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Piston Pumps for the Hydraulic Transport of Solids

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Summary

The author describes the various types of pumps at present available for the conveying of slurries. The advantages, disadvantages and field of application of each pump type are discussed and examples of their use detailed.

1. Introduction

Selection criteria for the economic employment of rotary pumps are, above all, the abrasivity of the medium to be pumped, the lifting pressure as well as the grain size of the solids. Nowadays, the following piston pump types are used for the hydraulic long-distance transport of solids:

a) duplex piston pumps
b) triplex piston pumps
c) plunger pumps
d) duplex piston diaphragm pumps
e) triplex piston diaphragm pumps.

For more than 80 years, rotary pumps have been included in the production program of Wirth GmbH, Erkelenz. At the turn of the century, the first pumps were employed in the oil drilling industry. Due to the constantly increasing requirements with regard to drilling depth and delivery, the originally small pumps with low driving power have turned into equipment with driving capacity of up to 1,500 kW.

The flushings to be conveyed by these pumps include solids. In general, pumps for the oil drilling industry are, however, not regarded as solids transport pumps.

Considering the large experience in the oil drilling industry it was obvious that Messrs. Wirth, as one of the first European companies, were engaged in the hydraulic transport of solids, in the middle of the 1950s.

The first remarkable success occurred in 1964, when Messrs. Alsen Breitenburg, Zement- und Kalkwerke GmbH, built a transport line for pumping chalk slurry from the pit to the production works. For this project, five duplex piston pumps, type LKP 71/4"x16"/425 were supplied (Fig. 1). They transport chalk slurry with 65% solids portion over a distance of 5 km. The max. delivery of the complete pumping station is 625 m³/h.

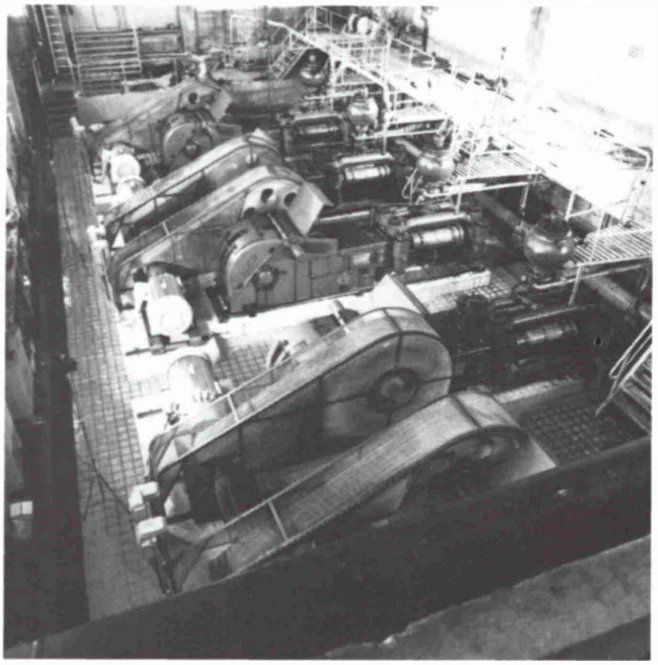


Fig. 1: Pumping station Alsen-Breitenburg

2. Duplex and Triplex Piston Pumps

Duplex and triplex piston pumps have a large field of employment. They can economically be utilized for the pumping of media with low or medium abrasivity, such as chalk slurry, coal, flotation material, drilling mud, sludge (Fig. 2). These pumps are directly actuated pumps, i.e., the piston and the packings are in direct contact with the medium.

As far as the duplex piston pump is concerned, two flow lines are arranged such that the pump is operating double action. The piston is contacted by the flow medium on both ends.

Triplex piston pumps have three flow lines, but are single-acting, i.e., the flow medium contacts the piston at one end. At its rear end, the cylinder liner is open.

