MTS FSE MODULAR TRAINING

252 Servovalve

January 14, 2019 Rev E

be certain.

Servovalve

- The core of a servohydraulic system is the servovalve.
- It is the final control element in most MTS closed-loop systems. The servovalve responds to command signals generated by the software and processed by the controller and output through the valve driver module.
- The servovalve regulates the direction and flow of the hydraulic fluid entering the actuator from the hydraulic pressure ports. The direction that the spools move determines the direction of fluid flow to the actuator. A pressure difference is what causes the fluid to move.

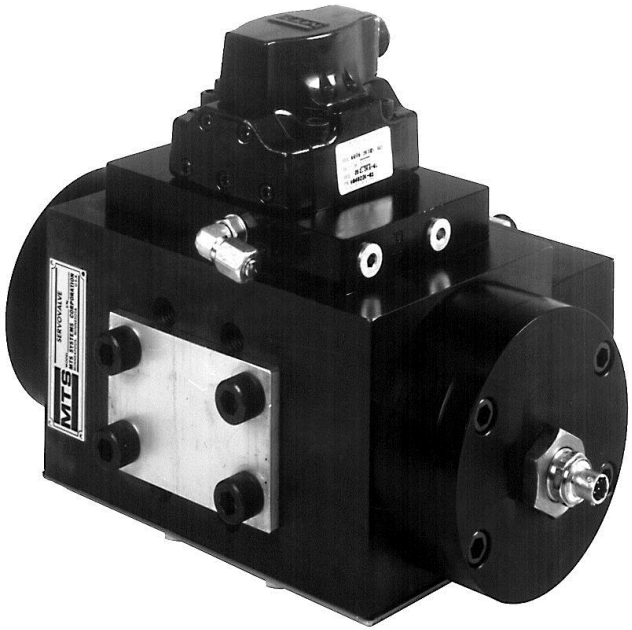
Servovalve

- Servovalves are available in several different configurations
- The MTS 252.2X series servo valve is the typical servo valve installed on standard performance hydraulic actuators. They have a flow rate of 1 to 15 GPM.
- High performance systems utilize the 252.4X series servovalve.
- Higher flow rates are available using the 252.3X series servovalve. These have flow rates up to 60 GPM.
- On system that require larger flows up to 400 GPM, a three stage 256 or similar servovalve would be used.

Servovalve

252.2X Series servovalve

256 Series 3-stage servovalve with 252 pilot valve

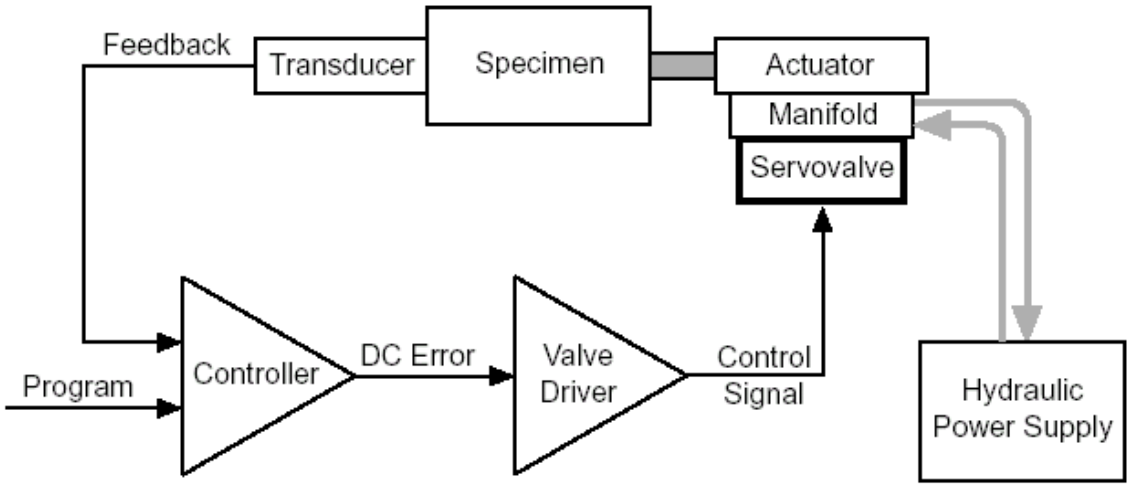


Servovalve

- The 252 series servovalve can be configured based on the application requirement
  - One 252 valve mounted on the servovalve manifold for smaller flow requirements
  - Two 252 valves for increased oil flow mounted on the servovalve manifold
  - One 252 valve used as a “pilot” valve on a 3-stage valve assembly
    - In a 3-stage valve configuration the “pilot” valve controls a second valve known as the main stage. The main stage directs oil flow into the actuator. These types of valves are used when large oil flows are required. For details on this type of valve assembly see the 256 3-stage valve training module

Servovalve Function

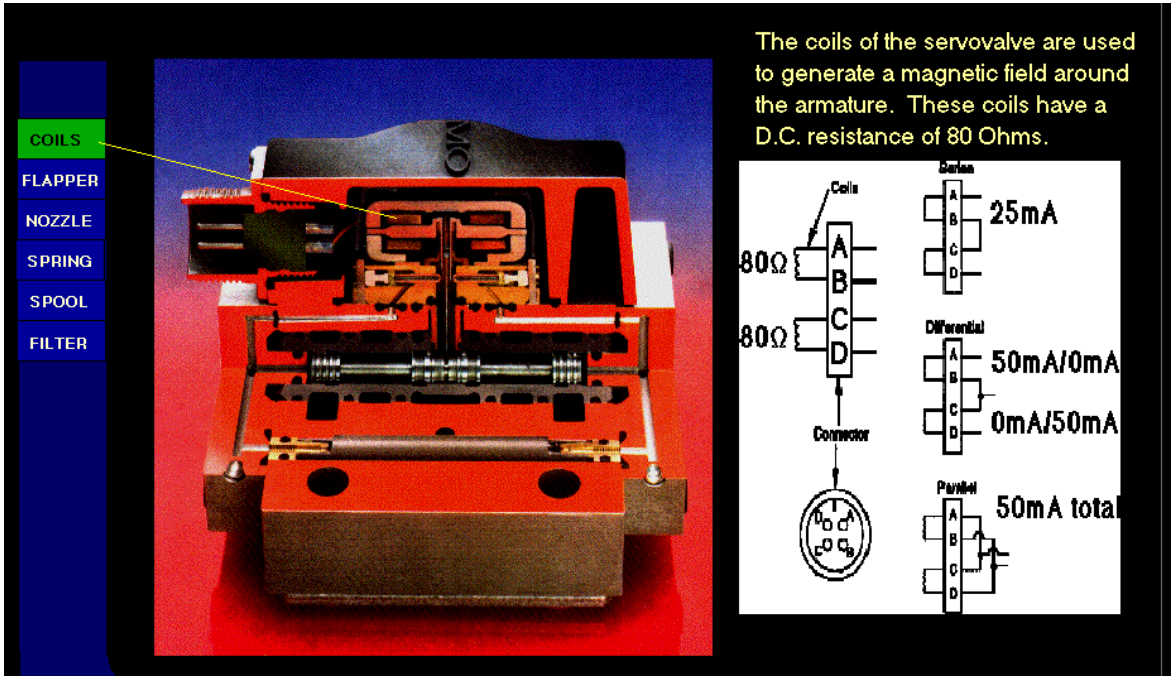
- Servo valves convert the output of the summing junction into actuator travel, either extension or retraction.
- Command is what we are asking the system to do and feedback is what the system is actually achieving.
- The summing junction outputs the difference between the two inputs.
- The output of the summing junction is called error



Typical Closed-Loop System

Servovalve Function

- The error signal is converted into a current signal in the Valve Driver circuit.
- The current signal is connected to the coils of the servovalve which drive the servovalve.
- How much movement depends on the amount of error which is the difference between command and actual feedback



Servovalve Full Scale

- +/- 50 mA = +/- Full flow rating
- Example: 252.24 servovalve rated 10 gallons per minute
  - + 50 mA = +10 gpm
  - - 50 mA = - 10 gpm
- Chart shows common servovalve model number and full flow rating

Model Number*	Full-Flow Rating†
252.21	4.0 L/min (1.0 gpm)
252.22	9.5 L/min (2.5 gpm)
252.23	19.0 L/min (5.0 gpm)
252.24	37.0 L/min (10.0 gpm)
252.25	56.0 L/min (15.0 gpm)

Internal Operation

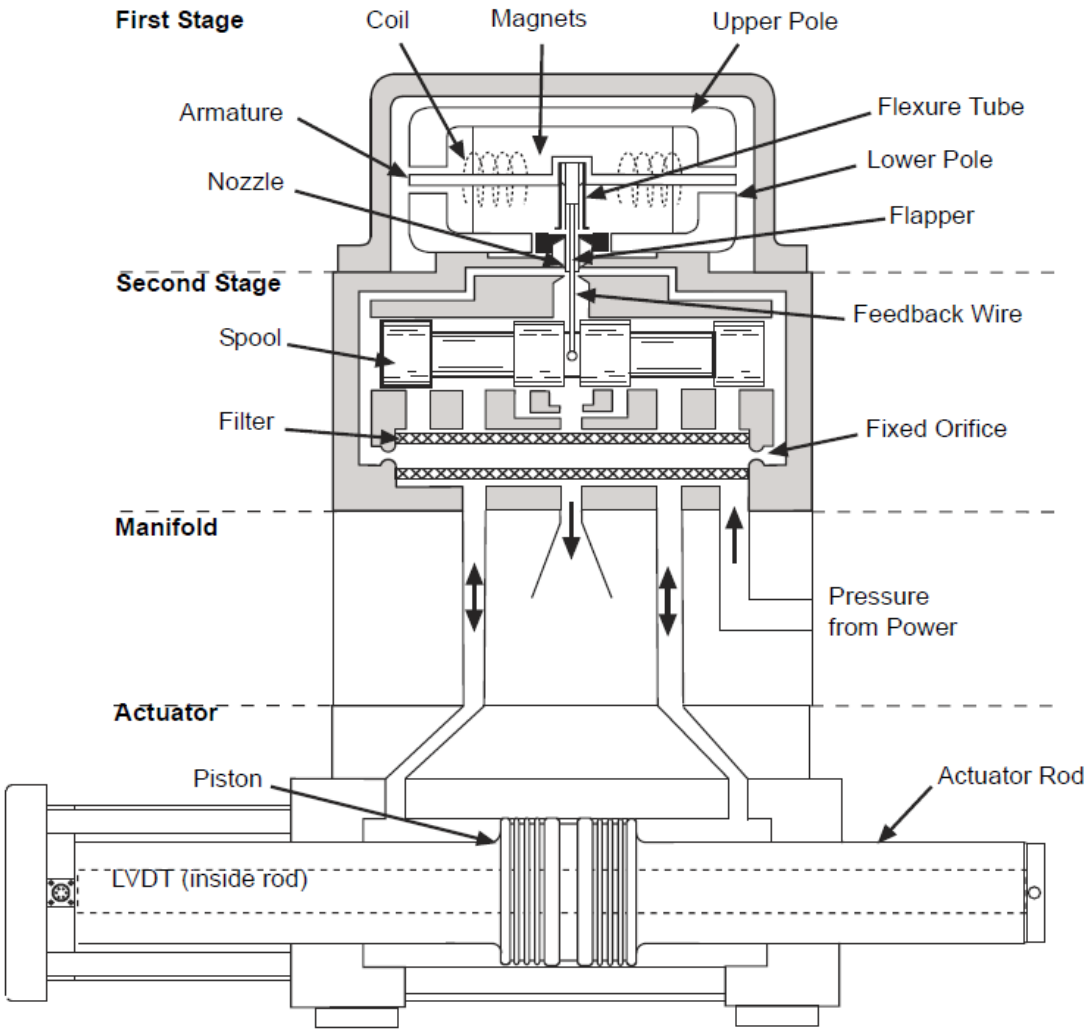
- Topics below illustrated on next page:

- The servovalves controlling element is the torque motor, which receives an electrical input from the controller. A flapper is attached to the armature of the torque motor. The flapper moves from side to side as the armature moves in response to control signals from the controller. The flapper assembly is mechanically attached to the armature. There are two nozzles, one on each side of the flapper.

