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"THE BASCULE BRIDGE FOR SEVILLE, A NEW CONCEPT OF HYDRAULIC CONTROL FOR BRIDGES"

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The bascule bridge for Seville, a new concept of hydraulic control for bridges

1. Pump control system versus valve control systen

The conventional method of controlling hydraulic drives is based on using proportional or servovalves systems. Though it does entirely satisfy the technical requirements, this control concept is based on throttle system with corresponding power losses. These power losses can be eliminated when flow (velocity, revolution) and pressure (force, torque) are directly controlled by the pump. The prerequisite for this is a variable displacement pump with a sufficient dynamic control characteristic.

But the valve control system does have its advantages, too. The control valve and the drive axis can be configurated as a compact unit. The compression volume is small and the drive has therefore a relatively high frequency and is stiff. Usually, the valve positively locks the drive, e.g. a cylinder.

These advantages are not directly available with a pump control. Physically, the pump is located at some distance from the drive axis. Due to the correspondingly high compression volume, the drive has a relatively low frequency and is less stiff. In addition, the drive is not positively locked. Compensating for these disadvantages demands more sophisticated technology in the pump control system.

Fig. 1 shows a basic throttle control system. The object of this system is to control the force or velocity of the linear axis using a throttle pressurised by a fixed displacement pump. As can be seen from **Fig. 2**, force and velocity are interdependent. It is also evident that only a small proportion of the power generated by the pump can be converted into drive power ($P = F \cdot v$)at the piston rod - in the best case 38%. Replacing the fixed displacement pump by a pressure compensated pump considerably improves the degree of efficiency, boosting it to about 66% at a comparable operating point.

Fig. 3 shows a basic pump control system. **Fig. 4** reveals clearly that force and velocity are independent of each other within the upper and lower performence limits. Power losses in the form of throttling losses no longer occur. Ignoring the efficiency levels of the individual components, the total efficiency of the system would theoretically be 100%. The pump control system is therefore an effective instrument to save energy provided one succeeds in mastering the technical requirements, i.e. controlling force, velocity, position and acceleration to the same degree as in the throttle control system.

2. Bascule bridge for Seville, an example for a pump control system

2.1 Short discription of the bridge

To cope with the traffic to be expected during the World Exposition 1992 in Seville, two three-lane road bridges and a one-track railway bridge were planned and built to span the Guadalquivir River.

The principal contractor for the bascule bridges and the approach roads was the Spanish company Dragados y Constructiones SA. The engineering of the steel structure of the bascule bridges was handled by Thyssen Engineering in Dortmund.

The hydraulic drives were entirely designed built and supplied by Mannesmann Rexroth, who also supervised their erection by Goimendi, the Rexroth representative in Spain.

When the bridges are open the clear width is 42m- through which passed as shown in **Fig. 5** , for instance, the replicas of the Santa Maria, Pinta and Nina, the ships with which Columbus discovered America.

To disrupt traffic as little as possible, the bridge leaves must be opened very rapidly and, once the ships have passed, closed just as quickly. The requirement was for a bridge leaf travelling time of 90s for both opening and closing.

2.2 The hydraulic system

The block diagram of the hydraulic system is shown in **Fig. 6**. The pump control system is achieved by axial piston pumps of the type A4VSO. On the road and the railway bridges each bridge leaf is equiped with two double-acting cylinders. Pressure generation on the road bridges is provided in the form of three pump sets per leaf, while the rail bridge has two pump sets per leaf. All pumps are identical with a maximum displacment of 125 cc and the same proportional control. The set up of such a pump is shown in **Fig. 7**.

The proportional valve which controls the stroke of each pump is directly mounted on the pump. The stroke of the pump is proportional to the flow and thus to the speed of the cylinder rods. The proportional valves of the type WRS6 are actuated by VT 5035 control cards with a prolonged ramp time - settable from 0 to 20 s. This extended ramp time is necessary to ensure slow acceleration of the steel structure of the bridge and avoid oscillation at the leaf tips.

As can be seen from the block diagram no control valves are used in the main lines. So no energy loss through throtteling occurs. The travel of the cylinder rod is set by a simple directional valve. We are talking about a modern pump control system.

To synchronize the motion of the double acting cylinders of one bridge leaf it was sufficient to keep the working pressures equal in both cylinders. When the bridge is in motion, these are linked by an equalising line. The cylinders can cope above all with the prevalent wind forces. The actual weight of the bridge leaves is compensated for by kentledges, but as the wind may blow in different directions and veer suddenly even while the bridge is moving,the back pressure of the cylinders is biassed at both ends by check-Q-meters. A check Q-meter as shown in Fig. 8 allows free flow into the cylinder from port A to port B. The flow out of the cylinder from port B to port A is controlled depending on control pressure.