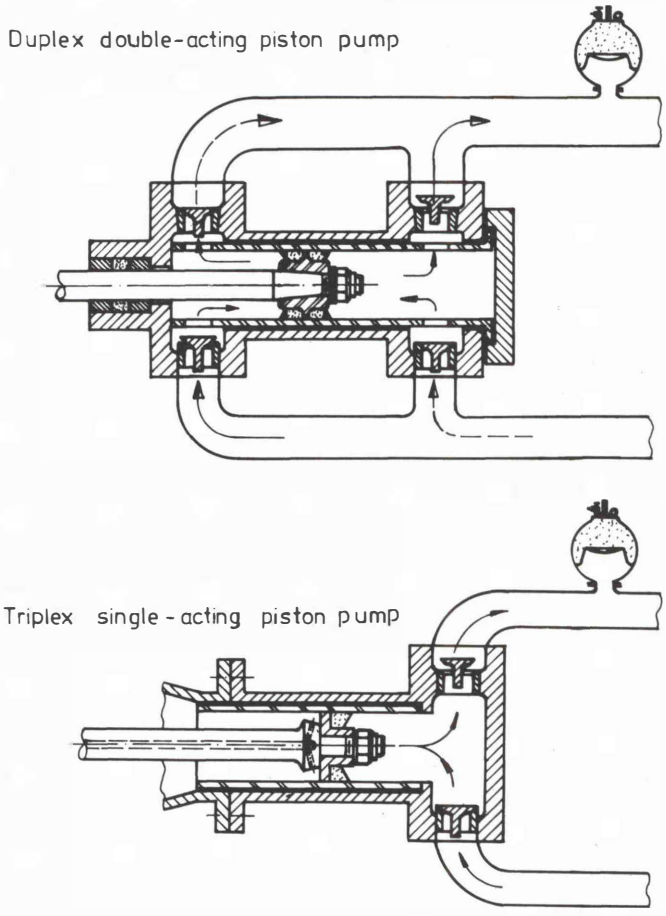


Fig. 2: Schematic duplex/triplex pump

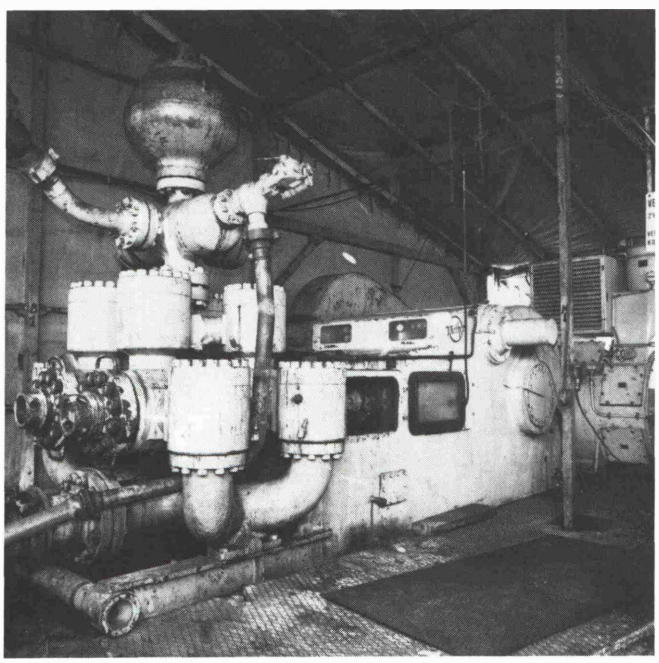


Fig. 3: Piston pump LK 73/4″ x 18″/1250. Driving power 920 kW

The duplex piston pump (Fig. 3) is the traditional pump having been employed for several decades. With increasing lifting pressures, the triplex piston pumps (Fig. 4) became more and more important in the sixties. Triplex piston pumps, however, have to be operated at a higher speed in order to achieve the same deliveries as the duplex piston pumps. Due

