

HYDRAULIC MASTER CYLINDERS

Straight bore, and two-stage master cylinders
for mobile and industrial applications



ZF Off-Highway Solutions Minnesota Inc. designs, manufactures, and markets hydraulic components, controls, and brake systems, primarily for off-highway markets.

Many of the world's largest Off-Highway OEMs value the knowledgeable staff at ZF Off-Highway Solutions Minnesota Inc. and work with us to make their products better. Our custom-engineered products are designed with the customer requirements as the primary driver. It is our intent to help customers build their systems with our expertise in hydraulic components, braking systems, and controls. Our goal is to meet or exceed our customers' expectations in every aspect of our business.

ZF Off-Highway Solutions Minnesota Inc. continuously strives for improvement, while remaining a quality leader in our field. We are a successful, customer driven business. We look forward to working with you!

Hydraulic Master Cylinders

The same dependability and performance that goes into every ZF Off-Highway Braking Solutions Minnesota Inc. product also goes into our versatile, high-performance Hydraulic Master Cylinders. This is an important consideration when you select a source of supply for your fluid power needs.

A detailed explanation of the straight-bore master cylinders can be found on pages 4 and 5. The two-stage master cylinders are explained briefly in the following paragraphs. For a more detailed explanation refer to pages 6 through 9.

The two-stage master cylinders are integrally designed to incorporate the advantage of a large piston for fluid volume and a small piston for high pressure. Transfer from the volume piston to the pressure piston is accomplished by means of a metered pressure relief valve.

Most master cylinders are available in two mounting styles. For further information regarding master cylinders consult ZF Off-Highway Braking Solutions Minnesota Inc.

Some master cylinders listed in this catalog include a Residual Check Valve (a device that allows free flow of fluid in one direction while maintaining a residual pressure from the opposing direction). For most disc brake applications a master cylinder without a residual check valve is needed.

This catalog is designed to assist you in making an initial selection of a master cylinder suited to your requirements. Complete the appropriate Application Data Sheet online, www.mico.com, and submit to sh-applications.NMN@ZF.com. The ZF Off-highway Solutions Minnesota Inc. Applications Department will analyze your specifications and based on your input recommend a master cylinder suitable for your requirements.

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You will find the current edition at www.mico.com

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Applications



Swing Drive Equipment



Agricultural Equipment



Heavy Construction Equipment



Mining Equipment



Forestry Equipment



In-Plant & Warehouse Equipment



Airport Support Vehicles

Operation of straight-bore master cylinders

Non-Actuated Position

(Refer to Figure 1)

When the brake pedal is completely released, the master cylinder is in a static position. The cylinder bore and reservoir are equalized at atmospheric pressure because air vent (6) and equalizing port (1) are open. (Models that use a filler cap designed for a remote reservoir must use a vented cap on the remote reservoir).

Residual check valve (2) is closed and sealed against check valve seat (3) causing the vehicle brake system to remain at residual pressure (approximately 8-16 PSI). Residual pressure in the vehicle brake system is retained to flare the lip of cup seal in the wheel cylinder to prevent leakage and/or air ingestion into the brake system.

Residual check valves are usually used in drum brake systems to maintain slight residual pressure in the hydraulic brake system while the brake pedal is released. Residual pressure may vary depending on the system application.

Residual check valves are not used in master cylinders that connect to disc brakes. Disc brake systems need to be free of residual pressure because residual pressure will hold the brake pads in contact with the disc. This will result in brake drag, over-heating of brake components, unnecessary wear and premature brake replacement.

Forward Movement of the Brake Pedal Until Fully Applied

(Refer to Figure 2)

When the brake pedal is applied, piston (4) is forced forward. Forward movement of piston (4) begins to transfer fluid from the cylinder bore through equalizing port (1) to reservoir and outlet port (7). Piston cup (5) moves past equalizing port (1) and prevents any additional fluid from flowing to the reservoir.

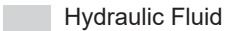
Further forward movement of piston (4) continues to transfer fluid from the cylinder bore through residual check valve (2) to outlet port (7) into the brake system. Brake system pressure is determined by the effective area of piston (4) and the mechanical force applied to it.

Brake Pedal Released

(Refer to Figure 3)

When the brake pedal is released the input force is removed from piston (4). Brake system components under pressure now cause fluid to return to the master cylinder through outlet port (7). This returning fluid must overcome a resistance of 8-16 PSI to force residual check valve (2) off check valve seat (3). When returning fluid can no longer overcome this resistance, residual check valve (2) closes and brake line pressure remains 8-16 PSI or residual pressure.

As the brake pedal returns to the static position, residual check valve (2) closes and spring (8) continues to retract piston (4). This creates a vacuum in the cylinder bore allowing fluid to pass over piston cup (5) and replenish the cylinder bore. When piston cup (5) is returned past equalizing port (1), bore and reservoir pressures are equalized.

Key	
1.	Equalizing Port
2.	Residual Check Valve
3.	Check Valve Seat
4.	Piston
5.	Piston Cup
6.	Air Outlet
7.	Outlet Port
8.	Spring
 Hydraulic Fluid	

