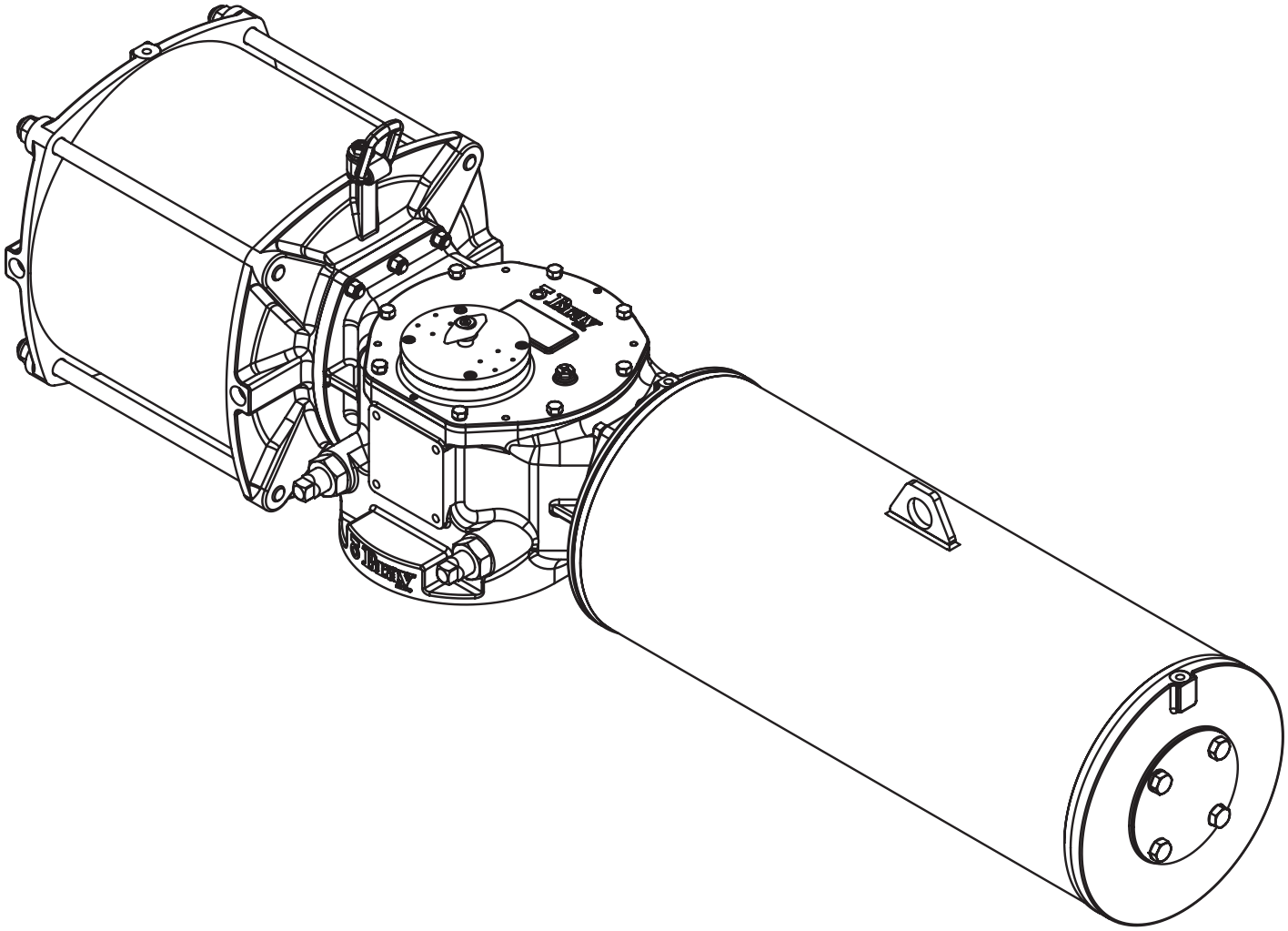
Bray SERIES 98

PNEUMATIC SCOTCH YOKE ACTUATOR

OPERATION AND MAINTENANCE MANUAL



The High Performance Company

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1.0 Safety Information - Definition of Terms

WARNING	indicates a potentially hazardous situation which, if not avoided, could result in death or serious injury.
CAUTION	indicates a potentially hazardous situation which, if not avoided, may result in minor or moderate injury.
NOTICE	used without the safety alert symbol indicates a potential situation which, if not avoided, may result in an undesirable result or state, including property damage.

1.1 Hazard-free use

This device left the factory in proper condition to be safely installed and operated in a hazard-free manner. The notes and warnings in this document must be observed by the user if this safe condition is to be maintained and hazard-free operation of the device assured.

- Take all necessary precautions to prevent damage due to rough handling, impact, or improper storage. Do not use abrasive compounds to clean, or scrape its surfaces with any objects.
- Configuration and calibration procedures are described in this document. Proper configuration and calibration is required for the safe operation of this product.
- The control system in which the unit is installed must have proper safeguards to prevent injury to personnel, or damage to equipment, should failure of system components occur.
- This document does not cover every detail about every version of the product described. It cannot take into account every potential occurrence in installation, operation, maintenance and use.
- If situations transpire that are not documented in sufficient detail, please request the required information from the Bray Distributor or Representative responsible for your area.

1.2 Qualified Personnel

A qualified person in terms of this document is one who is familiar with the installation, commissioning and operation of the product and who has appropriate qualifications, such as:

- Is trained in the operation and maintenance of pneumatic pressure equipment and systems in accordance with established safety practices.
- Is trained or authorized to energize, de-energize, ground, tag and lock electrical circuits and equipment in accordance with established safety practices.
- Is trained in the proper use and care of personal protective equipment (PPE) in accordance with established safety practices.
- Is trained in first aid.
- In cases where the device is installed in a potentially explosive (hazardous) location – is trained in the operation, commissioning, and maintenance of equipment in hazardous locations.

2.0 Introduction

The instructions and guidelines in this manual enable competent technicians to install, operate, adjust and carry out routine maintenance activities on Series 98 pneumatic actuators. Responsibility lies with the user to follow the instructions in this and in any additional documentation related to the product and accessories supplied with it.

User shall ensure the equipment is installed and operated in the environment that it is intended for and effective protections are provided against exposure to pressure and temperature in excess of maximum rating. Failing to do so may affect the product warranty. Only trained personnel, aware of precautions in hazardous environments and health and safety in the workplace should service the equipment.

Series 98 Actuators are designed for quarter turn rotary valves, in configurations as:

DA- Double Acting with a single cylinder

DD- Double Acting with dual cylinders

SC- Spring Return Fail Close (CW)

SO- Spring Return Fail Open (CCW)

Two output torque characteristic profiles are available in the form of Symmetrical Yoke and Canted Yoke.

Standard actuators have a mounting base to ISO 5211. MSS mounting base is available as an option.

Mounting of the shaft driven accessories is per VDE 3845/ NAMUR standard.

The maximum operating pressure of the Series 98 Pneumatic Scotch Yoke Actuators range from 40 to 150 psig, depending upon the size and configuration. Refer to the MOP (maximum operating pressure) charts or the name plate on the actuator for the maximum operating pressure.

Operating media shall be instrumentation air/natural gas, filtered to 40 microns or better, with dew point of -20°C (-4°F) or at least 10°C (18°F) below ambient temperature.

The user shall plan and implement a periodic maintenance program to ensure the service conditions continue as intended and the actuator is monitored and maintained per manufacturer's recommendations.

3.0 Installation

The S98 actuators are assembled, tested and delivered per the configuration ordered. The mounting of the actuator may be direct onto the valve or may require a mounting kit that would include a bracket, coupler shaft with keys and hardware.

⚠ WARNING

Use appropriate eye bolts and slings to lift the actuator. Refer to Table 8.0 for the approximate actuator weight. The lifting eye bolt holes provided are for lifting the actuator only and not for lifting the complete valve-actuator-accessory assembly.

NOTICE

1. The user shall ensure installation in intended service conditions and that the actuator is not covered with dirt/dust or other substances that may affect any heat dissipation capability, resulting in exceeding the maximum temperature rating of the actuator.
2. To prolong actuator seal life use only recommended filtered media.
3. The actuator shall not be installed in hazardous areas incompatible with the defined gas groups and temperature class.
4. When using manual override sandwich gearbox, ensure the gearbox has over travel at least equal to that of the actuator.
5. The actuators can be mounted on valves in different positions, but care shall be taken to reorient suitably, some accessories like filter regulation units, hydraulic override power pack reservoirs, etc. that are gravity dependent for functioning.

Before proceeding with installation, check compatibility of the valve stem to the actuator bore. The length, size and configurations (keyways / double D / square) must match. Additionally, check compatibility of valve and actuator bolting pattern. If using a mounting kit, physically check the coupler to assure it fits the actuator bore and the valve stem.

1. Ensure the pressure module is depressurized completely by venting the ports to atmosphere and any power sources to accessories are disconnected.

2. Ensure the valve and actuator are aligned to the same position (i.e., valve closed - actuator closed or both in open). For spring return actuators, align the valve to the fail safe position of the actuator. If a sandwich gearbox manual override is used, then also make sure it is aligned with the valve and actuator position.
3. Secure the valve, bolt the mounting bracket to the valve and fit the coupler shaft on the valve stem (when using mounting kit). Position the actuator to align the valve stem (or coupler shaft) with the yoke bore and slide the actuator on until the actuator seats on the bracket mounting surface (or on the valve top flange, in case of direct mounting).
4. When using a manual override sandwich gearbox between the actuator and valve, first couple and fix the gearbox on the valve following the gearbox installation procedure. Back off the gearbox travel stop bolts. Mount the actuator on the gearbox with the coupler shaft and bolt up the actuator on the gearbox flange.
5. In order to align the bolt holes, it may be necessary to loosen the valve-bracket bolting slightly. The actuator mounting bolts should easily thread into the actuator base without side loading on the bracket (or the valve top flange). If needed, turn the actuator a bit and/or adjust the actuator travel stops. Bolt up the actuator to the bracket / gearbox flange / valve as the case may be.
6. Before operating the actuator, declutch the manual override, if present. The travel stops of the actuator shall limit the stroke and not those on the gearbox/valve, if present.
7. Adjust the travel stop bolts of the actuator for the proper open and closed valve positions, per valve manufacturer's recommendations. Refer to the Series 98 specifications on page 24 for the travel adjustment range for different models.
8. Tighten the travel stop bolts lock nuts after adjusting the stop bolts. Ensure the travel stops on gearbox or valve, if provided, are now adjusted and locked to fractionally lag the actuator's stop position.
9. Ensure the manual overrides are de-clutched or fully retracted before putting the actuator to test in power operation mode.
10. Pneumatically stroke the actuator several times to check proper and smooth operation. If the actuator is equipped with a switchbox or other accessories, adjust them at this time.

NOTICE

It is recommended to ground the actuator assembly against static electricity..

4.0 Operation Guidelines

Series 98 actuators operate well in both on-off and modulating applications. The accessories, control elements, tubing and fittings shall be chosen for adequate flow rates so as not to constrict flow or cause high pressure drop affecting the performance of the actuator.

Maximum Operating Pressure (MOP) of the actuator is mentioned on the nameplate and shall not be exceeded. Suitable pressure regulator and safety valve shall be incorporated in the supply line, if the line pressure is higher than this.

⚠ CAUTION

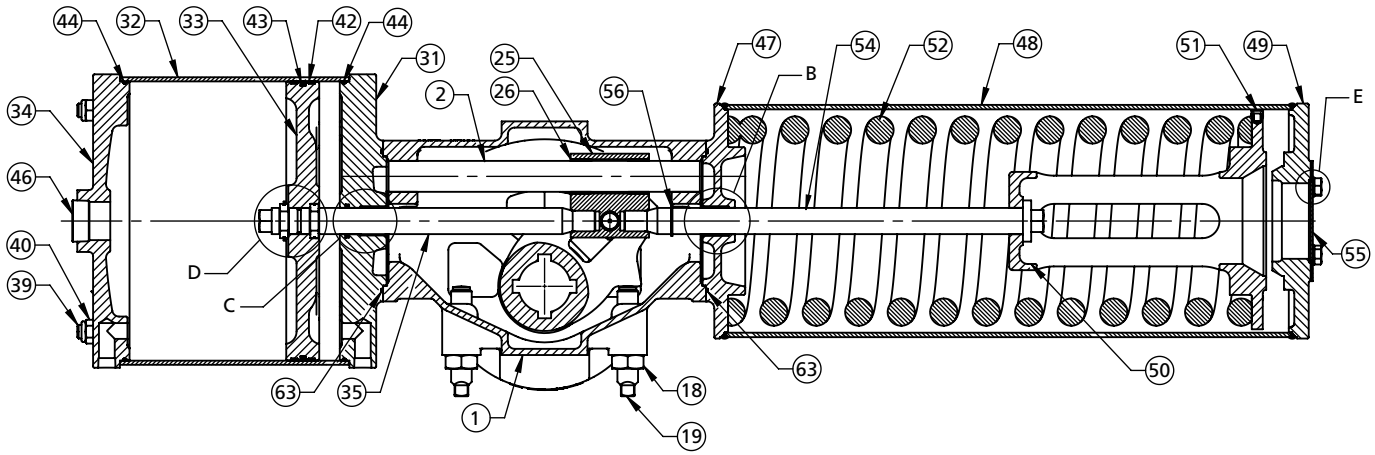
Do not pressurize from the cap end port of the spring return actuator. This port is normally fitted with a breather filter. If there is a possibility of the actuator being submerged temporarily in water due to flooding, then this port must be provided with an extension pipe with the breather filter on the pipe end, at a safe height above the water level.

