Linear Actuators

November 7, 2015 Rev A

be certain.

Actuator Description

- A linear actuator displaces and develops forces in the axial direction.

- This is accomplished by applying high pressure oil to the piston surface inside the actuator
  - Maximum Force = Piston Area X Pressure

- A double ended actuator has the same piston area in both the extension and retraction direction

- A single ended actuator has unequal piston areas and can develop more force in one direction than the other.

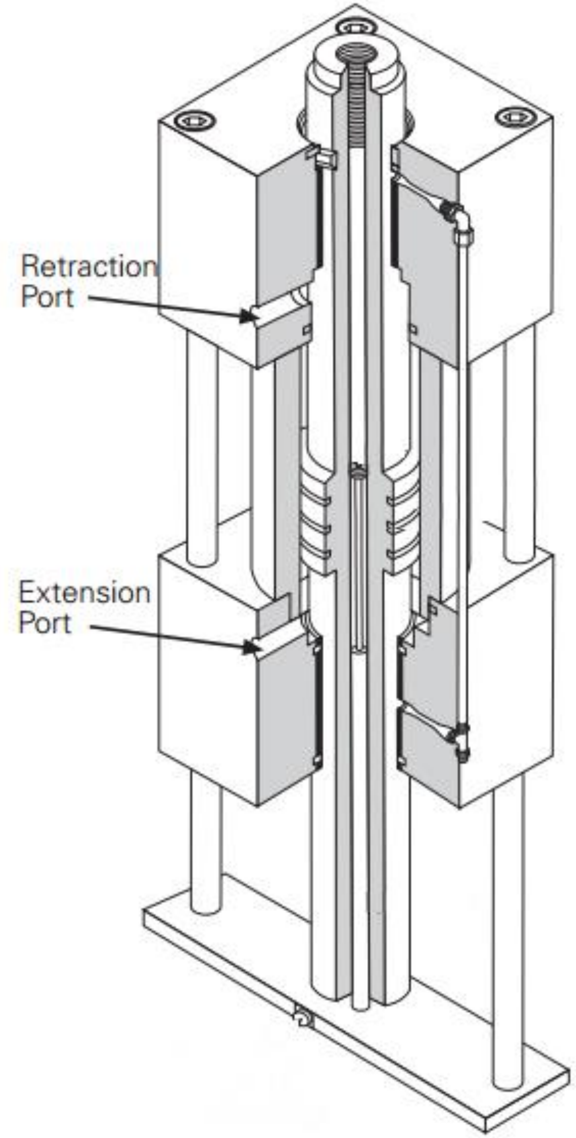
Actuator Models

» MTS has produced many different model actuators both in double ended and single ended configurations

Actuator	Style	Where Used	Piston Style
204	Structural	General purpose fatigue testing	Double Ended
204	Load Frame	312 Load frames	Double Ended
244	Structural	General purpose fatigue testing	Double Ended
244	Load Frame	318 Load Frames	Double Ended
248	Floor Standing	High Frequency vibration or Heavy mass loading	Double Ended
243	Structural	High Force – Quasi Static testing	Single Ended
370	Load Frame	Landmark Load Frames	Double Ended

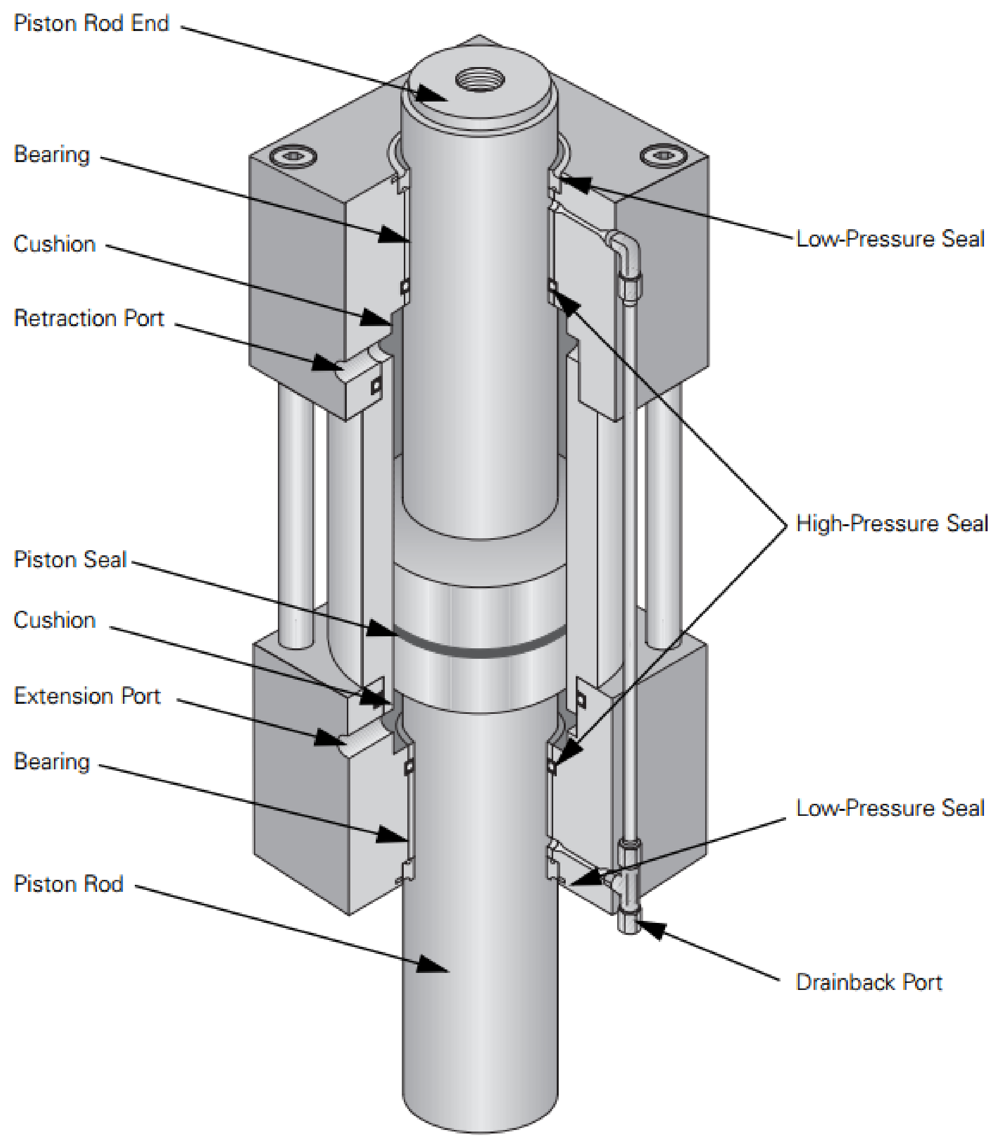
Actuator Operation

- » The servovalve controls the flow into the actuator to extend and retract or to apply compressive or tensile forces.
- » To extend the actuator pressure is coupled to the extension port and return is coupled to the retraction port
- » To retract the actuator the opposite is true. Pressure is coupled to the retraction port and return is coupled to the extension port
- » These ports are referred to as the C1 and C2 ports



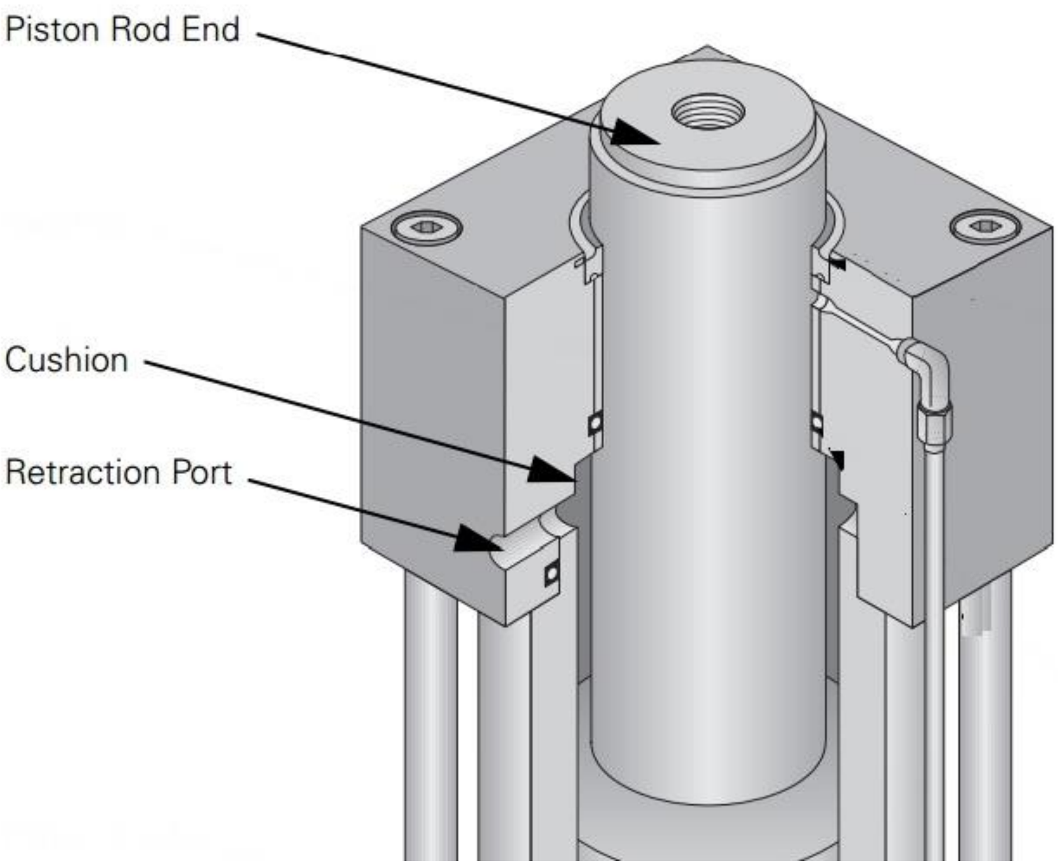
Actuator Internal Components

- An actuator has an upper and lower end cap.
- Each end cap has bearing material – typically nylon
- The piston is restrained by the bearing
- The oil seal configuration is dependent on the style of actuator



