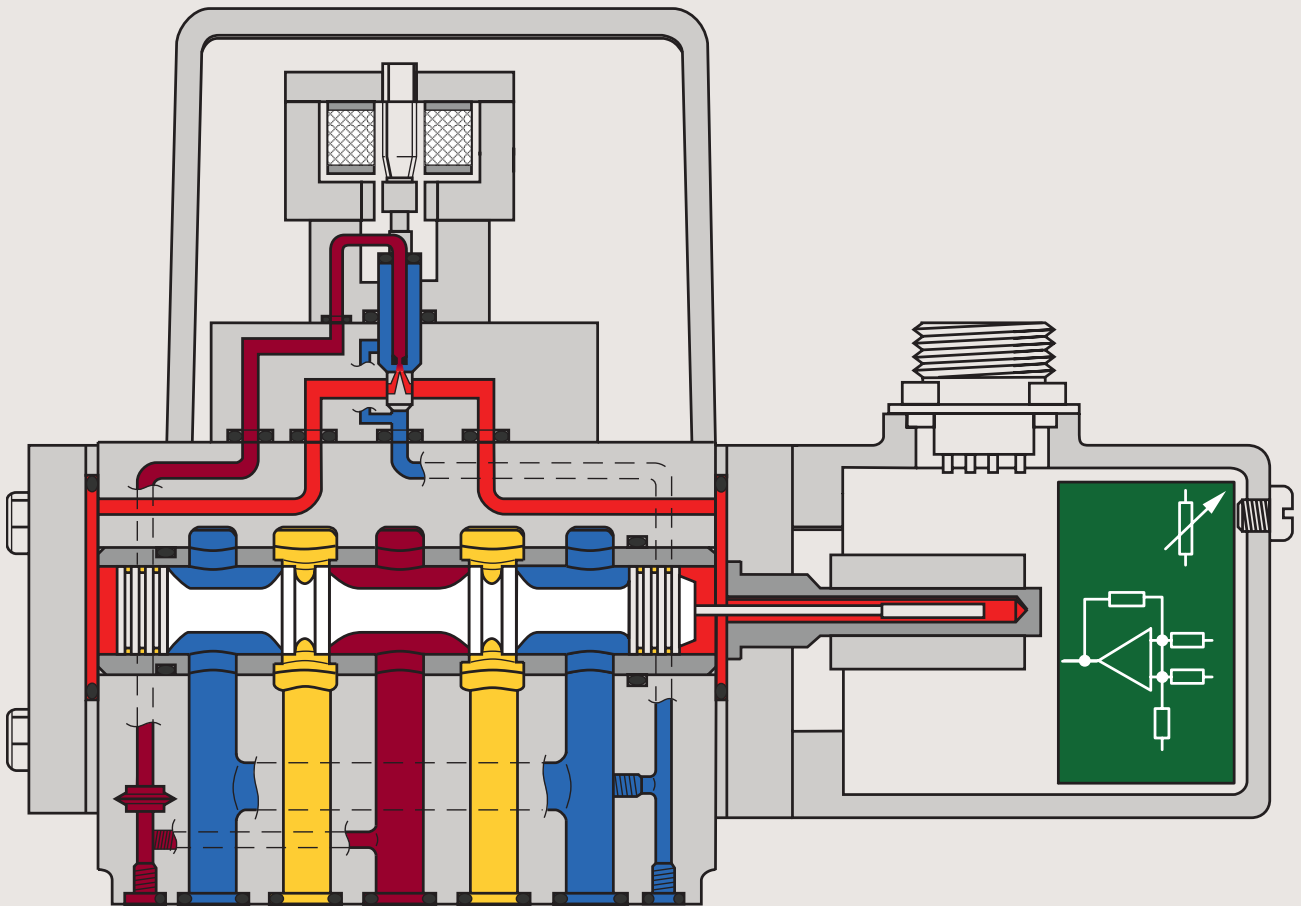


ELECTRO-HYDRAULIC-VALVES:

A TECHNICAL LOOK





CONTENTS

Moog has designed this guide to electro-hydraulic drives to advise customers on which solution will work best for their specific manufacturing environment.

- 05** Moog Valves Explained
- 11** Operating Principles
- 20** Valve Sizing and Selection
- 29** General Electro-hydraulic System Layout
- 34** Routine Maintenance

INTRODUCTION

MOOG INDUSTRIAL VALVES

Moog has been producing electro-hydraulic servo valves that control the position, velocity, pressure and force levels required by industrial manufacturing for more than sixty-five years. Servo and proportional valves are electrically operated valves that manage the flow of hydraulic fluid to actuators, and subsequently control hydraulic cylinders by way of a small electrical signal.

Moog Industrial's Servo and Proportional Valves are widely used across a broad range of markets and applications in the world of modern manufacturing. In the metal forming sector, for instance, Moog has led the way in developing motion control technology for a number of different applications. These include deep drawing presses, as well as powder, forging and recycling presses. Plastics production also benefits from Moog's motion control expertise, and the industry successfully applies our technology to key areas such as high performance injection molding and blow molding machinery.

Manufacturers successfully use Moog valves in even more challenging environments such as iron and steel production, which demands the highest levels of precision, reliability and productivity and often at very intense temperature levels. Moog Servo and Proportional Valves control the thickness of sheet steel in steel mills, and the industry deploys them across a number of other applications such as roll bending and shifting in hot steel mill finishing. Moog Valves control the stability of offshore oil exploration platforms, often in potentially explosive atmospheres, and they regulate the fuel injection process in marine diesel engines to optimize the combustion process and reduce emissions.

All of the above applications demand the accurate and precise control of complex manufacturing structures, and they are often subject to varying load levels that can adversely affect performance. Moog valve products overcome those effects through feedback. All Moog valves are equipped with an internal closed loop position control of the spool to ensure optimal performance under all operating conditions.

ABOUT THIS GUIDE

This guide contains an opening section on the different valve types currently available from Moog ranging from:

- Servo and Proportional valves
- Direct and Pilot operated valves
- Electrical and Mechanical Feedback valves
- Valves with analog and digital electronics
- Flow, pressure and axis control valves

A Technical Look sets out operating principles, and, in particular, the different pilot and spool actuation principles for Nozzle Flapper, Servojet and Linear Force Motor operated valves, together with the function of some pilot and direct operating EFB and MFB valves.

The selection of servo or proportional valves for a particular manufacturing application also involves careful consideration of the system built around the valve. The Valve Sizing section of this guide offers Moog customers practical advice on the different valve and system parameters that they should consider when selecting a valve. Finally, this brief introduction to electro-hydraulic valves presents a short overview of different Moog control circuits and, ultimately, the general electro-hydraulic system layout. It concludes with useful, eleven point guidelines for effective routine maintenance.

MOOG CUSTOMER SUPPORT

Moog engineering and sales expertise is available to help you find optimal solutions for your manufacturing motion control needs. Our specialist teams will support your position, velocity or force control requirements, often by developing and implementing customized designs and products tailored specifically to your manufacturing needs. Moog support is widely recognized across the global industrial sector. Simply contact us and let us know what support you would like to discuss with us.



MOOG VALVE TYPES EXPLAINED

Some basic information about Moog Servo and Proportional Valves and their different features.

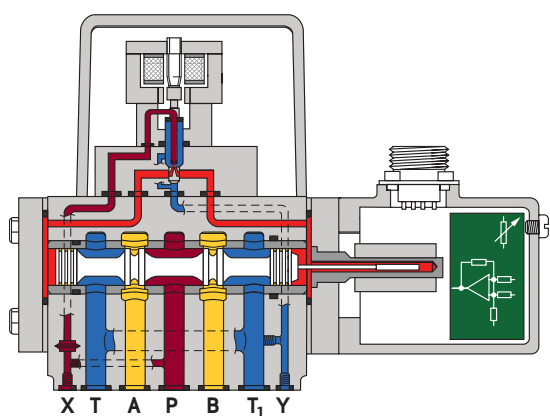
Moog develops and manufactures a number of different valve types that meet the specific application requirements of our customers. This section of the Technical Look guide to electro-hydraulic valves sets out the differences between the different Moog valve types. It establishes what servo, proportional, MFB, EFB, pQ and ACV valves are, and what, specifically, they are capable of doing.

SERVO AND PROPORTIONAL VALVES

Servo and proportional valves are electro-hydraulic valves that transform a changing analog or digital input signal into a stepless hydraulic output. In general terms, servo valves are largely considered high-end valves that optimize the performance of industrial machinery, whereas proportional valves are mostly used on more basic applications. The principal difference between servo and proportional valves is the spool overlap, when the spool is in the central position. A servo valve possesses a spool overlap of $<3\%$ of the spool stroke, while a proportional valve has an overlap of 3% or over, as defined by the ISO 5598 standard.

