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Experimental Investigations Performance for (VCC) Using 2-Way (PFCV) Type (2FRE)

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Abstract

In modern hydraulic control systems, the trend in hydraulic power applications is to improve efficiency and performance. “Proportional valve” is generally applied to pressure, flow and directional-control valves which continuously convert a variable input signal into a smooth and proportional hydraulic output signal. It creates a variable resistance (orifice) upstream and downstream of a hydraulic actuator, and is meter in/meter out circuit and hence pressure drop, and power losses are inevitable. If velocity (position) feedback is used, flow pattern control is possible. Without aforementioned flow pattern, control is very “loose” and relies on “visual” feed back by the operator. At this point, we should examine how this valve works and how can use it in electro-hydraulic circuit designs.

In this paper, constructed and compared velocity control cylinder (VCC) by using a proportional flow control valve (PFCV) and with a fine throttle valve. With the aid of a check valve and that check valve, the proportional valve can be made to act in the “lift” direction, and the fine throttle in the “lower” direction. As with all proportional valves, there is also some hysteresis in a proportional flow control valve. The valve used in this work with a hysteresis of <±1% of $Q_{\max}$. The repetition accuracy is quoted in data sheet as < 1% of $Q_{\max}$. The inferential results are good, acceptable and useful for designers which are working at hydraulic proportional field.

Keyword: *PFCV, VCC, Experimental, Investigation.*

1. Introduction

Proportional valve technology exactly does mean in hydraulic systems; An electrical input signal in the form of a voltage (mostly between 0 and+ 10V) is converted into an electrical current in an electronic amplifier corresponding to the voltage level, e.g.1 mV= 1 m A. proportionally to this electrical current as the input variable, the proportional solenoid produces the output variable-force and travel. These variables, i. e. force or travels, acting as the input signal for the hydraulic valve, signify proportionally a certain volumetric flow or pressure. For the consumer and therefore also for the working element of the machine this means , in addition to directional, steplessly variable control of speed and force. Simultaneously, acceleration or deceleration can be steplessly varied, e. g. change in volumetric flow with respect to time [1]. Hydraulic actuators are widely used on mobile equipment and robots, due to their high power density, environment tolerance, and compact size. One of the fundamental tasks in designing hydraulic actuating systems is the development of effective velocity control of the actuator using a control valve [2]. A practical approach to design a feed forward-plus-proportional-integral- derivative (FPID) controller for accurate and smooth velocity control on a hydraulic linear actuator is presented [3,4,5,6,]. Modeling and simulation a hydraulic servo system (HSS) presented and describes the design and implementation of a control system for the operation of a electro hydraulic systems [3, 7, 8].

This paper presents explain and discus the 2-way proportional flow control valve to controls a flow rate depending on the set electrical signal value, independently of pressure and viscosity. This means, for example, that a cylinder extends with constant velocity despite occurring interference variables (different loads).

In the experimental work we will build a circuit in which the extension velocity of a cylinder can be changed the aid of a 2-way proportional flow control valve. The load independence of this circuit will be demonstrated on test bench Figure (2) with the aid of the weight (30 kg).

2. Steady State Modeling

Generally, the steady state analysis cannot determine the complete performance of a valve because flow control valves contain moving parts. It used to obtain an estimate of valve characteristics. Figure (1) explains the physical configuration of flow control valve. There are two orifices in valve. The first is constant size. The second is varying in size as the pressure drop across the spool, $(p_s - p_v)$, changes. The spool has a spring force k_x and preload force (F) [9, 10, 11, and 12].

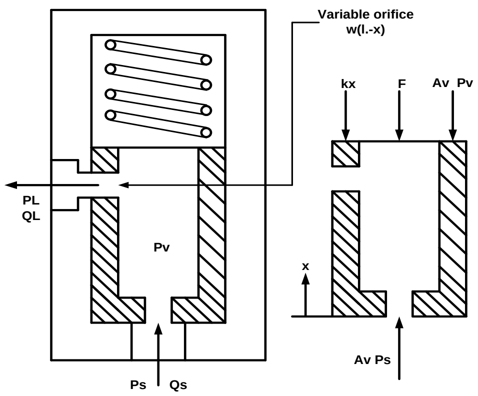

Fig. 1. Schematic of physical analysis of flow control valves.