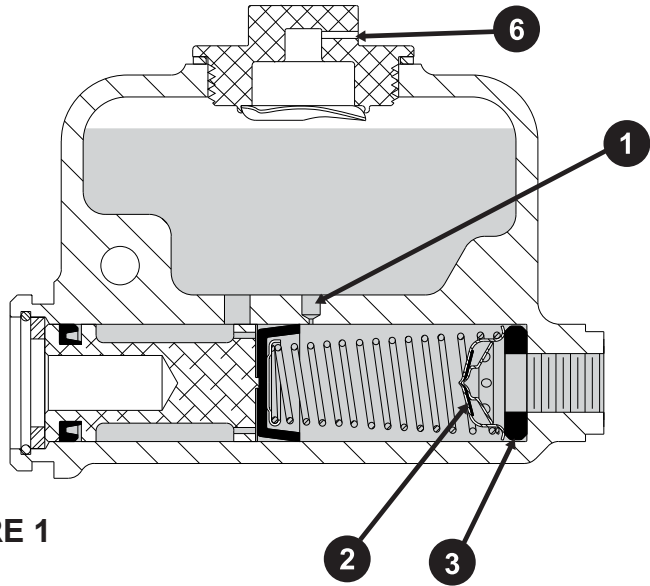


FIGURE 1

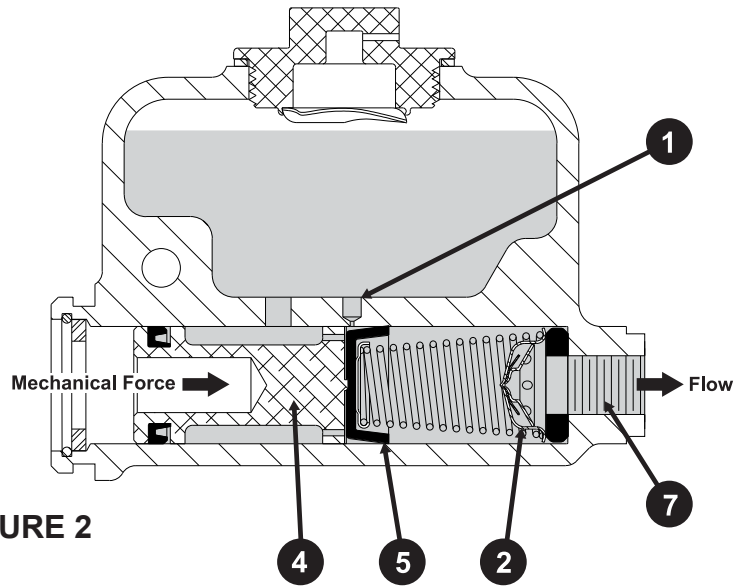


FIGURE 2

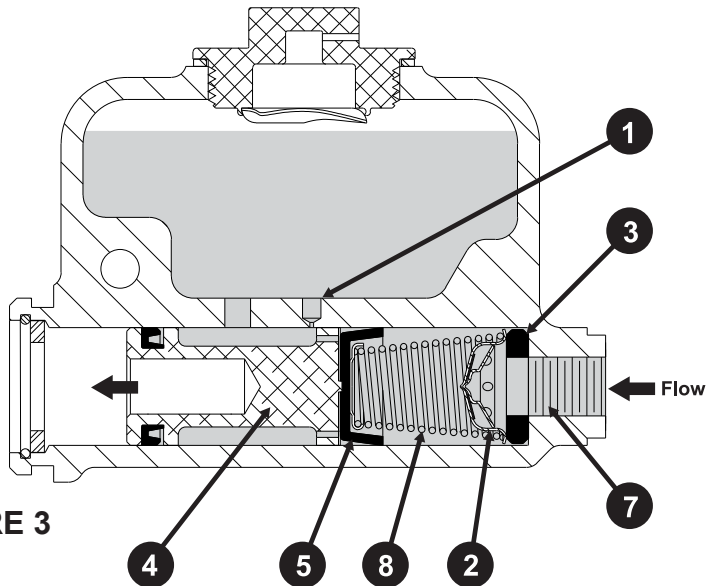


FIGURE 3

Operation of two-stage master cylinders

(Low Pressure Relief Valve)

Non-Actuated Position

(Refer to Figure 4)

When the brake pedal is completely released, the master cylinder is in a static position. The low and high pressure bores (11 & 12) and reservoir are equalized at atmospheric pressure because air vent (8) and equalizing port (2) are open. (Models that use a filler cap designed for a remote reservoir must use a vented cap on the remote reservoir.) Residual check valve (5) is closed and sealed against check valve seat (7) causing the vehicle brake system to remain at residual pressure (approximately 8-16 PSI). Residual pressure in the vehicle brake system is retained to flare the lip of the cup seal in the wheel cylinder to prevent leakage and/or air ingestion into the brake system.

Relief valve (1) is closed. High pressure piston (3) is not sealed against seat (4).

Residual check valves are usually used in drum brake systems to maintain slight residual pressure in the hydraulic brake system while the brake pedal is released. Residual pressure may vary depending on the system application.

Residual check valves are not used in master cylinders that connect to disc brakes. Disc brake systems need to be free of residual pressure because residual pressure will hold the brake pads in contact with the disc. This will result in brake drag, over-heating of brake components, unnecessary wear and premature brake replacement.

Forward Movement of the Brake Pedal Until Fully Applied

(Refer to Figure 5)

When the brake pedal is applied, low pressure piston (9) is forced forward. Forward movement of low pressure piston (9) begins to transfer fluid from low pressure bore (11) through equalizing port (2) to reservoir and outlet port (6). Low pressure cup (10) moves past equalizing port (2) preventing any additional fluid from flowing into the reservoir.

Continued forward pedal movement forces high pressure piston (3) against seat (4). Pressurized fluid in low pressure bore (11) is forced past high pressure cup (13) through outlet port (6) into the brake system. At this point, brake system pressure is determined by the area of low pressure piston (9) and the mechanical force applied to it.

Continued forward movement of low pressure piston (9) causes the brake system to reach relief valve (1)

pressure setting. Relief valve piston (15) opens and fluid in low pressure bore (11) flows into the reservoir past metering pin (14) and through relief valve ports (18). Fluid pressure in the low pressure bore (11) will remain at relief valve (1) setting. The velocity of discharged fluid through the relief valve (1) is controlled by the metering pin (14).

As forward movement of low pressure piston (9) continues, a pressure differential causes fluid in high pressure bore (12) to flare high pressure cup (13). This closes off fluid flow into high pressure bore (12) from low pressure bore (11). At this point, brake system pressure intensifies due to the smaller size of high pressure piston (3).

Brake Pedal Released

(Refer to Figure 6)

When the brake pedal is released, brake system components under fluid pressure and component springs under compression now cause fluid to return to the master cylinder through outlet port (6). This returning fluid must overcome a resistance of 8-16 PSI to force check valve (5) off of check valve seat (7). When returning fluid can no longer overcome this resistance, residual check valve (5) closes, and brake system pressure remains at 8-16 PSI (residual pressure).

