Hydraulic press construction for fitting the bearings to the housing
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Abstract (in English)
This report was written as a result of a Bachelor Degree Project, together with Swepart Transmission AB. The report contains the construction of a hydraulic press for the assembly operation. The project started with a new construction of a hydraulic press for the bearings’ assembly. The goal within the thesis work was to fit the three bearings to the housing by only one press motion. This operation should be very safety because of the sensitive tolerance at the bearings and housing. Construction of the cylinders, rams and bolster were the most important parts at this project because this parts’ functions are very important for this assembly. The next step of this thesis was to calculate the hydraulic press components’ parameters and then choose the suitable components. The focus was to choose more useful and reliable components. The hydraulic press was modeled in the CAD program Solid Works and 2D technical drawing was drawn in the Autocad. The frame material was chosen and the frame was analysesised in the Solid Works.

Key Words
Fitting, Volvo Trucks’ housing, bearing, hydraulic, press, cylinder, ram, bolster, modelling, analysis

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29 May, 2008

Izzettin Osman Egüz
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1. Introduction

This chapter describes the company information, background, problem description and goal for the thesis. It also describes the disposition of the report.

1.1 Swepart Transmission AB

The two brothers Axel and Bertil Bengtsson started their engineering shop in Hultaberg in the South of Sweden at 1945. Their business idea was to manufacture screw-vice, brass-spindles and hydraulic equipment. In 1956 the company was moved to Liatrop.

In 1955, Bertil passed away and the company’s second founder Axel died in a tragic aircraft accident at 1963. After these happens, Torsten who was the third brother engineer and Torsten’s son take charge of the whole business.

In 1963, the demand for gearwheels increased constantly and new modern machines for turning and gear-milling were acquired. The company was a stable supplier of transmission parts at this year.

At the beginning of seventies Saab, Scaina and Husqvarna were included among the newer costumers. Nowadays, Volvo and lots of big company are their costumers. The dominating business is the heavy vehicle industry but also automation, forestry and construction equipment industries can be counted in their costumer base.

Swepart Transmission AB that manufactures transmission products including gear wheels, spline axles and gearboxes shall, through continous improvements, achieve a quality level which surpasses the requirements of their customers [11].

1.2 Background

Swepart Transmission AB started up project that they want to do assembly operations more efficient. They want to make more effective and rationalized flow, also they want to create better work environment.
The present hydraulic system is wasting time, human power and energy. Following Figure 1.2 shows the present system. This system should be improved.

Figure 1.2 The present hydraulic system to assembled the bearings to the housing

The main idea of this project is assembled the bearings to the Volvo Trucks’ housing. This operation can be done by two different methods. This methods are press and shrink fitting.

Shrink fitting is a procedure in which heat is used to produce a joint between two pieces of metal, one of which is inserted into the other. We have to heat the housing and cool the bearing at this operation. The process of shrink fitting takes a long time. This thermal conditions of operation affect the diametral clearance. Bearing and housing has a very sensitive tolerance. Shrink fitting affects the tolerance in a negative way.

All this reasons, pressing operation is preferred for fitting the bearings to the housing.
1.3 Problem description

While fitting, there are some important rules. These are:

- Housing should be fixed on the bolster very safely.
- The maximum permitted press-fit force should not be exceeded. The maximum permitted press-fit force on the cups shall be 25 kN. Also this value is very important for beginning of the calculations.

Nowadays, the assembly operation is done by low efficient system. This operation is done three different steps because the present hydraulic press has only one conic ram but the housing have three bearings. Only one bearing is fitted to the housing at every step. So during this assembly; hydraulic press should be stopped after every step and housing’s position should be changed to the suitable position. This operation is really hard for human and it takes long time.

The study focuses construction of the new hydraulic press.

1.4 Goal

The goal with this thesis is to fit the three bearings to the Volvo Trucks’ housing. Following Figure 1.3 shows Volvo Trucks’ housing. This Figure helps us to understand the main problem and the goal.

![Volvo Trucks’ housing](image)

Figure 1.3 Volvo Trucks’ housing
In my goal, I have to find many problems solution. Some basic goal in the project:

- How shall I design a new hydraulic press to fit the three bearings to the Volvo Trucks’ Housing?
- How can the three bearings be fitted by only one press motion?
- How can the housing be fixed on a bolster?
- Calculations of the cylinder’s, electric motor’s, pump’s, the capacity of the oil reservoir’s etc..
- What kind of motor, pump and hydraulic accessories are more useful for the hydraulic press?
- The hydraulic system’s components selection.

The aim is to find a best solution for this problems. In the modern world of today, hydraulic plays a very important role in the day to day lives of people.

The purpose is to familiarize one with the underlying principles of hydraulic presses and construct the new hydraulic press.

1.5 Disposition of the study

This report is divided into five chapters. The first chapter contains history of Swepart Transmission AB, background, problem description and goal of this report. In chapter two, there is an information about industrial hydraulics and explain to why the hydraulic system was chosen for the assembly operation. Chapter three contains description of hydraulic press components. Chapter four describe the differences from another hydraulic press. Chapter five contains conclusion of this report. In addition all the calculations, the chosen components’ data sheets, the hydraulic system’s modelling&technical drawing and analysis of the frame can be found in the appendix.

Generally the thesis is divided into two parts, one the press construction part and one theoretical part. The construction part is to design the new hydraulic press that will fit three bearings to the housing. The theoretical study focuses on basic information about hydraulic presses and hydraulic press components.
2. Basics of Industrial Hydraulic Systems

The aim of this chapter is to explain why the hydraulic system is the best solution for the assembly. This chapter contains history of fluid power, comparison of hydraulic and pneumatic system, general structure of hydraulic systems and advantages of the hydraulic systems.

2.1 History of fluid power

"Fluid power is the technology that deals with the generation, control and transmission of power, using pressurized fluids" \(^1\).

Fluids as a source of power. In 1648, a French Physicist, Blaise Pascal, proved the phenomenon that water transmits pressure equally throughout a container. Later on this principle was used in industry to generate fluid force as in the Bramah’s press. Following Figure 2.1 shows the Bramahs principle \([3]\).

\[
F_2 = F_1 \left( \frac{A_2}{A_1} \right)
\]

![Figure 2.1 Working principle of Bramahs press [3].](image)

However due to the advent of electricity around 1850, the use of water power (water hydraulics) in industry declined until the outbreak of World War II. From 1920 onwards, oil hydraulics started appearing in various machine tool controls in Europe, USA, etc. Engineers started using fluids for power transmission and basic elements like pumps, control-valves, cylinders, etc. \(^2\)

Today fluid power is used widely in every branch of industry. Some typical applications are hydraulic presses, automobiles, agricultural machinery, robots etc.

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\(^1\) Esposito, 2003, page 1
\(^2\) Majumdar, 2003, page 2
2.2 Comparison of hydraulic and pneumatic system

At the beginning of this project, I asked Mr Ekman “Why don’t you use air for the pressing working”. Reply was clear. Because oil is more useful for pressing working. Hydraulic systems operate with oil but pneumatic systems operate with air. It is the basic differences of this systems.

When choosing the most suitable system for a particular design solution, the specifications on the overall operating conditions are to be strongly considered. Correct solution can be reached, based on the examples of applications for the different system types.

The right choice of system (or a combination of systems) requires precise information regarding the technical data of the components, their advantages and disadvantages. Table 2.2 shows the basic properties of hydraulic and pneumatic systems.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Hydraulics</th>
<th>Pneumatics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy Carrier</td>
<td>Oil/operational</td>
<td>Air</td>
</tr>
<tr>
<td>Energy transmission</td>
<td>Pipes, hoses, tubes, bores</td>
<td>Pipes, hoses, tubes, bores</td>
</tr>
<tr>
<td>Conversion from/into</td>
<td>Pumps, cylinders, air,</td>
<td>Compressors, Cylinders</td>
</tr>
<tr>
<td>Mechanical energy</td>
<td>hydraulic Motors</td>
<td></td>
</tr>
<tr>
<td>Most important Characteristics</td>
<td>Pressure p (30...400 bar)</td>
<td>Pressure p (approx. 6 bar)</td>
</tr>
<tr>
<td></td>
<td>Flow rate q</td>
<td>Flow rate q</td>
</tr>
<tr>
<td>Power efficiency</td>
<td>Very-good through high</td>
<td>Good but restricted because</td>
</tr>
<tr>
<td></td>
<td>operational Pressure (up to 400 bar)</td>
<td>Of the operational pressure of up to 6 bar</td>
</tr>
<tr>
<td>Precision of motion.</td>
<td>Very good because oil can</td>
<td>Not good because air is compressible</td>
</tr>
<tr>
<td>All systems are improved</td>
<td>Hardly be compressed</td>
<td></td>
</tr>
<tr>
<td>by positioning action</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Typical Application</td>
<td>Processing parts, linear actuation, presses, rotation (great forces)</td>
<td>Artisanry, mounting devices, Fitting-out</td>
</tr>
</tbody>
</table>

Table 2.2 Basic properties of hydraulic and pneumatic systems.

Most important characteristics pressure and the other criterias, designate that the best solution is hydraulic system for the press construction.

---

Götz & Bosch, 2002, page 9
2.3 Advantages of a hydraulic System

Hydraulic Presses continue to be the press of choice for today's modern manufacturers. There are very important reasons of this. This reasons are related between advantage of a hydraulic systems. The basic advantages of the hydraulic systems are:

1. Hydraulic power is easy to produce, transmit, store, regulate, control and transform.
2. Hydraulic systems can transmit power more economically.
3. Division and distribution of hydraulic power is simpler and easier than other forms of energy. This advantage is very important for the design because two different cylinders were used at the press construction.
4. Hydraulic forces are easily limited and balanced. Easy and accuracy of control by the use of simple levers and buttons.
5. Hydraulics is a better over-load safe power system. This can be easily achieved by using a pressure relief valve. The maximum permitted press fit force on the cups shall be 25 kN for fitting bearings. So if the force exceed 25 kN, the pressure can be easily decreased.
6. Frictional resistance of hydraulic power is much less than the other methods.
7. Hydraulic pump’s noise and vibration is minimal.
8. Hydraulic systems are cheaper if one considers the high efficiency of power transmission.
9. Maintenance of hydraulic system is easy.
10. Hydraulics is mechanically safe, compact and is adaptable to other forms of power.