The flow rate through the constant orifice is given by:

$$Q_L = C_d A_c \sqrt{\frac{2(p_s - p_v)}{\rho}} \quad \dots (1)$$

And flow rate through the constant orifice is given by:

$$Q_L = C_d w(l_i - x) \sqrt{\frac{2(p_s - p_l)}{\rho}} \quad \dots (2)$$

Combine equations (1, 2) yield an expression for p_v :

$$p_v = \frac{A_c^2 P_s - (\omega(l_i - x))^2 P_L}{A_c^2 + (\omega(l_i - x))^2} \quad \dots (3)$$

Static equilibrium for spool valve is:

$$p_s A_v = p_v A_v + F + k_x \quad \dots (4)$$

$$p_v = \frac{p_s A_v - F - k_x}{A_v} \quad \dots (5)$$

From equations (3 and 5) yield an expression:

$$\frac{P_s A_v - F - kx}{A_v} - \frac{A_c^2 P_s - (\omega(l_i - x))^2 P_L}{A_c^2 + (\omega(l_i - x))^2} = 0 \quad \dots (6)$$

Solve equation (6) explicitly in the form cubic polynomial in x.

When $F = m(mass) \times g$(acceleration)

After calculating the spool displacement, x, at different of p_s values, and from combining equations (1, 2) yield:

$$Q_L = C_d \frac{1}{\sqrt{\frac{1}{A_{c^\circ}^2} + \frac{1}{(\omega(l_i - x))^2}}} \sqrt{\frac{2(P_s - P_L)}{\rho}} \quad \dots (7)$$

Where

A_c	*Constant orifice area*	m^2
ω	*Variable orifice area gradient*	m^2/m
k_x	*Spring rate*	N/m
C_d	*Orifice discharge coefficient*	
l_i	*Initial varible orifice opening*	m
ρ	*Fluid density*	kg/m^3
P_L	*Load pressure*	*Pascal*
P_s	*System pressure*	*Pascal*
Q_L	*Load flow rate*	m^3/s

3. PFCV (2 FRE 6 B-2X/...K4RV)TECHNOLOGY

Proportional flow control valves Model 2 FRE are 2-way valves as shown in Figure (2), they allow a preset electrical signal to control an oil flow independent of pressure and temperature variation [13]. The assembly consists of a housing (1), a proportional solenoid with inductive positional transducer (2), measuring orifice (3), pressure compensator (4) and check valve (5), if required. The oil flow required is set using a potentiometer (0 ... 100 %), which in turn gives an input value to amplifier type VT 5010. This in turn controls the orifice (3) via the proportional solenoid. The position of the orifice (3) is determined by the inductive positional transducer, and any difference from the given input value is then corrected by the control system. The pressure drop across the measuring orifice (3) is held constant by the pressure compensator (4). The oil flow is therefore independent of load. The low temperature drift is achieved by suitable design of the measuring orifice. At an input level of 0 % the measuring orifice is closed. In the event of electrical failure, or if the wire to the positional transducer should break, the measuring orifice closes. A jump-free start is possible from the input value 0. The orifice may be opened and closed gradually by two ramps in the electronic amplifier. Free flow from B to A is possible via the non-return valve (5). With an additional rectifier sandwich plate Model Z4 S 6- mounted controlled both in meter-out and meter-in modes [14,15].

