MTS

Product Manual

Series 244 Hydraulic Actuator

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Section 1
Introduction

This section contains the functional description of the Series 244 Hydraulic Actuator and a description of the actuator components. It also contains the actuator specifications: model numbers, force ratings, dimensions, weights, etc.

1.1 Functional Description

The Series 244 Hydraulic Actuators (shown in Figure 1-1) are double-acting, double-ended, heavy-duty actuators that operate under precision servovalve control in MTS closed-loop servohydraulic systems. Typical applications for the actuators include static testing and cyclic tension-compression fatigue testing. Series 244 Hydraulic Actuators can also be used in systems requiring precision force generation and accurate control of piston rod displacement.

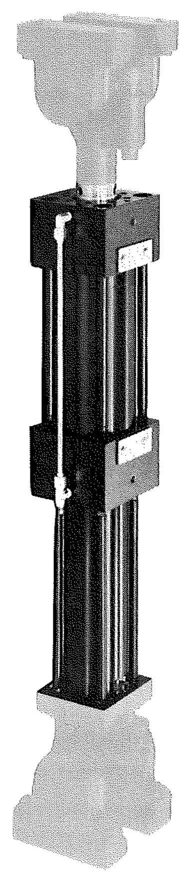

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Figure 1-1. Typical Series 244 Hydraulic Actuator (shown with swivel rod end and swivel base)

Series 244 Hydraulic Actuators are designed to accept a wide variety of options and accessories including force and displacement transducers, pedestal bases, swivel rod ends, and swivel bases. When equipped with the appropriate options and accessories, the actuators can be configured for precision testing of materials, structures and components.

Figure 1-2 shows a cutaway view of a typical 244 actuator cylinder assembly. The components called out in Figure 1-2 are described in Table 1-1.

Table 1-1. Description of Series 244 Hydraulic Actuator Components

Item	Component	Description
1	Piston rod end (fixture attachment end)	The piston rod has a hardened steel insert that provides an internal thread for mounting load cells, swivels, interface fixtures, etc.*
2	Porting	High-pressure hydraulic fluid is ported into the cylinder (item 2A) through the retraction port (item 2B) or the extension port (item 2C). Hydraulic fluid flow is regulated by a servovalve. As hydraulic pressure is applied to one port, the other port is opened to a return line, resulting in piston rod movement.
3	Piston rod	The 244 actuator is equipped with a double-ended piston rod. The double-ended piston has equal areas on both sides for balanced performance. It is machined from a single piece of heat-treated alloy steel and hard-chrome plated. The piston rod is hollow to allow for installation and accurate alignment of a displacement transducer.
4	Cushions	Upper and lower hydraulic cushions are provided to protect the actuator from the effects of high-speed and high-mass loads.**

* The Model 244.51 has no inserts; internal threads are machined directly into the piston rod end.
** Models 244.41 and 244.51 do not have hydraulic cushions.

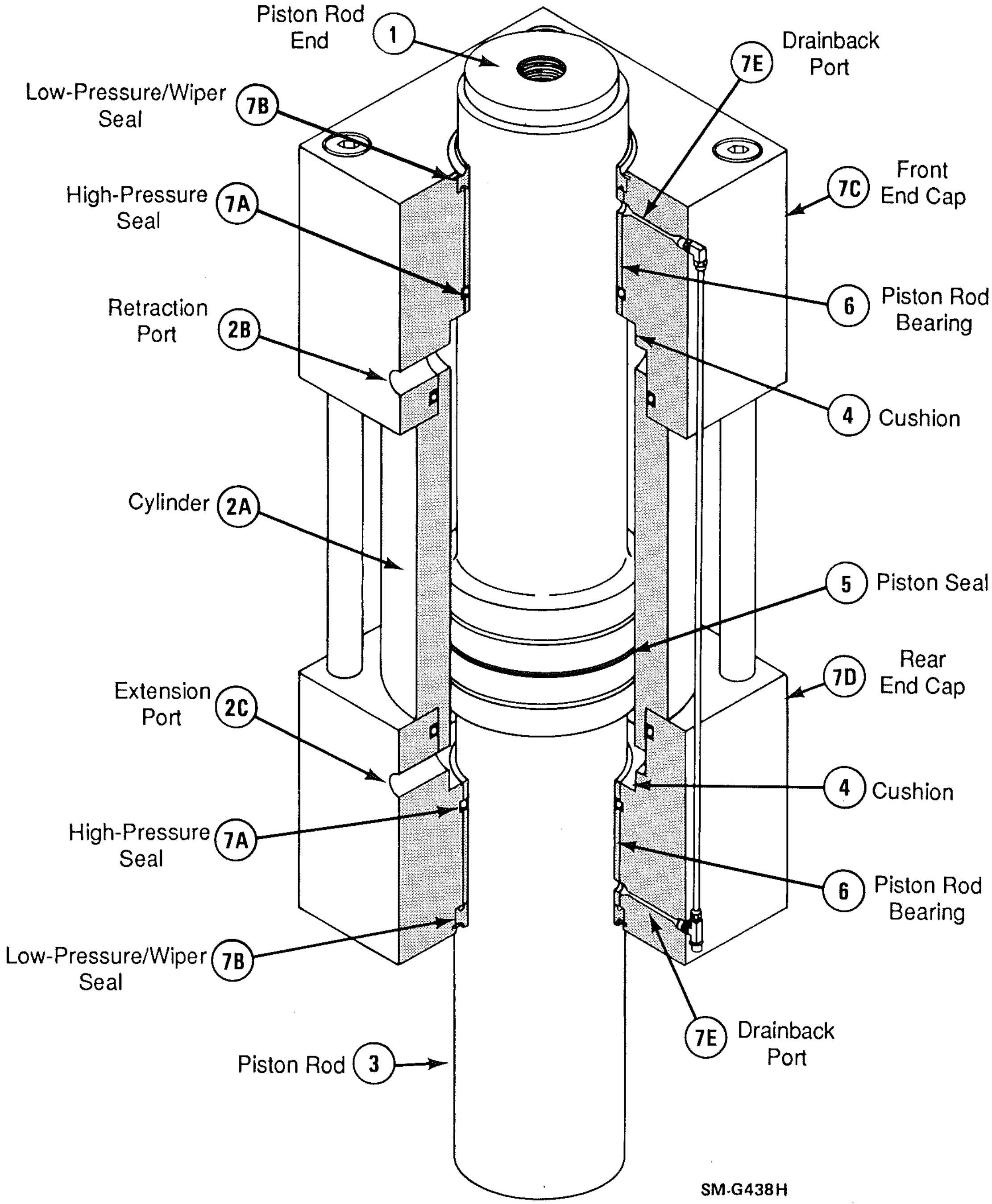


Figure 1-2. Cutaway View of a Typical Series 244 Hydraulic Actuator

Table 1-1. Description of Series 244 Hydraulic Actuator Components (continued)

Item	Component	Description
5	Piston seal	A reinforced Teflon® seal (if equipped) on the piston provides a positive seal and reduces friction. Grooves on the piston lubricate the piston surface during short-stroke, side-loaded tests. For high-speed cyclic testing applications, the piston seal can be omitted. The close tolerance fit provides an effective viscous seal.
6	Piston rod bearings	Series 244 actuators are supplied with high-capacity non-metallic bearings bonded directly to the end caps. The non-metallic bearings are standard because of their high side load tolerance and resistance to failure from galling and seizure.
7	Piston rod seals	The piston rod seals consist of a high-pressure seal (item 7A, if equipped) and a low-pressure/wiper seal (item 7B) in both the front end cap (item 7C) and the rear end cap (item 7D). Series 244.1X and 244.2X actuators with force ratings under 22 kip (100 kN), that are used in load frame/unit applications, do not contain high-pressure piston rod seals. The high-pressure seal is designed for long life, low friction and exceptional performance in high-frequency, low-displacement applications. A small amount of hydraulic fluid is allowed to flow past the high-pressure seal for continuous bearing lubrication. Drainback ports (item 7E) return the hydraulic fluid passed by the high-pressure seal back to the system hydraulic power supply. The inner part of the low-pressure/wiper seal provides a hydraulic seal, while the outer part of the seal functions as a scraper ring to minimize external contamination of the seals and bearings. When a high-pressure seal is present, the inner part of the low-pressure seal wipes hydraulic fluid passed by the high-pressure seal from the piston rod and guides the fluid into the drainback port.

1.2 Specifications

The Series 244 actuator models are listed in Table 1-2 according to their force ratings. Table 1-2 lists the specifications for the basic cylinder assembly shown in Figure 1-3. Tables 1-3 through 1-5 list the specifications for options and accessories illustrated in Figures 1-4 through 1-6. Refer to the footnotes on the tables for figure/table correlation.