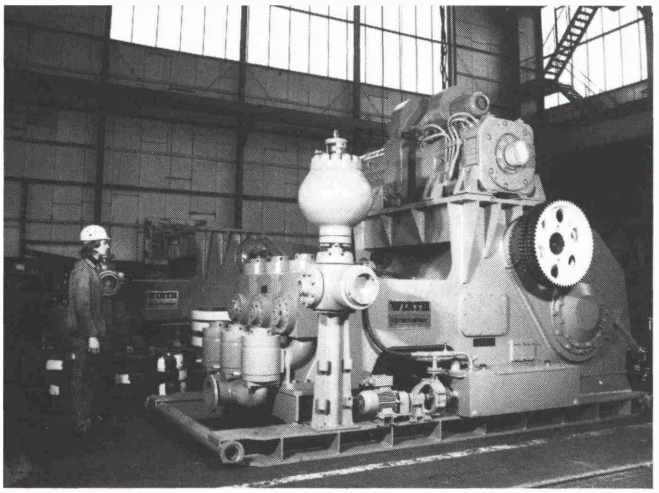


Fig. 4: Triplex pump TPK 7″ x 12″/1600. Driving power 1,200 kW

to the higher number of strokes, the lifetime of the wearing parts is shorter. A comparison of the wearing parts of both pump types shows a considerable difference in the quantity of wear parts. Due to the bilateral effect, the duplex piston pump has more wear parts than the triplex piston pump.

Duplex piston pump	**Triplex piston pump**
2 cylinder liners	3 cylinder liners
4 piston gaskets	3 piston gaskets
2 piston bodies	—
2 piston rods	—
2 piston rod packings	—
8 valves	6 valves

The piston rods of the triplex pump are not wearing parts, since these parts are no longer in direct contact with the medium to be conveyed.

The power produced by the drive (Fig. 5) is — both for duplex pump and triplex pump — converted into an oscillating movement over drive shaft, drive wheel, crankshaft and connecting rod up to the crosshead and is led by the crosshead rod and piston rod to the fluid end.

In the case of the duplex piston pump, the two crank pins are staggered by 90°, whereas the three pins of the triplex piston pump are staggered 120°. Hereby, the triplex pump has a lower degree of irregularity, i.e., the flow has a considerably lower degree of pulsations. Fig. 6 shows a flow variation of 46 % for the duplex pump, and of 23 % for the triplex pump.

Due to the crank dynamics, the residual pulsation of the flow of both pump types is compensated by Wirth diaphragm pulsation dampeners with a damping degree of approx. 98 %, triplex pumps requiring a smaller pulsation dampener than the duplex pumps, due to the better kinematics.

Nowadays, duplex and triplex pumps are built for driving capacities up to 1,500 kW. In the scope of the Black Mesa Coal Pipeline project in the USA, for instance, a total of 13 duplex pumps — each of them having a driving power of 1,250 kW, — transports 4.8 million tons of coal annually, over a distance of 440 km.

Fig. 7 shows a pumping station comprising two triplex pumps model TPK 7″ x 12″/1600.