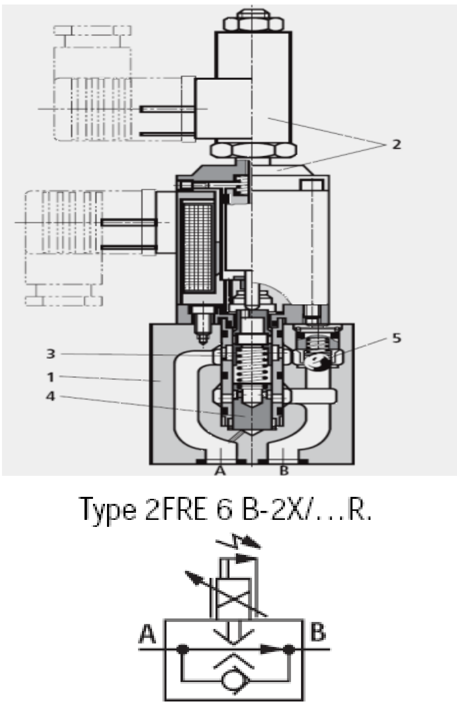

Fig. 2. Proportional flow control valve 2FRE 6 B-2X/…4RV [15].

4. Experimental Work

The hydraulic test bench shows in Figure (3) have been proportional flow control valve.

Fig. 3. Photograph of electro- hydraulic control unit test bench [15].

4.1. Electro- Hydraulic Control Circuit

Complete the circuit diagram as shown in Figure (4) so that the extension velocity of the cylinder can be controlled with the aid of a proportional flow control valve. It should be possible to alter the retraction velocity with the fine throttle. Limit the system pressure with a suitable pressure relief valve direct operated (50 bar).

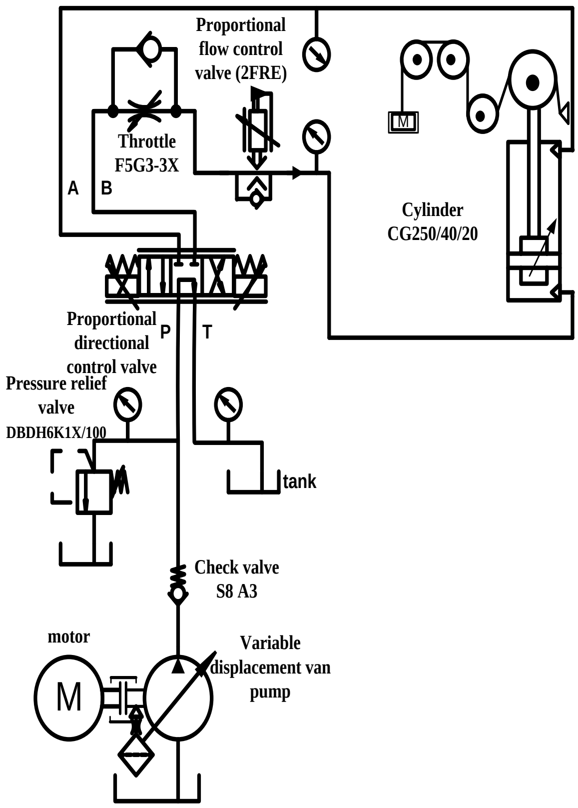

Fig. 4. Schematic diagram of connection Electro-hydraulic control circuit.

4.2. Electronic Control Circuit

Figures (5) explain the terminal connections / block circuit diagram electronic control: Amplifiers Model VT 5010 for velocity control.

Supposed and information for workers and engineers in the field of electro hydraulic control systems have special sciences facts. Each servo or proportional valves has amplifier card. Each company that produces these valves can product an electronic amplifiers card for its [15].

