Oil hydraulic drive system on the Herrenbrücke, Lübeck

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Foreword

During 1962 - 64, the 60-year-old, 2 lane swing bridge over the Trave, on the main road between Lübeck and Travemunde was replaced by a double bascule bridge consisting of 4 individual bascules.

The four bascule bridge, effectively a double bascule bridge for each direction of travel, complete with footway and bicycle track, together with its concrete approach bridges, was designed with a closed clearance height of 22 m, in order to reduce the number of times the bridge operated per day to approximately 6. At this point, it should be noted, that ship movements on the Trave take precedence over road traffic. The new bridge would therefore reduce the interference with road traffic.

By installing a separate bridge for each direction of travel, the option is left open of diverting road traffic over one bridge, should a fault occur in one section and also during the three yearly inspection laid down in the specification.

General details of the bascule bridges

In order to give the reader an insight into the weights to be moved and the sizes of the installation generally, the following list has been compiled.

Overall length of each bridge flap (34,00 m forward overhang, and 7,8 to rear of balance point)	41,80	m
Width of each flap	13,45	m
Opening angle	83	°
Weight of each flap	1970	kN
Counterweight	5000	kN
Height of bascule tip above water level with bridge open	56,00	m
Channel opening with bridge open	60,00	m

Each bascule is moved by two single rod cylinders, about a fixed rotary axis. The cylinders are connected by a torsion tube. In this way, each bascule can be operated by one cylinder. The hydraulic cylinders are connected to the main carries of the return arm.

The bascules are locked in the open position by locking cylinders. In the closed position, both the bascule tip and the rear end are locked. The tip of each bascule has one locking bolt.

Reasons for renewing the drive system

The original drives and interlocks were designed in an engineering design office in 1962, at the very start of oil hydraulic drives in this sphere of operation. The design concept contained various faults which led to a number of breakdowns between 1964 and 1982. In addition, a number of safety regulations were not catered for. A further problem, particularly from the point of view of shipping, was that according to DIN 1072 (bridge building), the drive could only work against a load of 500 N/m^2. Thus the bascules could theoretically only work up to wind speeds of 18,7 m/s (wind force 8 on the Beaufort scale), which meant that ships always had to allow for waiting time at the bridge.

The above problems led to the decision in 1981 to renew the hydraulic drive.

The planning and construction of the new drive

As a first step, the static strengths of the bridge and bridge piers was checked out in order to determine the increase in wind load that could be permitted. From this, it was found that the wind load could be increased by about 80%, i.e. an increase from 500 to 900 N/m^2, which corresponded to an increase to force 10 or 25 m/s, without exceeding the permitted loads.

As a basis of calculation for the sizing of the drive, DIN 19704 and 705 (Civil engineering) were used.

Further factors taken into account at the planning stage were reliability in service, high availability, ease of servicing and repair, and also efficiency, whilst available space and access for the placing of the new components also had to be considered.

*The above criteria led to the decision to select a hydro*static drive in open circuit, with each bascule having its own power unit. This design, combined with a cross over network in the bridge piers, emergency operation of the requisite valves, and a division of power between the two electric motor-driven variable pumps, ensured a high degree of availability and reliability.

In the following paragraphs the construction of the control and drive of one bridge flap will be explained in detail, beginning with the hydraulic fluid.

On space grounds and for efficient use of the bridge piers, one common oil tank for two bridge sections was mounted in each pier. This was designed so that in addition to accepting the differential volume of the cylinders, enough capacity was available to accept the complete volume of one cylinder for repair purposes, whilst also leaving sufficient oil in the tank at all times for the necessary cooling. The tank was equipped with so called standard equipment, such as a return line filter with clogging indicator, a full length oil sight, electrical minimum oil level warning and cut-off, silica gel absorber for condensation of the differential air volume, and also a filler/breather and drain cock. As the tank was mounted some 15 m above the road level, an extra filling line was laid to the road level.

For reasons of space the tank had to be installed above the pump unit. This also had the advantage of assisting the suction characteristics of the pumps.

All isolating valves in the suction line between the tank and the pumps are electrically monitored, in order to *avoid damage to the pumps due to running dry.*

Also due to space in the buildings, the pump and control units were separated. The pump stands included the axial piston pumps type A 2 V 107 with a drive power of 30 kW already mentioned for the bridge drive, and also the axial piston pumps type A 2 F for the pilot oil supply, and for the locking of the ends of the bridge sections, having drive powers of 7,5 and 11 kW.