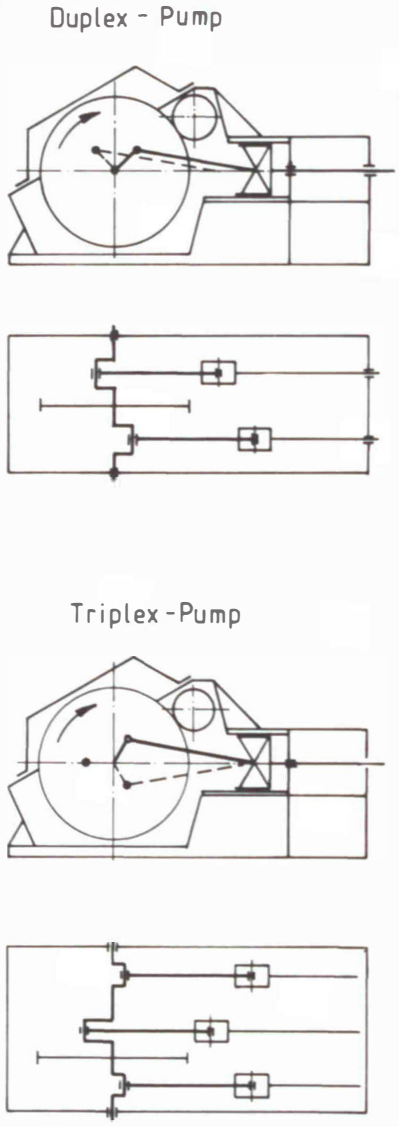


Fig. 5: Gear mechanism of duplex/triplex pump

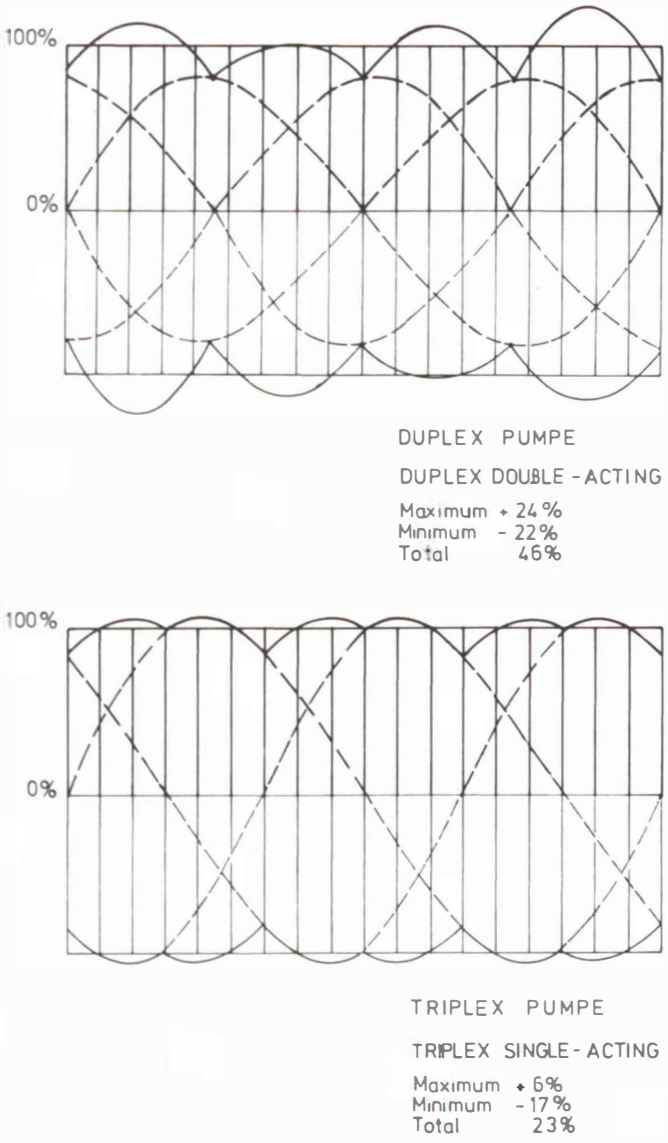
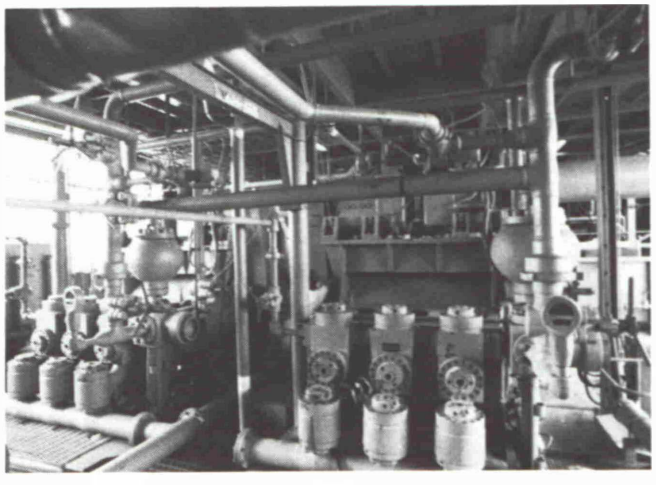


Fig. 7: Pumping station with 2 triplex pumps TPK 7" x 12"/1600

Fig. 6: Tangential pressure diagram duplex/triplex pump



3. Plunger Pumps

Just like the triplex pumps, plunger pumps are single-acting pumps, where the pistons are replaced by plungers (Fig. 8). The field of employment proper of plunger pumps is not in the hydraulic solids transport. These pumps — with relatively small plunger diameters — are used as high-pressure pumps. Only after the development of a suitable plunger flushing system, could these pumps be utilized for the transport of abrasive fluids. This flushing system keeps the medium to be transported from the contact surface of the plungers, thus, avoiding fast wear of the plunger due to abrasive solids.