Of course there are some advantages and disadvantages for every machine. But hydraulic system has a few disadvantages. The most important disadvantage is leakage of hydraulic oil poses but this problem can be compensable.

Now its very clear that why hydraulic press is more useful for the press construction.

2.4 Structure of a hydraulic system

The operation of a hydraulic system includes energy conversion, energy transmission and energy control. Firstly mechanical energy is transformed to hydraulic energy, then hydraulic energy is converted back to mechanical energy. This energy conversion is done by hydraulic components. The following Figure 2.2 shows a basic hydraulic system and the components from which it is built up.

---

4 Majumdar, 2003, page 2-4
5 Esposito, 2003, page 6-9
6 Götz & Bosch, 2002, page 8
Functionality of the components is shown on the left part of the figure. The corresponding standard symbol of each component is shown on the right part.

Figure 2.4 A basic hydraulic system and the components
3. Hydraulic Press Components

This part is intended to demonstrate components of hydraulic presses. This chapter contains a basic information of hydraulic cylinder, pump, electric motor and valve. Hydraulic is not complete with only pump, motor, cylinder and valve. There are other components in a hydraulic system listed under the hydraulic accessories category. This components are reservoir system, filter, accumulator, hydraulic pipes, hoses and fittings.

3.1 Hydraulic Cylinders

The cylinder is a basic component and the engineers are generally start hydraulic cylinders design in the design of hydraulic systems 7.

Hydraulic cylinder converts hydraulic energy to mechanical energy. Hydraulic cylinder contact with a piston rod to push or pull force to drive external load along a straight line path. Hydraulic cylinders are widely used in different types of high pressure applications in an industry 8.

The oil is delivered under pressure through the cylinder ports in the piston and this increase of pressure starts the piston motion. This is a very simple working principle for hydraulic cylinders. The Figure 3.1a shows construction of a hydraulic cylinder.

![Hydraulic Cylinder Diagram](image)

Figure 3.1a Cylinder construction: 1- Cylinder tube 2- Piston 3- Piston rod 4- Cylinder base 5- Cylinder cap 6- Piston seal 7- Piston bearing 8- Piston rod seal 9- Piston rod guide 10- Piston rod wiper

---

7 Götz & Bosch, 2002, page 10
8 Esposito, 2003, page 195-197
Different methods can be used for cylinder mounting. Cylinders mounting depends on the specific conditions of the system. Cylinders’ mounting can be done in three different way. These are: fixed mounting, dynamic mounting, mounting to the piston rod. Cylinders are widely fixed at the head. This type of mounting was used in the hydraulic press. Following Figure 3.1b is shown the cylinders’ mounting methods.

<table>
<thead>
<tr>
<th>Fixed mounting</th>
<th>Dynamic mounting</th>
<th>Mounting to the piston rod</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flange at the front (at the head)</td>
<td>Trunnion ear</td>
<td>Thread with a fixing nut</td>
</tr>
<tr>
<td>Flange at the back (at the bottom)</td>
<td>Clevis</td>
<td>Tongue mounting</td>
</tr>
<tr>
<td>Foot mounting</td>
<td>Trunnion mounting</td>
<td>Clevis mounting</td>
</tr>
</tbody>
</table>

![Cylinder mounting methods](image)

Figure 3.1b Cylinder mounting methods

Properties of the hydraulic press are quite different from an other hydraulic system. This differences are relatively low working force, low flow rate, two different cylinders etc. Cylinders can be manufactured with special order so the hydraulic press’es cylinders will be special ordered. The cylinders’ parameters calculation can be found in the appendix.

---

9 Götz & Bosch, 2002, page 16
3.2 Hydraulic Pumps

Engineers have to choose the most useful components for their construction. Hydraulic pumps have a large variety of construction types. When the pump selection, we should estimate some criteria. These are price, pressure, noise, durability, efficiency etc. The following Table 3.2 shows criteria estimation for some types of pump.

<table>
<thead>
<tr>
<th>Type of pump</th>
<th>Price</th>
<th>Pressure</th>
<th>Noise</th>
</tr>
</thead>
<tbody>
<tr>
<td>External gear pump</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Internal gear pump</td>
<td>2</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Vane pump</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Radial-piston pump</td>
<td>2</td>
<td>3</td>
<td>2</td>
</tr>
</tbody>
</table>

Table 3.2 Criteria estimation for some types of pump: 1-Low 2-Average 3-High

External gear pump is the best solution for the hydraulic system. Because external gear pump has a low cost and medium pressure which is need for the hydraulic press. In addition external gear pump has a high volumetric efficiency and this is most widely used in a hydraulic system.

“A pump which is the heart of a hydraulic system, converts mechanical energy, which is primarily rotational power from an electric motor, into hydraulic energy”. The external gear pump is the simplest construction, consists of just two close meshing gear wheels. Figure 3.2 shows the operation of an external gear pump.

Figure 3.2 External gear pump operation

10 Götz & Bosch, 2002, page 32
11 Doddannavar&Barnard, 2005, page 37-43
Pump was chosen from Bosch Rexroth [6] is called AZPB-22 $V=2 \text{ cm}^3 \text{ rev}^{-1}$.

The pump’s parameters calculation and technical data sheets of the chosen gear pump can be found in the appendix.

### 3.3 Electric Motors

Electric motors are rotary actuators. It means that electric motor provides rotational movement. Electric motors transform electricity energy to rotary mechanical energy.

Electric motors have a large variety. But 3-phase motors are the most used in an industry. 3 phase induction has a lot of advantages. It has a simple structure, easy maintenance, low cost, reliable operation, low noise, low vibration, energy saving and high efficiency. The chosen electric motor shown in Figure 3.3 [4].

![Electric Motor](image)

**Figure 3.3** Y2 series Aluminium 3-phase induction motor

Electric motor was chosen from Dasu Company [4] is called **Y2-90S-4 P=1.1 kW**.

Calculation of the electric motor power and data sheets of the used electric motor can be found in the appendix.

### 3.4 Control Valves

Control is very important for all fluid power systems. The hydraulic systems require control valves to direct and regulate the fluid flow from pump to the various load devices. The valves consist of a flow passage. The flow passages area can be changed. So we can control the fluid direction, pressure and flow easily. We have to think size, actuating technique and remote control capability for valve selection. There are three basic types of valves:
• Directional control valves: Direction control valves are determine the direction of the fluid in the hydraulic circuit. This valve starts, stops and changes the direction of the oil flow in a hydraulic system. For instance, valves establish the direction of motion of a hydraulic cylinder or motor.

• Pressure control valves: Pressure control valves protect the hydraulic system against overpressure, which may occur due to excessive actuator loads or due to the closing of valve. Pressure relief, pressure reducing, sequence, unloading, brake and counter balance are controlled by pressure valves in a hydraulic system.

• Flow control valves: Flow control valves are controlled the flow rate in a hydraulic system. The volume of oil is regulated different parts of hydraulic system by flow control valves. This valves automatically adjust to change in pressure 12.

Control valves are switched into various operating positions. In generally control valves are controlled by manually operated and manual controlling has a low price. So manual controlling was chosen for the construction. The construction has a two control buttons for controlling to the each cylinder.

Flow control valve with check valve was chosen from Bosch Rexroth [6] is called 2FRM 6 B36-3X/3QRV. Most important parameter is flow rate while flow control valve’s selection.

While pressure and direction valve selection, there are two types of valves at the Bosch Rexroth catalogue. These are “Direct and Pilot Operated” valves. Manuel controlling was chosen so Direct Operated valve should be selected 13.

The hydraulic system’s working pressure was chosen 150 bar (It can be found in the appendix). While pressure control valve’s selection, working pressure is the most important parameter.

Pressure control valve was chosen from Bosch Rexroth [6] is called Pressure Stage-H-KBD2H0AA/SV.

Direction control valve’s selection is very complex. Direction control valve can be chosen Types SMM (lever operation) from Bosch Rexroth [6].

Related Data sheets of the chosen valves can be found in the appendix.

---

12 Doddannavar&Barnard, 2005, page 94
13 Götz & Bosch, 2002, page 168
3.5 Hydraulic Accessories

3.5.1 Hydraulic Reservoirs

Every hydraulic system should have its own oil reservoir. The oil used stored in a reservoir to which it is turned after use. There are basically two types of hydraulic reservoirs. These are non-pressurized reservoirs and pressurized reservoirs. Non-pressurized reservoirs are the most suitable in a hydraulic system. The Figure 3.5.1 shows non-pressurized reservoir construction 14.

![Non-pressurized reservoir construction](image)


The design of the reservoir is very important for reliable operation. Many factors have to be considered when selecting and configuration of a hydraulic reservoir. But generally a reservoir is designed 3...5 times bigger than the flow rate [2]. Reservoirs are generally constructed from welded steel plate with thin side walls to heat transferred. The inside surfaces of the reservoir are painted to prevent the formation of rust 15.

Calculation of the oil tank capacity can be found in the appendix.

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14 Esposito, 2003, page 378-379
15 Parr, 2007, page 167-169
3.5.2 Filters

Contamination is the cause of most hydraulic failures. It is estimated that 75 to 85 % of hydraulic failures are directly related with contamination. Contaminations are measured by Micron size. Contaminants are added to hydraulic systems through external and internal sources. Generally contaminants commonly come from pumps, valves, bearings and cylinders [5].

The oils used in hydraulic systems contain lots of foreign matters. These can be solid and liquid. Which are mostly in solid form like dirt, dust, worn out metallic parts etc. and sometimes in liquid form like water, acids, paints etc. Filters are used to prevent foreign matters entering the sensitive parts of the system [6].

Filters must be used in a hydraulic system because filters:

- Improve system performance.
- Reduce components maintenance cost.
- Reduce system downtime.
- Reduce oil purchase and disposal costs.

Typical hydraulic systems should have more than one filter. Filters can be located various types.