When the bridge is in end position, whether open or closed, the leaves are locked, in the closed position. A directional valve fitted to the cylinder short-circuits the two cylinder chambers and links them to an expansion tank. The cylinder chambers are decompressed and the bridge leaves are free to oscillate with the vibration caused by moving road or rail traffic.

2.3 Drive diagram

The steel structure of the railway bridge leaves is designed so that they overlap when the bridge is closed. When the bridge opens, it is therefore necessary for the uppermost bridge leaf to start first and last when bridge closes as is shown in **Fig. 9**.

Although the steel structure of the road bridge leaves does not overlap (and an earlier start of the one bridge leaf is not necessary), the system was designed so that both leaves move synchronously with those of the railway bridge on opening and closing.

To ensure uniform velocity of all the bridge leaves, all pumps in the road and the railway bridges have their own monitoring system. If one or more pumps should fail, the same number of pumps will be shut down on the opposite side of the bridge.

As is usual in hydraulic steel structures, all pipework is monitored for leaks and pipe bursts. The entire pipework, from the power units to the cylinders and on the cylinders themselves, has been fabricated from stainless steel. The pipe unions are either of the welding nipple or flanged type.

3. Advantages of hydraulic drives for bascule bridges

The bascule bridges for Seville show clearly the advantages of the hydraulic drive. If compared to an electric mecanical drive the following features are of importance:

- The pump control systems offer low energy consumption
- Starting efficiency of hydraulic cylinders is high. The installed power can be almost reduced to the demands of running efficiency.
- Acceleration, decelleration and synchronization are smouth and controllable.
- Hydraulic cylinders are direct linear drives. Installation is pratically unlimited, as pump drive and actuators can be separated.
- If properly installed hydraulic drive are environmentally clean.

Some more general features of electric- mechanical drives versus hydraulic drives are shown in **Fig. 10**.

It is evident that hydraulic cylinder drives for bascule bridges are very attractive for civil engineering.

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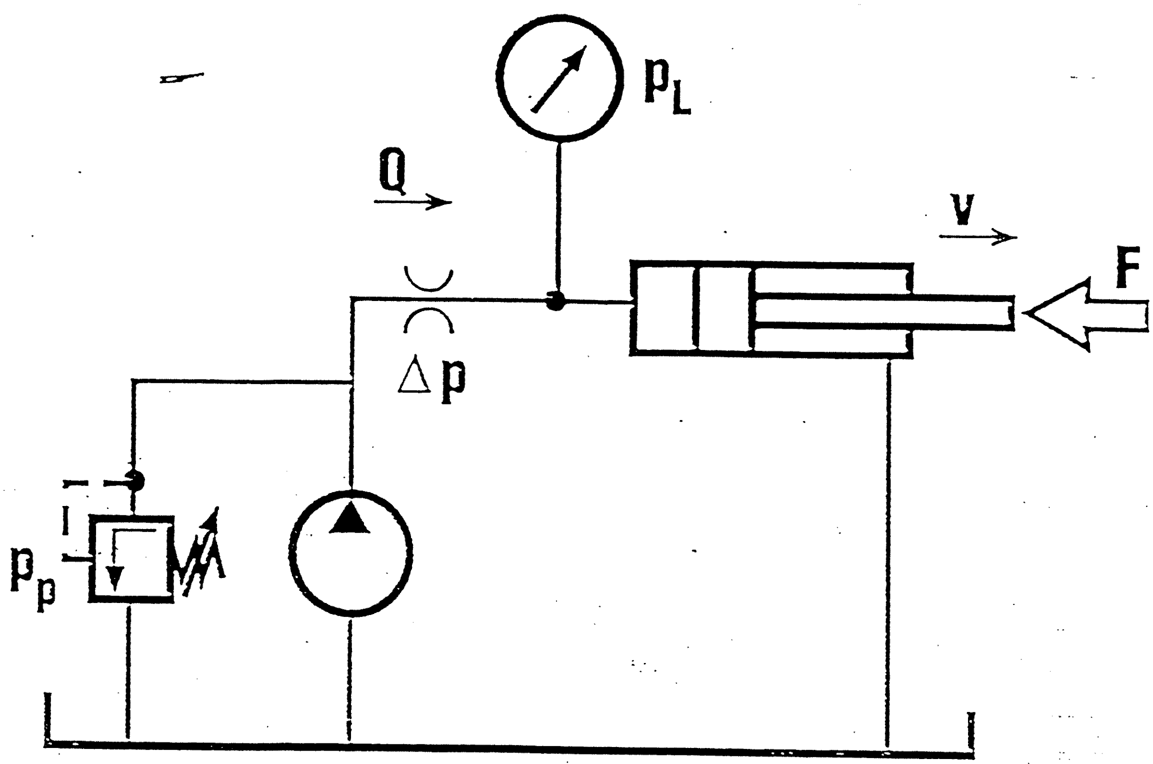