- Because the nozzle-flapper valve is the first control point of hydraulic fluid, it is called the first stage. As long as there is no command for actuator motion, the flapper is centered between the two nozzles.

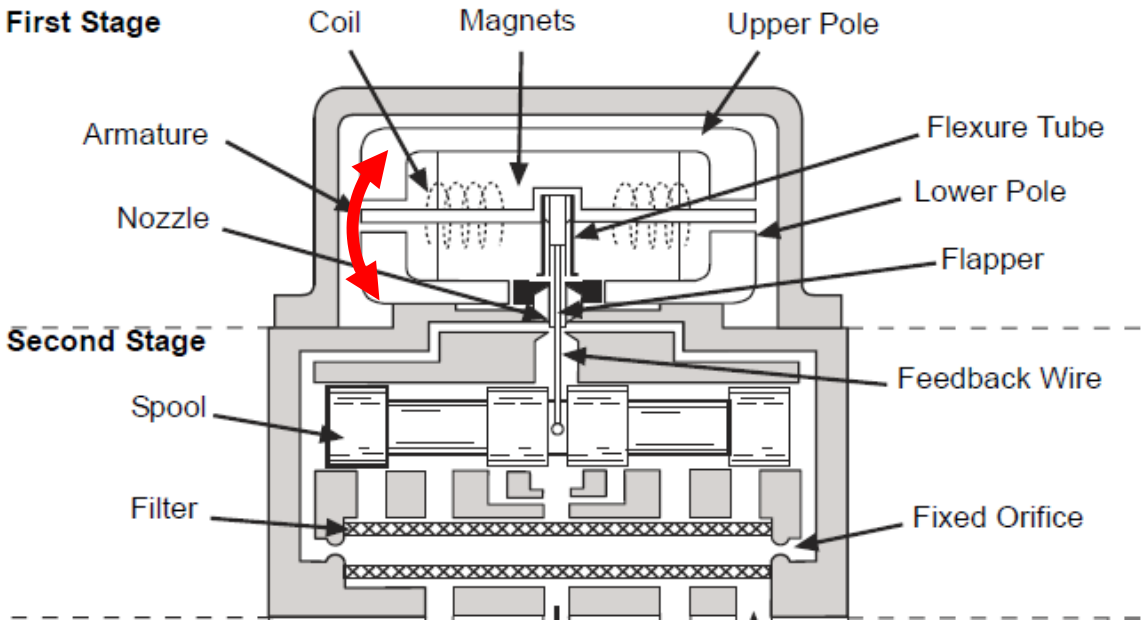
- At the same time, pressurized hydraulic fluid entering the valve is applied equally to both sides of the spool, which does not move. This is the second stage.

Internal Operation



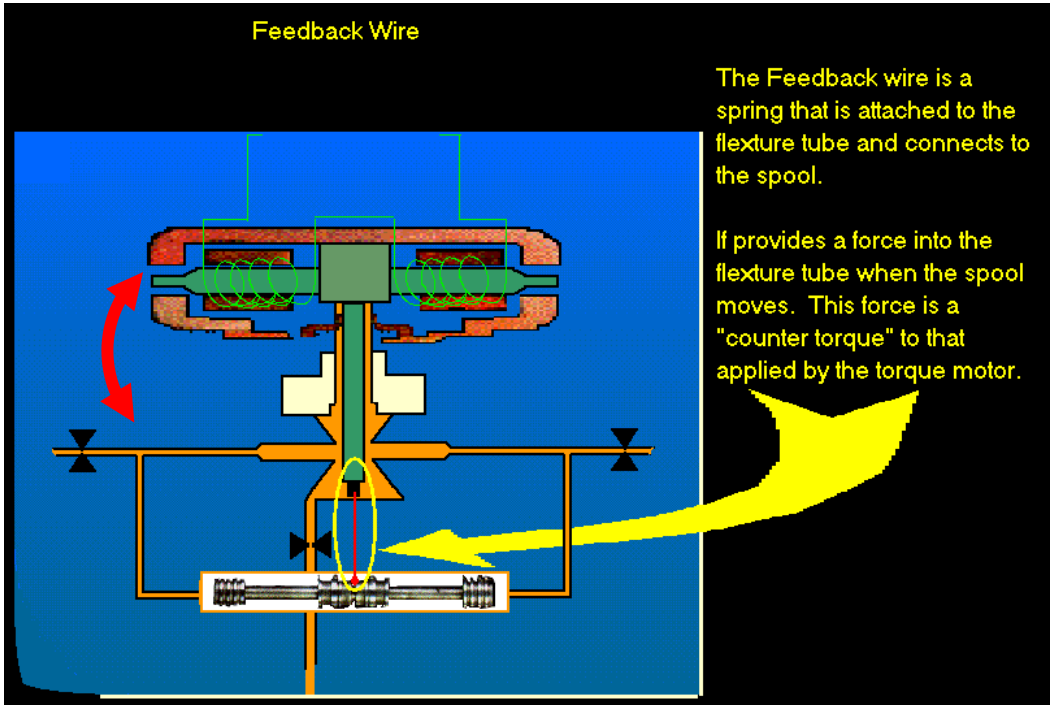
Internal Operation

» Valve command from the controller causes the armature to rotate clockwise or counterclockwise (depending on the polarity of the command). The command causes the flapper to block one of the nozzles, which diverts hydraulic flow to that end of the spool. The spool moves and opens hydraulic pressure to one control port and the return line to the other control port. The control ports are connected to each end of the actuator.



Internal Operation

- The feedback wire works like a spring. The spool moves until the force created by the feedback wire equals the torque from the magnetic forces. This causes the flapper to move back toward the centered position. The spool stops at this position. The spool position is proportional to the input command current.

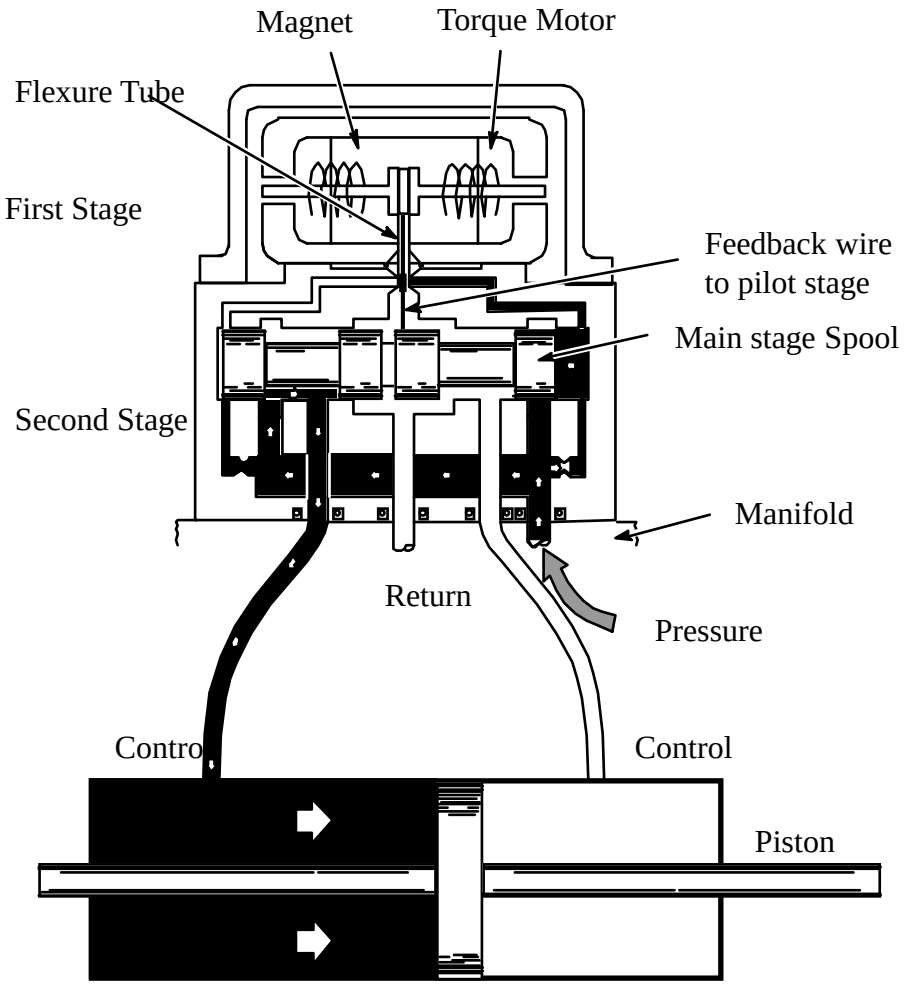


Internal Operation

- Although the pressures are equal on both sides of the spool (so the spool is no longer moving), control flow from the servovalve keeps the actuator moving.
- When the actuator has moved the desired amount, the valve drive command decreases to zero. Hydraulic fluid flow to the actuator stops, and so does the actuator.
- The flow through the servovalve producing actuator movement is illustrated on the next page

Internal Oil Flow

- Pressure is indicated by Black color in the oil passages
- Return is indicated by White color in the oil passages



Actuator

Servo Valve Specifications

- The 252 series servovalve is manufactured by Moog
- These valves are custom for MTS and carry a special orifice that reduces the potential for squealing. Standard Moog valves do not have this orifice.
- These valves are manufactured to MTS specifications
- Moog has a similar standard production valve however it is not manufactured to the same specification
- You cannot directly replace a MTS servovalve with a Moog servovalve

Servovalve ports

- The servovalve uses a small amount of incoming oil to provide control to the internal functions of the servovalve

- Servovalves are available in 2 configurations to supply the control pressure to the valve
  - 4 Port valves
    - Have 4 ports visible on bottom of valve
    - New style have 5 ports visible but are configured for 4 port operation
  - 5 Port Valve
    - Have 5 ports visible on bottom of valve
    - Not all 5 port valves support being configured for 4 port operation

Servovalve control pressure

- On 4 port valves this control pressure is delivered directly from the pressure port
  - Pressure port typically does not have high pressure until HSM is turned on
  - Servovalve will not be in control until pressure stabilizes

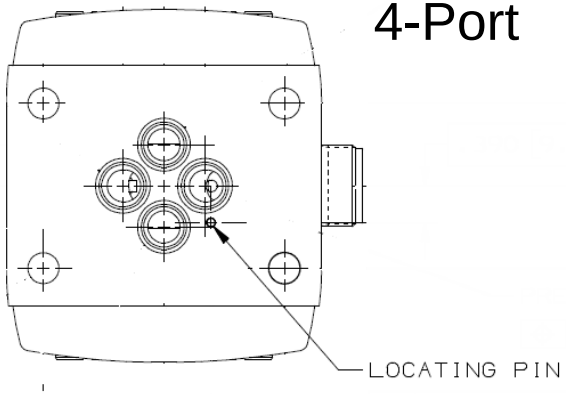
- On 5 port valves control pressures is delivered using the pilot pressure port.
  - Pilot pressure is typically always on with HPU on and not controlled by HSM
  - Servovalve is in control regardless of pressure port condition