- **Return line filters:** Return filters are the most widely used in a hydraulic system. Return filters protect pumps by limiting size of particles returned to the tank. These filters operate only low pressure. This filters are cheap, easy to maintain and covers the overall flow rate in a system.

- **Suction line filters:** Suction lines are usually fitted with strainers inside the tank, but strainers are removed relatively large metal particles and similar contaminants. For this reason suction filters are needed at this line to remove finer particles. Suction filters protect the pump on the inlet.

- **Pressurized line filters:** Pressure line filters mounted after the pump to protect valves and actuators. This filters operate at high pressure so its housing should be able to take high pressures. This makes them expensive [7].

Following Figure 3.5.2 shows these filters locations [8].

---

In generally both return and suction line filters are used in a hydraulic system. The hydraulic systems working pressure is medium and the flow rate is small so it does not need to use pressurized line filter. Return and suction line filters were used in the hydraulic system. Return and suction line filters can be chosen same. Filtration rating is very important to choose right filter. Filtration rating can be chosen 3 µm and 10 µm [6]. Gear pump was used in the hydraulic system and gear pumps' clearances are shown in Table 3.5.2.

<table>
<thead>
<tr>
<th>Item</th>
<th>Typical clearance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gear Pump (Pressure Loaded)</td>
<td></td>
</tr>
<tr>
<td>Gear to side plate</td>
<td>1/2–5</td>
</tr>
<tr>
<td>Gear tip to case</td>
<td>1/2–5</td>
</tr>
<tr>
<td>Vane Pump</td>
<td></td>
</tr>
<tr>
<td>Tip of vane</td>
<td>1/2–1*</td>
</tr>
<tr>
<td>Sides of vane</td>
<td>0.000,02–0.000,04</td>
</tr>
<tr>
<td>Piston Pumps</td>
<td></td>
</tr>
<tr>
<td>Piston to bore**</td>
<td>0.000,2–0.001,5</td>
</tr>
<tr>
<td>Valve plate to cylinder</td>
<td>1/2–5</td>
</tr>
<tr>
<td>Servo Valve</td>
<td></td>
</tr>
<tr>
<td>Orifice</td>
<td>0.005–0.018</td>
</tr>
<tr>
<td>Flapper wall</td>
<td>0.007–0.002,5</td>
</tr>
<tr>
<td>Spool sleeve (R)**</td>
<td>0.000,04–0.000,15</td>
</tr>
<tr>
<td>Control Valve</td>
<td></td>
</tr>
<tr>
<td>Orifice</td>
<td>130–450</td>
</tr>
<tr>
<td>Spool sleeve (R)**</td>
<td>18–63</td>
</tr>
<tr>
<td>Disc type</td>
<td>1/2–1*</td>
</tr>
<tr>
<td>Poppet type</td>
<td>0.000,5–0.001,5</td>
</tr>
<tr>
<td>Actuators</td>
<td></td>
</tr>
<tr>
<td>Hydrostatic bearings</td>
<td>1/2–5</td>
</tr>
<tr>
<td>Antifriction bearings</td>
<td>*1/2–</td>
</tr>
<tr>
<td>Side bearings</td>
<td>0.000,02–</td>
</tr>
</tbody>
</table>

Table 3.5.2 Typical critical clearance of fluid system components

19 Thank to Ilhan Akceylan, engineer at the “Hürsan Press” in Turkey. He informed me about this subject.
20 Majumdar, 2003, page 87
Table shows clearance of the gear pump is 1/2–5 μm so filtration rating should be chosen 3 μm.

Filters were chosen from Bosch Rexroth [6] is called ABZFR-S0040-03-1X/M-DIN […]-SAE.

The filters selection and data sheets of the chosen filters can be found in the appendix.

### 3.5.3 Hydraulic Pipes, Hoses and Fittings

Pipes, hoses and fittings are very important parts in a hydraulic system. The fluid flows through the pipes, hose and fittings. It carries the fluid from the reservoir through the operating components and back to the reservoir.

Return line flow velocity is different from pressurized line flow velocity in a hydraulic system. The lower velocity is specified for the return line to reduce the back pressure. Generally suction flow velocity is chosen 1.5 (m/s) and return line velocity is chosen 2 (m/s). Flow velocity of the pressurized line can be seen in Table 3.5.3 [2].

<table>
<thead>
<tr>
<th>Working Pressure (Bar)</th>
<th>Velocity (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>…50</td>
<td>4.0</td>
</tr>
<tr>
<td>51…100</td>
<td>4.5</td>
</tr>
<tr>
<td>101…150</td>
<td>5.0</td>
</tr>
<tr>
<td>151…200</td>
<td>5.5</td>
</tr>
<tr>
<td>201…250</td>
<td>6.0</td>
</tr>
</tbody>
</table>

Table 3.5.3  Flow velocity of the pressurized line

### 3.5.3.1 Hydraulic Pipes and Tubes

A pipe and tube is a functional connection for fluid flow in the hydraulic system. The fluid flow efficiency is influenced by the piping line.

Iron pipes and steel tubes can be used in a hydraulic system. Iron pipes are used for low to medium pressure. Heavy wall thickness and lack of annealing characteristics are basic problems for iron piping. Steel tubes are more widely used in an industry because of their advantages. Leaking is a big problem for the hydraulic system but steel tubes ensure maximum leak protection [21].

---

Generally hydraulic tubes are used at the pressurized line. Hydraulic tubes are chosen according to the DIN 2391 [9].

All these reasons, steel tubes was prefered at the pressurized line. The hydraulic tubes were chosen from “Hidro Kontrol Benteler” [7].

Calculation of the pressurized line pipes inner diameter can be found in the appendix. Also the hydraulic tubes selection and data sheets of the chosen tubes can be found in the appendix.

### 3.5.3.2 Hydraulic Hoses

In a hydraulic system, flexible conductors are called hose assemblies. The hoses help overcome severe vibration and absorb hydraulic impulse shocks. Hoses are generally manufactured complete with fittings. Hydraulic hoses must be installed without twists.

Hoses are mounted with some suitable equipment by the user. These are: 1-Thread 2-Nut 3-Hose end 4-Flange nipple. The hose mountings can be seen in Figure 3.5.3.2a [22].

![Figure 3.5.3.2.a Typical hose mountings](image)

Flexible hoses have a special rules for the assembled. The following figure 3.5.3.2b shows the assembly of flexible hoses [23].

1-Wrong 2-Correct

---

The hoses are made by synthetic rubber. Various types of synthetic materials could be used for hoses. Types of flexible hoses can be seen in Figure 3.5.3.2c. 

Figure 3.5.3.2b Assembly of flexible hoses

Figure 3.5.3.2c Types of flexible hoses a,b,c- Medium pressure d,e,f-Medium high pressure

24 Majumdar, 2003, page 458-459
Hoses were used at the return and suction line in the hydraulic system. The hydraulic system operates at medium pressure at the return and suction lines so SAE-100R3 is suitable for the hydraulic system.

Calculation of the return and suction line pipes inner diameter can be found in the appendix.

### 3.5.3.3 Hydraulic Fittings

This is the last step of a basic hydraulic press construction. Metal tube or synthetic hose is attached to the port of the hydraulic elements by fittings. There are some important functions of fitting. These are:

- “Changing the direction of the flow
- Providing branch connections
- Changing the size of line
- Clossing lines
- Connecting lines”  

Fittings are made of steel, bronze, cast iron, plastic or glass. Steel tube or synthetic hose is attached to the port of the hydraulic elements at the end of construction. Typical hydraulic fittings can be seen in Figure 3.5.3.c.

![Figure 3.5.3.c Typical hydraulic fittings (1- hose to tube, 2- tube to tube)](image)

---

25 Doddannavar&Barnard, 2005, page 160
26 Majumdar, 2003, page 442-443
4. Concepts for the hydraulic system

The purpose is to construct a hydraulic press for three bearings fitting to the Volvo Trucks’ housing. The housing holes and bearings tolerances are very sensitive. This system should operate very safety.

The main structure of the press containing frame, cylinders and working surface. Frame is very important to balance and carrying the load. Strength of the frame was analysed at the Solid Works Programme. This analysis can be found in the appendix.

In the hydraulic press, constructions of some parts are different from another hydraulic press.

These parts are: Two different cylinders, Rams and Bolster plate. This parts were designed. Constructions of two different cylinders, rams and bolster plate are described in the following chapters 4.1, 4.2 and 4.3.

4.1 Two different cylinders

There are two holes at the housing which are the same size and so close to each other. Two bearings can be fitted to this two holes by one cylinder. The other bearing is fitted by another cylinder. So two separate cylinders were used for the hydraulic press.

Maybe some people thinks that it is possible to done this work by only one cylinder. But this situation makes a lot of problem. This problems occur because:

- Housing has two different hole diameter. One is 72 mm and the other one is 82 mm.
- One bearing which has 82 mm diameter, it is placed 16.3 mm higher than the other two bearings.
- Slipping is occurred on the ram because the ram should be constructed much more bigger size at this situation.

Cylinders design can be found in the appendix.

4.2 Rams

Ram is a tool for driving or forcing something by impact. It is a plunger of a hydraulic press. Firstly bearings are held to the conic ram. After that bearings are fitted to the housing by the hydraulic press.

Three conic rams were used in the hydraulic system:
• Two of them are the same. These are attached to the circular ram and circular ram is attached to the pressing cylinder and two supporter rods. Supporter rods were used to prevent slipping.

• The other conic ram is directly attached to the pressing cylinder. Only this conic ram has one spring because lower part of the corresponding bearing’s hole is closed at the housing. The other two holes which are open so it does not need to use spring for the other two conic rams. When the operation of the bearing tightening is finished, the spring helps returning motion of the pressing cylinder.

Design of the circular ram and conic rams can be found in the appendix.

4.3 Bolster Plate

Bolster plate is designed to hold in place the lower die shoe. The bolster plate is attached to the top surface of the press bed.

Housing should be fixed on the bolster plate. While fixing, center of the housing holes and center of the related conic rams must be the same axis.

Six rods were attached on the bolster conveniently. This rods are passed through the convenient housing holes. In this way, the housing is fixed on the bolster.