Fig. 1: Basic principle of the throttle control system

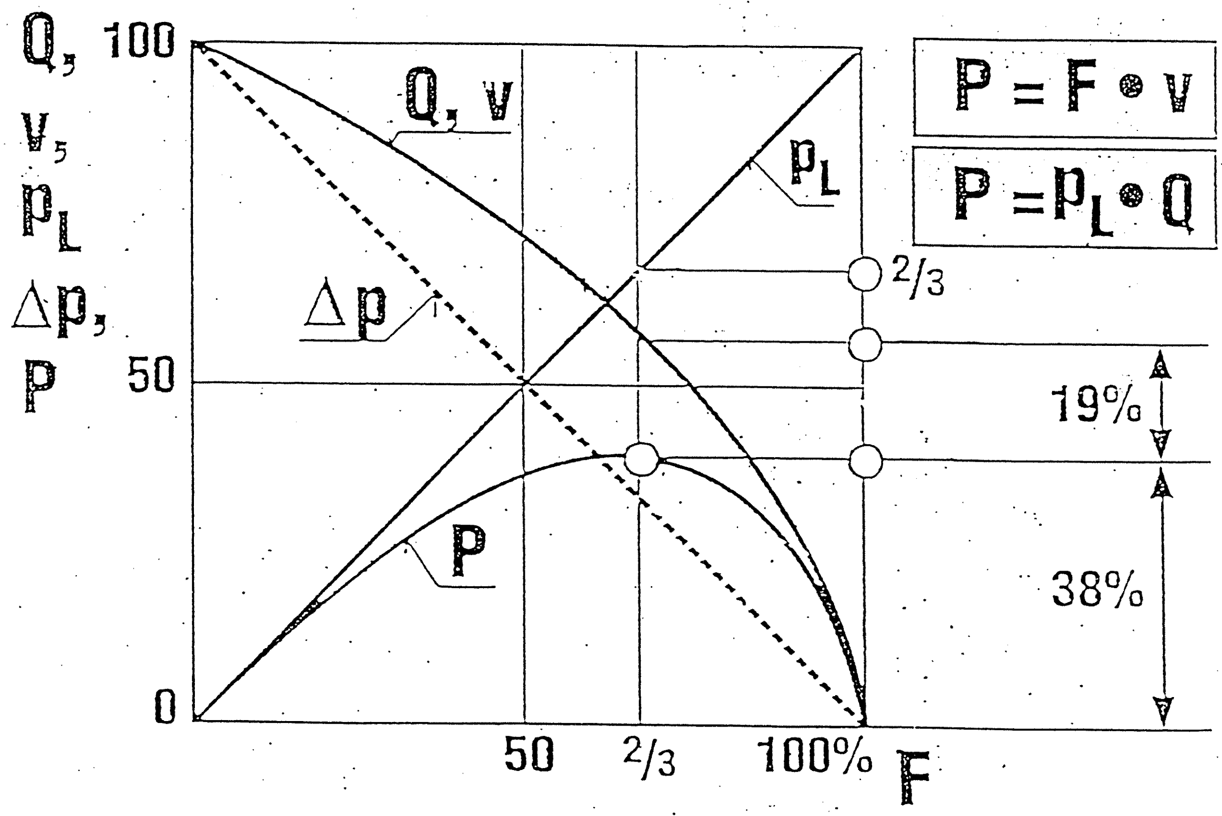

Fig. 2 : Performance potential of the throttle control system

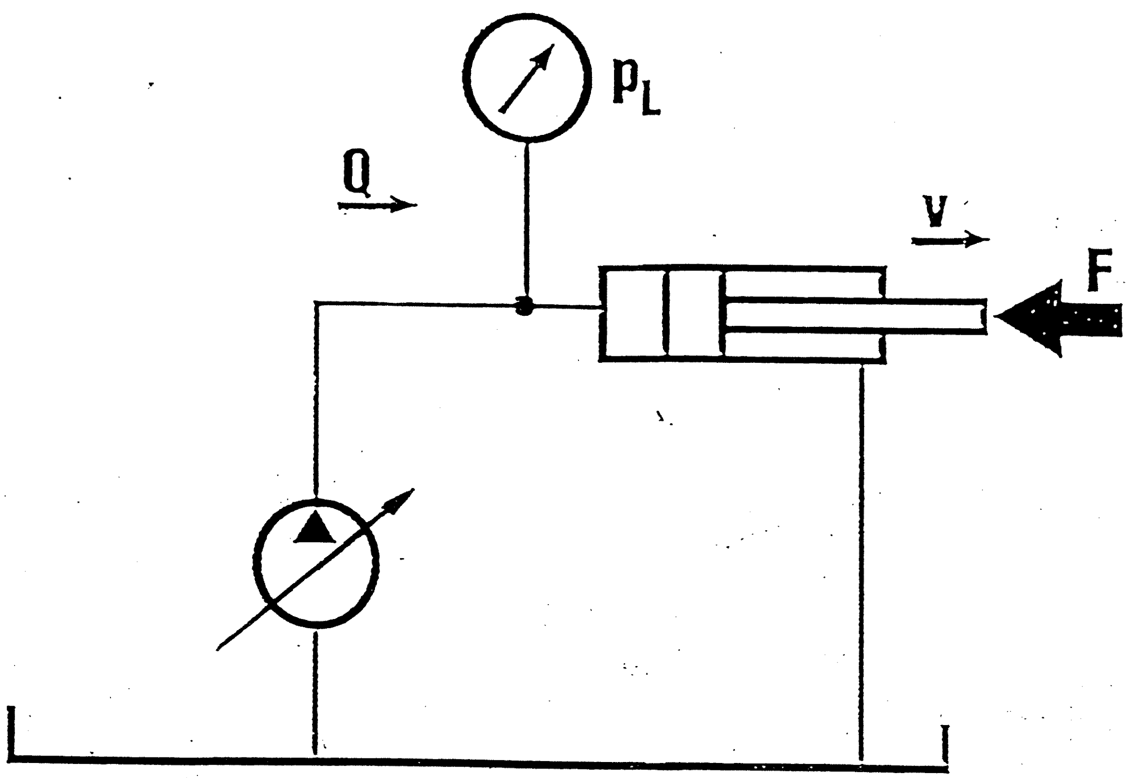

Fig. 3 : Basic principle of a pump control system