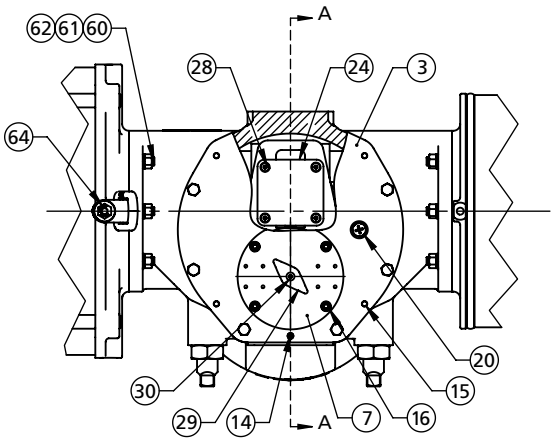
Spring Return actuators work on air stroke or spring stroke by pressurizing or venting respectively, the adaptor side port (rod end side). A 3/2 way valve is typically used.

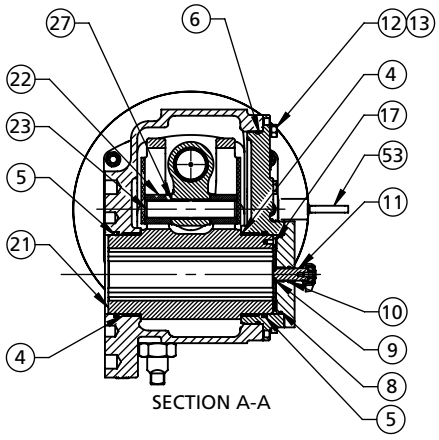
DA models require alternate ports to be pressurized and vented for stroking. A 5/2 way direction control valve or two 3/2 way valves may be used.

DD models have adaptor ports of the cylinders tubed in parallel with the end cap ports of the other side cylinder. The two cylinders work simultaneously with cap end of one and rod end of the other pressurized, at a time.

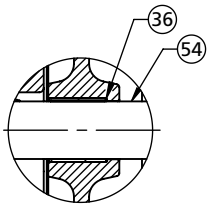
5.0 Spring Return Pneumatic Actuator Assembly Drawing and Materials of Construction



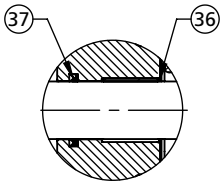




SECTION A-A



DETAIL B
SCALE 1 : 5



DETAIL C
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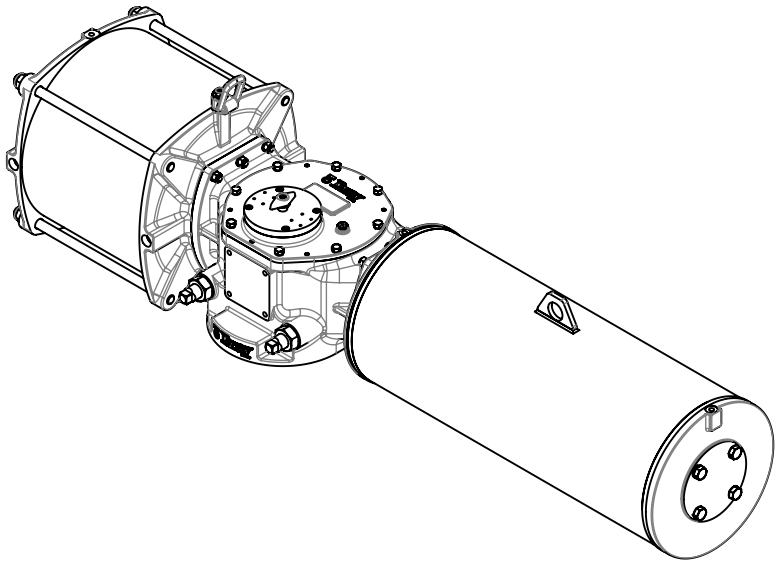
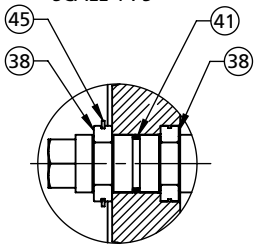
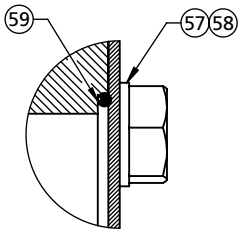




DETAIL D
SCALE 1 : 5



DETAIL E
SCALE 1 : 2

For reference only. Please refer to ES drawing for current information.

ITEM		DESCRIPTION	MATERIAL	QTY.
1		Yoke Housing	Ductile Iron	1
2		Guide Rod	Alloy Steel	1
3		Housing Cover	Ductile Iron	1
4	**	Bushing (Yoke)	PTFE Bronze	2
5	*	O-Ring (Yoke)	Buna-N	2
6	*	O-Ring (Cover)	Buna-N	1
7		Top Cover	Ductile Iron	1
8	*	O-Ring (Top Cover)	Buna-N	1
9	**	Flanged Bushing	PTFE Bronze	1
10	*	O-Ring (Accessory Drive)	Buna-N	1
11		Accessory Drive	Stainless Steel	1
12		Hex Bolt	Steel	8
13		Spring Washer	Spring Steel	8
14		Set Screw, Socket Head	Steel	2
15		Dowel Pin	Hardened Steel	4
16		Socket Head Caps Screw	Steel	4
17		Socket Head Caps Screw, Low Head	Steel	1
18		Seal Nut	Steel	2
19		Stop Bolt	Steel	2
20		Breather Vents	Carbon Steel	1
21		Yoke	Ductile Iron	1
22	**	Slider Block	Bronze	2
23		Yoke Pin	Alloy Steel	1
24		Retainer Plate	Plastic	2
25		Guide Block	Carbon Steel	1
26	**	Bushing (Guide Rod)	PTFE Bronze	2
27	**	Bushing (Yoke Pin)	PTFE Bronze	2
28		Cap Screw, Flat Head, Hex Socket	Steel	8
29		Position Indicator	Plastic	1
30		Cap Screw, Flat Head, Hex Socket	Steel	1
31		Adaptor, Pressure Module	Ductile Iron	1
32		Barrel	Carbon Steel	1

ITEM		DESCRIPTION	MATERIAL	QTY.
33		Piston	Ductile Iron	1
34		End Cap, Pressure Module	Ductile Iron	1
35		Piston Rod	Alloy Steel	1
36	**	Bushing (Adaptor)	PTFE Bronze	2
37	*	Seal, U-Cup	Buna-N	1
38		Split Collar	Alloy Steel	4
39		Tie Rod	Steel	4
40		Locknut, Nylok	Steel	4
41	*	O-Ring (Piston Rod)	Buna-N	1
42	*	Wear Ring	PTFE	2
43	*	Quad Seal	Buna-N	1
44	*	O-Ring (Barrel)	Buna-N	2
45		Retainer Ring	Stainless Steel	1
46		Pipe Plug	Carbon Steel	1
47		Adaptor, Spring Module	Carbon Steel	1
48		Pipe	Carbon Steel	1
49		End Cap, Spring Module	Carbon Steel	1
50		Spring Guide	Carbon Steel	1
51		Button	Plastic	9
52		Spring, Compression	Alloy Steel	1
53		Lifting Lug	Carbon Steel	1
54		Spring Rod	Alloy Steel	1
55		End Cover	Carbon Steel	1
56		Retainer Ring	Stainless Steel	1
57		Spring Washer	Spring Steel	4
58		Hex Bolt	Steel	4
59	*	O-Ring (End Cover)	Buna-N	1
60		Stud	Steel	12
61		Nut	Steel	12
62		Spring Washer	Spring Steel	12
63	*	O-Ring (Module)	Buna-N	2
64		Load Ring	Carbon Steel	1

*	Parts in Seal Kits	* / **	Parts in Repair Kits

For reference only. Please refer to ES drawing for current information.

6.0 Maintenance

Series 98 actuators are designed for long service periods between maintenance, in demanding conditions. However, a preventative maintenance program is essential for ensuring good performance, safe operation, extended life of equipment and to avoid expensive down time.

The service conditions, load and cycling frequency may vary largely, which would require the maintenance program to be suitably designed, with sound judgment of the working conditions. Contact manufacturer for assistance.

In general, the scheduled service shall include replacement of all seals and wear parts.

Seals shall be replaced if the actuator is in storage or inactive for long periods of time.

6.1 Lubricants and Maintenance Consumables

The Standard actuators use following lubricants

Shell Alvania EP2 (LF) grease for the Torque & Spring Modules

Molykote 55 for the Pressure Module.

ISO Grade 32 hydraulic fluid for hydraulic override

Thread lock compound: Loctite 243 (or equivalent)

Thread Sealant: Loctite 577(or equivalent)

Commercial leak check fluid: Snoop (or equivalent)

Anti seize compound: Loctite 77164 (or equivalent)

6.2 Disassembly, Service & Reassembly of Modules

CAUTION

Prior to disassembly of the actuator, disconnect all air and electrical supplies from actuator, remove all accessories from actuator and dismount actuator from valve (or override gearbox, if present).

NOTICE

Replacement of the DU (items 4, 9, 26 & 27) bushings may require workshop infrastructure to remove the worn bearings from their housing and to press fit new ones, without damaging the housings.

References:

Drawing # ES- 00019 – Spring Return Actuator Assembly
Drawing # ES- 00020 – DA Assembly
Drawing # ES- 00021 – DD Assembly

(Refer to the Bray website for current revisions of the drawings)

6.3 Spring Module

WARNING

Follow the sequence of steps as described below. Injury or damages may occur if critical steps are bypassed or shortcuts taken.

Never attempt to cut open the Spring Module welded assembly, the spring is energized and can cause severe injury or death and extensive damages.

Note: If the actuator is provided with a Jackscrew or Hydraulic override cylinder on the Spring Module, first ensure to back off the override fully, to unload it from any spring force. Remove the override assembly before disassembling Spring Module.

6.3.1 Removing the Spring Module

(Refer to drawing on page 6)

1. Slacken the Spring Module side Travel Stop Bolt Lock Nuts (18) on the torque module (and extended stopper, if provided). Apply air pressure to pressure module adaptor port (rod end port), raising pressure slowly, enough to release spring force on the Travel Stop Bolt (19).
2. Mark the set position and back off fully both the Stop Bolts (and Extended Stopper/Jackscrew, if present) and release air pressure. This will relieve the spring preload.

CAUTION

Never try to remove the Spring Rod without completely relieving the spring load on it.

3. Remove the Extended Stopper/ override assembly, if present, from the Spring Module by unfastening the bolts holding the assembly on the End Plate.

WARNING

The Spring Module is welded into an integral component and the internal components cannot be disassembled.

Spring within is compressed. Never attempt to modify or cut open this moduloe

4. To take the Spring Module off the actuator, unscrew the End Cover Bolts (58) and remove the End Cover (55) and the O-ring (59). Using an extended socket spanner /tube spanner, unscrew and disconnect the Spring Rod (54) from the Guide Block (25) in Torque Module. A retainer ring on the threaded side of the Spring Rod stops it from being taken out of the Spring Module.

5. Sling and support the Spring Module and remove the Module's mounting flange Stud Nuts (61) and Lock washers (62). Spring Module can now be pulled off the Torque Module. Pull off the module carefully so as not to damage the threads on the Spring Rod and the Adaptor Plate Studs.

6.3.2 Service & Reassembly of the Spring Module

1. Take the Retainer Ring (56) off and pull the Spring Rod out from the cover end.
2. Replace the Rod Guide Bushing (36), clean and lubricate the Spring Rod and slide it back in.
3. Install the Retainer Ring back in the Spring Rod groove.
4. Fit the Module back on Torque Module with new O-ring (63).
5. Fit End Cover back with new O-ring (59).

6.4 Pressure Module

⚠ CAUTION

Ensure the ports are vented to atmosphere before disassembly of Pressure Module. Failure to do so could cause severe injury.

To take the Pressure Module off the Spring Return Actuator, first the Spring Module must be removed or at least the Spring Rod must be disconnected from the Guide Block (steps 1-3), as described in section 6.3.1.

If the actuator is provided with a Jackscrew or Extended Travel Stop on the Pressure Module, first ensure to back them off fully and remove them from the Pressure Module by unfastening the bolts holding the assembly on the End Cap.

6.4.1 Removing the Pressure Module from Actuator

1. Remove the Plug (46) (or cover plate) on the End Cap (34).
2. Use an extended socket or tube spanner and unscrew the Piston Rod (35) from the Guide Block (25) in Torque Module.
3. Sling and support the Pressure Module. Remove the Adaptor Stud Nuts (61) and Lock washers (62). Pressure Module can now be pulled off the Torque Module. Pull off the module carefully so as not to damage the threads on the Piston Rod and on the Adaptor Plate Studs.
4. Ensure the Module sealing O-ring (63) is retained in the groove.

6.4.2 Disassembling the Pressure Module

1. Secure the Module and unscrew the Tie Rod Nuts (40).
2. Gently tap the End Plate (34) off the cylinder Barrel (32) with a plastic mallet and remove the End Plate.
3. Slide the Cylinder Barrel over and off the Adaptor Plate (31) and Piston (33), being careful not to scratch or dent the honed and chrome plated surface of the barrel.
4. Take the Piston Assembly off the Adaptor Plate, taking care not to damage the threads.
5. Tie Rods (39) may be unscrewed from the Adaptor Plate.
6. Remove the Retainer Ring (45) and take the Split Collars (38) off the Piston Rod (35) upper groove. Pull the Piston Rod off the Piston and remove the Split Collars from the lower groove.

6.4.3 Service & Reassembly of the Pressure Module

NOTICE

The wear parts (all seals, piston wear bands and rod guide bushings in the Repair Kit) shall be replaced during the maintenance cycle. Ensure the replacement seals are suitable for the service temperature

The assembly of the Pressure Module is done in vertical orientation.

Use Dow Corning Molykote 55 lubricant in the Pressure Module.