Volvo Truck’s housings are made of aluminium. Unfortunately, Aluminums have low strength. While tightening, housing can be distorted. So two big cylindrical supporters attached on the bolster. This two big cylindrical supporters contact around the housing’s holes. In this way, housing’s safety is ensured.

Design of the bolster can be found in the appendix.
5. Conclusion

Swepart Transmission AB started up project that they want to do assembly operations more efficient. For this purpose, new hydraulic press was constructed including modelling, technical drawings, all parameters’ calculations, selection of the hydraulic components and strength analysis of the frame.

The goal of this thesis work was to construct a hydraulic press to fitting three bearings at the same time. Of course this hydraulic presses should be more efficient and more reliable.

During the constructing, following articles were very important:

- At the beginning, working pressure assumed 150 bar because this is a typical pressure of an hydraulic system\(^{27}\). After that hydraulic’s pressing force and cylinders’ parameters were calculated. Because these are basics in the design of hydraulic systems.
- While the piston rods’ diameters calculation, the rods’ diameters were found small with theoretical approach. But in real life, engineers choose the piston rod’s diameter bigger than the theoretical result. If this theoretical result is chose, piston’s turning motion will be very fast so cylinder will be damaged. All this reasons, piston rods’ diameters were chosen bigger than the theoretical result.
- Bearings should be tightened very slowly to their holes so I assumed that pressing velocity is 5 mm/s. After this assumption, pump’s and electric motor’s parameters were calculated. Then hydraulic accessories’ parameters were calculated.

Humans security is another important thing. Suddenly, somebody may put their hand under the rams during this operation. In this instance the machine should be stopped very quickly. So ‘Big Emergency Button’ was constructed for the hydraulic press.

While operation, pressure should be controlled to protect the hydraulic system against overpressure. Two separate pressure indicators were constructed for this purpose.

Electric motor and reservoir was constructed near the cylinder. The main idea of this to minimized the hoses length and gravitational potential differences between cylinder and reservoir. Short hoses means that less friction losses while fluid flowing and less hose usage. Small gravitational potential differences means that less energy loses.

Now at the end of this bachelor thesis, I am very happy for my hydraulic construction. Because Mr Ekman said that ”it’s a good construction and this is the solution for us”.

\(^{27}\) Parr, 2007, page 4
CALCULATIONS

1. Calculation of Pressing Forces

The maximum permitted press fit force on the cups should be 25 kN.

In housing there are 3 bearings so

\[ 25 \times 3 = 75kN \]

Now the press force has to be calculated

\[ F = \frac{75000N}{9.81} \quad F = 7645kg \]

The hydraulic press is selected \( F = 12000kg = 12ton \). Two cylinders will be used in the hydraulic system.

- One cylinder fits two bearings and this system is called Group 1.
- The other cylinder fits one bearing and this system is called Group 2. This group names will be used during the calculations.

2. Assumption for the Group 1

The hydraulic system’s pressure is controlled easily by buttons. In addition all systems lose energy while operating. So pressing force should be chosen bigger than the fitting force 50kN=5000kg for two bearings.

Maximum Press Force = 8 ton = 8000 kg.

Working Pressure = 150 Bar = 150 kg/cm\(^2\) [This is a typical hydraulic pressure (Parr, 2007)]

3. Assumption for the Group 2

Because of the same reason pressing force is selected bigger than the 25kN \( \cong 2500kg \) for one bearing fitting.

Maximum Press Force = 4 ton = 4000 kg

Working Pressure = 150 Bar = 150 kg/cm\(^2\)
4. Calculation of Piston Parameters

4.1. Calculation of Piston Pressing Diameter

Designations:

$F_{pr} = \text{Pressing Force (kg)}$

$P_{pr} = \text{Working Pressure (bar or kg/cm}^2\text{)}$

$A_{pr} = \text{Cylinders Pressing Total Area (cm}^2\text{)}$

$D_{pr} = \text{Pistons Pressing Diameter (mm)}$

Formulas:

$A_{pr} = \frac{F_{pr}}{P_{pr}}$

$D_{pr} = \left(\frac{4A_{pr}}{\pi}\right)^{0.5}$

4.1.1. Calculation for the Group 1

$A_{pr} = \frac{F_{pr}}{P_{pr}}$

$A_{pr} = \frac{8000}{150}$

$A_{pr} = 53,33cm^2$

$A_{pr} = \frac{\pi D_{pr}^2}{4}$

$D_{pr} = \left(\frac{4A_{pr}}{\pi}\right)^{0.5}$

$D_{pr} = \left(\frac{4 \times 53,33}{\pi}\right)^{0.5}$

$D_{pr} = 8,162cm = 81,62mm$

The first piston’s pressing diameter is chosen $D_{pr} = 82mm$. 
4.1.2. Calculation for the Group 2

\[ A_{pr} = \frac{F_{pr}}{P_{pr}} \]

\[ A_{pr} = \frac{4000}{150} \quad A_{pr} = 26,66 cm^2 \]

\[ A_{pr} = \frac{\pi D_{pr}^2}{4} \quad D_{pr} = \left( \frac{4 * A_{pr}}{\pi} \right)^{0.5} \]

\[ D_{pr} = \left( \frac{4 * 26,66}{\pi} \right)^{0.5} \]

\[ D_{pr} = 5,81 cm = 58,1 mm \]

The first piston’s pressing diameter is chosen 58mm.

4.2. Calculation of Piston Rod Diameter

Using the “EULER METHOD” to calculate the piston rods diameter.

Designations:
K= Buckling load
\[ S_k = \text{Free buckling length (cm)} \]
E= Elasticity Module \( (kg/cm^2) \)
J= Moment of Inertia \( (cm^4) \)
S= Safety Factor

Safety factor is chosen 3 for piston rod. \( S=3 \)

\[ S_k = 21 cm \quad [8] \]
\[ E = 2,1.10^9 \text{ kg/cm}^2 \quad \text{(For steel)} \]

Formulas:
\[ K = \left( \pi^2 EJ \right) / S_k^2 \]
\[ J = \left( d^4 \pi \right) / 64 \]
\[ F = K / S \quad K = F * S \]
4.2.1. Calculation for the Group 1

F = 8000 kg

\[ K = F \cdot S \]

K = 8000 \times 3

K = 24000 kg

\[ J = \frac{d^4 \pi}{64} \]

\[ d^4 = \frac{64 \cdot J}{\pi} \]

\[ K = \frac{\pi^2 EJ}{S K^2} \]

\[ J = \frac{K \cdot S K^2}{\pi^2 E} \]

\[ J = \frac{24000 \cdot 21^2}{\pi^2 \cdot 2,1 \cdot 10^6} \]

J = 0,51

\[ d^4 = \frac{64 \cdot 0,51}{\pi} \]

\[ d = 1,79 \text{ cm} = 17,9 \text{ mm} \]

This result is exactly correct at theoretical approach. But in the real life, the rods diameter should be selected bigger than this result. If this theoretical result is selected, the piston turning motion will be very fast and it damages to the cylinder.

The piston diameter of the first cylinder is D = 82 mm. Related with the piston diameter:

The piston rod diameter is chosen 50 mm for Group 1.

\[ D_{pistonrod} = 50 \text{ mm} \]
4.2.2. Calculation for the Group 2

\[ F = 4000\text{kg} \]
\[ K = F \times S \]
\[ K = 4000 \times 3 \quad K = 12000\text{kg} \]

\[ J = \frac{d^4 \pi}{64} \quad d^4 = \frac{64 \times J}{\pi} \]

\[ K = \left(\pi^2 EJ\right)/S_k^2 \quad J = \frac{K \times S_k^2}{\pi^2 E} \]

\[ J = \frac{12000 \times 21^2}{\pi^2 \times 2.1 \times 10^6} \]

\[ J = 0.255 \]

\[ d^4 = \frac{64 \times 0.255}{\pi} \quad d = 1.51\text{cm} = 15.1\text{mm} \]

Again the same reasons, the piston rod’s diameter is selected bigger than this result.

The piston diameter of the second cylinder is \(D = 58\text{ mm}\). Related with the piston diameter:

The piston rod diameter is chosen 30 mm for Group 2.

\[ D_{\text{pistonrod}} = 30\text{mm} \]
5. Calculation of Pump Parameters

Designation:

\( q \) = Output flow rate  \\
\( D_p \) = Pumps displacement  \\
\( n_p \) = Pumps rotation speed  \\
\( n_{vol} \) = Volumetric efficiency  \\
\( V \) = Velocity  \\

Formulas:

\[ q = A \cdot V \] (1)  \\
\[ q = D_p \cdot n_p \cdot n_{vol} \] (2)

Formula (1) and (2) gives:

\[ D_p = \frac{A \cdot V}{n_p \cdot n_{vol}} \]

Assume that \( n_{vol} = 0.85 \).

Gear pumps revolution are generally limited at 1400 rpm.

Assume maximum rotation speed is \( n_p = \frac{1400}{60} = 23.33 \text{ rps} \).

Assume maximum velocity on the cylinder is \( V = 5 \text{ mm/s} = 0.005 \text{ m/s} \). The velocity is chosen smaller from another hydraulic press because housing and bearing has a very sensitive tolerance. So bearings should be fitted to the housing very slowly.

5.1. Calculation for the Group 1

\( A = 53.33 \text{ cm}^2 = 0.005333 \text{ m}^2 \) (Calculated at 4.1.1.)
5.1.1. Calculation of Pumps Displacement for Group 1 Needed

\[ D_p = \frac{A*V}{n_p*n_{vol}} \]

\[ D_p = \frac{0.005333*0.005}{23.33*0.85} \]

\[ D_p = 1.3446*10^{-6} \, m^3/rev \]

5.1.2. Calculation of Pumps Output Flow Rate

\[ q = A*V \]

\[ q = 0.005333*0.005 \quad q = 26.665*10^{-6} \, m^3/s \]

5.2. Calculation for the Group 2:

\[ A = 26.66 cm^2 = 0.002666 m^2 \quad (Calculated \ at \ 4.1.2.) \]

5.2.1. Calculation of Pumps Displacement for Group 2 Needed

\[ D_p = \frac{A*V}{n_p*n_{vol}} \]

\[ D_p = \frac{0.002666*0.005}{23.33*0.85} \]

\[ D_p = 6.722*10^{-7} \, m^3/rev \]

5.2.2. Calculation of Pumps Output Flow Rate

\[ q = A*V \]
\[
q = 0,002666 \times 0,005
\]
\[
q = 13,33 \times 10^{-6} \text{ m}^3/\text{s}
\]

Pumps’ total displacement
\[
D_{\text{p\_total}} = D_{\text{p\_1}} + D_{\text{p\_2}}
\]
\[
D_{\text{p\_total}} = (1,3446 + 0,6722) \times 10^{-6}
\]
\[
D_{\text{p\_total}} = 2,0 \times 10^{-6} \text{ m}^3/\text{rev}
\]

Pump was chosen from Bosch Rexroth [6] is called AZPB–22 V=2 \text{ cm}^3/\text{rev}.