Low pressure piston (9) returns to the point where fluid was displaced into the reservoir through relief valve (1) during forward stroke. Residual check valve (5) is closed and springs continue to retract low pressure piston (9) and high pressure piston (3). This creates a vacuum in the low pressure bore (11). Fluid in the reservoir is forced through replenishing ports (16), opening disc check valve (17), and into low and high pressure bores (11 & 12) until piston (9) is returned to the static condition. Reservoir and bore pressures are equalized.

Key

1. Relief Valve
2. Equalizing Port
3. High Pressure Piston
4. Seat
5. Residual Check Valve
6. Outlet Port
7. Check Valve Seat
8. Air Vent
9. Low Pressure Piston
10. Low Pressure Cup
11. Low Pressure Bore
12. High Pressure Bore
13. High Pressure Cup
14. Metering Pin
15. Relief Valve Piston
16. Replenishing Port
17. Disc Check Valve
18. Relief Valve Port

Hydraulic Fluid

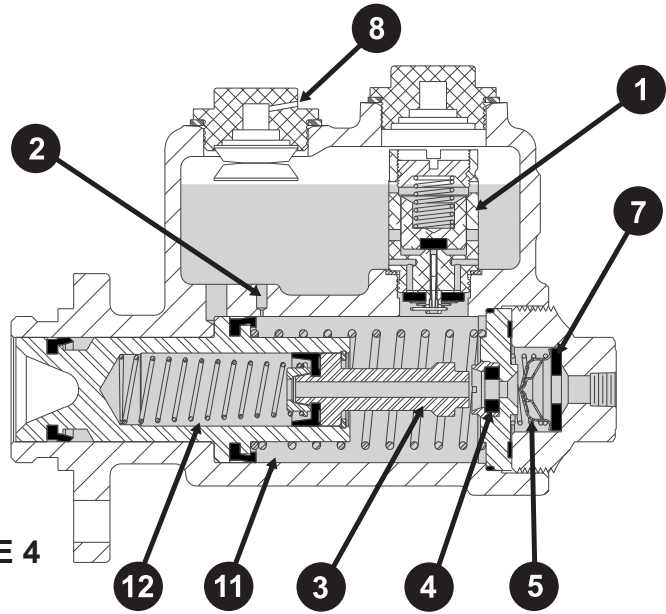


FIGURE 4

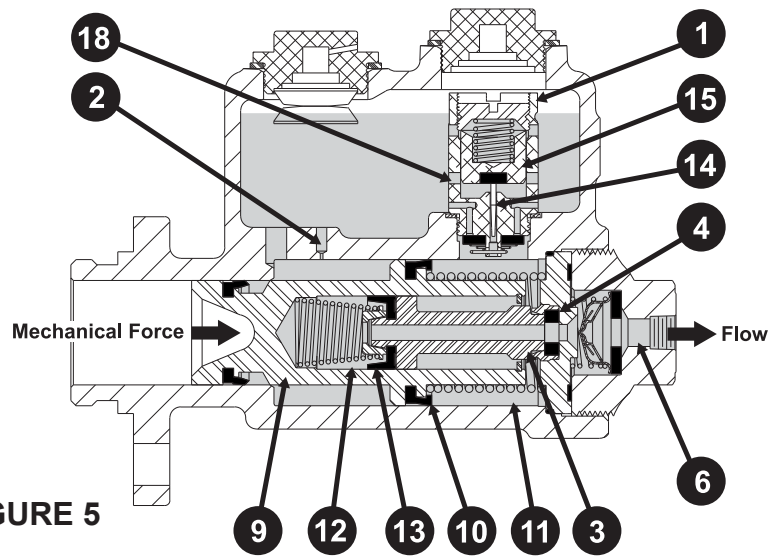


FIGURE 5

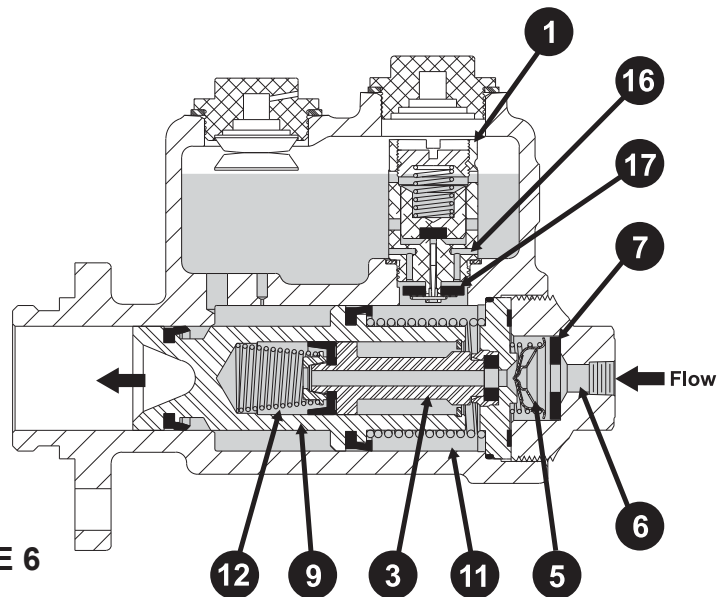


FIGURE 6

Operation of two-stage master cylinders

(High Pressure Relief Valve)

Non-Actuated Position

(Refer to Figure 4)

When the brake pedal is completely released, the master cylinder is in a static position. The low and high pressure bores (11 & 12) and reservoir are equalized at atmospheric pressure because air vent (8) and equalizing port (2) are open. (Models that use a filler cap designed for a remote reservoir must use a vented cap on the remote reservoir.) Residual check valve (5) is closed and sealed against check valve seat (7) causing the vehicle brake system to remain at residual pressure (approximately 8-16 PSI). Residual pressure in the vehicle brake system is retained to flare the lip of the cup seal in the wheel cylinder to prevent leakage and/or air ingestion into the brake system.

Relief valve (1) is closed. High pressure piston (3) is not sealed against seat (4).

Residual check valves are usually used in drum brake systems to maintain slight residual pressure in the hydraulic brake system while the brake pedal is released. Residual pressure may vary depending on the system application.

Residual check valves are not used in master cylinders that connect to disc brakes. Disc brake systems need to be free of residual pressure because residual pressure will hold the brake pads in contact with the disc. This will result in brake drag, over-heating of brake components, unnecessary wear and premature brake replacement.