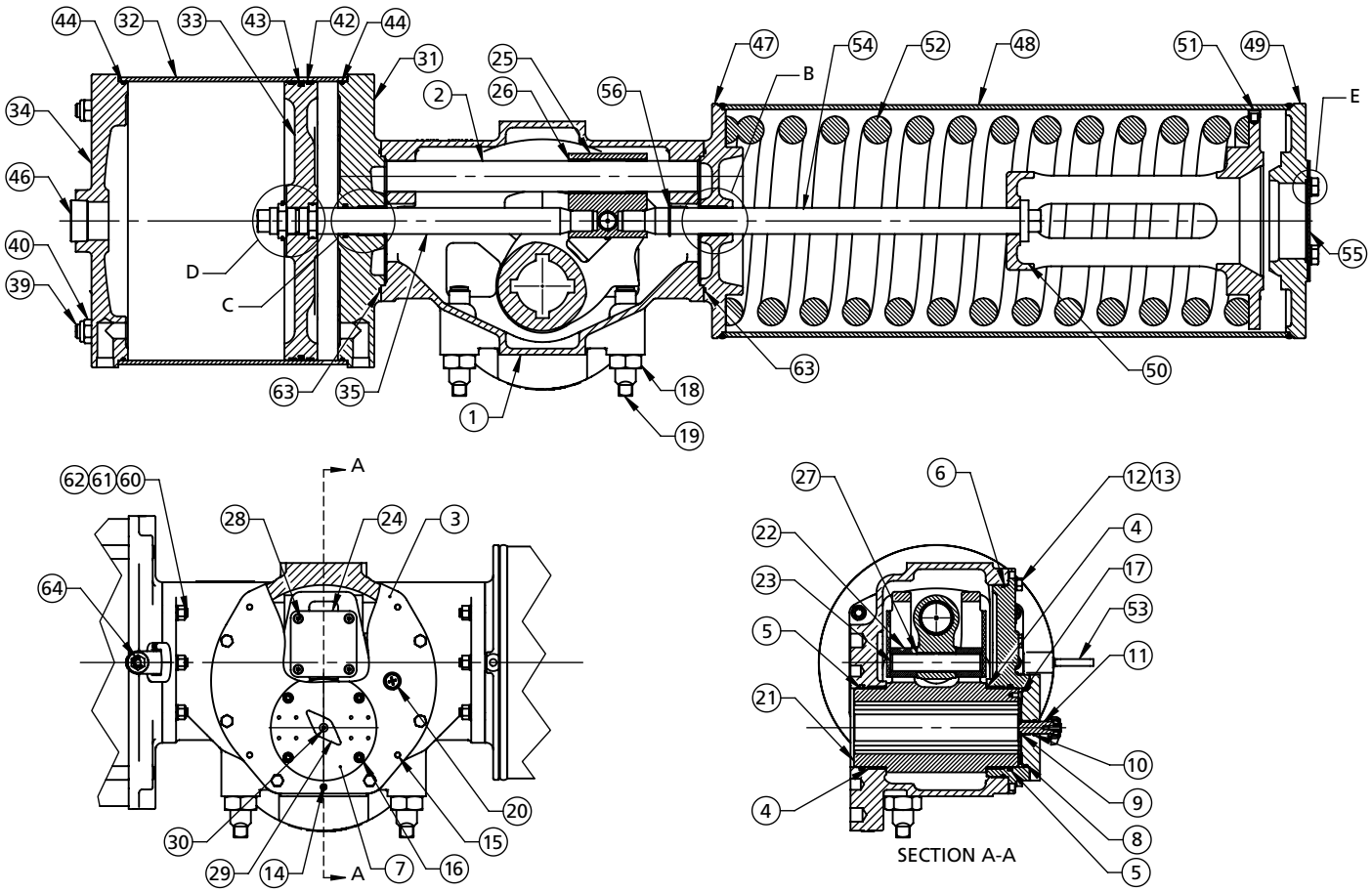
1. To reassemble, secure the Adaptor Plate horizontally, after replacing the Rod Guide Bushing (36), with sufficient space below, to accommodate the Piston Rod. The rod seal groove side of the Adaptor faces upwards.
2. Lubricate the piston rod U-cup Seal (37) and insert it in the groove in Adaptor Plate with the seal lip towards piston side.
3. Lubricate and install the Adaptor O-ring (44).
4. Lubricate the piston rod O-ring (41) and install in the groove on the piston rod.
5. Grease and slip in the Split Collars on the Piston Rod lower groove and slide in the Piston Rod (hex side) through the Piston till the split collars locate in the counter bore in the piston.
6. Install the Split Collars on the upper groove similarly and secure it by the Spiral Retainer Ring.
7. Lubricate the Piston Rod and carefully slide in the Piston Assembly through the Rod Seal and Guide Bushing in the Adaptor Plate. Beware of the pinch points between the Piston and the Adaptor plate while lowering the Piston Assembly on the Adaptor Plate inner face.
8. Lubricate and install the Wear Bands (42) and the Piston Quad Seal (43) on the Piston.

9. Carefully lift and slide in the Barrel over the Piston Wear Bands, Quad Seal and Adaptor O-ring and push it down on to the Adaptor Plate.
10. Thread the Tie Rods into the Adaptor Plate, use thread lock compound on the threads.
11. Lubricate the inside of the Barrel and slide in the End Cap, aligning the ports on the Adaptor and the End Cap.
12. Apply a little anti-seize compound on tie rod threads and fasten the assembly with Tie Rod Nuts to the recommended torque (Refer to page 18 Bolting Torque Tables)
13. Lift the Module using lifting eye bolts threaded into the End Cap and place it horizontally. Put back the Plug/Cover Plate on the End Cap to test the module.
14. Apply 10-15 psi air pressure to ports alternately to check for smooth stroking for 5-10 cycles and then raise to 80 psi and hold the pressure to check for any leaks past the Piston, through the Rod Seal and the Barrel O-rings.

    Do a bubble test for piston seal leak and for other seals check visually using commercial leak check fluids (like Snoop).

    Leakage rate after hold down time shall not be much higher than 1-2 bubbles per minute with a ¼" ID tube.

    Stroke the piston a few times to set the seals if leakage is higher, and repeat the bubble test. If still not within the limits, dismantle the module to examine the cause.
15. If no abnormalities are seen, the Module is ready for assembly on the Torque Module.



6.5 Torque Module

6.5.1 Disassembling the Torque Module

NOTICE

Either the Spring Module or the Pressure Module must be removed from the Torque Module to allow for removal of the Guide Bar and Yoke Assembly from the Torque Module.

1. Disconnect the Piston Rod (35) and the Spring Rod (34) from the Guide Block prior to disassembly.
2. Remove the position Indicator (29), if provided.
3. Remove Top Cover Bolts (16) and the Top Cover (7).
4. Take off the Accessory Drive Shaft Assembly (11) from top of the Yoke.
5. Remove the Housing Cover Bolts (12) and Lock Washers (13).
6. Tighten the two Set Screws (14) on the Housing Cover (3), half turn at a time alternately till the Housing Cover is separated enough to pry off the Housing with a blunt tool.
7. Gently tap with plastic hammer or pull off the Guide Bar (2) from the Guide Block (25) and the Housing (1).
8. Rotate and center the Yoke Assembly, move the Guide Block towards the Yoke center and lift the Yoke Assembly out of Housing.

NOTICE

For smaller models (up to 14E3) this can be done by hand. Larger models may require use of a hoist to support the weight of the Yoke Sub assembly. For this, remove the Screw (17) off the Yoke and fit an eye bolt in place.

9. Secure the Yoke Assembly and remove the Retainer Plate Screws (28) and the Retainer Plate (24).
10. Pull out the Yoke Pin (23), and the upper Slider Block (22).
11. Slide the Guide Block out of the Yoke (21) and remove the bottom Slider Block.
12. Remove the Yoke sealing O-rings (5) from the Housing and Housing Cover, if replacement is required.
13. The Yoke Bearings (4) in the Housing and the Housing Cover, the Guide Bar Bearings (26) and Yoke Pin Bearings (27) in the Guide Block are press fitted bearings and can only be removed for replacement with suitable tools.

6.5.2 Service & Reassembly of the Torque Module

1. Replace the DU bushings in the Housing, the Housing Cover and the Guide Block.
2. Secure the Yoke and fit the bottom Retainer Plate (24) with Screws (28), applying a drop of thread lock compound on the screw threads.
3. Flip the Yoke over, grease the bottom slot and the Slider Block (22) generously and slide the Slider Block into the slot.
4. Grease the Guide Block bushings and slide the Guide Block between the arms of the Yoke aligning the Yoke Pin bushings with the lower Slider Block pin hole.
5. Grease the Yoke Pin (23) and slide it through the upper slot in the Yoke and the Guide Block pin bearings, locating it in the lower Slider Block hole. Push the Yoke Pin down to touch the bottom Retainer Plate.
6. Grease the upper slot and the Slider Block and slide it down on the Yoke Pin through the upper slot till it rests on the Guide Block.
7. Fit the upper Retainer Plate to complete the Yoke Assembly.
8. Lubricate and Install the Yoke O-ring (5) in the Housing and grease the bearing in the Housing and the Yoke seating raised face.
9. Carefully slide in the Yoke Assembly into the Housing bearing and push it down to seat it on the raised seating face in the Housing.
10. Grease and slide in the Guide Bar (2) through the Housing and Guide Block.
11. Screw in the accessory drive shaft assembly Screw (17) on top of the Yoke, applying a drop of thread lock compound. Grease the upper journal of the Yoke.
12. Lubricate and install the Yoke O-ring and Cover O-ring (6) in the Housing Cover and locate it on the Yoke upper journal and fit the Housing Cover on the Housing with the Cover Bolts (12). Ensure the set screws on the Housing Cover are backed off fully.
13. Locate the Accessory Drive Shaft Assembly on the top of the Yoke, and set the screw on Yoke into the slot in the plate.
14. Replace the flanged bushing and the O-rings in the Top cover and fit it back on the Housing Cover with the Top Plate Bolts. Fit the indicator on the drive shaft.
15. Thread the travel Stop Bolts with the Lock Nuts into the Torque Module Housing

6.6 Reassembly of Actuator

1. Secure the Torque Module on its base.
2. Back off the travel Stop Bolts (19) fully and manually turn the Yoke to one side on which the Pressure Module is to be fixed.
3. Lift the Pressure Module, lubricate and place the module flange O-ring in the groove. Apply a drop of thread lock compound on the Piston Rod threads and locate the module on the Torque Module's mounting flange.
4. Carefully guide the Studs into the flange and center the module on the spigot.
5. Apply a little anti seize compound on the Stud threads and fasten the modules with Spring Washers and Stud Nuts, referring to the tables on page 18 for torque values.
6. Take the Plug/End Cover off the End Cap of the Pressure Module and couple the Piston Rod threads to the Guide block, using an extended socket or tube spanner. Refer to the tables on page 18 for torque values.
7. Install the Plug (or End Cover) with thread sealant and apply low pressure air (5psi) on the End Cap port till the Yoke reaches end of stroke. Restrain the Guide Bar from sliding out of the Housing while stroking.
8. For DA models (refer to Drawing #ES-00020-DA Assembly), fit the DA End Cover (52) with O-ring (47) in the groove, using Studs (51), Nuts (50) and Spring Washers (49). Skip to step 12.
9. For DD models, mount the second Pressure Module on the other side of Torque Module, following relevant actions from steps 3 through 7.
10. For Spring Return Models, mount the Spring Module on the other side of the Torque Module in same manner as the Pressure Module and couple the Spring Rod to Guide Block just as was done with the Piston Rod. Always ensure to tighten the Piston and the Spring Rod to the recommended torque.
11. Fix the End Cover Plate with O-ring on the Spring Module (or the Extended Travel Stop/Jackscrew Assembly/Hydraulic override cylinder, if provided).
12. Set the Travel Stops to previously marked positions.
13. Test the actuator for smooth operation at the Maximum Operating Pressure, as noted on the nameplate.

7.0 Field Conversions

7.1 Fail Safe Condition (for Spring Return Actuators)

The fail safe direction on Series 98 spring return actuator can be reversed from fail CW to fail CCW and vise versa. This requires interchanging the position of Pressure and Spring Modules.

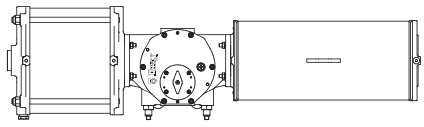
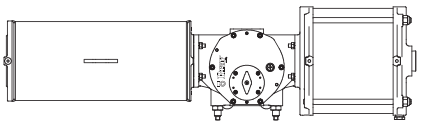
NOTICE

Though the direction change is possible to be accomplished without removing the Torque Module off the Valve (or Manual override gearbox), it is strongly recommended to take the actuator off the valve to do the fail safe reversal. The reason being, the actuator travel stop bolts need to be backed off completely to turn the Yoke sufficiently to safely disconnect the Spring Rod of the Spring Module, which may be prevented by the valve travel stop or the override gearbox, if present.

CAUTION

Never try to unscrew and remove the Spring Rod without completely relieving the spring load on it.

1. Follow the steps for removing the Spring and Pressure Modules from the actuator, as described in Sections 6.3 and 6.4 respectively (pages 8 and 9).
2. Switch the positions of the two modules, mount the Pressure Module first. Take care to seat the module sealing O-ring properly in the groove.
3. Follow instructions in Section 6.6 (page 12) for Reassembly of the Actuator.
4. Mount the Actuator back on the valve/gearbox and adjust the travel stop bolts, as required for proper valve operation. Tighten the sealing Lock Nuts on the travel Stop Bolts.
5. Check actuator for proper operation, using the rated working pressure.

Actuator Configuration	Fail Direction
	CW 
	CCW 

NOTICE

Actuator Designation needs to be suitably changed (from FCW to FCCW or vise versa) on the name plate, after completing this configuration change.

7.2 Double Acting to Spring Return

1. To convert the DA actuator to Spring Return (SC or SO), a Spring Module will need to be mounted opposite the Pressure Module with a Module Mounting Kit.
2. If the Pressure Module needs to be shifted, for the required configuration of the Spring Return actuator, then first remove the Pressure Module from the actuator. Follow the procedure in Section 6.4 to remove the Pressure Module and Section 6.6 for Reassembly of Actuator. Skip this step if shifting the Pressure Module is not required.
3. Remove the DA End Cover (52), (refer to Drawing #ES-00020 – DA Assembly).
4. Tighten the Studs from Module Mounting Kit into the Spring Module Adaptor Plate, applying thread lock compound on the threads. Install the module O-ring in adaptor groove.
5. Follow steps in Section 6.6 for Reassembly of the Actuator.
6. Set the travel Stop Bolts on the Torque Module as required for proper valve seating.
7. Remove the air connection from the End Cap port of the Pressure Module and replace the connector with a breather-filter.
8. The Spring Return Actuator requires air connection only on the Adaptor port.

