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THE ENERGY BALANCE OF PUMPS EQUIPPED WITH PRESSURE, FLOW AND POWER REGULATORS

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Abstract: *This article analyses the behaviour of energy efficient pumps equipped with the most common types of regulators: pressure, flow and power.*

Keywords*: Energetic efficiency, hydraulic system, adjustable pumps, flow, pressure and power regulators.*

1. Introduction

Hydraulic open centre systems using pumps with constant capacity (constant flow) are inefficient in terms of energy because the flow surplus, namely the difference between the flow discharged by the pump and flow necessary to consumer, is sent back to the basin at the maximum pressure at which system safety valve is adjusted. Unconsumed power is lost, turning into heat that is transmitted to the working fluid.
Hydraulic systems using pumps with variable capacity (variable flow) can provide precisely the necessary flow at the pressure required by the load, which leads to a high energy efficiency by reducing losses that generate heating of the working fluid. [1]

2. Fixed capacity pump

In an "open centre" hydraulic system, the fixed capacity pump delivers a fixed flow of oil. The pressure at the pump discharge depends on the resistors along the hydraulic drive circuit. Maximum pressure in the system is limited to the value adjusted by the safety valve.

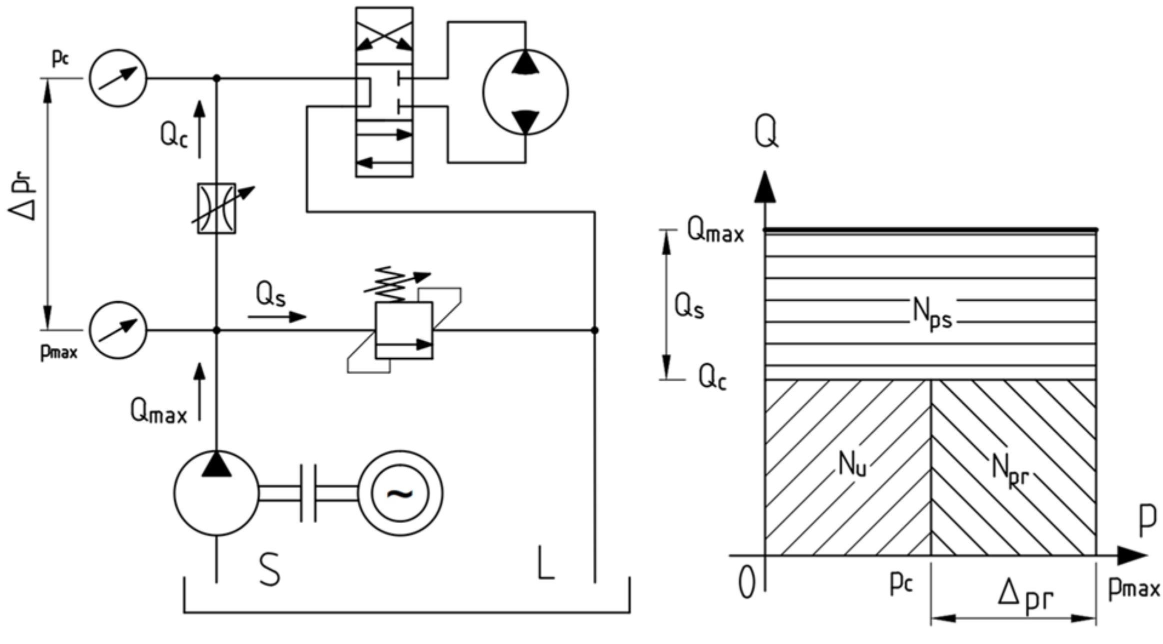

Fig. 1. Fixed displacement pump in "open centre" hydraulic system

N_u – useful power;
N_{pr} – lost power in 2-way flow regulator;
N_{ps} – lost power in safety valve;
Q_{max} – the maximum flow rate of pump;
Q_c – consumer flow;
Q_s – flow through the safety valve; $Q_s = Q_{max} – Q_c$;
p_{max} – pressure of the safety valve;
p_c –pressure at the consumer;
Δp_r –pressure drop through the control throttle; $\Delta p_r = p_{max} - p_c$;
$N_u \sim p_c \cdot Q_c$; $N_{pr} \sim \Delta_{pr} \cdot Q_c$; $N_{ps} \sim p_{max} \cdot Q_s$.

