SERIES 204
HYDRAULIC ACTUATORS
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Figure 1 Typical Series 204 Hydraulic Actuator

The Series 204 Hydraulic Actuator is a linear Actuator designed specially for use in high-frequency applications such as structures and materials fatigue testing.

All 204 Actuators are double-acting and double-ended to present a balanced hydraulic configuration. Although the double-ended piston rod extends from the Actuator in both directions, one rod-end is frequently contained within a housing which is used for mounting swivel bases and/or stroke transducers such as linear variable differential transformers (LVDT's).

When supplied for structures testing, the Actuator assembly is usually equipped with swivels on one or both ends and may also include a Load Cell. A pattern of bolt holes in one end cap allows the Actuator to be installed in a Load Frame for materials testing.

The Servovalve regulates the amount of fluid flow, and speed and direction of piston rod movement. Parts of the Actuator are shown in figure 2.
Figure 2  Typical 204 Actuator Assembly Cutaway View
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Figure 1  Mechanically Actuated Limit Switches
INTRODUCTION

This manual contains adjustment procedures for various options frequently supplied with series 204, 205, and 209 Hydraulic Actuators.

ADJUSTING THE LIMIT SWITCHES

Two limit switch adjustment procedures are given in this manual: one for mechanically actuated limit switches and one for magnetically operated proximity-type limit switches.

Mechanically Actuated Limit Switches

The upper and lower limit switches are mounted on a track which allows them to slide to any desired tripping position when the associated locking bolts are loosened. The adjustment procedure follows (Figure 1):

1. Free the Actuator piston rod from contact with the specimen so that it can be moved up and down without applying force.

2. If you have not already done so, null the Controller meter (DC AMP or DC ERROR position) with the SET POINT control and apply high pressure.

   NOTE: On MTS systems, a tripped limit switch opens the Control Panel interlock and removes hydraulic pressure from the Servo-valve. To keep hydraulic pressure applied during limit switch adjustment, have someone push and hold the RESET button on the system control panel.

3. Loosen the locking bolts on the upper limit switch and slide the switch to its approximate tripping position.

4. Use the SET POINT control to move the Actuator piston to the desired upper stroke limit position. (If the system is not in stroke (displacement) control, it will be necessary to return the SET POINT control to its zero command position to stop the Actuator piston).

5. Alternately adjust the limit switch and the SET POINT control until the switch trips at the desired position. A distinct click will be heard when the limit switch actuates.

6. Tighten the locking bolt.

7. Repeat the procedure for the lower limit switch.
Figure 2  Proximity Limit Switches On Load Frame

Figure 3  Proximity Limit Switches Mounted Directly to Lower Housing of Actuator
Magnetically Operated Proximity Limit Switches

The upper and lower limit switches are mounted on a track which allows them to slide to any desired tripping position when the associated locking screws are loosened. The adjustment procedure follows (Figures 2 and 3):

1. Free the actuator piston rod from contact with the specimen so that it can be moved up and down without applying force.

2. If you have not already done so, null the Servo Controller's meter (DC AMP or DC ERROR position) with the SET POINT control and apply high pressure.

Note: On MTS systems, a tripped limit switch opens the control panel interlock and removes hydraulic pressure from the Servovalve. To keep hydraulic pressure applied during limit switch adjustment, have someone push and hold the RESET button on the system control panel.

3. Loosen the locking screw on the upper limit switch and slide the switch to its approximate tripping position.

4. Use the SET POINT control to move the actuator piston to the desired upper stroke limit position. (If the system is not in stroke (displacement) control, it will be necessary to return the SET POINT control to its zero command position to stop the piston.)

5. Alternately adjust the limit switch and the SET POINT control until the switch trips at the desired position. The associated STROKE LIMIT indicator on the Control Panel will light when the limit switch actuates.

6. Tighten the locking screw.

7. Repeat the procedure for the lower limit switch.

STROKE LIMIT RECOVERY

When a stroke limit occurs, the control panel interlock will open, removing Servovalve pressure. On the control panel, the appropriate STROKE LIMIT indicator and the RESET switch-indicator will light. Two stroke limit recovery procedures follow: one for mechanically actuated limit switches and one for magnetically operated proximity-type limit switches.

Mechanically Actuated Limit Switches

1. Push RESET on the system control panel. If the STROKE LIMIT and RESET indicators extinguish and stay extinguished, no further recovery is necessary. Simply apply hydraulic pressure in the usual way.
2. If the STROKE LIMIT and RESET indicators will not extinguish, the limit switch is still actuated. If possible, return the switch's lever to its normal position manually and push RESET. No further recovery is necessary.