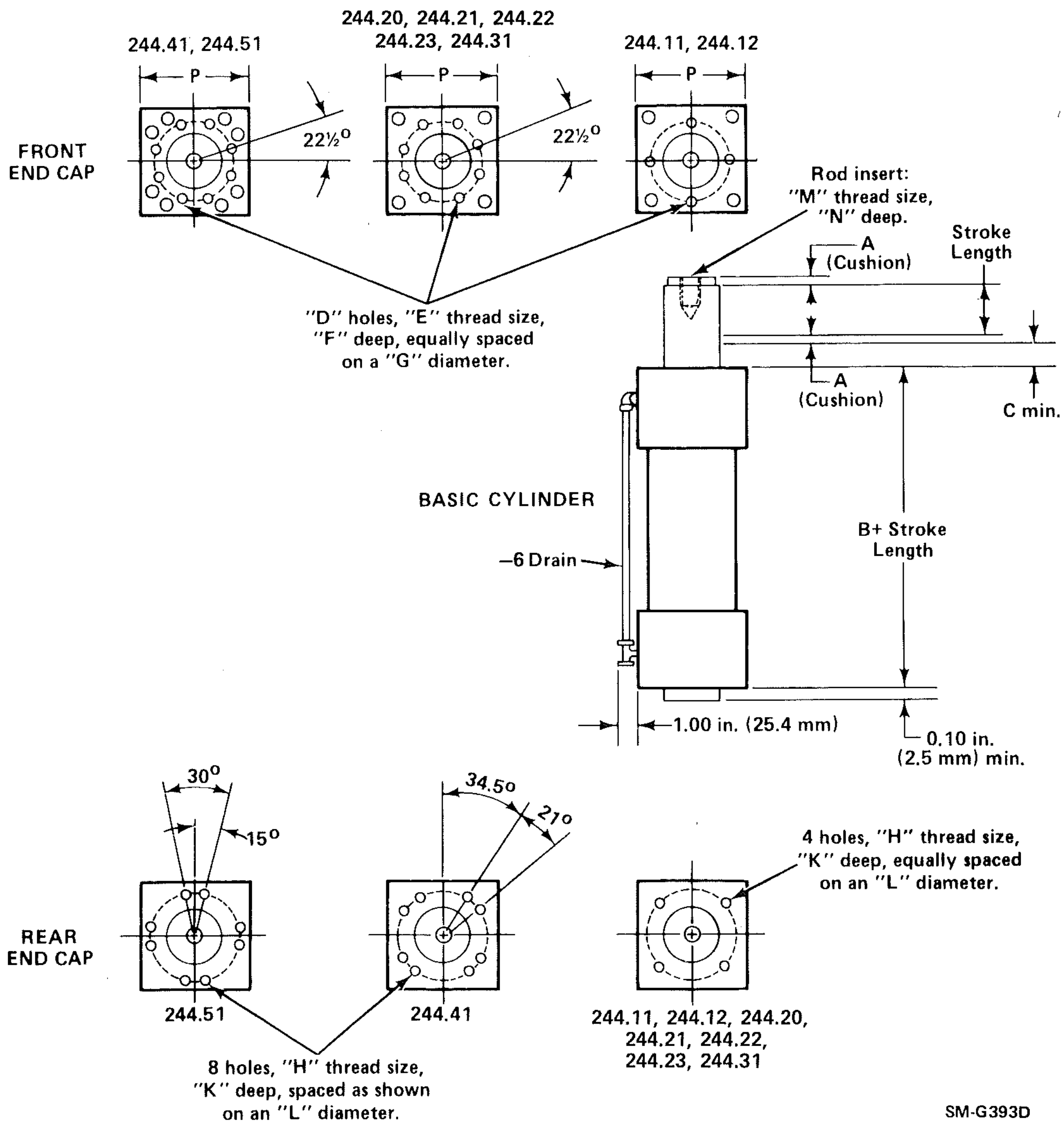


Figure 1-3. Series 244 Actuator Basic Cylinder Dimensional Drawing

Table 1-2. Specifications for Basic Cylinder Assembly*

Model	Force Rating**		Stroke Length†		Rod Diameter		Effective Piston Area		Cushions (A)		B		C††		D	E
	kip	kN	in.	mm	in.	mm	$in.^2$	cm^2	in.	mm	in.	mm	in.	mm	holes	U.S. Cust.
244.11	3.3	15	6	152.4	1.75	44.5	1.17	7.50	0.60	15.2	9.38	238.3	1.00	25.4	4	3/8 - 16
244.12	5.5	25	6	152.4	1.75	44.5	2.10	13.50	0.60	15.2	9.38	238.3	1.00	25.4	4	3/8 - 16
244.21	11.0	50	6	152.4	2.75	69.9	3.90	25.16	0.40	10.2	9.70	246.4	1.00	25.4	8	1/2 - 13
244.20	15.0	68	6	152.4	2.75	69.9	5.22	33.68	0.40	10.2	9.70	246.4	1.00	25.4	8	1/2 - 13
244.22	22.0	100	6	152.4	2.75	69.9	7.57	48.84	0.30	7.6	9.20	233.7	1.00	25.4	8	1/2 - 13
244.23	35.0	150	6	152.4	2.75	69.9	12.73	82.13	0.25	6.4	9.20	233.7	1.00	25.4	8	1/2 - 13
244.31	55.0	250	6	152.4	3.75	95.3	19.63	126.65	0.20	5.1	10.10	256.5	1.00	25.4	8	5/8 - 11
244.41	110.0	500	6	152.4	5.25	133.4	38.48	248.28	none	none	12.27	311.6	1.12	28.4	8	1 - 8
244.51	220.0	1000	6	152.4	6.00	152.4	75.60	487.70	none	none	13.49	342.6	1.50	38.1	8	1 - 8

Model	F		G		H	K		L		M		N‡		P	
	in.	mm	in.	mm	U.S. Cust.	in	mm	in.	mm	U.S. Cust.	SI Metric	in.	mm	in.	mm
244.11	0.75	19.1	3.20	81.3	3/8 - 16	0.75	19.1	3.50	88.9	1/2 - 20	M12 x 1.25 mm	1.75	44.5	4.00	101.6
244.12	0.75	19.1	3.20	81.3	3/8 - 16	0.75	19.1	3.50	88.9	1/2 - 20	M12 x 1.25 mm	1.75	44.5	4.00	101.6
244.21	0.75	19.1	4.10	104.1	5/8 - 11	1.00	25.4	5.00	127.0	1 - 14	M27 x 2 mm	3.02	76.7	5.00	127.0
244.20	0.75	19.1	4.10	104.1	5/8 - 11	1.00	25.4	5.00	127.0	1 - 14	M27 x 2 mm	3.02	76.7	5.50	139.7
244.22	0.75	19.1	4.10	104.1	5/8 - 11	1.00	25.4	5.00	127.0	1 - 14	M27 x 2 mm	3.02	76.7	6.00	152.4
244.23	0.75	19.1	4.10	104.1	5/8 - 11	1.00	25.4	5.00	127.0	1 - 14	M27 x 2 mm	1.98	50.3	6.50	165.1
244.31	1.00	25.4	5.50	139.7	7/8 - 9	1.50	38.1	7.53	191.3	1 1/2 - 12	M36 x 2 mm	4.18	106.2	8.50	215.9
244.41	1.75	44.5	10.37	263.4	7/8 - 9	1.50	38.1	10.00	254.0	2 - 12	M52 x 2 mm	5.11	129.8	11.75	298.5
244.51	1.75	44.5	10.37	263.4	1 - 8	1.75	44.5	11.06	280.9	3 - 12‡‡	M76 x 2 mm‡‡	4.50‡‡	114.3‡‡	15.25	387.4

* Specifications in this table refer to Figure 1-3.
** Nominal force achieved with 3000 psi (21.0 MPa) hydraulic pressure.
† Stroke length does not include actuator cushions (specification A).
†† This specification applies to standard length piston rod fully retracted.
‡ Dimension is from end of piston rod to bottom of internal threads.
‡‡ The 244.51 does not use a threaded rod insert.

Specifications are subject to change without notice. Contact MTS for verification of specifications critical to your needs.

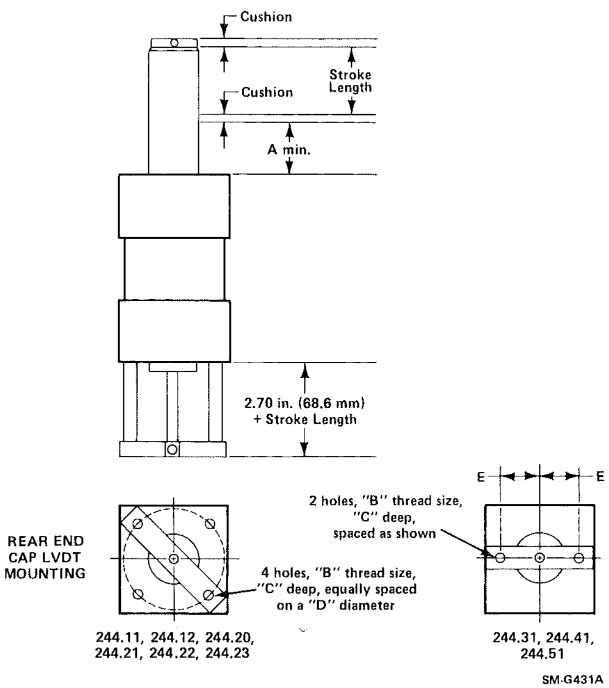


Figure 1-4. Series 244 Actuator with Extra Piston Rod Length and Open Housing LVDT

Table 1-3. Specifications for Extra Piston Rod Length and Open Housing LVDT*

Model	A**,†		B	C		D		E		Weight††	
	in.	mm	U.S. Cust.	in.	mm	in.	mm	in.	mm	lb	kg
244.11	5.90	149.9	3/8-16	0.75	19.1	3.50	89.9	N/A‡	N/A	39	17.7
244.12	5.90	149.9	3/8-16	0.75	19.1	3.50	89.9	N/A	N/A	41	18.6
244.21	7.07	179.6	3/8-16‡‡	1.00	25.4	5.00	127.0	N/A	N/A	122	55.3
244.20	7.07	179.6	3/8-16‡‡	1.00	25.4	5.00	127.0	N/A	N/A	126	57.1
244.22	7.07	179.6	3/8-16‡‡	1.00	25.4	5.00	127.0	N/A	N/A	133	60.3
244.23	7.07	179.6	3/8-16‡‡	1.00	25.4	5.00	127.0	N/A	N/A	151	68.5
244.31	8.85	224.8	3/8-16	0.60	15.2	N/A	N/A	3.06	77.7	282	127.9
244.41	9.25	234.9	3/8-16	0.60	15.2	N/A	N/A	3.96	100.6	645	292.6
244.51	9.82	249.4	3/8-16	0.60	15.2	N/A	N/A	3.96	100.6	1135	514.8

* Specifications in this table refer to Figure 1-4. Specifications not listed in this table can be found in Table 1- 2.
** This specification applies to standard extra length piston rod fully retracted.
† Optional rod lengths are available for crosshead actuator mounting or other special mounting configurations.
†† Includes basic load frame/load unit cylinder assembly and open housing LVDT.
‡ Not applicable (N/A).
‡‡ Requires 5/8-11 to 3/8-16 insert thread (supplied on open housing LVDT assembly).

Specifications are subject to change without notice. Contact MTS for verification of specifications critical to your needs.

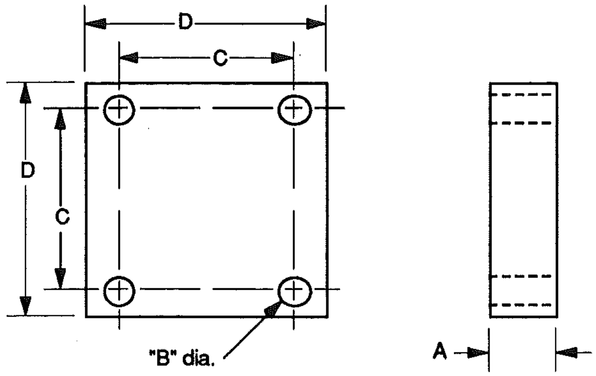


Figure 1-5. Series 244 Pedestal Base

Table 1-4. Specifications for Pedestal Base*

Model	A		B		C		D		Weight	
	in.	mm	in.	mm	in.	mm	in.	mm	lb	kg
244.11	1.50	38.1	0.56	14.2	4.50	114.3	5.50	139.7	13	5.9
244.12	1.50	38.1	0.56	14.2	4.50	114.3	5.50	139.7	13	5.9
244.21	1.75	44.4	0.68	17.3	5.75	146.0	7.38	187.4	27	12.2
244.20	1.75	44.4	0.68	17.3	5.75	146.0	7.38	187.4	27	12.2
244.22	1.75	44.4	0.68	17.3	5.75	146.0	7.38	187.4	27	12.2
244.23	1.75	44.4	0.68	17.3	5.75	146.0	7.38	187.4	27	12.2
244.31	2.50	63.5	0.94	23.9	7.25	184.2	9.00	228.6	58	26.3
244.41	2.50	63.5	1.31	33.3	11.00	279.4	13.88	352.6	137	62.1
244.51	3.00	76.2	1.56	39.6	11.00	279.4	14.00	355.6	165	74.8

* Specifications in this table refer to Figure 1-5. Specifications not listed in this table can be found in Table 1- 2.

Specifications are subject to change without notice. Contact MTS for verification of specifications critical to your needs.