Forward Movement of the Brake Pedal Until Fully Applied

(Refer to Figure 5)

When the brake pedal is applied, low pressure piston (9) is forced forward. Forward movement of low pressure piston (9) begins to transfer fluid from low pressure bore (11) through equalizing port (2) to reservoir and outlet port (6). Low pressure cup (10) moves past equalizing port (2) preventing any additional fluid from flowing into the reservoir.

Continued forward pedal movement forces high pressure piston (3) against seat (4). Pressurized fluid in low pressure bore (11) is forced past high pressure cup (13) through outlet port (6) into the brake system. At this point, brake system pressure is determined by the area of low pressure piston (9) and the mechanical force applied to it.

Continued forward movement of low pressure piston (9) causes the brake system to reach relief valve (1) pressure setting. Relief valve piston (15) opens and fluid in low pressure bore (11) flows into the reservoir past metering pin (14) and through relief valve ports (18). Fluid pressure in the low pressure bore (11) will remain at relief valve (1) setting. The velocity of discharged fluid through the relief valve (1) is controlled by the metering pin (14).

As forward movement of low pressure piston (9) continues, a pressure differential causes fluid in high pressure bore (12) to flare high pressure cup (13). This closes off fluid flow into high pressure bore (12) from low pressure bore (11). At this point, brake system pressure intensifies due to the smaller size of high pressure piston (3).

Brake Pedal Released

(Refer to Figure 6)

When the brake pedal is released, brake system components under fluid pressure and component springs under compression now cause fluid to return to the master cylinder through outlet port (6). This returning fluid must overcome a resistance of 8-16 PSI to force check valve (5) off of check valve seat (7). When returning fluid can no longer overcome this resistance, residual check valve (5) closes, and brake system pressure remains at 8-16 PSI (residual pressure).

Low pressure piston (9) returns to the point where fluid was displaced into the reservoir through relief valve (1) during forward stroke. Residual check valve (5) is closed and springs continue to retract low pressure piston (9) and high pressure piston (3). This creates a vacuum in the low pressure bore (11). Fluid in the reservoir is forced through replenishing ports (16), opening disc check valve (17), and into low and high pressure bores (11 & 12) until piston (9) is returned to the static condition. Reservoir and bore pressures are equalized.

Key

1. Relief Valve
2. Equalizing Port
3. High Pressure Piston
4. Seat
5. Residual Check Valve
6. Outlet Port
7. Check Valve Seat
8. Air Vent
9. Low Pressure Piston
10. Low Pressure Cup
11. Low Pressure Bore
12. High Pressure Bore
13. High Pressure Cup
14. Reservoir Port
15. Disc Check Valve
16. Pilot Line
17. Relief Valve Piston
18. Metering Pin