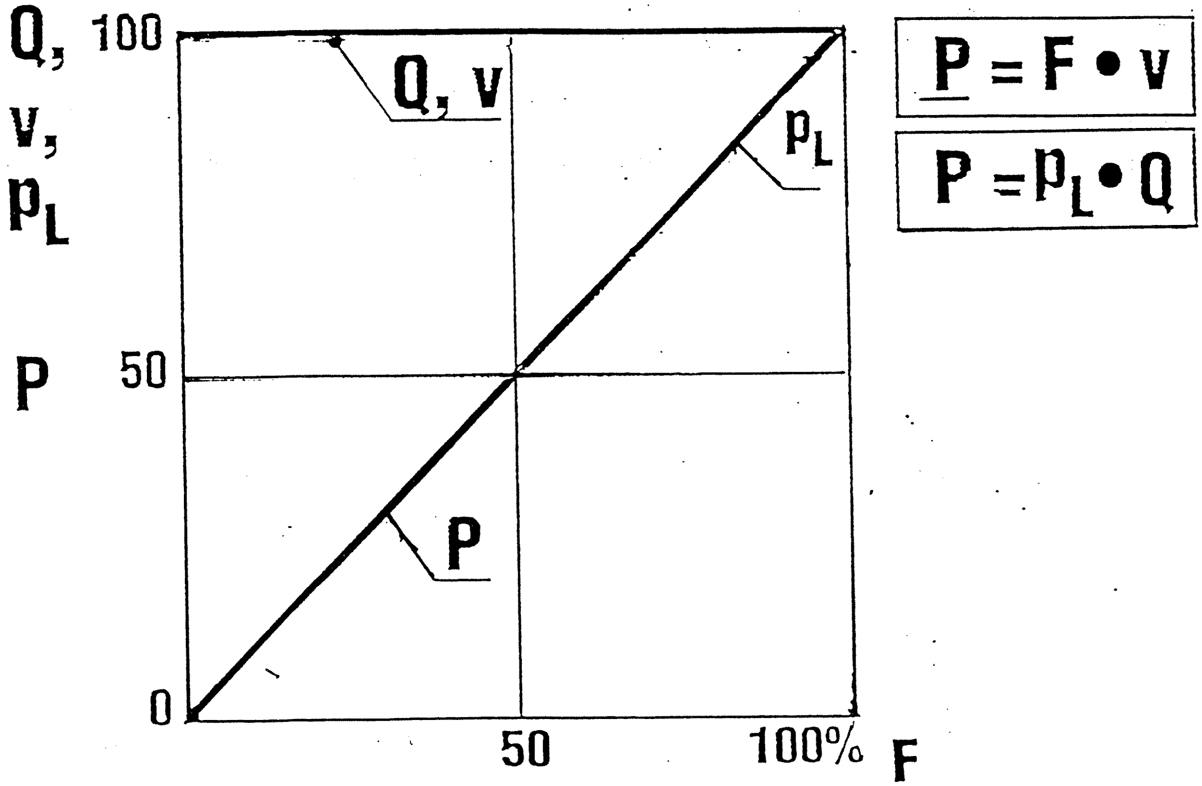

Fig. 4: Performance potential of the pump control system

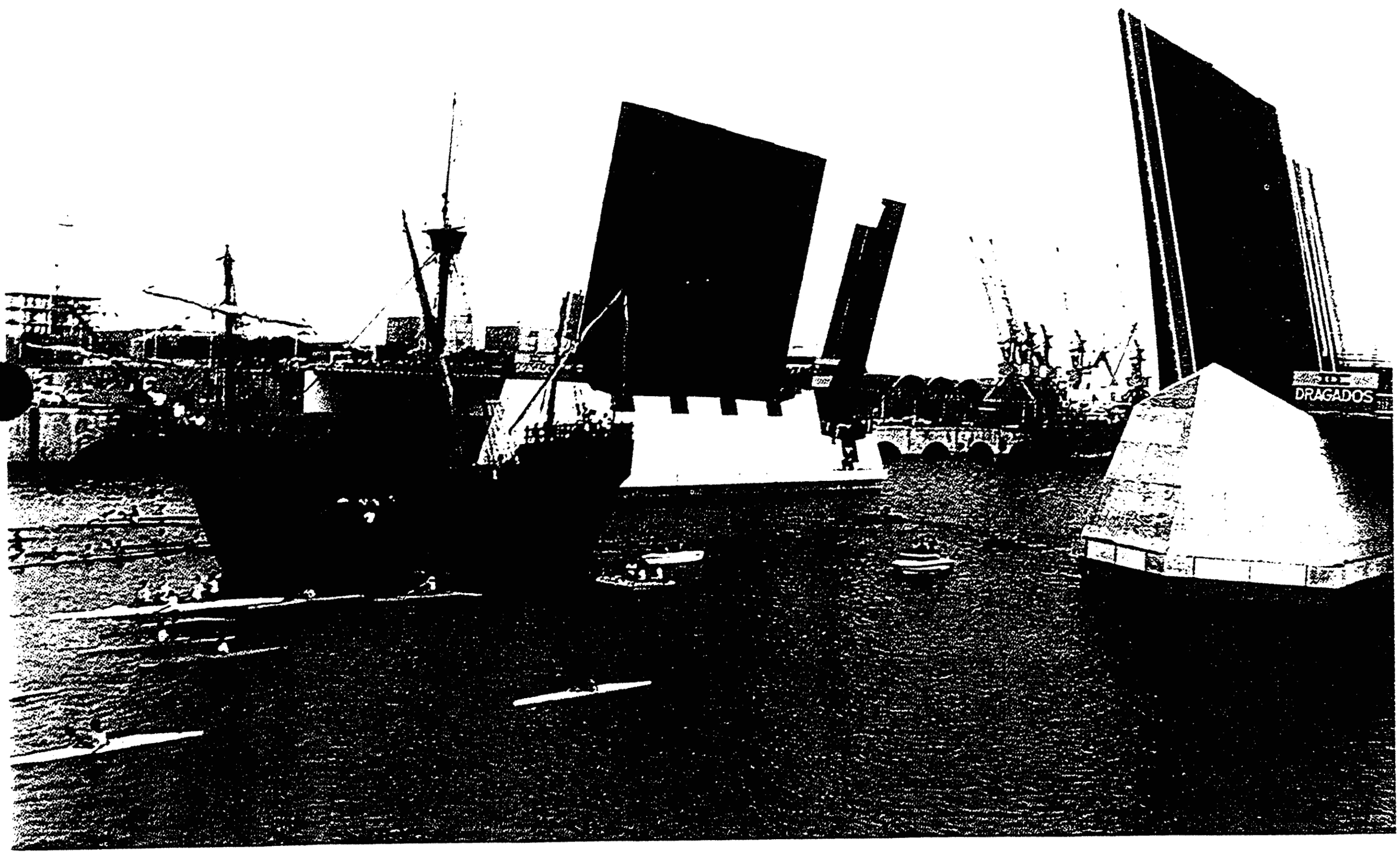

Fig. 5: The Santa Maria passing the bascule bridges

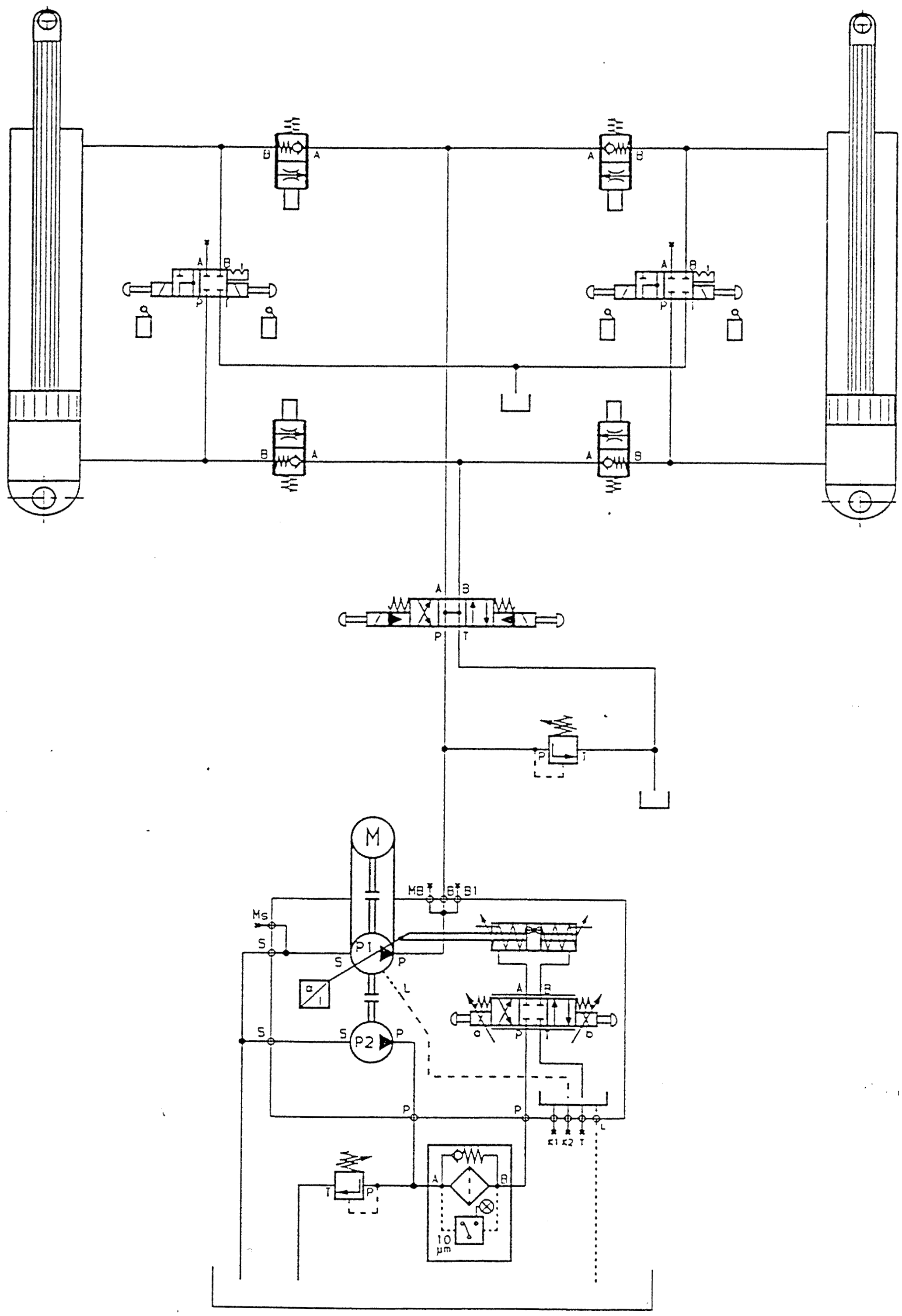

Fig. 6: Block diagram of hydraulic system