Legacy 4 Port Vs. 5 Port Valves

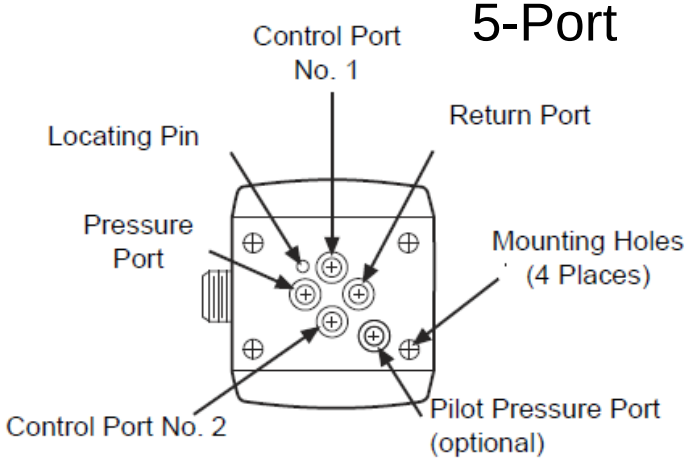
» 4 port servo valves do no require external pilot pressure. These valves carried the -01 in the model number.
  - Example: 252-25C-01 which is a 15 GPM 4 port servo valve

» 5 port servo valves require that external pilot pressure be connected to the servo valve. The model numbers for the 5 port valves carried a -04 in the model number.
  - Example: 252-21C-04 which is a 1 GPM 5 port servo valve.

4-Port

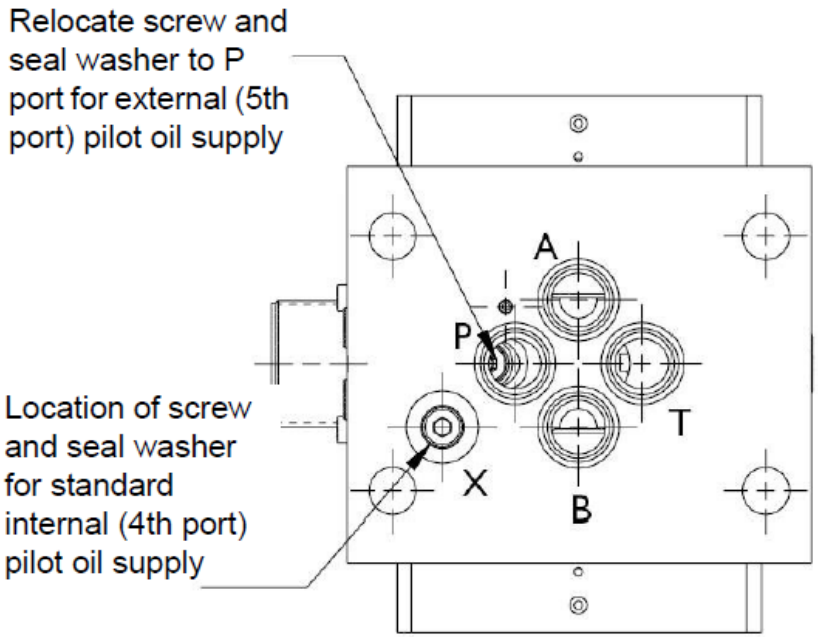


5-Port



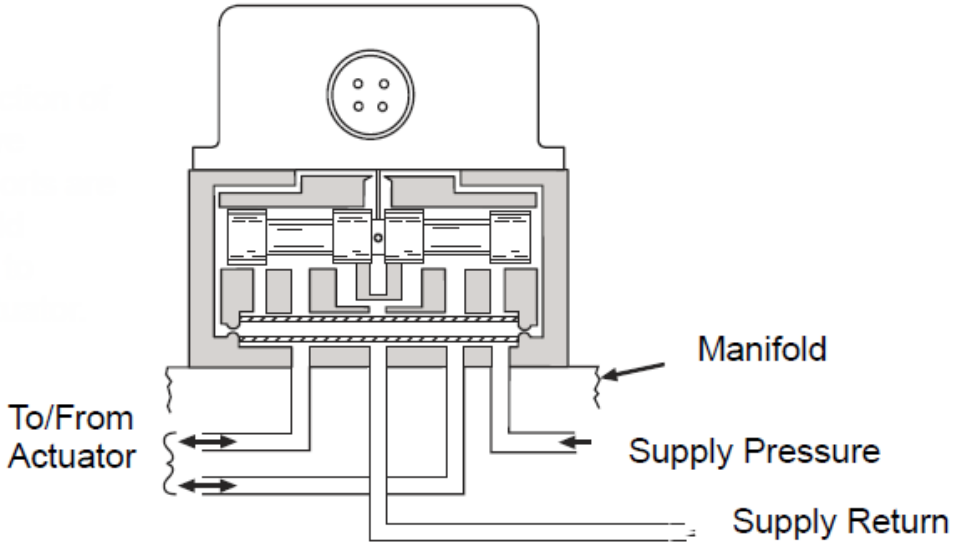
Modern 4 or 5 Port Servovalve

- Prior to the introduction of the MTS 252.2x G series servo valve, the servo valves were manufactured as 4 or 5 port servo valves.
- This picture shows the newer G series servo valve which can be configured as either type. Note the location of the P (pressure), T (return) and A & B which are the C1 & C2 ports.



Servovalve Ports

- Hydraulic pressure from the pump is connected to the P port. The return flow, T, is connected to the return side of the HPU.
- C1 and C2 are connected through the manifold to the actuator, one to each side of the piston.
- Pilot pressure is used on 5 port valves to provide 3000 PSI of pressure to control the servo valve.
- Pilot pressure is normally supplied from the service manifold, but there are some special systems where pilot pressure is supplied directly from the pump.

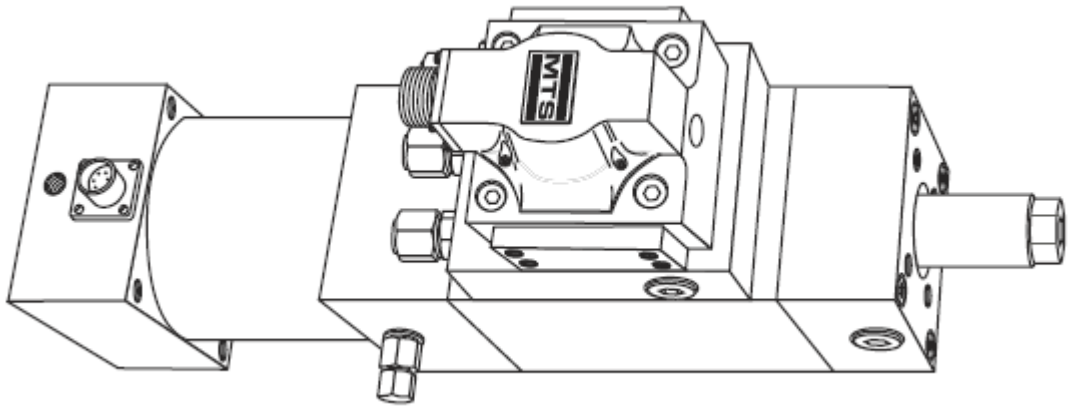


Servovalve Mounting

- An actuator can have 1, 2, or even more servovalves attached to a single actuator
- The number of valves is based on the performance requirement
- It is not uncommon to install 2 different sized servo valves on a actuator.
  - This allows a large servovalve and a small servovalve to be installed
  - The user selects the correct one to match the performance requirements of the test
  - This is performed with the use of a port shut off to hydraulically disconnect the servovalve not in use.
- Many servovalve manifolds have locations for mounting 2 servovalves
  - Sometimes only one is servovalve is supplied
  - The second location must be blocked by a high pressure blocking plate when the servovalve is not in place

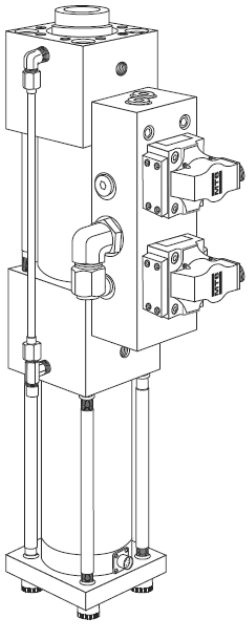
Single Servovalve

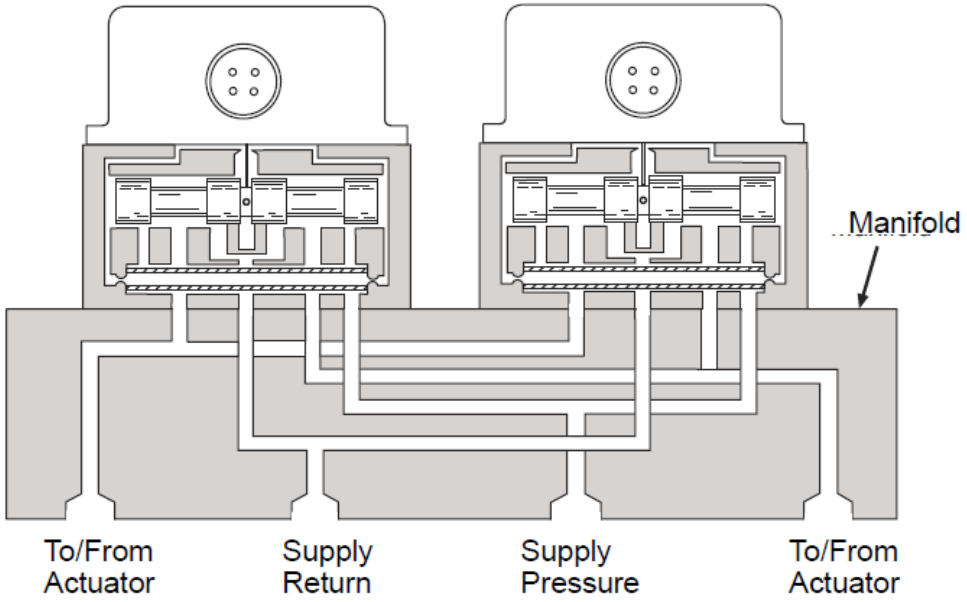
» Some actuator servovalve manifolds only accommodate a single servovalve.