Hydraulic Fluid

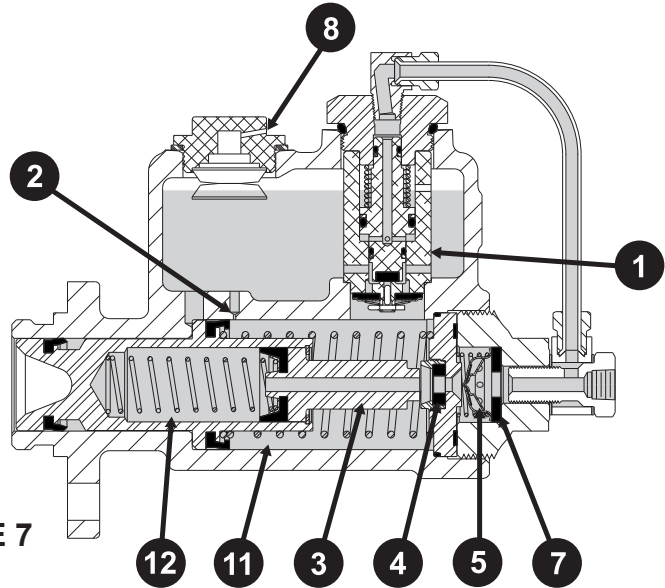


FIGURE 7

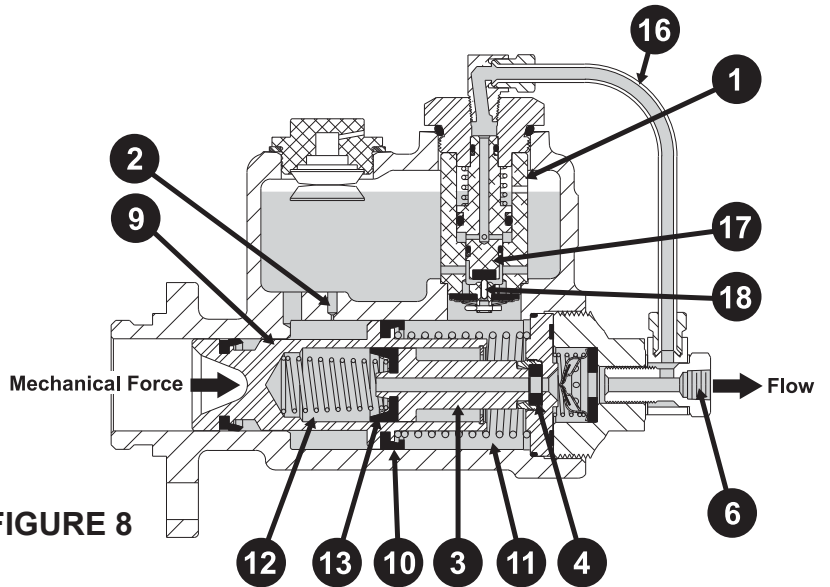


FIGURE 8

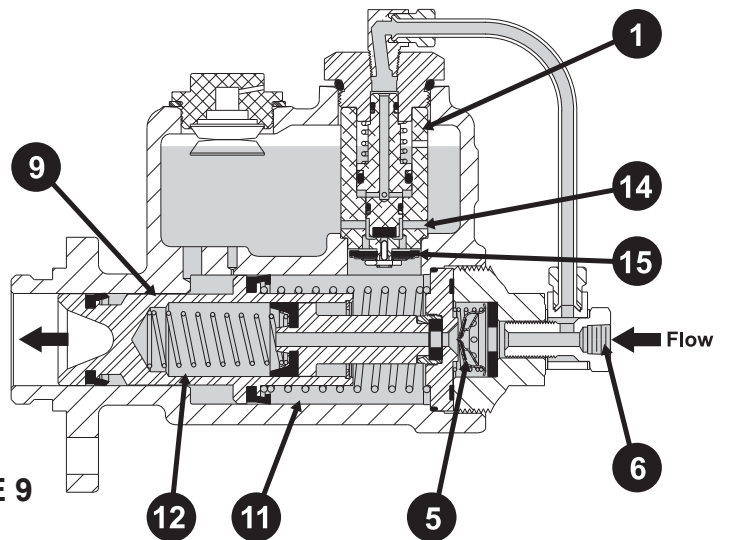


FIGURE 9

Choosing the Proper Cylinder

Straight-bore Master Cylinder Displacement

Fluid displacement from master cylinders can be determined by square inch area of the bore multiplied by stroke.

Two-stage Master Cylinder Displacement

Initial fluid displacement from the two-stage master cylinder is caused by movement of the large diameter piston until the relief valve opens. When the relief valve opens, fluid displacement by the large diameter piston is diverted into the reservoir. At this point further fluid displaced from the two-stage master cylinder is from the high pressure bore (small diameter piston). See Table 1 for displacement ranges.

TABLE 1

Inch Bore Size Diameters	* Inch ³ Displacement Range
1 1/4 over 3/4	0.44 to 1.20
1 3/8 over 7/8	0.60 to 1.48
1 1/2 over 3/4	0.55 to 2.20
1 1/2 over 7/8	0.75 to 2.20
1 3/4 over 7/8	0.75 to 3.00
1 3/4 over 1	0.98 to 3.00
1 3/4 over 1 1/8	1.20 to 3.00
2 1/4 over 1	1.57 to 7.00
2 1/4 over 1 1/8	2.00 to 7.00

* Displacements are only an approximation and will vary depending on the relief valve setting and overall system characteristics.

Understanding Pedal Ratio

Pedal ratio is calculated using the formula:

$$\frac{A \times B}{C} = \text{Pedal Ratio}$$

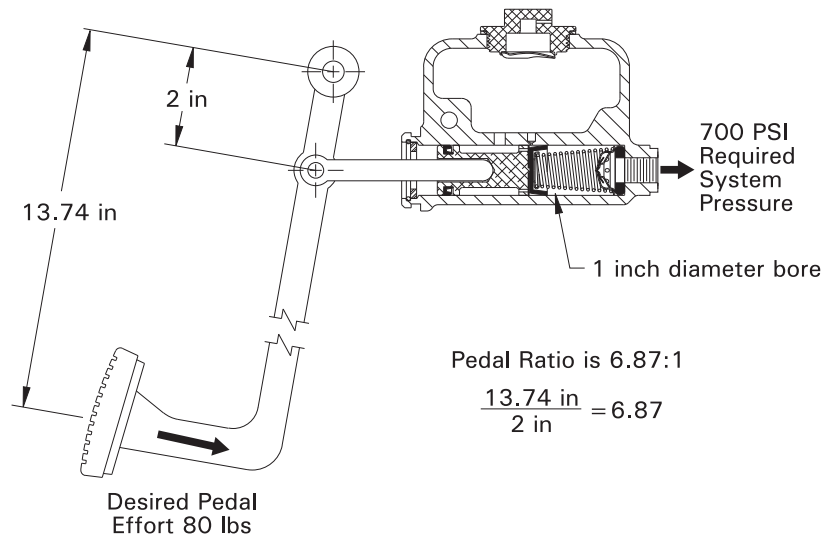
Where:

- A = required brake system pressure
- B = area of piston
- C = desired pedal effort

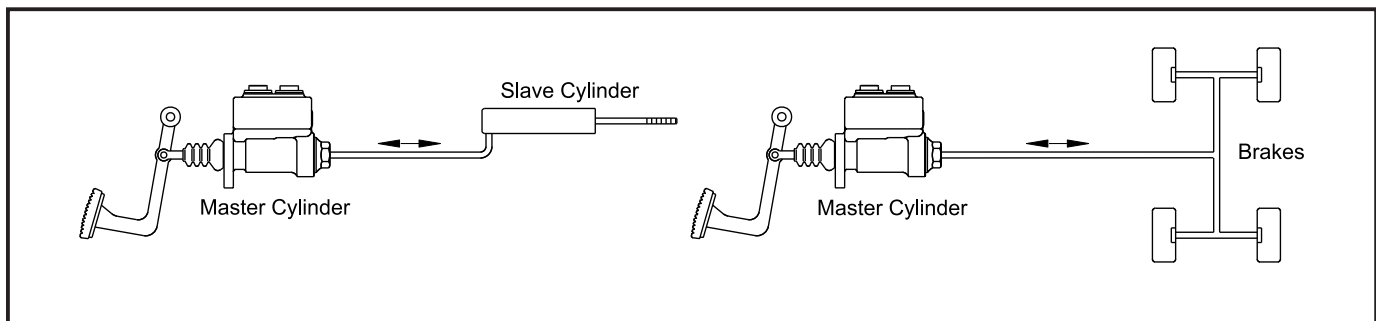
Example:

- A = 700 PSI
- B = 0.7854 in² (area of 1 inch piston)
- C = 80 lbs

$$\frac{700 \times 0.7854}{80} = 6.87$$



Typical Applications

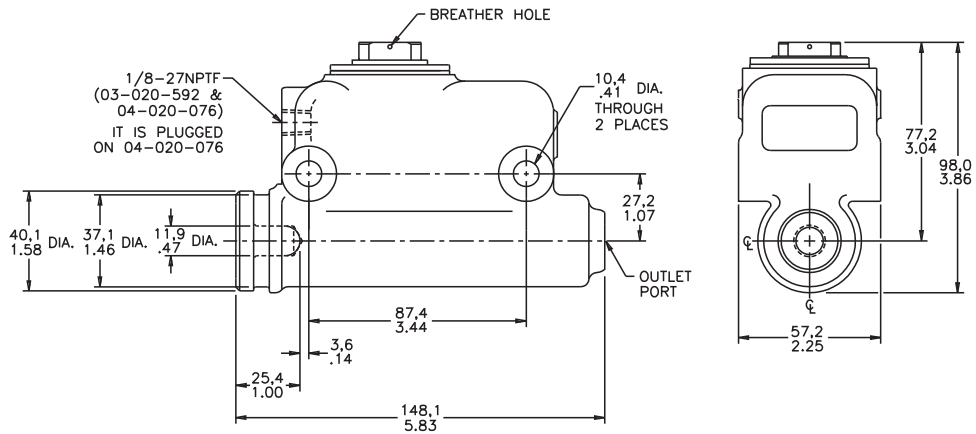


Straight-bore Master Cylinders



Typical model show. Dimensions may vary slightly between units.

millimeters
inches



SPECIFICATIONS

Model Number	Bore Diameter	Effective Stroke	Fluid Type	Push Rod (refer to page 33)	Boot (refer to page 33)	Residual Check Valve	*Outlet Port
02-020-382	1.250 in	1.25 in	HO	None	None	No	1/2-20 UNF-2B
+ 03-020-592	1.000 in	1.44 in	HO	None	32-570-006	No	7/16-24 inverted flare
+ 04-020-076	1.000 in	1.44 in	HO	None	32-570-004	No	1/8-27NPTF

HO = mineral base hydraulic oil.

+ Reservoir has 1/8-27NPTF remote reservoir port.

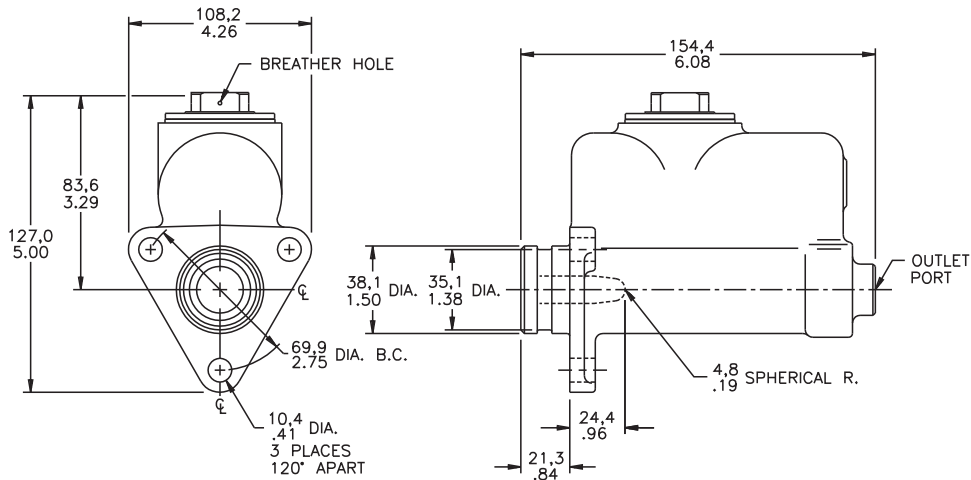
* Contact ZF Off-Highway Solutions Minnesota Inc. for available outlet port adapters.

Straight-bore Master Cylinders



Typical model show. Dimensions may vary slightly between units.

millimeters
inches



SPECIFICATIONS

Model Number	Bore Diameter	Effective Stroke	Fluid Type	Push Rod (refer to page 33)	Boot (refer to page 33)	Residual Check Valve	*Outlet Port
04-020-005	1.000 in	1.44 in	BF	None	32-570-005	Yes	1/2-20UNF-2B
04-020-022	1.000 in	1.44 in	HO	None	32-570-065	No	1/2-20UNF-2B
04-020-070	1.000 in	1.44 in	HO	29-020-033	32-570-065	No	1/2-20UNF-2B
04-021-005	1.000 in	1.44 in	BF	None	32-570-005	No	1/2-20UNF-2B

HO = mineral base hydraulic oil. BF = DOT 3, 4, 5 and 5.1 brake fluid.

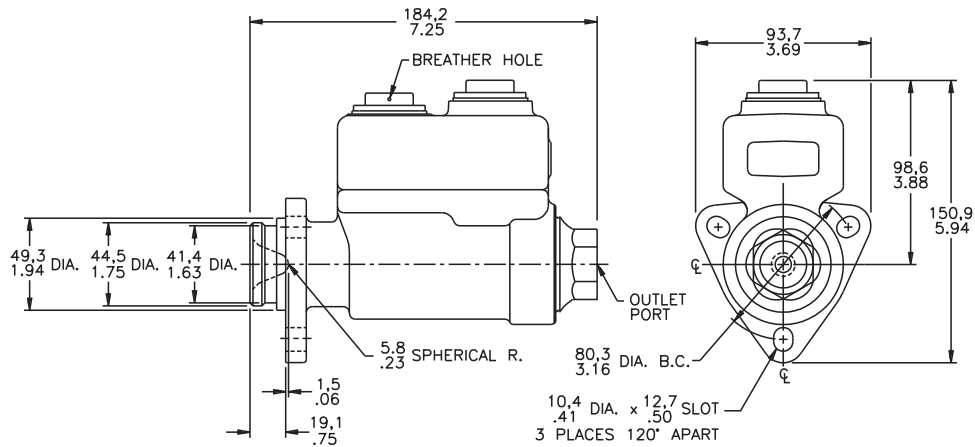
* Contact ZF Off-Highway Solutions Minnesota Inc. for available outlet port adapters.

Straight-bore Master Cylinders



Typical model show. Dimensions may vary slightly between units.

millimeters
inches



SPECIFICATIONS

Model Number	Bore Diameter	Effective Stroke	Fluid Type	Push Rod (refer to page 34)	Boot (refer to page 33)	Residual Check Valve	* Outlet Port
+ 03-020-400	1.750 in	1.44 in	HO	None	None	No	1/2-20UNF-2B
03-020-405	1.750 in	1.44 in	BF	None	None	Yes	1/2-20UNF-2B
+ 03-020-412	1.750 in	1.44 in	HO	30-020-020	32-570-065	No	1/8-27NPTF
03-021-405	1.750 in	1.44 in	BF	None	None	No	1/2-20UNF-2B

HO = mineral base hydraulic oil. BF = DOT 3, 4, 5 and 5.1 brake fluid.