NOTICE

Actuator Designation needs to be suitably changed and Maximum Operating Pressure of the actuator to be suitably updated on the name plate, after completing this configuration change.

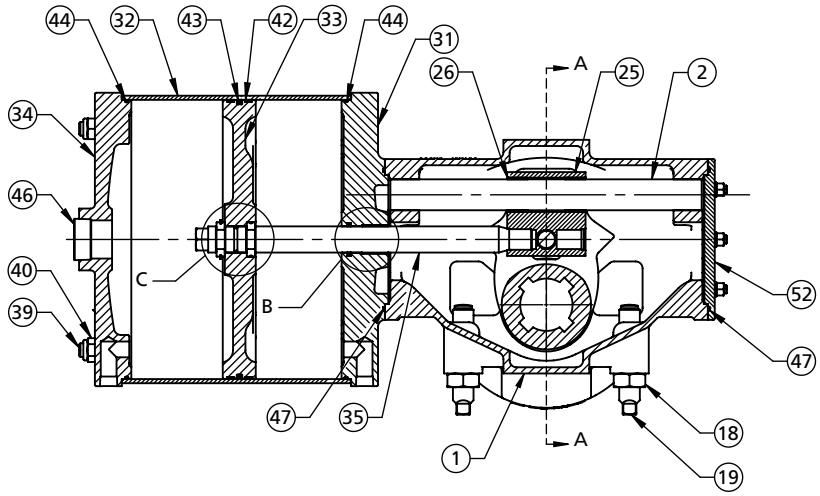
7.3 Spring Return to Double Acting

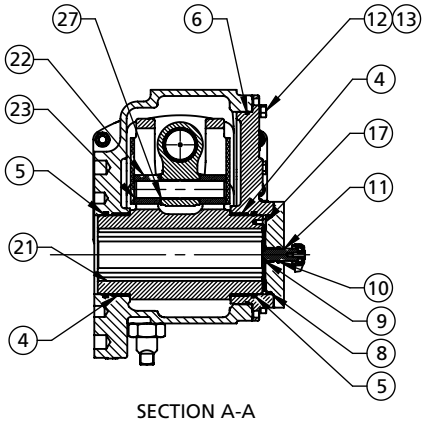
1. Remove Spring Module from actuator (refer to Section 6.3).
2. Fit DA End Cover with O-ring and fasteners from the DA Cover Kit.
3. Adjust travel Stop Bolts, as required.
4. Remove the breather-filter from the End Cap of the Pressure Module and connect suitable connector for connecting the air line from the direction control valve.

NOTICE

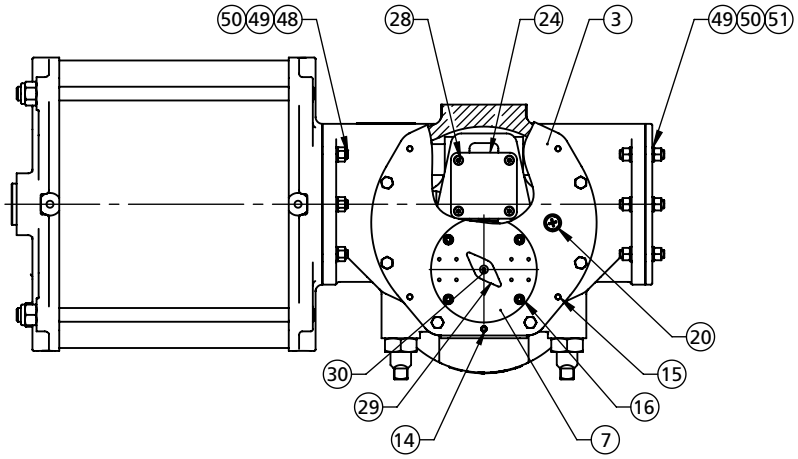
Actuator Designation needs to be suitably changed and Maximum Operating Pressure of the actuator to be suitably updated on the name plate, after completing this configuration change.

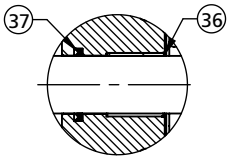
8.0 Pneumatic Actuator - Double Acting, Single Cylinder Assembly and Materials of Construction



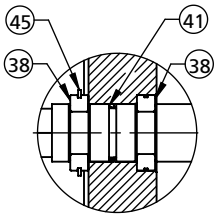


SECTION A-A

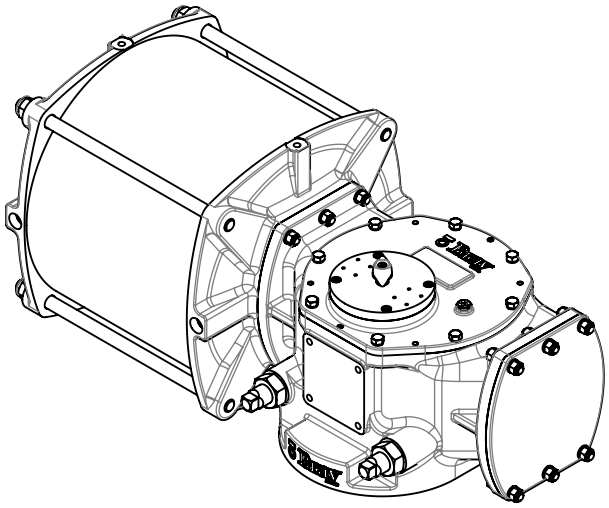




DETAIL B
SCALE 1 : 5



DETAIL C
SCALE 1 : 5



For reference only. Please refer to ES drawing for current information.

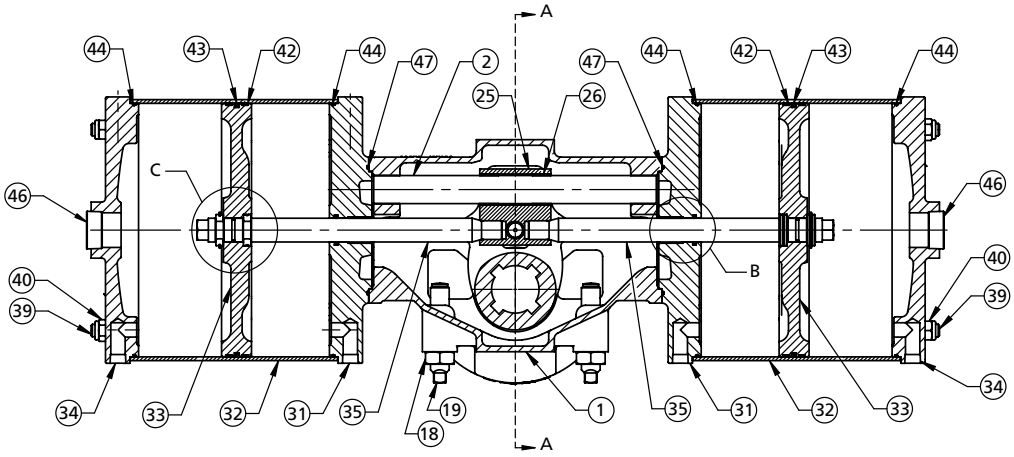
ITEM		DESCRIPTION	MATERIAL	QTY.
1		Yoke Housing	Ductile Iron	1
2		Guide Rod	Alloy Steel	1
3		Housing Cover	Ductile Iron	1
4	**	Bushing (Yoke)	PTFE Bronze	2
5	*	O-Ring (Yoke)	Buna-N	2
6	*	O-Ring (Cover)	Buna-N	1
7		Top Cover	Ductile Iron	1
8	*	O-Ring (Top Cover)	Buna-N	1
9	**	Flanged Bushing	PTFE Bronze	1
10	*	O-Ring (Accessory Drive)	Buna-N	1
11		Accessory Drive	Stainless Steel	1
12		Hex Bolt	Steel	8
13		Spring Washer	Spring Steel	8
14		Set Screw, Socket Head	Steel	2
15		Dowel Pin	Hardened Steel	4
16		Socket Head Caps Screw	Steel	4
17		Socket Head Caps Screw, Low Head	Steel	1
18		Seal Nut	Steel	2
19		Stop Bolt	Steel	2
20		Breather Vents	Carbon Steel	1
21		Yoke	Ductile Iron	1
22	**	Slider Block	Bronze	2
23		Yoke Pin	Alloy Steel	1
24		Retainer Plate	Plastic	2
25		Guide Block	Carbon Steel	1
26	**	Bushing (Guide Rod)	PTFE Bronze	2

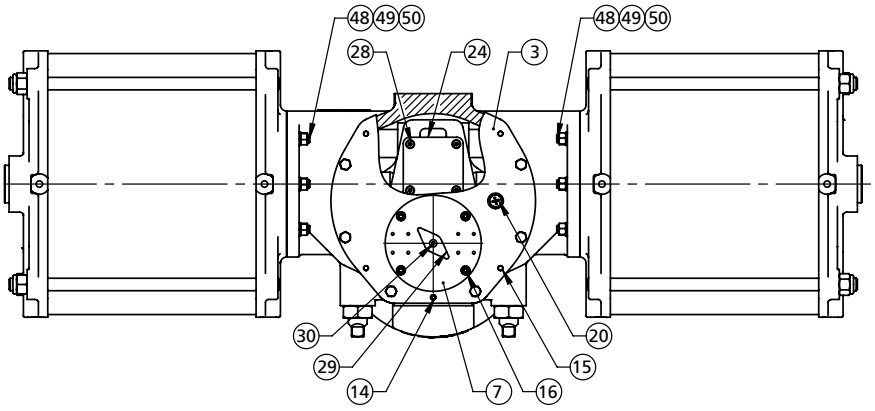
ITEM		DESCRIPTION	MATERIAL	QTY.
27	**	Bushing (Yoke Pin)	PTFE Bronze	2
28		Cap Screw, Flat Head, Hex Socket	Steel	8
29		Position Indicator	Plastic	1
30		Cap Screw, Flat Head, Hex Socket	Steel	1
31		Adaptor, Pressure Module	Ductile Iron	1
32		Barrel	Carbon Steel	1
33		Piston	Ductile Iron	1
34		End Cap, Pressure Module	Ductile Iron	1
35		Piston Rod	Alloy Steel	1
36	**	Bushing (Adaptor)	PTFE Bronze	1
37	*	Seal, U-Cup	Buna-N	1
38		Split Collar	Alloy Steel	4
39		Tie Rod	Steel	4
40		Locknut, Nylok	Steel	4
41	*	O-Ring (Piston Rod)	Buna-N	1
42	*	Wear Ring	PTFE	2
43	*	Quad Seal	Buna-N	1
44	*	O-Ring (Barrel)	Buna-N	2
45		Retainer Ring	Stainless Steel	1
46		Pipe Plug	Carbon Steel	1
47	*	O-Ring (Module)	Buna-N	2
48		Stud	Steel	6
49		Spring Washer	Spring Steel	18
50		Nut	Steel	18
51		Stud	Steel	6
52		End Cover, DA	Ductile Iron	1

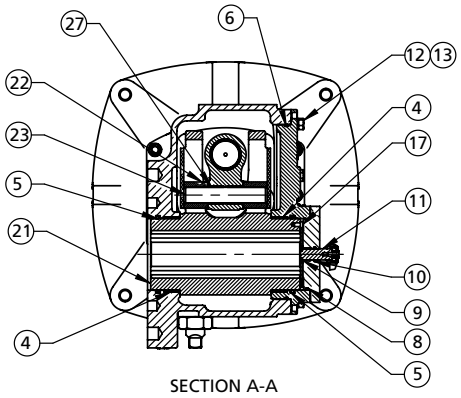
*	Parts in Seal Kits	* / **	Parts in Repair Kits

For reference only. Please refer to ES drawing for current information.

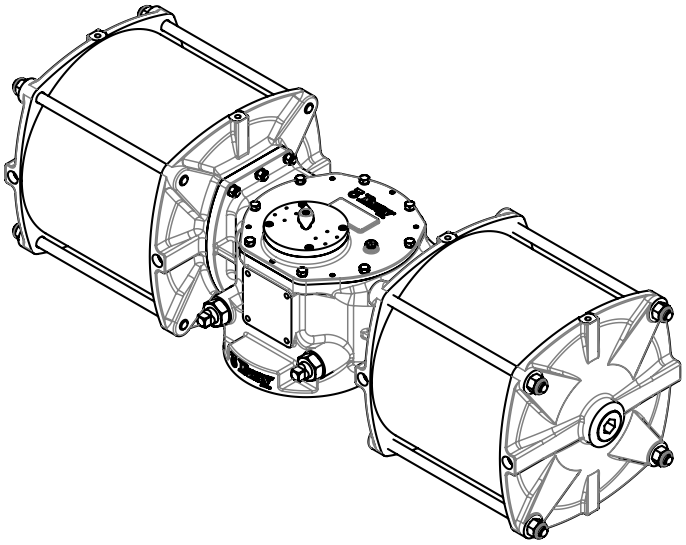
9.0 Pneumatic Actuator - Double Acting, Dual Cylinder Assembly and Materials of Construction

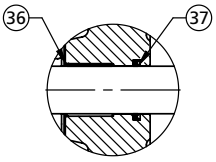




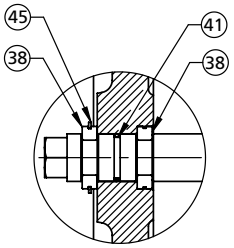


SECTION A-A





DETAIL B
SCALE 2 : 11



DETAIL C
SCALE 2 : 11

For reference only. Please refer to ES drawing for current information.

