ISSN 1454 - 8003
Proceedings of 2022 International Conference on Hydraulics and Pneumatics - HERVEX
November 9-10, Băile Govora, Romania

HIGH-PRESSURE POWER SOURCES – STATE OF THE ART, PERSPECTIVES

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Abstract: *The paper presents the current status regarding the use of high pressures in the field of hydraulic drives as well as the possibility of adapting existing drive solutions in order to obtain these pressures at low costs. The trend of increasing the level of pressure used is complemented by the expansion of branches that use high operating pressures, which leads to beneficial results regarding the reduction of dimensions and weight of elements and systems, better manoeuvrability and reduction of manufacturing costs, a fact also complemented by the latest research in the field of materials and manufacturing technologies, it being known that some materials and technologies, currently used in the manufacture of medium pressure equipment, do not provide the desired performance, especially durability and reliability, in the field of high pressures. The technical solutions that can generate pressures of up to 1000 bar are identified, whose main advantages are satisfying the requirements of force, speed, manoeuvrability, precision, etc. as well as the automation of the work process: equipping the hydraulic systems with high-pressure radial pumps with all the related equipment and pipes, and the second solution is the creation of standard pumping units to which a pressure amplifier - miniBOOSTER - chosen according to the application is attached.*

Keywords: *High pressure, hydraulics, applications*

1. Introduction

In today's hydraulic systems, the term "high pressure" is increasingly used when referring to values greater than 450 bar. The use of these pressure values is required by mechanical applications that need to make precise and fast movements in tight spaces or generate high forces for handling/moving large and very heavy weights. The delimitation of values for medium pressures and high pressures is not clearly established globally, but it is accepted that operation at pressures above 315 and 350 bar respectively (depending on the established program) can be considered as operation at high pressures. If the lower limit of the high-pressure range is relatively established, the upper limit is more difficult to define; it starts at 500 bar and can go up to 1000...1200 bar. Beyond these values is considered the zone of ultra-high working pressures. Most companies producing hydraulic equipment produce both in the medium pressure range and in the high-pressure range; however, there are also companies specialized only in the production of high pressure equipment

2. Trends in the field of working pressures of hydraulic equipment

Currently, the development of hydraulic equipment is manifested in multiple directions, such as: increasing working pressures (concentration in time), ensuring multiple functions for a certain element-module construction (functional concentration), increasing energy indicators (power concentration), increasing reliability and durability. The use of equipment with high working pressures is found in various fields, exploiting their advantages and looking for solutions to minimize/reduce the disadvantages. Specialized companies focus their production on pressure levels in both the medium and high-pressure range. However, there are also companies specialized only in the production of high-pressure equipment. The most representative are:
- the HAWE company - produces hydraulic equipment with a maximum working pressure of 700 bar;

