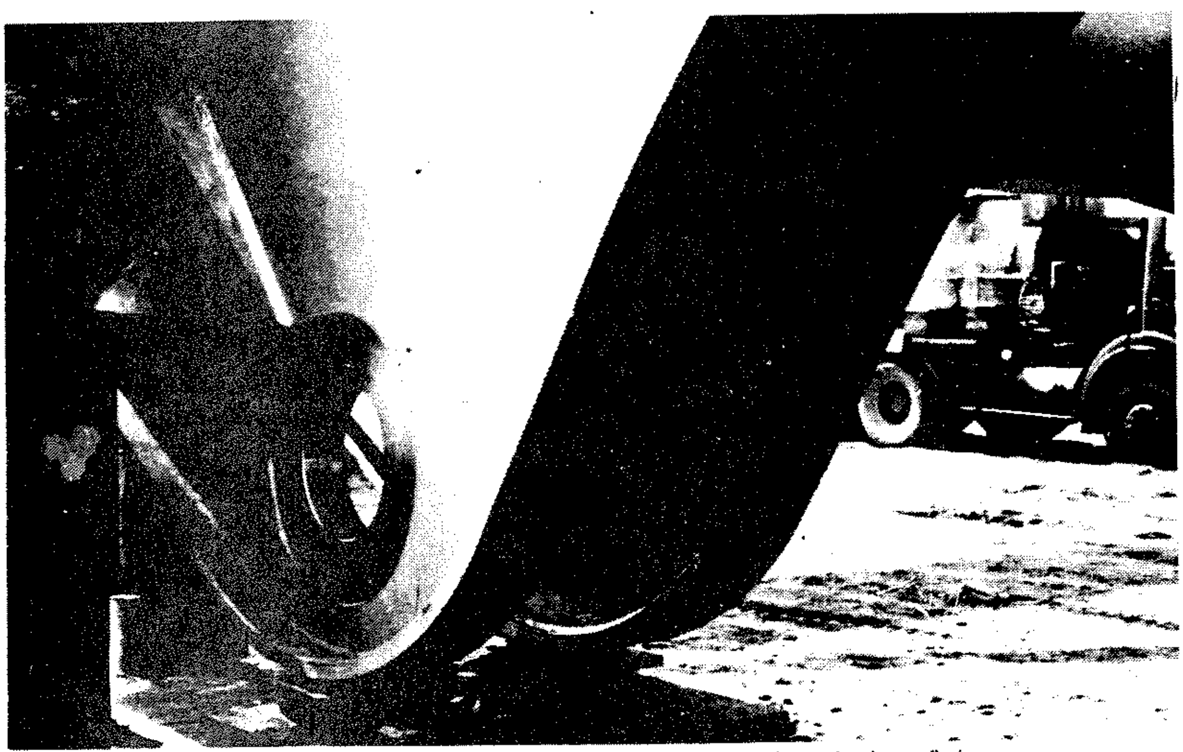

Fig. 14: *Frederik Hendrik bridge, main girder construction at the junction to the bascule mechanism cylinder*