ITEM		DESCRIPTION	MATERIAL	QTY
1		Yoke Housing	Ductile Iron	1
2		Guide Rod	Alloy Steel	1
3		Housing Cover	Ductile Iron	1
4	**	Bushing (Yoke)	PTFE Bronze	2
5	*	O-Ring (Yoke)	Buna-N	2
6	*	O-Ring (Cover)	Buna-N	1
7		Top Cover	Ductile Iron	1
8	*	O-Ring (Top Cover)	Buna-N	1
9	**	Flanged Bushing	PTFE Bronze	1
10	*	O-Ring (Accessory Drive)	Buna-N	1
11		Accessory Drive	Stainless Steel	1
12		Hex Bolt	Steel	8
13		Spring Washer	Spring Steel	8
14		Set Screw, Socket Head	Steel	2
15		Dowel Pin	Hardened Steel	4
16		Socket Head Caps Screw	Steel	4
17		Socket Head Caps Screw, Low Head	Steel	1
18		Seal Nut	Steel	2
19		Stop Bolt	Steel	2
20		Breather Vents	Carbon Steel	1
21		Yoke	Ductile Iron	1
22	**	Slider Block	Bronze	2
23		Yoke Pin	Alloy Steel	1
24		Retainer Plate	Plastic	2
25		Guide Block	Carbon Steel	1

ITEM		DESCRIPTION	MATERIAL	QTY
26	**	Bushing (Guide Rod)	PTFE Bronze	2
27	**	Bushing (Yoke Pin)	PTFE Bronze	2
28		Cap Screw, Flat Head, Hex Socket	Steel	8
29		Position Indicator	Plastic	1
30		Cap Screw, Flat Head, Hex Socket	Steel	1
31		Adaptor, Pressure Module	Ductile Iron	2
32		Barrel	Carbon Steel	2
33		Piston	Ductile Iron	2
34		End Cap, Pressure Module	Ductile Iron	2
35		Piston Rod	Alloy Steel	2
36	**	Bushing (Adaptor)	PTFE Bronze	2
37	*	Seal, U-Cup	Buna-N	2
38		Split Collar	Alloy Steel	8
39		Tie Rod	Steel	8
40		Locknut, Nylok	Steel	8
41	*	O-Ring (Piston Rod)	Buna-N	2
42	*	Wear Ring	PTFE	4
43	*	Quad Seal	Buna-N	2
44	*	O-Ring (Barrel)	Buna-N	4
45		Retainer Ring	Stainless Steel	2
46		Pipe Plug	Carbon Steel	2
47	*	O-Ring (Module)	Buna-N	2
48		Stud	Steel	12
49		Spring Washer	Spring Steel	12
50		Nut	Steel	12

*	Parts in Seal Kits	* / **	Parts in Repair Kits

For reference only. Please refer to ES drawing for current information.

10.0 Bolting Torques and Tools

PRESSURE MODULE											
	8	9	10	12	14	16	18	20	22	24	28
Tie Rod Thread	M10	M12	M12	M16	M16	M20	M20	M24	M24	M30	M30
Spanner Size, Metric	16	18	18	24	24	30	30	36	36	46	46
Torque, Nm	26	38	47	89	121	197	249	369	446	669	455
End Plug, NPT	1.25	1.5"	1.5"	2"	2"	2"					
Allen Key	.75"	1"	1"	1"	1"	1"					
End Plate Bolts							M10	M10	M10	M10	M16
Spanner Size, Metric							17	17	17	17	24
Torque, Nm							20	20	20	20	60

TORQUE MODULE					
MODEL	45 E2	73 E2	14 E3	24 E3	45 E3
Housing Cover Bolts/Stud	M8	M8	M10	M12	M12
Spanner Size, Metric	13	13	16	18	18
Torque, Nm	16	16	27	30	30
Retainer plate Screws	M5	M6	M6	M6	M6
Allen Key	3	4	4	4	4
Acc Drive Screw	M6	M6	M6	M8	M8
Allen Key	5	5	5	6	6
Top Plate Bolts	M6	M8	M8	M8	M8
Allen Key	5	6	6		
Spanner Size, Metric				13	13
Torque, Nm				16	16

SPRING MODULE					
MODEL	45 E2	73 E2	14 E3	24 E3	45 E3
Piston/Spring Rod Dia, inch	1	1.25	1.5	1.75	2.25
Rod Thread	M24 x 2	M27 x 2	M30 x 2	M36 x 3	M48 x 3
Piston/Spring Rod Hex A/F, mm	21	26	32	36	46
Torque, Nm	150	150	175	175	200

ACTUATOR ASSEMBLY					
MODEL	45 E2	73 E2	14 E3	24 E3	45 E3
ISO Base	F16/F12	F16/F12	F25/F16	F30/F25	F35/F30
Base Bolting Size	M20/M12	M20/M12	M16/M20	M20/M16	M30/M20
Module Mounting Stud-Nut Size	M10	M12	M12	M16	M16
Spanner Size, Metric	16	18	18	24	24
Torque, Nm	40	64	64	174	174
Spring Module End Cover Bolts	M12	M12	M16	M20	M16
Spanner Size, Metric	19	19	24	30	24
Acc Drive Screw	M6	M6	M6	M8	M8
Allen Key	5	5	5	6	6
Top Plate Bolts	M6	M8	M8	M8	M8
Allen Key	5	6	6		
Spanner Size, Metric				13	13

11.0 Maximum Operating Pressure

11.1 DA (Double Acting - Single Cylinder)

MAXIMUM OPERATING PRESSURE FOR DOUBLE ACTING - SINGLE CYLINDER ACTUATOR - Symmetrical Yoke/Canted Yoke														
	Rated Torq													
Model	Nm	Lb-in	Cyl	8	9	10	12	14	16	18	20	22	24	28
			S	150	144	117	81	59						
45 E2	4,500	39,830	C	150	119	96	67	49						
			S			150	107	78	60					
73 E2	7,300	64,612	C			127	88	65	49					
			S				150	127	97	77	62			
14 E3	14,000	123,914	C				142	104	80	63	51			
			S					150	124	98	80	66	55	
24 E3	24,000	212,424	C					134	102	81	66	54	46	
			S							150	121	100	84	62
45 E3	45,000	398,295	C							123	100	83	69	51

11.2 DD (Double Acting - Dual Cylinder)

MAXIMUM OPERATING PRESSURE FOR DOUBLE ACTING - DUAL CYLINDER ACTUATOR - Symmetrical Yoke/Canted Yoke														
	Rated Torq													
Model	Nm	Lb-in	Cyl	8	9	10	12	14	16	18	20	22	24	28
			S	92	72	59	41							
45 E2	4,500	39,830	C	76	60	48								
			S			77	54							
73 E2	7,300	64,612	C			64	44							
			S				87	64	49					
14 E3	14,000	123,914	C				72	52	40					
			S					82	63	49	40			
24 E3	24,000	212,424	C					67	52					
			S							75	61	50	42	
45 E3	45,000	398,295	C							62	50	41		

11.0 Maximum Operating Pressure (cont.)

11.3 Spring Return (PSI)

MAXIMUM OPERATING PRESSURE FOR SPRING RETURN ACTUATOR - Symmetrical Yoke / Canted Yoke													
Model	Rated Torq		Cyl Size	Pressure, psi									
				S1		S2		S3		S4		S5	
	Nm	Lb-in		S	C	S	C	S	C	S	C	S	C
45 E2	4500	39,830	P08	150	150	150	150	150	150				
			P09	150	150	150	150	150	150	150	150		
			P10	146	125	150	135	150	148	150	150		
			P12	101	87	108	93	117	103	121	107		
			P14	74	63	79	69	86	75	89	79		
73 E2	7300	64,612	P10	150	150	150	150	150	150	150	150		
			P12	139	120	144	125	150	133	150	141		
			P14	102	88	105	91	111	98	117	103		
			P16	78	67	80	70	85	75	90	79		
14 E3	14000	123,914	P12	150	150	150	150	150	150	150	150	150	150
			P14	150	137	150	142	150	148	150	150	150	150
			P16	122	105	126	108	130	113	138	121	143	126
			P18	96	83	99	86	103	89	109	95	113	99
			P20	78	67	80	69	83	72	88	77	91	80
24 E3	24000	212,424	P14	150	150	150	150	150	150	150	150		
			P16	150	138	150	145	150	150	150	150	150	150
			P18	126	109	132	114	139	122	145	127	150	133
			P20	102	88	106	92	113	99	117	103	122	108
			P22	84	73	88	76	93	81	97	85	101	89
			P24	71	61	74	64	78	68	81	71	84	75
45 E3	45000	398,295	P18	150	150	150	150	150	150	150	150	150	150
			P20	150	134	150	138	150	147	150	150	150	150
			P22	128	110	132	114	139	122	144	126	149	131
			P24	107	93	111	96	117	102	120	105	125	110
			P28	79	68	81	70	86	75	88	77	91	80

11.0 Maximum Operating Pressure (cont.)

11.4 Spring Return (Bar)

MAXIMUM OPERATING PRESSURE FOR SPRING RETURN ACTUATOR - Symmetrical Yoke / Canted Yoke

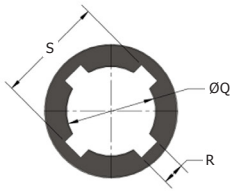
Model	Rated Torq		Cyl Size	Pressure, bar									
				S1		S2		S3		S4		S5	
	Nm	Lb-in		S	C	S	C	S	C	S	C	S	C
45 E2	4500	39830	P08	10.3	10.3	10.3	10.3	10.3	10.3				
			P09	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3		
			P10	10.1	8.6	10.3	9.3	10.3	10.2	10.3	10.3		
			P12	7.0	6.0	7.4	6.4	8.1	7.1	8.4	7.4		
			P14	5.1	4.4	5.5	4.7	5.9	5.2	6.1	5.4		
73 E2	7300	64612	P10	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3		
			P12	9.6	8.3	9.9	8.6	10.3	9.2	10.3	9.7		
			P14	7.0	6.1	7.3	6.3	7.7	6.7	8.1	7.1		
			P16	5.4	4.6	5.5	4.8	5.9	5.1	6.2	5.4		
14 E3	14000	123914	P12	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3
			P14	10.3	9.5	10.3	9.8	10.3	10.2	10.3	10.3	10.3	10.3
			P16	8.4	7.2	8.7	7.5	9.0	7.8	9.5	8.3	9.9	8.7
			P18	6.6	5.7	6.8	5.9	7.1	6.1	7.5	6.6	7.8	6.8
			P20	5.4	4.6	5.5	4.8	5.7	5.0	6.1	5.3	6.3	5.5
24 E3	24000	212424	P14	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3		
			P16	10.3	9.5	10.3	10.0	10.3	10.3	10.3	10.3	10.3	10.3
			P18	8.7	7.5	9.1	7.9	9.6	8.4	10.0	8.8	10.3	9.2
			P20	7.0	6.1	7.3	6.4	7.8	6.8	8.1	7.1	8.4	7.4
			P22	5.8	5.0	6.1	5.3	6.4	5.6	6.7	5.9	6.9	6.1
			P24	4.9	4.2	5.1	4.4	5.4	4.7	5.6	4.9	5.8	5.1
45 E3	45000	398295	P18	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3
			P20	10.3	9.2	10.3	9.5	10.3	10.2	10.3	10.3	10.3	10.3
			P22	8.8	7.6	9.1	7.9	9.6	8.4	9.9	8.7	10.3	9.0
			P24	7.4	6.4	7.6	6.6	8.1	7.0	8.3	7.3	8.6	7.6
			P28	5.4	4.7	5.6	4.8	5.9	5.2	6.1	5.3	6.3	5.5

12.0 Module Weights

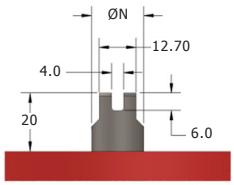
MODULE WEIGHTS (APPROX), Lbs																		
Model	Rated Torq. Lb-in	Torque Module												Spring Modules				
			8	9	10	12	14	16	18	20	22	24	28	1	2	3	4	5
45 E2	39,830	84	60	68	88	126	183							134	146	152	172	
73 E2	64,612	146			99	134	185	254						214	216	238	293	
14 E3	123,914	236				150	201	271	355	485				362	384	403	430	452
24 E3	212,424	428					229	293	373	514	613	780		575	593	619	677	679
45 E3	398,295	666							439	575	679	849	1276	1065	1116	1259	1369	1431

MODULE WEIGHTS (APPROX), Kg																		
Model	Rated Torq. Nm	Torque Module												Spring Modules				
			8	9	10	12	14	16	18	20	22	24	28	1	2	3	4	5
45 E2	4,500	38	27	31	40	57	83							61	66	69	78	
73 E2	7,300	66			45	61	84	115						97	98	108	133	
14 E3	14,000	107				68	91	123	161	220				164	174	183	195	205
24 E3	24,000	194					104	133	169	233	278	354		261	269	281	307	308
45 E3	45,000	302							199	261	308	385	579	483	506	571	621	649