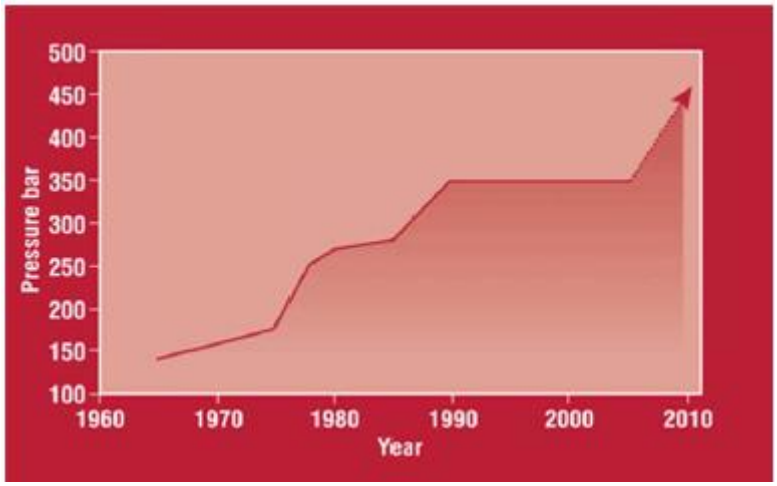

Fig. 1. Modern hydraulics working pressures evolution

- the company ATOS (Italy) - produces hydraulic equipment in the medium pressure range up to 350 bar and equipment with a maximum working pressure of 500 bar;
- the BIERI company (Switzerland) - belonging to HYDAC, specializes in high pressure hydraulic equipment (up to 700 – 1000 bar);
- the BOSCH – REXROTH company, one of the world leaders in the production of hydraulic equipment, produces in the medium pressure range (350 – 420 bar) or with a maximum pressure of 630 bar;
- the HYDAC company (Germany) produces medium pressure (320 bar) and high pressure (630 bar) equipment.

Limit values in the range of high pressure products 700-1000 bar and above this value are found at companies specialized in hydraulics for constructions, interventions in various situations, where the equipment works at pressures from 700 bar to 2500 bar and even more (LUKAS, ENERPAC, NIKE Hydraulics, etc.). In the current global context, regarding the protection of the environment by reducing emissions and optimizing energy consumption, the use of hydrostatic transmissions in the actuation of mobile machinery is of real benefit, as it is possible to conserve dynamic energy and reduce emissions, thanks to the possibilities of making the drives more efficient.

Ever since the widespread use of hydraulic drives, the values of working pressures have seen a continuous increase, the evolution shown in figure 1. The trend of increasing working pressures is also present in other fields, such as aviation, military and civil.

In the studies developed by various companies producing hydraulic equipment such as VICKERS, BOSCH - REXROTH, etc., working pressures of 500 and even 700 bar are indicated for the next years, and the current technical means allow pressure values of 1000...2000 bar to be achieved without difficulty; the problem that arises, however, is to ensure, simultaneously with the increase of the working pressure, the durability of the hydraulic equipment. Another consequence of increasing the working pressure in a system is the need to use working fluids with superior characteristics.

3. Equipment for generating high pressures

Obtaining high working pressures can be ensured by two types of pumping groups: a) pumping groups containing volumetric pumps and high-pressure hydraulic equipment; they directly feed linear or rotary volumetric hydraulic motors. These are used in dynamic applications, where the linear or rotary movement of large loads with uniform speeds is required. In static applications, they show reduced energy properties, and are not recommended.

b) pumping groups containing volumetric pumps and low-pressure hydraulic equipment; they feed the pressurized closed volumes or volumetric hydraulic motors by means of pressure amplifiers,

which are placed between the pumping group and the hydraulic consumers. This category is energy efficient in power-dissipating applications, but has disadvantages in high-load dynamic applications

3.1. High pressure hydraulic pumps

Hydraulic pumps do not generate pressure in a system, but have the role of supporting pressure requests through the assured flow. The main types of pumps used, are shown in figure 2.