Hydraulic Cushion

» Dynamic actuators have a hydraulic cushion in each end cap



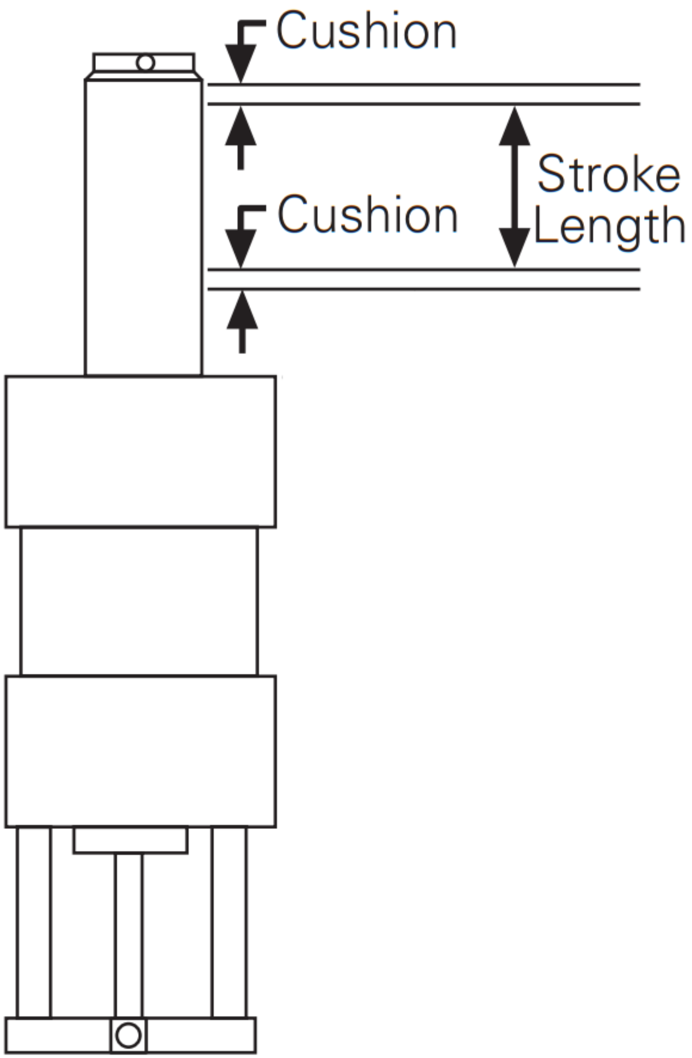
Hydraulic Cushion

- » The cushion decelerates the piston rod near the end of travel
  - Prevents the rod from contacting the end cap at a high velocity
  - Prevents metal to metal contact

- » The cushion works when the piston moves in front of the C1 or C2 port which effectively closes off the port and traps a cushion of oil between the piston surface and the end cap.

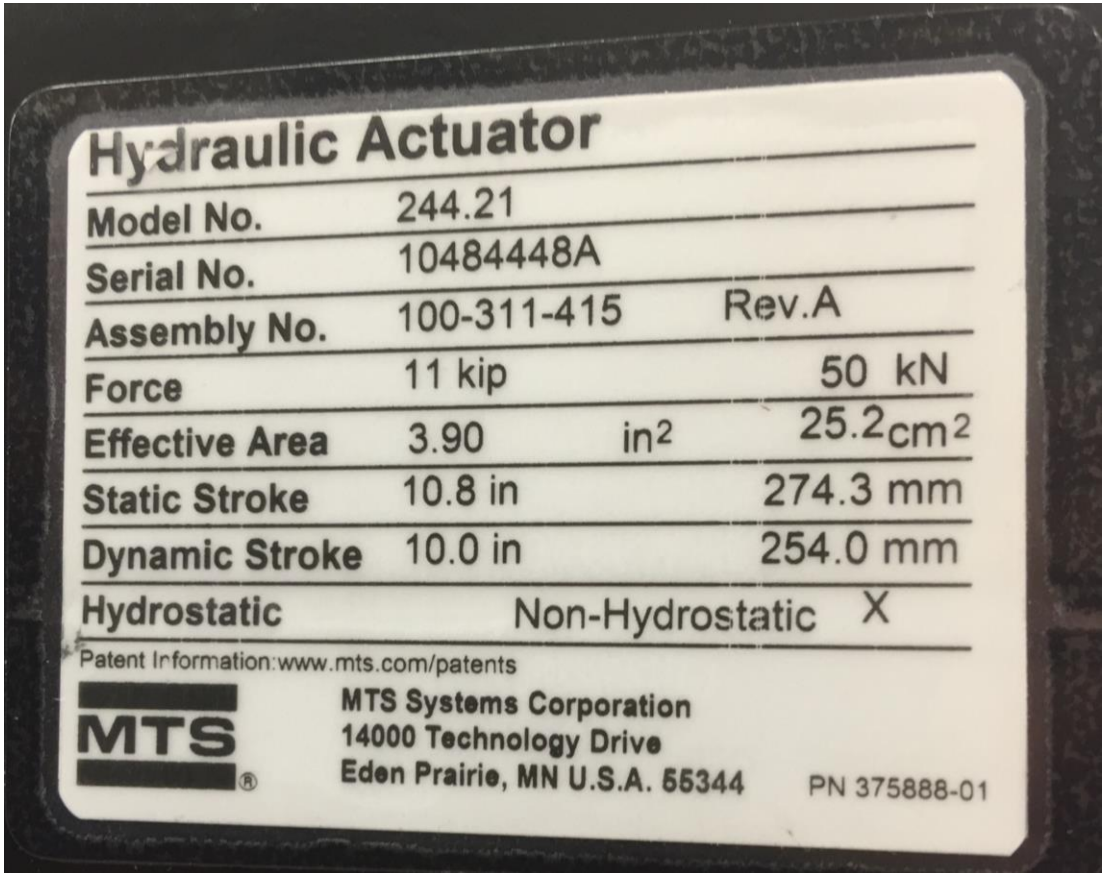
Hydraulic Cushion

- Because of the hydraulic cushion most dynamically rated actuators have 2 specifications for displacement
- The dynamic rating (Stroke Length) is the travel range between the 2 hydraulic cushions.
- The static rating is the absolute overall travel range including the distance the piston rod moves into the cushion



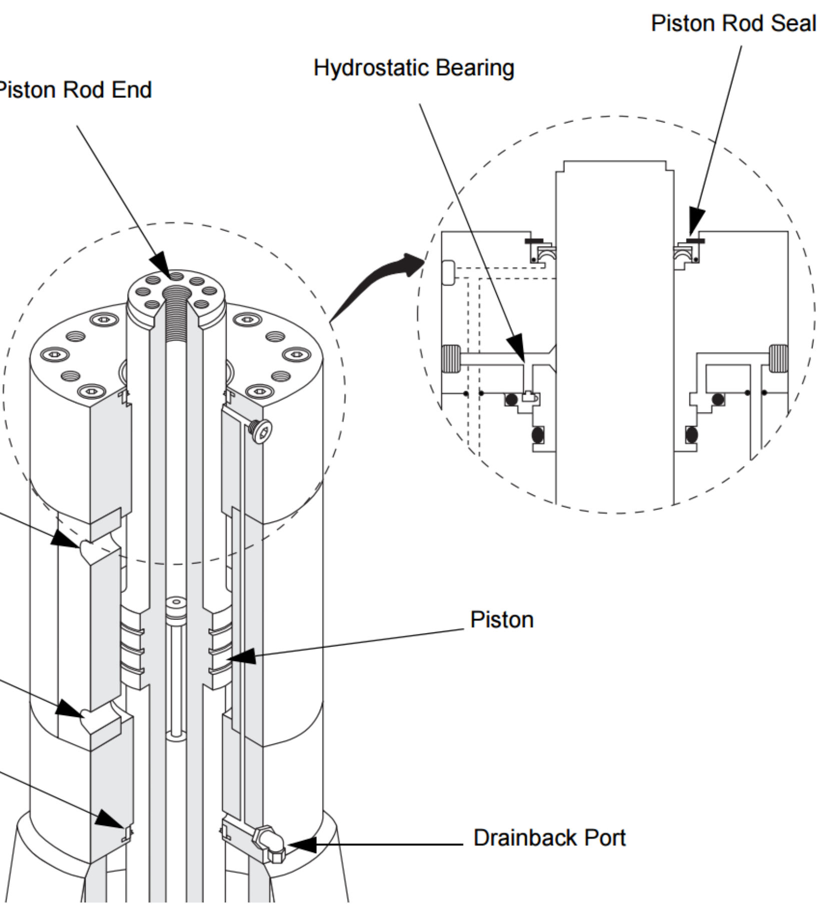
Hydraulic Cushion

- Both the dynamic and static stroke ranges are listed on the actuator nameplate
- Testing can only be performed in the area of the dynamic stroke range.



Hydrostatic Bearings

» Some actuators have hydrostatic bearings in each end cap. This option is used for systems where high side load forces are present.



Hydrostatic Bearings

» Hydrostatic bearings provide a film of oil between the nylon bearing in the end cap and the actuator rod. The actuator rod rides on this film of oil preventing direct contact of the actuator rod to the end cap.

» 3000 PSI Hydraulic oil from the HPU is supplied directly to the end cap.

» Hydrostatic bearing actuators require a larger drain hose due to the additional flow from the hydrostatic bearings.