The variable pumps have electrical controls. The swivel *time of the pumps is 16 secs. from 0 to* Q_{max}. *The varying* flows required from the pumps is controlled by cams and limit switches. In addition, the swivelling in of the pump to creep speed for final approach to the end positions is carefully monitored. This avoids the possibility of the bridge travelling into its end stops at full speed, should the limit switches or the pump control unit fail.

As already explained, the reliability and availability of the bridge has been considerably increased by the use of two pumps, as the pump can be operated on the normal *automatic control, should a pump fail. Naturally the* bridge will travel at half speed and take twice as long to operate.

From the point of view of electrical energy supply, this power division has an economic advantage. By halving the power and offsetting the starting time of the motors, and also by bypassing the pumps on start up, the start up power has been considerably reduced. This not only reduces the energy taken from the supply, but also requires smaller transformers, switching devices, and cables.

The pumps are connected via flexible elements to both the suction and pressure lines, in order to avoid the transmission of oscillations and noise to the hydraulic lines.

All the directional, pressure reducing valves and pressure relief valves are mounted on a manifold which in turn is mounted on a control stand near the pump station. All monitoring devices, such as pressure gauges and pressure switches are mounted on a front panel in groups associated with their valve groups, so that setting and hand operation may be easily carried out. An H-spool in the main directional valve of the bridge drive, and a venting pressure relief valve in the lock drive ensure that the pumps can be bypassed at low pressure.

The locks are held firmly in position at each end of the stroke by means of pilot operated check valves set after the directional valves. Should the lock mechanisms drift out of position in spite of this, they are immediately redirected into the end position, by means of proximity switches.

The direction of the main cylinders driving the bridge itself is controlled by a 4/3 way directional valve. The fluid is then passed to an intermediate hinge bracket/ manifold block from where the flow is then divided between the two cylinders. This intermediate hinge block also acts as a load lowering valve (check-Q-meter) and a pilot operated check valve. These components are mounted at this point instead of on the cylinders themselves, due to the poor accessibility of the cylinders. As the check-Q-meters also act as anti-burst valves, the piping between the hinge block and the cylinders is made, so as to ensure that it will not burst.

The additional pilot operated check valve after the check-Q-meter serves in this case to allow smooth braking of the bascules to any required intermediate position. This is achieved by *delaying the decay in the pilot pressure.*

In addition to the above components, the hinge block also holds an accumulator and directional valve for the pilot circuit, and also two unloading valves set in parallel.

These unloading valves unload the cylinder when the bridge is in the "road traffic" position, connecting them to the overhead tank. This considerably reduces shocks and oscillations being transmitted to the structure due to heavy traffic conditions.

As already mentioned, two single rod cylinders are fitted *per bridge section. These are 340/180 diameter*, with a stroke of 3500 metres. Piston rods are of stainless steel (material 1.4021 (UNS S42000)). The rod surface is hard chrome plated to a thickness of 30 µm, and ground. The hydraulic cylinders have a maximum pull 1320 kN when opening the bridge, and a maximum pushing force of 1250 kN when closing the bridge. To prevent overloads, the cylinders are protected by pressure relief valves set at 251 and 165 bar.

In order to prevent side loads occurring on the cylinder rods, the forces are transmitted to the bridge via service free swivel clevis bearings.

In consideration of the masses to be moved, and the wind loading which must be permitted, and also considering the economic design of the overall hydraulic installation, the designed opening time of each double bascule was set at 4 mins 30 secs, and the closing time at 3 mins. 20 secs.

Without wishing to go into the exact operational cycle of each bridge element in detail, it should be noted, that each section is pressed into place at both end positions in order to lock and unlock it. This avoids the possibility of excessive locking forces occuring during locking, due to, for example, gusts of wind etc. All end positions and approach positions and also the possibility of the lower of the two flap ends running away were monitored by proximity switches.

The cross coupling circuit in the bridge piers already mentioned, *should also be explained in more detail*, as this only comes into play during a total breakdown of a power unit. In this mode, the relevant isolating valves are opened by hand, and the bridge then operated manually. To date, this has never been required, and we naturally hope, that it never will.

Each power unit has its own switch cabinet, in which the motor controls and overload safety devices as well as the whole of the bridge controls and interlock functions are mounted. The front panels hold all the operating controls and also the operational and fault lamps.

The operational and fault warning lights on all four power units are also repeated in a central control desk allowing faults to be rapidly and accurately corrected.

The bridge is operated from a central control desk in the service centre. On this desk, all operating conditions are indicated by lights. As no fault-finding can be achieved from this point, however, only a single overall fault light is included for each bridge section.

Finally, it should be noted that the conversion took some 8 months at a cost of about 4,1 million DM.