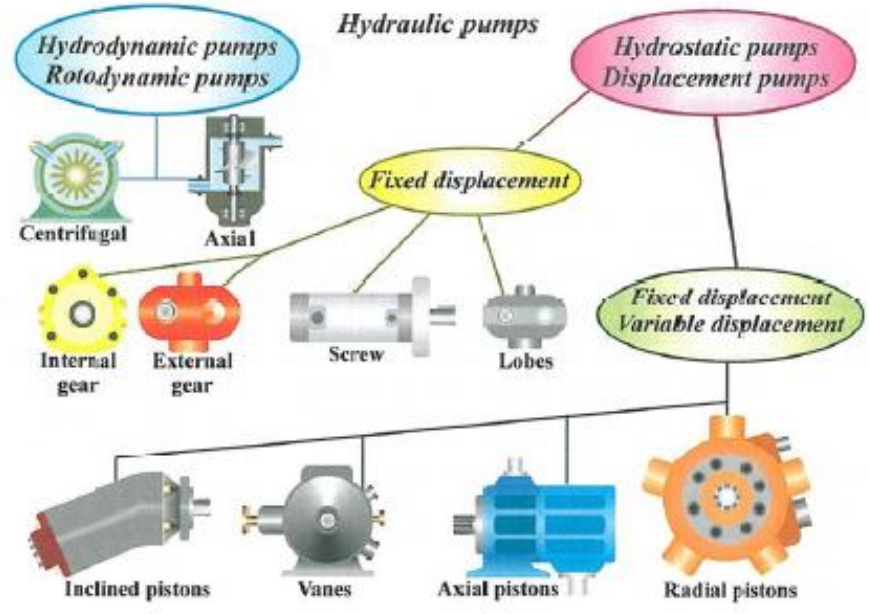

Fig. 2. Types of hydrodynamic and hydrostatic pumps

High-pressure pumps belong to the category of hydraulic generators, which, through a systematic dosing of the amount of fluid, achieve very high pressures. By the generated pressure level, from a constructive point of view the pumps can be (table 1):

Table 1: Pump types

No.	Constructive type of the pump	Working pressure
1.	Axial piston pumps	up to 350 bar
2.	In-line piston pumps	up to 1000 bar
3.	Radial piston pumps	up to 1500 bar
4.	Manual pumps	up to 2500 bar
5.	Piston pressure intensifiers	up to 5000 bar

3.2. Constructive examples of pumps

a) High-pressure radial piston pumps manufactured by Bosch – Rexroth, figure 3, ensure good sealing due to the spherical seating surface. They are pumps with a simple construction, they have a very good suction, but they ensure a lower volumetric efficiency when the working pressure is very high, a fact that determined the limitation of operation to a maximum pressure of 630 bar.

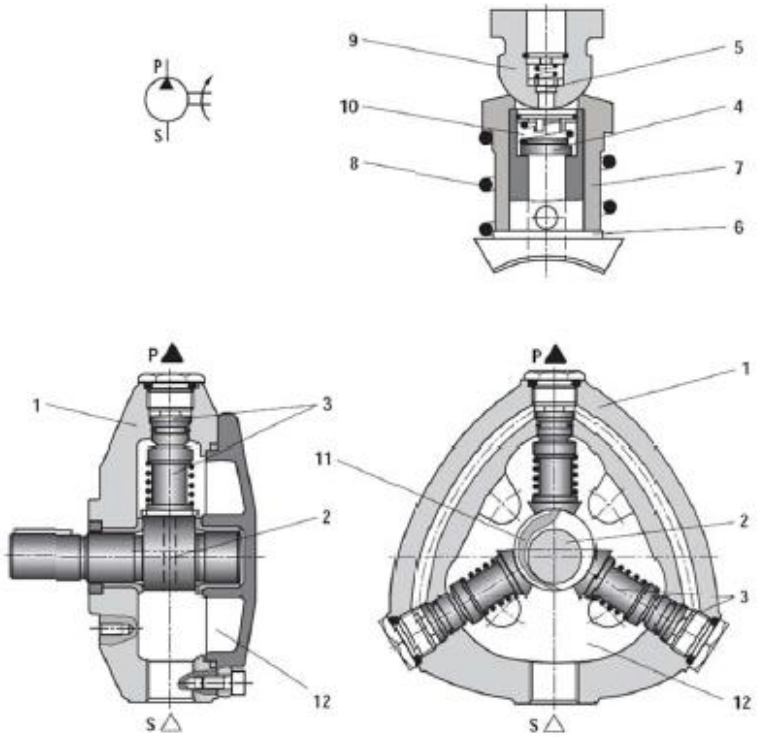

Fig. 3. Bosch – Rexroth radial piston pump [1]

b) Hydraulic pump controlled by air under pressure LP, figure 4.
This type of pump, not being powered by electricity, is recommended for working in environments with a risk of explosion, being able to be used up to pressures of 1500 bar. The operating principle is that of a pneumatic-hydraulic pressure booster.