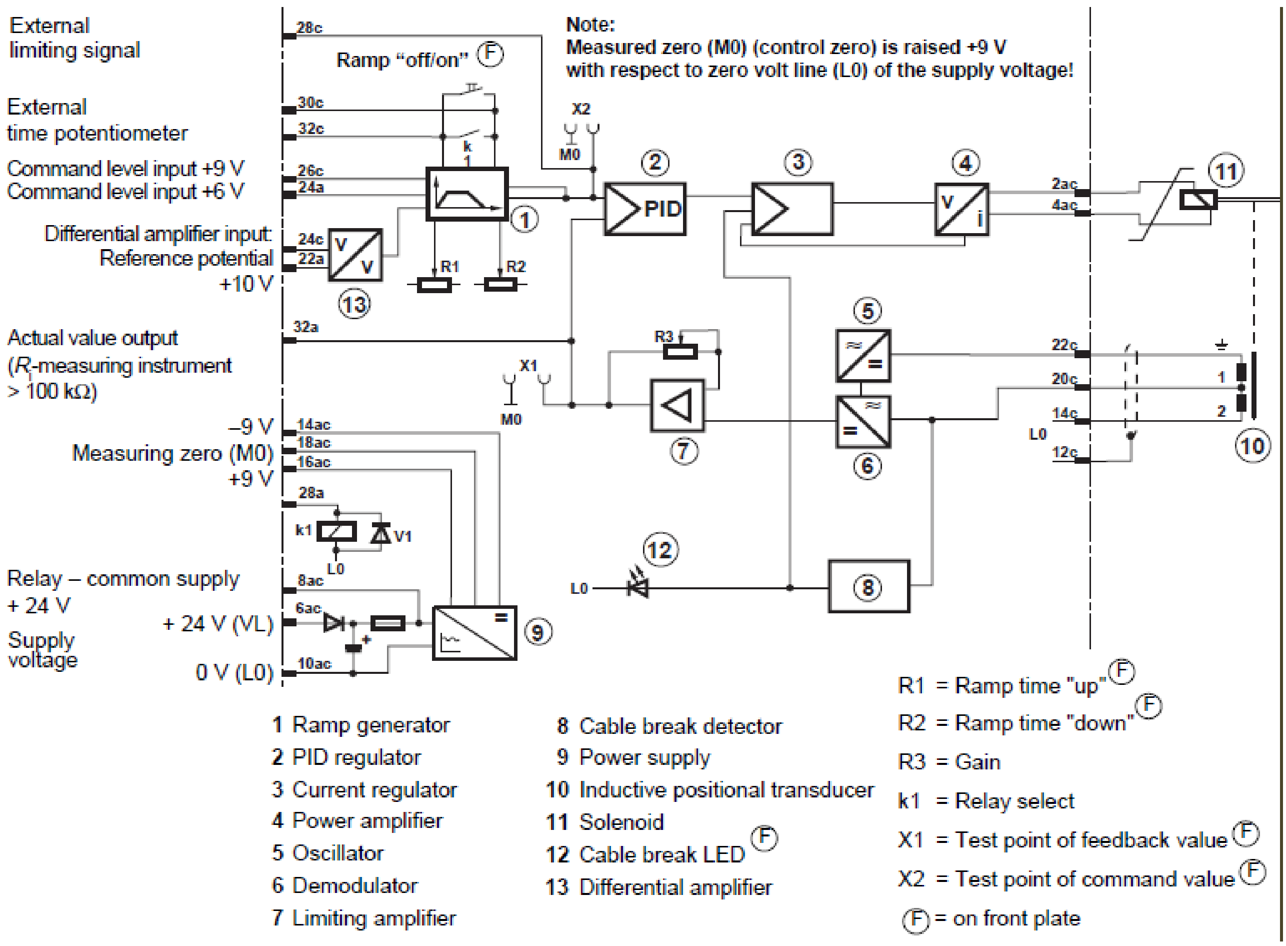

Fig. 5. Terminal Connections / Block Circuit Diagram Electronic control: Amplifiers Model VT 5010 for velocity control [15].

5. Dynamic Considerations

Figure (6) is model of a 2-way proportional flow control valve. The 2-way proportional flow control valve is a self-contained closed control loop. The dynamics of such a closed control loop. A possible way of measuring the dynamic behavior of the flow control valve is to examine the so-called step-function. Two possibilities are available: the stepwise change of specified signal value and the stepwise change of the interference variable (load pressure). Step of interference variables can be subdivided into load steps and starting steps. By the term load steps is meant stepwise changes in load pressure that occur within the control range of a valve Figure (7) range B, whilst starting steps are changes in load starting from the work points, that lie within the minimum pressure difference Δp_{min} Figure(7) range A. The greatest starting step occurs when the load connection of the flow control valve is opened. Figure (8) shows a step response o a 2-way flow control valve to a load step. The load pressure p_2 acting on the valve is then suddenly reduced by opening the second throttle, which is connected in parallel. This leads to a temporarily increased flow rate because the valve requires a certain time (transient process) to match itself to the changed load pressure conditions (closed loop control) [9].