+ Has one filler cap tapped (1/4-18NPTF) for remote reservoir port.

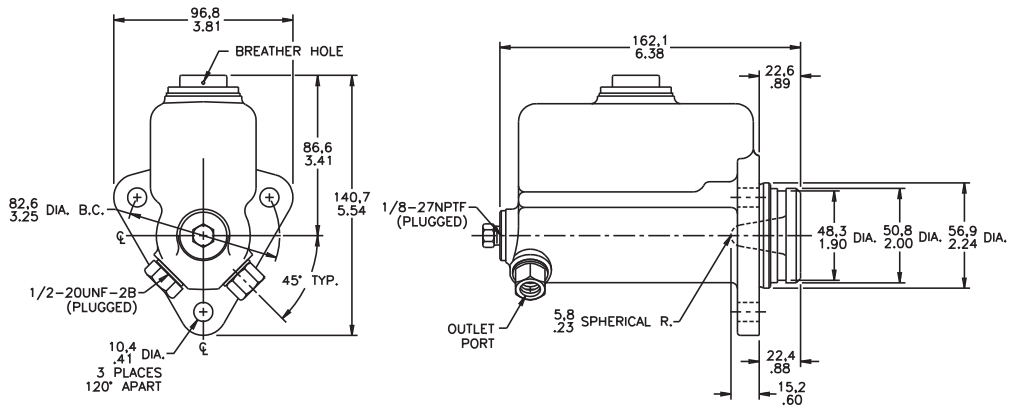
* Contact ZF Off-Highway Solutions Minnesota Inc. for available outlet port adapters.

Straight-bore Master Cylinders



Typical model show. Dimensions may vary slightly between units.

millimeters
inches



SPECIFICATIONS

Model Number	Bore Diameter	Effective Stroke	Fluid Type	Push Rod (refer to page 34)	Boot (refer to page 33)	Residual Check Valve	*Outlet Port
03-020-493	1.50 in	1.50 in	BF	30-020-152	32-570-068	No	7/16-24 inverted flare

BF = DOT 3, 4, 5 and 5.1 brake fluid.

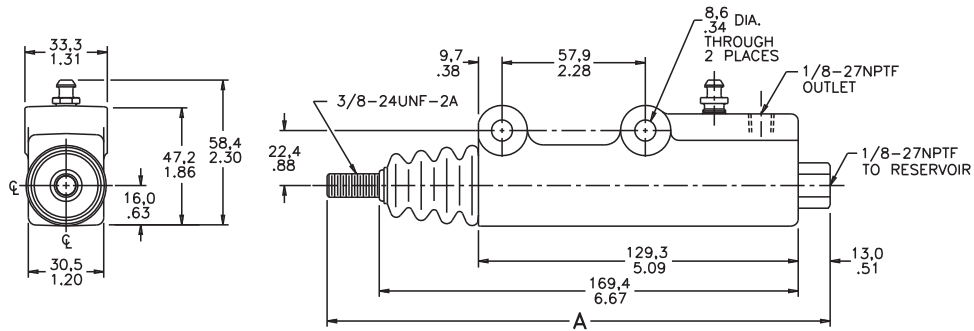
* Contact ZF Off-Highway Solutions Minnesota Inc. for available outlet port adapters.

Straight-bore Master Cylinders



Typical model show. Dimensions may vary slightly between units.

millimeters
inches



SPECIFICATIONS

Model Number	Bore Diameter	Effective Stroke	"A" Dimension	Fluid Type	Push Rod (refer to page 34)	Boot (refer to page 33)	* Outlet Port
04-020-082	0.750 in	1.30 in	8.01 in	HO	30-020-192	32-570-089	1/8-27NPTF
04-020-093	0.750 in	1.30 in	8.01 in	BF	30-020-192	32-570-089	1/8-27NPTF
04-020-099	0.750 in	1.30 in	10.50 in	BF	30-020-184	32-570-089	1/8-27NPTF

HO = mineral base hydraulic oil. BF = DOT 3, 4, 5 and 5.1 brake fluid.

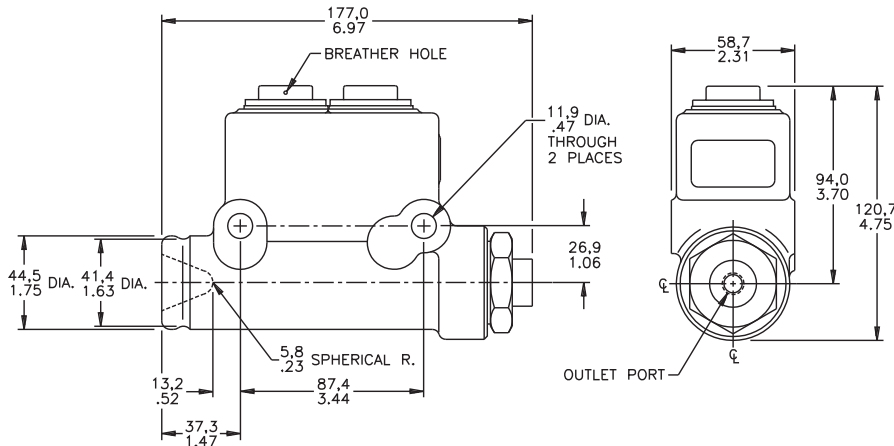
* Contact ZF Off-Highway Solutions Minnesota Inc. for available outlet port adapters.

Two-stage Master Cylinders

Low Pressure Relief Valve



Typical model show. Dimensions may vary slightly between units.