Plunger pumps for solids transport are operated with 80—120 strokes per minute, depending on the medium to be transported resulting in a high wear of valves and packings. Due to the multi-cylinder design, there is a pro rata increase in the number of wear parts.

In comparison to the piston diaphragm pumps described later, the plunger pumps are more favourable in purchase price, but require more wear parts and, consequently, require a higher expenditure in maintenance.

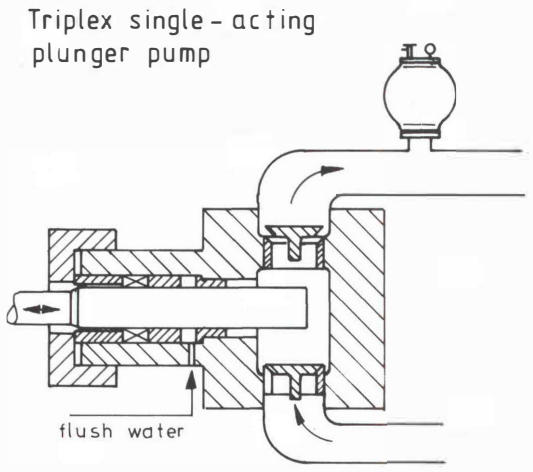


Fig. 8: Schematic plunger pump

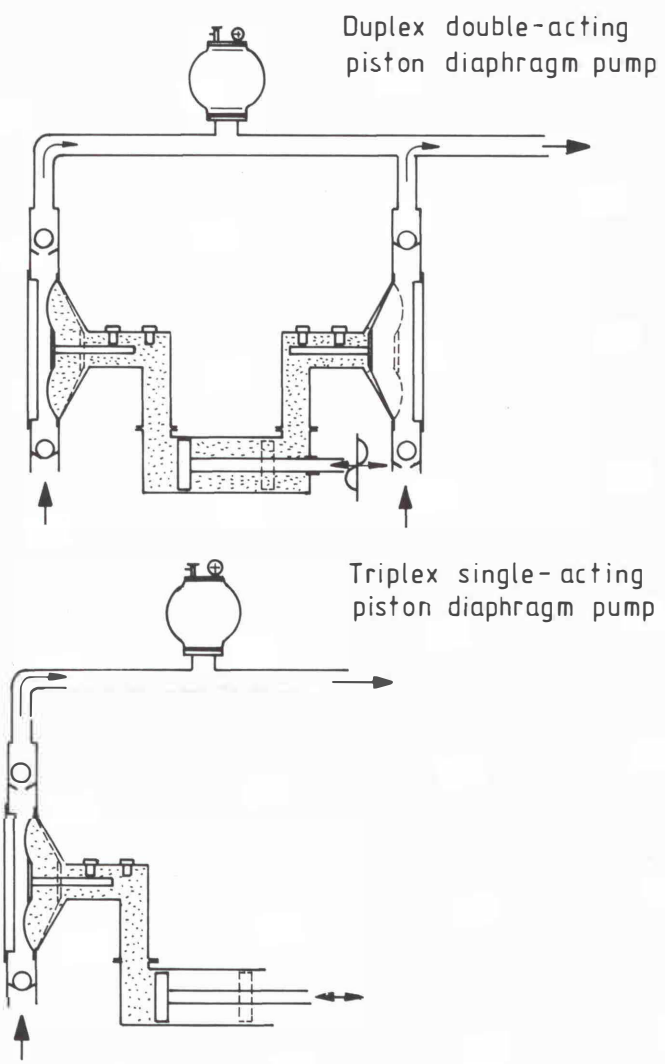


Fig. 9: Schematic duplex/triplex piston diaphragm pump

In the scope of the Samarco ore pipeline project in Brazil, 14 plunger pumps — drive power of 920 kW each — deliver 12 million tons of iron ore per year over a distance of approx. 400 km.