The general arrangement together with the design of the bridge system are shown in *Figures 1 to 4.*

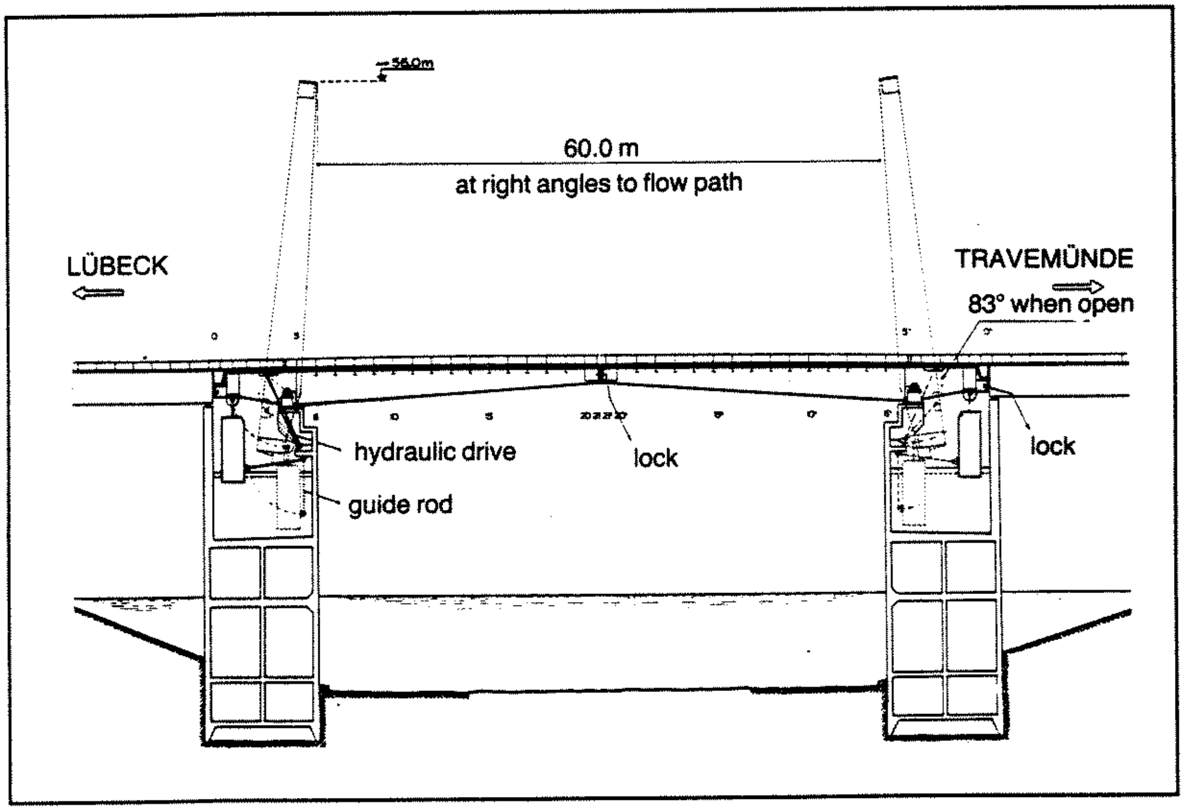


Figure 1

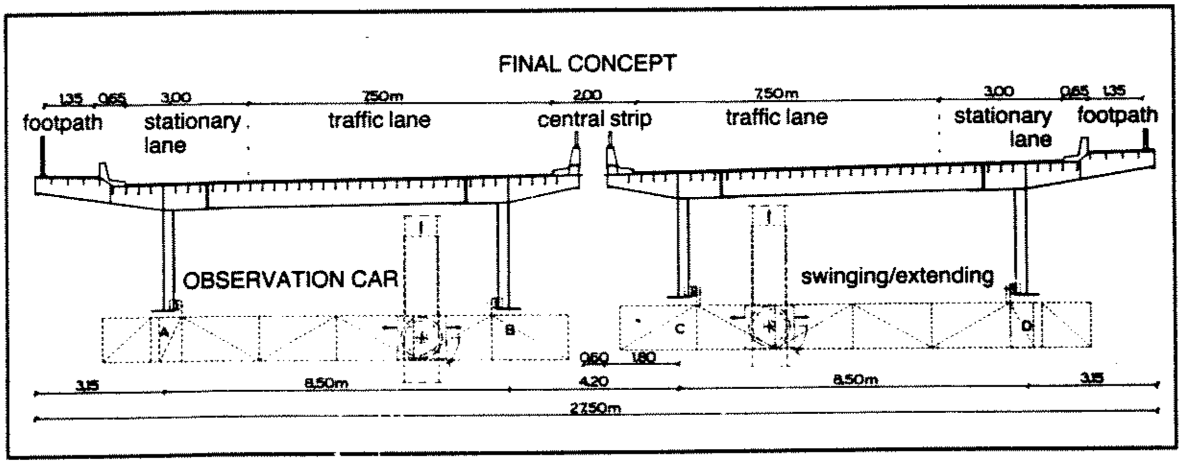


Figure 2

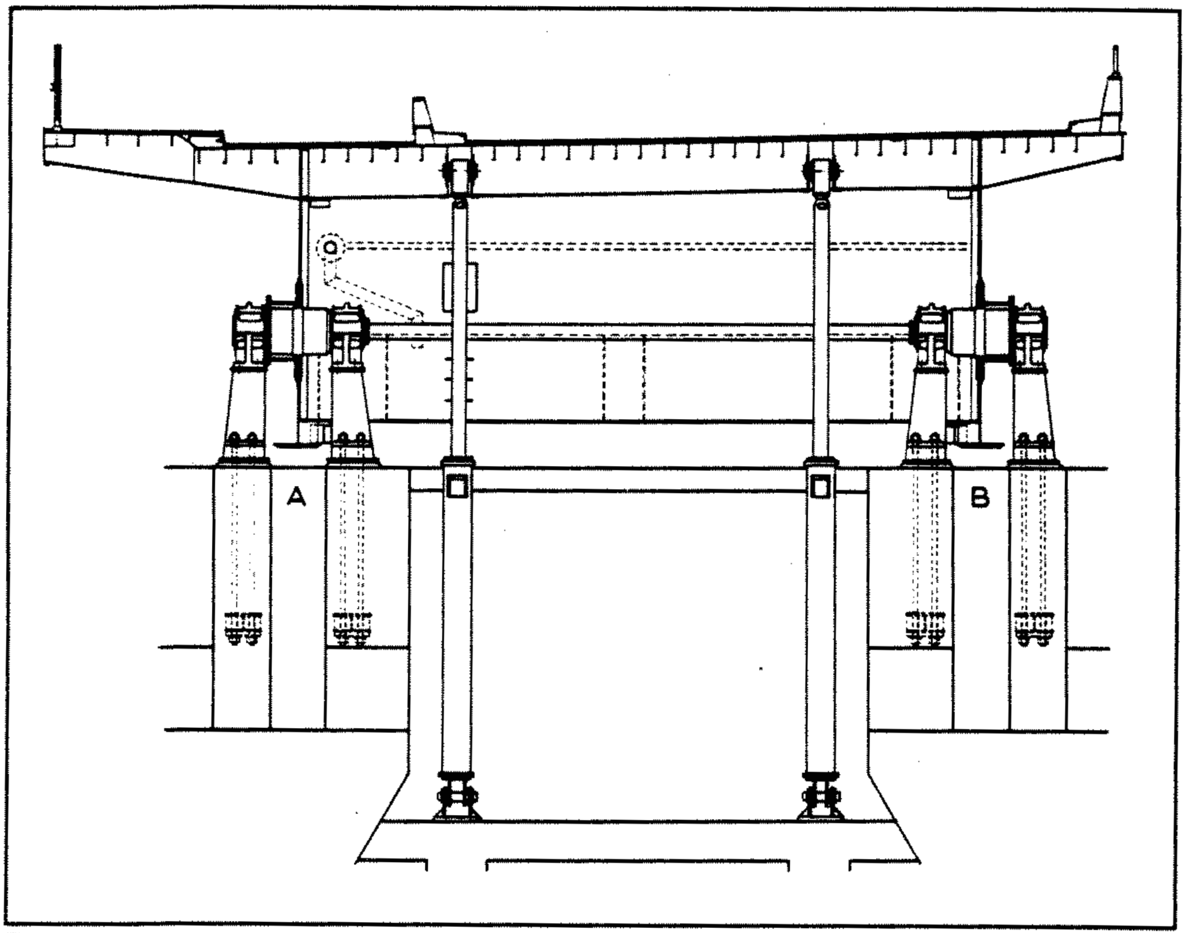