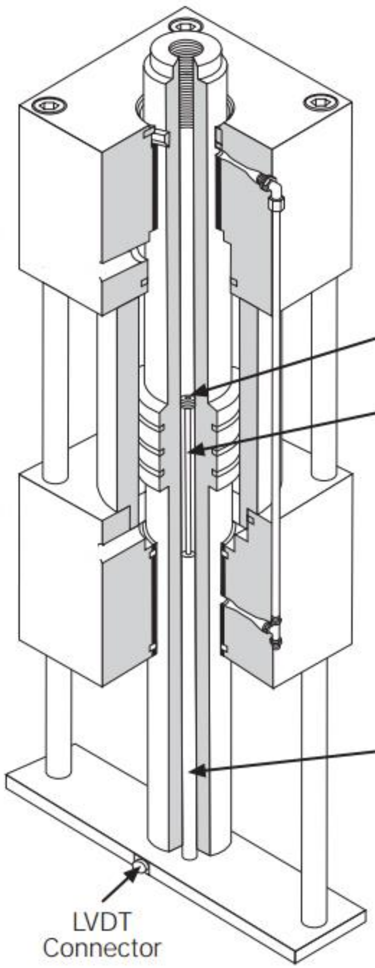
» The hydraulic oil is metered by capillaries installed into the end cap. These are a very small diameter tube which the oil flows though to the end cap bearing pad.

Hydrostatic Bearings

- There are 4 bearing pads in each end cap.
- The actuator rod to end cap tolerance is very small allowing only a small amount of oil from the hydrostatic bearing to flow. This maintains equal pressure on all bearing pads.
- If the actuator rod is forced off center due to side load the gap widens and the hydrostatic bearing pressure drops.
- The pressure on the opposite side forces the actuator rod back to center where the pressures once again equalize.
- If a capillary plugs or if there is an issue with the hydrostatic bearing the actuator rod will be forced into the opposite side of the end cap requiring high force to move.

Position Feedback

- Actuators have either a LVDT (Linear variable Differential Transformer) or a Temposonics displacement transducer for position feedback.
- The LVDT outputs a signal proportional to the displacement.
- See the transducers module for details on LVDT operation.



LVDT Connector

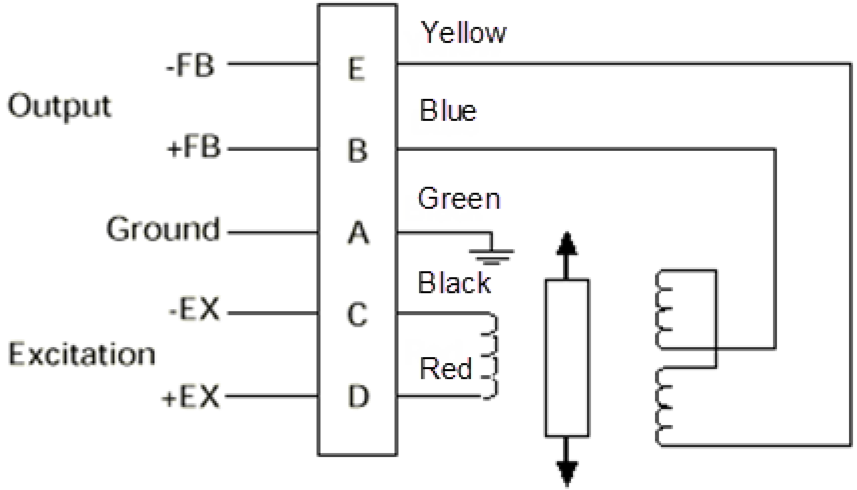
» The LVDT connector is either a 6 pin PT connector or a 13 pin JT connector.
- The 6 pin connector is used without TED's identification.
- The 13 pin connector is used with TED's identification.

6 Pin PT connector – NON TED's	13 Pin JT connector –TED's

LVDT Connector Wiring

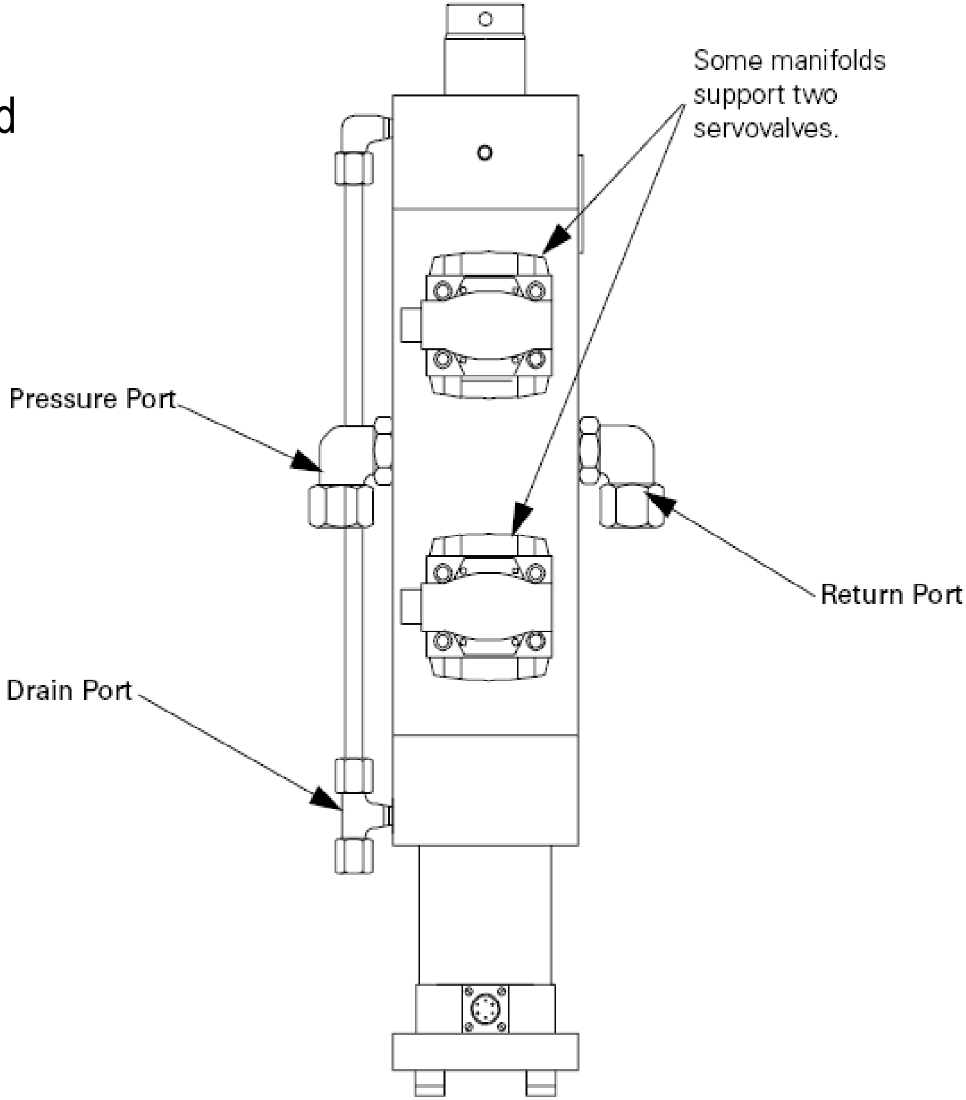
» The typical LVDT 6 pin connection at the actuator is shown below
  - When using a TED's 13 pin JT connector the wires are soldered directly to the TED's circuit board inside the connector to the terminals labeled with the signal name

6 pin Non-TEDs PT connector



Actuator Hose Connections

- Pressure and return hoses are connected to the fittings located on the servovalve manifold.
- The letter P is stamped into the manifold for the pressure hose, and a R for the return hose.
- The drain connection originates on the side of the end caps rather than the servovalve manifold. On a new actuator the drain has a red cap.
- DO NOT cross the pressure and return ports!
  - Doing this will cause damage to the servovalves



Drain

- Most modern Load Frame Actuators do not contain high pressure seals
  - Drain flow is minimized by a close tolerance of the end cap nylon bearing material to the piston rod
  - Drain connection size is typically -6 or larger for load frames.
  - Do not install a hose smaller than the actuator drain line fitting.

- Most structural actuators have high pressure seals
  - High pressure seals minimize the amount of drain flow
  - Drain connection size is typically -4 or larger for structural actuators
  - Do not install a hose smaller than the actuator drain line fitting

Drain Line Pressure

- These actuators were designed so that the maximum drain line back pressure should be < 5 PSI.
- Pressure > the 5 PSI may result is actuator leakage or seal damage.
- If the back pressure is to large, it can force the low pressure seals out of the end cap.
- Ensure the drain hose is not blocked, pinched, or otherwise restricting flow.
  - When a drain hose is blocked the low pressure seals will be blown out by pressure build up and damaged. This produces a loud bang and results in oil leakage.

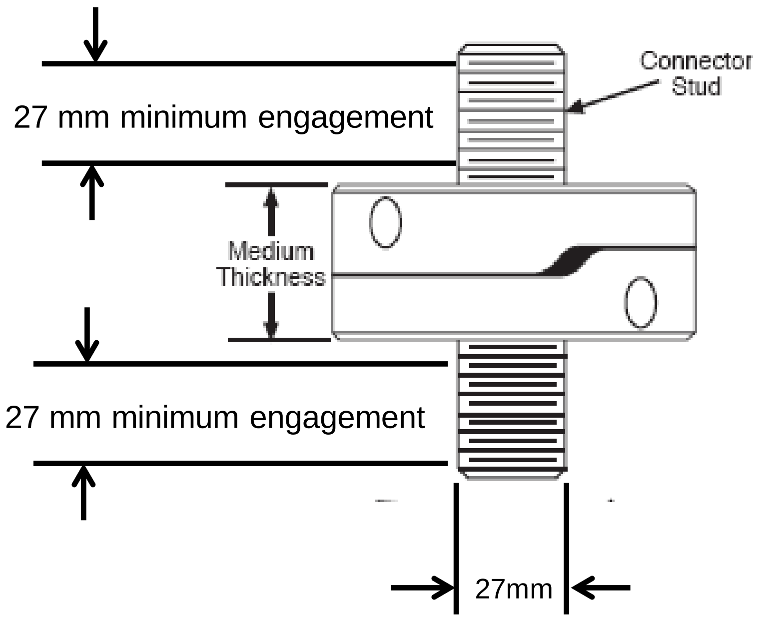
Drain Line Best Practices

- Never reduce the size of the drain line hose. The drain fitting on the actuator establishes the minimum size.
- Never connect the load frame cross head lifts / locks drain to the actuator drain connection.
- Use a separate drain line all the way back to the pump for load frame drain
- When connecting multiple 244 series actuators together via a common hydraulic line a sump pump may be required for collecting the drain flow.
- Never block the drain line.
- Never run the drain line back to the pump overhead.
  - Each 8’ of vertical lift adds 1 PSI to the drain line pressure

Installing a Fixture or Load cell to an Actuator

» The recommended minimum thread engagement into any device is equal to one times the thread diameter of the stud.