4. Duplex and Triplex Piston Diaphragm Pumps

Piston diaphragm pumps are used for the transport of very abrasive media, such as iron ore, copper ore, bauxite, red mud and sand (Fig. 9). The medium to be transported is not in direct contact with pistons and packings, but is mechanically separated by a diaphragm and intermediate medium. Hereby, the pistons, piston rods and cylinder liners are no longer wear parts.

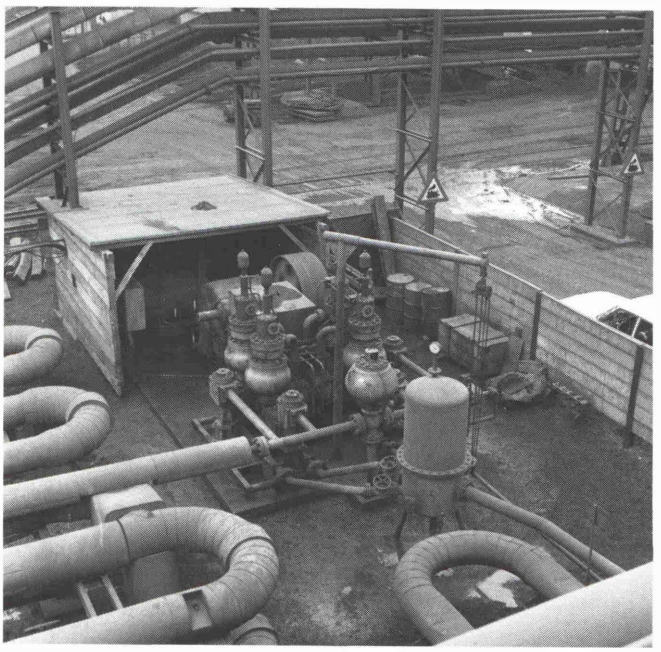
Due to the mechanical separation between piston and media to be transported, the advantages of the piston pump are maintained. The difference in features between duplex piston diaphragm pump and triplex piston diaphragm pump correspond to those of the duplex and triplex piston pump.

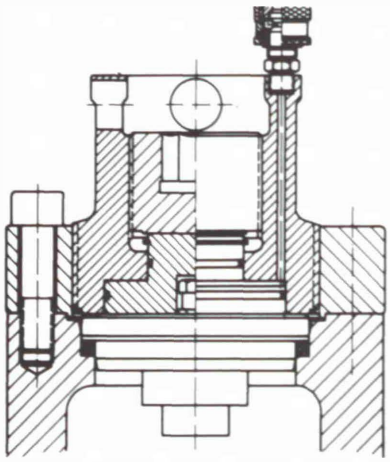
Already in 1968, Messrs. Wirth were engaged in the development of diaphragm pumps. Fig. 10 shows a duplex piston diaphragm pump built in 1969 for pumping sand. Using this pump, a quartz/water mixture with 375 g sand per liter of mixture has been transported at a delivery pressure of 100—120 bar. Operating time — under these conditions — was 1,000 hours without exchange of wear parts. On the occasion of a subsequent employment, a bauxite suspension was pumped with a temperature of 80° at a lifting pressure of 150—170 bar. The results confirmed the expectations for this pump type.

A steady further development of the wearing parts has made it possible that, nowadays, diaphragm pumps are utilisable for the transport of highly abrasive media. Diaphragm lifetimes of 6,000 hours are, for instance, no rarity today.

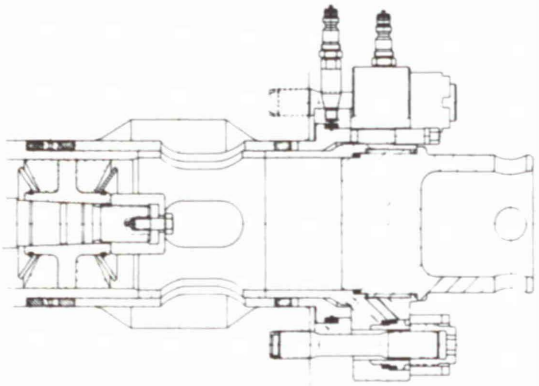
The investment costs of diaphragm pumps are higher than those of plunger pumps. This disadvantage is, however, compensated within a few years due to the longer life of wearing parts and the lower expenditure in maintenance connected therewith.