Figure 3

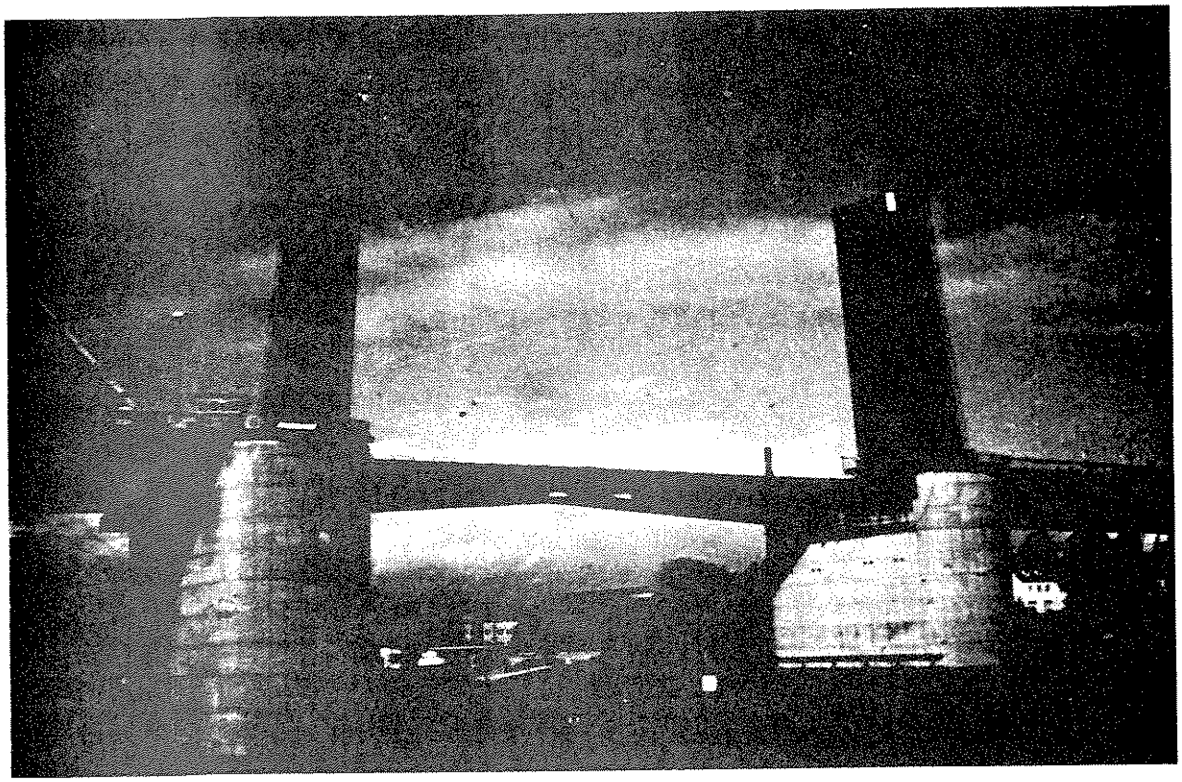


Figure 4

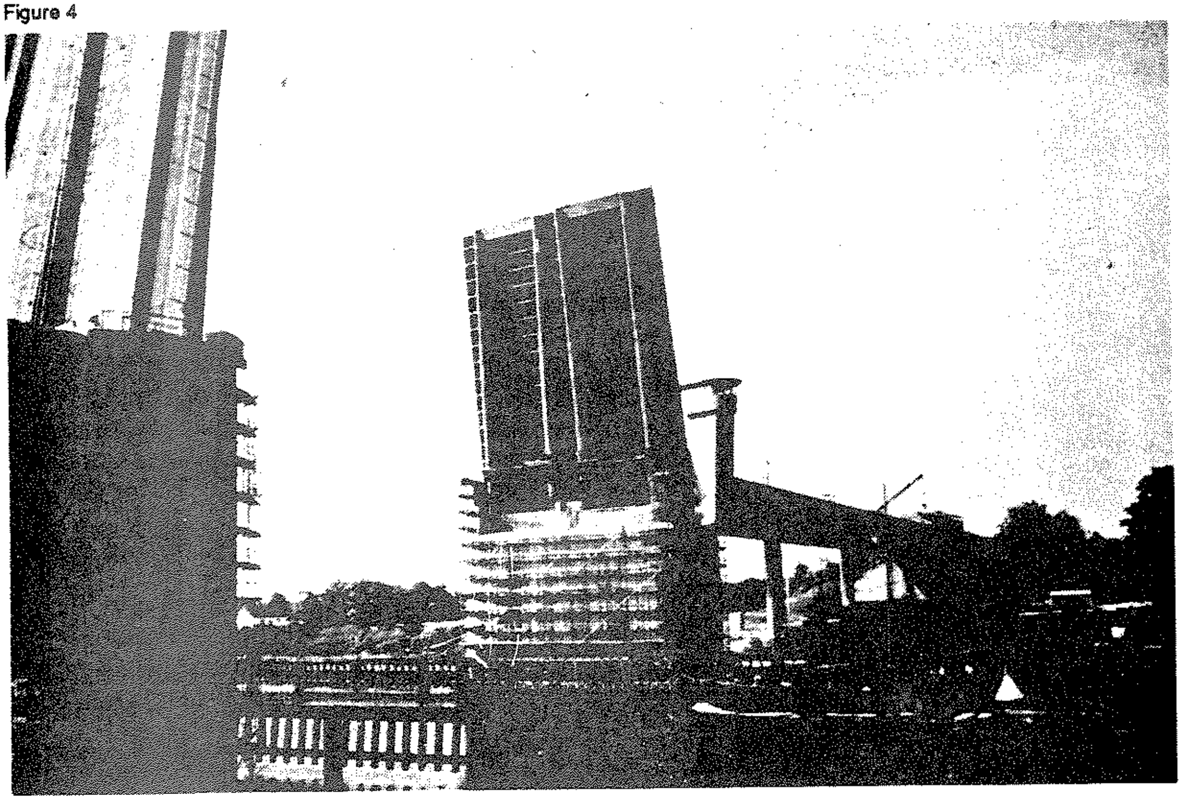