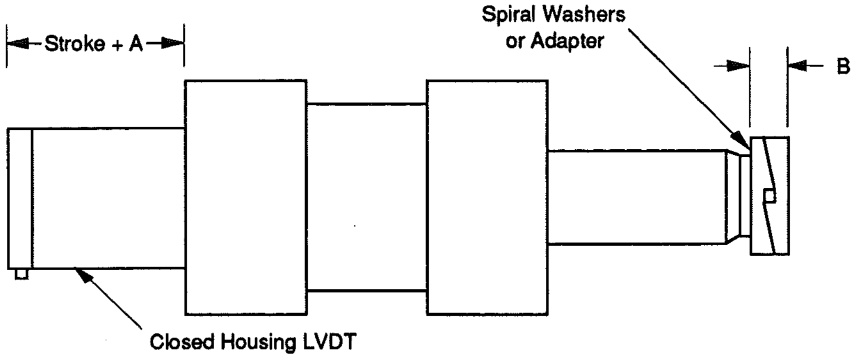


Figure 1-6. Series 244 Actuator Closed Housing LVDT

Table 1-5. Specifications for Series 244 Actuator and Closed Housing LVDT*

Model	A**		B		Weight†	
	in.	mm	in.	mm	lb	kg
244.11	3.18	80.8	____††	____††	43	19.5
244.12	3.18	80.8	____††	____††	45	20.4
244.21	2.76	70.2	____††	____††	124	56.2
244.20	2.76	70.2	1.04	26.4	128	58.1
244.22	2.76	70.2	1.04	26.4	135	61.2
244.23	2.76	70.2	1.04	26.4	153	69.4
244.31	2.36	69.9	1.30	33.0	295	133.8
244.41	1.96	49.8	3.62‡	92.0‡	712	322.9
244.51	0.38	9.6	4.00‡	101.6‡	1307	592.8

* Specifications in this table refer to Figure 1-6. Specifications not listed in this table can be found in Table 1- 2.
** Measurement A refers to the length of the closed housing LVDT assembly.
† Includes basic cylinder assembly and closed housing LVDT assembly.
†† Models 244.11, 244.12, and 244.21 do not require spiral washers or an adapter.
‡ Models 244.41 and 244.51 use an adapter instead of spiral washers.

Specifications are subject to change without notice. Contact MTS for verification of specifications critical to your needs.

Section 2
Operation

This section discusses the operation of the Series 244 Hydraulic Actuator and the internally mounted linear variable differential transformer (LVDT). It also includes recommendations regarding the use of the actuator for different types of tests.

2.1 Series 244 Actuator Operation

Actuator piston rod movement is accomplished by supplying high-pressure hydraulic fluid to one side of the actuator piston and opening the other side to a return line. The differential pressure across the piston forces the piston rod to move. The amount of hydraulic fluid and the speed and direction of piston rod movement is controlled by a servovalve (refer to the servovalve product manual for additional information).

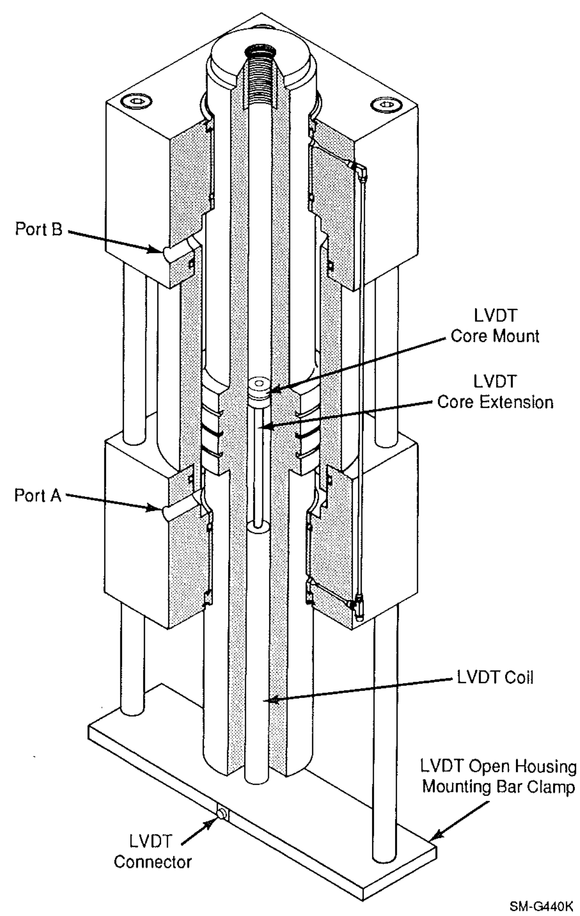


Figure 2-1. Cutaway View of a Typical Series 244 Hydraulic Actuator for Load Frame Applications

Refer to Figure 2-1. When hydraulic pressure is applied to port A and port B is opened to the return line, the piston rod extends from the actuator. When hydraulic pressure is applied to port B and port A is opened to the return line, the piston rod retracts. The force applied to a specimen attached between the actuator piston rod end and a reaction mass is the product of the applied differential hydraulic pressure and the effective piston area. Refer to specification Table 1-2 for the effective piston area.

2.2 Internal LVDT Operation

The internally mounted LVDT (refer to Figure 2-1) provides an indication of the actuator piston rod displacement.

The LVDT is an electromechanical device that provides an output voltage which is proportional to the displacement of a moveable core extension. The core extension is attached to a core mount that is secured inside the piston. The core extension is axially oriented in the LVDT coil. The LVDT coil is connected to an LVDT mounting that secures the LVDT assembly. (The LVDT mounting shown in Figure 2-1 is typical. Actual LVDT mounting will depend on system design considerations.)

Refer to Section 3 for instructions on adjusting the LVDT.

2.3 Operating Considerations for Tests Involving Cyclic, Short Stroke Actuator Operation

Piston rod banding can occur if the actuator is operated for a long period of time at a moderate to high frequency, with short stroke displacement and loads of 25% or more of the actuator capacity. Piston rod banding is the aggravated erosion of the piston rod chrome plating in a band slightly wider than the width of the seal encircling the circumference of the piston rod.

If the actuator is being used for this type of testing, the starting position of the actuator piston rod should be changed approximately every one million cycles. This will extend the life of the piston rod and minimize the possibility of banding. If the system configuration allows it, the piston rod starting position can be changed by using the displacement transducer conditioner zero control and repositioning the load frame crosshead or fixture.

2.4 Operating Considerations for Tests Involving Non-Axial Actuator Loading

To avoid damaging the actuator bearings and to ensure proper actuator operation, tests that subject the actuator to non-axial loads require special consideration. Non-axial loading can occur from sideload forces applied directly to the piston rod (refer to P in Figure 2-2) and from moments caused by off-center loads (refer to F in Figure 2-2). There are four things that must be considered to determine the suitability of an actuator for non-axial loaded tests:

- the total sideload force that will be applied during the test,
- whether the total sideload will be continuous or cyclic,
- the average piston rod velocity during the test, and
- the frequency of the applied sideload.

Procedure

The following procedure provides the user with information to determine the suitability of a particular actuator model for tests requiring non-axial loading.

NOTE The equations included in this procedure assume that the values of F and P are measured in pounds force and that B and C are measured in inches.

---

1. Determine the magnitude of non-axial forces F and P (refer to Figure 2-2) and the point of application of these forces (B and C, respectively). These parameters are determined by the user and are dependent on the test setup configuration. If any parameter is variable during the test, maximum values should be used.

2. Calculate the moment force applied to the front bearing using the following formula:

   $$M = (F)(B) + P\,(C + A)$$

   where:

M	=	resultant sideload of the moment force applied to the bearing in inch pounds force (in.-lbf)
F and P	=	non-axial forces in pounds force (lbf) found in step 1
B and C	=	position of applied forces in inches (in.) determined in step 1
A	=	a constant associated with the particular actuator model (refer to Figure 2-2)

3. Determine the resultant sideload (S_M) due to the end moment force using the appropriate graph in Figure 2-2. If the vertical line from the moment force applied at the front bearing does not intersect the appropriate actuator line, the actuator is not suitable for the test and a larger actuator should be used.

NOTE The graphs in Figure 2-2 provide sideload criteria for 6- and 10-inch stroke actuators. Contact MTS Systems Corporation for sideload tolerance information for other stroke lengths.

---

4. Calculate the total bearing sideload using the following formula:

$$S_T = P + S_M$$

where:

S_T = total sideload in lbf

P = non-axial force determined in step 1

S_M = resultant sideload of the moment force determined in step 3

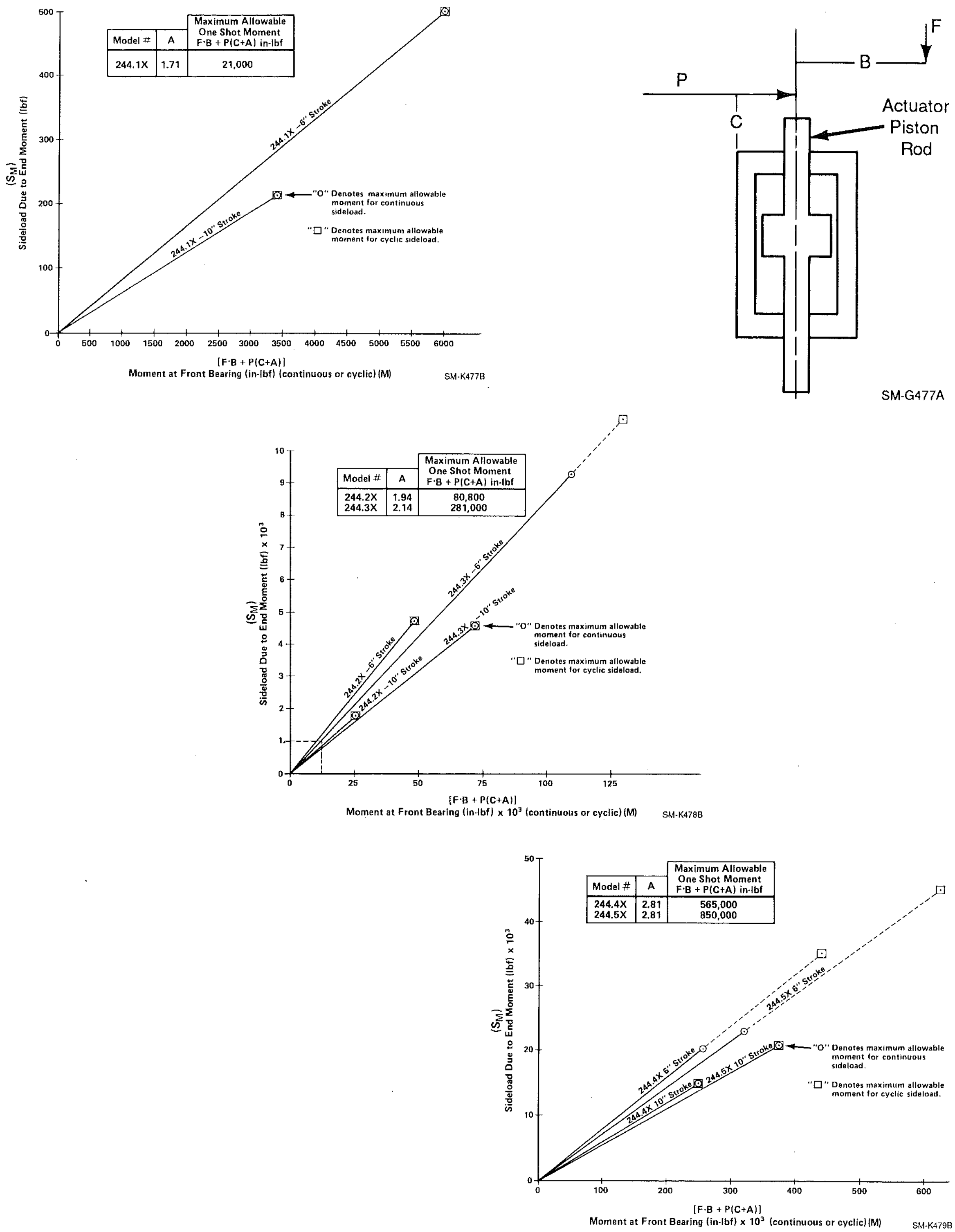


Figure 2-2. Sideload Due to End Moment vs Moment at Front Bearing

NOTE Once the total sideload (S_T) is determined, the next criteria for determining actuator suitability is whether the sideload is continuous or cyclic. If the sideload is continuous (total sideload varies in force, but does not pass through zero) the suitability of the actuator depends on the average velocity of the actuator piston rod during the test. If the sideload is cyclic (total sideload force varies through zero), the suitability of the actuator depends on the cyclic frequency of the sideload.