A further criterion of the dynamic behavior is the measurement of the frequency response. Here, too, one distinguishes between change of signal value (control frequency response) and change of load (load pressure, interference frequency response). In measuring the control frequency response, the frequency of the control signal is continuously increased to "amplitude drop", and produced consequent change of phase (phase lag). In concrete terms, this means ; the valve cannot longer follow the specified signal value above a certain frequency. In control engineering the term "corner frequency" is introduced at this point. The comer frequency is that frequency at which the amplitude drop is 3 dB. In measuring the interference frequency response for the control signal is held constant. For example in the flow control valve, the load pressure (interference variable) is varied. Above a certain frequency of the interference variable, valve cannot longer able to compensate the interference variable when an amplitude drop and phase lag occurs [16, 17, 18, and 19].

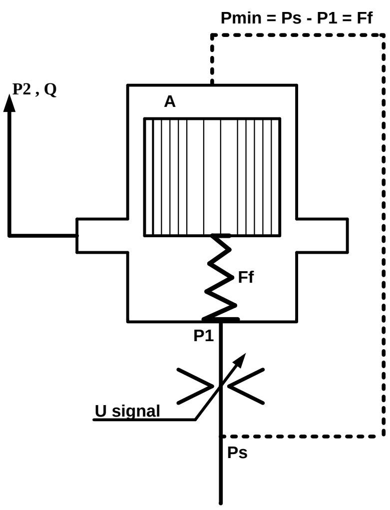

Fig. 6. Model of a 2-way proportional flow control valve.

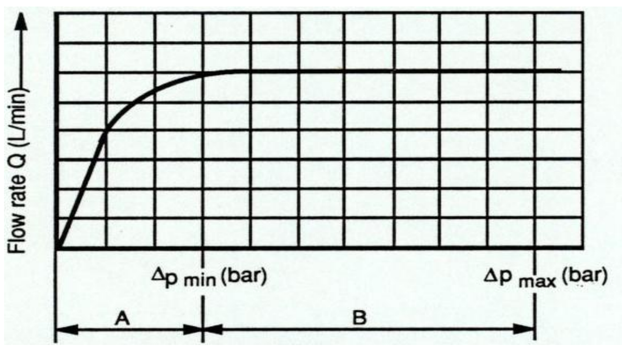

Fig. 7. Qualitative characteristic curve of a flow control valve [16].

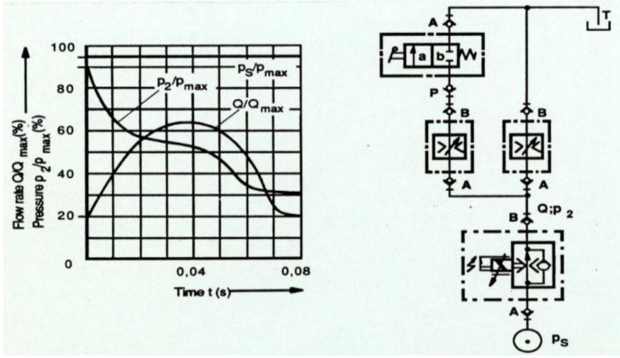

Fig. 8. Step response of a flow control valve to a step load [16].

6. Result and Discussion

All of evaluation experimental work data explain in tables (1, 2, 3, and 4). And Characteristic curves (measured at ν = $36\,mm^2/s$ and T = 50 °C. Explanation of experimental results: figure (9) explain the characteristic curves for tables (1, 3). Considering the two curves of characteristic curves 1, it is clear that the extension velocity is independent of the load (the two curves are practically identical).

By adjusting the potentiometer and thereby the proportional flow control valve, the extension velocity can be changed independent of load according to characteristic curve (6 Q) in figure (10). The velocity changes not proportionally, but progressively with the signal value. This characteristic curve, however, permits a finer adjustment of the velocity in low velocity ranges. Figure (11) explain the characteristic curves for tables (2, 4). The curves of characteristic curves 2 are not dependent on the setting of the proportional flow control valve but only on the setting of the fine throttle.