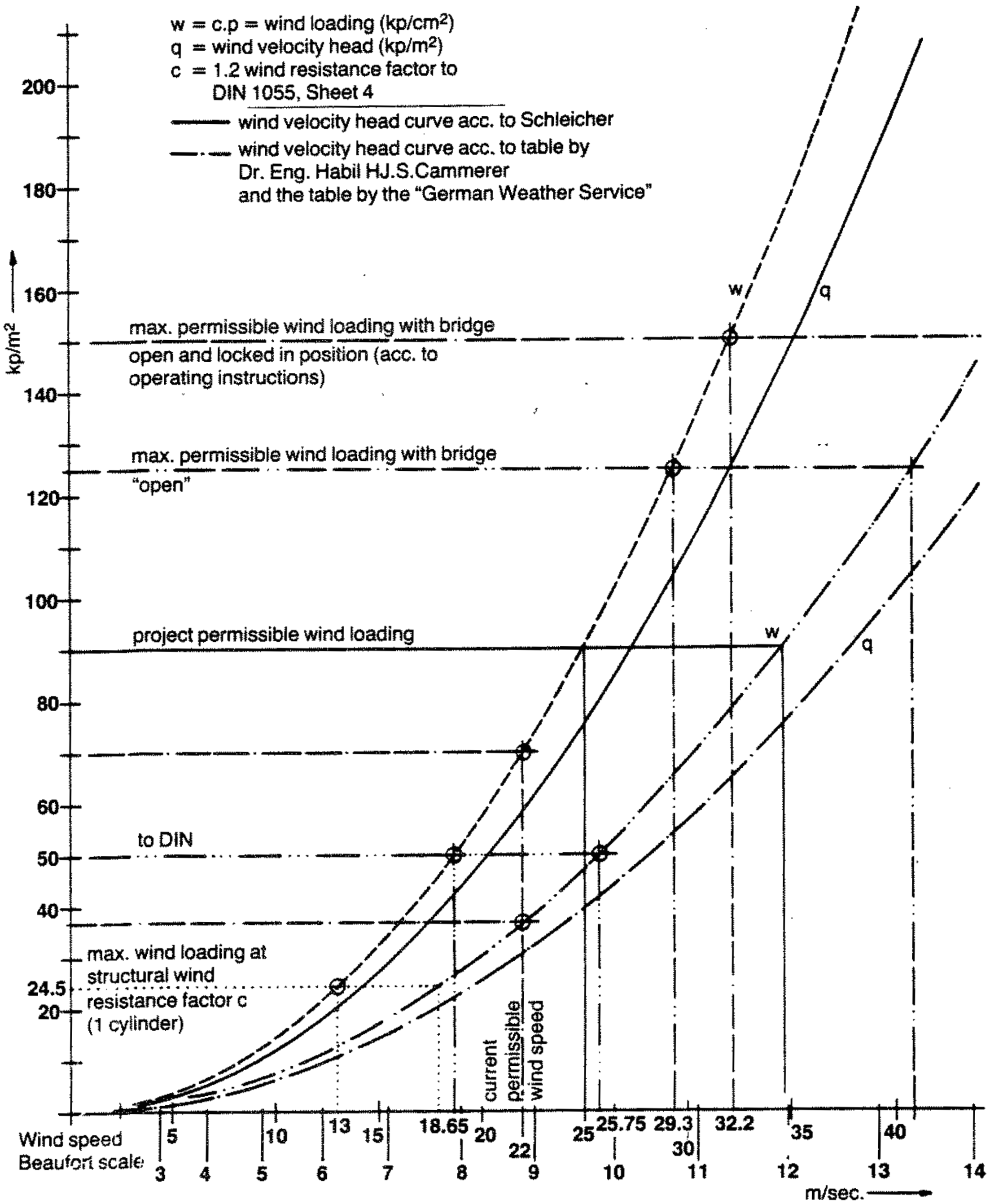


Figure 5



Wind loading "w" (kp/m²) in Relation to Wind Speed (m/sec.)