3. If the actuator is holding the limit switch in its actuated position, making manual recovery impossible, push and hold the RESET button on the Control Panel.

4. Null the servo controller meter (DC AMP or DC ERROR position) with the SET POINT control.

5. Apply full hydraulic pressure to the Servovalve.

6. Turn the SET POINT control toward its zero command position (500 or 000). The actuator piston will move slowly away from the limit switch, allowing the control panel interlock to RESET permanently.

Magnetically Operated Proximity Limit Switches

1. Push RESET on the system control panel. If the STROKE LIMIT and RESET indicators extinguish and stay extinguished, no further recovery is necessary. Simply apply hydraulic pressure in the usual way.

2. If the STROKE LIMIT and RESET indicators will not extinguish, push and hold the RESET button on the control panel.

3. Null the servo controller meter (DC AMP or DC ERROR position) with the SET POINT control.

4. Apply full hydraulic pressure to the Servovalve.

5. Turn the SET POINT control toward its zero command position (500 or 000). The actuator piston will move slowly away from the limit switch, allowing the control panel interlock to RESET permanently.

POSITIONING THE ANTI-COMPRESSION VALVE

The anti-compression valve can be opened, to allow tension only, or closed, to allow tension and compression forces. The control knob for this valve is located on the 204 Hydraulic Actuator manifold.
Turn the control knob fully counterclockwise to open the valve. This prevents the application of a compressive force to the specimen.

Turn the control knob fully clockwise to close the valve. This permits either tensile or compressive forces to be applied to the specimen.

POSITIONING THE ANTI-TENSION VALVE

The Anti-tension valve can be opened, to allow compression only, or closed, to allow compression and tension forces. The control knob for this valve is located on the Hydraulic Actuator manifold.

Turn the control knob fully counterclockwise to open the valve. This prevents the application of a tensile force to the specimen.

Turn the control knob fully clockwise to close the valve. This permits either compressive or tensile forces to be applied to the specimen.
INTRODUCTION

The ball-socket swivel assembly is designed for structural fatigue applications. The bearing preload can be manually adjusted during operation to reduce the backlash close to zero and yet provide freedom to swivel.

Adjustment to zero backlash is necessary only if the particular test requires loading through zero at moderate or higher frequencies. In this case, preloading the bearing will eliminate impact noise and improve the load zero crossing waveform. For lower frequencies, or for tension-only or compression-only operation, the life of the bearing will be prolonged if the cap screws are tightened only as much as necessary to remove major backlash and not to actually place a preload on the bearing clearances.

ADJUSTING THE SWIVEL BEARING

If it is desired to preload the bearing, observe the following procedure:

1. Connect the actuator to a suitable tension-compression load.
2. Loosen the socket-head setscrews. See figure 1.
3. Lube the two socket-head cap screws and tighten them to remove excessive backlash. Alternately torque them in the increment shown until the backlash is reduced to an acceptable
level, but in no case exceed the maximum torque shown below:

<table>
<thead>
<tr>
<th>Swivel Assembly Load Rating</th>
<th>Cap Screw Size</th>
<th>Torque Increment</th>
<th>Cap Screw Max. Torque</th>
<th>Setscrew Torque</th>
</tr>
</thead>
<tbody>
<tr>
<td>12 KIP</td>
<td>1/2-20</td>
<td>20 ft-lbs</td>
<td>100 ft-lbs</td>
<td>50 ft-lbs</td>
</tr>
<tr>
<td>35 KIP</td>
<td>5/8-11</td>
<td>35 ft-lbs</td>
<td>170 ft-lbs</td>
<td>80 ft-lbs</td>
</tr>
<tr>
<td>70 KIP</td>
<td>1-8</td>
<td>100 ft-lbs</td>
<td>600 ft-lbs</td>
<td>100 ft-lbs</td>
</tr>
</tbody>
</table>

Cycle the actuator through its full tension-compression load cycle and check for backlash. If a sine wave is used to cycle the actuator, backlash will be represented by a discontinuity in the load readout near zero. If excessive backlash is still evident after the cap screws have been tightened to the maximum listed above, the swivel bearing is worn and needs replacement.

4. Tighten the socket-head setscrews to the torque listed in step 3.

RIGID MOUNTING

The swivel assembly is not suitable for rigidly supporting the actuator. A satisfactory method of locking the actuator so it will not swivel is to drill and bend four strong steel strips to fit between the actuator end-cap bolt-hole pattern and a solid structure such as the floor. Mount the strips at right angles to each other and at a substantial angle away from the actuator to provide firm omni-directional support.