Dual Servovalves

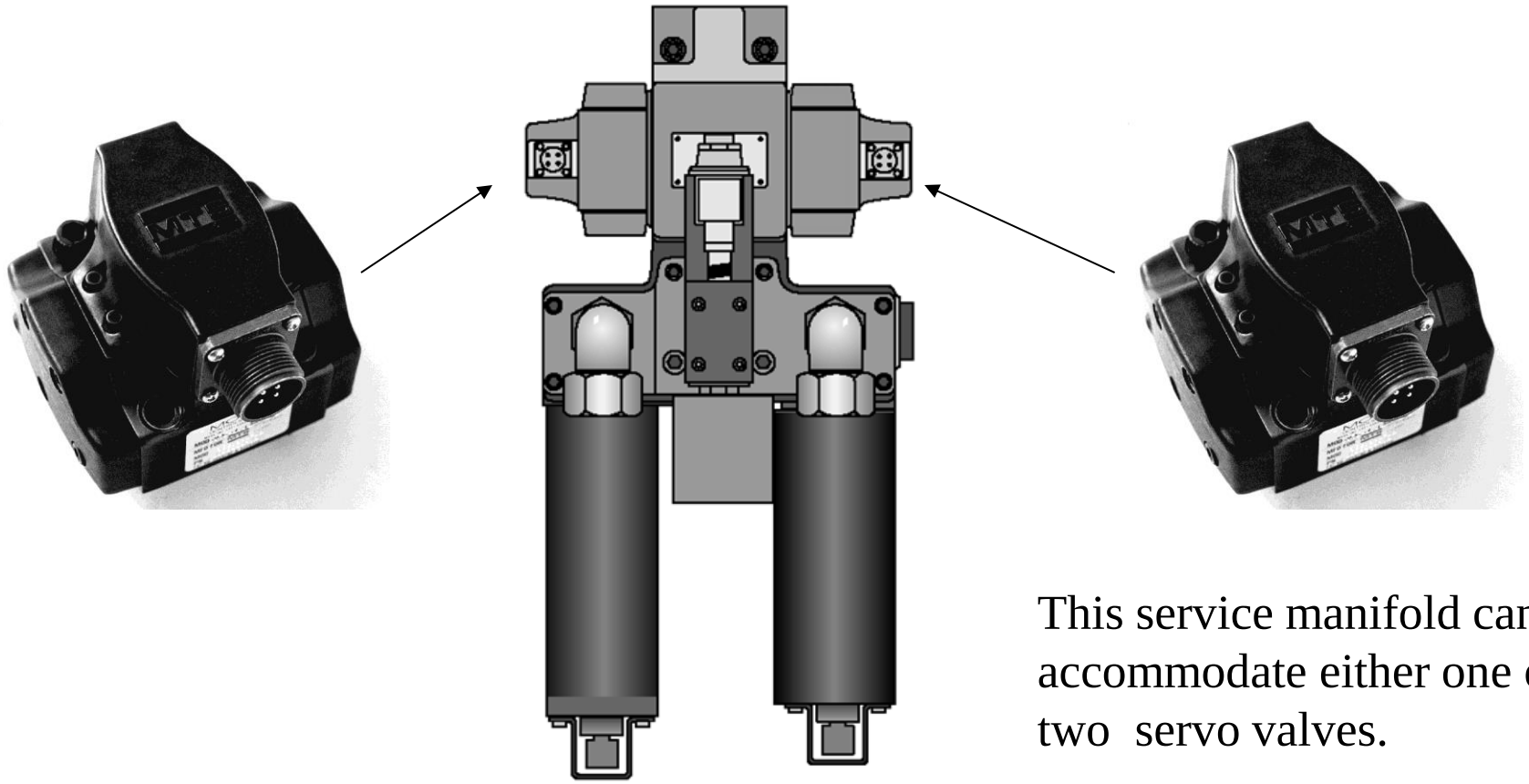
- When using more than one servovalve the manifold connects the appropriate ports together.
- One pressure and one return hose can supply both servovalves
- Output C1 and C2 ports are connected according to design requirements
- The image below is typical structural application





Dual Servovalves

» On the typical material testing application, the servo valve is mounted on the hydraulic service manifold which is mounted to the actuator.



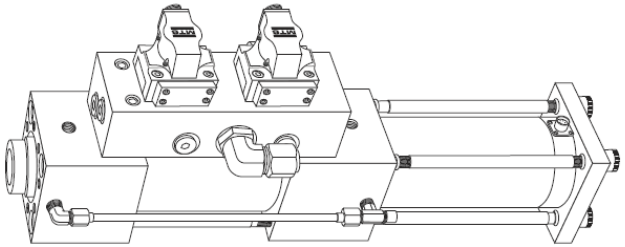
Model 298.12 Actuator Manifold

This service manifold can accommodate either one or two servo valves.

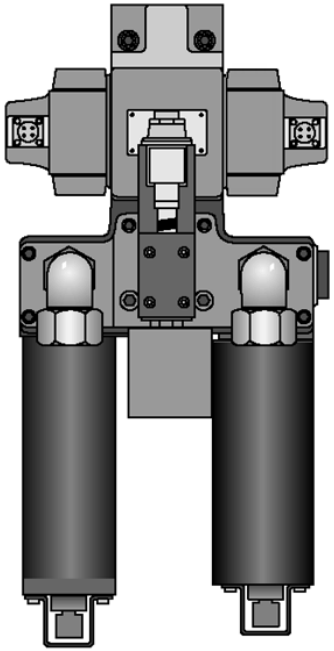
Dual Servovalve Phasing

- When using more than one servovalve it is necessary to determine if the valves are in or out of phase with each other.
- The servovalve cable type is selected for either in-phase or out-of-phase valve mounting
- Generally if the 2 servovalves are mounted alongside each other they are typically in-phase. If the valves are mounted opposite each other they are typically out-of-phase
- Using the incorrect cable will cause the system to have no control
  - An indication of this is a loud rushing noise of oil flow with no actuator movement

In-Phase



Out-of-Phase



Model 298.12 Actuator Manifold

Servovalve Polarity

- Servovalves need to have the valve polarity configured properly to ensure that they control the actuator travel.
  - Positive command results in Positive actuator travel.
  - Polarity is selected in the controller
  - See appropriate controller manual for servovalve polarity adjustment

- When you install or replace a servo valve you need to check the valve polarity.
  - Select displacement control
  - Apply a positive command
  - If actuator moves in a direction that creates positive feedback the polarity is correct
  - If actuator moves in the opposite direction and goes to the end cap or if it fails to move at all the servovalve polarity needs to be changed

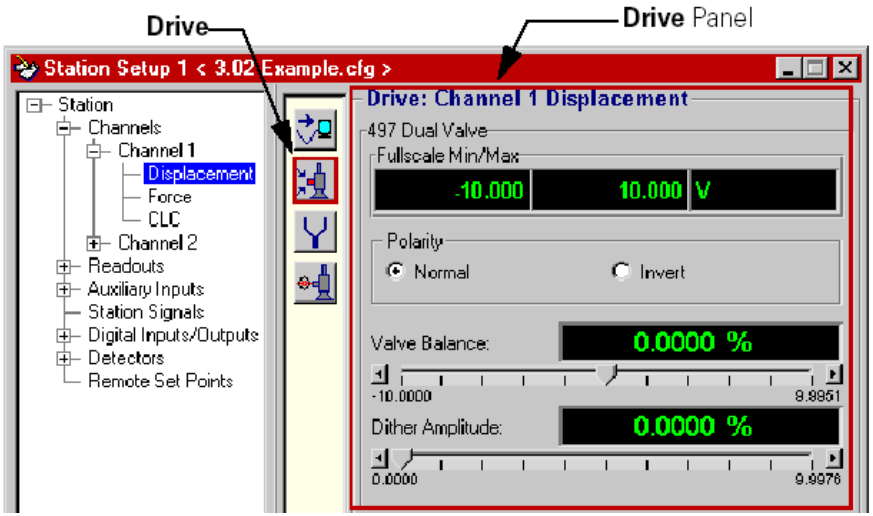
Valve Balance

- There are two types of valve balance, electrical and mechanical.
- MTS controllers have an electronic mechanical null adjustment called valve balance. The valve balance adjustment is a convenient way to compensate for a servovalve that needs a mechanical null adjustment. The adjustment introduces an electrical offset signal that causes the servovalve to hold the position of the actuator when a zero command is issued.
- Adjust the electrical balance first and only make mechanical adjustments if needed.

Electrical Valve Balance

- With hydraulic pressure on and the system in stroke control.
- Adjust tuning I gain to zero
- Adjust the command signal to zero
- Monitor the displacement feedback.
- Adjust the electrical valve balance to make the feedback equal zero.
  - An alternative is to adjust the electrical valve balance to make the error zero. This can be performed either in displacement or force control
- See appropriate controller manual for adjustment location

Example electrical valve balance adjustment found in 793 software



Mechanical Null - Valve Balance

» If you can not achieve correct valve balance using the electrical balance, then proceed to perform a mechanical null.

» There are 2 methods used to perform this adjustment
- Method 1 is used on digital controllers where the electrical valve balance adjustment can be adjusted to zero
- Method 2 is used on analog controllers where it is not possible to adjust the electrical valve balance to a known value of zero.

Mechanical Null – Digital Controller

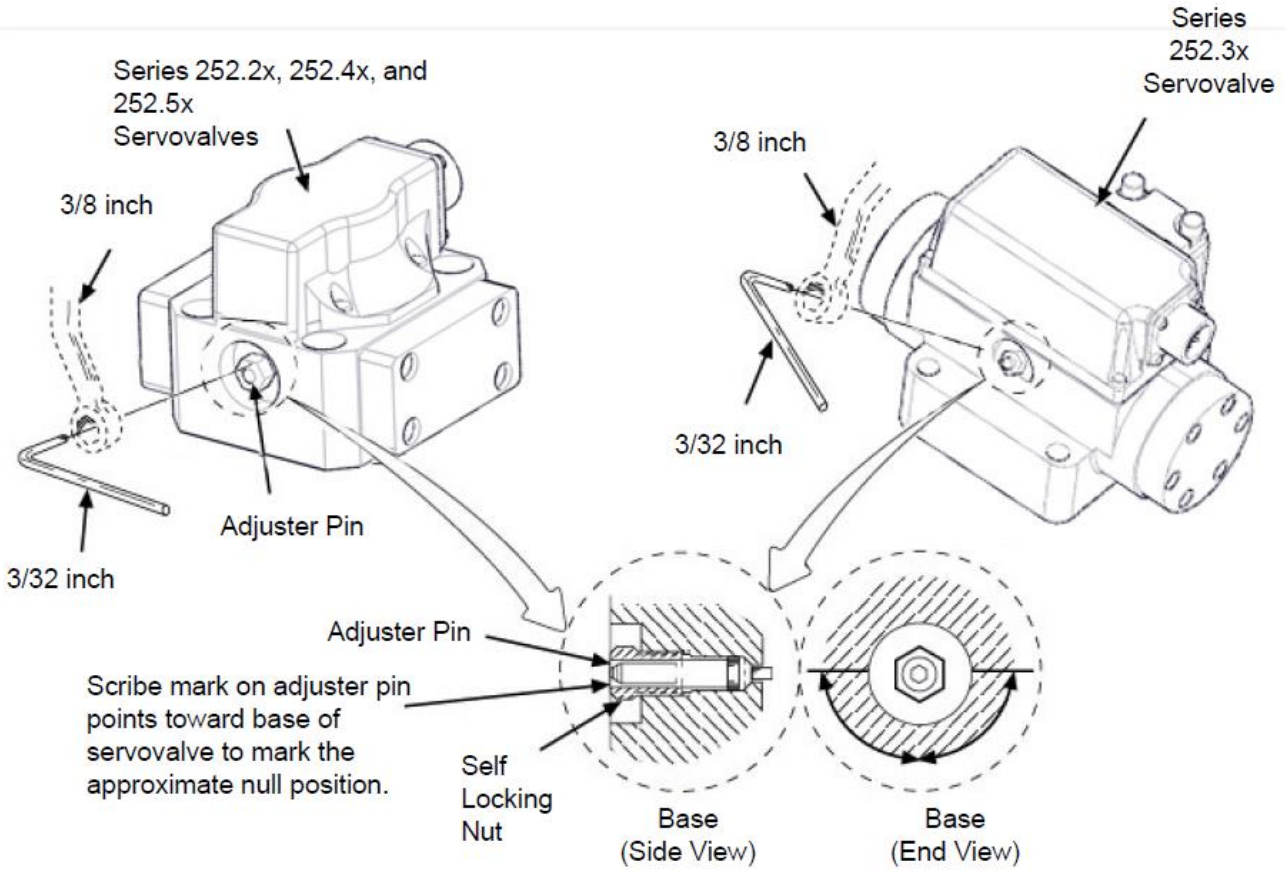
- The actuator should be exercised to warm it up. Electrical and mechanical adjustments are more repeatable after the actuator is warmed up.
- Select displacement control for the controller.
- Adjust the actuator for mid-displacement.
- Define a 50%, 0.1 Hz sine wave command and allow the actuator to warm up for approximately one-half hour.
- After the warm up period, stop the test program.