6. Calculation of Electric Motor Power

Designation:

\[P = \text{Power}\]
\[P_{pr} = \text{Working Pressure}\]
\[n_{hm} = \text{Hydraulic Mechanical Efficiency}\]
\[q = \text{Flow Rate}\]

Formulas:

\[
P = \frac{q \times P_{pr}}{n_{vol} \times n_{hm}}
\]

Assume that \(n_{hm} = 0,95\).

Assume that \(n_{vol} = 0,85\).

\[
P_{pr} = \text{Working pressure} = 150 \frac{\text{kg}}{\text{cm}^2} = 150 \times 9,81 \times 10^{-4} = 14715000 \frac{N}{m^2}
\]
6.1. Calculation of electric motor power for Group 1 Needed

\[ q = 26,665 \times 10^{-6} \text{ m}^3/\text{s} \] (Calculated at 5.1.2.)

\[ P = \frac{q \times P_{pr}}{n_{vol} \times n_{hm}} \]

\[ P_1 = \frac{26,655 \times 10^{-6} \times 14715000}{0.95 \times 0.85} \]

\[ P_1 = 486 \text{ W} \]

6.2. Electric Motors Power Calculation for Group 2 Needed

\[ q = 13,33 \times 10^{-6} \text{ m}^3/\text{s} \] (calculated part 5.2.2)

\[ P = \frac{q \times P_{pr}}{n_{vol} \times n_{hm}} \]

\[ P_2 = \frac{13,33 \times 10^{-6} \times 14715000}{0.95 \times 0.85} \]

\[ P_2 = 243 \text{ W} \]

6.3. Electric Motor Selection

Total power needed for both cylinders

\[ P_{Total} = P_1 + P_2 \]

\[ P_{Total} = 486W + 243W \]

\[ P_{Total} = 729W \]

Electric motor was chosen from Dasu Company [4] is called Y2-90S-4 \( P=1,1 \text{ kW} \).
7. Calculation of Cylinder Parameters

7.1. Calculation of Cylinder Tubes Thickness and Cylinder Diameters

Designations:

- \( G_{\text{yield}} \) = Yield Strength \( \text{daN/mm}^2 \)
- \( S \) = Safety Factor
- \( P \) = Pressure
- \( S_o \) = Thickness
- \( d_a \) = Cylinders Diameter
- \( d_i \) = Pistons Diameter

\[ G_{\text{yield}} = 23 \text{daN/mm}^2 \quad \text{for Steel 35} \]  \[ \text{[1]} \]

Assume that \( S = 2 \)

\( P = 150 \text{Bar} \approx 150 \text{MPa} \)

\[ \frac{d_a}{d_i} = 1,7 \quad \text{(for DIN 2413)} \]  \[ \text{[1]} \]

\[ d_a = 1,7d_i \]

Formulas:

We can calculate thickness from the thin wall container formulation \[ [1] \]:

\[ S_o = \frac{d_a \cdot P \cdot S}{200 \cdot G_{\text{yield}}} \]
7.1.1. **Calculation for the Group 1**

7.1.1.1. **Calculation of Cylinder Tubes Thickness**

\[ d_i = 82\, \text{mm} \quad \text{(Calculated at 4.1.1.)} \]

\[
S_o = \frac{1.7d_i \cdot P \cdot S}{200 \cdot G_{\text{yield}}}
\]

\[ S_o = \frac{1.7 \times 82 \times 150 \times 2}{200 \times 23} \]

\[ S_o = 9\, \text{mm} \]

7.1.1.2. **Calculation of Cylinder Diameter**

\[ d_o = d_i + 2S_o \]

\[ d_o = 82 + 2 \times 9 \]

\[ d_o = 100\, \text{mm} \]

7.1.2. **Calculation for the Group 2**

7.1.2.1. **Calculation of Cylinder Tubes Thickness**

\[ d_i = 58\, \text{mm} \quad \text{(Calculated at 4.1.2.)} \]

\[
S_o = \frac{1.7d_i \cdot P \cdot S}{200 \cdot G_{\text{yield}}}
\]

\[ S_o = \frac{1.7 \times 58 \times 150 \times 2}{200 \times 23} \]

\[ S_o = 6.0\, \text{mm} \]

7.1.2.2. **Calculation of Cylinder Diameter**

\[ d_o = d_i + 2S_o \]
\[ d_a = 58 + 2 \times 6.5 \]
\[ d_a = 70 \text{mm} \]

### 7.2. Calculation of Cylinders Base Thickness

**Designations:**
- \( G_{yield} \) = Yield Strength \( daN/mm^2 \)
- \( S \) = Safety Factor
- \( P \) = Pressure
- \( d_a \) = Cylinders Diameter

Assume that \( S = 2 \)
\( P = 150 \text{ Bar} \cong 150 \text{ MPa} \)

**Formulas:**
\[ S_o = \frac{d_a \times P \times S}{100 \times G_{yield}} \]

#### 7.2.1. Calculation for the Group 1

\( d_a = 100 \text{mm} \)  (Calculated at 7.1.1.2.)
\[ S_o = \frac{100 \times 150 \times 2}{100 \times 23} \]
\[ S_o = 13 \text{mm} \]

#### 7.2.2. Calculation for the Group 2

\( d_a = 71 \text{mm} \)  (Calculated at 7.1.2.2.)
\[ S_o = \frac{71 \times 150 \times 2}{100 \times 23} \]
\[ S_o = 9.26 \text{mm} \]

It can be assumed \( S_o = 10 \text{mm} \).
7.3. Calculation of all Output and Input Flow Rate at the Cylinders

Designations:

\( X \) = Coefficient

\( D_{pr} \) = Piston Pressing Diameter

\( d \) = Piston Rods Diameter

\( q_{in} \) = Input Flow Rate

\( q_{out} \) = Output Flow Rate

Formulas:

\[
X = \frac{D^2}{(D^2 - d^2)}
\]

\[
q_{out} = \frac{q_{in}}{X}
\]

7.3.1. Calculation for the Group 1

\( D_{pr} = 82\, mm \)  \text{(Calculated at 4.1.1.)}

\( d = 50\, mm \)  \text{(Calculated at 4.2.1.)}

\[
X = \frac{82^2}{(82^2 - 50^2)}
\]

\( X = 1,592 \)

\[
q_{in} = 26,665 \times 10^{-6} \, m^3/s \quad \text{(q pump output = q cylinder input Calculated Part 5.1.2.)}
\]

\[
q_{in} = 26,665 \times 10^{-6} \times 10^3 \times 60
\]

\( q_{in} = 1,6 \, lt/min \)

\[
q_{out} = \frac{q_{in}}{X}
\]

\[
q_{out} = \frac{1,6}{1,592}
\]

\( q_{out} = 1 \, lt/min \)
7.3.2. Calculation for the Group 2

\[ D_{pr} = 58 \text{ mm} \quad \text{(calculated Part 4.1.2.)} \]
\[ d = 30 \text{ mm} \quad \text{(calculated Part 4.2.2.)} \]

\[ X = \frac{D^2}{(D^2 - d^2)} \]
\[ X = \frac{58^2}{(58^2 - 30^2)} \]
\[ X = 1,365 \]

\[ q_{in} = 13,33 \times 10^{-6} \text{ m}^3/s \quad \text{(q pump output= q cylinder input calculated Part 5.2.2.)} \]
\[ q_{in} = 13,33 \times 10^{-6} \times 10^3 \times 60 \]
\[ q_{in} = 0,8 \text{ lt/min} \]

\[ q_{out} = \frac{q_{in}}{X} \]
\[ q_{out} = \frac{0,8}{1,365} \]
\[ q_{out} = 0,59 \text{ lt/min} \]

7.3.3. Total Oil Input and Output Flow Rate

\[ q_{intotal} = q_{in} + q_{in2} \]
\[ q_{intotal} = 1,6 + 0,8 \]
\[ q_{intotal} = 2,4 \text{ lt/min} \]

\[ q_{outtotal} = q_{out1} + q_{out2} \]
\[ q_{outtotal} = 1 + 0,59 \]
\[ q_{outtotal} = 1,59 \text{ lt/min} \]

NOTE: Cylinder Stroke is chosen maximum 400mm for Group 1 and Group 2.
8. Calculation of Hoses and Tubes Inner Diameter

Designations:

\( q = \) Pumps Flow Rate (\(lt/min\))

\( V = \) Flow Velocity

\( d = \) Inner Diameter (mm)

\( d_{suc} = \) Suction Hose Inner Diameter (mm)

\( d_{pr} = \) Pressurized Tube Inner Diameter (mm)

\( d_{rt} = \) Return Line Hose Inner Diameter (mm)

Separate hoses and tubes are used for both cylinder. Flow velocity should be chosen.

If working pressure equals to 150 bar, the pressing flow velocity equals to \( V_{pr} = 5\, m/s \).

Generally suction flow velocity equal to \( V_{suc} = 1,5\, m/s \). And return line flow velocity is equal to \( V_{rt} = 2\, m/s \).