Normally, Moog servo valves are characterized by a spool sliding within a hardened steel bushing. Proportional valves, on the other hand, have the spool sliding directly inside the cast iron valve housing. (Note: Moog also produce some proportional valves with a bushing spool assembly). The diagrams below demonstrate the layout and chief characteristics of both valve types:

MOOG SERVO VALVES



Spool sliding in hardened steel bushing

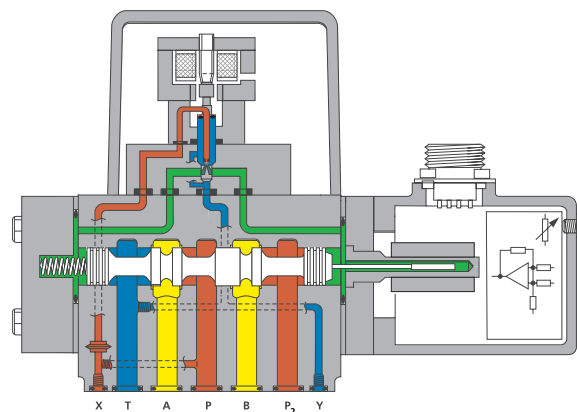
Features

- Bushing-spool (BSA) design
- Spool overlap $< \pm 1\%$
- Very high pressure gain
- Very high accuracy and dynamics
- Rated flow specified at 70 bar (1,000 psi) pressure drop

MOOG PROPORTIONAL VALVES

Features

- Spool-in-Body (SiB) design
- Spool overlap $\pm 3\%$ or more
- Lower accuracy and dynamics than servo valves
- Higher rated flows than servo valves
- Nominal flow specified at 10 bar (150 psi) pressure drop



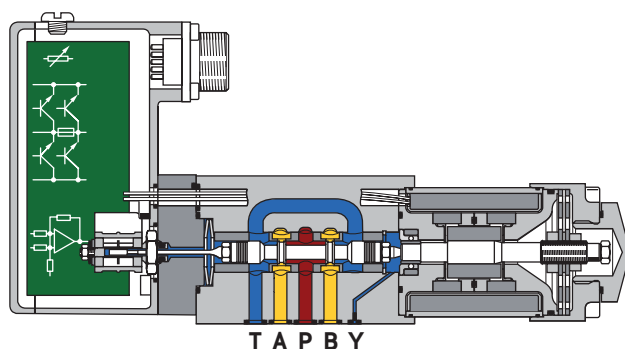
Spool sliding in valve housing

DIRECTLY AND PILOT OPERATED VALVES

Directly operated valves feature spools that are mechanically attached to, and directly moved by, an electro mechanical actuation device. In order to limit the size and cost of this type of actuator, the operating forces must be limited. Given that the forces required to move a spool increase as a result of flow and pressure drop, directly operated valves normally operate with smaller flows and, consequently, are limited to smaller valve sizes. Moog's Directly Operated Valves are largely powered by a Linear Force Motor and are known as Direct Drive Valves (DDV).

A pilot valve hydraulically operates the main spool of pilot operated valves, and this ultimately increases the spool actuation force. Pilot operated valves are able to achieve very high spool actuation forces through hydraulic amplification of the electrical command signal. In turn, valves can thus be built up to very large rated flows. Normally, pilot valves are smaller, directly operated and specifically designed for use as a pilot valve. Under normal operational conditions, Moog makes use of nozzle flapper, jetpipe or direct drive spool valves, although occasionally we also utilize two-stage pilot operated valves to increase performance.

MOOG DIRECT DRIVE (DDV) VALVES



Features

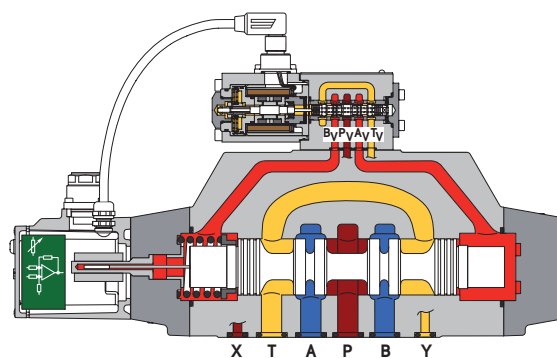
- Actuated by Linear Force Motor (LFM) with push-pull operation
- Low internal leakage losses
- Low energy consumption in center position
- Dynamics mostly independent from supply pressure
- Higher forces than proportional solenoids, thus higher pressure drops possible

MOOG PILOT OPERATED VALVES

Features

Pilot principles:

- Nozzle flapper
- ServoJet®
- Direct Drive Valve
- High flow rates
- Available as servo and proportional valves
- With mechanical or electrical feedback

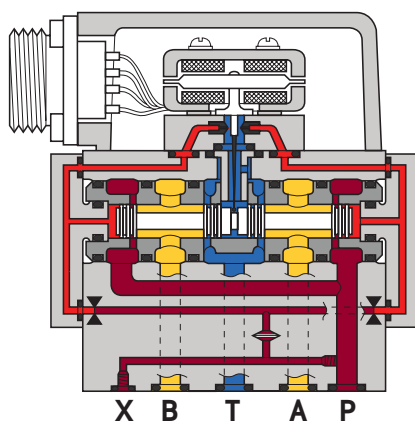


ELECTRICAL AND MECHANICAL FEEDBACK VALVES

Moog's Servo and Proportional Valves are each fitted with a closed loop spool position control, and consequently require a spool position feedback, of which Moog makes use of two different types: mechanical and electrical feedback. Mechanical feedback (MFB) valves feature a feedback spring tensed by the spool deflection, and this provides the torque motor with mechanical feedback. MFB valves do not require onboard electronics as part of their operational process.

Electronic feedback (EFB) valves, on the other hand, make use of an electronic position transducer in order to measure the spool position. The signal enabling this is fed back electrically, and therefore all EFB valves are operated via control electronics. Moog valves mostly have these electronics integrated into the actual design of the valve, and hence have no need of external controller cards.

MOOG MECHANICAL FEEDBACK (MFB) VALVES



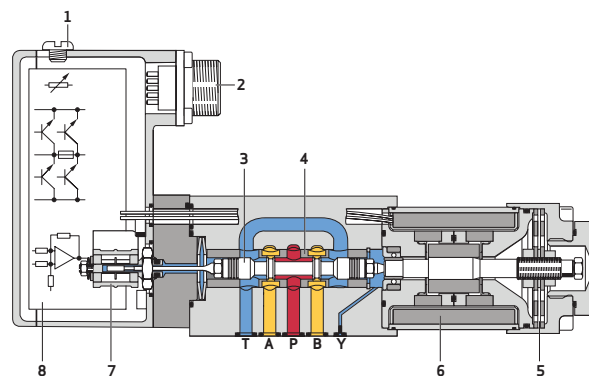
Features

- 'Classic' servo valve design
- Nozzle flapper pilot
- No onboard electronics
- Closed loop position control of the spool by mechanical feedback wire

MOOG ELECTRICAL FEEDBACK (EFB) VALVES

Features

- Directly or pilot operated
- ServoJet® or Linear Force Motor operated
- Onboard electronics for closed loop position control of the spool
- Analog or digital electronics available
- Optional fieldbus interfaces
- Flow, pressure or axis control options

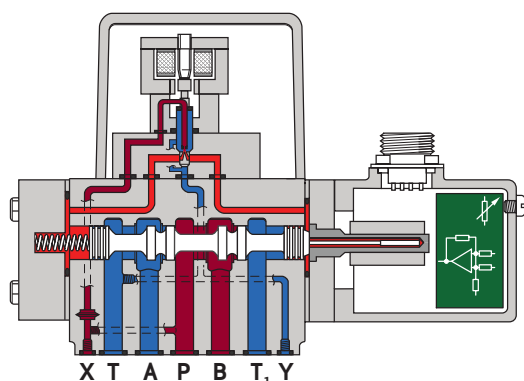


EFB VALVES WITH ANALOG OR DIGITAL ELECTRONICS

Moog's Electrical Feedback (EFB) Valves are equipped with different onboard electronics. The basic EFB Valve model is operated with an analog circuit board, and features the analog interfaces needed for a spool position control. Some versions of this valve come equipped with additional functionality, such as error and safety monitoring outputs.

Digital electronics operate via a microprocessor-based circuit board, which realizes most of its functions through software. This generates increased valve performance, and provides operators with the option of having fieldbus interfaces. In turn, these valves can also integrate additional control options such as pressure and axis control. These types of valve are, additionally, equipped with various monitoring and fault detection options, and are known as Moog Digital Control Valves (DCV).

MOOG ELECTRICAL FEEDBACK (EFB) VALVES WITH ANALOG ONBOARD ELECTRONICS



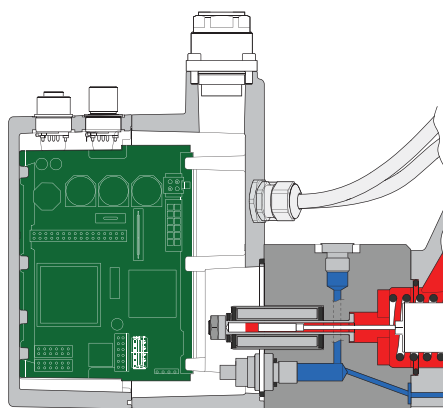
Features

- Analog controller circuits
- Spool position control
- Analog input for command signal
- Analog output for spool position feedback
- Optional digital inputs and outputs (enable, status, error monitoring)

MOOG DIGITAL CONTROL VALVES (DCV)

Features

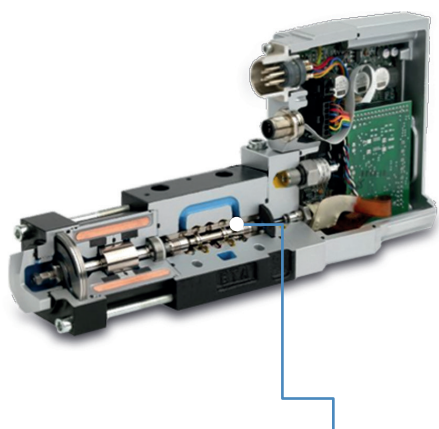
- Microprocessor based controller
- Spool position, pressure and axis control
- Optional fieldbus interface
- All valve parameters available via fieldbus
- Error monitoring, fault reactions
- Valve setup via laptop



PRESSURE AND FLOW CONTROL AND AXIS CONTROL VALVES

Moog Digital Control Valves (DCV) are also available with extended control functionality, and can offer pressure and flow control (p_Q) or axis control (ACV). p_Q valves are equipped with a spool position controller for flow control functions, and are also capable of controlling the pressure of one axis using a pressure transducer that is integrated into the valve. This means, for instance, that these valves can be used for an actuator positioning function with force limitation. Axis control valves are able to control one axis, and can perform position, speed or force control functions on, for instance, a cylinder.