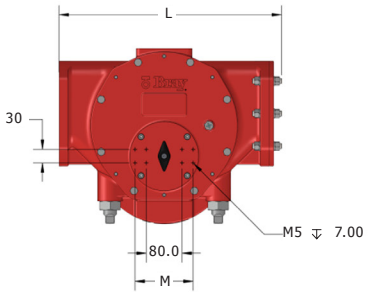
13.0 Series 98 Dimensions



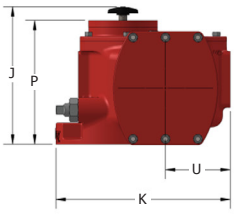
STEM BORE DETAIL



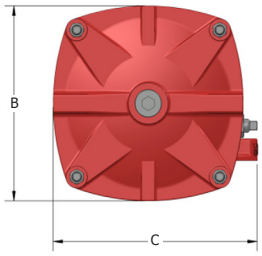
ACCESSORY DRIVE DETAILS



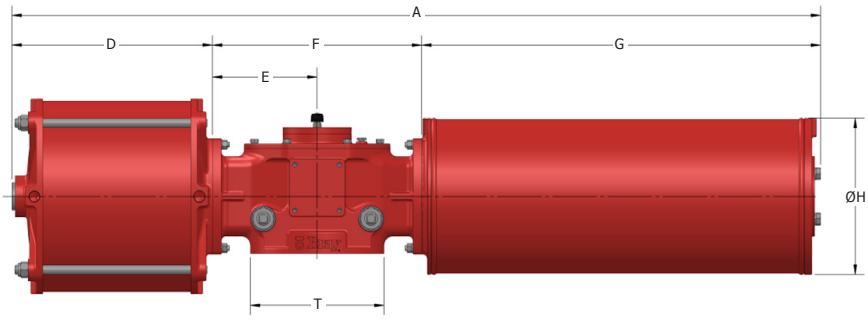
TOP VIEW



RIGHT VIEW



LEFT VIEW



FRONT VIEW

SERIES 98 MAX DIMENSIONS, inch

Model	ISO Base	A	B	C	D	E	F	G	H	J	K	L	M	N	P	Q	R	S	T	U
45E2	F16/F12	52.8	14.8	14.8	14.2	6.3	12.5	26.2	9.4	9.7	9.4	13.4	–	0.7	8.5	2.0	0.5	2.3	7.7	3.8
73E2	F16/F12	60.1	16.8	16.8	15.8	7.9	15.8	28.5	12.8	11.8	11.3	16.9	–	0.7	9.8	2.5	0.625	3.1	7.8	5.1
14E3	F25/16	72.6	21.3	21.3	18.8	9.3	18.5	35.3	13.5	12.1	15.4	19.6	5.1	0.7	10.9	3.0	0.75	3.7	11.8	5.7
24E3	F30/25	90.0	25.1	25.1	21.9	11.5	22.9	45.2	15.6	14.3	19.3	24.3	5.1	1.0	13.1	4.5	1.0	5.2	13.8	7.3
45E3	F35/30	113.3	33.3	33.3	25.8	14.3	28.6	58.9	18.7	15.3	22.8	30.0	5.1	1.0	14.1	6.0	1.5	6.8	16.3	8.3

SERIES 98 MAX DIMENSIONS, mm

Model	ISO Base	A	B	C	D	E	F	G	H	J	K	L	M	N	P	Q	R	S	T	U
45E2	F16/F12	1342	376	376	360	159	318	664	240	246	240	341	--	18	216	50	12.0	59	195	96
73E2	F16/F12	1526	427	427	400	201	402	723	326	300	288	430	--	18	249	64	15.88	78	197	129
14E3	F25/16	1843	542	542	477	235	470	896	342	307	390	498	130	18	276	76	19.05	93	300	145
24E3	F30/25	2287	638	638	556	291	582	1148	397	364	491	618	130	25	334	114	25.4	131	350	186
45E3	F35/30	2877	845	845	656	363	726	1495	476	388	580	762	130	25	357	152	38.1	173	415	212

Refer ES drawings for dimensions of specific models

14.0 Series 98 General Specifications

GENERAL SPECIFICATIONS											
RANGE											
Model	ISO Mounting Base	Rated Torque		Spring End Torque Nm		Largest Cylinder Size	MOP DA- Symm	Maximum Stem Acceptance Diameter		Maximum Stem Height	Over Travel (on either side)
		Nm	Lb-in	Min	Max	inch	psi	mm	inch	mm	± degrees
45 E2	F12/F16	4,500	39,830	1,070	2,675	14	59	50.0	1.97	183	5
73 E2	F12/F16	7,300	64,612	2,130	4,280	16	60	63.5	2.50	216	5
14 E3	F16/F25	14,000	123,914	3,485	7,845	20	62	76.2	3.00	240	5
24 E3	F25/F30	24,000	212,424	6,555	15,150	24	55	114.3	4.50	295	3
45 E3	F30/F35	45,000	398,295	11,950	25,595	28	62	152.4	6.00	318	3

CONFIGURATIONS	
DA	Double Acting- Single Cylinder
DD	Double Acting- Dual Cylinders
SC	Spring Return- Fail CW
SO	Spring Return- Fail CCW

OPERATING CONDITIONS		
Pressure Range	40 - 150 psi	
Media	Dry Compressed Air / Natural Gas	Contact factory for other media
Temperature Range - Standard Options	Standard : -20°F to 200°F (-29°C to 93°C)	
	High Temp : Up to 300°F (149°C)	Contact factory for extended ranges
	Low Temp : Down to -50°F (-46°C)	

COMPLIANCES	
Torque Base	Mounting dimensions options per ISO 5211: 2001(E) or MSS SP-101-1989
Accessories	Shaft Driven Accessories Mounting as per NAMUR-VDE
Testing	In accordance with EN 15714-3:2009
Ingress Protection	IP66/IP67M per IEC 60529
Safety	ATEX, SIL 3

15.0 Hydraulic Override

Hydraulic overrides on S98 actuators provide low effort, high thrust in a compact size for manually operating the actuator. The hydraulic override cylinders are single acting on the SR models and double acting on the DA models of the Actuators. These are available on Models 73E2 through 45E3.

The hydraulic override consists of a power pack with a hand operated high pressure pump and oil reservoir connected by tubing to the hydraulic override cylinder. The hydraulic cylinder is mounted on the Spring Module end thrust base on SR models and on the Torque Module flange on the DA models.

The hydraulic override cylinders are designed for 3,000 psi max working pressure and provide adequate thrust to output the required valve torque. The operating pressure required is set on the hand pump assembly through a built-in relief valve.

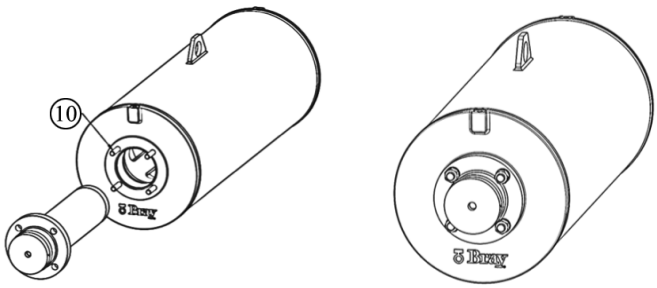
15.1 Installation

Series 98 standard actuators with hydraulic overrides are shipped pre-assembled with the cylinder, hand pump, bypass valves and tubing complete. The hand pump unit is selected, factory installed and the hydraulic pressure valve set per the application. No additional customer installation/adjustment is usually required.

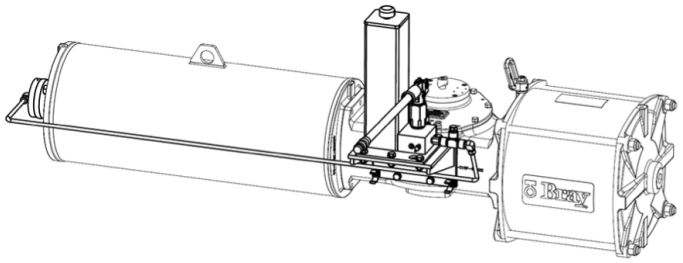
Actuators in service, without this override option, can be retrofitted with the override kit as described below.

15.1.1 Installing Hydraulic Override on Spring Return Actuators

1. Disconnect air pressure and electrical power from actuator.
2. In fail safe position of the actuator, remove the end cover plate retaining the O-ring on the Spring Module end.
3. Firmly thread the studs (10) supplied with the override mounting kit, into the thrust base. With the ram fully retracted, insert the Hydraulic Cylinder into the Spring Module mating the cylinder flange to the thrust base while positioning the air venting plug at the top.



4. Secure the cylinder flange on the thrust base of the Spring Module with the spring washers and nuts from the override mounting kit.
5. Thread in the hydraulic connector into the cylinder port (if not already fitted into the cylinder). Use a commercial hydraulic fitting thread sealant (Loctite 542 or equivalent).
6. Fit a 3-way valve, rated for 150 psi (10.3 bar) working pressure, to the pneumatic module's port (Refer to Figure A on page 26).Turn the valve to venting position so that the pneumatic cylinder's port is connected to atmosphere.
7. Fit the hydraulic hand pump assembly bracket on the rear accessories mounting pad of the Torque Module with the 4 bolts supplied in the kit. Tube the cylinder port to the pump outlet port, as in Figure A. The standard mounting, as shown, is for the actuator in horizontal orientation. Special brackets for other orientations of the actuator can be supplied upon request.
8. On the Tee at the pump outlet, remove the plug and install a suitable pressure gage (0-4000psi).



9. Fill the hand pump reservoir to the required level with hydraulic fluid (ISO 32 grade for general application). Install the breather cap on the reservoir (do not substitute the breather cap with a plug). Stroke the pump a few times with the pressure release valve on the pump open to bleed air out of pump.
10. Lightly loosen the air vent screw on the cylinder flange to bleed off air from the hydraulic lines. Close the pressure release valve on the pump and stroke the hydraulic pump till the pressure builds up. Tighten the vent plug when no more air bubbles bleed out. The ram advances to press against the Spring Rod's end face and the thrust from the hydraulic cylinder ram effects the override function.
11. Note the maximum hydraulic pressure setting for the actuator model (refer to the MOP table on page 26). Check the hydraulic pressure on the gage at the end of the actuator's stroke. Refer to the hand pump service manual and adjust the overload valve setting on the pump to the MOP.

MOP for SR Hydraulic Overrides						
Model	MOP	Spring Number				
		1	2	3	4	5
73 E2	psi	1730	2045	2630	2980	
	bar	119	141	181	205	
14 E3	psi	1445	1660	1930	2460	2930
	bar	100	114	133	170	202
24 E3	psi	1400	1670	2125	2450	2815
	bar	97	115	147	169	194
45 E3	psi	1290	1535	1765	2020	2340
	bar	89	106	122	139	161

15.1.2 Operation - Spring Return Hydraulic Override

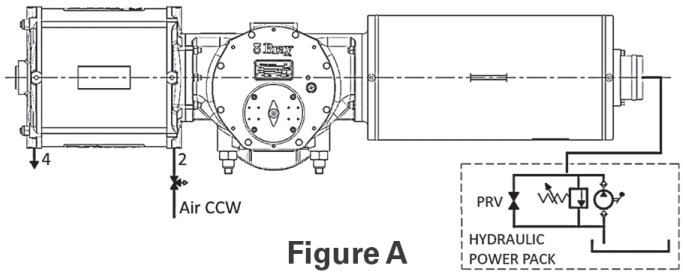


Figure A

1. To operate the override, turn the 3/2 way valve on the pressure module to vent the cylinder port to atmosphere and Close the pressure release valve (PRV) on the hand pump manifold. Operating the Hand Pump on the power pack extends the ram, pushes the Spring Rod while compressing the spring and operates the actuator manually.
2. Opening the pressure release valve relieves the hydraulic pressure to reservoir. The spring returns the ram of override cylinder to retracted position and the actuator to fail safe position.
3. To restore normal Automatic operation, turn the pressure release valve to full Open and switch the 3/2 way valve on pneumatic cylinder, to connect the cylinder port to the air supply pressure.

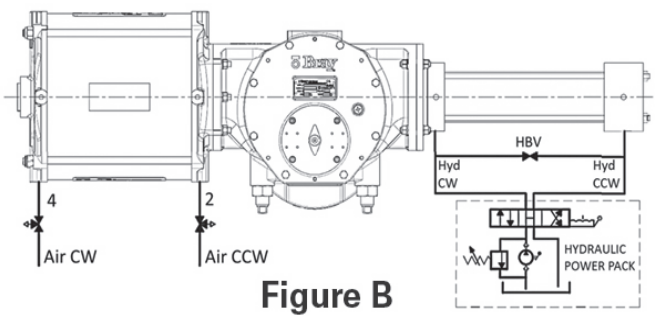


Figure B

15.2 Installing Hydraulic Override on DA Actuator

1. Turn the actuator so that the guide block is at the cover end side of the Torque Module and ensure it stays in this position after disconnecting air pressure and electrical power from actuator.
2. Remove the DA cover plate from the torque module and mount the DA hydraulic override cylinder assembly with the hardware supplied in mounting kit. Make sure to install the flange O-ring.
3. Remove the end cap of the hydraulic cylinder. With a suitable socket/tube spanner located on the hex head of the hydraulic piston end, thread and tighten the piston rod into the threading on Guide Block inside the Torque Module. Refer to the table below for tightening torque.

Piston Rod Tightening Torque		
Model	Torque	
	Lb-ft	Nm
73 E2	110	150
14 E3	130	180
24 E3	130	180
45 E3	150	200

4. Replace the end cap, taking care not to damage the cap seal, and tighten the tie rod nuts of the hydraulic cylinder.
5. Install the 3-way valves, rated for 150 psi (10.3 bar) working pressure, on the pneumatic cylinder ports (Refer to Figure B) and turn them to venting position.
6. Mount the hydraulic pump assembly on the Torque Module's rear accessories pad, as described in previous section.
7. Tube the ports of the hydraulic cylinder to the direction control valve's ports, on the hydraulic hand pump unit. (Refer to Figure B)
8. Turn the direction control valve on the hand pump unit to direct oil flow to one of the cylinder ports. Loosen the corresponding vent plug on the cylinder and stroke the hand pump to vent out air in the lines. Tighten the vent plug when no more air bubbles are seen. Repeat the same for the other side of the cylinder.
9. Check and ensure the Hydraulic pressure setting of the pump does not exceed the MOP setting, refer to the table on page 27. Use the plugged port on the pressure line Tee to connect a suitable pressure gage.

MOP for DA Hydraulic Overrides		
Model	MOP	
73 E2	psi	1930
	bar	133
14 E3	psi	1970
	bar	136
24 E3	psi	2080
	bar	143
45 E3	psi	1965
	bar	135

15.2.1 Operation – DA Hydraulic Override

1. For Manual Override operation, turn the 3-way valves on the pressure module to vent the cylinder ports to atmosphere and Close the hydraulic bypass valve, (HBV). Turn the lever on the direction control valve on the hand pump unit to select the direction of the actuator rotation and stroke the hydraulic pump.
2. To restore Automatic operation, turn the direction control valve to center position, the HBV to Open position and switch the vent valves to connect the cylinder ports to the air supply lines.