Formula:

\[ d^2 = \left( \frac{21\, q}{V} \right) \]  

[9]

8.1. Calculation for Group 1

\( q = 1,6\, lt/min \) (Calculated at 7.3.1.)

\[ d_{suc}^2 = \left( \frac{21\, q}{V_{suc}} \right) \]

\[ d_{suc}^2 = 21\times1,6/1,5 \]

\[ d_{suc} = 4,8mm \]

\[ d_{pr}^2 = \left( \frac{21\, q}{V_{pr}} \right) \]

\[ d_{pr}^2 = (21\times1,6)/5 \]

\[ d_{pr} = 2,6mm \]
\[ d_{rt}^2 = \frac{(21 \cdot q)}{V_{pr}} \]
\[ d_{rt}^2 = \frac{(21 \cdot 1,6)}{2} \]
\[ d_{rt} = 4mm \]

8.2. Calculation for Group 2

\[ q = 0,8lt/min \text{ (Calculated at 7.3.2.)} \]
\[ d_{suc}^2 = \frac{(21 \cdot q)}{V_{ab}} \]
\[ d_{suc}^2 = 21 \cdot 0,8/1,5 \]
\[ d_{suc} = 3,35mm \]

\[ d_{pr}^2 = \frac{(21 \cdot q)}{V_{pr}} \]
\[ d_{pr}^2 = \frac{(21 \cdot 0,8)}{5} \]
\[ d_{pr} = 1,9mm \]

\[ d_{rt}^2 = \frac{(21 \cdot q)}{V_{pr}} \]
\[ d_{rt}^2 = \frac{(21 \cdot 0,8)}{2} \]
\[ d_{rt} = 2,9mm \]

The pipes’ inner diameter can be chosen a little bigger than this result because of the standard dimensions.

The chosen tubes’ properties are: **Outer diameter=6mm, Wall thickness=1,5mm**.

Tubes were chosen from “Hidro Kontrol Benteler” [7].

**SAE-100R3** types of hoses were chosen. There is a large variety for the hoses dimensions. It can be selected any company.
9. Calculation of Oil Tank Capacity

In real life, tank capacity is chosen 3…5 times bigger than the flow rate [2].

\[ q_{total} = 2.4 \, lt/min \quad \text{(Calculated at 7.3.3.)} \]

Oil’s cooling is very important for an hydraulic system so more oil using is better for the cooling.

Oil tank capacity = 2.4 * 5

Oil tank capacity = 12lt
DATA SHEETS

1. Data sheet of the Gear pump

Specifications

<table>
<thead>
<tr>
<th>General</th>
<th></th>
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</thead>
<tbody>
<tr>
<td>Construction</td>
<td>External gear pump</td>
</tr>
<tr>
<td>Mounting</td>
<td>Flange or through-bolting with spigot</td>
</tr>
<tr>
<td>Line ports</td>
<td>Internal thread, flange</td>
</tr>
<tr>
<td>Direction of rotation (looking on shaft)</td>
<td>Clockwise or counterclockwise, the pump may only be driven in the direction indicated</td>
</tr>
<tr>
<td>Installation position</td>
<td>Any</td>
</tr>
<tr>
<td>Load on shaft</td>
<td>Radial and axial forces after consulting</td>
</tr>
<tr>
<td>Ambient temperature range</td>
<td>-30°C...+80°C with NBR seal, -20°C...+110°C with FPM seal</td>
</tr>
<tr>
<td>Fluids</td>
<td>Mineral oil compliant with DIN 51 524, 1–3, however under higher load at least HLP compliant with DIN 51 524 Part 2 recommended. Further operating fluids possible after consultation.</td>
</tr>
<tr>
<td>Viscosity</td>
<td>12...800 mm²/s permissible range</td>
</tr>
<tr>
<td>Fluid temperature range</td>
<td>-30°C...+80°C</td>
</tr>
<tr>
<td>Filtration(*)</td>
<td>At least cleanliness level 2/18/15 compliant with ISO 4406 (1996)</td>
</tr>
</tbody>
</table>

Definition of direction of rotation

Always look on the drive shaft.

Caution: Dimensions drawings always show clockwise-rotation pumps. On counterclockwise-rotation pumps the positions of the drive shaft and the suction and pressure ports are different.

Definitions of pressures

<table>
<thead>
<tr>
<th>AZPB-22 Displacement</th>
<th>V cm³/rev</th>
<th>1</th>
<th>2</th>
<th>2.5</th>
<th>3.15</th>
<th>4</th>
<th>4.5</th>
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<th>6.3</th>
<th>7.1</th>
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<tr>
<td>Suction pressure p₁</td>
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<td>0.7...3 (absolute)</td>
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<td>max. continuous pressure p₂</td>
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<td>max. peak pressure p₄</td>
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</tr>
<tr>
<td>min. rotational speed</td>
<td>rpm</td>
<td>750 750 750 750 750 750 750 750 750 750</td>
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<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>max. rotational speed at p₅</td>
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</tr>
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</table>

Data Figure 1.a Data sheet of gear pump AZPB-22 V=2 cm³/rev
### Unit dimensions

**Standard range**

![Diagram of gear pump AZPB-22 V=2](image)

**Ordering code:**

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<td>32.8  87.9  12  30</td>
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<td>280</td>
<td>5,000</td>
<td>1.5</td>
<td>33.8  69.8  12  30</td>
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<tr>
<td>3.15</td>
<td>0 510 120 312 0 510 120 014</td>
<td>280</td>
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<td>1.5</td>
<td>35.6  72.3  15  35</td>
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<tr>
<td>4</td>
<td>0 510 120 313 0 510 120 015</td>
<td>280</td>
<td>4,000</td>
<td>1.6</td>
<td>36.6  75.5  15  35</td>
</tr>
<tr>
<td>4.5</td>
<td>0 510 120 314 0 510 120 016</td>
<td>260</td>
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<td>1.6</td>
<td>37.8  77.4  15  35</td>
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<tr>
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<td>0 510 120 315 0 510 120 017</td>
<td>260</td>
<td>4,000</td>
<td>1.6</td>
<td>38.6  79.5  15  35</td>
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<tr>
<td>6.3</td>
<td>0 510 120 316 0 510 120 018</td>
<td>255</td>
<td>3,500</td>
<td>1.7</td>
<td>41.0  84.2  15  35</td>
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<td>7.1</td>
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<td>3,500</td>
<td>1.7</td>
<td>42.5  87.3  15  35</td>
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</table>

Data Figure 1.b  Data sheet of gear pump AZPB-22  V=2  rev
## 2. Data sheet of the Electric Motor

### 380/50Hz Synchronous Speed 3000 r/min (2poles)

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<th>TYPE</th>
<th>Output IN</th>
<th>Speed (r/min)</th>
<th>Efficiency(%)</th>
<th>Power Factor cos</th>
<th>Torque (Nm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>380V</td>
<td>400V</td>
<td>415V</td>
<td>100%</td>
<td>75%</td>
</tr>
<tr>
<td></td>
<td>Kw/HP</td>
<td>A</td>
<td>A (Cosφ)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Y2-63L-2</td>
<td>0.18/0.25</td>
<td>0.53</td>
<td>0.50</td>
<td>0.49</td>
<td>2720</td>
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<td></td>
<td></td>
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<td>64</td>
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<td>0.80</td>
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</tr>
<tr>
<td>Y2-71L-2</td>
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<td>0.94</td>
<td>0.91</td>
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</tr>
<tr>
<td></td>
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<td>Y2-80L-1</td>
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### 380/50Hz Synchronous Speed 1500 r/min (4poles)

<table>
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<tr>
<th>TYPE</th>
<th>Output IN</th>
<th>Speed (r/min)</th>
<th>Efficiency(%)</th>
<th>Power Factor cos</th>
<th>Torque (Nm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>380V</td>
<td>400V</td>
<td>415V</td>
<td>100%</td>
<td>75%</td>
</tr>
<tr>
<td></td>
<td>Kw/HP</td>
<td>A</td>
<td>A (Cosφ)</td>
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<tr>
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<td>1.49</td>
<td>1.44</td>
<td>1390</td>
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### 380V/50Hz Synchronous Speed 3000 r/min (2poles)

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<th>Efficiency(%)</th>
<th>Power Factor cos</th>
<th>Torque (Nm)</th>
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<td>415V</td>
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<td>75%</td>
</tr>
<tr>
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<td>A (Cosφ)</td>
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### 380V/50Hz Synchronous Speed 1500 r/min (4poles)

<table>
<thead>
<tr>
<th>TYPE</th>
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<th>Speed (r/min)</th>
<th>Efficiency(%)</th>
<th>Power Factor cos</th>
<th>Torque (Nm)</th>
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<td>A (Cosφ)</td>
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<td>0.65</td>
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<tr>
<td>Y2-80L-4</td>
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<td>1.86</td>
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</tbody>
</table>

---

Data Figure 2. Data sheet of electric motor Y2-90S-4 P=1.1 kW
3. Data sheet of the valves

3.1 Data sheet of the flow control valve

Ordering details: 2-way flow control valve

- 2FRM 6 6 – 3X/ V +

| 2FRM | 6 | 6 – 3X/ | V | *
|------|----|---------|---|---
| 2-way flow control valve |
| Nominal size 6 = 6 |
| With external closing of the pressure compensator = A (suppression of the start-up jump) |
| Without external closing of the pressure compensator = B |
| For panel mounting |
| Adjustment elements |
| Lockable rotary knob with scale 1) = 3 |
| Rotary knob with scale = 7 |
| Zero position of the marking at port P = 6 |
| Series 30 to 39 (30 to 39 unchanged installation and connection dimensions) = 3X |

1) H key with Material No. R900008158 is included within the scope of supply
2) Locating pin 3 x 8 DIN ISO 8752, Material No. R900005594 (separate order)

Further details in clear text
- No code = Without locating pin hole
- 6/0 = With locating pin hole
- V = FKM seals (other seals on request)

Attention!
The compatibility of the seals and pressure fluid has to be taken into account!