Figure 2 Rigid Mounting of Actuator
RIGHT-ANGLE MOUNTING

If the swivel assembly is mounted to a surface such that the surface is approximately parallel to the direction of applied force, slipping can be anticipated at loads greater than those shown in the table below. If greater loads are required, separate retaining stops with larger bolts must be installed adjacent to the swivel assembly.

![Swivel Assembly Diagram]

Figure 3 Swivel Assembly Right-Angle Mounting

Before mounting the swivel assembly, clean the surface of all dirt and oil. The values in the table below are based on a Coefficient of Friction of approximately 0.1, which is readily attainable with steel-on-steel clamping.

<table>
<thead>
<tr>
<th>Swivel Assembly Load Rating</th>
<th>Mounting Bolt Size</th>
<th>Mounting Bolt Grade</th>
<th>Mounting Bolt Max. Torque</th>
<th>Approx. Load at Slip</th>
</tr>
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<tr>
<td>12 KIP</td>
<td>1/2-13</td>
<td>5</td>
<td>55 ft-lb</td>
<td>3-1/2 KIP</td>
</tr>
<tr>
<td>12 KIP</td>
<td>1/2-13</td>
<td>8</td>
<td>80 ft-lb</td>
<td>5 KIP</td>
</tr>
<tr>
<td>35 KIP</td>
<td>5/8-11</td>
<td>5</td>
<td>110 ft-lb</td>
<td>5-3/4 KIP</td>
</tr>
<tr>
<td>35 KIP</td>
<td>5/8-11</td>
<td>8</td>
<td>170 ft-lb</td>
<td>8 KIP</td>
</tr>
<tr>
<td>70 KIP</td>
<td>3/4-10</td>
<td>5</td>
<td>200 ft-lb</td>
<td>8-1/2 KIP</td>
</tr>
<tr>
<td>70 KIP</td>
<td>3/4-10</td>
<td>8</td>
<td>280 ft-lb</td>
<td>12 KIP</td>
</tr>
</tbody>
</table>

SWIVEL BEARING LUBRICATION

The swivel bearing should be lubricated approximately every 8 operating hours or at longer intervals if less severe operating conditions permit. Lubricate with "Mobil Grease Special" or an equivalent lithium-base grease containing one percent molybdenum disulfide (MoS₂).
Figure 1 Typical Series 204 Hydraulic Actuator

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The series 204 Actuator is designed for long periods of trouble-free service without extensive maintenance. Routine preventive maintenance can usually be restricted to keeping the exposed piston rod clean.

**REPLACEMENT OF LOW-PRESSURE ROD SEALS**

Oil leakage past the low-pressure rod seals is a sign of seal wear. The seals can be replaced without disassembling the cylinder assembly, except for models 204.08 and 204.09 where the seals are in end cap grooves and require removal of the end cap from the Actuator rod for replacement. Perform the following procedure; refer to figure 2 which shows all parts of the seal assembly. NOTE: Low-pressure seals are used in both end caps of the Actuator.

![Diagram of Actuator Rod and Seal Assembly]

**Figure 2  Low-Pressure Rod Seal Assembly**

1. Remove the snap ring from the end cap by inserting a screwdriver into the slot on top of the ring and prying toward the rod.

2. Disconnect the drainback fitting from the end cap.

3. Apply pressurized shop air through the drainback port to blow the low pressure seal, seal retainer and scraper ring out of the end cap.

4. When reassembling, be sure the "O" ring slot in the new seal faces inward. Be sure the seal is in place before inserting the seal retainer. If necessary, gently work the seal into place from the top with a thin steel shim or scale. Take care to avoid cutting the seal.

5. Insert the seal retainer with the flat side facing inward.

6. Insert the scraper ring (also with the flat side facing inward).

7. Insert the snap ring.
Figure 3  Typical Series 204 Actuator Assembly Cut-away View
DISASSEMBLY, INSPECTION AND REASSEMBLY

The Actuator should not be disassembled except to replace the high pressure rod seals and the piston seal or to remove them for viscous seal operation, or to replace the low-pressure rod seals for models 204.08 and 204.09.

NOTE: Some 204 Actuators are supplied without piston seals for better high-frequency operation.

If inspection of disassembled parts reveals damage or excessive wear, consult MTS before attempting to remedy the problem.

Refer to figures 3 and 4 while performing this disassembly procedure.

1. Remove all accessories from the Actuator (Load Cells, manifolds, pedestal base, etc.). Remove any specimen attachment fixtures from the rod. Cover all hydraulic ports that may expose the Servovalve to contamination.