Fig. 10: Piston diaphragm pump KMP 63/4" x 12"/350 for pumping of sand

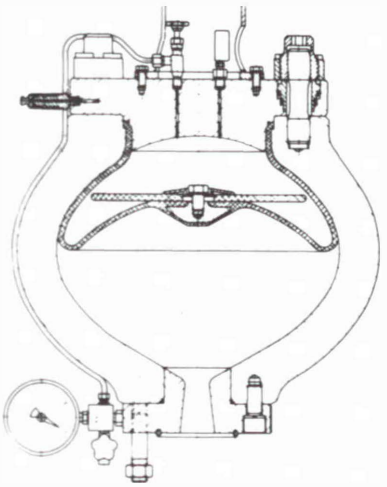




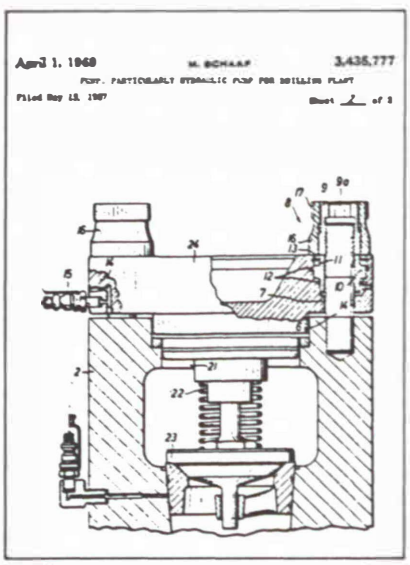
Hydraulic valve covers

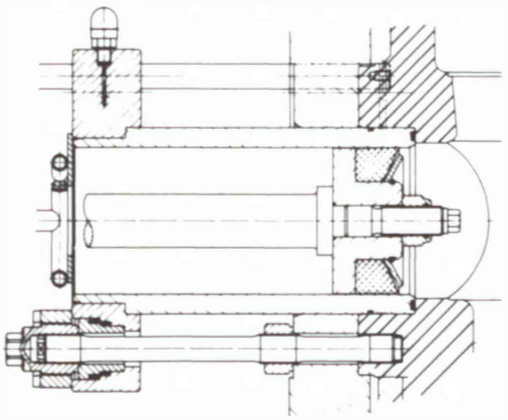


Hydraulic cylinder covers with screwed lock and separate hydraulic tightening of cylinder stuffing box packing for DUPLEX PUMPS

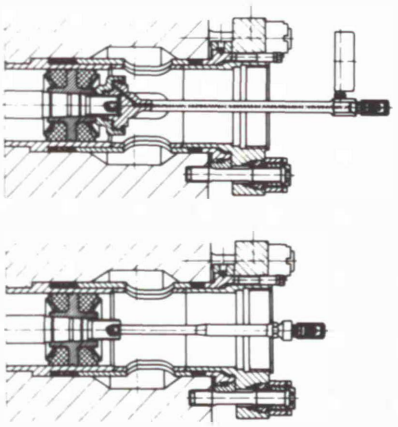


Pulsation dampener with hydraulic tightening of cover screws





Hydraulic cylinder covers with screwed lock and separate hydraulic tightening of cylinder stuffing box packing for TRIPLEX PUMPS



Installation and replacement of piston

Fig. 11: Hydraulic auxiliary tools

5. Hydraulic Accessories

A speciality of the Wirth pumps are the many hydraulic auxiliary tools (Fig. 11) which have been designed for the simple handling and quicker exchange of the wear parts. Worldwide patents protect these technical advantages.

Already in 1983 for the pumps constructed for the chalk slurry unit it was possible to hydraulically extract the valve seats.

The hydraulic accessories indicated below are part of the standard equipment of Wirth pumps:

a) hydraulic valve-cover closure,
b) hydraulic cylinder-liner clamping for duplex pumps,
c) hydraulic cylinder-liner clamping for triplex pumps,
d) hydraulic piston pressing-in and piston pulling, device,
e) hydraulic housing cover for pulsation dampener.