Excess flow is discharged through the safety valve at maximum pressure. Power losses through the control throttle and safety valve are converted into heat, which is transmitted to the working fluid. [2]

3. The pump with variable flow and pressure regulator

A pump equipped with pressure regulator provides maximum flow as long as the pressure at the discharge port is smaller than the adjusted pressure. When it reaches the adjusted pressure, pump flow (capacity) begins to decline and reaches zero if the pressure increases further. Hydraulic diagram and p-Q diagram of pump with adjustable flow rate and power regulator is shown in Fig. 2 [3].
ΔQ is the internal loss of flow due to pressure. It is highlighted on the drainage in pumps with external drainage.
Δp corresponds to piston spring feature that maintains the pump at V_g = max.

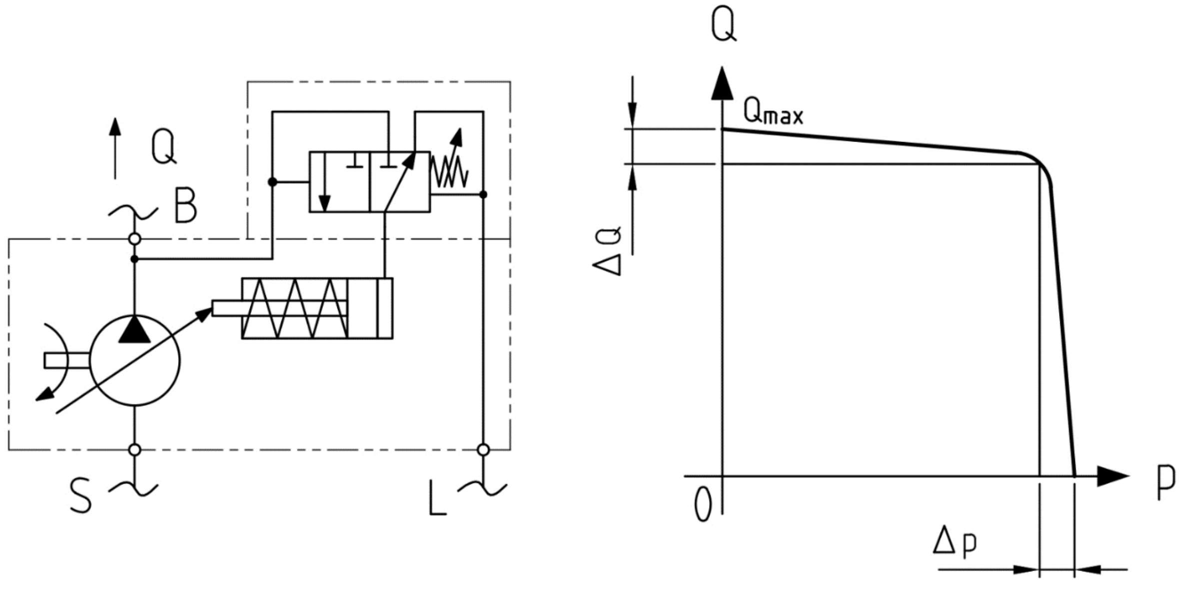

Fig. 2. Pump with pressure regulator

Typical application for the pump equipped with pressure regulator is a hydraulic press, see Fig. 3. Maximum flow is for the entire pressing stroke. When the pressure has reached the adjusted value the flow begins to decrease to zero and the pump delivers at maximum pressure a very low flow rate. [4]