MOOG PRESSURE AND FLOW CONTROL (p_Q) VALVES



Integrated pressure transducer in port A

Features

- Integrated pressure transducer in port A

Operating modes:

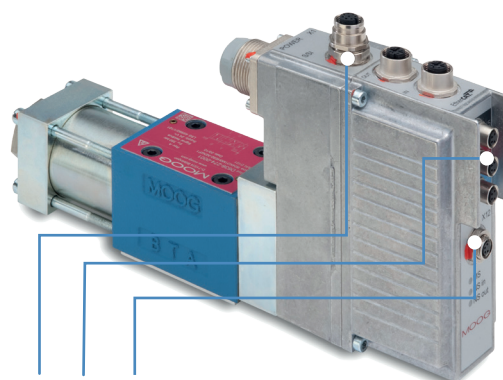
- Flow control
- Pressure control
- Flow and pressure control
- Differential pressure control via external pressure transducers

MOOG AXIS CONTROL VALVES (ACV)

Features

Interfaces for analog or digital transducers:

- Analog inputs
- SSI input
- Encoder input
- Strain gauge input
- Fieldbus transducers
- Position, speed or force control for one axis



Transducer inputs



OPERATING PRINCIPLES

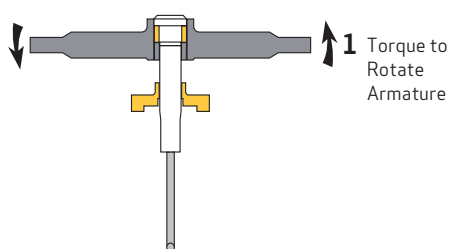
This chapter provides an overview of the various operating principles that apply to Moog valves. It sets out the different pilot and spool actuation principles, as well as the operating functions of some pilot and direct operated EFB and MFB valves.

TORQUE MOTORS

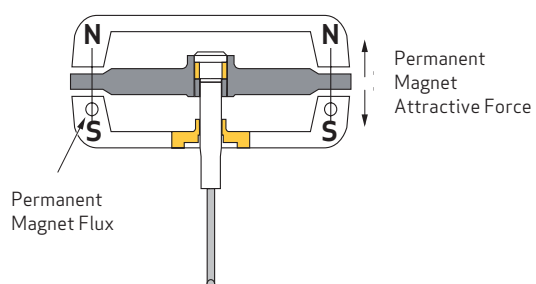
Torque motors are rotary actuators that combine permanent magnets and solenoids to create an actuation force. The design set out below is used in Moog's nozzle-flapper pilot stages. ServoJet® pilot stages also use a torque motor, but with a slightly different design.

A torque motor is composed of permanent magnets, an upper and lower pole piece, an armature and a coil. The torque motor's operating principle can be illustrated as follows:

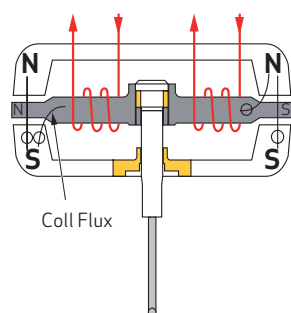
TORQUE MOTOR OPERATING PRINCIPLE



The basic principle is to create a torque that rotates the armature around its fixed point.



The charged permanent magnets polarize the pole pieces.



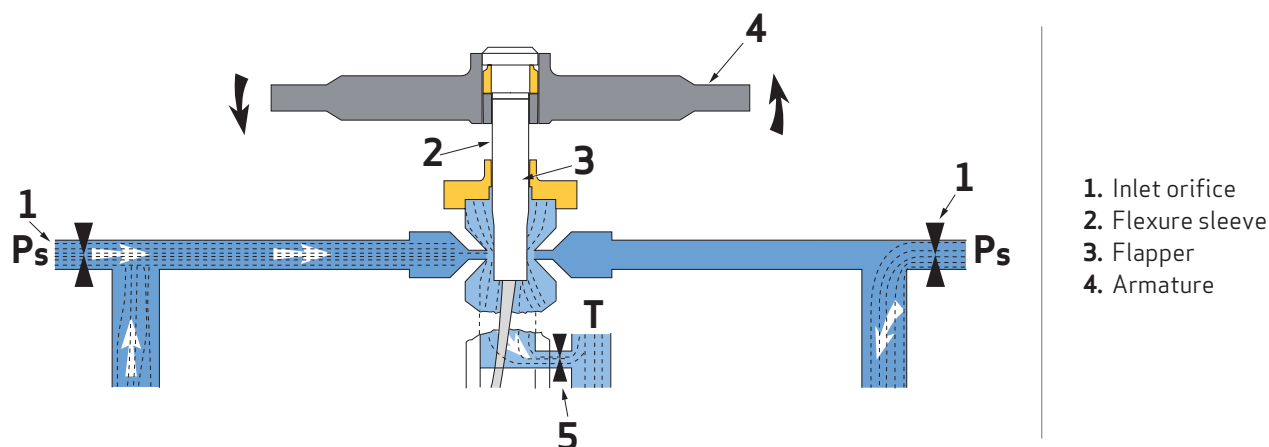
A DC current applied to the coils causes an increased force in diagonally opposite air gaps. The magnitude of the force is proportional to the current. The direction of the force depends on the direction of the current.

NOZZLE-FLAPPER HYDRAULIC AMPLIFIER

The torque motor's armature is tightly connected to a flapper, and this connection is supported by a thin wall flexure sleeve that acts as a centering spring for the torque motor. Furthermore, the flexure sleeve seals off the electromagnetic from the hydraulic sections of the valve.

The nozzle-flapper amplifier's functional principal is illustrated below:

NOZZLE-FLAPPER AMPLIFIER FUNCTIONAL PRINCIPLE

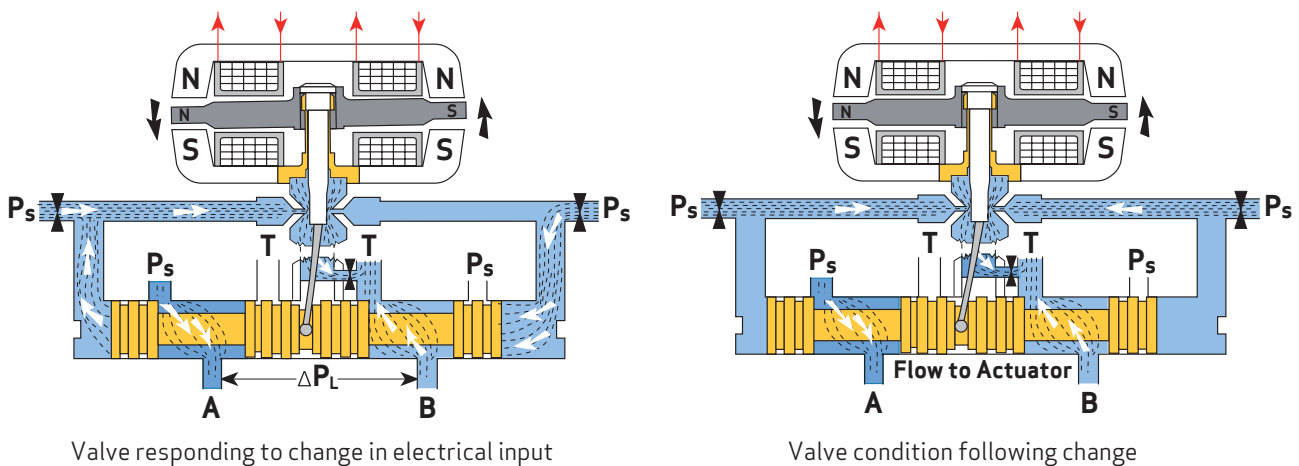


Fluid flows continually from the pressure side p_s , through both inlet orifices and past the twin nozzles into the nozzle flapper space. From this point, fluid passes through the drain orifice and into the tank. A rotary motion of the armature and flapper then throttles the fluid flow through one or other of the nozzles, creating a pressure differential between both sides and diverting the flow to one end of the spool.

NOZZLE-FLAPPER PILOTED VALVE WITH MECHANICAL FEEDBACK

The diagrams below illustrate the operating process of a nozzle-flapper amplifier within a two-stage valve with mechanical position feedback. This valve type contains a closed loop control circuit to manage the position of the spool, and is often termed a mechanical feedback valve (MFB), given that the spool position's feedback is conveyed by way of a mechanical feedback spring.

NOZZLE-FLAPPER AMPLIFIER OPERATING PROCESS



The feedback wire is connected to the flapper on one side, and has a carbide ball welded at the opposite end. The ball end of the feedback wire is fastened to a hole in the spool, so that the spool's movement deflects the feedback spring and thus creates a force on the armature/flapper assembly.

If the spool is moved by stimulating the flapper and creating a pressure differential, the feedback force transmitted by the spring will return the flapper to its center position, and the pressure differential will decrease. This will keep the spool in balance, and it will maintain its position until the command signal is changed.

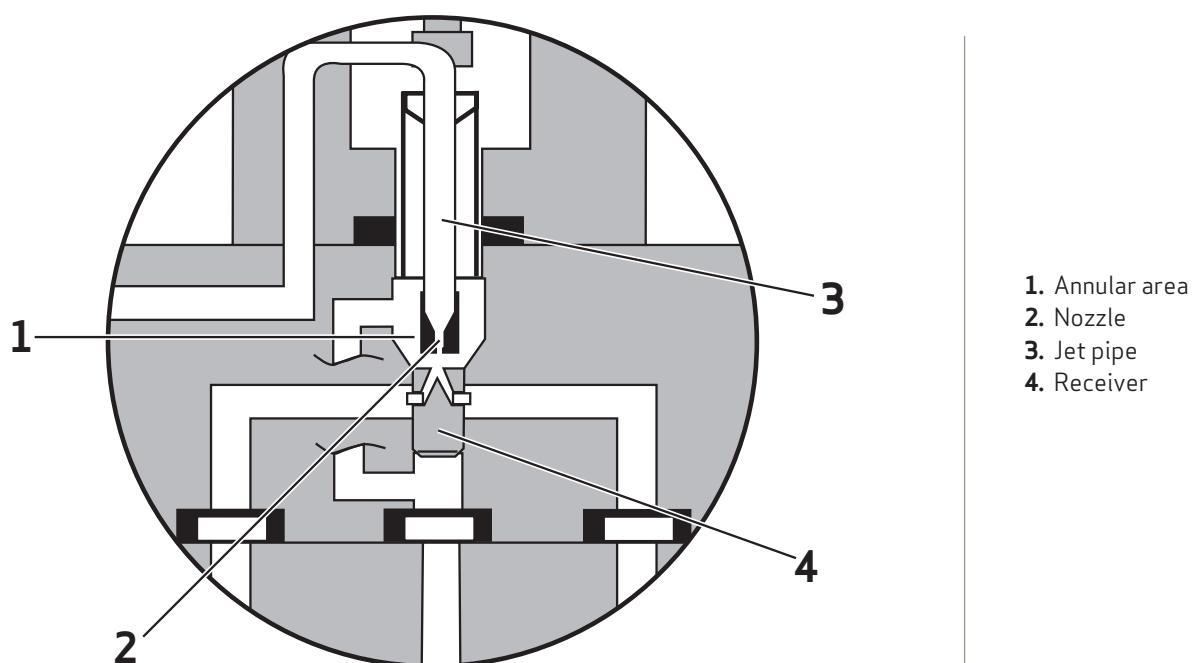
SERVOJET® OPERATED VALVES

ServoJet® piloted Moog valves are produced exclusively as electrical feedback valves (EFB valves), which means that the valve's internal spool position control loop is closed by an electronic controller and position transducer. Onboard, analog or microcontroller based electronics control the current to the torque motor coils.