2. Disconnect the drainback hose and remove the drainback plumbing between the two end caps.

3. If the Actuator has an internally mounted LVDT, for models with a sliding core retainer, remove the core as shown in figure 4: thread an adjusting wrench into the core retainer, loosen the retainer with a 3/16-inch (4,76 mm) hex key and pull the retainer-core assembly out of the rod with the adjusting wrench. For model 204.08 or 204.09 use a hex key to remove the locking setscrew, and then the core retainer setscrew and core (turn counterclockwise).

Model 204.5X/.6X/.7X/.8X/.9X Actuators

Model 204.08/.09 Actuators

Figure 4 LVDT Core Removal
4. Remove the four Allen nuts, in the top end cap, from the tie rods.

5. Carefully slide the end caps off the rod. It may be necessary to tap the end caps with a plastic mallet to loosen them.

6. Carefully slide the piston out of the cylinder.

7. Inspect the bearing surfaces on the piston and on the inside of the end caps. Measure the eccentricity of the bearing surfaces on each end cap. It should not exceed .002 inches (0.051 mm).

NOTE: In performing steps 8 and 9 (removal of the piston seal and high-pressure rod seal) it is virtually impossible to avoid damaging the seals. Therefore, do not attempt to remove them unless new seals are available or they are to be left out for viscous seal operation.

8. Remove the piston seal by working it out of its groove with a probe. Be very careful to avoid scratching or lifting the non-metallic bearing surfaces. Carefully work the seal over the bearings to the end of the piston.

9. Remove the high-pressure rod seals from the end caps by working them out of their grooves with a probe. Use the same precautions as in step 8.

10. To install a new piston seal, gently stretch the new seal to fit it over the piston. Carefully work the new seal by hand over the bearings and into its groove.

11. To install new high-pressure rod seals, use a thin steel shim or scale to gently work the seals into their grooves. Be sure the seals are in place before reassembling.

12. To reassemble the Actuator, reverse the disassembly procedure. When placing the piston back into the cylinder, compress the piston seal (if included) with a clamp and tap the end of the rod with a plastic mallet until the seal is inside the cylinder.

Before tightening the tie rods, mount the Servovalve manifold loosely to align the end caps.

Coat the Allen nuts with grease and tighten the tie rods moderately. Check for binding or friction (be sure the piston can stroke freely).

Torque the tie rods to the torque specified on the Actuator cylinder assembly drawing. Check for piston rod binding. Use a spanner to rotate the piston rod and free it from seal friction, then stroke it. If binding is detected, contact MTS Service Department.

Tighten the manifold and reconnect all hoses, fittings and accessories. Flush the Actuator according to the procedure under FLUSHING, on page 6.
13. To assemble the LVDT core (if included) proceed as follows for models with a sliding core retainer. Refer to figure 5.

*** WARNING ***

Actuator rod movement can be sudden, fast, and with high force, even with low hydraulic pressure if large core adjustments are made while the control is adjusted for either positive or negative SET POINT commands. Move the crosshead and Load Cell if necessary to allow ample clearance for Actuator rod movement when the adjusting wrench and operator's hands are above the end of the fully extended rod.

Select LOW HYDRAULIC PRESSURE on the Control Panel. Select STROKE control on the Controller. Adjust SET POINT to move the Actuator rod all the way down, or in, into the cushion if any, until it bottoms. Push HYDRAULIC OFF on the Control Panel. Before inserting the core coat it with Texaco MOLYTEX #2 grease or equivalent. Insert the core, carefully guiding it into the LVDT. Keep grease away from the piston rod bore. (The core retainer will not lock on grease). Push the core all the way in and pull it back 0.50 inch (12.70 mm) then lock it just enough to hold it securely in place. Measure the distance from the top of the Actuator rod to the top of the cylinder end cap. Push LOW HYDRAULIC PRESSURE on the Control Panel. Move the Actuator rod all the way out and again measure from the rod end to the end cap. Add the two measurements and divide by 2. Move the Actuator rod down to this distance (this is the mid-point of the piston rod stroke). Push HYDRAULIC OFF on the Control Panel. Monitor the AC signal on an oscilloscope, and adjust the LVDT core to minimize trace amplitude (by tapping the adjusting wrench with a plastic hammer). Then lock the core retainer.