5. For continuous sideloaded testing applications, the main consideration for determining actuator suitability is the average velocity of the actuator piston rod with the predetermined total sideload.

   Refer to Figure 2-3 to determine the maximum allowable average velocity of the actuator piston rod with the predetermined total sideload. If the test requires higher velocities, a larger force rated actuator should be considered.

6. For cyclic sideloaded testing applications, the main consideration for determining actuator suitability is the frequency of the applied sideload during the test.

   Refer to Figure 2-4 to determine the minimum allowable sideload cyclic frequency with the predetermined total sideload. If the test requires lower cyclic sideload frequencies, contact MTS Systems Corporation for special actuator design considerations.

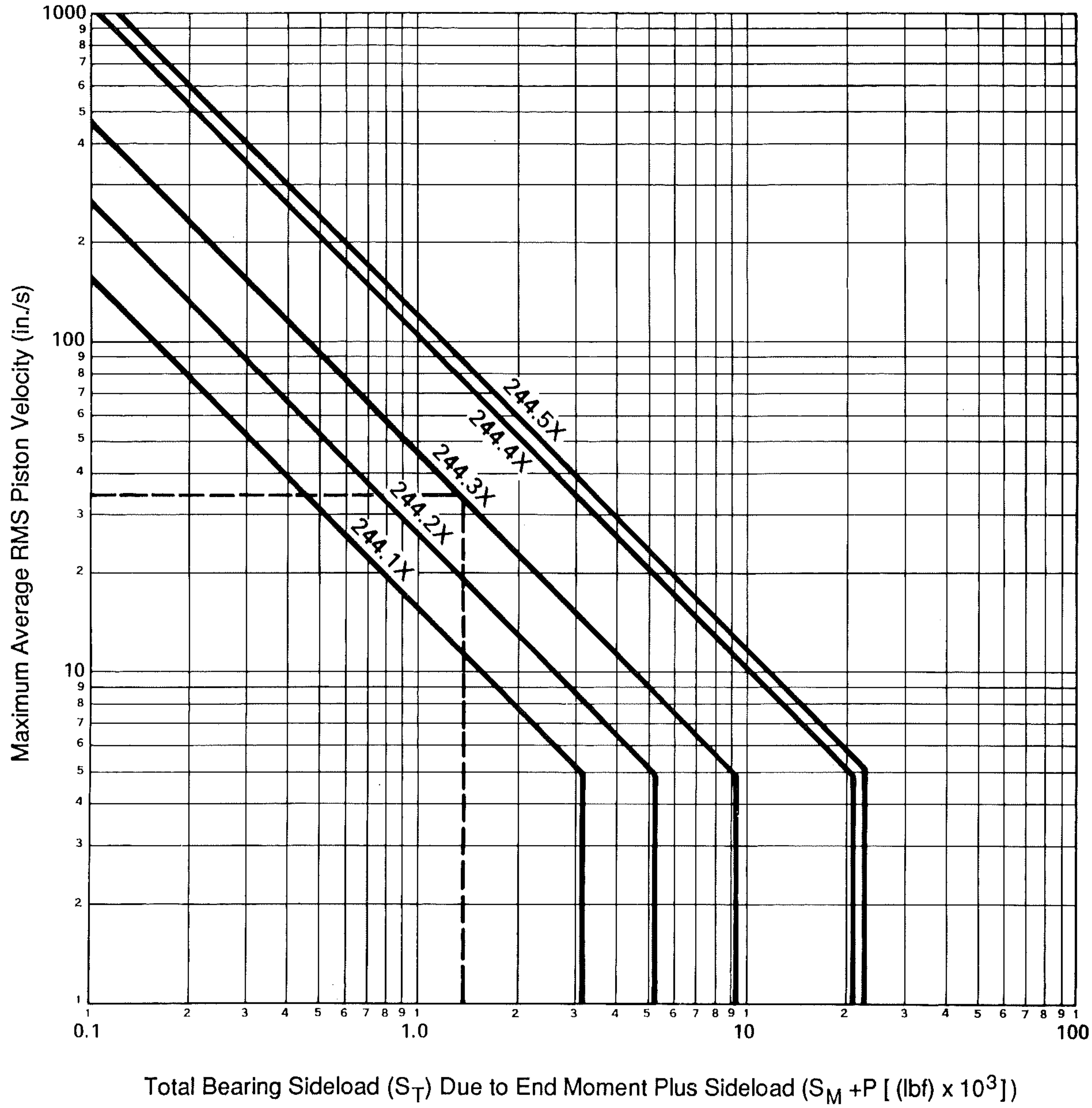


Figure 2-3. Average Maximum Velocity vs Total Bearing Sideload

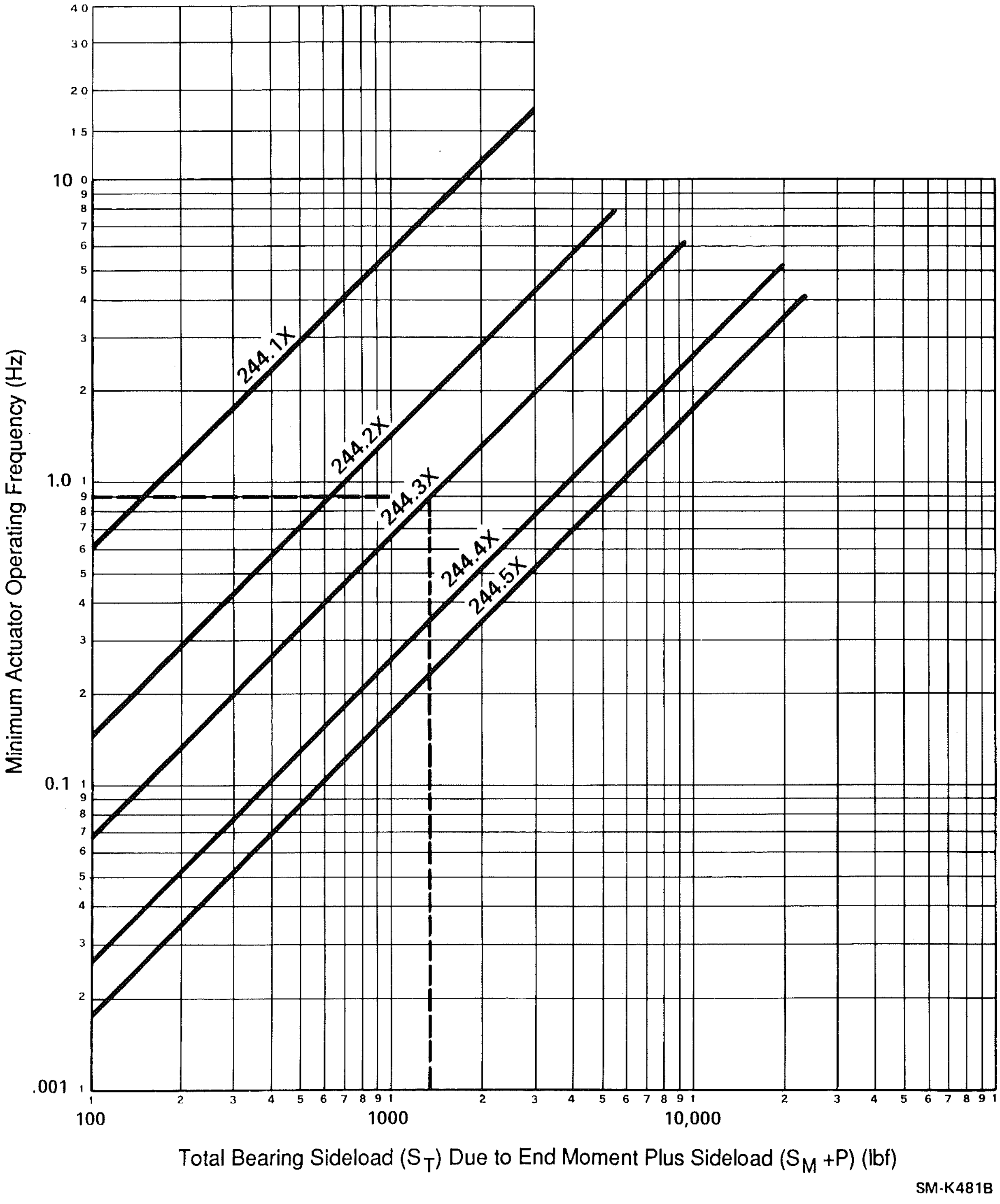


Figure 2-4. Minimum Frequency vs Total Bearing Sideload

Example

The following example uses the preceding procedure to determine the suitability of a Model 244.31 actuator with a 6-inch stroke for a specific test. The numbered steps in this example correspond to the numbered steps in the preceding procedure.

1. Test Conditions determined by the user based on setup configuration and test parameters:

   F = 3000 lbf

   P = 500 lbf

   B = 3.00 in.

   C = 3.5 in.

2. From the center graph in Figure 2-2, the value for the constant A is 2.14. With the above conditions, the moment force at the front bearing is:

   $$\begin{aligned} M &= (F)(B) + P\,(C+A) \\ &= (3000)(3.00) + 500\,(3.50 + 2.14) \\ &= 11{,}820 \text{ in.-lbf} \\ &= 11.820 \times 10^3 \text{ in.-lbf} \end{aligned}$$

3. Using the center graph in Figure 2-2, the sideload due to the moment force (from step 2) is approximately 900 lbf.

4. The total sideload is:

   $$\begin{aligned} S_T &= S_M + P \\ &= 900 + 500 \\ &= 1400 \\ &= 1.4 \times 10^3 \text{ lbf} \end{aligned}$$

5. For continuous sideload applications, the maximum average piston rod velocity from the graph in Figure 2-3 is 35 in./s.