SERVOJET® HYDRAULIC AMPLIFIER

The ServoJet® pilot stage consists mainly of a torque motor, a jet pipe and a receiver. The jetpipe is connected to the torque motor, and is deflected by its movements. The diagram below demonstrates the jetpipe and receiver parts of the ServoJet®.

SERVOJET® JET PIPE AND RECEIVER



An electrical current applied to the torque motor displaces the jet pipe from its neutral position, and this displacement, when combined with the specific shape of the nozzle, directs a focused fluid jet from both receiver openings toward one of them. This creates a pressure difference between the two lines connected to the receiver, and thus an actuating force on the spool.

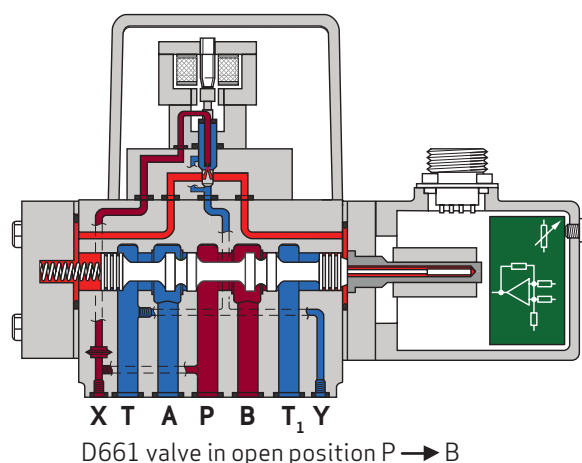
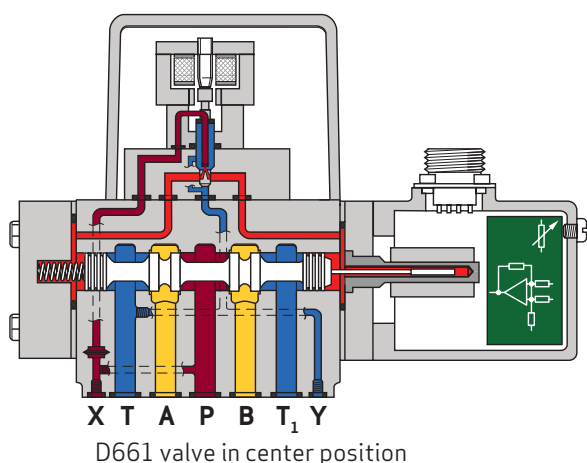
SERVOJET® PILOTED VALVE WITH ELECTRICAL FEEDBACK

The ServoJet's® two receiver lines are connected to the main spool's control areas. A pressure differential between both areas will create a force and deflect the spool.

If an electrical command signal is applied to the valve electronics, it will compare the actual spool position provided by the position transducer with the desired spool position. In case of any deviation, a current that is proportional to the deviation will be applied to the torque motor. This will cause a deflection of the jetpipe, and a movement of the spool.

When the spool has reached its designated position, the control deviation will be zero, the electronics will reduce the current to the torque motor and the jetpipe will return to its center position. By way of this continuously operating spool position control circuit, the spool position is kept proportional to the externally applied command signal.

SERVOJET® PILOTED VALVE WITH ELECTRICAL FEEDBACK



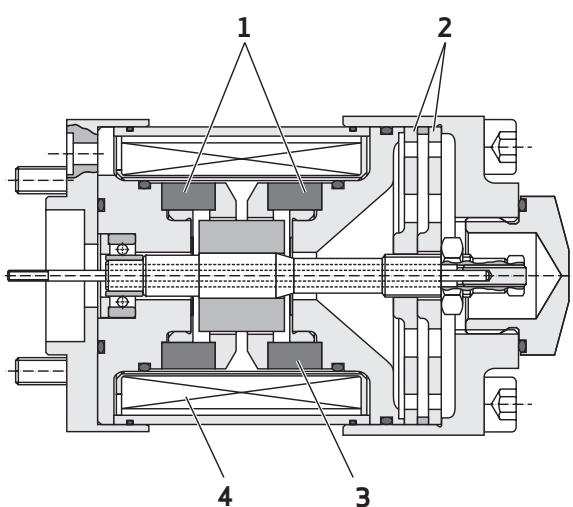
LINEAR FORCE MOTOR OPERATED VALVES

Direct Drive Valves (DDV) are powered by Moog's Linear Force Motor, a magnetized differential motor for which permanent magnets provide a part of the required magnetic force. The Motor operates from a neutral mid-position from where it generates force and stroke in both directions, a clear advantage over a proportional solenoid drive that operates only in one direction. The Linear Motor's force and stroke are proportional to the applied current.

FUNCTIONAL PRINCIPLE OF THE LINEAR FORCE MOTOR

The main operating parts of a Moog Linear Force Motor are two high energy, rare earth magnets, a coil, an armature and centering springs.

OPERATING PARTS OF THE LINEAR FORCE MOTOR



1. Permanent magnets
2. Centering springs
3. Armature
4. Coil

As long as there is no current applied to the coil, the permanent magnets and springs hold the armature at equilibrium. If a current is applied, the coil will create an electromagnetic field that disturbs the equilibrium and creates a force that moves the armature against the springs. A superimposition of electromagnetic and permanent magnetic forces creates a higher actuating force than that created by a pure electromagnet. In this instance a proportional solenoid, for instance, will suffice.

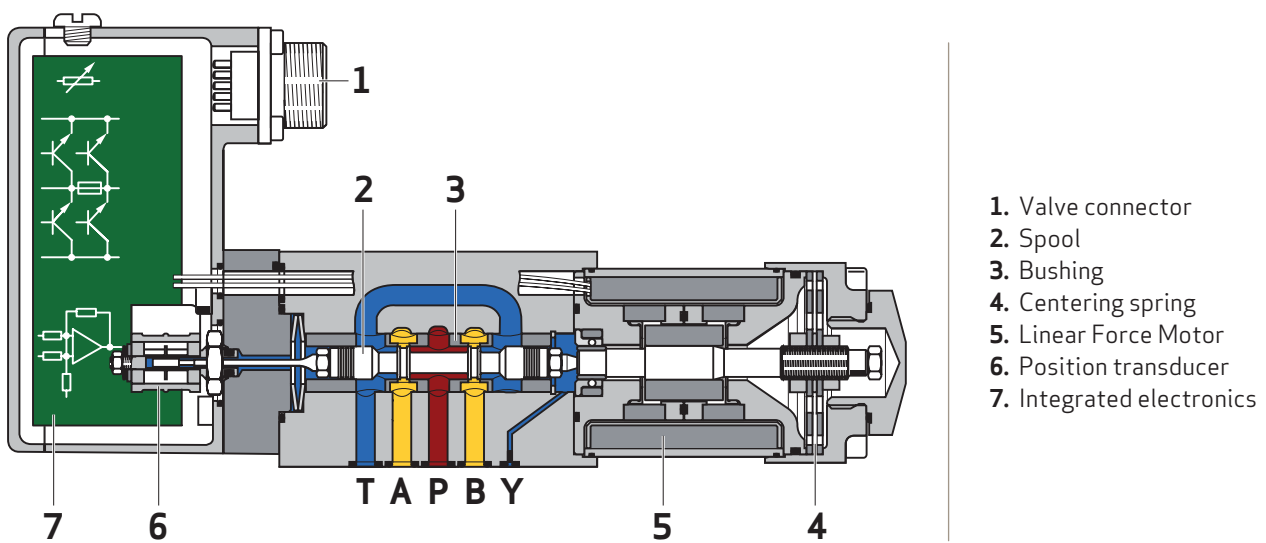
The direction of the actuating force depends on that of the electrical current applied to the coil. This current renders the Linear Force Motor a bidirectional actuator, as opposed to conventional solenoids that are unidirectional actuators. This means that a Linear Force Motor can move the spool in both directions (in a push-pull operation), which will support the spring return of the spool to its center position. It will equally provide an additional spool driving force for the return movement. This makes a Linear Force Motor driven valve less sensitive to contamination. Another advantage of the Linear Force Motor is that it operates with a very low current while in the spring-centered position. This reduces energy losses and the heat produced by the actuator.

Proportional solenoids, on the other hand, operate either on the basis of a pure spring return, or with two opposing solenoids connected to the same spool.

DIRECT DRIVE VALVE (DDV) WITH ELECTRICAL FEEDBACK

Generally speaking, Moog produces Direct Drive Valves as electrical feedback valves that incorporate integrated electronics and an electronic closed loop spool position control circuit.

MOOG DIRECT DRIVE VALVE



The spool of a Moog Direct Drive Valve is connected to the Linear Force Motor on one side, and to a position transducer on the other side. A command signal applied to the electronics will cause a control deviation, and this results in a pulse width modulated (PWM) current being applied to the Linear Force Motor's coil. This produces a deflection of the valve's spool. The position change reduces the control deviation measured by the position transducer, which results in a reduction in the PWM current, and the spool stopping at the desired position.