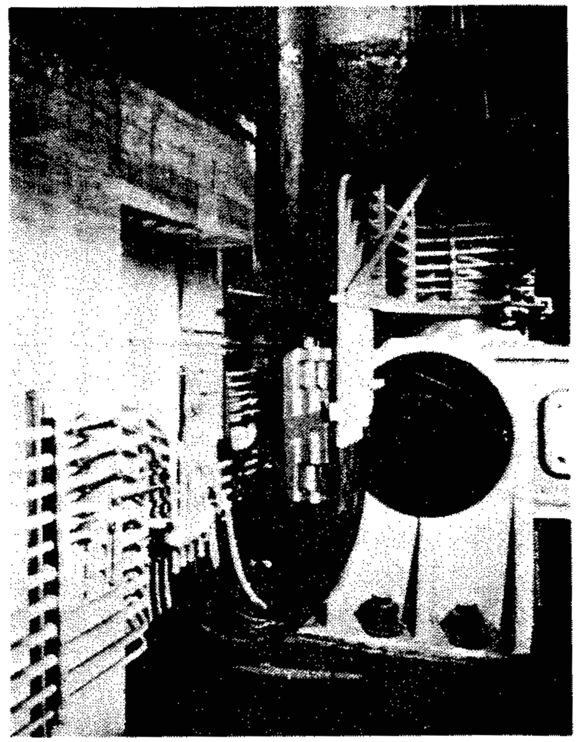

Fig. 15: *Frederik Hendrik bridge bascule mechanism, cylinder and piping*

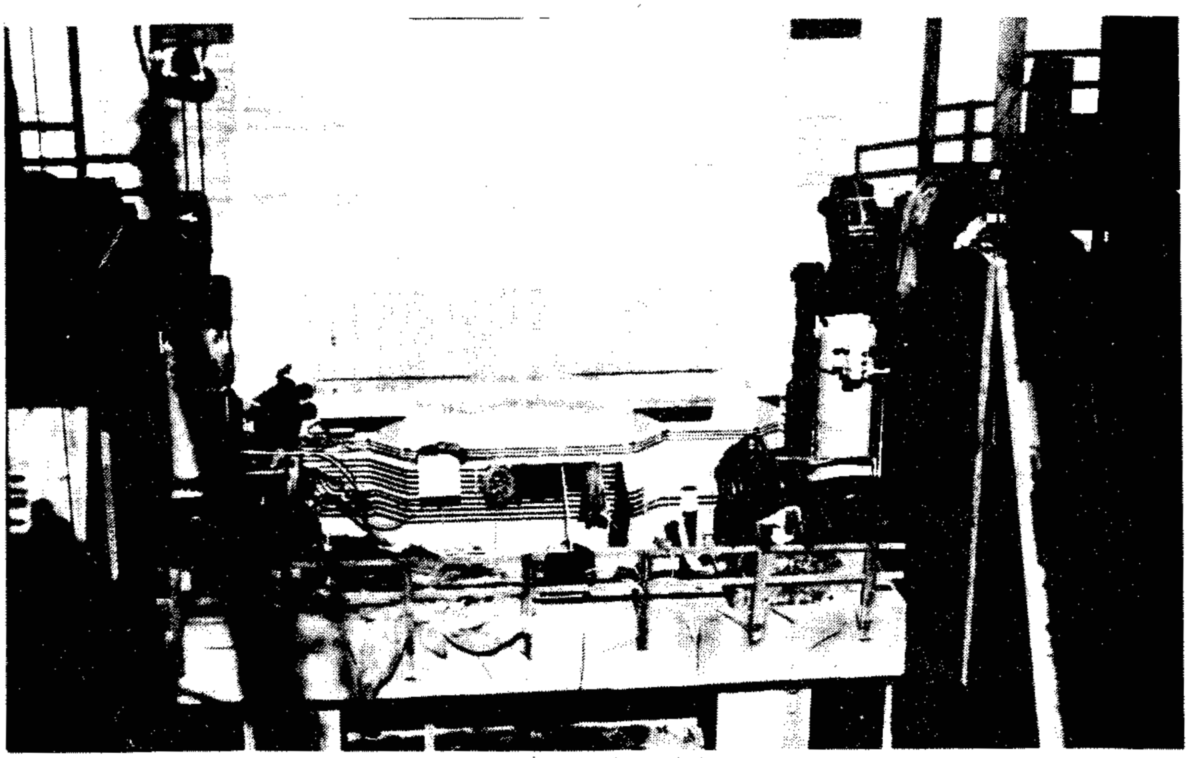

Fig. 16: *Frederik Hendrik bridge, disposition of the bascule mechanism cylinders*