6. For cyclic sideload applications, the minimum cycle sideload frequency from the graph in Figure 2-4 is 0.9 Hz.

Section 3
Service

This section contains information regarding routine maintenance, seal replacement, and linear variable differential transformer (LVDT) core adjustment and replacement. It also contains placard location and description information.

NOTE	Procedures in this section assume the operator is familiar with all operating aspects of the system electronic console and all interlock restrictions that apply to the hydromechanical equipment.

3.1 Routine Maintenance

Series 244 Hydraulic Actuators are designed for extended periods of operation without extensive maintenance requirements. A summary of the routine maintenance procedures is listed below. The following subsections describe the recommended procedures.

Weekly

Clean exposed areas of the actuator piston rod with a clean, dry, lint free rag. If the actuator is continually exposed to a dirty operating environment, clean the piston rod on a daily basis.

Monthly

Inspect actuator piston rod and seals for excessive wear and/or leakage. Small scratches in the axial direction of the piston rod or polishing of the rod surface is considered normal operating wear.

Yearly

Change actuator seals if necessary. Actuator assemblies may require more or less frequent seal changes depending on usage. External oil leakage and/or decreased performance are indicators of seal wear.

3.2 Actuator Seal Replacement

A typical Series 244 Hydraulic Actuator is equipped with low-pressure/wiper seals, high-pressure seals and a piston seal. Depending upon the usage, the high-pressure seals may be omitted and in rare cases, the piston seal. High-pressure seals are not used in load frame/load unit applications that contain a 244 actuator with a force rating of 22 kip (100 kN) or less.

The low-pressure/wiper seal (refer to Figure 3-1) should be replaced when fluid leakage past the seal becomes excessive. An excessively leaky low-pressure/wiper seal is usually apparent by the amount of hydraulic fluid visible. Low-pressure seals are used in both end caps of the actuator.

The low pressure/wiper seals are pre-energized seals and cannot be removed from an assembled actuator without destroying the seal. Special seal insertion tools are required when installing a new low-pressure/wiper seal into an assembled actuator. These tools are available by special order from MTS.

Seal insertion tool part numbers are:

401258-01 for the 244.11/.12
401256-01 for the 244.21/.20/.22/.23
401272-01 for the 244.31
401273-01 for the 244.41
401274-01 for the 244.51

On actuators equipped with low-pressure/wiper seals, high-pressure seals and a piston seal, the low pressure/wiper seals are generally expected to have a service life greater than or equal to the service life of the piston seal and high-pressure seals. Therefore, a worn low-pressure/wiper seal is usually an indication that the actuator should be disassembled, cleaned, inspected, and reassembled with all new seals. Complete seal kits are available from MTS for all Series 244 Hydraulic Actuators.

244.11 3.3 KIP

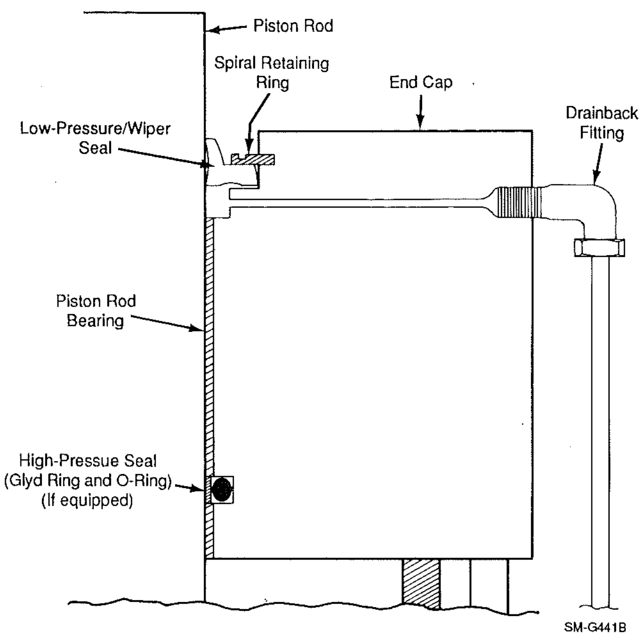


Figure 3-1. Illustration of Piston Rod Seals and Bearing

Replacing the low-pressure seals (without a special seal insertion tool), high-pressure seals, or piston seal requires actuator disassembly. The actuator should not be disassembled except to replace these seals.

NOTE It is recommended that this procedure be read before attempting to remove and disassemble the actuator. Because of the physical size and weight of the actuator and the facilities present on site, disassembly and reassembly may not be feasible. It is possible to disassemble and reassemble a small actuator on a flat horizontal surface, but a large actuator may require disassembly/reassembly in a vertical position using an overhead lifting device, large clamps, lifting fixtures and a shop air supply. Contact MTS for advice and assistance.

The following procedure provides disassembly, seal replacement, and assembly information. Refer to Figures 3-1 and 3-2 when performing the procedure.

NOTE Perform the seal replacement procedure in a clean environment to prevent contaminants from entering the actuator.

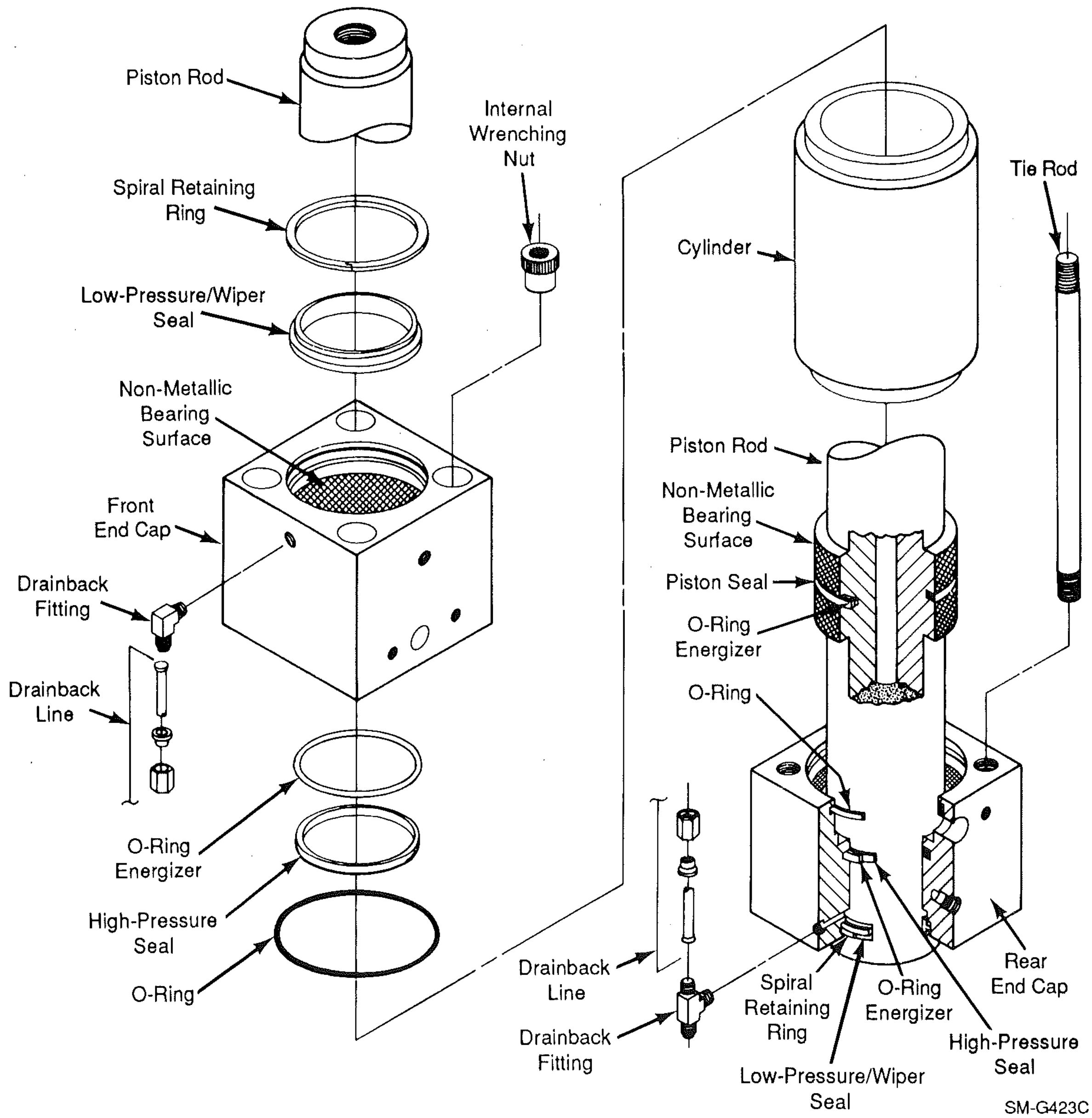


Figure 3-2. Series 244 Actuator Exploded View

NOTE When the high- or low-pressure seals or the piston seal is removed, the seals will probably be damaged. It is recommended that a seal kit be available before performing the following procedure. Complete seal kits are available from MTS for all Series 244 Hydraulic Actuators.

1. Turn off system hydraulic pressure and ensure that all residual pressure (including service manifold accumulator pressure) has bled off.

2. If spiral washers are installed in the force train, complete the following steps:

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

   B. Select force control at the system controller.

⚠ WARNING

Do not apply hydraulic pressure to the system unless the servovalve command (dc error) has been zeroed.

If the servovalve command (dc error) does not equal zero when hydraulic pressure is applied to the system, equipment damage and/or personal injury can result.

Always ensure that the dc error is zero before applying hydraulic pressure to the system.

   C. Adjust the system controller for zero dc error and apply system hydraulic pressure according to applicable system procedures.

WARNING

Do not exceed the maximum HPS output pressure or force train component limits without first contacting MTS Systems Corporation.

To achieve the tensile load required in step D, the hydraulic power supply (HPS) output pressure may have to be adjusted to a higher level. If the output pressure of the HPS is increased, or a tensile load that exceeds the capacity of any element in the force train is applied, equipment damage and/or personal injury can result.

Refer to the HPS and force train component product manuals for the recommended maximum output pressure and force limits. If the maximum HPS output pressure or force train component limits must be exceeded to achieve the tensile load in step D, contact MTS Systems Corporation.

D. Apply a static tensile load 10 to 20% higher than the maximum load to be applied during testing.

E. Use the spanner wrenches to rotate the spiral washers to reduce their combined thickness to a minimum.

F. Reduce tensile load to zero and remove hydraulic pressure.

3. Ensure that all residual pressure (including service manifold accumulator pressure) has bled off. Remove all force train components (load cell, swivel rod end, grips, fixtures, etc) attached to the actuator.

4. Remove all components connected to the hydraulic ports in the actuator end caps (e.g., manifold, servovalve, drainback line, etc). Cover the exposed ports on the removed components.

5. Remove the actuator from the test fixture.

6. If applicable, remove the internally mounted LVDT as follows (refer to Figure 3-5 and the applicable LVDT illustrated by Figures 3-6, 3-7 or 3-8):

NOTE On series 244.1X actuators, the LVDT core cannot be removed until the threaded insert adaptor in the end of the piston rod is removed.