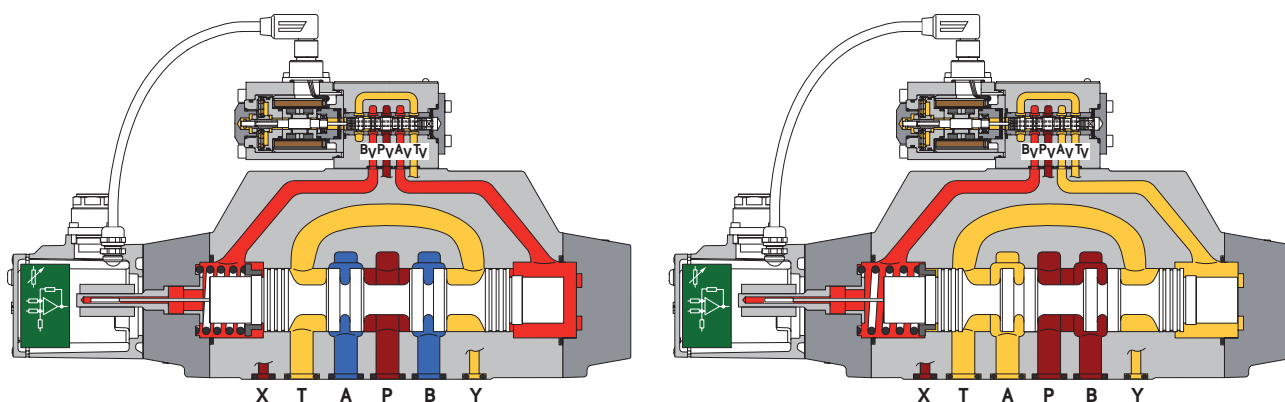
The resulting spool position is thereby proportional to the electrical command signal.

PILOT OPERATED VALVE WITH DDV PILOT

In addition to the nozzle-flapper and ServoJet® pilot stages, Moog also manufactures Direct Drive Valves as pilot stages for pilot operated valves. The main stages of these pilot operated valves are always designed as electrical feedback valves, with a position transducer and onboard electronics.

The DDV pilot is used either as an open loop pilot valve without electrical feedback, or as a closed loop controlled pilot valve with its own spool position control loop. The latter version of the valve contains two cascaded position control loops, one for the pilot valve and one for the main stage. The advantages of this are slightly increased dynamic performance, reduced series variation and the improved contamination resistance of the whole valve.

A D684 SERIES VALVE WITH OPEN LOOP CONTROLLED PILOT VALVE



D684 valve in center position

D684 valve in open position P→B

The electronics compare the command signal with the actual position signal. Depending on the control deviation, a PWM current is applied to the pilot valve. The pilot valve is deflected and creates a movement of the main stage spool. Once the control deviation is zero, the pilot valve is closed and the main stage spool is kept at the desired position.



VALVE SIZING AND SELECTION

Selecting the correct size and type of servo or proportional valve for an application, relies on recognizing the boundary conditions of the system in question. These boundary conditions include parameters like cylinder dimensions, strokes, loads and desired speeds that collectively determine the right size of the valve. Other system parameters, such as moving masses, natural frequencies and desired system dynamics will also be required in determining the appropriate valve type.

This chapter provides a simple example of how to calculate the rated flow needed to move an equal area cylinder at a desired speed. It also provides general guidelines on, for example, valve dynamics and overlaps. Finally, it offers assistance on selecting the right type of valve. Depending on application requirements, choosing the right valve and planning the optimal system layout can be a complex process. We recommend that you contact Moog for assistance with this process.

DETERMINING REQUIRED FLOW RATE

Valve rated flow requirement is determined through a calculation of required movement velocities, the cylinder's working area and the external loads.

Note: The following calculations apply only to equal area actuators with 4-port connected valves. In the case of unequal area or regen connected actuators, the different surface areas of the piston and rod sides should be taken into consideration.

Determining the required flow of the valve under load is calculated as follows:

THE REQUIRED FLOW OF THE VALVE UNDER FLOW

$$Q_L = 0.00006 * A_{Cyl} * v$$

With

Q_L = Volume flow under load (l/min)

A_{Cyl} = Area of the cylinder (in²)

v = Maximum movement velocity (in/s)

Or in imperial units

$$Q_L = A_{Cyl} * v$$

With

Q_L = Volume flow under load (in³/sec)

A_{Cyl} = Area of the cylinder (in²)

v = Maximum movement velocity (in/sec)

THE REQUIRED RATED FLOW OF THE VALVE

$$Q_{\text{Rated}} = 1.2 * Q_L * \sqrt{\frac{\Delta p_{\text{Rated}}}{P_S - P_L}}$$

With

Q_{Rated} = Rated flow (l/min or in³/sec)

Q_L = Volume flow under load (l/min or in³/sec)

p_S = System pressure (bar or psi)

p_L = Load pressure (bar or psi)

Δp_{Rated} = Rated pressure drop of the valve :
10 bar (150 psi) for proportional valves
70 bar (1000 psi) for servo valves

Notes:

The equation above establishes that the 1.2 factor results from the fact that rated valve flow must be selected, in order for the valve to reach the required load flow when 70 – 80% open. Subsequently, this ensures that the valve offers sufficient reserve allowing the control system to compensate for external disturbances, such as short-term peak loads.

If operating a servo or proportional valve in a closed loop, then the ideal pressure drop over the valve is 1/3 of the system pressure. This means that the load pressure should be approximately 2/3 of the system pressure. Greater pressure drops over the valve generate unnecessary energy losses, while smaller pressure drops degrade control behavior and result in valve dimensioning being larger than otherwise necessary.

VALVE DYNAMICS

STEP RESPONSE TIMES OF A PILOT OPERATED PROPORTIONAL VALVE

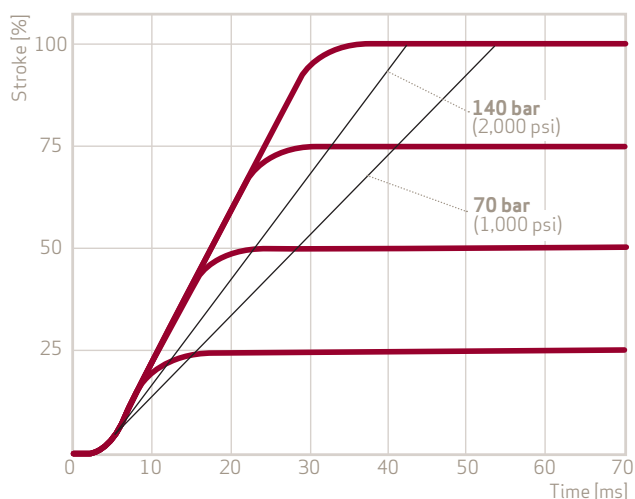


Fig. 1. Operating times of a pilot-operated proportional valve

FREQUENCY RESPONSE OF A PILOT OPERATED PROPORTIONAL VALVE

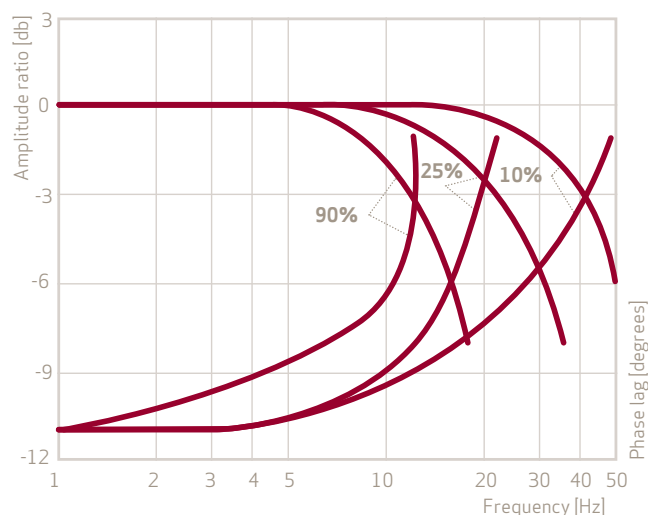


Fig. 2. Bode diagram of a pilot-operated proportional valve

Principally, a valve's dynamic behavior can be defined by its actuating time, and by frequency response behavior. Actuating time is the time required by the valve to arrive at a required set point value and, subsequently, volume flow from the middle position. In other words, actuating time determines the acceleration and deceleration behavior of an actuator. Moog valve catalogs generally define this as 'step responses' (Fig. 1), and these indicate a valve's reaction to various degrees of set point jumps.

Equally relevant in terms of the control related design of any system is frequency response behavior. In valve terms, frequency response is usually conveyed by way of a Bode diagram which illustrates the amplitude curve in dB, along with the phase curve (in °) of a valve when stimulated by sinusoidal signals of varying frequency. Valve catalogs normally illustrate frequency response curves for small, medium and large stimulation amplitudes. This is exemplified in the above diagram (Fig. 2), where they are represented as 10%, 25% and 90% values.

Frequencies -3dB and -90° and damping usually constitute the characteristic values of a valve's dynamics. The -3dB frequency marks the point at which the amplitude curve of the valve has reached -3dB, and therefore the stage at which this amplitude reaches approximately 70% of the set point. -90° is the cut off frequency of the valve, in other words the frequency at which the valve responds to sinusoidal stimulation with a phase shift of -90°. Valve damping is calculated from the fall in amplitude at the -90° point. Detailed control loop designs primarily require the damping and the natural resonant frequency. The latter is also calculated from the frequency response data.

The dynamic performance of a system not only depends on the valve dynamics, but also on other factors like the intended type of control (position, velocity or pressure / force control), the load behavior, natural frequencies, piping etc. If, for example, the natural frequency of the load is too slow, then the whole control strategy has to be adapted to achieve optimum performance.

SUPPLY AND PILOT PRESSURE

When referring to catalog values, please note that dynamic properties are normally measured at a system or pilot pressure of 3000 psi. Where pilot-controlled valves are concerned, the dynamics decrease simultaneously with pilot pressure. The dynamics of directly actuated valves are, on the other hand, mostly independent of system pressure. They are impacted by the pressure drop across the valve, and with a rising drop in pressure. Valve dynamics are reduced by higher flow forces. Nevertheless, this impact is significantly lower than that of the pilot pressure on pilot-controlled valves. For further information about supply and pilot pressure, please see the relevant section on electro-hydraulic systems design.