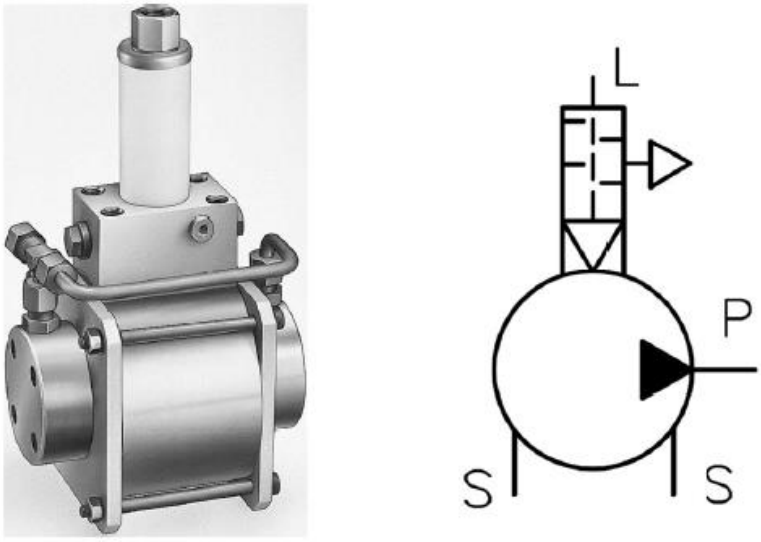

Fig. 4. Air driven pump under pressure, LP [2]

c) KKP combined pump
Combined pumps type KKP, figure 5, are radial pumps, with low weight and high compactness, with two stages (HP / LP) with tubular shaft, which allows obtaining a reduced dimension with the motor mounted directly on the pump.

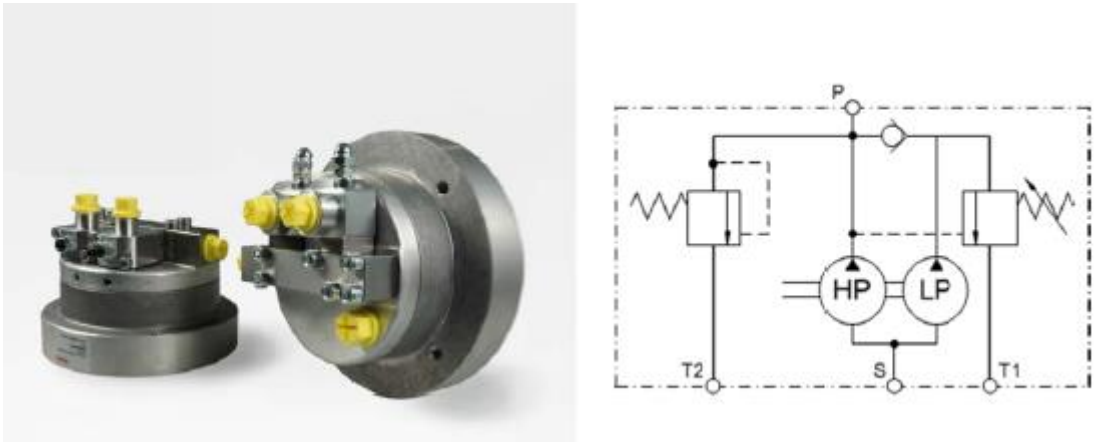

Fig. 5. KKP combined pump [3]

d) High pressure pump made by IHP Bucharest
It is a technical solution that brings together two pumps and contains the operating mode switching device attached to the outside of the pump, figure 6. It has six radial pistons, three large and three small, placed alternatively in the same plane, which realize the operation of both pumps.