A. Thread the adjusting wrench into the LVDT core mount.

B. Using a hex head wrench, loosen the core mount locking screw.

C. Using the adjusting wrench, pull the core mount and core extension out of the piston rod.

D. On open housing LVDT models, remove the internal wrenching nuts from the tie rods securing the LVDT mounting bar clamp. Remove the LVDT mounting bar clamp containing the LVDT coil. Remove the tie rods and mounting bar spacers from the rear end cap.

On closed housing LVDT models, remove the internal wrenching nuts from the tie rods securing the pedestal base or swivel base to the actuator assembly. Remove the LVDT clamp collar containing the LVDT coil. Remove the spacer tube and tie rods from the rear end cap.

NOTE The actuator should now be disassembled down to the basic cylinder assembly.

7. Remove the internal wrenching nuts in the front end cap from the tie rods.
8. Carefully remove the front end cap from the cylinder and lift it off of the piston rod. It might be necessary to tap the end cap with a plastic mallet to loosen it.
9. Remove the tie rods from the rear end cap. Separate the rear end cap from the cylinder and lift it off of the piston rod.
10. Carefully slide the piston rod out of the cylinder.
11. Inspect all parts and bearing surfaces for damage and excessive wear. If inspection of the disassembled parts reveals damage or excessive wear, contact MTS before attempting to remedy the problem.

⚠ CAUTION

When removing or installing the piston seal and the high-pressure seal, do not scratch the non-metallic bearing surface.

If the bearing surface is scratched, the piston rod and/or end caps must be replaced or returned to MTS Systems Corporation for repair.

Use extreme care to avoid scratching the non-metallic bearing surface when removing or installing the piston and high-pressure seals.

12. Carefully remove the piston seal by working it out of the groove and over the bearing surface to the end of the piston. Remove the piston seal O-ring energizer in the same manner.
13. Remove the spiral retaining ring from each end cap by inserting a small screwdriver into the notch on top of the ring and prying toward the center of the end cap.
14. Remove the low-pressure/wiper seal from each end cap.

15. Carefully remove the high-pressure seal from the end cap by working it out of the groove, over the bearing surface and out of the end cap. Remove the high-pressure O-ring energizer in the same manner. Repeat this step for the other end cap.

NOTE Lightly lubricate the new O-rings and seals with clean hydraulic fluid before installing. Refer to Figure 3-1 and 3-2 for seal orientation.

---

16. Observe the caution preceding step 12. Install a new piston seal O-ring energizer into the groove on the piston. Gently stretch a new piston seal over the piston and carefully work it over the bearing surface and into the groove above the piston seal O-ring energizer.

17. Observe the caution preceding step 12. Install a new high-pressure O-ring energizer into the groove in the end cap. Carefully work a new high-pressure seal over the bearing surface and into the groove above the high-pressure O-ring energizer. Repeat this step for the other end cap.

18. Insert a new low-pressure/wiper seal in the end cap and secure it with the spiral retaining ring. Repeat this step for the other end cap.

19. Remove the large diameter O-ring in the front and rear end caps that seal the end caps to the cylinder. Replace them with new, lubricated O-rings.

NOTE When reassembling the actuator, orient the end caps so the appropriate hydraulic ports are on the same side of the actuator.

---

20. Lightly lubricate the piston, piston rod, and cylinder walls with clean hydraulic fluid.

21. Place the rear end cap on two wooden blocks. Refer to Figure 3-3.

22. Install the cylinder into the rear end cap, taking care not to damage the O-ring seal between the rear end cap and the cylinder.

23. Grease one end of each tie rod. Thread the greased end of each tie rod into the rear end cap.

24. Gently push the piston rod into the cylinder, ensuring that it is properly oriented with the fixture attachment end at the top. Avoid any misalignment that could damage the bearing surfaces. When properly installed in the cylinder, the piston rod end will extend slightly beyond the rear end cap, between the wood blocks.

25. Install the front end cap by gently sliding it down the piston rod and tie rods until it contacts the cylinder. Take care not to damage the O-ring seal between the front end cap and the cylinder.

26. Grease the threads of the internal wrenching nuts and install them on the tie rod ends in the front end cap. Tighten sufficiently to hold the assembled actuator together.

27. Lay the actuator down with its machined side (the side with the hydraulic ports) on a flat surface. Align the end caps and cylinder by tapping them down onto the flat surface.

28. Tighten the internal wrenching nuts to 10 lbf-ft (13.5 N-m) in the order shown in Figure 3-4.

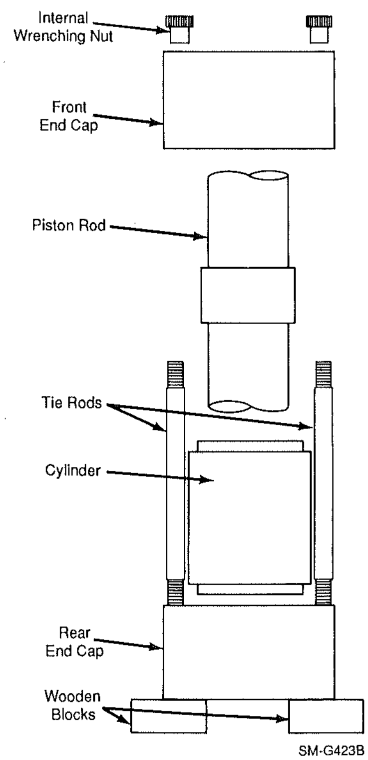
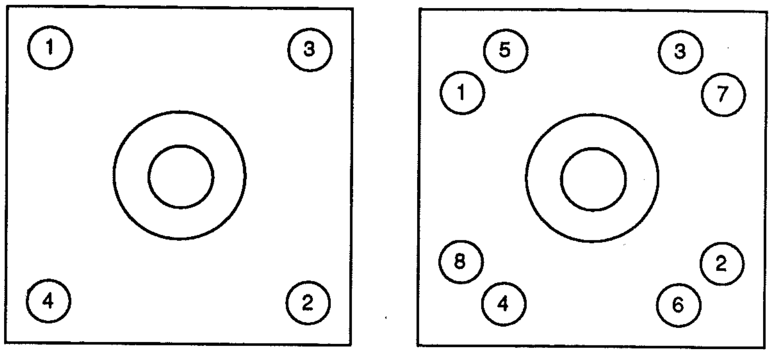


Figure 3-3. Actuator Assembly Illustration



244.1X/.2X/.3X   244.41/.51

Figure 3-4. Internal Wrenching Nut Tightening Order

29. Ensure that the piston rod moves freely in the cylinder by pushing and pulling it by hand.

    For larger actuator models, moving the piston rod by hand may be difficult. In this case, air pressure (100 psi max.) applied to the hydraulic ports should be sufficient to move the piston rod.

NOTE As the internal wrenching nuts are tightened in the following step, those previously tightened will loose clamping force. Continue tightening until all internal wrenching nuts are at the specified torque.

---

30. Tighten the internal wrenching nuts in the order shown in Figure 3-4. Complete the following steps to achieve the proper torque.

    A. Tighten the internal wrenching nuts to 30% of the torque specified in Table 3-1. Repeat step 29.

    B. Tighten the internal wrenching nuts to 60% of the torque specified. Repeat step 29.

    C. Tighten the internal wrenching nuts to 100% of the torque specified. Repeat step 29. When fully tightened, the internal wrenching nuts should have full thread engagement on the tie rods.

Table 3-1. Front End Cap Internal Wrenching Nut Torque Specifications

Model	Open Housing LVDT	
	lbf-ft	N•m
244.11	55	74.57
244.12	55	74.57
244.21	70	94.91
244.20	80	108.00
244.22	135	183.04
244.23	200	271.16
244.31	410	555.88
244.41	380	515.21
244.51	600	813.49

31. Because the actuator has been disassembled and new components have been added, the possibility exists that contamination has been introduced. Before placing the actuator back into service, the actuator should be flushed. To flush the actuator, perform the following procedures.

    A. Reconnect all hydraulic hoses.

    B. Mount an MTS Series 291 Four-Way Flushing Valve (or equivalent) to the actuator.

    C. Ensure the piston rod is free to travel its full length without obstruction.

    D. Select force control and apply low hydraulic pressure. Check for leaks.

    E. Apply high hydraulic pressure. Check for leaks.

    F. Use a wrench to turn the shaft on the flushing valve to cycle the actuator between extend and retract for approximately 10 minutes. System filters will collect any solid contaminants of 10 microns or larger. Stop with the actuator fully retracted.

    G. Turn off system hydraulic pressure and ensure that all residual pressure (including service manifold accumulator pressure) has bled off.

    H. Remove the flushing valve.

    I. Remove the hydraulic hoses and cap the open ends. Cover the open ports on the actuator.

32. Install the LVDT assembly using the appropriate procedure in Subsection 3.3.

3.3 LVDT Installation and Adjustment

This subsection provides the procedure for installing an open housing or closed housing LVDT into an actuator. This procedure is typically performed only when the actuator has been disassembled or the LVDT is being replaced. Refer to Figure 3-5 for an illustration of an LVDT installed in a piston rod.

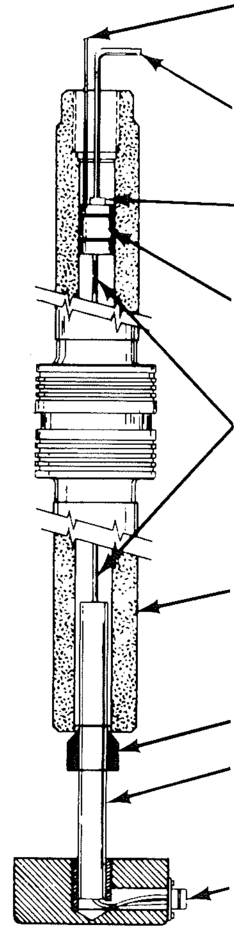


Figure 3-5. Illustration of LVDT Installed in a Piston Rod

3.3.1 LVDT Installation Open Housing LVDT

Refer to Figure 3-6 during the following procedure.

1. Ensure that the piston rod is fully retracted and all residual hydraulic pressure to the actuator (including service manifold accumulator pressure) has bled off.

2. Lubricate the tie rod ends and thread the tie rods into the rear end cap. Slide the mounting bar spacers over the tie rods.

3. Install the LVDT coil (with attached guide bushing and LVDT mounting bar clamp) into the piston rod. Position the guide bushing on the coil so that it fits into the piston rod and centers the LVDT coil.

4. Lubricate and torque the internal wrenching nuts that secure the LVDT mounting bar clamp to the rear end cap. Torque the wrenching nuts in alternate steps to the torque specifications shown in Table 3-2.

5. Slide the guide bushing down the coil until it no longer contacts the piston rod.

⚠ CAUTION

When pushing the core extension/core mount into the coil, do not damage the wires or allow the core extension to extend below the end of the coil.

The LVDT core extension can extend through the LVDT coil and damage the wires to the connector.

When pushing the core extension into the coil, ensure that the wires are out of the way and the core extension does not extend below the end of the coil.

6. Gently push the core extension/core mount into the piston rod end until the core is fully within the coil. Then, pull the core extension/core mount out 0.50 in. (12.70 mm).

7. Tighten the core mount locking screw (refer to Figure 3-5 for the location of the locking screw) just enough to secure the core.