For model 204.08 or 204.09 proceed as above, except insert the core and turn the screw clockwise until it is flush with the end of the Actuator rod. To adjust the core, turn the setscrew with the hex key to minimize the oscilloscope trace amplitude. Then insert the locking setscrew and lock the core in place.
Figure 5 LVDT Mounting
FLUSHING

Flushing the Actuator will remove contaminants, ensuring smooth operation and minimum wear. The Actuator should be flushed after reassembly or any time it is suspected that contamination has entered the cylinder.

1. Remove the Servovalve and cover its exposed ports with a clean Servovalve cover plate.

2. Mount an MTS series 291 4-way flushing valve in place of the Servovalve.

3. Remove from the piston rod any specimen, fixture or other apparatus which would restrict movement. The rod must be free to stroke the full length of the cylinder.

4. Energize the Hydraulic Power Supply and apply full operating pressure to the Actuator.

5. Stroke the Actuator up and down by working the flushing valve handle. Continue this action for about 10 minutes.

6. Turn off the Hydraulic Power Supply. Remove the flushing valve and reinstall the Servovalve. Be sure the Servovalve cable is connected. Cover the exposed ports on the flushing valve with the Servovalve cover plate.

CHECKING LVDT INSTALLATION

Vibration testing may loosen the screws that support the LVDT, or cause the core retainer to loosen. Check frequently to make certain that all these screws are tightened to the proper torque and that the core retainer is locked in the correct relationship to the piston rod. Refer to Service Bulletin 930.07 for screw torques. Refer to procedure 13, under DISASSEMBLY, INSPECTION AND REASSEMBLY for core adjustment (in this manual).

*** WARNING ***

If the LVDT or core loosen and shift, sudden high-speed Actuator rod movements that are uncontrolled may occur.
SPIRAL WASHER OPERATION

The Model 601 Spiral Washers are accessories typically used with the actuator to provide fatigue resistant connections between elements of the force train and to minimize the effects of backlash. If the operating procedure requires changing of the load cell, grips, etc, the spiral washers must be readjusted. The spiral washers are placed over the connector studs at each connection, and adjusted to place a constant preload on the stud. When cyclic loads below the tensile force level of the preload are applied to the connections, the load is distributed between the surfaces of the spiral washers and the stud in a ratio of the relative stiffness of the parts. The spiral washers, having a large surface area and therefore greater stiffness, react most of the load so that stress in the stud is kept below its fatigue runout level. In addition to providing fatigue-resistant connections, the spiral washers also minimize the possibility of backlash due to loose-fitting or worn stud threads.

The following steps describe the recommended procedure for installing the spiral washers and preloading the connector studs (refer to figure 1-1). The following procedure requires two spanner wrenches. This procedure assumes the operator is familiar with all operating aspects of the system electronic controls, and interlock restrictions that apply to the hydromechanical equipment.

1. Remove system hydraulic pressure.

2. Place the spiral washers together, with the spiral surfaces facing each other.

3. Install the spiral washers over the connector stud and thread the stud into two elements of the force train (for example, a load cell and a specimen grip). Use threaded adaptors if necessary. Avoid using stepped studs.

4. Rotate the spiral washers to a point where the combined thickness is minimum, and tighten the two force train elements against the spiral washers by hand.

5. Repeat steps 2, 3, and 4 for all spiral washers in the force train.

6. Connect a coupling (e.g., dummy specimen) in the force train or install the actuator into a suitable fixture such that a tensile load can be applied to the connector stud installed in step 3. The coupling or fixture must be able to withstand a tensile load 10 to 20% greater than the maximum load to be applied during testing.

7. Select load control and apply system hydraulic pressure.
CAUTION

If the spiral washers are not sufficiently tightened, the connector stud can be subjected to cyclic loads which can cause eventual fatigue, resulting in connector stud breakage.

CAUTION

When spiral washers are installed in a swivel head/load cell combination (refer to figure 1-1), the spiral washers between the swivel head and load cell must be tightened first. Then, when tightening the spiral washers between the load cell and piston rod, only the spiral washer next to the piston rod should be turned (the load cell must not rotate). Failure to comply with this caution can result in improper connector stud preload which can cause eventual fatigue, resulting in connector stud breakage.

9. Using the spanner wrenches, rotate the spiral washers to increase their combined thickness until the washers tightly wedge against the two force train components. Hand tightening the spiral washers is sufficient; no additional force is required.

10. Reduce the tensile load to zero and remove system hydraulic pressure.

11. To disassemble, perform steps 6, 7, and 8. Then, using the spanner wrenches, rotate the spiral washers to reduce their combined thickness to a minimum. Reduce tensile load to zero and remove hydraulic pressure. The force train elements can now be loosened for spiral washer removal.