» The typical 100 kN actuator mounting stud is a 27 mm thread. A minimum of 27 mm of thread must be installed into both the actuator and the fixture.

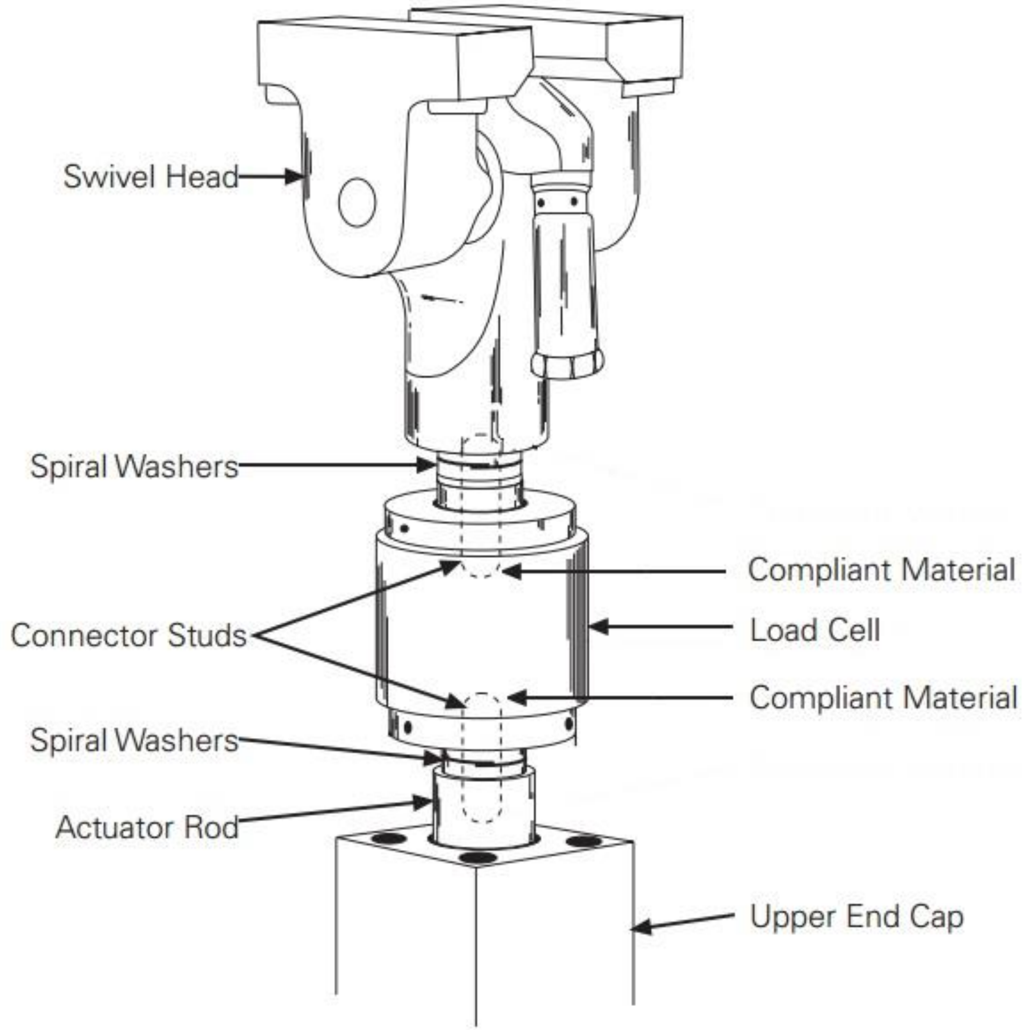


Stud Installation

- When inserting a stud into a load cell it should never be inserted until it bottoms out. This will cause errors in the calibration
- Prior to installing a stud into a load cell you should insert a thin piece of compliant material such as paper or thin cardboard into the load cell to prevent the stud from having direct contact with the bottom surface of the load cell threads.
- The threaded surfaces of the stud should be coated with Molykote gn paste prior to inserting the stud into the actuator or load cell.

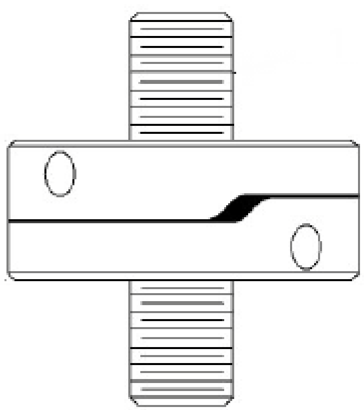
Load Cell / Swivel Attachment

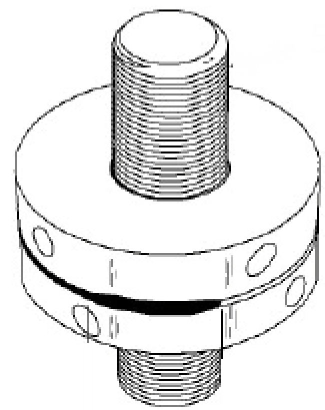
- It is common to use spiral washers to attach a load cell or swivels to a hydraulic actuator.



Pre-Loading Spiral Washers

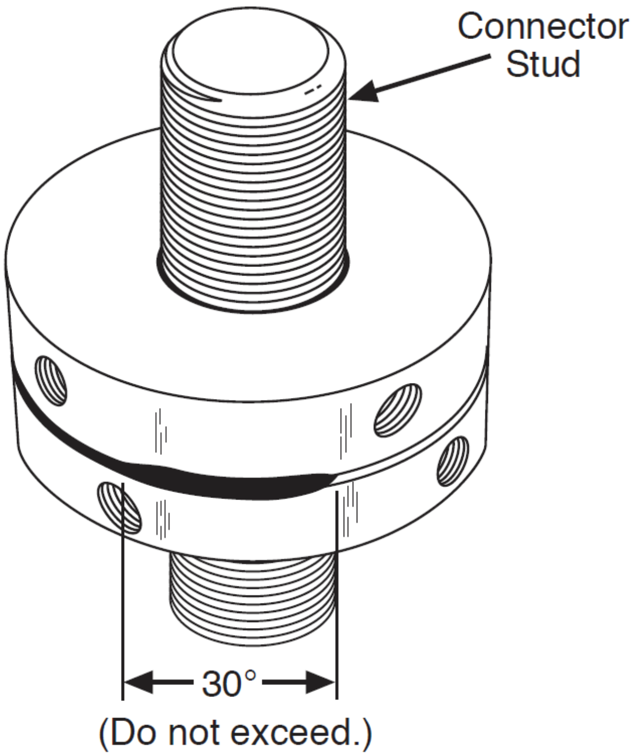
- Assemble fixtures or swivels so spiral washers have a small gap as illustrated in left picture below when hand tightened
- Attach actuator to a fixture which can sustain maximum load capacity.
- Using the hydraulic actuator apply a static load in the tensile direction of at least 10% to 20% greater than expected test loads.
  - Spiral washers preloaded to 110% system capacity at factory when requested





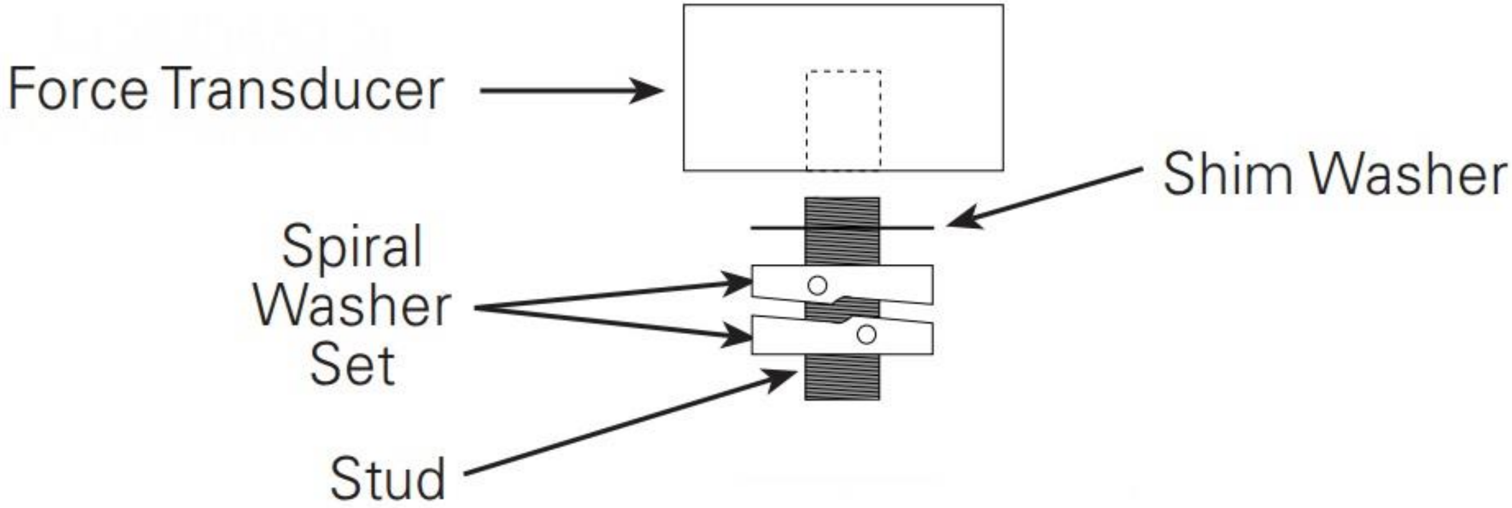
Pre-Loading Spiral Washers

- Using spanner wrenches rotate the two washers in opposite directions until they tighten.
  - Opening cannot exceed 30 degrees. If this happens, decrease initial gap size.
- Reduce force to zero
- Remove specimen



Spiral Washer Shims

» If you are installing a fixture or swivel on an actuator with an anti-rotate or on a fixed reaction base which does not rotate you may need to add a shim to align the fixture in order to keep the maximum opening of the spiral washers less than 30 degrees.