Mechanical Null – Digital Controller

- Set the supply pressure to the normal operating pressure (typically 3000 psi).
- The actuator should be in position control, with the reset integrator disabled or set to zero.
  - See controller manual for adjustment location
- Set the electrical valve balance to zero.
  - See controller manual for adjustment location
- Monitor both command (actuator displacement command,) and feedback (actuator position feedback.)

Mechanical Null – Digital Controller

» Slightly loosen the self-locking nut.



Mechanical Null Adjustor Pin

Mechanical Null – Digital Controller

- Insert a 3/32-inch hex key into the adjustor pin socket. See the previous figure for the location of the adjustor pin.
- **Do not apply more than 1.36 N•m (12 lbf-in.) of torqueing force to the adjustor pin.**
- **Excessive torqueing may shear off the adjustor pin eccentric.**
- If the pin does not turn using very little force, gently loosen the self-locking nut more, then try turning the pin again.

Mechanical Null – Digital Controller

- Check that the scribe mark on the adjuster pin is pointed toward the base (oriented in the lower 180° of the adjustment range). If necessary, rotate the adjuster pin so that the scribe mark is pointed towards the base.

- While monitoring the command and feedback signals, slowly rotate the adjustor pin until command equals feedback.
  - The adjustment range is the bottom 180 degrees of rotation of the adjuster pin
  - Further adjustment or turning multiple turns does not increase adjustment range

- Verify that the scribe on the adjuster pin is pointed approximately towards the base.

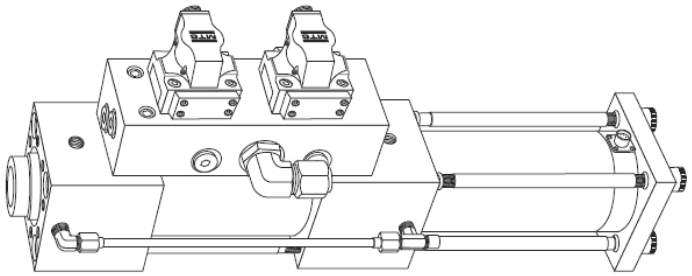
- While holding the adjuster pin in position, tighten the self-locking nut until it is snug, (1.13 to 1.35 N*m, 10 to 12 in*lbf) while monitoring the command and feedback signals to ensure that the command equals feedback.

Mechanical Null – Analog Controller

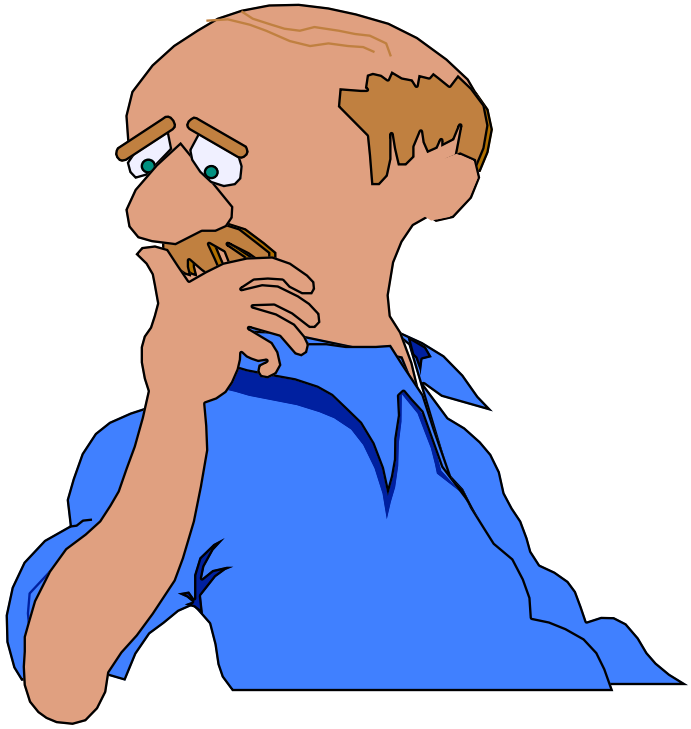
- Ensure the actuator can move full travel without any obstruction
- Exercise the actuator to warm it up as described in the Mechanical Null – Digital Controller procedure
- Adjust actuator in displacement control to middle of travel
- Disconnect the servovalve cable
- Slowly rotate the adjuster pin until the actuator movement stops or is reduced to a minimum
  - Follow procedure as described in Mechanical Null – Digital Controller to loosen self-locking nut, adjust, and tighten self-locking nut.
  - If adjustment is not completed prior to actuator travel reaching the end cap reattach servovalve cable and move actuator to middle of travel and repeat

Mechanical Null – Dual Servovalves

- When you perform a mechanical valve balance on dual servo valves you must isolate the servo valve(s) hydraulically when you make mechanical null adjustments.
- Perform the electrical valve balance normally.
- Determine if mechanical null adjustment is required.
- Physically remove one of the valves from the actuator and install a blocking plate in its place.
- Ensure that both servo valves are electrically connected.
- Perform the mechanical valve balance on the valve still installed on the frame.
- Re-install the second servovalve. Make sure both are connected electrically, and then adjust the mechanical null on the other valve



Servovalve sizing



How do I calculate the required size of servovalve for my application?

Servovalve Sizing

- MTS has custom tools to help evaluate the requirements for servovalve sizing
  - Spool can be used for system performance including servovalve sizing

- For a sinusoidal test on a linear actuator a simple formula can be used to approximate the amount of oil flow required to perform the test

Servovalve Sizing

- Peak Flow in gpm = f*A*X/1.23
  - f = the frequency of the test
  - A = the area of the piston in square inches
  - X = the peak – peak displacement in inches
- Peak Flow in L/min = f*A*X/5.3
  - f = the frequency of the test
  - A = the area of the piston in square centimeters
  - X = the peak – peak displacement in centimeters
- These formulas will generate peak flow required for a specific test when using a linear actuator.
  - Peak flow is used to determine minimum servovalve size

Servovalve Sizing Example

- For a 5 Hz test operating +/- 0.25 inches (0.5 inches peak-peak) using a 244.22 100 kN (22 kip) actuator
- First find the piston area of the actuator. This can be located on the label attached to the actuator.
  - If you do not have access to the actuator label or the specification sheet area can be approximated by taking the rated force capacity and dividing by 3000 PSI
  - For this example the 244.22 actuator has a piston area of 7.57 square inches
- Peak flow = (5 * 7.57 * 0.5) / 1.23
- Peak flow = 15.38 gpm
- Using standard 252.2X series servovalves this test would require that the system be equipped with two 10 or two 15 gpm valves.

Servovalve Sizing Example

- Using the same system but reducing the displacement to +/- 0.002 inches would have the following peak oil flow requirement
- Peak Flow = 5 * 7.57 * 0.004 / 1.23
- Peak Flow = 0.12 gpm
- This would be OK with a 1 GPM valve, but not Dual 15 GPM valves.

Rule of Thumb

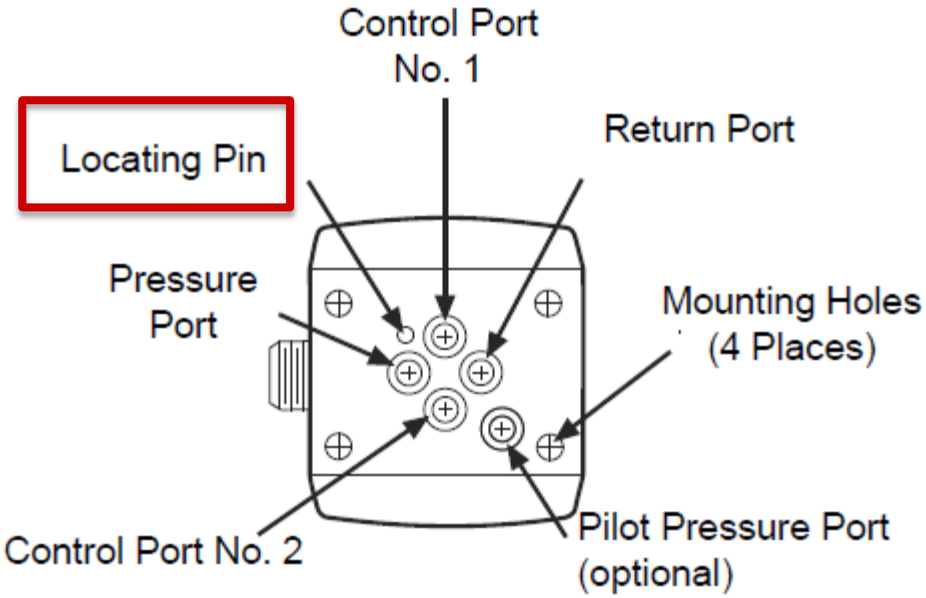
- Each servo valve has approximately 1% internal leakage by design.
- We can not expect a servovalve to control properly when the desired flow is less than this leakage.
- A flow of 0.12 GPM as in the previous example when used with a 1 GPM valve would result in a flow of 12 % full flow capacity
  - This is a usable servovalve for this test
- Consider the same flow on a 15 GPM servovalve.
- The required flow of 0.12 GPM would only be 0.8% of full flow capacity on a 15 GPM valve which is below the 1% leakage flow
  - Use of this servovalve would result in poor performance

Servovalve Installation

- Move actuator to end of travel in the direction gravity will cause the piston to fall
  - If valve or blocking plate removed and piston drops due to gravity oil in the cylinder cavity will spray out of the open ports in the manifold
- Ensure pressure is off
- Remove old valve or blocking plate
- Lightly oil the O-rings on the servovalve
- Place the valve on the manifold noting the locating pin

Servovalve Installation

- The servovalve locating pin correctly orients the valve ports to the manifold
  - Ensure the servovalve is oriented so the locating pin is aligned with the correct position
  - If no locating pin is present such as older valves be sure to match where the locating pin should be on the valve and install accordingly