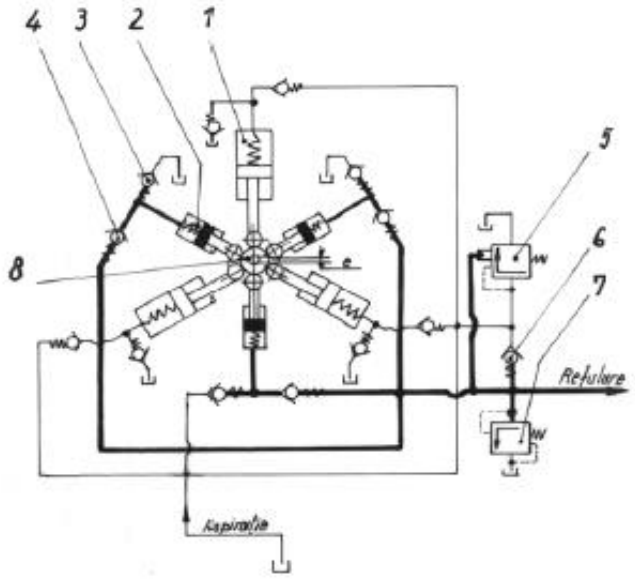

Fig. 6. High-pressure pump made by IHP Bucharest

e) LUKAS manual pumps
These are pumps that use muscle power as an energy source and have low flow rates, figure 7. These can be operated in two steps, including a valve that allows the automatic change of the working regime, from low pressure to high pressure. The HKP series pumps can reach a pressure of 2500 bar, have a single pressure stage, and are used for assembly/disassembly operations, test work, etc.

Fig. 7. LUKAS manual pumps for pressures up to 1000 ... 2500 bar [4]

4. Hydraulic pressure amplifiers

During the performance of a work cycle of a hydraulically operated installation or machine, there are certain work phases in which the powered volume motors, hydraulic cylinders or rotary hydraulic motors, are required to develop large, static or dynamic forces and moments, which requires their power supply at high pressures (over 450 bar). These pressures can be generated by two types of pumping groups:

a. pumping groups containing high-pressure (HP) volumetric pumps and high-pressure hydraulic equipment; they directly feed linear or rotary volumetric hydraulic motors. They are more expensive equipment due to the high price of pumps and command and control components. They are used in dynamic applications, where linear or rotary movement of large loads at uniform speeds is required.

b. pumping groups that contain volumetric pumps (LP) and low-pressure hydraulic equipment and feed the volumetric hydraulic motors by means of pressure amplifiers, which are placed between the pumping group and the hydraulic consumers with the role of raising the pressure to the value imposed by the demand at the level of the hydraulic motor. These pumping groups make energy-dissipating applications energy efficient, with the disadvantage of low and pulsating flows for dynamic applications.

The operation of fixed or mobile installations driven by hydraulic systems has phases of the work cycle which, in order to be achieved, require pressure increases of up to 1000 ... 2000 bar under low flow conditions. Classic solutions require the use of high-pressure radial pumps, which leads to high costs, so to avoid these costs, pressure amplifiers, also known as pressure intensifiers, boosters, miniboosters, were made.

The hydraulic pressure booster is a device used to increase the pressure intensity of any hydraulic fluid or water, with the help of the hydraulic energy available due to high values of the flow of water or hydraulic oil at low pressure. These devices are very important in the case of hydraulic machines, the best example being hydraulic presses, which require in their operation fluid at high pressure (HP) that the pumping group cannot provide directly; with their help, the existing pressure level is increased with minimal effort, resulting in minimal costs and maximum effect regarding the action of the hydraulic installation in achieving the work cycle. The basis of the operation of hydraulic pressure amplifiers is the simple principle of Pascal's law and the difference in area between the two pistons; even though the oil only acts at 15,000 psi, the area it presses on is huge compared to the small piston, and so a pressure of 150,000 psi appears. This increase is achieved with a ratio of the areas of the two pistons of 10:1. The material from which they are made is an alloy steel, heat treated to withstand high pressures and to preserve the surface quality and technological tolerances for as long as possible.

4.1. Pressure intensifier circuits – constructive types

Pressure intensifiers are circuits that generate high pressure from a low-pressure source. Pressure boosters can work with any type of fluid used in standard hydraulic installations. Among the most important benefits can be mentioned the low cost price, reduced space required for installation and

last but not least the energy saving of the system.
In figure 8, the schematics of some hydraulic air-oil pressure intensifiers are presented, which work on the principle of hydraulic cylinders, in which the cylinder operated by air has a larger diameter compared to the cylinder operating with hydraulic oil. The ratio between the two areas represents the pressure multiplication ratio, the volume of liquid expelled depending on the length of the cylinder stroke.