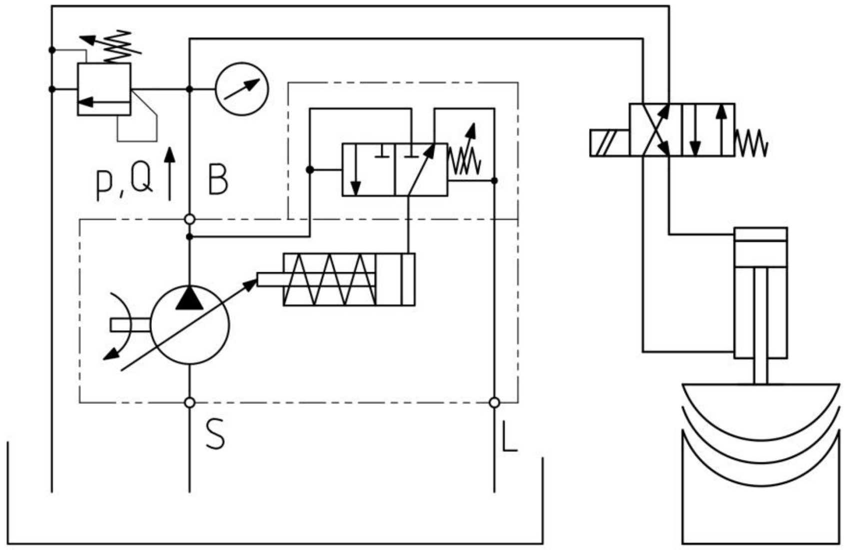

Fig. 3. Application of a pump with pressure regulator

4. Flow control of pumps equipped with pressure regulator

Flow control of a pump equipped with pressure regulator when the pressure at consumer is lower than that of the pressure regulator is done using a 2-way flow regulator, as shown in Fig. 4.