Servovalve Installation

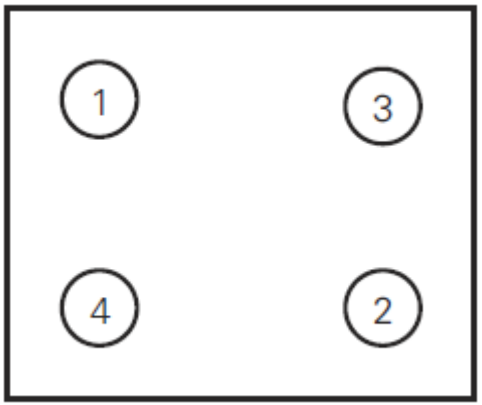
» Install the proper bolt and torque to specification
  - Select Metric or US Customary thread to match manifold

Servovalve Family	US Customary Thread	Torque
252.2X and 252.4X	5/16 – 18 X 1 ½ Inch	13-19 lbf•ft
252.3X	3/8 – 16 X 1 ¾ Inch	23-34 lbf•ft

Servovalve Family	Metric Thread	Torque
252.2X and 252.4X	M8 x 1.25 mm x 40 mm	19-28 N•m
252.3X	M10 x 1.5 mm x 45 mm	36-53 N•m

Servovalve Installation

- Initially torque all bolts to 5 lfb•ft using the pattern shown below
- Torque in the sequence shown below to final torque
- As fastener torque is increased on each bolt the previously torqued bolts may relax slightly. Check final torque a second time.
  - Most torque wrench manufacturers recommend setting the torque wrench to 0 prior to storage



Servovalve Installation

- Apply Low hydraulic power
  - Check for leaks
- Apply High hydraulic power
  - Check for leaks
- Confirm actuator control not affected by valve change
  - Run in displacement control
  - If not in control validate valve polarity setting as required
- Warm up servovalve
- Perform electrical valve balance
  - Reference appropriate product manual for electrical valve balance adjustment location

Servovalve – Dirt or Silt

- A dirty or silted servo valve will appear as wandering or hunting of the response when you are trying to hold a force or stain value.
- It can also appear as a distortion on the waveform.
  - Low frequency sine wave will have flat spots
  - Turn around points may be distorted
- Under normal use, oil flow thru the servovalve is sufficient to carry away contaminates in the oil.
- However, when the test requirements result in a very small amount of flow, the valve can become contaminated. This is called silting.

Servovalve – Dirt or Silt

- There are two possibilities for improving performance with a dirty or silted servovalve.

- Replace the servovalve
  - Send the valve to MTS for cleaning
  - Exchange the servo valve.

- Dislodge dirt and silt by running a large amplitude square wave with high P-gain and high dither
  - This is sometimes a temporary fix
  - If performance increases after running square wave discuss valve replacement with customer. For critical testing needs the valve should be replaced.

Servovalve – Dirt or Silt

- Set the frequency and amplitude so that the system is producing a sharp response.
- Run for at least 30 minutes.
- After 30 minutes of running the square wave, return the system to it's normal conditions.
- If the response is not better, then the valve must be returned for cleaning or exchanged.

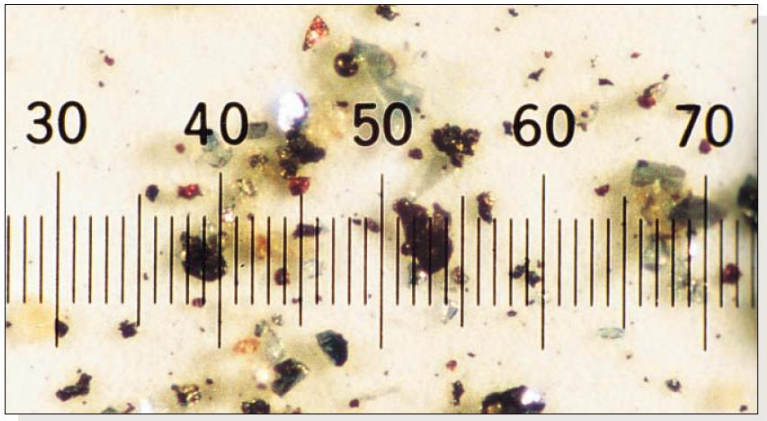
Servovalve - Dither

- Increasing the dither on a dirty or silted servovalve can improve performance.
- Dither is a high frequency sine wave applied to both sides of the servovalve coil at the same time.
  - Default value dither frequency = 528 Hz.
  - High response systems dither exceeds 1000 Hz
- Adjust the dither amplitude till you can hear it.
  - If performance increases this is an indicator of a dirty or silted valve

Servovalve – Contaminated Oil

- Oil which does not meet the cleanliness requirements will cause poor performance from servovalves
  - Dirt will plug control orifice and contaminate filter
  - This will cause either poor performance or no response at all
  - Filters on early 252.2X servovalves prior to the “G” version are not field replaceable and must be returned for service or exchange

- Oil which has been overheated or is kept in service beyond its usable life will cause servovalve internal surfaces to varnish
  - This valve will need to be replaced

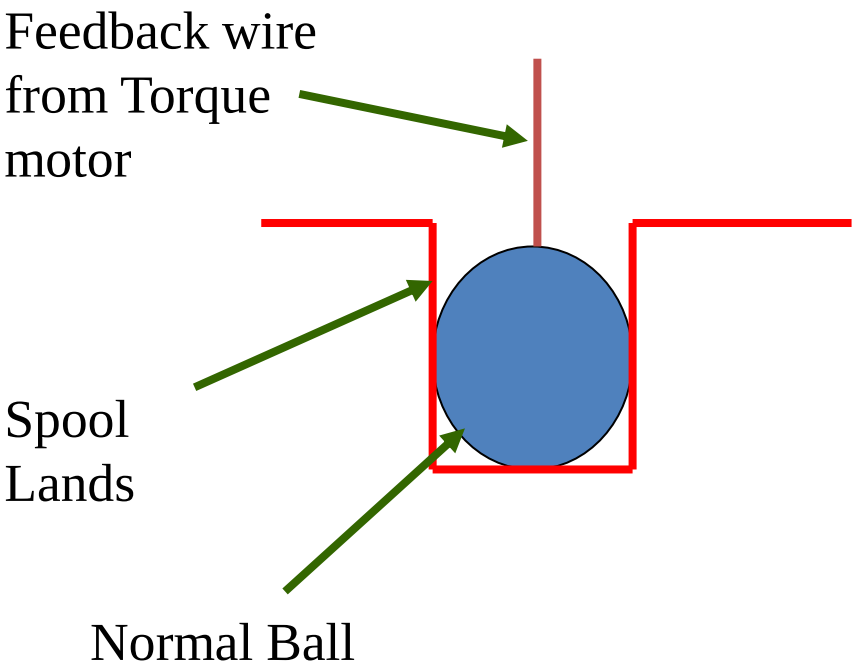


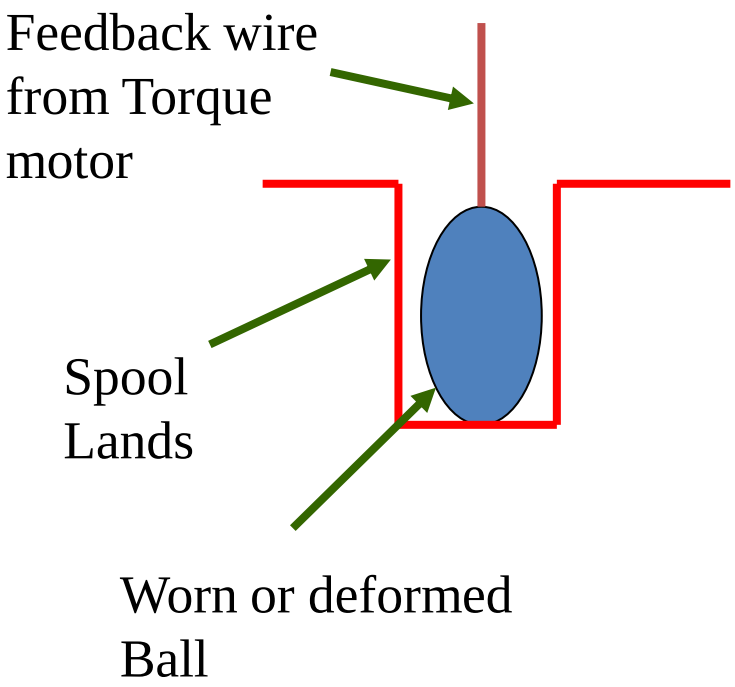
Actual photomicrograph of particulate contamination
(Magnified 100x Scale: 1 division = 20 microns)

Worn Feedback Ball

- A worn feedback ball is commonly noticed when the FSE is performing a system calibration.
- It is very difficult to achieve a zero load setting.
- The load will approach zero, then suddenly jump thru zero.
- This can be caused by a worn Ball, at the end of the Feedback wire

Worn Feedback Ball





Worn Feedback Ball Evaluation

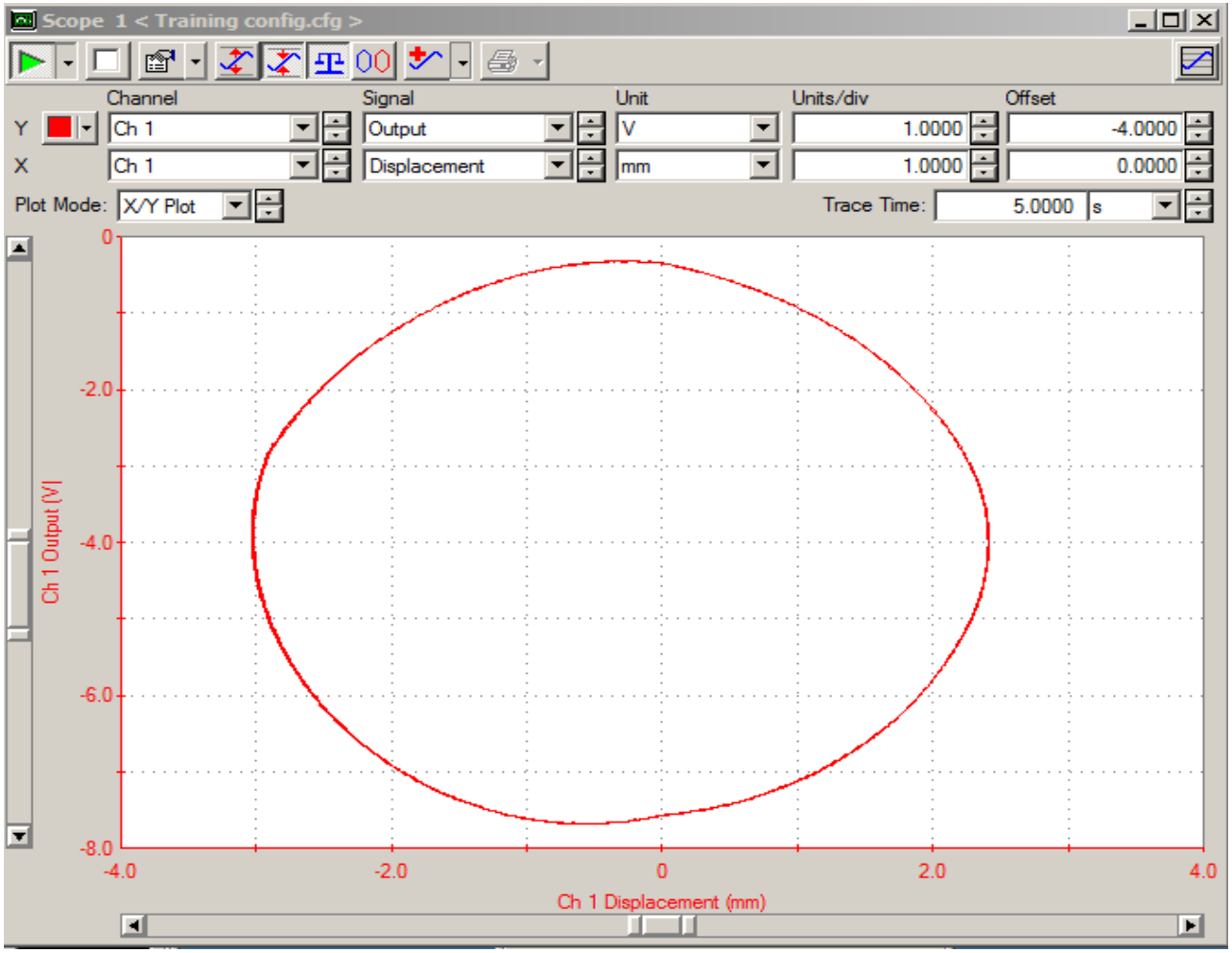
- Start up the system and get control of the actuator in displacement mode.
- Make sure the cross head is out of the way and that the actuator can move un-obstructed through the full range of motion.
- Run a slow sine wave until system comes up to full operating temperature (usually less than 10 minutes).
- Open the scope and set up for an XY plot with “output” on one of the axis and “displacement” on the other.
  - You also can select “output” vs “command” as well, either way will work.