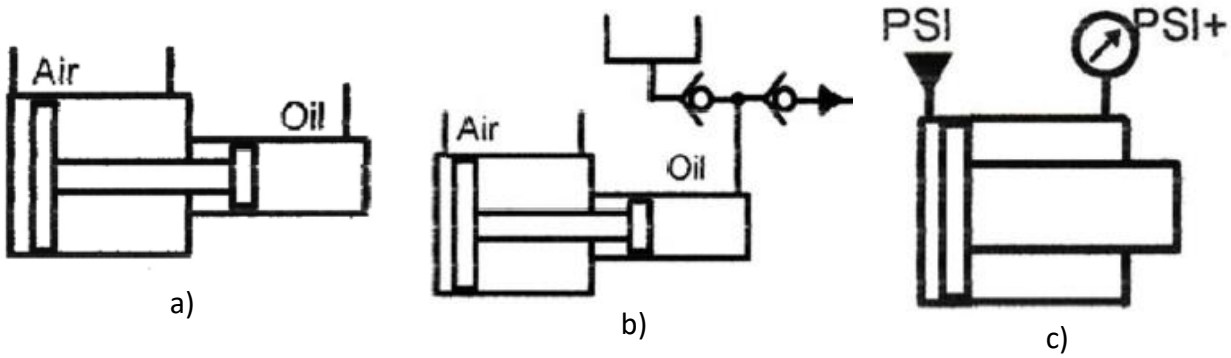

Fig. 8. Hydraulic air-oil pressure intensifiers - constructive types [5]

Pressure booster circuits, can also be made from cylinders of standard construction, being a way of obtaining the high pressure required for a defined action that requires a large force to be performed. The assembly of the circuit is done directly on the structure of the machine, hydraulic cylinders being able to perform the advance stroke both at high pressure, figure 9, and at low pressure.

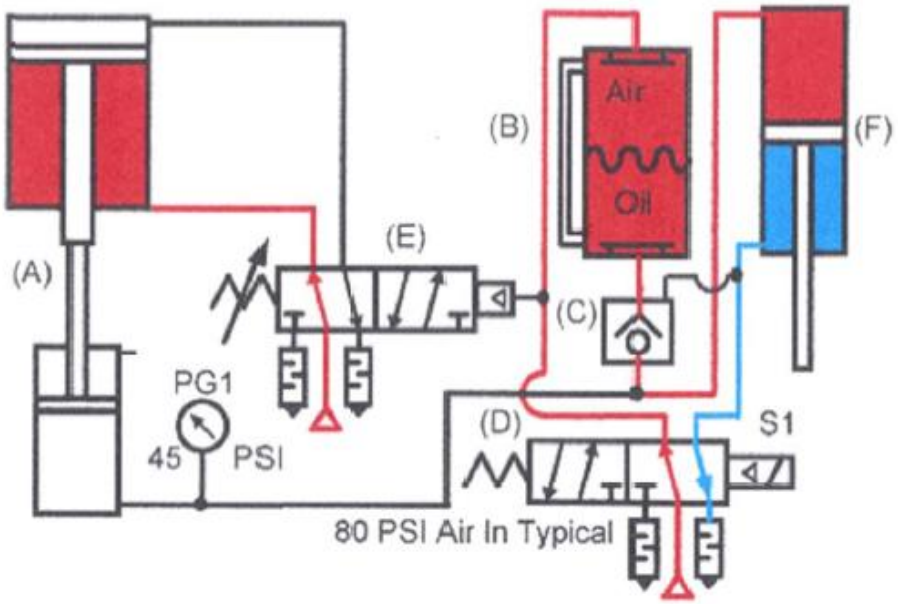

Fig. 9. Pressure amplifier circuit with standard cylinders: A – amplifier assembly; B – hydraulic air-oil reservoir; C – pilot valve; D- pneumatic distributor; E – electric distributor; F – working cylinder [5]

4.2. Oscillating hydraulic pressure intensifier - miniBOOSTER

In general, hydraulic pressure boosters are used to provide high pressure in applications where hydraulic cylinders must develop high-imposed forces. These types of amplifiers have optimal applicability in machinery and equipment used in construction, etc.