Spiral Washer Shims

» Kits which contain several thickness shims are available in different sizes to match standard MTS stud diameters.

» The chart on the following page lists shim kit part numbers along with the correct shim thickness and part number to use for common rotational increments.

» Example: If you have a ½" – 20 stud one complete turn is 0.050" travel. If you need to rotate the fixture 90 degrees you would use a 0.012" thickness shim P/N 443665-17

				APROX. ½ TURN (180°)	APROX. ¼ TURN (90°)	APROX. ⅛ TURN (45°)	APROX. 1/16 TURN (22.5°)
PART NUMBER (KIT NUMBER)	REV	THREAD SIZE ACTUATOR (OD)	REF. TRAVEL OF FULL TH'D	SHIM NUMBER THICK. (QTY)	SHIM NUMBER THICK. (QTY)	SHIM NUMBER THICK. (QTY)	SHIM NUMBER THICK. (QTY)
521050-01	B	½" - 20 358 ACT (1.12)	.050"	443665-16 .025 (1)	443665-17 .012 (1)	443665-13 .006 (1)	443665-18 .003 (1)

Shim Kit Part Number Reference

				APROX. ½ TURN (180°)	APROX. ¼ TURN (90°)	APROX. ⅛ TURN (45°)	APROX. 1/16 TURN (22.5°)
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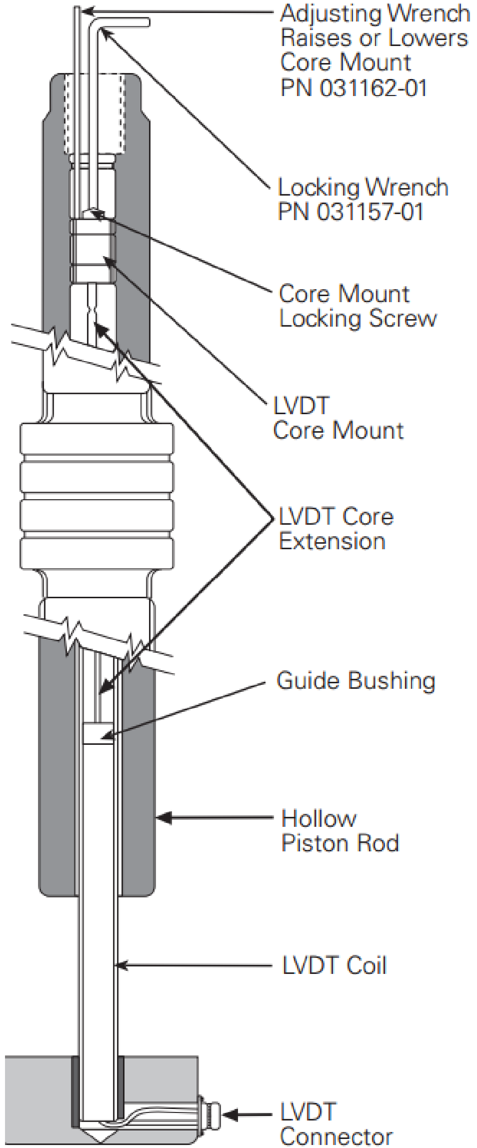
521050-01	B	½" - 20 358 ACT (1.12)	.050"	443665-16 .025 (1)	443665-17 .012 (1)	443665-13 .006 (1)	443665-18 .003 (1)
521050-02	A	M12 x 1.25mm 358 ACT (1.12)	.049"	443665-16 .025 (1)	443665-17 .012 (1)	443665-13 .006 (1)	443665-18 .003 (1)
521050-03	A	½" - 20 318 ACT (1.62)	.050"	443665-19 .025 (1)	443665-20 .012 (1)	443665-07 .006 (1)	443665-21 .003 (1)
521050-04	A	M12 x 1.25mm 318 ACT (1.62)	.049"	443665-19 .025 (1)	443665-20 .012 (1)	443665-07 .006 (1)	443665-21 .003 (1)
521050-05	A	1" - 14 318 ACT (2.62)	.071"	443665-22 .035 (1)	443665-24 .009 (2)	443665-24 .009 (1)	443665-25 .005 (1)
521050-06	A	M27 x 2mm 318 ACT (2.62)	.079"	443665-23 .020 (2)	443665-23 .020 (1)	443665-24 .009 (1)	443665-25 .005 (1)
521050-07	A	1-1/2" - 12 318 ACT (3.62)	.083"	443665-26 .020 (2)	443665-26 .020 (1)	443665-02 .006 (2)	443665-02 .006 (1)
521050-08	A	M36 x 2mm 318 ACT (3.62)	.079"	443665-26 .020 (2)	443665-26 .020 (1)	443665-27 .005 (2)	443665-27 .005 (1)
521050-09	A	2" - 12 318 ACT (4.62)	.083"	443665-28 .020 (2)	443665-28 .020 (1)	443665-15 .010 (1)	443665-29 .005 (1)
521050-10	A	M52 x 2mm 318 ACT (4.62)	.079"	443665-28 .020 (2)	443665-28 .020 (1)	443665-15 .010 (1)	443665-29 .005 (1)
521050-11	A	M76 x 2mm 311 ACT (7.00)	.079"	443665-35 .020 (2)	443665-35 .020 (1)	443665-36 .010 (1)	443665-37 .005 (1)
521050-12	A	M27 x 2mm 311 ACT (3.62)	.079"	443665-47 .020 (2)	443665-47 .020 (1)	443665-48 .009 (1)	443665-49 .005 (1)

LVDT Core Mount (Retainer)

- There are two Buna N O-Rings On the core mount (retainer).
- These expand as the bolt is tightened and clamp to the inside of the piston.
- After time these often become brittle or become hard.
- When this happens the LVDT will often slip, limiting the amount of displacement travel.

LVDT Core Adjustment

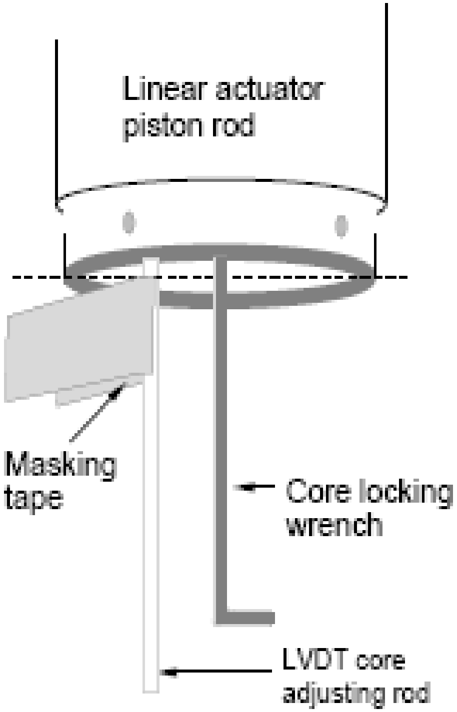
- To adjust the LVDT core perform the following.
- Remove the threaded insert in the end of the actuator if one is present.
- Screw the adjusting wrench into the LVDT Core mount (retainer).
  - The threaded hole in the LVDT core mount (retainer) is off center near the edge.
- Inert the long hex key locking wrench into the socket head cap screw.
  - The cap screw is in the center of the LVDT core mount (retainer)
- Loosen the core mount (retainer) with the locking wrench. Using the adjusting wrench move the core to the correct position and tighten the cap screw.



LVDT Core Adjustment

- To provide a reference mark, once the LVDT core adjusting wrench is fully installed and before moving the core place a piece of tape on the adjusting wrench as a marker at the edge of the piston rod. This will give you a visual indicator of the initial LVDT core location before the adjustment started.

- This technique can also be used when disassembling an actuator to replace the seals. When reassembling the actuator this will give you a reference where to initially set the LVDT core before performing the final adjustment.



LVDT Centering

- If an LVDT core becomes improperly centered in the coil an adjustment is required.
- The core can move during high velocity piston movement if the core mount is degraded or damaged
- This can be detected by an offset in the displacement.
- With the controller offset at zero the actuator cannot reach full travel in one direction while in the opposite direction the piston rod moves fully into the end cap but the transducer does not read full travel.

LVDT Centering

Determining the actuator midpoint

1. Ensure that the piston rod is fully retracted and all hydraulic pressure to the actuator (including service manifold accumulator pressure) has bled off.
2. Remove any accessory or specimen attachment fixture (such as a load cell or grip) from the piston rod.
3. Measure and record the distance from the top of the piston rod to the top of the cylinder end cap.
4. Apply low system hydraulic pressure.
5. Fully extend the actuator piston rod.
6. Measure and record the distance from the top of the piston rod to the top of the cylinder end cap.
7. Add the distance recorded in Step 3 to the distance recorded in Step 6 and divide the sum by 2.
8. Position the piston rod such that the distance between the top of the piston rod and cylinder end cap is the value determined in Step 7. This is the midpoint of the piston rod stroke.
9. Turn off system hydraulic pressure and ensure that all residual pressure (including service manifold accumulator pressure) has bled off.