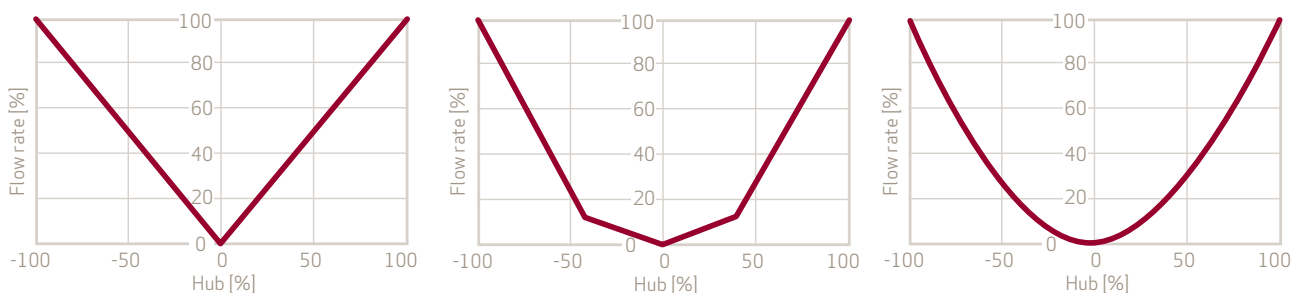
FLOW CHARACTERISTIC AND OVERLAP

Moog offer servo and proportional valves with different flow characteristics and overlaps, and the various options available are listed in the individual valve catalogs. Additional options are available on request.

FLOW CHARACTERISTIC

The most common valve flow characteristics are set out in the diagram below, which demonstrates linear, dual gain and progressive flow-signal curves moving from left to right. Other options are, for example, curves that adapt flow rates to the surface area ratio of a differential cylinder. These include A:B = 2:1, along with other specific characteristics for certain types of application.

DIFFERENT FLOW SIGNAL CURVES OF SERVO AND PROPORTIONAL VALVES

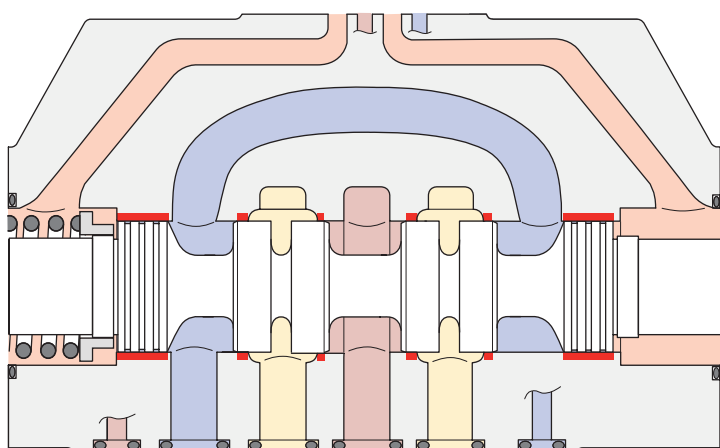


Generally, valves with a linear flow characteristic curve are simpler to integrate into a control loop, given that it is possible to work with a linear controller. However, in cases where a valve is likely to perform a variety of functions, such as for velocity and force control, there is likely to be a conflict of objectives. In short, a high volume flow is needed for velocity control (a large valve), while force control requires a smaller flow gain, or a small valve. To cover both applications with just one valve, a large valve with a progressive or dual volume flow characteristic curve can be used by way of a compromise. When controlling higher velocities, the valve opens further and achieves sufficiently high speeds thanks to the larger flow gain with large openings. Conversely, in terms of controlling force, the range around zero with low flow gain is used, so that the resolution and fine controllability of a smaller valve can be achieved.

OVERLAP

The seal between individual ports in the valve's mid position is achieved via annular gaps between the spool and valve body or control bushing. The height of this gap is dependent on the clearance between the spool and the valve body, whereas the length of the gap is determined by the so-called overlap of the spool. A small quantity of oil – known as internal leakage – permanently flows through this gap, depending on the applied pressures.

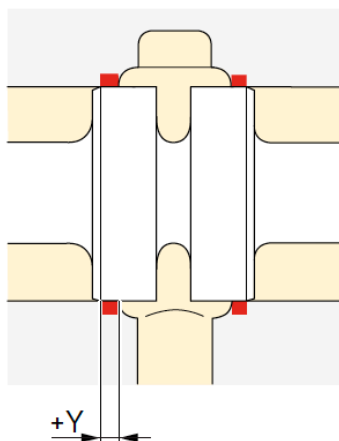
THE SEALING OF PORTS VIA THE SEALING GAP BETWEEN SPOOL AND RUNNING SURFACE



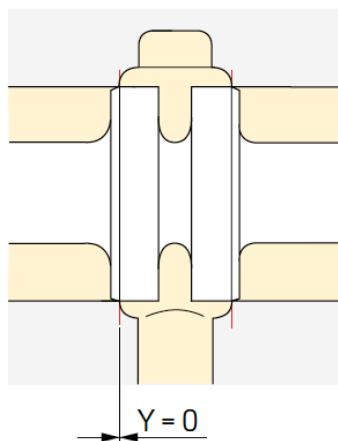
The position that the spool must reach in order to enable a control edge to open for flow through is known as the valve overlap. This overlap is normally registered as a percentage of the nominal stroke. There are three types of overlap: positive overlap, null cut (= zero overlap) and underlap (= negative overlap).

As far as positive overlap is concerned, the spool surface area that closes the annular groove within the valve body is wider than the groove itself. Therefore, the spool must travel a certain distance before the control edge opens. In case of a null cut, the surface area of the spool is the same width as the annular groove within the valve body or control bushing. With underlap, the surface area of the spool is smaller than the annular groove, and this is why the ports are never fully closed.

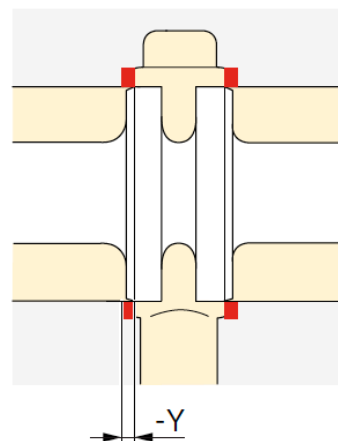
POSITIVE OVERLAP



NULL CUT



UNDERLAP



Overall, the following applies: the larger the overlap the lower the leak volume flow, or the lower the energy losses of the valve while in the middle position. This signifies that maximum overlap is preferable in energy efficiency terms, although smaller overlaps are often used for functional reasons.

ADDITIONAL INFORMATION ON OVERLAP USE

Larger positive overlaps of between 10 and 20% are chiefly used to enable the safe shut down of actuators with low leakage levels, in other words a low creep rate. However, in such cases the spool has to move through the overlap before the actuator starts moving, which is detrimental in terms of dynamics and positioning accuracy.

Smaller positive overlaps of between 3 and 5% can harm performance; they may, to cite one instance, affect positioning accuracy, but are more energy efficient than null cuts or underlaps. That is why they are widely used on many applications. Null cuts are ideal for positioning tasks, given that the high-pressure gain allows for dynamic and exact positioning.

Smaller underlaps of -3% to 0% are well suited for pressure or force regulation applications, although they are unfavorable in terms of energy efficiency. For that reason, spools with a slightly positive overlap are also used for such applications.

Moog recommends larger negative overlaps of between -5% and -15% for the relief of actuators. Usually, only control edges connected to the tank port (A-T and B-T) are underlapped while the pressure connections (P-A and P-B) have a positive overlap.

SELECTING A VALVE TYPE

Moog offers various types of servo and proportional valve, and in this section we provide some advice on matching valve types with specific applications.

DIRECT ACTUATION OR PILOT OPERATED

Directly operated valves are more energy efficient and affordable than their pilot-controlled counterparts, as they do not require pilot oil and have a simpler design. As the actuation forces are not dependent on pilot pressure, these valves are well suited to systems that have fluctuating operating pressures. On the other hand, compared to pilot operated valves, this valve type lowers the actuating forces for the control spool owing to the fact that the control spool itself is directly actuated by way of a Linear Force Motor. It is for this reason that directly actuated valves are only available for limited flow rates up to nominal size 10 (ISO 4401 size 05).

Pilot operated valves should be used when very high flow rates and pressure drops are anticipated, and particularly so during single edge operation, or under conditions in which the dynamics of directly actuated valves are insufficient. From size 16 (ISO 4401 size 07) upwards, Moog offers only pilot-controlled valves.

SERVO OR PROPORTIONAL VALVE

Any decision on whether to use a servo or proportional valve for any specific application is primarily contingent on the application's specific requirements.

Servo valves have a very tight tolerance for overlap and low clearance levels between the control spool and bushing, which ensures very low standard dispersion and good reproducibility. They have a high-pressure gain, making them suitable for dynamic and precise positioning. The hardened control bushing ensures low wear, thus ensuring the long service life of the valve.

Proportional valves are not as suitable as servo valves when considering the issues mentioned above. When of the same nominal size, however, they provide a higher nominal flow rate than servo valves, and are more affordable on the basis that they have no hardened control bushing.

EFB OR MFB VALVES

MFB valves normally featuring nozzle-flapper pilot control, and are robust and simple servo valves with no integrated electronics. This feature renders them suitable for challenging conditions that include high temperature environments and strong vibratory forces. At the same time, they also demand less installation space. Nevertheless, due to their mechanical positioning feedback, they have a higher hysteresis and threshold than EFB valves.

Ongoing product development has eliminated the, formerly typical, wear and tear affecting the ball between feedback wire and the control spool of MFB valves. Moog now makes use of carbide balls that are placed in a hole within the piston instead of a slot.

Due to mechanical positioning feedback, MFB valves remain in a constantly closed loop controlled condition, even in the event of an electricity supply failure. Hence, they default to the center position or to a biased position.

EFB valves are equipped with electronic positioning feedback and integrated electronics for position control. Moog's robust electronic systems, some of which are uncoupled from the valve by elastomeric mounting, are highly resilient against vibration. Having said this, the permitted environmental and fluid temperatures are lower than those of MFB valves.