8. Adjust the LVDT using the procedure described in Subsection 3.4.

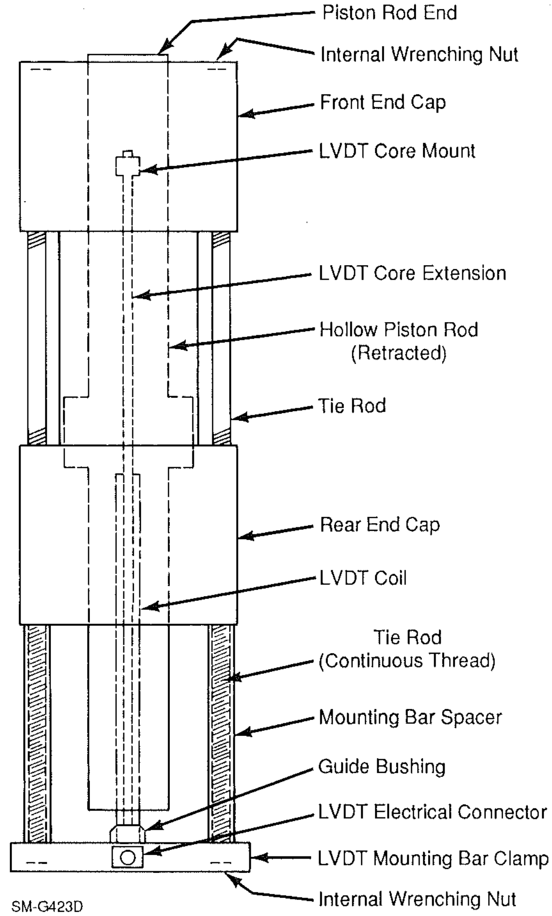


Figure 3-6. Open Housing LVDT Illustration

Table 3-2. LVDT Internal Wrenching Nut Torque Specifications

Model	Open Housing LVDT		Closed Housing LVDT	
	lbf-ft	N•m	lbf-ft	N•m
244.11	20	27.11	20	27.11
244.12	20	27.11	20	27.11
244.21	20	27.11	90	122.02
244.20	20	27.11	90	122.02
244.22	20	27.11	90	122.02
244.23	20	27.11	125	169.47
244.31	20	27.11	260	352.51
244.41	20	27.11	270	366.07
244.51	20	27.11	440	596.55

3.3.2 LVDT Installation Closed Housing LVDT – Swivel Base

Refer to Figure 3-7 during the following procedure.

1. Ensure that the piston rod is fully retracted and all residual hydraulic pressure to the actuator (including service manifold accumulator pressure) has bled off.

2. Lubricate the tie rod ends and thread the tie rods into the rear end cap.

3. Place the spacer tube over the piston rod. Support the spacer tube while centering it between the tie rods and aligning it to the rear end cap.

4. Position the guide bushing on the coil so that it fits into the piston rod and centers the LVDT coil.

5. Install the LVDT coil and attached LVDT clamp collar in the piston rod. Ensure that the LVDT clamp collar is supported, and align it to the spacer tube.

6. Support the swivel base and slide it over the tie rod ends. Center the swivel base with respect to the LVDT clamp collar and spacer tube. Ensure that this alignment is maintained while performing the next step.

7. Lubricate and install the internal wrenching nuts that secure the swivel base to the rear end cap. Following the order shown in Figure 3-4, incrementally torque the wrenching nuts to the torque specified in Table 3-2.

⚠ CAUTION

When pushing the core extension/core mount into the coil, do not damage the wires or allow the core extension to extend below the end of the coil.

The LVDT core extension can extend through the LVDT coil and damage the wires to the connector.

When pushing the core extension into the coil, ensure that the wires are out of the way and the core extension does not extend below the end of the coil.

8. Gently push the core extension/core mount into the piston rod end until the core is fully within the coil. Then, pull the core extension/core mount out 0.50 in. (12.70 mm).

9. Tighten the core mount locking screw (refer to Figure 3-5 for the location of the locking screw) just enough to secure the core.

10. Adjust the LVDT using the procedure described in Subsection 3.4.

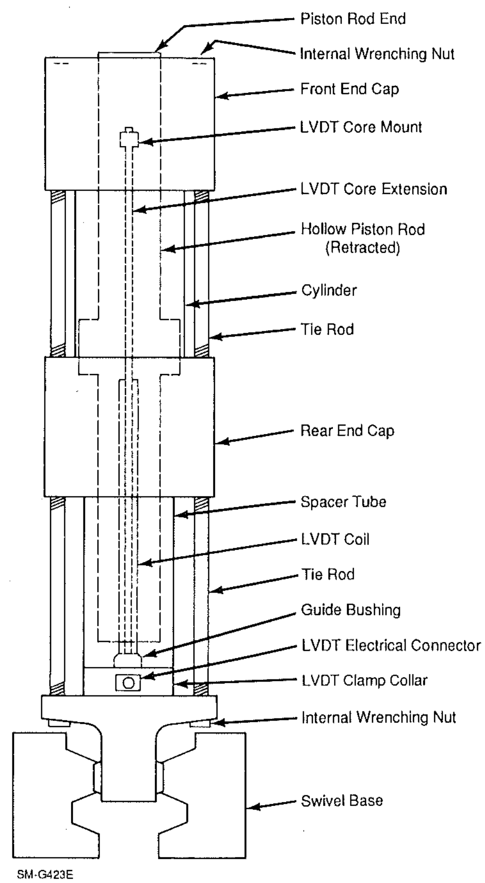


Figure 3-7. Closed Housing LVDT – Swivel Base Illustration

3.3.3 LVDT Installation Closed Housing LVDT – Pedestal Base

1. Ensure that the piston rod is fully retracted and all residual hydraulic pressure to the actuator (including service manifold accumulator pressure) has bled off.

2. Lubricate the tie rod ends and thread the tie rods into the rear end cap.

3. Place the spacer tube over the piston rod. Support the spacer tube while centering it between the tie rods and aligning it to the rear end cap.

4. Position the guide bushing on the coil so that it fits into the piston rod and centers the LVDT coil.

5. Install the LVDT coil and attached LVDT clamp collar in the piston rod. Ensure that the LVDT clamp collar is supported, and align it to the spacer tube.

6. Support the pedestal base and slide it over the tie rod ends. Center the pedestal base with respect to the LVDT clamp collar and spacer tube. Ensure that this alignment is maintained while performing the next step.

7. Lubricate and install the internal wrenching nuts that secure the swivel base to the rear end cap. Following the order shown in Figure 3-4, incrementally torque the wrenching nuts to the torque specified in Table 3-2.

8. Gently push the core extension/core mount into the piston rod end until the core is fully within the coil. Then, pull the core extension/core mount out 0.50 in. (12.70 mm).

9. Tighten the core mount locking screw (refer to Figure 3-5 for the location of the locking screw) just enough to secure the core.

10. Adjust the LVDT using the procedure described in Subsection 3.4.

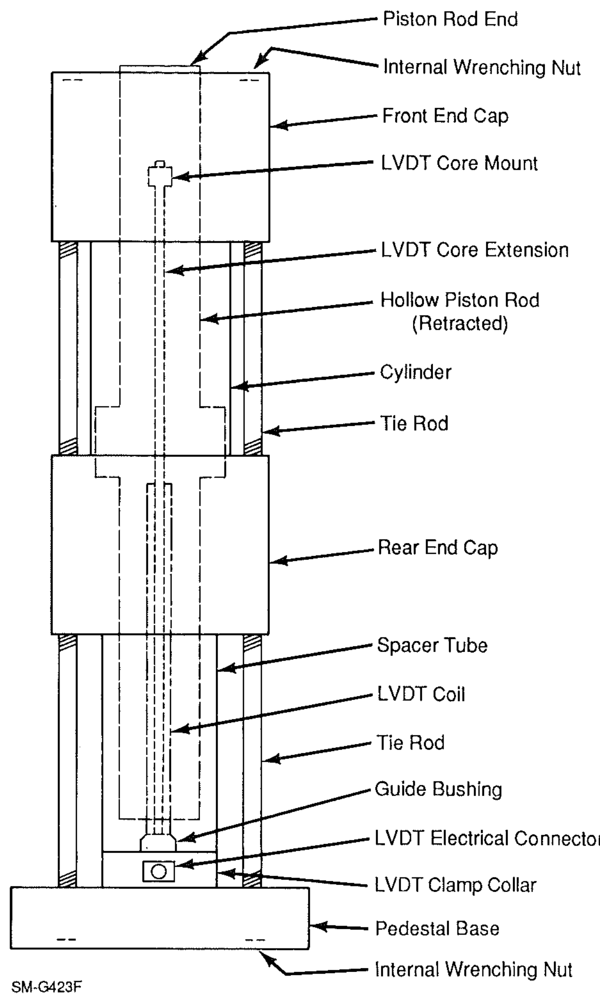


Figure 3-8. Closed Housing LVDT – Pedestal Base Illustration

3.4 LVDT Adjustment

This subsection provides a procedure to adjust the LVDT core for a mechanical zero reference point. Typically, this procedure is performed to achieve a mid-stroke zero reference point after an LVDT has been installed. Refer to Subsection 3.3 for LVDT installation procedures. Refer to Figure 3-5 for the location of components referenced in this procedure. This procedure requires an oscilloscope and assumes that the actuator is hydraulically and electronically connected to a control system.

NOTE If, after performing this procedure, a zero reference point other than mid-displacement is required for system operation, the operator should use the electrical zero control (typically located on the displacement transducer conditioner front panel) to achieve the desired reference point.

---

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 load cell, grip, etc) 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 mid-point 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.

10. Thread the adjusting wrench into the LVDT core mount.

11. Insert the hex head wrench into the core mount locking screw.

⚠ WARNING

Do not attempt to 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 core when residual hydraulic pressure exists can cause unexpected actuator motion and result in injury to personnel and/or damage to equipment.

Before adjusting the LVDT core, ensure that all hydraulic power to the system is off and residual hydraulic pressure in the system is at zero.

12. Monitor the ac signal from the ac transducer conditioner 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. After adjusting the LVDT, check the electronic calibration of the LVDT ac transducer conditioner. It may be necessary to recalibrate the LVDT electronically. Refer to the appropriate transducer conditioner product manual for the electronic calibration procedure.

3.5 Swivel Bearings

Swivel bearings are maintenance free, except for the backlash adjustment. For further information on swivels, refer to the Series 249 Swivel Product Manual (MTS part number 117756-00).

3.6 Description of Placard

The placard on the Series 244 Actuator (typically located on the front end cap opposite the drain line) contains the following information:

- model number,
- serial number,
- assembly number,
- force rating,
- area, and
- stroke specifications.

This information is required when contacting MTS Systems Corporation regarding the actuator. Also contained on this placard is the following warning:

⚠ WARNING

SUBJECTING THIS EQUIPMENT TO WORKING PRESSURE ABOVE 3000 PSI (20.7 MPa) CAN RESULT IN COMPONENT RUPTURE AND INJURY TO PERSONNEL. SEE THE PRODUCT MANUAL FOR SAFETY PRECAUTIONS BEFORE OPERATING.