LVDT Centering

WARNING

Do not adjust the LVDT core unless hydraulic power to the system is off, and residual hydraulic pressure in the system is at zero.

Adjusting the LVDT can generate a command signal that residual hydraulic pressure can use to unexpectedly move the actuator.

Ensure that all hydraulic power to the system is off and residual hydraulic pressure in the system pressure is at zero before adjusting the LVDT core.

Adjusting the core mount

10. Thread the adjusting wrench into the LVDT core mount.
11. Insert the hex head wrench into the core mount locking screw.
12. Monitor the AC signal from the LVDT (AC conditioner output) with an oscilloscope and adjust the LVDT core for minimum sine wave amplitude. If necessary, the adjusting wrench can be gently tapped with a plastic hammer.
13. Tighten the core mount locking screw to secure the core. Remove the adjusting wrench.
14. Check the calibration of the LVDT/conditioner pair. It may be necessary to recalibrate the LVDT. See the appropriate controller manual for a procedure to calibrate the LVDT or displacement.

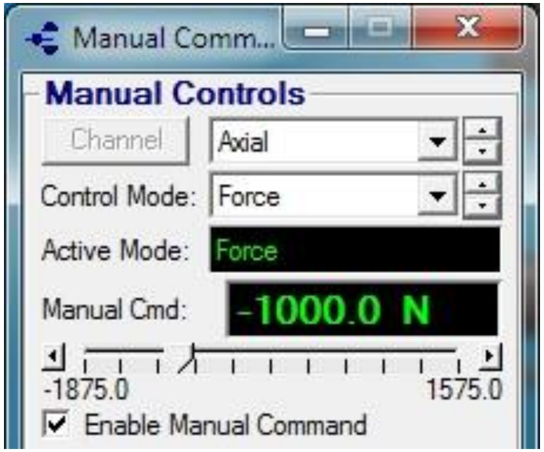
Alternate LVDT Centering

- If the actuator does not remain stationary when hydraulic power is turned off such as a vertically mounted actuator use this alternative method to center the LVDT.
- Fully retract the piston rod. Ensure it is fully in the end cap. Use force control if possible. If not, use the displacement offset to ensure the actuator is fully retracted.
- Record the value of the displacement channel feedback (LVDT feedback).

Alternate LVDT Centering

- Extend the piston rod fully to the opposite end cap.
- Record the value of the displacement channel feedback (LVDT feedback).
- Add the two values together and then divide by 2

  60 + (-90) = -30   -30 / 2 = -15



Alternate LVDT Centering

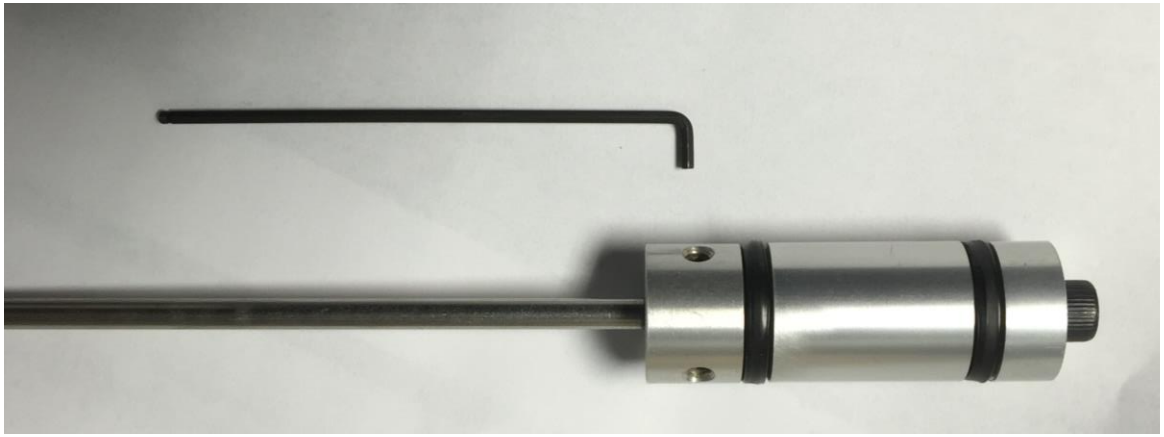
- This is the amount of offset of the current LVDT core position. If the sensor is not calibrated it will be approximate. This is OK. It will be calibrated later.
  - The LVDT core is approximately -15 mm offset.
- The offset can be subtracted from either fully extended or fully retracted reading to give the correct full scale travel the LVDT should read when fully extended or retracted.
  - 60 – (-15) = 75 mm full scale retracted.
  - -90 – (-15) = -75 mm full scale extended
- Move the actuator to the fully retracted position and turn off hydraulic power.
- Adjust the LVDT core while watching the feedback to the correct full scale value.
- In this case the core would move approximately 15 mm to make the transducer read 75 mm.
- Move the actuator to the opposite end cap and verify the value.

LVDT Replacement

- When replacing the LVDT the new core will be much longer than the one it is replacing. The replacement core needs to be cut to the correct length for the actuator.

- Remove the core from the retainer by loosening the set screws with a hex key. Cut the replacement core using a hacksaw to the same length as the one which was removed.

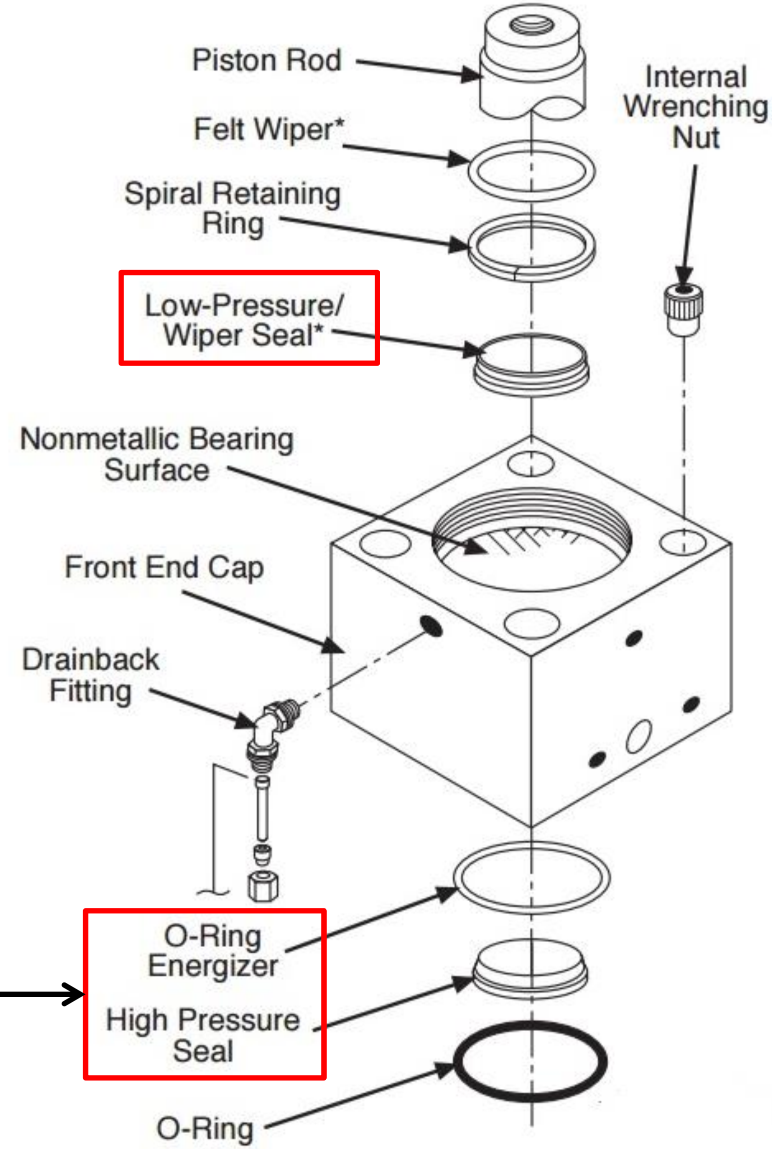
- Lubricate the core with Molykote gn paste prior to inserting it into the coil.



Actuator Seals

- Actuators are available both in a structural configuration and a load frame configuration.
- Most structural actuators contain high pressure seals
- Many Load frame actuators do not have high pressure seals

Not present on many load frame actuators



Actuator Seals – Drain Line Flow

- A good measure of the quality of the actuator seals is the amount of oil flowing out of the drain line.

- There is no specification on the amount of flow expected.

- This is best determined by observing the trend over time of oil flow from the drain line.
  - A significant increase in flow indicates the seals are wearing.