⚠ CAUTION

Over thrust by the hydraulic override may cause actuator damage. Prevent unsafe conditions and damage by adjusting the overload valve on the pump to limit the hydraulic pressure as per the MOP tables.

15.3 Maintenance of Hydraulic Override

15.3.1 Spring Return Hydraulic Override Cylinder

Leakage of hydraulic fluid past the piston seal can be a cause for failure to hold the position when operating the override. Leakage can be confirmed if oil can be seen dripping out of the weep hole on the cylinder. To correct this problem the cylinder must be taken off the spring module.

15.3.2 Disassembly of Hydraulic Cylinder

1. Disconnect the air pressure and the electrical power from the actuator and ensure the actuator turns to the fail safe position.
2. Disconnect the hydraulic tubing from the override cylinder port.
3. Remove the nuts and spring washers from the studs (10) holding the cylinder flange on the Spring Module end.
4. Pull the cylinder out of the Spring Module and inspect for leakage from the weep hole near the guide nut at the rod end. Proceed to replace seals if leakage is confirmed or as part of preventive maintenance.
5. Secure the cylinder, loosen and remove the rod end guide nut.
6. Pull the piston assembly out of the cylinder.

15.3.3 Servicing Hydraulic Cylinder

1. Remove the old seal from the piston and replace it with a new U-cup seal. Install the face of the seal on the hydraulic pressure side.
2. Replace the wear ring on the piston with a new one. Lubricate the seal and the wear ring with hydraulic fluid and carefully slide the piston into the cylinder.
3. Replace the o-ring and guide on the rod side nut and install the nut.
4. Reassemble the cylinder on the Spring module, connect the tubing and vent out the air from the line, as described in the Installation Section.
5. Operate the hydraulic override to test for correct operation.

15.4 DA Override Cylinder

15.4.1 Disassembly of Hydraulic Cylinder

1. Operate the actuator so that the hydraulic cylinder piston is at the cap end side.
2. Shift the direction control valve on the hand pump unit to mid position, disconnect the air pressure and the electrical power from actuator and ensure it stays in this position.
3. Disconnect the hydraulic tubing from the cylinder ports.
4. Remove the tie rod nuts off the hydraulic cylinder and pull the end cap off the barrel.
5. With a socket spanner located on the hex head of the hydraulic cylinder's piston, loosen and disengage the piston rod from the Guide Block in the Torque Module.
6. Remove the fasteners holding the hydraulic cylinder's flange on the Torque Module end.
7. Take the cylinder assembly off the Torque Module.

15.4.2 Servicing Hydraulic Cylinder

1. Drain the oil from the rod side of the cylinder and pull the barrel with the piston and the piston rod out of the Adaptor side block.
2. Pull the barrel off the piston, remove the old seals and wear band.
3. Inspect the barrel and the piston for any damage or scoring. Replace any damaged parts.
4. Replace the seals, wear rings, guide bushings, o-rings on the adaptor and end caps. Reassemble the cylinder and install it on the Torque Module as described in the Installation Section.
5. Check the hydraulic fluid in reservoir to be certain it is at the required level before testing the operation of the override.

15.5 Servicing Hand Pump Unit

Refer to the hand pump unit manufacturer's service manual supplied for maintenance instructions.

16.0 Jackscrew Override

Jackscrews provide an economical manual override option on the actuator for use in case of air failure. These jackscrews come in two types, direct hand wheel operated and bevel gearbox driven.

The direct hand wheel jackscrew has a rotating screw threading into a bronze nut when installed on the Torque module of DA actuators and on the Spring module of Spring Return actuators. The hand wheel directly turns the screw or nut to move the jackscrew forward or back.

The bevel gearbox driven jackscrews are required to reduce the manual effort on larger actuator models and stiffer springs that require higher thrust to compress. Here the screw translates with an anti-rotation arrangement.

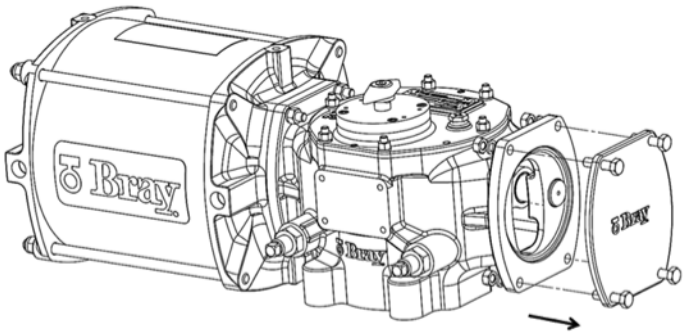
16.1 Installation

Jackscrew overrides are usually factory installed on the actuator. Override units are shipped with the jackscrew assembly installed on the actuator so that the actuator is ready for installation in the auto operation mode. No additional customer installation is required.

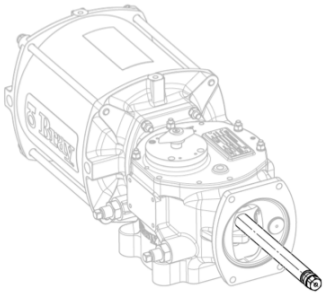
If a field retrofit is required on actuators without a manual override, the installation instructions provide a guide for a qualified technician to install and operate the Jackscrew overrides.

16.1.1 Installing DA Jackscrew Override

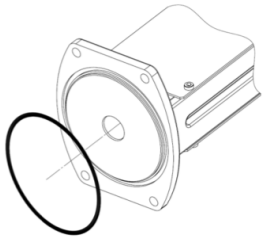
1. Disconnect the air pressure and the electrical power from actuator.
2. Remove the DA end cover plate from the actuator.



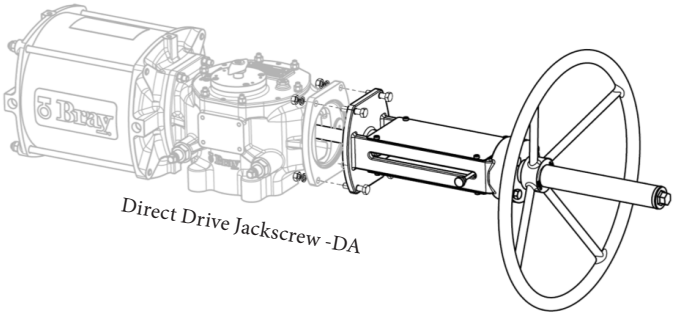
3. Free the Extension Rod from the Jackscrew assembly, apply a drop of medium strength thread lock compound on the extension rod threads and firmly tighten it into the threading in the Guide Block inside the Torque Module.



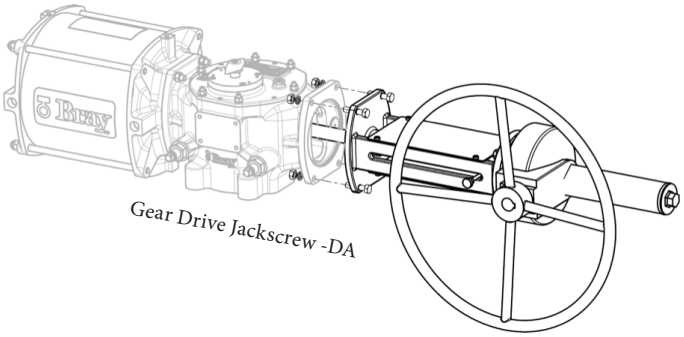
4. Coat the extension rod with NLGI2 grease.
5. Lubricate and place the flange O-ring into the groove on the jackscrew assembly flange



6. Back off the jackscrew fully in the assembly and carefully slide the mounting flange of the jackscrew assembly on the extension rod. Take care in locating the bushing and the flange seal on the extension rod.
7. Slide the assembly to locate and mate the flanges. Use the hardware supplied in the kit to fasten the assembly to the Torque Module flange.



Direct Drive Jackscrew -DA



Gear Drive Jackscrew -DA

8. Install a suitable 3 position manual valve to the pneumatic cylinder's ports, which will either connect the ports to the air supply or vent them to atmosphere. The ports must be vented when operating the manual override (Refer to Figure C).

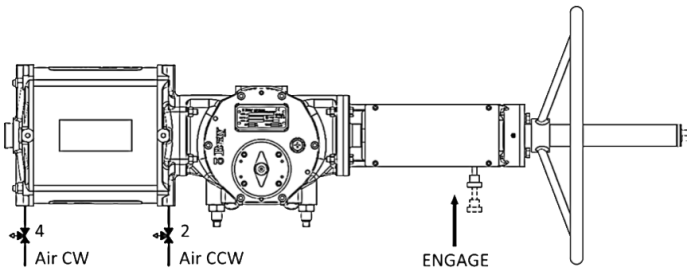
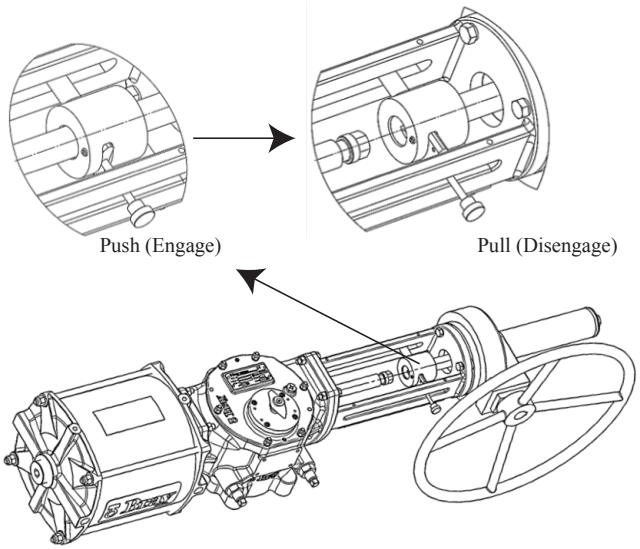


Figure C

16.1.2 Operating DA Jackscrew Override

1. To test / operate the override, shut off the main air supply and turn the 3 position valves on the cylinder ports to vent the ports to atmosphere.
2. Turn the hand wheel on the jackscrew assembly to move the screw forward, until it touches the extension rod's end.
3. Push the slide key into the jackscrew head to couple it with the extension rod.



4. Turn the hand wheel to turn the actuator in required direction (see direction markers on the hand wheel).
5. After completing the manual override stroke, disengage the coupler by pulling out the slide key. Back off the jackscrew completely before restoring automatic operation.

NOTICE

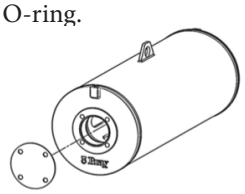
The jackscrew is not designed as an extended travel stop. It must be taken to fully backed-off position for the actuator to work normally in automatic mode. Turn the 3 position valves to connect the air supply to restore automatic operation.

CAUTION

The extension rod moves back and forth in normal operation. Do not remove any protective covers on the DA jackscrew assembly without ensuring the air supply is cut off and that the automatic operation of actuator is disabled.

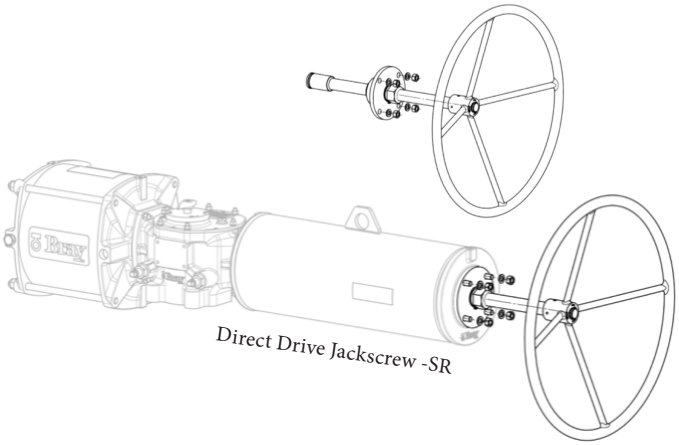
16.2 Installing SR Jackscrew Override

1. Disconnect the air pressure and the electrical power from actuator and ensure the actuator is at its fail safe position.
2. Remove the end cover plate on the Spring module. Retain / replace the cover O-ring.

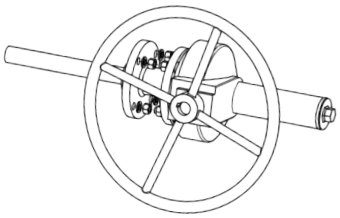


3. Firmly tighten the mounting studs, supplied in the kit, into the spring module end plate. Use a drop of thread lock compound to retain the studs in the end plate threads.

4. Back off the jackscrew fully in the assembly and mount the jackscrew assembly on the spring module end plate thrust base.



5. Locate the Jackscrew assembly flange into the studs and fasten with the supplied nuts and lock washers.



6. Install a suitable 3 position manual valve to the pneumatic cylinder's rod end port (Refer to Figure D).

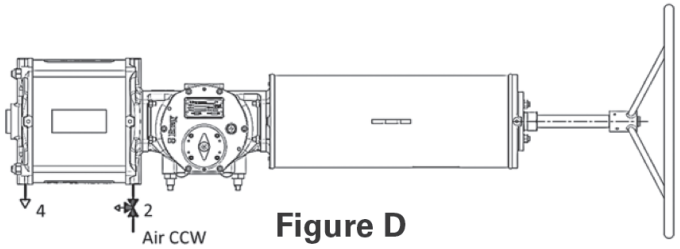


Figure D

16.2.1 Operating SR Jackscrew Override

1. To test / operate the override, shut off the main air supply and turn the 3 position valve on the cylinder port to vent the cylinder port to atmosphere. The actuator should move to its fail safe position.
2. Turn the hand wheel on the jackscrew to advance the screw into the spring module (see direction markers on the hand wheel).
3. Resistance will be felt when the thrust head of the jackscrew touches the end of the spring rod.
4. Turning the hand wheel further will compress the spring and simultaneously turn the actuator.