Figure 6: *The wind speeds shown correlated to the Beaufort scale, have been international since 1.1.1949 Wind speed is based on a measurement height valid of 10 m above ground, at 30 m height at 20%.*

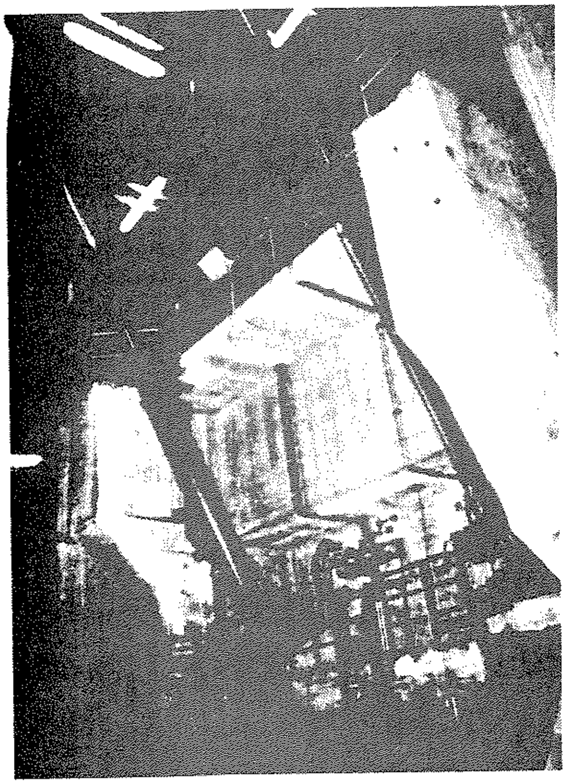


Figure 7