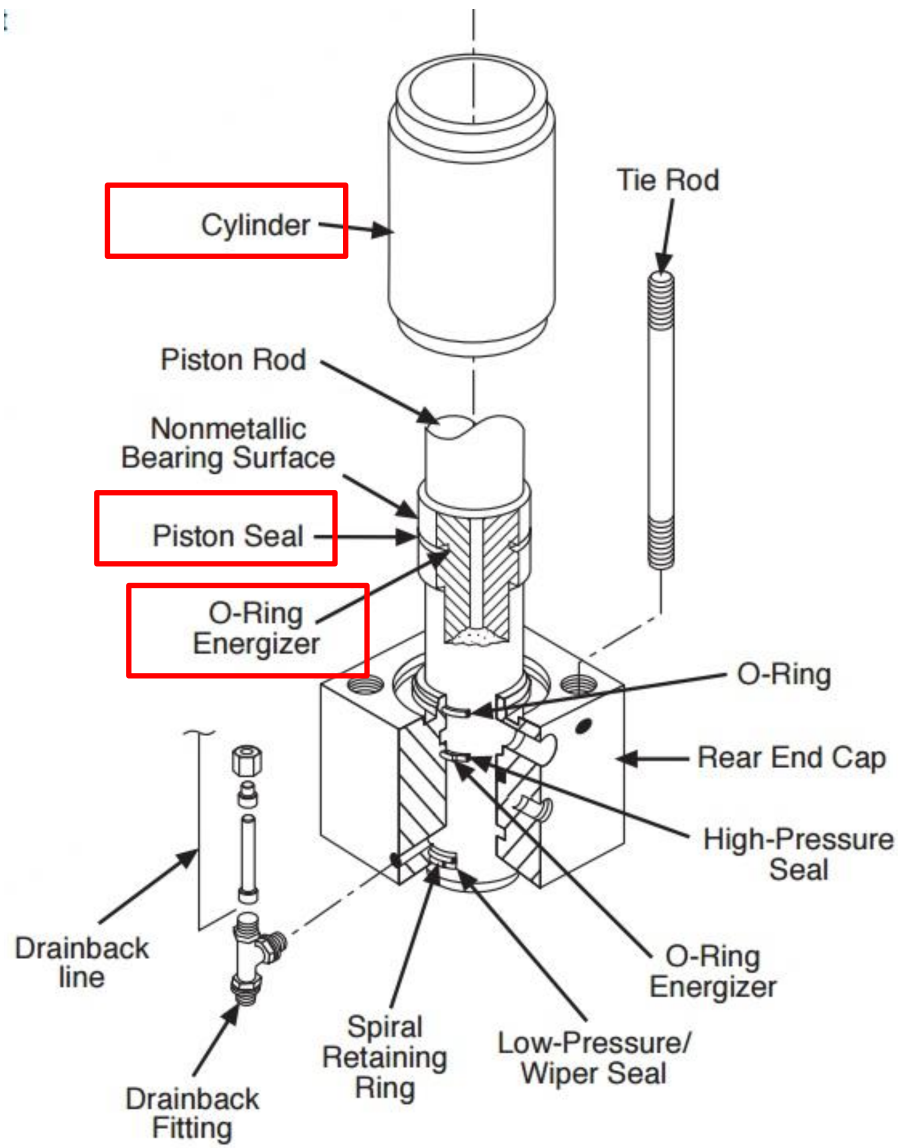
- Measure the drain line flow at regular intervals or when required for the routine maintenance interval.

Actuator Seals – Drain Line Flow

- A typical load frame actuator in new condition has much more flow than a structural actuator.
- A load frame actuator may normally flow 0.25 to 0.75 gallons per minute
- A structural actuator will have low flow such as a 0.05 to 0.10 gallons per minute.

Actuator Seals – Piston Seal

- When the seal on the piston wears the system will not be able to achieve full rated actuator capacity.
- This can also be caused by wear on the cylinder interior surface.



Actuator Seals – Piston Seal

- System tuning and HPU pressure can produce similar symptoms of not being able to achieve full load.
- Ensure the system is tuned and HPU pressure is at correct setting when the actuator will not achieve full load.
- If all performance adjustments are correct expect the piston seal has worn

Replacing Actuator Seals

MTS FSE MODULAR TRAINING

- It is not possible to remove a seal from an actuator without damaging it. You cannot remove a seal and then reinstall the same seal. Prior to disassembly order a seal kit so you have replacements available.

- Use the service catalog to locate a part number for the seal kit required.

244.xx Seal Kits (Load Frames)

Model	Rating	Description	Part Number
244.11	15 kN/3.3 kip	Seal Kit	008-710-067
244.12	25 kN/5.5 kip	Seal Kit	008-710-068
244.21	50 kN/11 kip	Seal Kit	008-710-069
			008-710-070
			008-710-071
			008-710-072
			008-710-073
			008-710-074

244.xx Seal Kits (Structural Applications)

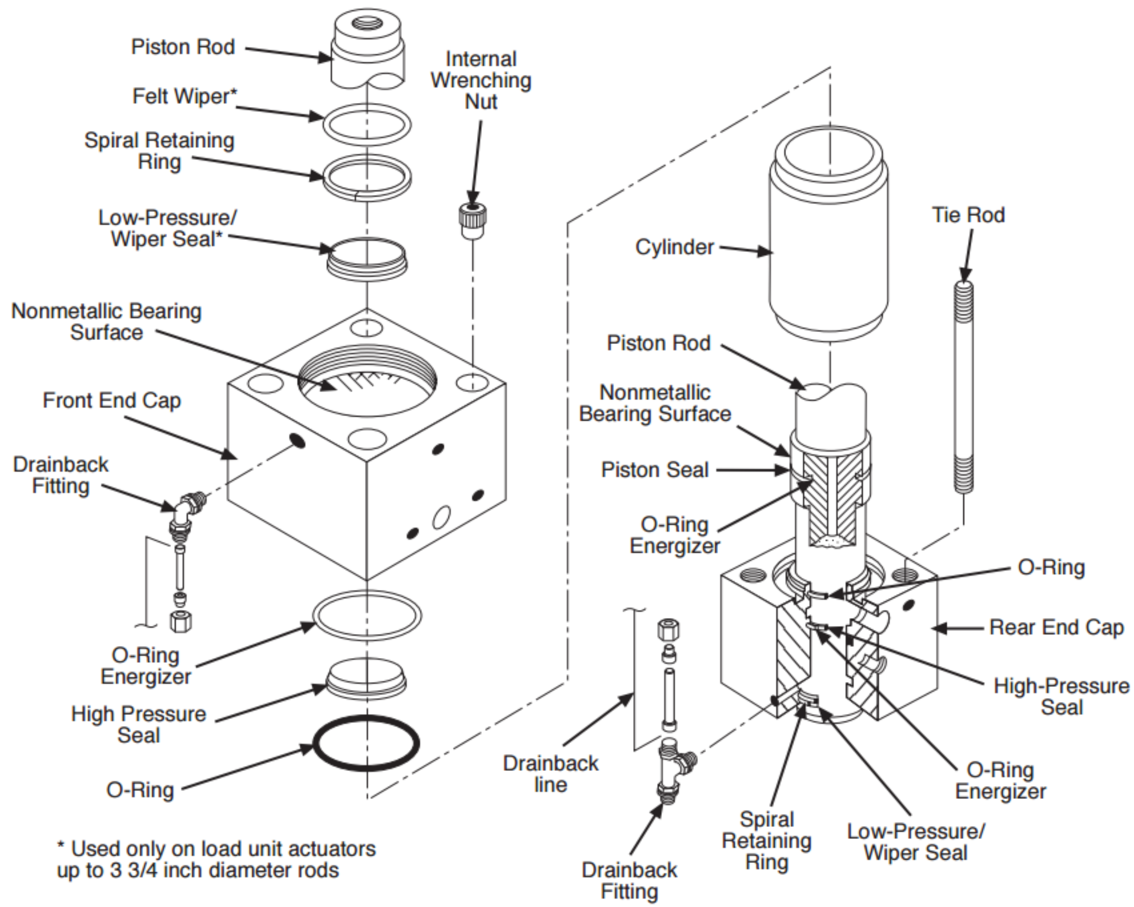
Model	Rating	Description	Part Number
244.11	15 kN/3.3 kip	Seal Kit	008-710-046
244.12	25 kN/5.5 kip	Seal Kit	008-710-047
244.20	68 kN/15 kip	Seal Kit	008-710-075
244.21	50 kN/11 kip	Seal Kit	008-710-048
244.22	100 kN/22 kip	Seal Kit	008-710-049
244.23	160 kN/35 kip	Seal Kit	008-710-050
244.31	250 kN/55 kip	Seal Kit	008-710-051
244.41	500 kN/110 kip	Seal Kit	008-710-052
244.51	1000 kN/220 kip	Seal Kit	008-710-053
O-Ring For Servovalve Manifold			010-010-710

Replacing Actuator Seals

- Turn off HPU and use proper lock out / tag out procedures.
- Ensure all stored energy is dissipated.
- Disconnect pressure, return, and drain hoses from actuator.
- Remove LVDT core to prevent damage.
- Remove front end cap.
- Remove piston rod and cylinder.

Replacing Actuator Seals

- Do not scratch the nylon bearing surfaces on the piston rod or the end cap.
- Use plastic or brass tools.
- Lubricate all seals prior to installation.



Series 244 Actuator Exploded View

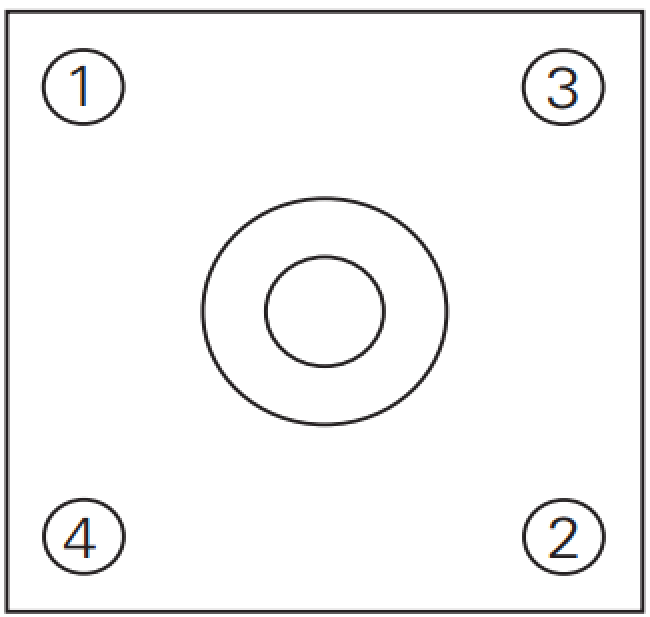
Replacing Actuator Seals

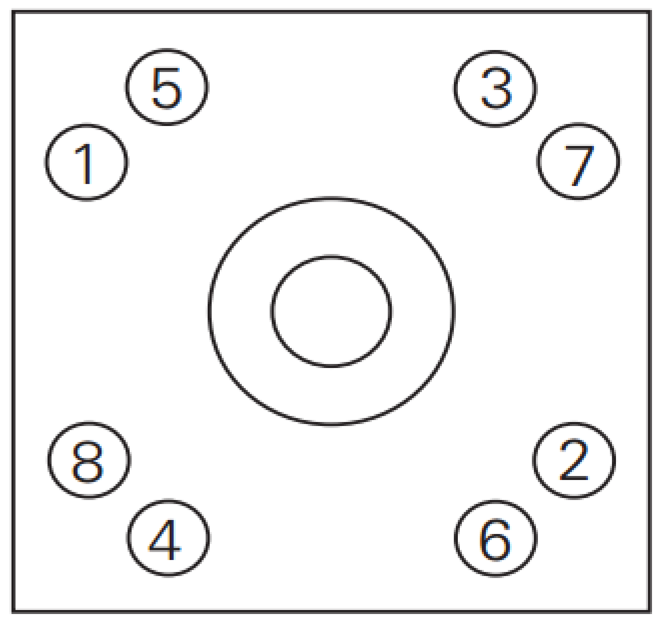
- Replace all O-Rings, high pressure seals, and low pressure seals.
- Reassemble actuator being sure to properly torque all fasteners.
- Reinsert the LVDT core.
- Center the core.