Flow (A → B)
- 0.2Q = Up to 0.2 L/min
- 0.6Q = Up to 0.6 L/min
- 1.5Q = Up to 1.5 L/min
- 3Q = Up to 3.0 L/min
- 6Q = Up to 6.0 L/min
- 10Q = Up to 10.0 L/min
- 16Q = Up to 16.0 L/min
- 25Q = Up to 25.0 L/min
- 32Q = Up to 32.0 L/min

Ordering details: rectifier sandwich plate, not for panel mounting

- Z4S 6 – 1X/ V +

| Z4S | 6 – 1X/ | V | *
|-----|---------|---|---
| Rectifier sandwich plate |
| Nominal size 6 = 6 |
| (10 to 19 unchanged installation and connection dimensions) = 1X |

Further details in clear text
- V = FKM seals (other seals on request)

Attention!
The compatibility of the seals and pressure fluid has to be taken into account!

Preferred types

<table>
<thead>
<tr>
<th>Type 2FRM</th>
<th>Material number</th>
</tr>
</thead>
<tbody>
<tr>
<td>2FRM 6 B36-3X/1QMV</td>
<td>R900205577</td>
</tr>
<tr>
<td>2FRM 6 B36-3X/6QMV</td>
<td>R900205578</td>
</tr>
<tr>
<td>2FRM 6 B36-3X/1QMVR</td>
<td>R900205507</td>
</tr>
<tr>
<td>2FRM 6 B36-3X/9QRV</td>
<td>R900205516</td>
</tr>
<tr>
<td>2FRM 6 B36-3X/9QRV</td>
<td>R900205517</td>
</tr>
<tr>
<td>2FRM 6 B36-3X/6QMVR</td>
<td>R900205518</td>
</tr>
<tr>
<td>2FRM 6 B36-3X/9QRVR</td>
<td>R900205519</td>
</tr>
<tr>
<td>2FRM 6 B36-3X/1QMV</td>
<td>R900205508</td>
</tr>
<tr>
<td>2FRM 6 B36-3X/1QVR</td>
<td>R900205509</td>
</tr>
<tr>
<td>2FRM 6 B36-3X/1QVR</td>
<td>R900205511</td>
</tr>
<tr>
<td>2FRM 6 B36-3X/2QVR</td>
<td>R900205513</td>
</tr>
<tr>
<td>2FRM 6 B36-3X/2QVR</td>
<td>R900205515</td>
</tr>
</tbody>
</table>

Preferred types

<table>
<thead>
<tr>
<th>Type Z4S</th>
<th>Material number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Z4S 6-1X/V</td>
<td>R900489356</td>
</tr>
</tbody>
</table>

Further preferred types and standard components can be found in the EPS (Standard Price List).

Data Figure 3.1a Data sheet of flow control valve with check valve 2FRM 6 B36-3X/3QRV
Function, section, circuit example: type 2FRM 6 A...

Flow control valve type 2FRM 6 A..., 3X/..RV
(with external closing, with check valve)

The function of this valve is basically the same as that of valve type 2FRM 6 B..., 3X/..MV.

However, this type of flow control valve is provided with an external port permitting the pressure compensator (4) to be pressurised via port P (9). The external pressure acting in port P (9), via orifice (10), holds the pressure compensator (4) closed against the force of compression spring (6). When the connected directional valve (11) is actuated to permit flow from P to B, control is achieved as with type 2FRM 6 B. Thus a jump on start-up is avoided.

This version with external closing of the compensator may only be used for meter-in control.

Free return flow from port B to port A is via check valve (8).

Actuator

Technical data: 2-way flow control valve (for applications outside these parameters, please consult us!)

<table>
<thead>
<tr>
<th>General</th>
</tr>
</thead>
<tbody>
<tr>
<td>Installation</td>
</tr>
<tr>
<td>Ambient temperature range</td>
</tr>
<tr>
<td>Weight</td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Hydraulic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum operating pressure in port A</td>
</tr>
<tr>
<td>Pressure differential $\Delta p$ for free return flow B $\rightarrow$ A</td>
</tr>
<tr>
<td>Minimum pressure differential</td>
</tr>
<tr>
<td>Pressure stability up to $\Delta p = 315$ bar</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Flow</th>
<th>$q_{\text{max}}$</th>
<th>L/min</th>
<th>0.2</th>
<th>0.6</th>
<th>1.5</th>
<th>3.0</th>
<th>6.0</th>
<th>10.0</th>
<th>16.0</th>
<th>25.0</th>
<th>32.0</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$q_{\text{up to 100 bar}}$</td>
<td>cm³/min</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>25</td>
<td>50</td>
<td>70</td>
<td>100</td>
<td>250</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$q_{\text{up to 315 bar}}$</td>
<td>cm³/min</td>
<td>25</td>
<td>25</td>
<td>25</td>
<td>25</td>
<td>50</td>
<td>70</td>
<td>100</td>
<td>250</td>
<td></td>
</tr>
</tbody>
</table>

| Pressure fluid   | Mineral oil (HL, HLP) to DIN 51 524; fast bio-degradable pressure fluids to VDMA 24 368 (also see RE 90 227); HETG (rape seed oil); HEPG (polyglycol); HEEH (synthetic ester); Other pressure fluids on request |

| Pressure fluid temperature range | °C | -20 to +80 |
| Viscosity range              | mm²/s | 10 to 800  |

| Cleanliness class to ISO code | Maximum permissible degree of contamination of the pressure fluid is to ISO 4406 (C) class 20/18/15³¹ |

³¹ The cleanliness class stated for the components must be adhered to in hydraulic systems. Effective filtration prevents faults from occurring and at the same time increases the component service life.

⚠️ Attention! The pressure loss from P at the inlet of the directional valve to A at the inlet of the flow control valve is noticeable at low flows.

2FRM 6 51/10 RE 29 163/04.01

Data Figure 3.1b Data sheet of flow control valve with check valve 2FRM 6 B36-3X/3QRV
3.2 Data sheet of the pressure control valve

### Ordering code

<table>
<thead>
<tr>
<th>KBD</th>
<th>2</th>
<th>0</th>
<th>A</th>
<th>A'</th>
<th>V</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct operated pressure relief valve with mechanical operation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adjustment element Set screw with hexagon</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pressure stage 70 bar</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>150 bar</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>250 bar</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>500 bar</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Component size</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Design principle Seat valve</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- No code = Without pressure pre-setting, without protective cap.  
- ... = With pressure pre-setting, without protective cap.  
- P... = With pressure pre-setting, sealed, with protective cap.  
- P = Without pressure pre-setting, sealed, with protective cap.  
- S = Standard Performance and mounting cavity R/T-162A  
- U = Standard Performance and mounting cavity R/UNF  
- A = Component series

---

### Standard types

<table>
<thead>
<tr>
<th>Pressure stage</th>
<th>Type</th>
<th>Material number</th>
</tr>
</thead>
<tbody>
<tr>
<td>E</td>
<td>KBD2E0AA/SV</td>
<td>R001005720</td>
</tr>
<tr>
<td>H</td>
<td>KBD2H0AA/SV</td>
<td>R001005724</td>
</tr>
<tr>
<td>N</td>
<td>KBD2N0AA/SV</td>
<td>R001005723</td>
</tr>
<tr>
<td>R</td>
<td>KBD2R0AA/SV</td>
<td>R001005726</td>
</tr>
</tbody>
</table>

### Function, section, symbol

**General**

This cartridge-type pressure relief valve is designed as direct operated poppet valve. It is used to limit the system pressure.

The valve consists of the screw-in part (1), tapered piston (2), spring housing (3), compression spring (4), adjustment element (5), locknut (6) with seal, retaining ring (7) for limiting the stroke, protective cap (8) (available only in conjunction with sealed/sealable variant) and O-ring (9) as damping element (hysteresis).

**Function**

When the pressure in P exceeds the value set on spring (4), the tapered piston (2) opens against the compression spring (4) and the hydraulic fluid flows from channel P to T.

In order to obtain a good pressure adjustment over the entire pressure range, the total pressure range is subdivided into 4 pressure stages. A pressure stage corresponds to a certain spring for a settable maximum operating pressure.

---

Data Figure 3.2a Data sheet of pressure control valve H-KBD2H0AA/SV.
Technical data (for applications outside these parameters, please consult us!)

**General**
- Weight: 0.12 kg
- Installation position: Optional

**Hydraulic**
- Maximum operating pressure $^{11}$: 350 bar
- Maximum set pressure $^{2,3}$:
  - Version "E": 75 bar
  - Version "H": 150 bar
  - Version "N": 250 bar
  - Version "R": 350 bar
- Max. permissible return flow pressure (main port 2): 50 bar
- Maximum flow: 40 l/min

**Hydraulic fluid**
- Mineral oil HLP, HLP68 to DIN 51524; fast bio-degradable hydraulic fluids to VDMA 24568 (see also RE 90221): HETG (rape-seed oil); HEPG (polyglycols); HEES (synthetic esters); other hydraulic fluids on enquiry

**Hydraulic fluid temperature range**
- $^{11}$ $^{2,3}$ $^{4}$
  - $^{11}$ Caution! The maximum operating pressure is the sum of the set pressure and the return flow pressure!
  - $^{2,3}$ Pressures below 25 bar cannot be set exactly for hysteresis reasons.
  - $^{4}$ When the maximum set pressure is exceeded (e.g., pressure peeks), select the next higher pressure stage.

**Viscosity range**
- mm$^2$/s: 10 to 400

**Max. permissible degree of contamination of the hydraulic fluid - cleanliness class to ISO 4406 (c)**
- Class 20/18/15 $^{4}$

**Load cycles**
- 2 million (at 350 bar)

**Max. pressure buildup velocity**
- mm/s: 30000

---

**Characteristics curves** (measured with HLP46, $T_{\text{oil}} = 50 \, ^{\circ}C \pm 5 \, ^{\circ}C$)

---

**Note!**
- The characteristic curves are valid for an output pressure $p_2 = 0$ bar over the entire flow range and without housing resistance.
- They refer to the specified nominal values of the pressure stages (75, 150, 250, 350 bar). Below the nominal pressure, the characteristic curves become increasingly steeper.

---

*Data Figure 3.2b  Data sheet of pressure control valve H-KBD2H0AA/SV.*
4. Data sheet of the Filters

Data Figure 4.a Data sheet of filter ABZFR-S0040-03-1X/M-DIN [...-SAE].
### Technical data (for applications outside these parameters, please consult us!)