NOTICE

The spring constantly loads on the jackscrew and returns the actuator to fail safe state when the jackscrew is retracted. Bring the actuator to fail safe position and turn the 3 position valve on cylinder port to connect to air supply to restore auto operation mode.

⚠ CAUTION

Never disassemble the Jackscrew assembly with the spring load on the screw. Severe injuries/damage can result due to non-compliance.

Retract the jackscrew completely to free the load, before attempting any maintenance on the assembly.

17.0 Extended Stoppers

Extended Stoppers allow adjustment of the actuator rotation angle higher than what the travel stops provided on the Torque Module. These Extended Stoppers modules fit on the Torque Module for single cylinder double acting actuators and on the Spring Module for the spring return actuators.

The standard extended stops restrict the linear stroke of the Guide Block to provide the rotation adjustment up to 45 degrees from the end. A 90 degree extended stop is an option.

17.1 Installation

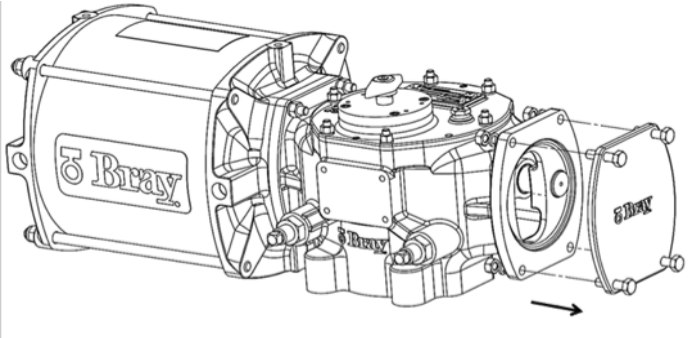
Extended Stoppers are usually factory installed on the actuator and adjusted to the angle per customer's requirement if supplied as a valve-actuator package. If supplied fitted on actuator alone, then the stoppers are backed off fully, to permit installation at site on the valve and they must be adjusted after installation.

If a field retrofit is required on actuators without the extended stopper, the installation instructions provide a guide for a qualified technician to install and adjust them.

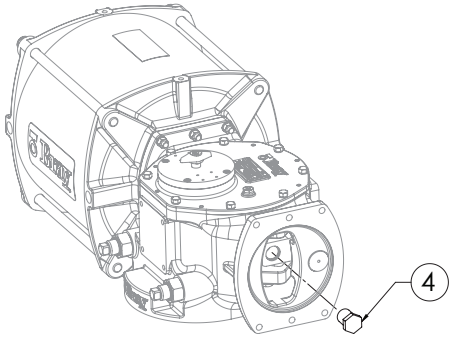
17.1.1 Installing Extended Stopper for Torque Module

This Extended Stopper module is installed only on Single Cylinder DA actuators.

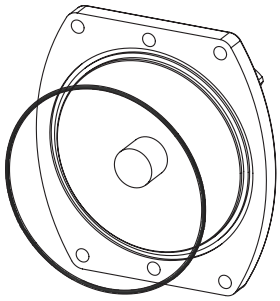
1. Disconnect the air pressure and the electrical power from actuator.
2. Remove the DA end cover plate from the actuator.



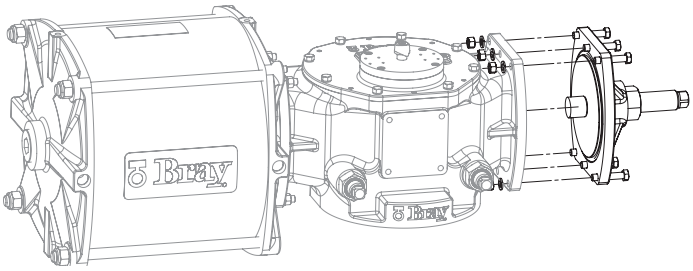
3. Clean threads on the Guide Block.
4. Apply medium strength thread lock compound to the threads of the Bolt (4) and thread it into the Guide Block and tighten to lock the Bolt on the Guide Block face.



5. Loosen the Lock Nut and back off the Extended Stopper in the assembly.
6. Lubricate and locate the flange O-ring in the groove on the assembly's flange and mount the assembly on the torque module.

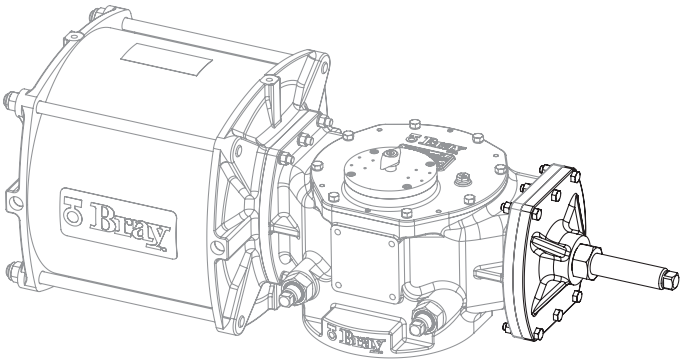


7. Secure the assembly with the mounting bolts, nuts and lock washers from the mounting kit.



17.1.2 Adjusting Extended Stopper

Connect air supply to the rod end side port of the pneumatic cylinder, adjust the extended stopper screw to required position, and reverse the actuator direction to stop movement by the extended stopper. Confirm position and tighten the seal-nut to lock the position.



NOTICE

The Extended Stopper is not designed as a jackscrew. Do not use this to manually override the actuator. Always adjust the stopper with no load on it.

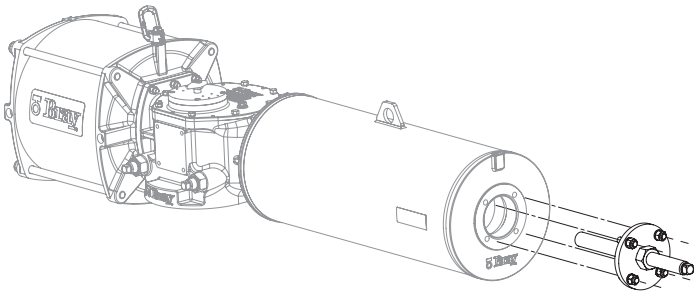
WARNING

Never remove the assembly fasteners without first backing off the Extended Stopper fully to release any load on it.

17.2 Installing Extended Stopper for Spring Module

This Extended Stopper module is installed only on Spring Return actuators.

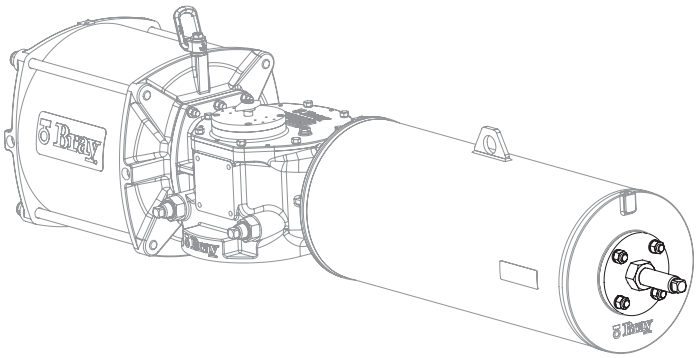
1. Disconnect air pressure and any electrical power from actuator.
2. Remove the end cover plate on the Spring Module.
3. Thread in and tighten the studs from the mounting kit, into the Spring Module thrust base. Use thread lock (Loctite 242 or equivalent). Locate the end cover O-ring in the groove.
4. Back off the stopper bolt and mount the Extended Stopper assembly on the Spring Module end plate.



5. Tighten the nuts with spring washers; refer to bolt torque table for the nut size.

17.2.1 Adjusting Extended Stopper

1. Connect air supply to the rod end side (Adaptor) port of the pneumatic cylinder; tighten the extended stopper screw to approximately required position. Release air so that the actuator will reverse direction by the spring action and stop against the extended stopper. Repeat to get to final position.
2. Confirm position and tighten the seal-nut to lock the position.



NOTICE

The Extended Stopper is not designed as a jackscrew. Do not use this to manually override the actuator. Always adjust the stopper with no load on it.

WARNING

Never remove the assembly fasteners without first backing off the Extended Stopper fully to release any load on it.

Reference Drawings

Description	Drg #
Hydraulic Override Assembly DA	ES 00094
Hydraulic Override Assembly SR	ES 00095
Jackscrew Assembly, DA Direct Drive	ES 00105
Jackscrew Assembly, DA Gear Drive	ES 00106
Jackscrew Assembly, SR Direct	ES 00113
Jackscrew Assembly, SR Gear Drive	ES 00114
Sandwich Gearbox	ES 00126
Extended Stoppers, SR	ES 00127
Extended Stoppers, DA	ES 00201

Trouble shooting potential problems

FAULT	POSSIBLE CAUSES	RECOMMENDED ACTIONS
Erratic Movement	Inconsistent supply /dirty operating media/ clogged filters	Check media supply pressure and line filters, correct as necessary. Refer to Introduction section in this manual for operating media requirements.
	Inadequate Lubrication	Disassemble and lubricate. Refer to Maintenance section in this manual for lubricant specs.
	Worn /damaged Parts	Disassemble and inspect. Replace worn/damaged parts. Refer to Disassembly, Service & Reassembly of Modules section in this manual.
	Seal set due to long periods of inactivity	Operate for 5-10 cycles and check. Replace seals if not resolved. Refer to the procedures under Pressure Module section in this manual, for replacement and testing procedures.
	Valve problem- bearing/seal friction, damaged parts	Refer to valve manufacturer's IOM.
Incomplete Stroke	Stoppers set incorrectly	Check and adjust.
	Foreign object left inside during maintenance	Disassemble, inspect for damages and correct.
	Manual override in wrong position	Check and fully retract manual override devices for proper automatic operation.
	Valve problem- Restriction, friction,incorrect valve stopper	Refer to valve manufacturer's IOM .
Loss of power	Supply pressure inadequate	Check and correct supply pressure to operating pressure.
	Inadequate flow	Check flow control devices and adjust for suffiecient flow. Repair any kinked tubing.
	Tubing or exhaust vents blocked	Check and clean the vents ,silencers and tubing
	Pressure Module seals leaking	Check leaks and replace seals.Refer to the procedures under Pressure Module section in this manual, for replacement and testing procedures.
	Defective Accessories/Inadequate capacity	Refer to accessory manufacturer's OM manual and specs.
	Valve jammed or requires higher torque	Refer to valve manufacturer's IOM.
No response to energizing	Altered schematic	Check if the control circuit is as per the supplied schematic. Correct the circuit, if altered.
	Solenoid valve /positioner/control elements mal-function	Check /Refer to accessory manufacturer's OM manual for troubleshooting.
	Disengaged piston rod/ broken connection/ jammed mechanism	Refer to Maintenance section for module/actuator disassembly procedures to disassemble appropriate module for inspection.
	Valve problem- jammed	Refer to valve manufacturer's IOM.
Fails to go to the failsafe position	Altered schematics	Check if the control circuit is as per the supplied schematic. Correct the circuit, if altered.
	Control component malfunction/failure	Check and replace
	Choked exhaust silencer/foreign object blocking exhaust line	Remove vent to confirm normal operation. Clean/replace exhaust silencer
	Spring rod disengaged/connection broken.	Refer to Maintenance section for module/actuator disassembly procecures to disassemble appropriate module for inspection
	Valve problem- jammed	Refer to valve manufacturer's IOM.

POTENTIAL MISUSE	PREVENTION MEASURES
Use in unintended conditions	Refer to Introduction & Installation sections in this manual and supporting product documentation.If in doubt, contact manufacturer.
Supply pressure greater than the actuator MOP to compensate for valve problems / incorrect selection.	Use of appropriate pressure limiting devices in the supply pressure line to limit the pressure to actuator's MOP is highly recommended and shall be ensured by the end user. Refer to the Maximum Operating Pressure sections in this manual. Actutaor MOP is printed on the name plate for ready reference.
Actuator subjected to temperatures out of permissible limits	Refer to name plate and to General Specifications section for the limits of service temerature of the supplied trim. Ensuring the environmental conditions do not cause over the limit temperatures, is end user's responsibility.
Used with operating media that does not conform to specification	Clean dry media of instrumentation grade only shall be supplied. Refer to Introduction section of this manual for specs.
Lifting actuator-valve-accessories assembly using lifting lugs on actuator that are meant only for the actuator.	Read Warnings in the Installation section of this manual and on the stickers pasted on actuators. Use slings and tackles of sufficient capacity appropriately for lifting assemblies. Actuator weight is printed on the name plate for ready reference.
Pressurizing cap end port on spring return actuators to overcome valve jamming or to compensate valve sealing problems.	Refer to Operation Guidelines section of this manual.Pressurizing pneumatic cylinder to aid spring may cause over load on valve stem and actuator parts resulting in damages to valve/actuator. Do not substitute the vent provided on cap end port of cylinder with a pipe fitting.
Maintenance by unauthorized personnel	See Safety Information section.Do not permit anyone, other than qualified technicians who have read and fully understood the installation and maintenance instructions, to perform any maintenance/adjustments on the actuator.
Maintenance without de-energizing	Refer to Disassembly, Service & Reassembly of Modules section of this manual. Under no circumstances shall attempt be made to disassemble the pressure module or any fastener/plug be loosened, without isolating supply pressure and venting the cylinder ports to atmosphere.
Operating the actuator without end covers	Never operate the actuator in partially disassembled condition or with the Spring Module / Pressure Module end plate removed.
Altering the design to increase spring end load for compensating valve seating problems.	Strictly prohibit change of any component design or adding spacers to increase the spring end load. The Spring Rod thread engagement will be compromised and this can have disastrous consequences resulting in equipmet damage and/or severe personal injury.

RESIDUAL RISKS
This document does not cover every detail about every version of the product described. It cannot take into account every potential occurrence in installation, operation,maintenance and use.
End user shall devise and provide adequate protection against hazards such as:
External Fire
Impacts during installation/servicing
Hazardous emissions when Natural Gas is operating media
Contact with metal surfaces due to high/low ambient temperatures or conduction/ radiation
Static electricity.

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