It can be clearly recognized that the retraction velocity with load is greater than that with no load. Compare the two diagrams; then you can see the effect of the velocity control with the 2-way proportional flow control valve and the effect of velocity control with the fine throttle. With proportional flow control valve is load independent but with throttle load dependent.

Table 1,
Extension hydraulic cylinder with no load.

Signal value of flow control valve (2 FRE)	0	1	2	3	4	5	6	Volt
Time without load		215.00	48.00	19.00	10.00	7.00	4.40	Sec
Velocity without load	0.00	0.15	0.66	1.68	3.12	5.18	7.25	cm/s

Table 2,
Retraction hydraulic cylinder with no load.

Signal value of throttle	0	1	2	3	4	5	6	setting
Time without load	135.00	39.00	12.00	7.00	4.00	3.00	2.90	Sec
Velocity without load	0.00	0.80	2.65	5.19	7.97	9.71	11.09	cm/s

Table 3,
Extension hydraulic cylinder with load.

Signal value of flow control valve (2 FRE)	0	1	2	3	4	5	6	Volt
Time with load		207.00	47.00	19.00	11.00	6.5 0	4.50	Sec
Velocity with load	0.00	0.16	0.67	1.68	3.12	5.00	7.40	cm/s

Table 4,
Retraction hydraulic cylinder with load.

Signal value of throttle	0	1	2	3	4	5	6	setting
Time with load	103.00	29.00	10.00	5.50	4.00	2.50	2.30	Sec
Velocity with load	0.00	1.12	3.45	6.91	10.71	12.94	14.78	cm/s

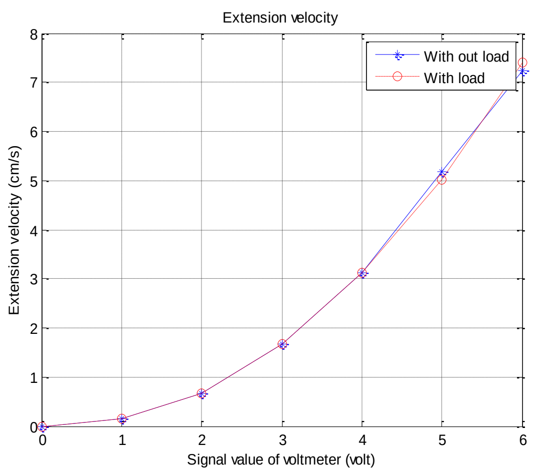

Fig . 9. Characteristic curves for table 1 and 3.

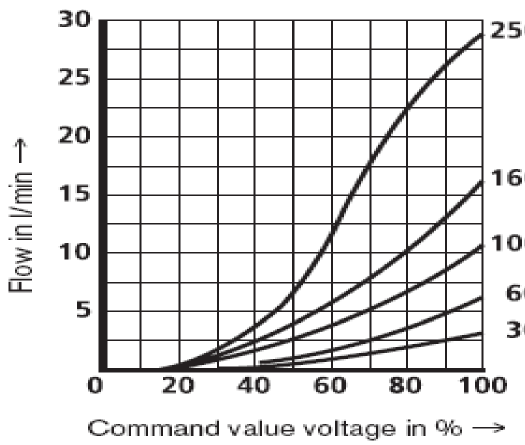

Fig. 10. Dependency flow rate on signal value voltage for different valve size [15].

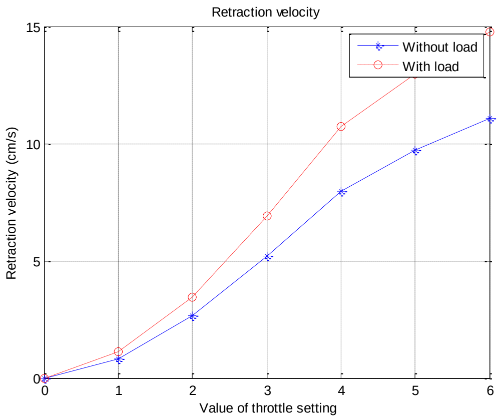

Fig. 11. Characteristic curves for table 2 and 4.