Section 4
Installation

The mounting configuration of the Series 244 Hydraulic Actuator depends on the testing application. For materials or component testing, the actuator is typically installed in a load frame or fixture. For structural or vibration testing, the actuator is typically secured to a reaction mass using a swivel or pedestal base.

4.1 Mounting of 244 Actuator with Pedestal or Swivel Base

A 244 actuator equipped with a pedestal base typically has the pedestal base bolted to a reaction mass. Refer to Table 4-1 for the mounting bolt specifications.

Table 4-1. Mounting Bolt Size, Torque, and Grade Requirements

Model	Recommended Mounting Bolt Size		Mounting Bolt Torque		Recommended Bolt Grade	
	U.S. Cust.	SI Metric	lbf-ft	N•m	SAE	ISO
244.11	1/2-13	M12 x 1.25	84	93	8	12.9
244.12	1/2-13	M12 x 1.25	84	93	8	12.9
244.21	1/2-13	M12 x 1.25	84	93	8	12.9
244.20	1/2-13	M12 x 1.25	84	93	8	12.9
244.22	5/8-11	M16 x 2.00	160	230	8	12.9
244.23	5/8-11	M16 x 2.00	160	230	8	12.9
244.31	1-8	M24 x 3.00	680	780	8	12.9
244.41	1 1/4-7	M30 x 3.50	1360	1600	8	12.9
244.51	1 1/2-4	M42 x 4.00	2400	3200	8	12.9

If the Series 244 Actuator is equipped with a swivel base, the swivel base is also typically bolted to a reaction mass and the applied load is perpendicular to the swivel base mounting. Refer to the Series 249 Swivel Product Manual (MTS part number 117756-XX) for information on swivel mounting.

4.2 Mounting of 244 Actuator in a Load Frame Configuration

When the 244 actuator is mounted in a load frame configuration, the actuator is installed in the load frame at the factory. The optional servovalve(s), associated servovalve manifold, service manifold, etc, are also installed on the actuator at the factory. The only installation required is to connect system hydraulic hoses and system electrical cables.

Refer to the system assembly drawing, system functional drawing, and console assembly drawing (typically located in the system Reference Manual supplied with the system documentation) for information about hydraulic and electrical connections.

4.3 Spiral Washers

The optional Model 601 Spiral Washers are typically used 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 and keep the stress in the stud 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 4-1). The procedure requires two spanner wrenches and assumes that the operator is familiar with all operating aspects of the system electronic controls and interlock restrictions that apply to the hydromechanical equipment.

1. Turn off system hydraulic pressure and ensure that all residual pressure (including service manifold accumulator pressure) has bled off.

2. Clean the connector studs and the internal threads of the force train element(s). Inspect the thread mating surfaces for signs of contamination or corrosion. All damaged threads should be repaired or the component replaced.

3. Apply a thin layer of Molykote® G paste, or equivalent, to all thread mating surfaces.

4. When installing a load cell, place a small piece of compliant material inside the load cell to keep the stud from contacting the bottom of the hole (refer to Figure 4-1).

5. Slowly turn the connector stud into an element of the force train (for example, the actuator rod). The connector stud should turn freely. If any resistance is encountered, disassemble and correct the problem before proceeding.

6. Place the spiral washers together with the spiral surfaces facing each other.

7. Place the set of spiral washers over the connector stud and rotate them until they are at minimum thickness (refer to Figure 4-2). Mount the appropriate fixture (load cell, grip, etc.) on the connector stud and tighten the fixture against the spiral washers by hand.

8. Repeat steps 2 through 7 for all spiral washers in the force train.

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

10. Select force control at the system controller.

⚠ WARNING

Do not apply hydraulic pressure to the system unless the servovalve command (dc error) has been zeroed.

If the servovalve command (dc error) does not equal zero when hydraulic pressure is applied to the system, equipment damage and/or personal injury can result.

Always ensure that the dc error is zero before applying hydraulic pressure to the system.

11. Adjust the system controller for zero dc error and apply system hydraulic pressure according to applicable system procedures.

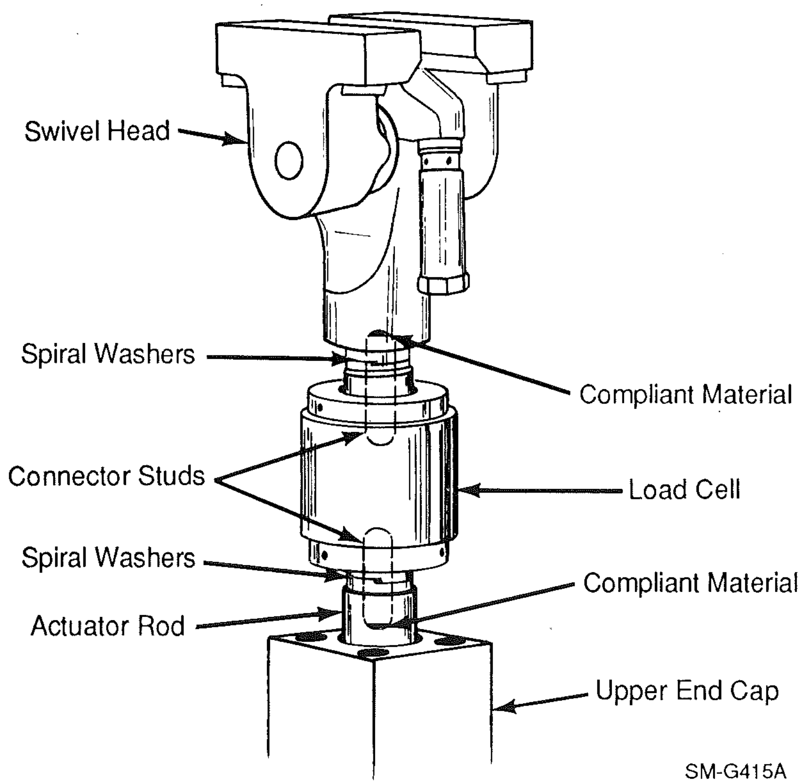


Figure 4-1. Spiral Washers Installed in a Typical Force Train

WARNING

Do not exceed the maximum HPS output pressure or force train component limits without first contacting MTS Systems Corporation.

To achieve the tensile load required in step 12, the hydraulic power supply (HPS) output pressure may have to be adjusted to a higher level. If the output pressure of the HPS is increased, or a tensile load that exceeds the capacity of any element in the force train is applied, equipment damage and/or personal injury can result.

Refer to the HPS and force train component product manuals for the recommended maximum output pressure and force limits. If the maximum HPS output pressure or force train component limits must be exceeded to achieve the tensile load in step 12, contact MTS Systems Corporation.

12. Apply a static tensile load 10 to 20% higher than the maximum load to be applied during testing.

CAUTION

When installing spiral washers in a swivel rod end/load cell combination, do not turn the spiral washer next to the load cell or allow the load cell to rotate (refer to Figure 4-1).

Tightening the spiral washer against the load cell, or allowing the load cell to rotate can result in improper connector stud preload and cause fatigue which will result in connector stud breakage.

When tightening the spiral washers between the load cell and the piston rod, only the spiral washer next to the piston rod should be turned and the load cell must not be allowed to rotate.

CAUTION

If the spiral washers are not sufficiently tightened, the connector stud can break when subjected to cyclic loads.

Follow the instructions in step 13 and ensure that the spiral washers are properly tightened.

13. Using the spanner wrenches, rotate the spiral washers in opposite directions to tighten them. The opening between the washers must not exceed an arc of 30° from the closed position (refer to Figure 4-2).

    If more than a 30° arc is created, remove the tensile load from the specimen. Then remove the specimen and the connector stud. Examine the connector stud for any signs of thread wear. If wear is noticed, replace the stud and repeat steps 1 through 13.

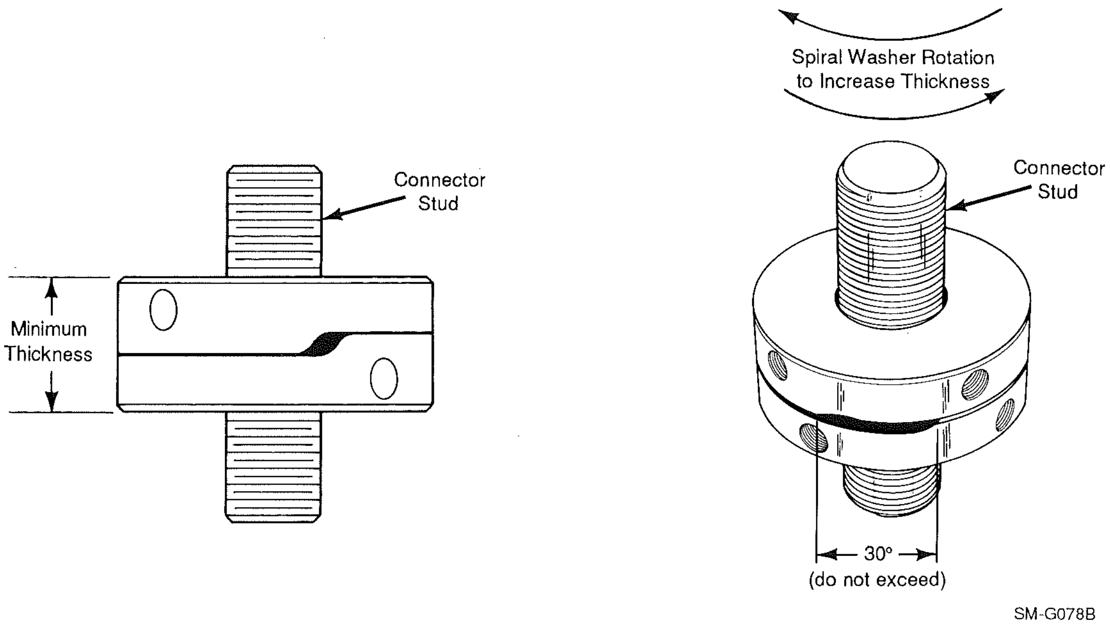


Figure 4-2. Connector Stud and Spiral Washers

14. To disassemble, perform steps 9 through 12. Use the spanner wrenches to 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.

PART NO.	DESCRIPTION	VENDOR NAME AND PART NO.	QTY	UM	ITM
367712-02	ACT ASSY-244.11-07,10 IN STROKE 3.3 KIP		1.00	EA	001
310910-69	MANIFOLD ASSY-S/V,252.55 10" STROKE, 244.11		1.00	EA	002
472775-01	SWIVEL ASSY-BASE END, 5.5 KIP		1.00	EA	004
429250-88	LOAD CELL CAL PLAN FOR UNIV. OF NOTRE DAME		1.00	EA	006
472770-01	SWIVEL ASSY-ROD END, 5.5 KIP		1.00	EA	009
096687-31	STUD-CONTINUOUS THREAD 1/2-20UNF-2A		1.00	EA	010
362533-01	INSERT-SCREW THREAD 1-14 UNS X 1/2-20 UNF		1.00	EA	011
096687-02	STUD-CONTINOUS THREAD 1/2-20UNF-2A X 1.50 LG.		1.00	EA	012
414408-01	SPACER-LOAD CELL MTG., 244.1X		1.00	EA	013