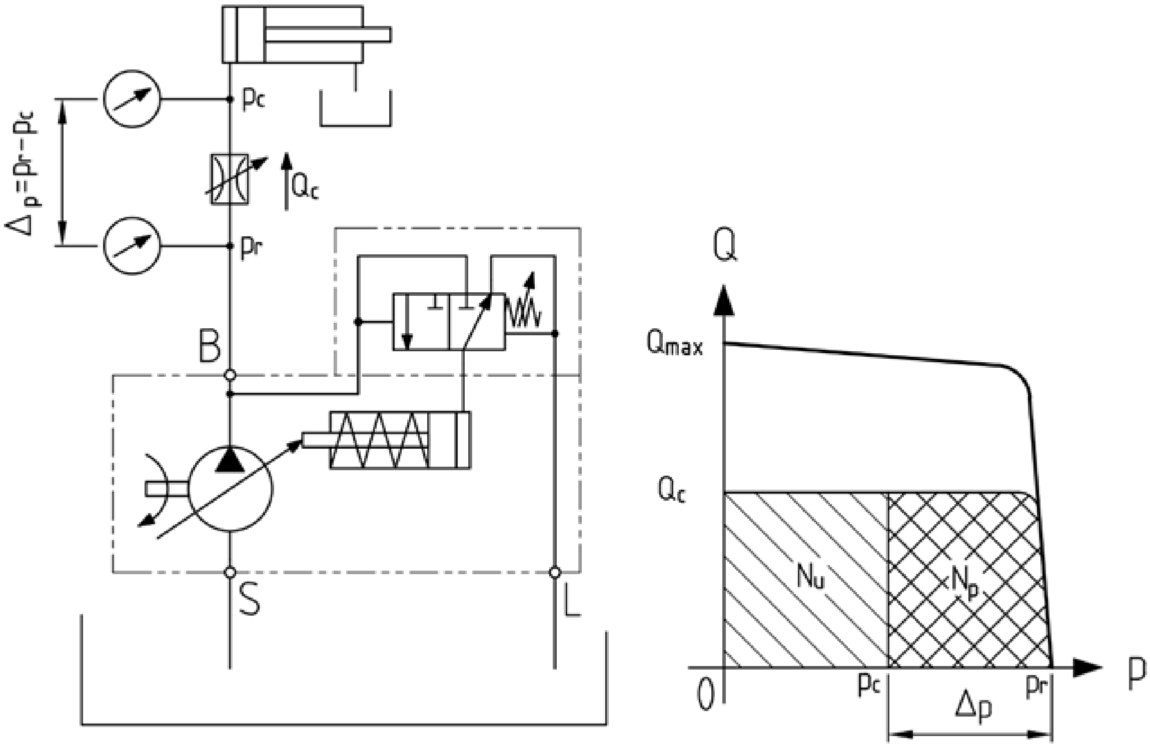

Fig. 4. Flow control in pumps equipped with pressure regulator

N_u – output power;
N_p - lost power;
Q_c - flow to the consumer;
p_c – pressure to the consumer;
Q_{max} - maximum pump flow;
p_r - pressure of the regulator.

The output power has the expression: $N_u \sim p_c \cdot Q_r$

Lost power has the expression: $N_p \sim (p_r - p_c) \cdot Q_r$

Power loss can be reduced if we adjust regulator p_r pressure to a value as close as possible to the maximum pressure of the p_c consumer, so that $\Delta p = p_r - p_C$ to be minimal.

5. Pump with pressure and flow regulator (Load Sensing)

Pump equipped with flow and pressure regulator has the advantage that it provides the required flow to the pressure that the consumer demands for, pressure which is lower than the pressure of the pressure regulator. [5]

"Load Sensing" is a hydraulic system that detects and delivers only the pressure and flow required by the consumer.