EFB valves do, however, have significantly lower hysteresis and threshold than MFB valves, and can also be monitored continuously by way of feedback of the control spool position. Digital electronics also facilitate numerous additional functions, such as fieldbus integration, pressure and axis control along with detailed error monitoring.

WHICH PILOT PRINCIPLE

Moog offers three different pilot principles for pilot-controlled valves, namely Nozzle-flapper amplifiers, ServoJet® jet pipe amplifiers and DDV pilot valves actuated by a linear motor.

Nozzle-flapper amplifiers offer a high degree of dynamics as well as stable operation. By design, however, they require a constant flow of pilot oil, which is also consumed when the pilot valve is in center position. Due to the small nozzle diameters, it is necessary to ensure high levels of oil cleanliness during operation; otherwise, the integrated control oil filter (60µm) may be contaminated, leading to a drop in control pressure. The electric power required for activation is very low, and for this reason many MFB valves that feature a nozzle flapper amplifier are also offered in an intrinsically safe version for hazardous environments.

ServoJet® jet pipe amplifiers are very robust and offer a high degree of dynamics, although they also require a constant flow of oil, which results in greater consumption levels. The ServoJet's® large nozzle diameter, which is larger than those of the nozzle-flapper amplifier, means that it is largely unsusceptible to fluid contamination. In short, it will operate reliably even when the oil is highly contaminated. Any contamination is limited by the integrated control filter, which has a filtering level of 200 µm. In cases of serious contamination, this may clog.

Linear motor-actuated pilot valves offer a high degree of dynamics and high nominal volume flow even at the first pilot stage. This results in short regulating times at the main stage, even for large control volumes. They exhibit significantly lower internal leakage than nozzle-flapper and jet pipe amplifiers, which results in lower control oil consumption while in standby mode. The low clearance between control bushing and spool, however, make this type of valve more prone to fine contamination than nozzle flapper and jet pipe amplifiers. Owing to their exceptionally high-pressure gain, DDV pilot valves are well suited for applications with low and/or variable pilot pressures.



GENERAL ELECTRO- HYDRAULIC SYSTEM LAYOUT

A short overview of important guidelines for systems planning.

When assembling an electro-hydraulic system a number of system components and characteristics must be taken into consideration. In the following section, we provide an overview of the key guidelines to be considered when developing a system.

GENERAL ELECTRO-HYDRAULIC SYSTEM LAYOUT

It is particularly important that a constant pressure system be used for highly dynamic applications. Please make use of accumulators to compensate for the pressure ripples of pumps, and the flow fluctuations of variable displacement pumps.

POWER UNITS

When using pilot operated valves with high dynamic systems, supply the pilot valve externally. It is always helpful to use an additional accumulator for the p_x -line to compensate for pilot flow surges caused by rapid valve movements. Please refer to the peak pilot flows of the individual valves given in the Moog valve catalogs.

Wherever possible, preload the return line to a pressure of between 2 and 5 bar (30 and 70 psi) in order to avoid empty pipes and to prevent cavitation.

If feeding more than one critical system from one pump, isolate each system by using check valves and accumulators, as doing so avoids cross-communication.

In cases where high, long-term control accuracy is of critical importance to the system, the fluid temperature should be controlled.

Adjust pressure relief valves accordingly so that they do not open during normal operation, because any fluid flowing over a relief valve constitutes wasted energy.

SUPPLY AND PILOT PRESSURES

Valves with nozzle-flapper or ServoJet® pilot valves are designed for operation with constant supply or pilot pressure, and require a constant pilot oil flow. Moog's valve catalogs set out the required flow, and this must be considered when dimensioning the flow rate of the supply unit.

The operating performance of direct operated valves is more or less independent of the supply pressure. Thus, these valves are suitable for use in systems with varying supply pressures.

Pilot operated valves with DDV pilots are also suitable for use in systems with varying or low pilot pressures. However, it should be noted that the dynamic behavior of these valves is influenced by pilot pressure. Furthermore, when these valves are operated dynamically, strong surges of the pilot oil demand may occur. This should be taken into account when dimensioning the pilot supply's flow requirements.

The minimum required supply pressure depends on the valve series: while direct operated valves will work with 0 psi, pilot operated valves need minimum supply or pilot pressure to work. Please refer to the individual catalogs for this value. The maximum supply or pilot pressure also depends on the valve series and the pilot valve, and this is usually between the range of 210 and 350 bar (3000 and 5000 psi).

For valves with separate pilot supply p_x (which can be chosen as an option from the catalog), the ratio between the pilot and the supply pressure must be considered to ensure a reliable valve operation. If the pilot pressure is too low when compared to the supply pressure, then the spool may not be operated reliably when working with high flow rates or pressure drops.

HYDRAULIC FLUIDS

Fluid requirements can vary between different valve series, as set out in the following general guidelines:

Fluid types: Most Moog valves work best with fluids recommended by the DIN 51524 parts 1 to 3 and ISO 11158 standards. If using a fluid that is not listed, please contact Moog to avoid incompatibilities between the fluid and the materials (especially seal materials) used in the valve.

Fluid viscosity: The individual valve catalogs provide a recommended fluid viscosity range within which the valve will function according to specification. For viscosities outside this range and within the maximum permissible range, impacts on valve performance may occur.

Fluid cleanliness: Moog valve catalogs usually recommend two different fluid cleanliness classes – one for functional safety to ensure reliable valve operation, and one for longer service life. We recommend the latter to ensure that valves remain in operation as long as possible.

FILTRATION

Moog's approach to filtration can be summarized as follows:

Always use a 10 to 15 micron absolute, non-bypass high-pressure filter that precedes the servo or proportional valve, and use filters in the flow direction before an accumulator. Filters should never be subjected to reverse flow. To ensure this, place a check valve between the filter and accumulator. For pilot operated valves with an external pilot supply (port X), a separate high-pressure filter for the pilot supply should be used.

If required, use a 3 micron low-pressure filter in the return line.

Employ a 3 to 5 micron low-pressure filter in an off line filtration loop. Using a separate filtration (and cooling) loop ensures constant oil quality, and the reservoir volume should be circulated about five times per hour through this loop. This type of system layout is capable of achieving the following:

The high-pressure filter in the supply line protects the system's components. Since the main cleaning effect takes place in the off-line filter, the high-pressure filter can be equipped with a larger mesh size.

A return filter will clean any oil returning to the reservoir, thereby ensuring that any contamination from the system does not reach the tank.

The off-line filter constantly filters the entire oil volume, thus ensuring a permanent supply of high quality oil. Since this separate circuit is not subject to flow or pressure surges, inexpensive low pressure filter elements can be used.

Further recommendations:

The oil reservoir should be equipped with a breather filter, which is especially necessary if the fluid level in the tank fluctuates during operation. This filter prevents contamination particles from the surrounding air from being drawn into the tank and contaminating the fluid.

Always use filters with contamination indicators or pressure switches to ensure the exchange of the filter elements before the filter becomes clogged.

Use inexpensive low-pressure filter elements to flush the system during commissioning, always bearing in mind that new oil is 'dirty oil', because it will be contaminated as a consequence of the transportation and packaging processes.

Moog recommends the following process for system flushing:

Flush the system thoroughly according to the machine manufacturer's instructions.

To achieve the best possible results, make sure the fluid is either at or higher than operating temperature.

The flow rates during flushing should be at least as high they would be during operation. If possible, flushing at higher flow rates will improve results.

Monitor the oil cleanliness during flushing- e.g. with an on-line particle counter - and do not complete the flushing procedure until the recommended oil cleanliness levels (see above) are achieved.

The minimum flushing time can be calculated as follows:

$t [h] = 5 \cdot V / Q$	Where
	t [hours] = Flushing time
	V [liters/gallons] = Tank capacity
	Q [l/min/gpm] = Pump flow during flushing

SERVO AND PROPORTIONAL VALVE PLACEMENT

Mount this valve type as closely as possible to the actuator in order to reduce any trapped oil volumes. Oil is compressible, and pipes act as low-pass filters or low damped oscillators which can limit dynamic system behavior. Ideally, servo and proportional valves are mounted directly onto the cylinder.

As a rule, flexible lines connecting the valve and actuator should be avoided because they significantly reduce the system's robustness.

When using long flexible supply or return lines it is helpful to install accumulators in the P and T lines close to the valve, to compensate for the low-pass effect of the pipes or hoses.

Moog servo and proportional valves can be installed in any orientation. If using direct operated valves driven by a Linear Force Motor, or pilot operated valves with Linear Force Motor pilots, please avoid placing the valve at the highest point in the hydraulic system. If this cannot be avoided, the return line connected to the Linear Force Motor (T or Y port depending on the configuration) should be pre-loaded to between 2 and 5 bar (30 and 70 psi) by using a check valve. This should prevent the Linear Force Motor from draining.

FEEDBACK TRANSDUCERS

Feedback transducers close the loop and hence their characteristics are fundamentally important, and particularly:

- The linearity and the range in which they are linear
- The resolution and hysteresis
- Drift with temperature or time
- Frequency response - which must be 3 to 10 times faster than the slowest element in the system
- If using valves with digital electronics and fieldbus interface, then various digital or analog sensors can be directly connected to the valve, and sensor signals distributed by the valve via the fieldbus
- Placing the transducer on the actuator output may help eliminate most control problems, largely by excluding spring-mass systems and play. However, this may not provide accuracy at the required point

PLC/AXIS CONTROLLER

Control electronics dynamics are often better than those of servo valves and other hydraulic and mechanical components, and therefore they can frequently be neglected.

On the other hand, some digital systems lack the required level of dynamics, and if this proves to be a problem please check the following:

- i. That the update rate of the PLC is approximately 10 times faster than the -90° frequency of the valve.
- ii. That the update rate of the digital to analog converter sending the command signal to the valve is faster than the valve. Normally, the converter should be a minimum of 20 times faster, and preferably 100 times quicker than the -90° frequency of the valve.
- iii. Utilize a 12-bit or higher digital to analog converter, as anything lower could compromise the valve's resolution.
- iv. Most of today's advanced control units offer the opportunity to implement complex controller structures. Please note that 90% of all position loops can be handled by a straight 'P' controller, whose set up and operational troubleshooting simplicity is invaluable.