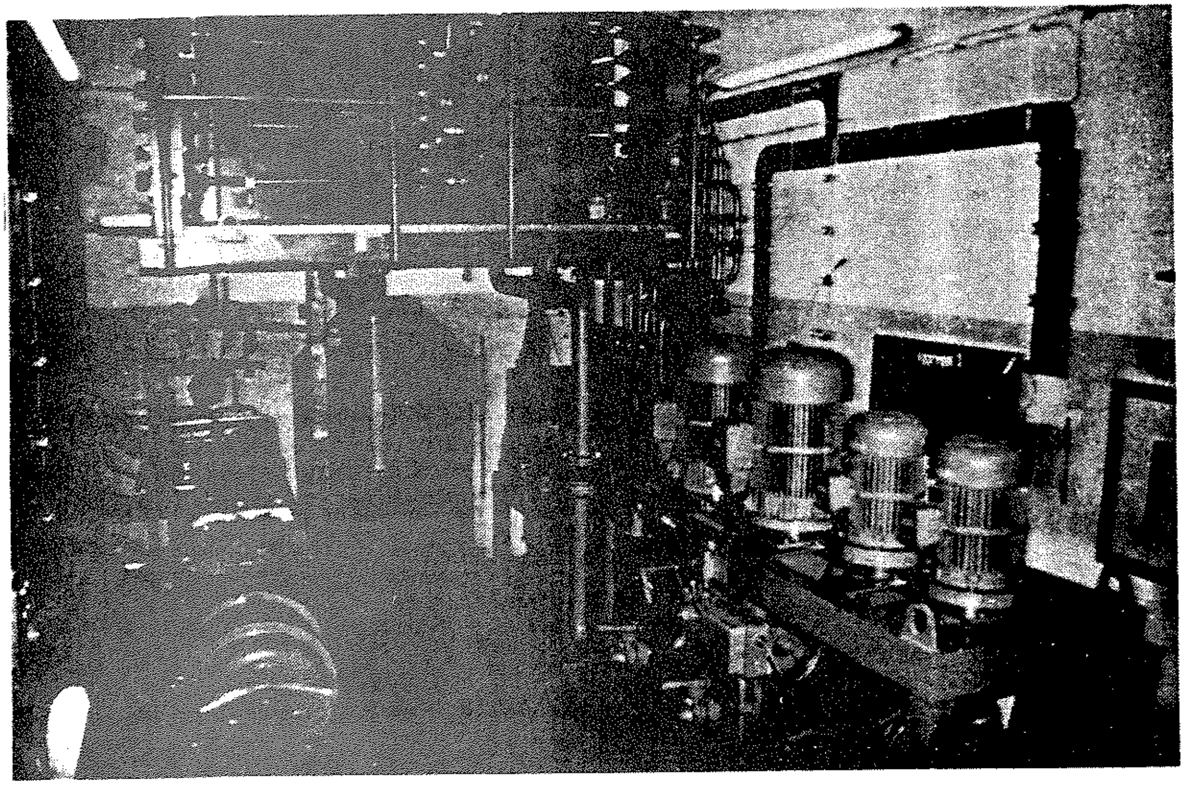


Figure 8

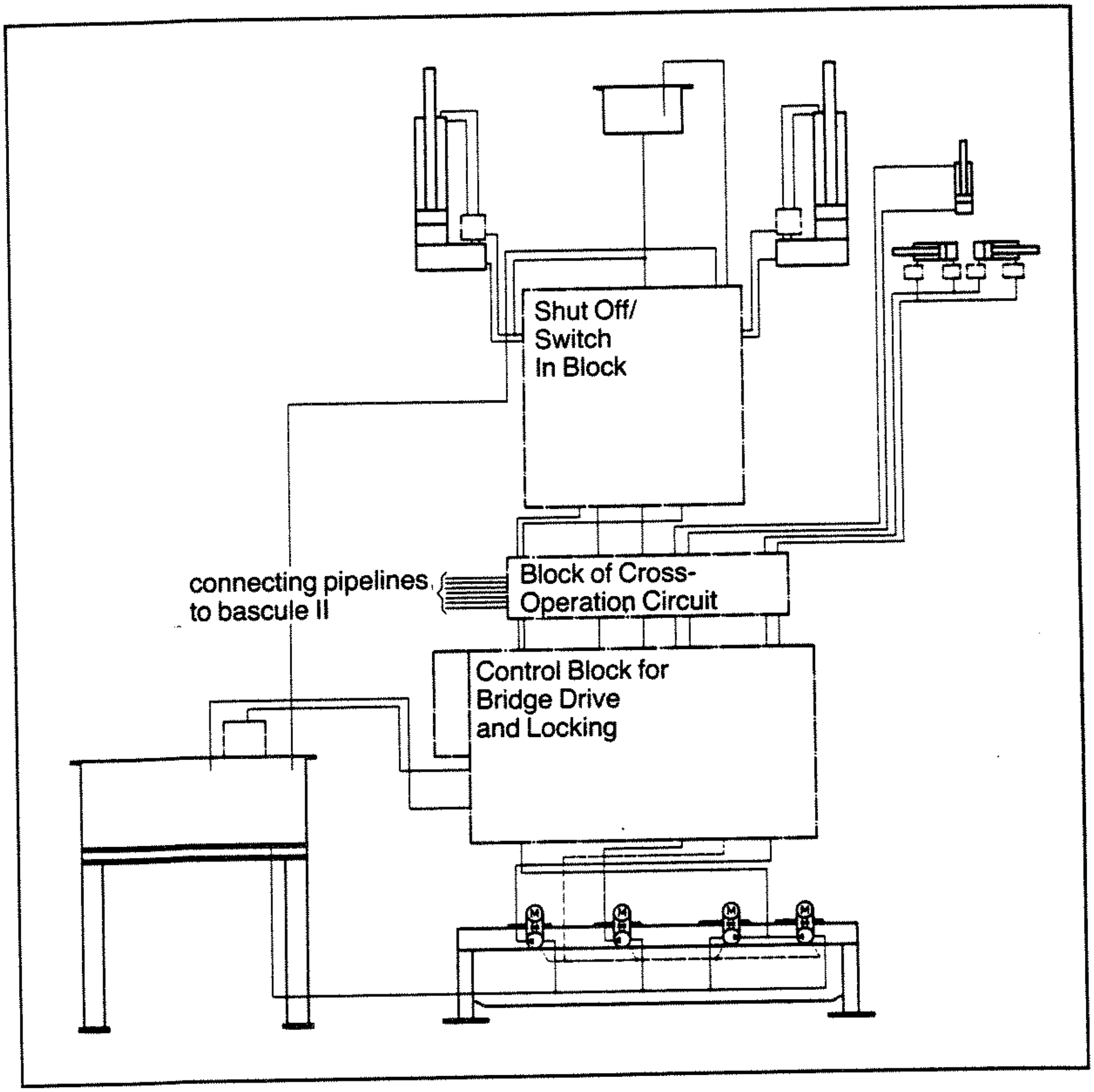

Shut Off/
Switch
In Block
connecting pipelines
to bascule II
Block of Cross-
Operation Circuit
Control Block for
Bridge Drive
and Locking
M
M
M
M

Figure 9

Notes