OHPI – oscillating hydraulic pressure intensifier mounted on a mobile crusher – ensures a high force with a small cylinder on the mobile wall of the crusher, figure 10.a. In figure 10.b., the pressure amplifier set used to increase the performance of the trailer pick-up system. The solution can be used for loading system with a capacity between 15 and 30 tons.

a) b)

Fig. 10. Examples of the use of pressure amplifiers [6]

For demolition machines with cutting and/or crushing materials equipment, during work due to the random variation of the resistance of the demolished elements, a high-pressure demand may occur at the engine level. The requirement is ensured by mounting a miniBOOSTER, figure 11.a, which ensures high speed and force, so minimum power consumption can be maintained. In figure 11.b, the pressure amplifier is mounted on an excavator, the aim being to optimize the drive systems to reach characteristics close to the maximum limit.

a) b)

Fig. 11. Pressure intensifiers mounted on construction machinery [6]

The miniBOOSTER pressure boosters also called HC, increase the low inlet pressure (ranging from 20 bar to 200 bar) to a high outlet pressure value (up to 800 bar / 2,000 bar). Adjusting the outlet pressure is done by adjusting the inlet pressure, being directly proportional. These boosters initially provide the consumer with low pressure at a high flow rate (for example, to quickly move a cylinder), then there is an automatic switching of operation in high-pressure pulses. Therefore, they allow both high flow rates at low pressures and low flow rates at high pressures, in figure 12 the hydraulic diagram of such a miniBOOSTER is being presented.

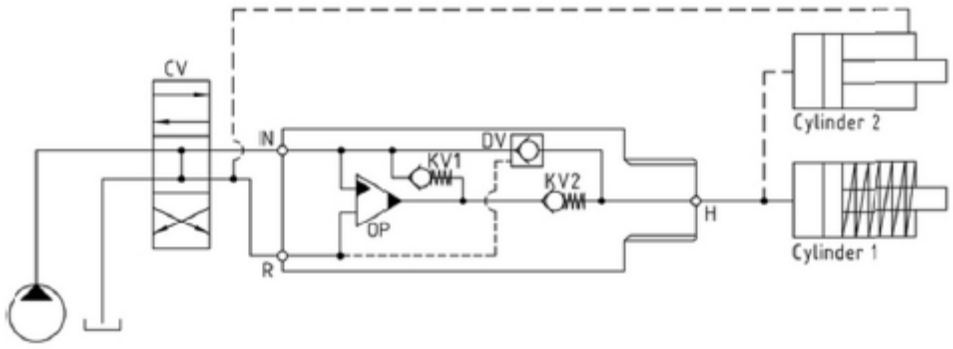

Fig. 12. Hydraulic diagram of a miniBOOSTER type HC1 [7]

This type of construction is used to amplify the pressure of low-pressure pumping groups that supply hydraulic cylinders with single or double action that move heavy loads linearly at the end of the advance stroke or achieve and maintain high pressure in a closed enclosure.

5. Conclusions

The general trend is to increase the level of pressure used and to expand the branches that use high operating pressures, with beneficial consequences in terms of reducing the size and weight of elements and systems, better manoeuvrability and reducing manufacturing prices. The latest research in the field of manufacturing materials and technologies contributes to this, as it is known that some materials and technologies, currently used in the manufacture of medium pressure equipment, do not provide the desired performance, especially durability and reliability, in the field of high pressures. The field of high pressures is increasingly attractive for various applications of mobile or fixed hydraulic drive systems.
The requirements of the internal market, but especially external, for equipment and systems to generate high pressures in hydraulic circuits (1000 bar) are still at a high level, because the production of fixed or mobile hydraulic installations that satisfy the conditions of force, speed, manoeuvrability, precision in movements, high reliability, automation of the work process, impose from the start of their design, the condition of their operation at high pressure, this being the main technical parameter that would lead to the realization of the parameters imposed by the beneficiary. The use of high-pressure generation systems with a low-pressure pump associated with a pressure amplifier as the power source ensures a low cost of the installation, its safety conditions and high reliability.

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