Worn Feedback Ball Evaluation

- Auto scale the plot with the system running.
- A good servo valve with no ball slop should have a nice round or oval profile without jagged edges or spikes. See next pages for examples.
- Adjust to different amplitudes or frequencies to try to capture any servo valve performance issues that you may encounter. Please be aware that if you begin to run into an oil limited condition beyond the performance limits of the system or beyond its capability, you will begin to see that the circle is going flat at the top and bottom or on the sides. This is normal. You are just trying to operate the system beyond its capabilities such as pump limited oil flow, servo valve maxed out, etc. If this happens, lower either the frequency or the amplitude (or both) of the sine wave running in the function generator.

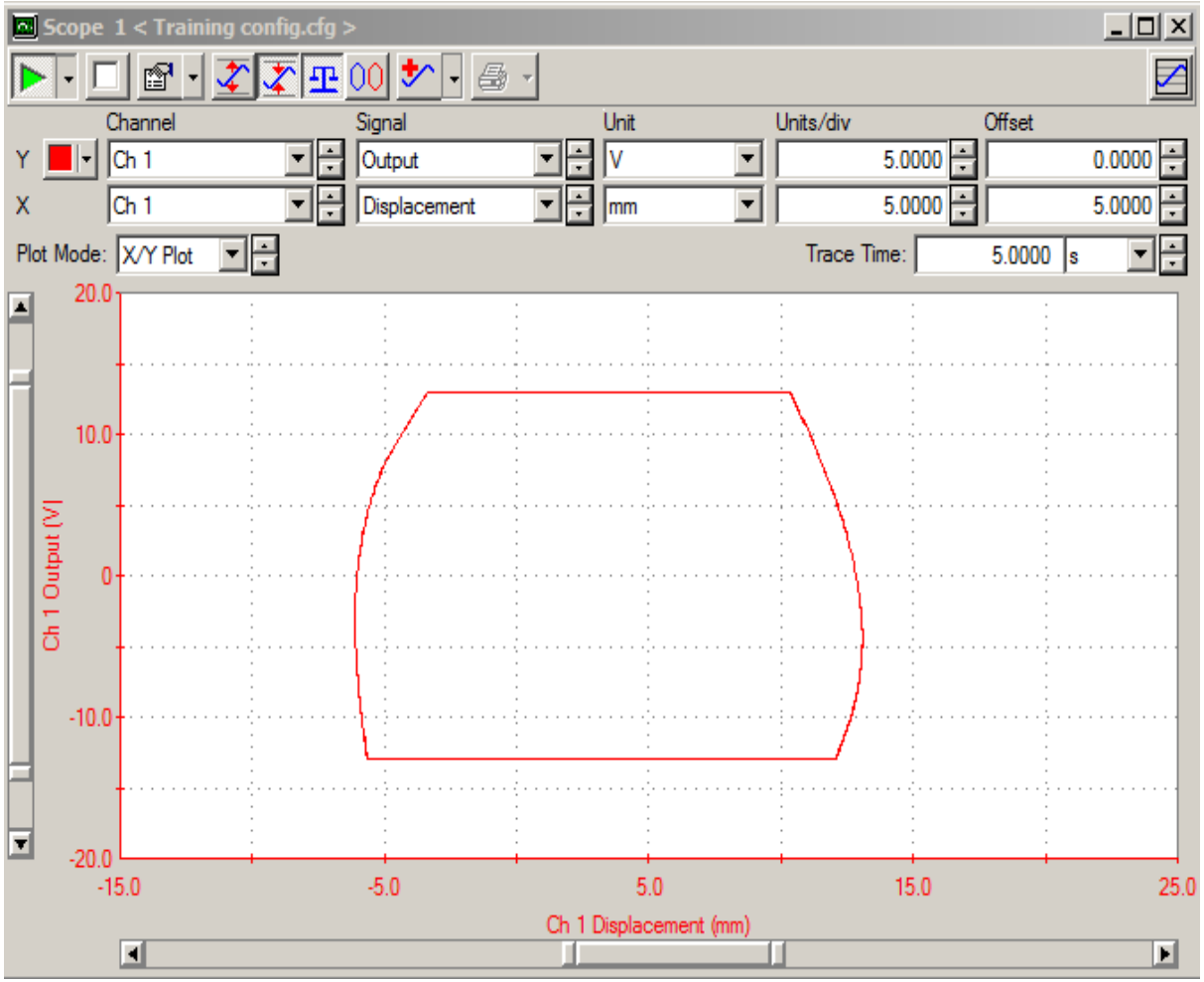
Worn Feedback Ball Evaluation

» Good servovalve, feedback ball not worn



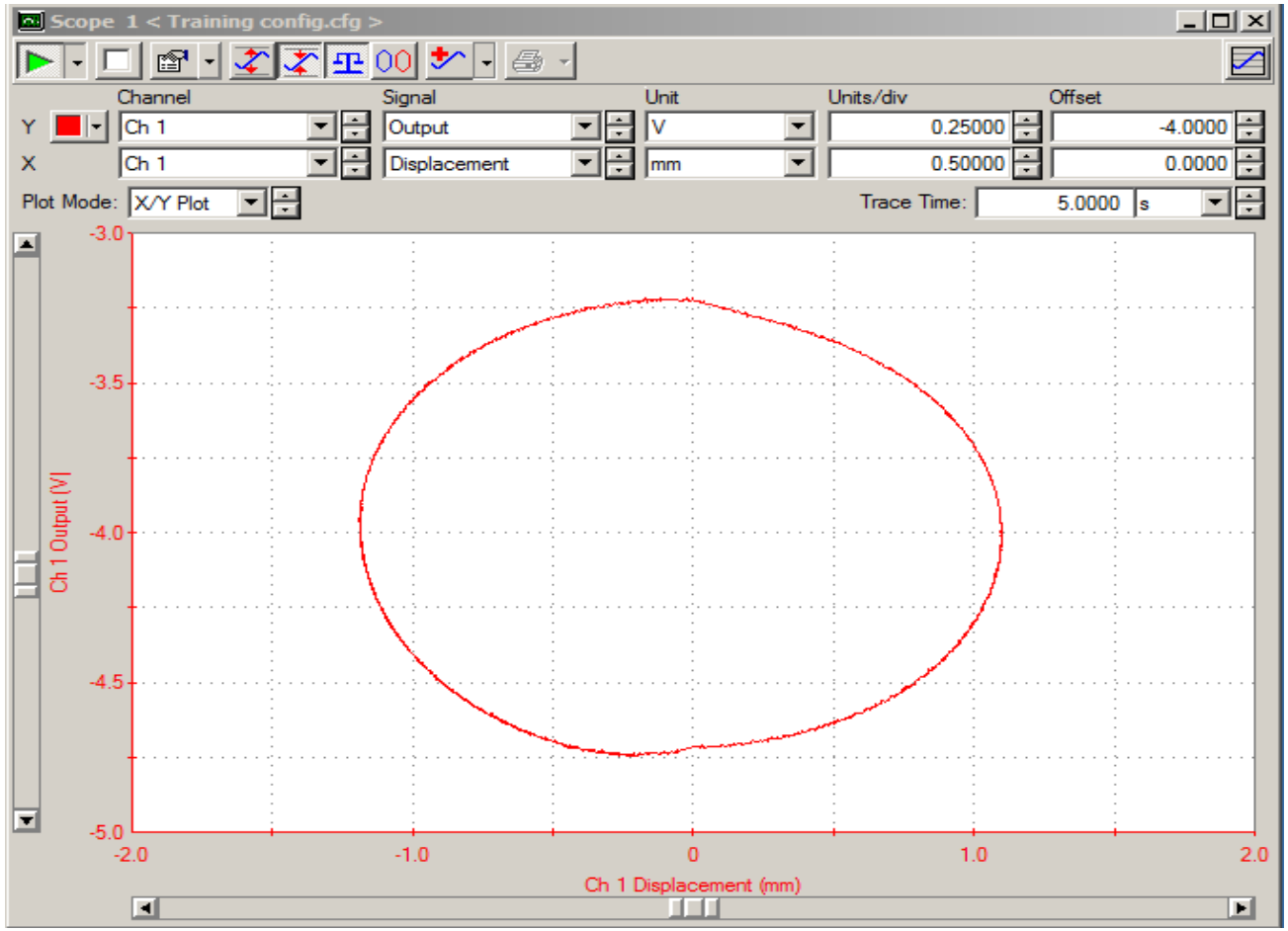
Worn Feedback Ball Evaluation

» Oil Limited Condition – System operated beyond capability



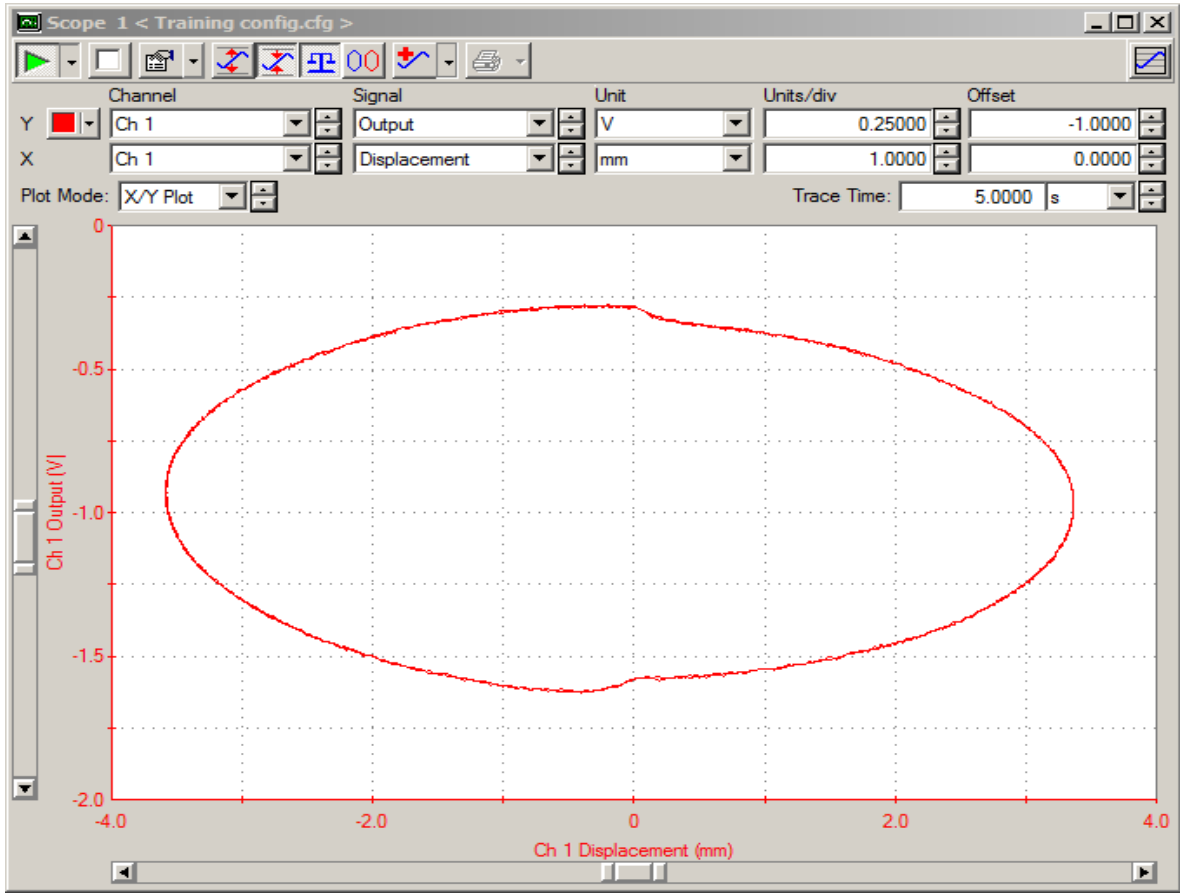
Worn Feedback Ball Evaluation

» Marginal condition – Minor Wear Present



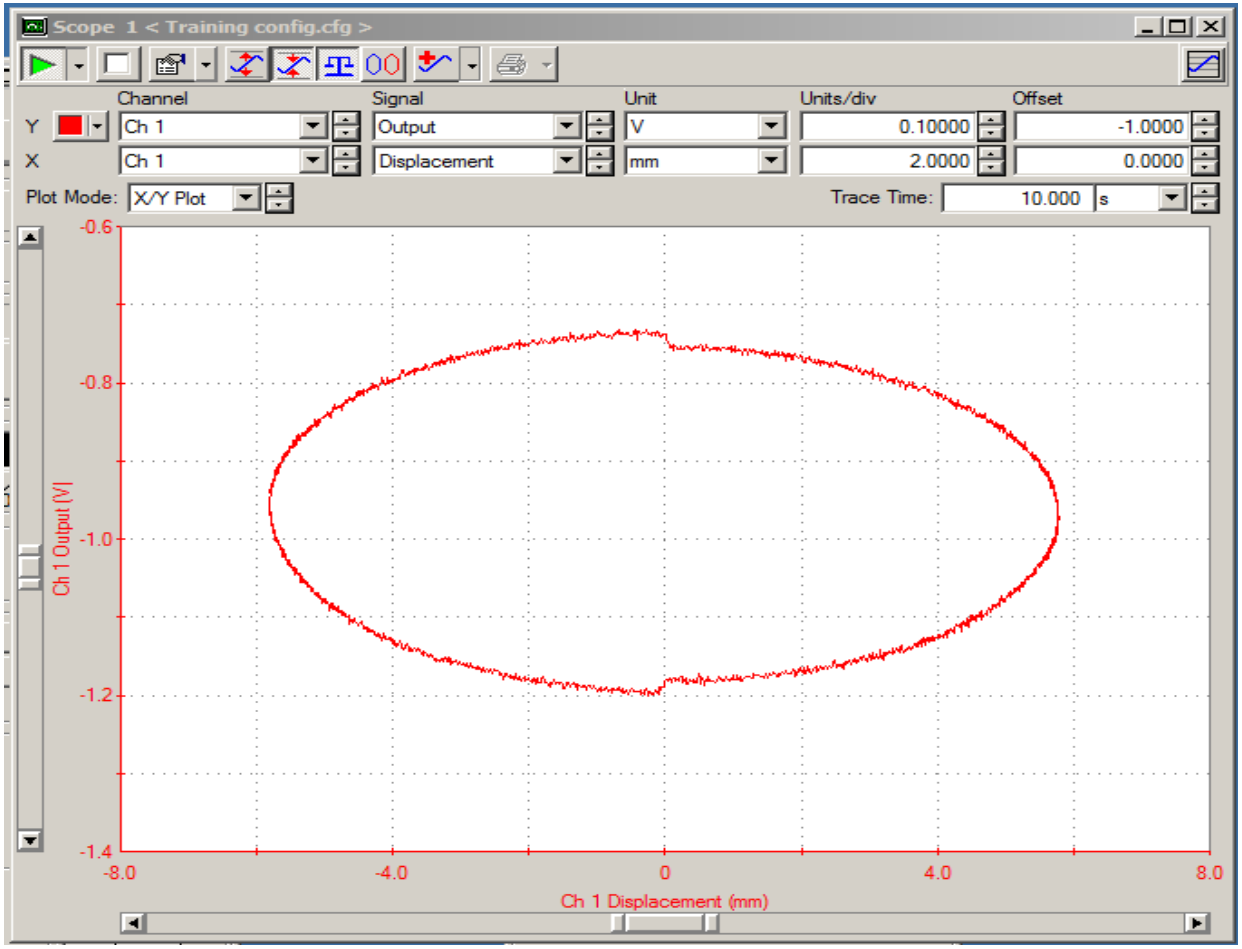
Worn Feedback Ball Evaluation

» Degraded condition – Wear Present



Worn Feedback Ball Evaluation

» Degraded condition – Significant Wear Present



Servovalve - Exchange

- MTS offers an exchange program for servovalve replacement
  - More cost effective than replacing with a new valve
  - Can be done rapidly. No waiting for repair time.
- The customer receives a remanufactured servovalve
- The valve which was replaced gets returned to MTS
- For complete guidelines including limitations see the service catalog

Servovalve Exchange

- Currently, If your customer has a servo valve that is either an A or B series servo valve, MTS can not exchange these valves.