Many years of experience in using hydraulic equipment led to a high degree of operational safety, and easy and quick installation and removal of wear parts.

6. Case Studies

6.1 Sophia Jacoba Mine

In the Sophia Jacoba mine in Hückelhoven a total of 22 Wirth high-pressure duplex piston pumps are working underground. The pumps deliver aggressive mine water with solids content. Fig. 12 shows a pump station on the 770 m level, with 2 Wirth high-pressure piston pumps type 6 1/4" x 8"/60. One pump is equipped with electric drive, whereas the second one has a compressed-air motor. In case of a power failure it is thereby ensured that delivery will continue. The natural aggressive mine water with salt-, sulphate-, and chloride components, and the abrasive water with solids due to mining operations are collected in a sump. The pumps deliver the mixture over 178 m vertically, and over 800 m horizontally to a sump line. The delivery capacity of a pump is approx. 620 ltrs/min at a pressure of 31 bar.

6.2 Carl Funke Mine

In the field of hydromechanical coal extraction, 3 Wirth high-pressure duplex piston pumps, type LK 63/4" x 12"/500 were

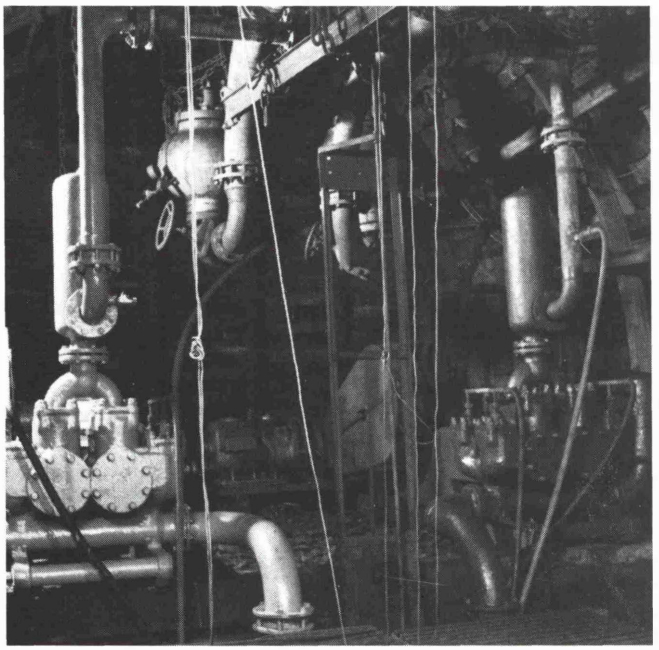


Fig. 12: Underground pumping station with 2 piston pumps type LK 63/4″ x 8″/60.

Fig. 13: Piston pumps type LK 63/4 x 12″/50 for pumping fine coal with waste.

pumping fine coal (Fig. 13) at the Carl Funke IV/VI mine of the Essener Steinkohlen-Bergwerke AG, until this mine was closed in 1973. 200 m³/h of slurry with a fine coal content of 400 g/l were delivered to settling ponds aboveground, over 5,500 m horizontally, and 760 m vertically. The maximum discharge pressure of the pumps was 140 bar, and normally the effective pressure was 100—130 bar. Control of the 3 pumps was executed from a central switch room.

7. Conclusions

The steady increase of the hydraulic transport of solids means that nowadays pumps with deliveries up to 700 m³/h are manufacured. One of these pumps is, for instance, capable of pumping approx. 350 tons of coal per hour.

In order to achieve long, disturbance-free operating times of the pumps, the lifting pressure should not exceed 100 bar. An exception is the drilling mud pump operating with continuous operating pressure of more than 200 bar.

The max. grain size of solids should not exceed 6 mm for all rotary pumps. The reason for this are the automatically operating pump valves.

Duplex and triplex piston pumps are used for the hydraulic transport of solids mixtures of medium abrasivity such as coal, chalk slurry, drilling mud and sludge.

Duplex and triplex piston diaphragm pumps are suitable for the pumping of solids mixtures of highest abrasivity like iron ore, copper ore, pyrites, sands, ashes, bauxite and red mud.