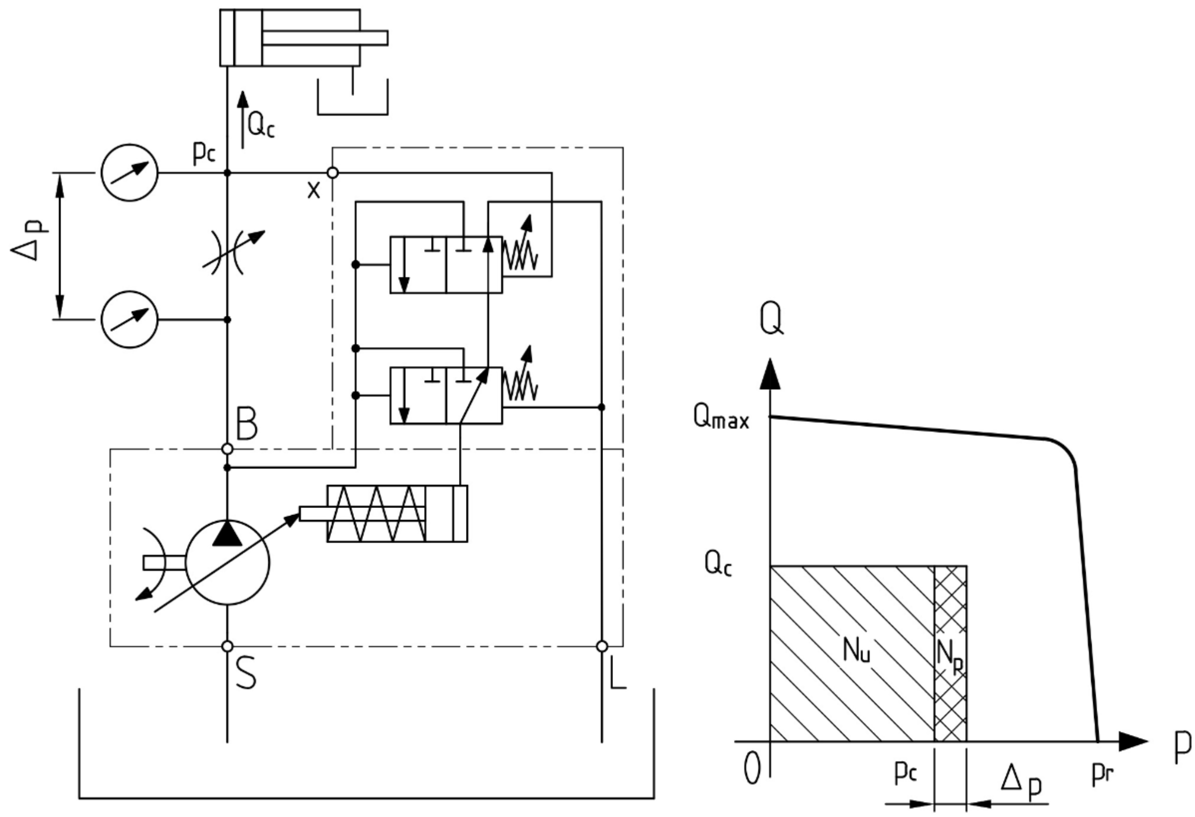

Fig. 5. Pump equipped with flow and pressure regulator

N_u – output power;
N_p - lost power;
Q_c - flow to the consumer;
p_c – pressure to the consumer;
Q_{max} - maximum pump flow;
p_r – pressure of the pressure regulator;
Δ_p - pressure drop through the measurement aperture.

The output power has the expression: $N_u \sim p_c \cdot Q_c$

Lost power has the expression: $N_u \sim \Delta p \cdot Q_c$

The advantages of the pump with Load Sensing are:

- The flow is constant, unaffected by pressure variations at the consumer;
- Energy losses are minimized.

The only power loss, very small, occurs because of pressure drop Δp = 14 ... 20 bar through the measurement aperture.

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6. Pump with pressure, flow and power regulator

Power regulator does not influence the energy balance of the pump; it only serves to limit the hydraulic power to a maximum adjusted value. Flow and pressure can be adjusted only within the range of maximum adjusted power. [6]