- MOOG Servo Hydraulics, the original manufacture of the valves, no longer has replacement parts for these valves. The customer will have to purchase a new G series servo valve.

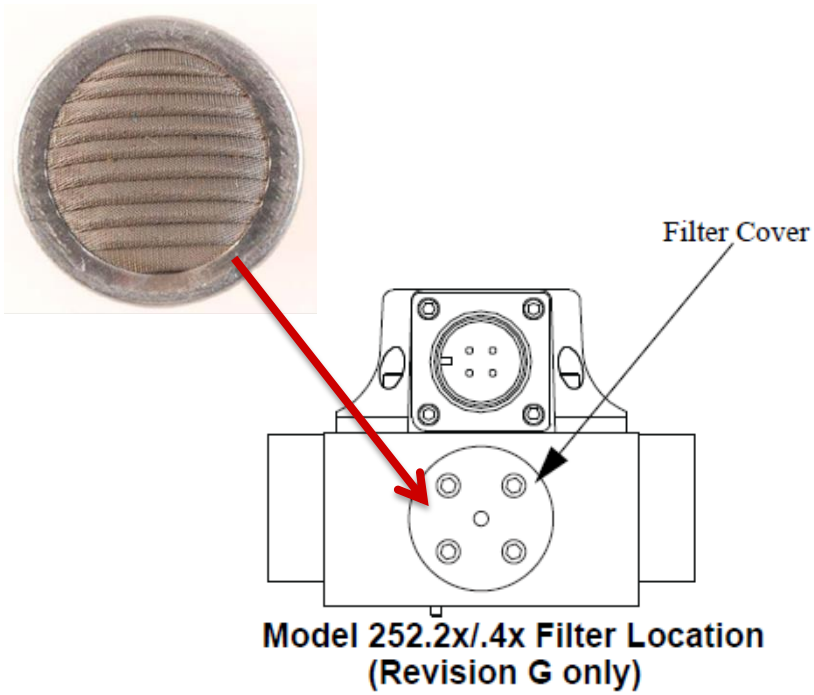
- An A or B series valve maybe returned to MTS for evaluation. MTS will only advise the customer on the status of the valve. No repairs will be performed. The customer is charged for this evaluation.

O-Ring Replacement

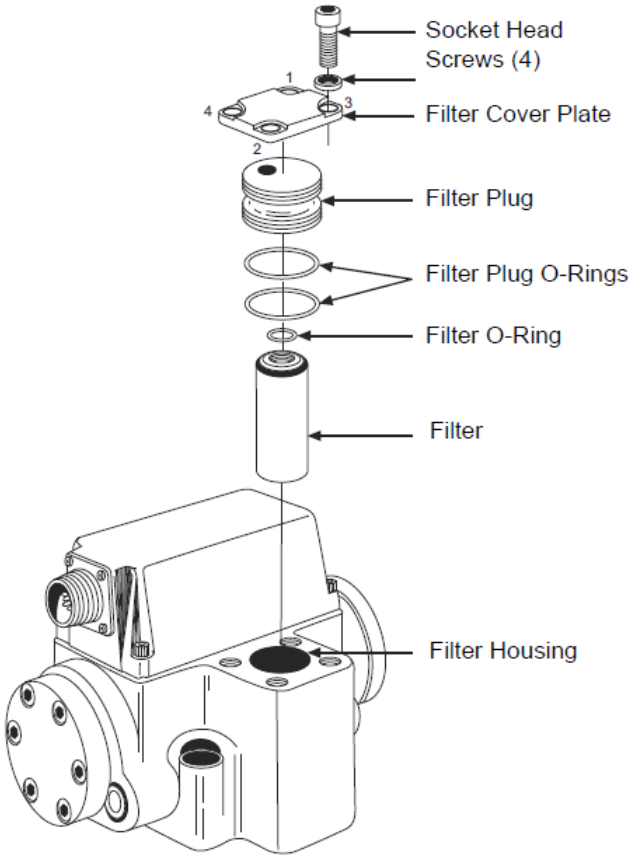
- When removing a servovalve from a manifold it is common that the O-rings have become flattened from being pressed against the manifold for an extended period of time – sometime years.
- When the O-rings are in this condition it is common for them to leak once the valve is reinstalled.
- Be prepared to change O-rings on older valves if they are being removed during troubleshooting
  - 252 main port O-ring
    - MTS P/N 010-010-510
      - .070X 90D BUNA-N .426ID
      - AS568A-013 90 Durometer
  - On older style 252 valves the pilot pressure port O-ring has a smaller diameter than the 4 main port O-rings.
    - MTS P/N 010-010-509
      - .070X 90D BUNA-N .364ID
      - AS568A-012 90 Durometer

Filter Replacement

» The 252.3X servovalve and the 252.2X G series servovalves have replaceable filters
  - Refer to appropriate product manual for replacement part number and procedure



Model 252.2x/.4x Filter Location (Revision G only)



Model 252.3x Filter Assembly

Valve Disassembly

» Never remove the torque motor or spool from the servovalve

- The torque motor mounting position is adjusted at manufacture
- It is not possible to reattach the torque motor and have the valve operate correctly
- Removing the spool while the toque motor is attached will damage the feedback wire. The valve will no longer be usable