7. Conclusions

The results confirmed that the performance of velocity control cylinder (VCC) depends on the performance of the 2- way proportional flow control valve (PFCV) type (2FRE)

- Any variation in the value of fin throttle valve will lead to a change of flow rate and velocity control cylinder (VCC).
- Any variation in the input signal (volt) to 2-way proportional flow control valve (PFCV) type (2FRE) will leads to a variation of flow rate and velocity control cylinder (VCC).
- The viscosity of hydraulic fluid is independence of the 2-way proportional flow control valve achieved because the form of the metering orifice.

The velocity control cylinder (VCC) depends on measuring orifice of the 2-way proportional flow control valve

- The measuring orifice can be opened and closed with a delay two ramps in the electronic amplifier for 2- way proportional flow control valve (PFCV) type (2FRE).
- Through the use of different measuring orifice, various maximum flow rates can be achieved at 100% input signal value.
- The characteristic flow curves progressive depending on the shape of the measuring orifice.
- When comparing characteristic flow curves for this work with the manufacturer company of (PFCV) show that there is a difference. The reason for this lies in the additional flow resistances of hoses, pipes and quick release coupling.

To ensure is perfect operation of 2-way proportional flow control valve. We must make sure of the following notes;

- It is necessary to bleed the solenoid of the 2-way proportional flow control valve at the highest point of the valve during initial operation.
- Under certain installation conditions, the tank line must be prevented from running empty by the installation of a preload valve.
- The actuator (cylinder) can be controlled both in meter-out and meter-in modes.

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التحقق العملي للسيطرة على اداء سرعة اسطوانة باستخدام صمام تناسبي للتحكم بالتدفق بطريقيين نوع (2FRE)

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الخلاصة

الاتجاه العام في انظمة السيطرة الهيدروليكية الحديثة وفي تطبيقات الطاقة الهيدروليكية هو تحسين الكفاءة والأداء. الصمام التناسبي بصورة عامة يستخدم صمامات للسيطرة على الضغط – التدفق-اتجاه الجريان والذي يحول باستمرار اشارة الدخل المتغيرة الى اشارة خرج هيدروليكية تناسبية غير مصحوبة بارتجاج (ناعمة).

كذلك الصمام التناسبي مقاومة متغيرة ضد ومع الجريان لاي مستخدم هيدروليكي (دائرة السيطرة على سرعة الاسطوانة الهيدروليكية) . ومن هنا التغيرات بالضغط وفقدان القدرة حتمية ومن المتعذر اجتنابها ان استخدام الصمام لتغذية مرتدة للسيطرة على السرعة(الموضع) فنموذج السيطرةعلى التدفق ممكن. وبدون نموذج التدفق المذكور انفا تصبح السيطرة غير محكمة وكذلك التغذية المرتدة تكون للمشغل غير واضحة المعالم (شيئية). من هنا يجب علينا اختبار عمل الصمام وكيفية استخدامه في الدوائر الكهروهيدروليكية المصممة . في هذا البحث الدائرة المصممة والمبنية تجيز السيطرة لنا على السرعة باستخدام صمام تناسبي للتحكم بالتدفق مع صمام خانق دقيق والمقارنة بينهما . وبمساعدة توحيد الصمام اللارجعي مع الصمام التناسبي للتحكم بالتدفق . يستطيع الصمام التناسبي ان يؤثر على اتجاه الحركة للاعلى والصمام الخانق الدقيق على اتجاه الحركة للاسفل(للاسطوانة). كل الصمامات التناسبية وكذلك الصمام التاسبي للتحكم بالتدفق تحصل فيها تخلفية والصمام المستخدم في هذا العمل فيه تخلفية ومعدل دقة التكراربمقادير معينة تستنبط من جداول الشركة المصنعة للصمام.

النتائج العملية المستنبطة من هذا البحث جيدة ومقبولة ومفيدة جدا للمصممين والعاملين في تنفيذ تصاميم الدوائر الهيدروليكية التناسبية.