#### General
<table>
<thead>
<tr>
<th>Installation position</th>
<th>Vertical</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direction of flow</td>
<td>Inlet at the side, outlet vertically downwards</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Size</th>
<th>40</th>
<th>63</th>
<th>100</th>
<th>160</th>
<th>250</th>
<th>400</th>
<th>630</th>
<th>1000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight</td>
<td>0.8 [lbs]</td>
<td>0.9 [lbs]</td>
<td>1.6 [lbs]</td>
<td>2.0 [lbs]</td>
<td>3.2 [lbs]</td>
<td>7.0 [lbs]</td>
<td>6.4 [lbs]</td>
<td>15.2 [lbs]</td>
</tr>
</tbody>
</table>

#### Material
- Filter head: Aluminum
- Filter bowl: Plastic
- Filter cover: Aluminum
- Visual clogging indicator: Aluminum
- Electrical switching element: Plastic RM6

#### Hydraulic
- Maximum operating pressure: 10 [bar] (145 [psi])
- Cracking pressure of bypass valve: 3.5 ± 0.35 [bar] (50.7 ± 5) [psi]
- Response pressure of clogging indicator: 2.2 ± 0.25 [bar] (31.9 ± 3.6) [psi]
- Hydraulic fluid temperature range: -30 to +100 (-22 to 212) [°C / °F]

#### Electrical (electrical switching element)
- Electrical connection: Circular plug-in connection M12 x 1, 4-pin Plug-in connection to DIN EN 175201-804, 6-pin + PE Plug-in connection to DIN EN 175201-803, 3-pin + PE

<table>
<thead>
<tr>
<th>Contact load</th>
<th>A max. 1</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Voltage range</th>
<th>E1SP-M12x1 V DC/AC</th>
<th>max. 150</th>
</tr>
</thead>
<tbody>
<tr>
<td>E2SP-DIN43650 V DC/AC</td>
<td>200 / 250</td>
<td></td>
</tr>
<tr>
<td>E2SP Y DC</td>
<td>10 to 30</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Type of switching</th>
<th>E1SP-M12x1 Changeover contact</th>
</tr>
</thead>
<tbody>
<tr>
<td>E1SP-DIN43650</td>
<td>Normally closed contact</td>
</tr>
<tr>
<td>E2SP-M12x1</td>
<td>Normally open contact at 75% of response pressure, normally closed contact at 100% of response pressure</td>
</tr>
<tr>
<td>E2SP-DIN43650</td>
<td>Changeover contact at 75 and 100% of response pressure</td>
</tr>
<tr>
<td>E2SPSU-M12x1</td>
<td>Normally open contact at 75% of response pressure, normally closed contact at 100% of response pressure</td>
</tr>
<tr>
<td>E2SPSU-DIN43650</td>
<td>Changeover contact at 75 and 100% of response pressure</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Signalling by LEDs in the electrical switching element</th>
<th>E2SP...</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ready (LED green)</td>
<td>75% switching point (LED yellow)</td>
</tr>
<tr>
<td>100% switching point (LED red)</td>
<td></td>
</tr>
</tbody>
</table>

| Type of protection to EN 60529 | IP 65 |

<table>
<thead>
<tr>
<th>Weight Electrical switching element with circular plug-in connection M12 x 1</th>
<th>0.1 [lbs] [0.22]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrical switching element with plug-in connection to DIN EN 175201-804</td>
<td>0.17 [lbs] [0.37]</td>
</tr>
</tbody>
</table>

Data Figure 4.b Data sheet of filter ABZFR-S0040-03-1X/M-DIN [...-SAE].
5. Data sheet of the Hose

**HYDRAULIC TUBES**

<table>
<thead>
<tr>
<th>Outer Diameter (mm)</th>
<th>Wall thickness (mm)</th>
<th>Weight (kg/m)</th>
<th>Maximum Pressure (Bar)</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>1</td>
<td>0,12</td>
<td>320</td>
</tr>
<tr>
<td>6</td>
<td>1,5</td>
<td>0,14</td>
<td>350</td>
</tr>
<tr>
<td>8</td>
<td>1</td>
<td>0,17</td>
<td>290</td>
</tr>
<tr>
<td>8</td>
<td>1,5</td>
<td>0,24</td>
<td>441</td>
</tr>
<tr>
<td>10</td>
<td>1,5</td>
<td>0,31</td>
<td>350</td>
</tr>
<tr>
<td>10</td>
<td>2</td>
<td>0,39</td>
<td>499</td>
</tr>
<tr>
<td>12</td>
<td>1,5</td>
<td>0,39</td>
<td>305</td>
</tr>
<tr>
<td>12</td>
<td>2</td>
<td>0,49</td>
<td>320</td>
</tr>
<tr>
<td>12</td>
<td>2,5</td>
<td>0,55</td>
<td>350</td>
</tr>
<tr>
<td>15</td>
<td>1,5</td>
<td>0,50</td>
<td>290</td>
</tr>
<tr>
<td>16</td>
<td>2</td>
<td>0,69</td>
<td>305</td>
</tr>
<tr>
<td>16</td>
<td>2,5</td>
<td>0,83</td>
<td>389</td>
</tr>
<tr>
<td>16</td>
<td>3</td>
<td>0,89</td>
<td>420</td>
</tr>
<tr>
<td>18</td>
<td>1,5</td>
<td>0,61</td>
<td>210</td>
</tr>
<tr>
<td>20</td>
<td>2</td>
<td>0,89</td>
<td>250</td>
</tr>
<tr>
<td>20</td>
<td>2,5</td>
<td>1,08</td>
<td>320</td>
</tr>
<tr>
<td>20</td>
<td>3</td>
<td>1,25</td>
<td>332</td>
</tr>
<tr>
<td>22</td>
<td>2</td>
<td>0,99</td>
<td>225</td>
</tr>
<tr>
<td>25</td>
<td>2,5</td>
<td>1,39</td>
<td>250</td>
</tr>
<tr>
<td>25</td>
<td>3</td>
<td>1,63</td>
<td>250</td>
</tr>
<tr>
<td>28</td>
<td>2</td>
<td>1,28</td>
<td>180</td>
</tr>
<tr>
<td>30</td>
<td>3</td>
<td>2,00</td>
<td>250</td>
</tr>
<tr>
<td>30</td>
<td>4</td>
<td>2,56</td>
<td>332</td>
</tr>
<tr>
<td>35</td>
<td>3</td>
<td>2,37</td>
<td>215</td>
</tr>
<tr>
<td>38</td>
<td>4</td>
<td>3,35</td>
<td>260</td>
</tr>
<tr>
<td>38</td>
<td>5</td>
<td>4,06</td>
<td>290</td>
</tr>
<tr>
<td>42</td>
<td>4</td>
<td>3,75</td>
<td>238</td>
</tr>
</tbody>
</table>

Standart length is 6 m with plactic stopper and Hose are covered by phosphate.

With **DIN 2391/C norms and ST 37.4 NBK quality.**

Data Figure 5. Data sheet of the tube
Modelling of the Hydraulic Press

The hydraulic press was modeled in the CAD program Solid Works.

Model Figure 1. General view
Model Figure 2. Pressure indicators’ View

Model Figure 3. Side view
Model Figure 4. Bolster’s View

Model Figure 5. Rams’, Emergency and Pressure Buttons’ View
Analysis of the Frame

The frame’s material was chosen cast carbon steel. Cast carbon steel frame is preferred to have a low working stress and minimum deformation under load. The frame is a mono block construction so it has a high structural rigidity and this gives an ideal frame profile with minimum stress concentrations [10].

Cast carbon steel’s important properties are: Yield Strength $2.4817 \times 10^8 \text{ N/m}^2$ and Elastic modulus $2 \times 10^{11} \text{ N/m}^2$.

Frame was analysed in the CAD program Solid Works. The analysis was done two different way. The load was applied under the conic rams and supporters which were placed on the bolster. The load was applied on the vertical axis. While analysing, the load is selected a little bigger than the working load for reliable analysis.
1. If the load is applied to the supporters

Apply normal force 18000 N using uniform distribution on eight supporters’ faces.

Safety Factor was found \( SF=2,16524 \) with this analysis. So frame is reliable at this analysis.

**Stress Resultant**

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>Min. ( \frac{N}{m^2} )</th>
<th>Location</th>
<th>Max. ( \frac{N}{m^2} )</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plot 1</td>
<td>VON:von Mises stress</td>
<td>21,168</td>
<td>(507,003mm, -315mm, 176,528mm)</td>
<td>1,14615 • 10^8</td>
<td>(727,836mm, -720mm, -29,107mm)</td>
</tr>
</tbody>
</table>

Analysis Figure 1. Stress resultant on the bolster
Displacement resultant

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>Min.</th>
<th>Location</th>
<th>Max.</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plot 2</td>
<td>URES: Resultant displacement</td>
<td>0m</td>
<td>(7,64491mm, -1420mm, -19,1071mm)</td>
<td>0.000497556m</td>
<td>(409,499mm, -676,8mm, 112,415mm)</td>
</tr>
</tbody>
</table>

Analysis Figure 2. Displacement resultant on the bolster
2. If the load is applied under the conic rams’ faces

Apply normal force 48000 N using uniform distribution on three conic rams’ faces.

Safety Factor was found \( SF = 3,27924 \) with this analysis. So frame is reliable at this analysis.

### Stress Resultant

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>Min.</th>
<th>Location</th>
<th>Max.</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plot 1</td>
<td>VON: von Mises stress</td>
<td>122,243</td>
<td>(659,37mm, -637.5mm, 223.67mm)</td>
<td>(7.56785 \times 10^7)</td>
<td>(612.011mm, -364.528mm, 169.035mm)</td>
</tr>
</tbody>
</table>

![Stress Resultant](image)

Analysis Figure 3. Stress resultant on the ram
## Displacement resultant

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>Min.</th>
<th>Location</th>
<th>Max.</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plot 2</td>
<td>URES: Resultant displacement</td>
<td>0m</td>
<td>(7,64491mm, -1420mm, -19,1071mm)</td>
<td>0.00037465m</td>
<td>(489,956mm, -430mm, 186,535mm)</td>
</tr>
</tbody>
</table>

Analysis Figure 4. Displacement resultant on the ram
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