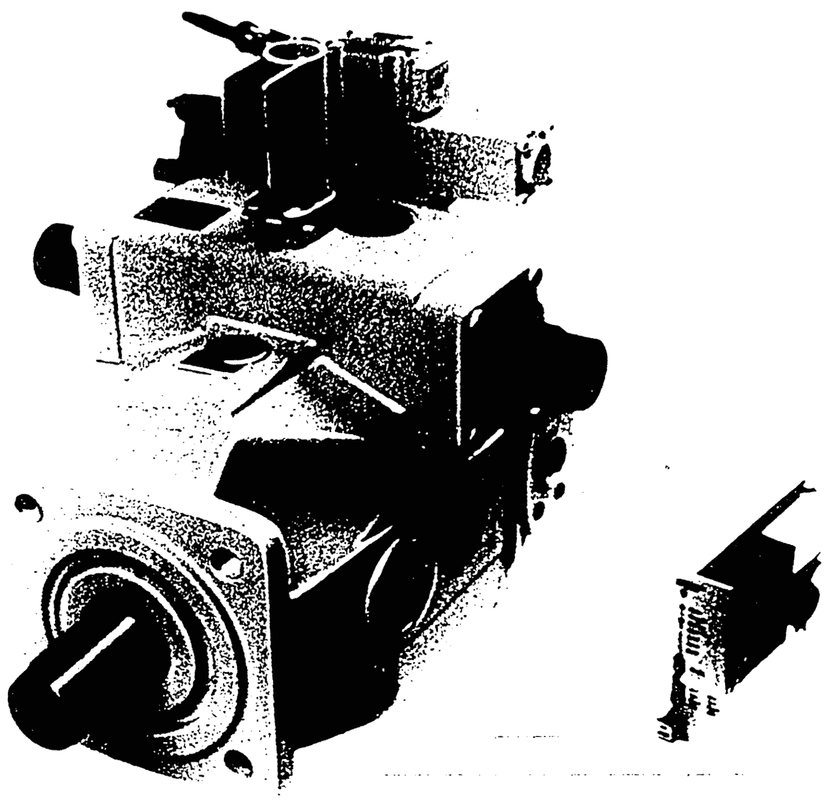

Fig. 7: A4VSO pumpe with control card VT 5035

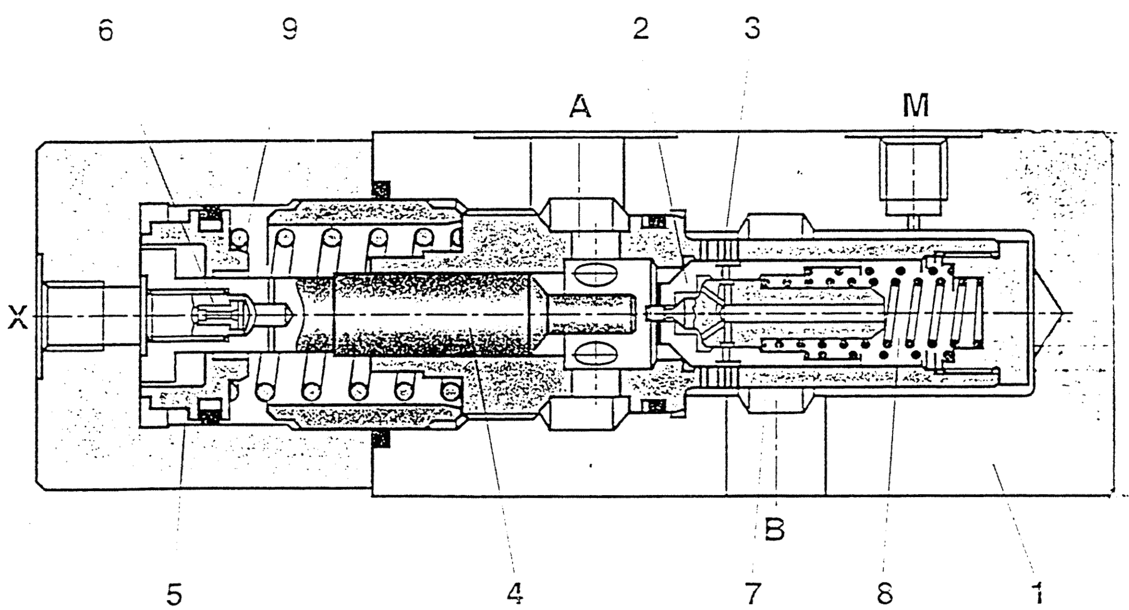

Fig. 8 : cross section of a check Q-meter

Diagrama de translacion

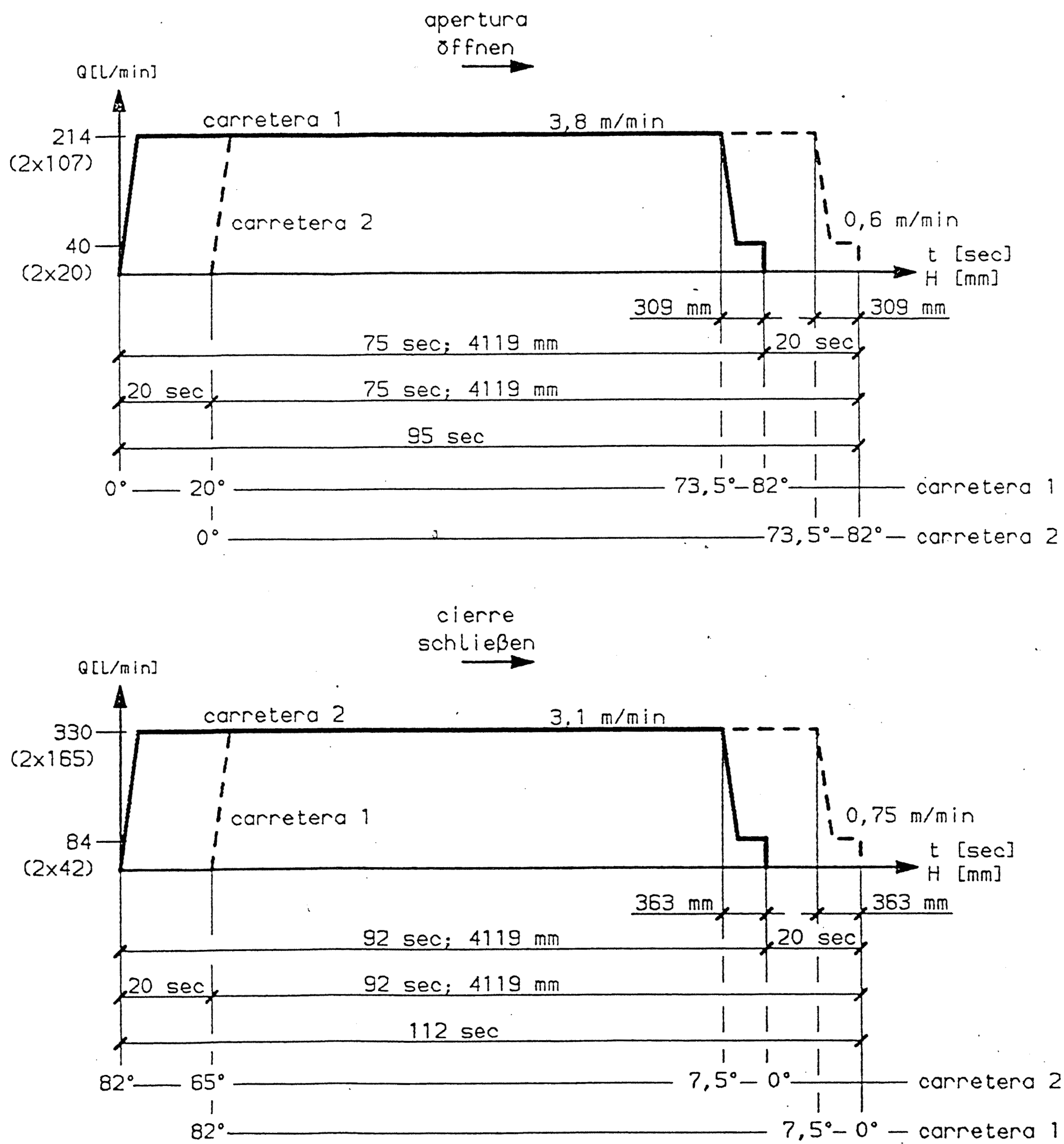

Fig. 9 : Drive digram of the railway bridge
Puente basuclante-Sevilla, Puente ferroviario

Features	Electric mechanical drive	Hydraulic cylinder drive
Starting torque/force	η EM x η Gear	η Cyl. (high)
Acceleration Deceleration Synchronization	less controlable	smooth, controlable
Installation	limited due to mech. drive train	unlimited (direct linear drive)
Service Maintenance	lubrication mech. gear	no service, reliable after years
Environment	grease from mech. parts	clean if properly installed
Structural vibration (Bridges)	critical at stiff structures (slack gear)	not sensitive to vibration
Position measuring system	external	internal, integrated in cylinder, (option)
Corrosion	metallic parts (shafts)	ceramic piston rod

Fig. 10 : Civil Engineering

Electric mechanical drive versus hydraulic cylinder drive