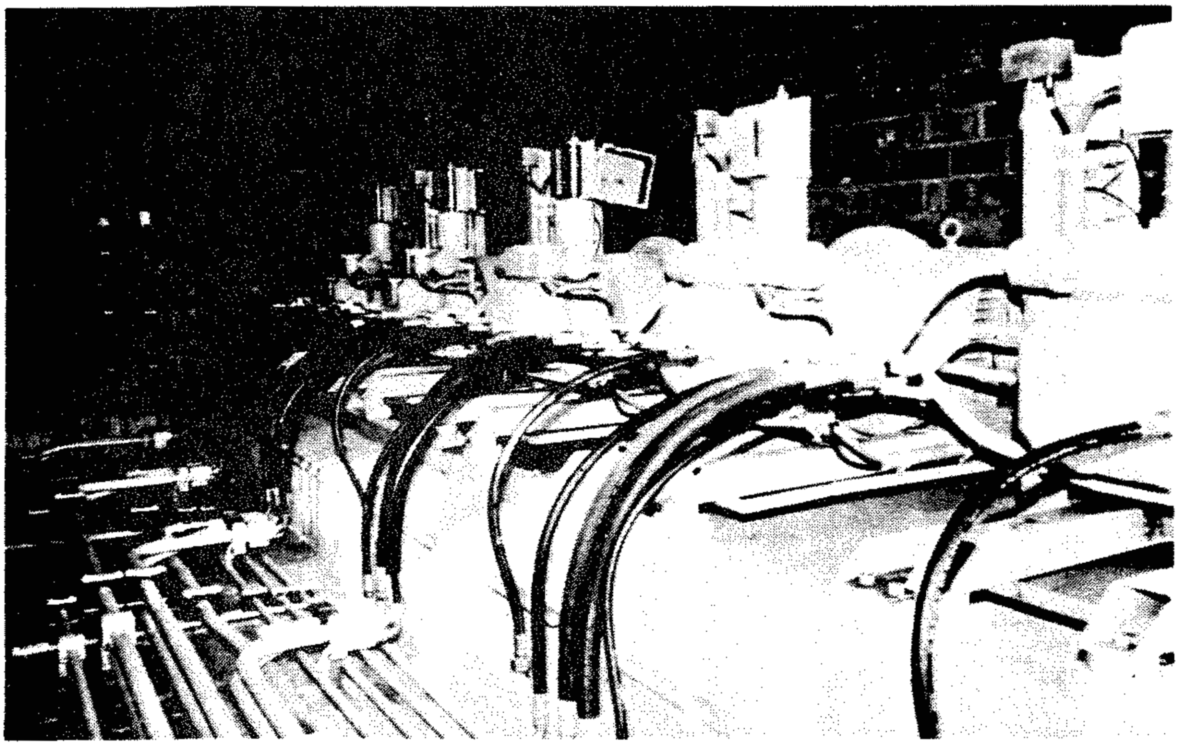

Fig. 17: *Frederik Hendrik bridge, bascule mechanism - hydraulic groups and piping*