End Cap Fastener Torqueing

- When reassembling an actuator ensure the end cap fasteners are tightened to the proper torque using the correct pattern.

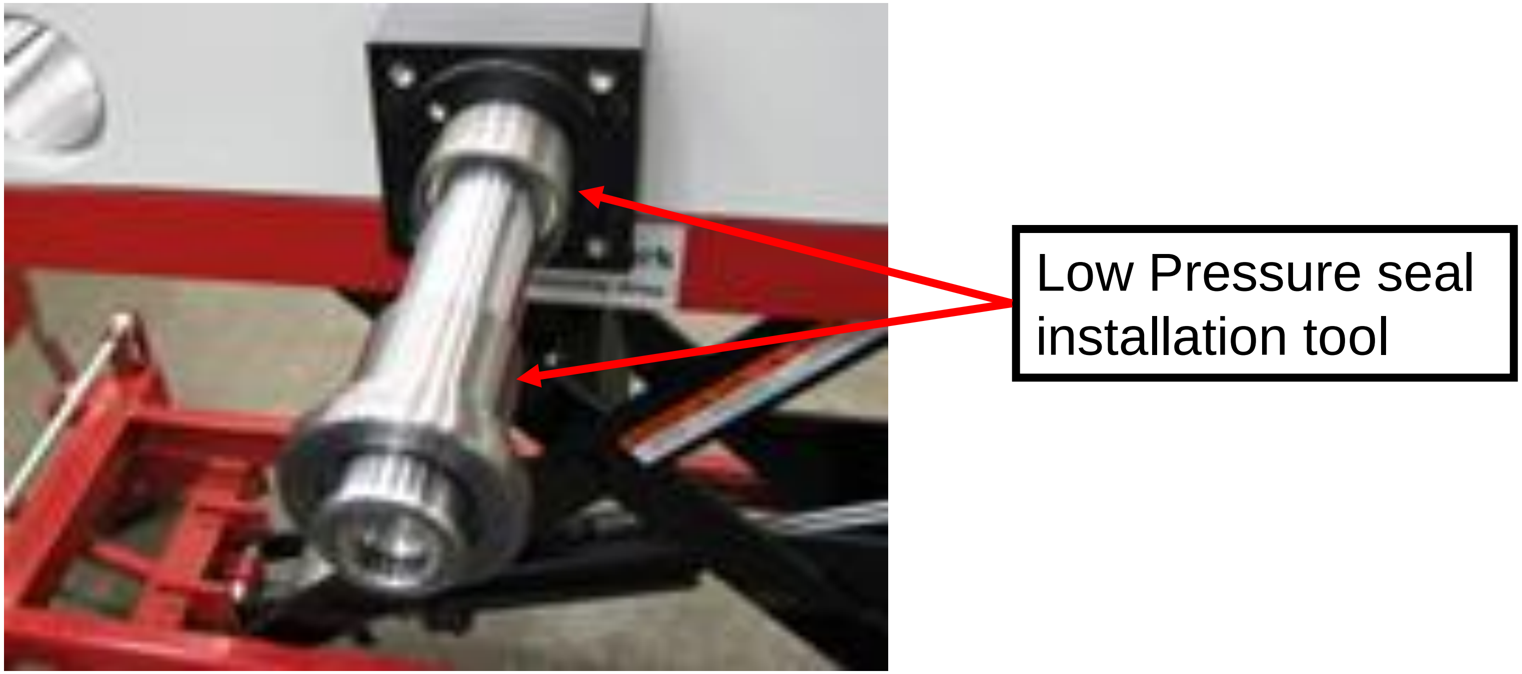
- The typical pattern for an actuator endcap is shown here.
  - Refer to the appropriate manual for toque values and pattern.





Seal Insertion Tools

» To replace the low pressure seal without removing the end cap requires the use of a seal insertion tool. This is a tapered ring to guide and compress the seal and a tool to push the seal into the end cap.



Seal Insertion Tools

- To remove the low pressure seal without taking off the end cap, remove the spiral retaining ring, remove the drain line to the end cap, and blow compressed air into the end cap through the drain line fitting.

- To reinstall use a seal insertion tool. These are available in sizes that fit MTS standard piston rod diameters.

Seal Insertion Tools

Actuator	Part Number
244.11/.12	465919-01
244.20/.21/.22/.23	465920-01
244.31	465922-01
244.41	465921-01
244.51	465923-01

Piston Rod Banding

- Piston rod banding can occur when the actuator is used in the same spot for millions of cycles on short displacement high frequency testing.
- When this happens the hard chrome surface of the piston rod is worn away.
- The actuator rod is damaged beyond repair if you can feel a groove with your fingernail where the banding occurs.
- The only way to repair this is to either replace the piston rod or send the actuator in for repair and have the piston rod ground and chrome plated.
- To prevent this type of damage the actuator starting position at the beginning of test should be changed every 1 million cycles.

204 Actuators

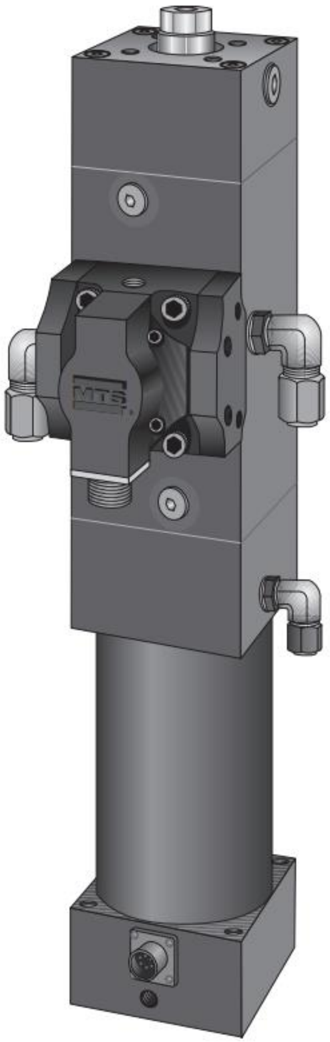
- The 204 series actuator is a medium to high force, double ended, fatigue rated actuator. This actuator has been replaced by the 244 series actuator and is no longer in production.
- These actuators are basically the same as the 244 series with the following differences:
- The 204 series actuator can show signs of drag when used in low force applications due to a very tight seal design. The 244 has a much lower drag due to lower seal friction.
- A normal 204 actuator may have only a drop or two of drain flow leakage per hour where as the 244 has a constant flow.
- If constant drain flow is observed on the 204 series actuator, the actuator must be resealed.
- The 244 was designed as a replacement for the 204. However, it is not always a direct replacement. Verify the mounting of the actuator into the load frame

242 Actuators

» The 242 is a low force, double ended, fatigue rated actuator.

» Actuator force capacities are listed below.

- 242.00 0.6 kip (2.7 kN)
- 242.01 1.0 kip (4.5 kN)
- 242.02 2.2 kip (9.8 kN)
- 242.03 3.3 kip (14.7 kN)



243 Actuators

» The 243 is a single ended actuator. These have a different force rating in tension and compression. These actuators are not fatigue rated and should only be used for static or quasi-static testing.

244 Actuators

» Model 244 actuators are medium to high force, double ended, fatigue rated actuator. This is the current production actuator used in the majority of MTS systems.

Model	Force Rating* kip	Force Rating* kN
244.11	3.3	15
244.12	5.5	25
244.21	11	50
244.20	15	68
244.22	22	100
244.23	35	150
244.31	55	250
244.41	110	500
244.51	220	1000

Series 244 Hydraulic Actuator with Optional Load Cell, Servovalve, Manifold, and Swivels

248 Actuators

» The 248 actuator is a pedestal mount, double ended, fatigue rated actuator. This actuator is used in high frequency vibration testing or testing which requires supporting a large mass.

Model	Force Rating KN	Force Rating lbs
284.01	10	2,200
248.02	16	3,500
248.03	28	5,500
248.04	38	7,700
248.05	50	11,000
248.11	100	22,000
248.12	160	35,000

Tools

- 003-116-201 Rod – Threaded End – LVDT Adjust
- 003-115-701 Key – Socket Head – LVDT Adjust
- 010-099-313 Spanner Wrench – Spiral Washers 19 mm to 50 mm (0.75 in to 2 in), Pin Diameter 3.2 mm (0.125 in)
- 010-099-304 Spanner Wrench – Spiral Washers 32 mm to 76 mm (1.25 in to 3 in), Pin Diameter 6.4 mm (0.250 in)
- 010-099-301 Spanner Wrench – Spiral Washers 50 mm to 120 mm (2 in to 4.75 in), Pin Diameter 6.4 mm (0.250 in)
- 010-099-303 Spanner Wrench – Spiral Washers 115 mm to 158 mm (4.5 in to 6.25 in), Pin Diameter 9.5 mm (0.375 in)