Avoid positioning the axis controller close to electric motor controllers or any other components generating high electromagnetic fields, and consider shielding if it becomes necessary.

Any interconnectivity to the valve and the feedback transducer should involve shielded twisted pair cables in order to minimize interference. To prevent ground loops be sure to ground only the chassis end, and see Moog note TN353 for further information on grounding and shielding EFB valves.



ROUTINE MAINTENANCE

Recommended guidelines for effective maintenance and repair of various Moog valve types.

ROUTINE MAINTENANCE

OPENING THE SYSTEM

Generally speaking, hydraulic components and circuits should never be disturbed or opened during normal operation.

This particularly applies to servo or proportional valves, which should not be removed unless trouble-shooting demonstrates that they are malfunctioning.

If the system does require opening – to replace pipework, hoses, valves or actuators for instance – then all subplate mounted valves should be removed and replaced with a flushing plate. The new system start up procedure should then be followed.

VALVE REMOVAL AND REPLACEMENT

If a valve requires removal, the area surrounding the subplate should be thoroughly cleansed using lint free materials before lifting the valve from the surface.

In cases where the valve function is critical, a spare servo or proportional valve should always be held in stock. The spare valve should replace the removed valve, and the shipping plate of the spare should be mounted to the original valve and returned to Moog for servicing. If the highest levels of cleanliness are not observed, newly installed valves may develop faults shortly after fitting.

For further advice on valve storage, please see technical note TN516 *Storage recommendations for valves, spare parts and accessories*.

If no spare valve is available, the valve mounting surface should be covered with clean plastic sheet in order to limit the possibility of contamination, and the removed valve should be returned to Moog for servicing.

VALVE NULL ADJUSTMENT

Most Moog valves are fitted with null adjust pins or potentiometers, or a mechanical null adjuster. With the exception of valves with digital onboard electronics, no other adjustments are possible in an operational environment.

Null adjustments are set during valve production, and for many installations do not need to be changed in the field.

In circumstances where valves indicate an excessive null drift this may suggest contamination.

For MFB valves, it is recommended that the valve connector is disconnected when carrying out this adjustment.

With critical axis cut spools, the null may drift marginally as a result of temperature change and valve age. A one to two per cent drift is permissible, and may be corrected by the closed loop controller.

Instructions regarding valve null adjustment may be found in the individual valve data sheets.

FIELD REPAIR WARNING

Torque motors and Linear Force Motors are factory set precision devices that use matched components, individually adjusted for high performance spool actuation. No attempt should be made to remove, dismantle or exchange them, as this will result in permanent and costly damage.

Field adjustment is not possible and may compromise the valve fail-safe operation, resulting in dangerous axis movements in instances of failure.

Similarly, never attempt to remove the main stage spool.

In all cases, return the valve to Moog for servicing.

MOOG REPAIR POLICY

Moog will not carry out partial valve repairs, and our policy is always to restore the original specification. This includes valves with digital electronics where the user parameters will be reset to factory settings. In this case, Moog recommends that the parameters be saved in a log file, together with the Moog Valve and Pump Configuration Software. For further information, please contact Moog or refer to the relevant user manuals.

OIL CLEANLINESS CONSIDERATIONS

The servo valve is a precision instrument requiring the highest standards of fluid cleanliness. There are two filtration considerations where servo or proportional valves are concerned:

Particle Contamination – Hydraulically piloted servo or proportional valves have a built in, so called ‘last chance’ pilot screen filter, designed to catch dangerously large particles which could cause failure – for example particles that are 40 microns or over in size. Smaller particles are allowed through the screen to prevent clogging, but these also need to be reduced in number via efficient system filtering. The pilot screen is not designed for this task, and the need for efficient system filtering of even the smallest particles cannot be over emphasized. Please see the chapter on general electro-hydraulic system layouts for further details on filtration.

Silt Contamination – Under certain extreme and rare circumstances, where high levels of silt contamination exist, this can lead to seizure of the main spool in the bushing. However, small micron or even sub-micron level particles can cause an increase in valve threshold and spool metering edge wear. This, therefore, should be considered in the system filtration design.

Please note, DDV pilot valves can be more sensitive to silting than 2 stage pilot valves, given that the actuating forces are lower.

CONTAMINATION CONTROL

Contamination enters the fluid at various points:

New oil supplied by refineries contains noticeable residue at the bottom of empty barrels, and particles of 100 microns plus are not uncommon.

Contamination can be transmitted via dirty funnels or by other unhygienic filling methods. To avoid this, Moog recommends a transfer pump upstream of the 3 micron low pressure filter. If in doubt, simply remove the valve, fit a flushing block and flush the system out before refitting the valve.

Many factories have dusty air in the proximity of hydraulic power units, and occasionally this dust is corrosive. For systems that have large airflows in and out of the reservoir, Moog recommends the use of a 3 micron breather filter.

Airborne contaminants also gather on the rod end of hydraulic cylinders, and are drawn into the cylinder to varying degrees, dependent on rod wiper efficiency. These are mostly collected in the 3 micron low-pressure filter.

Contaminants derived from rubber hose, pumps, Teflon tape and the metal silt particles from wearing valves all contribute to fluid contamination.

Moog recommends regular analysis of oil on a quarterly basis:

Besides making use of the laser particle count test, also include a water content analysis if continuous water monitoring equipment is not installed in the system.

Oil should be checked at least once a year using the patch count method, as this is more precise.

Monitor the system using predictive maintenance, for instance by using on-line particle counters.

FLUID CHANGE SCHEDULING

The frequency with which fluid is changed is dependent on whether the filtration quality is high, the oil temperature is maintained at reasonable levels, moisture condensation is low and the oil itself is not degrading.

Frequent monitoring of oil color through a sight glass should give a rough indication of the fluid quality.

If the fluid stays clear and normal machine operating conditions prevail, there should be no need to change the fluid, as there is no fixed rule governing fluid change. Hydraulic system fluids are not like engine oils as they are not subject to continuous chemical contamination.

If a fluid change is scheduled at a point when filters provide no indication of contamination, then the existing filters should remain in place for one or two days before they are replaced with new ones.

In cases where the hydraulic power unit is dedicated to the valve alone, it could be a number of years before an oil change is rendered necessary. If valves are supplied from a larger power unit which also services other functions, then a more regular change may be required.

TROUBLESHOOTING EQUIPMENT

Troubleshooting a closed loop system in order to identify and isolate faulty components is a difficult process, and the simplest way to test a valve is to make use of a Moog Valve Tester.

Attention: If manually applying command signals to the valve during troubleshooting, make sure that no unwanted actuator movements can occur in order to avoid harm to people and machinery.

Moog produce a range of valve testers for both mechanical and electrical feedback valves. More details on this can be found at: www.moog.com

Moog testers permit the valve to be driven by way of a manually adjustable command signal from an independent source. Testing allows the Servoactuator to be positioned or moved around its stroke length, while also permitting the observation of proportionality between command and speed. In addition, the position feedback signal of EFB valves is displayed by the valve tester.

Valves with digital electronics can be adjusted and monitored using Moog Valve and Pump Configuration Software. This software is freely downloadable on our website: www.moogsoftwaredownload.com

If making use of this software a TD3999-137 commissioning cable, a C43094-001 USB to CAN-adaptor and an M12x1 to M8x1 CA 40934-001 adaptor will be required.

For further details contact Moog directly, refer to the relevant manuals or follow the link above.

ABOUT MOOG

Moog Inc. is a worldwide designer, manufacturer and integrator of precision control components and systems. Moog's Industrial Group designs and manufactures high performance motion control solutions combining electric, hydraulic, and hybrid technologies with expert consultative support in a range of applications including energy production and generation machinery, industrial production machinery and simulation and test equipment. We help performance-driven companies design and develop their next-generation machines.

Moog maintains facilities in 40 countries around the globe. This vast scope ensures that our engineers remain close to the needs of machine builders and provide flexible design solutions and technical expertise tailored to our customers' toughest challenges.

Our experts work in close collaboration with machine builders and application engineers to design motion control systems for greater productivity, higher reliability, superior connectivity, less costly maintenance and more effective operations. Our regional presence, industry knowledge and design flexibility ensures Moog motion control solutions are tailored to their environment—from meeting operating regulations and performance standards, to taking machine performance to a higher level.

Products

At the heart of every Moog solution is an array of products engineered for precision, high performance and reliability. For more than six decades, Moog products have been specified for critical machine applications.

Some are developed specifically for unique operating environments. Others are standard equipment on machines across many industries. All are continuously improved to take advantage of the latest technology breakthroughs and advancements.

Moog products include:

- Servo Valves and Proportional Valves
- Servo Motors and Servo Drives
- Servo Controllers and Software
- Radial Piston Pumps
- Actuators
- Integrated Hydraulic Manifold Systems and Cartridge Valves
- Slip Rings
- Motion Bases

Moog Global Support

Moog Global Support is our promise to offer world-class Repair and Maintenance Services delivered expertly by our trained technicians. With the reliability only available from a leading manufacturer with facilities around the world, Moog offers you service and expertise you can count on to keep your equipment operating as it should.

This promise offers many benefits to our customers including:

- Reduce your downtime by keeping critical machines running in peak performance
- Protect your investment by ensuring reliability, versatility and long-life of products
- Better plan your maintenance activities and make systematic upgrades
- Leverage our flexible programs to meet the unique service requirements of your facility

Look to Moog for global support including:

- Repair services using OEM parts are performed by trained technicians to the latest specifications
- Stock management of spare parts and products to prevent unplanned downtime
- Flexible programs, tailored to your needs such as upgrades, preventative maintenance and annual/multi-year contracts
- On-site services bring the expertise to you, providing quicker commissioning, set-up and diagnostics
- Access to reliable services that are guaranteed to offer consistent quality anywhere in the world

For more information on Moog Global Support visit www.moog.com/industrial/service



MORE PRODUCTS. MORE SUPPORT.

Moog designs a range of motion control products that complement the performance of those featured in this catalog. Moog also provides service and support for all of our products. Visit our website for more information and contact the Moog facility nearest you.

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