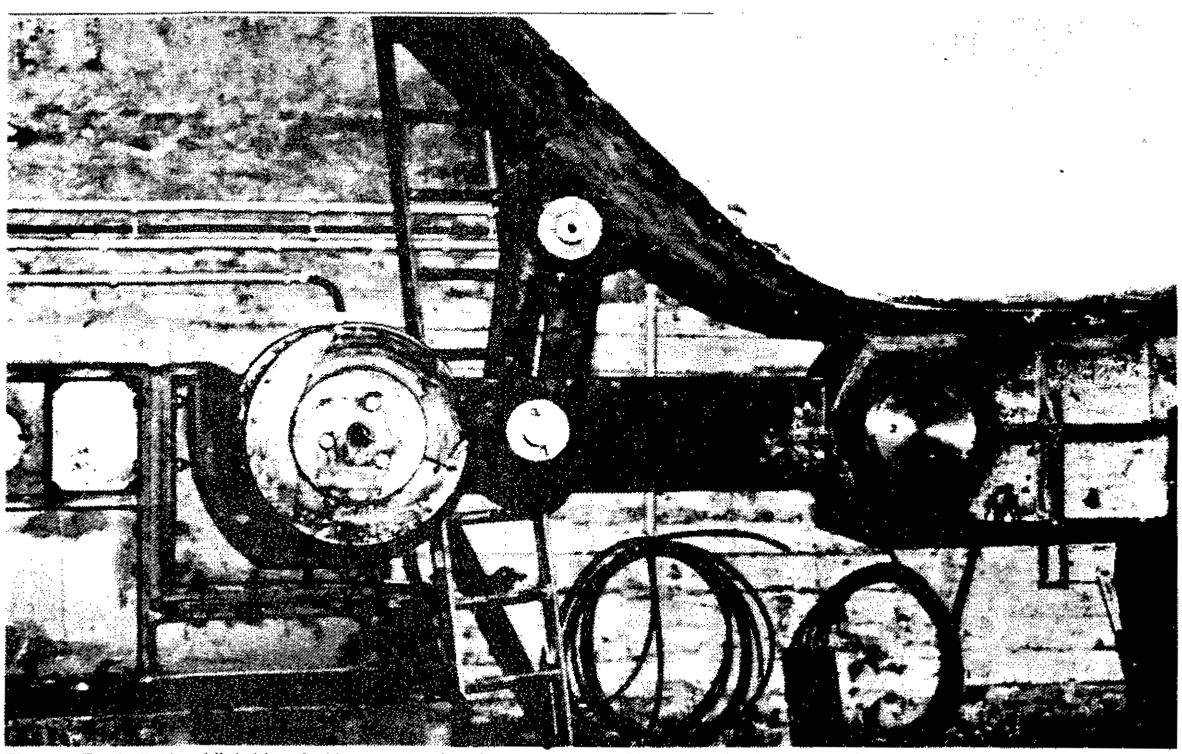

Fig. 18: *Frederik Hendrik bridge, bolting mechanism for the open position of the bridge - side view*

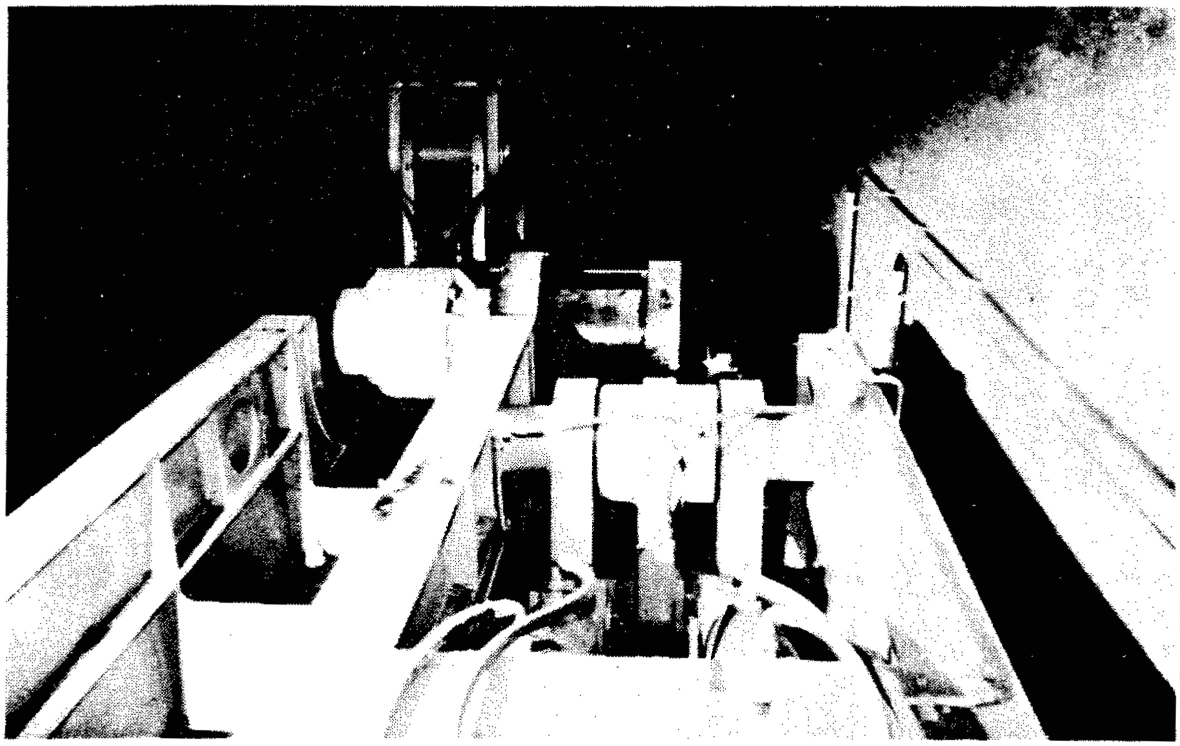

Fig. 19: *Frederik Hendrik bridge, bolting mechanism for the open position of the bridge - front view*

Notes