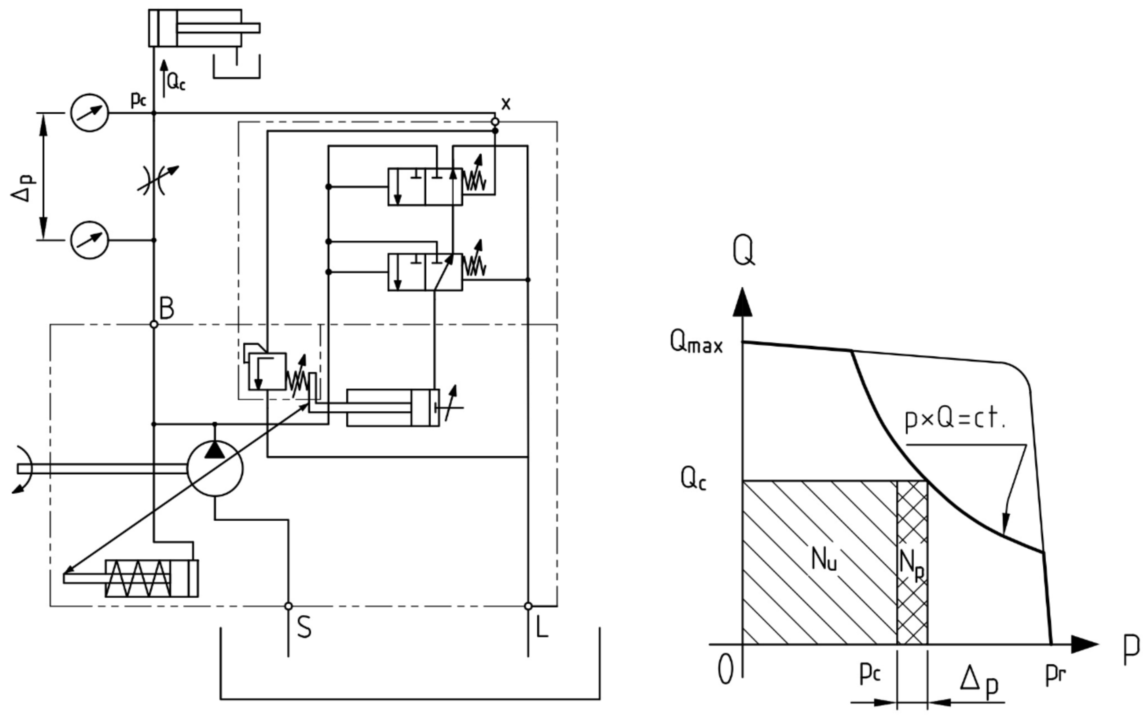

Fig. 6. Pump with pressure, flow and power regulator

7. Variable pumps with direct flow control

Hydraulic system with the best energy efficiency is that in which the pump flow is adjusted directly in line with consumer speed demand. Pump flow can be adjusted with hydraulic, pneumatic, electric devices, remote controlled, stepwise or continuously. [7, 8]

N_u – output power;
N_p - lost power;
Q_c - flow to the consumer;
p_c – pressure to the consumer;
Q_{max} - maximum pump flow;
p_r – pressure of the pressure regulator;
Δ_p - pressure drop through the measurement aperture.
The power output has the expression: $N_u \sim p_c \cdot Q_c$
Lost power has the expression: $N_u \sim \Delta_p \cdot Q_c$

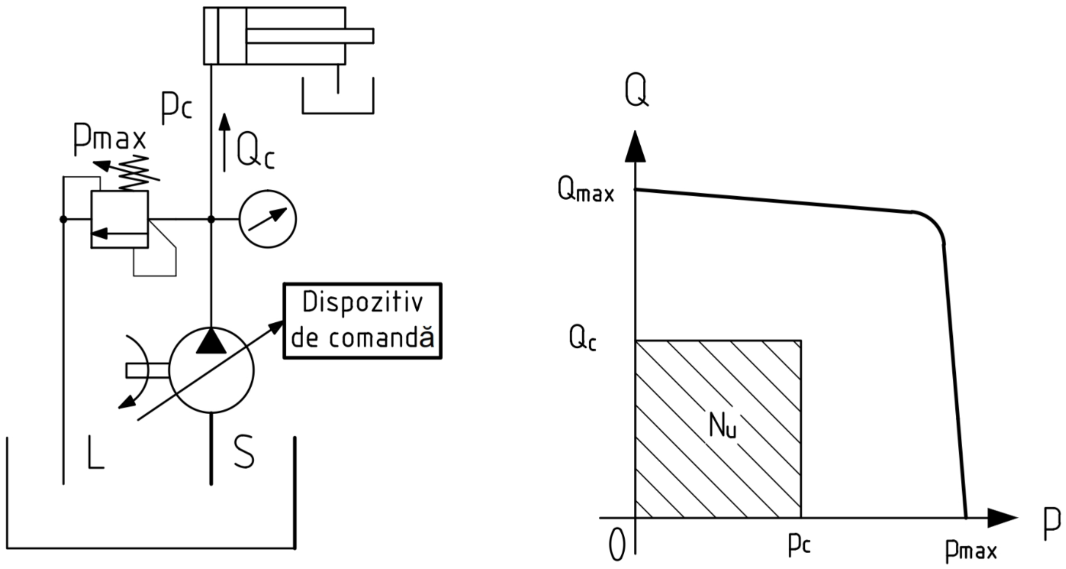

Fig. 7. Direct control of pumps with variable flow

8. Conclusion

Variable flow pumps equipped with various regulators have high energy efficiency because flow and pressure automatically adapt to customer needs.
Reducing energy losses which cause overheating of hydraulic oil leads to simplification of hydraulic system by:

- Possibility to mount a smaller capacity tank;
- Possibility to remove the oil cooler;
- Possibility to remove the pressure reduction valve or electrical decoupling valves.

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