Bore Combinations:

- 1 1/4 inch over 3/4 inch
- 1 3/8 inch over 7/8 inch

millimeters
inches

SPECIFICATIONS

Model Number	Large Bore Diameter	Small Bore Diameter	Effective Stroke	Relief Valve Pressure Setting	Fluid Type	Push Rod (refer to page 34)	Boot (refer to page 33)	Residual Check Valve	*Outlet Port
02-020-231	1.250 in	0.750 in	1.25 in	90 PSI	BF	None	None	Yes	1/8-27NPTF
02-020-257	1.375 in	0.875 in	1.25 in	150 PSI	BF	30-020-020	32-570-005	Yes	7/16-24 inverted flare
02-020-258	1.375 in	0.875 in	1.25 in	160 PSI	HO	30-020-020	32-570-065	Yes	7/16-24 inverted flare
02-020-259	1.375 in	0.875 in	1.25 in	90 PSI	BF	None	None	Yes	1/2-20UNF-2B
+ 02-020-261	1.375 in	0.875 in	1.25 in	175 PSI	BF	30-020-020	32-570-005	No	1/2-20UNF-2B
02-020-266	1.250 in	0.750 in	1.25 in	90 PSI	HO	None	None	Yes	1/2-20UNF-2B
02-020-268	1.375 in	0.875 in	1.25 in	90 PSI	HO	None	None	Yes	1/2-20UNF-2B
02-020-317	1.375 in	0.875 in	1.25 in	125 PSI	BF	None	None	Yes	1/8-27NPTF
02-020-343	1.250 in	0.750 in	1.25 in	150 PSI	BF	30-020-022	32-570-005	Yes	1/8-27NPTF & 7/16-24 inverted flare
02-021-231	1.250 in	0.750 in	1.25 in	90 PSI	BF	None	None	No	1/8-27NPTF
02-021-258	1.375 in	0.875 in	1.25 in	160 PSI	HO	30-020-020	32-570-065	No	7/16-24 inverted flare
02-021-259	1.375 in	0.875 in	1.25 in	90 PSI	BF	None	None	No	1/2-20UNF-2B
02-021-266	1.250 in	0.750 in	1.25 in	90 PSI	HO	None	None	No	1/2-20UNF-2B
02-021-268	1.375 in	0.875 in	1.25 in	90 PSI	HO	None	None	No	1/2-20UNF-2B
02-021-343	1.250 in	0.750 in	1.25 in	150 PSI	BF	30-020-022	32-570-005	No	1/8-27NPTF & 7/16-24 inverted flare
03-020-309	1.250 in	0.750 in	1.25 in	80 PSI	BF	30-020-083	32-570-005	No	1/8-27NPTF
03-020-509	1.250 in	0.750 in	1.25 in	75 PSI	BF	30-020-083	32-570-077	Yes	1/2-20UNF-2B

HO = mineral base hydraulic oil. BF = DOT 3, 4, 5 and 5.1 brake fluid.

+ Has one filler cap tapped (1/8-27NPTF) for remote reservoir.

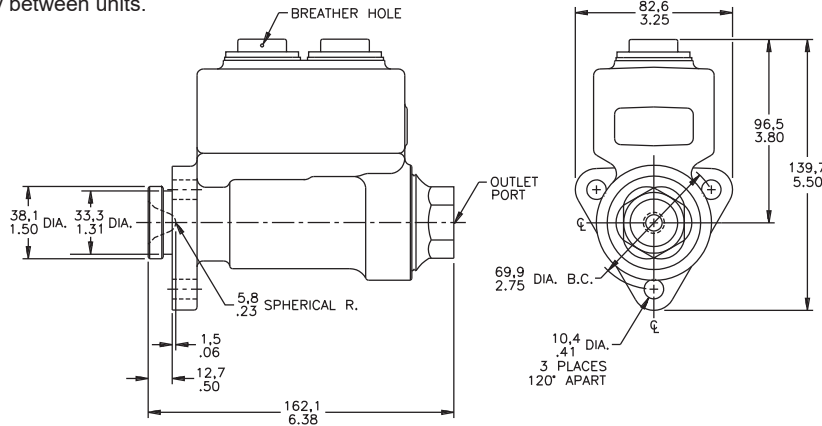
* Contact ZF Off-Highway Solutions Minnesota Inc. for available outlet port adapters.

Two-stage Master Cylinders

Low Pressure Relief Valve



Typical model show. Dimensions may vary slightly between units.



Bore Combinations:

- 1 1/2 inch over 3/4 inch
- 1 1/2 inch over 7/8 inch

millimeters
inches

SPECIFICATIONS

Model Number	Large Bore Diameter	Small Bore Diameter	Effective Stroke	Relief Valve Pressure Setting	Fluid Type	Push Rod (refer to page 34)	Boot (refer to page 33)	Residual Check Valve	*Outlet Port
02-020-312	1.500 in	0.875 in	1.44 in	100 PSI	HO	None	32-570-004	Yes	1/2-20UNF-2B
02-020-313	1.500 in	0.875 in	1.44 in	75 PSI	BF	None	32-570-004	Yes	+ 1/2-20UNF-2B
02-020-316	1.500 in	0.875 in	1.44 in	115 PSI	HO	None	None	Yes	1/2-20UNF-2B
02-021-313	1.500 in	0.875 in	1.44 in	75 PSI	BF	None	32-570-004	No	+ 1/2-20UNF-2B
02-021-316	1.500 in	0.875 in	1.44 in	115 PSI	HO	None	None	No	1/2-20UNF-2B
03-020-396	1.500 in	0.875 in	1.44 in	125 PSI	HO	None	32-570-004	Yes	1/2-20UNF-2B
03-020-411	1.500 in	0.750 in	1.44 in	75 PSI	BF	None	32-570-004	Yes	1/2-20UNF-2B
* 03-020-418	1.500 in	0.750 in	1.44 in	160 PSI	HO	None	None	No	9/16-18UNF-2B
03-020-420	1.500 in	0.750 in	1.44 in	115 PSI	HO	None	32-570-004	Yes	1/8-27NPTF
03-020-421	1.500 in	0.750 in	1.44 in	90 PSI	BF	None	32-570-004	Yes	1/8-27NPTF
03-020-461	1.500 in	0.875 in	1.44 in	150 PSI	BF	None	None	Yes	1/2-20UNF-2B
03-020-479	1.500 in	0.875 in	1.44 in	75 PSI	BF	30-020-057	32-570-004	No	■ 1/8-27NPTF
03-020-533	1.500 in	0.875 in	1.44 in	100 PSI	BF	None	32-570-004	Yes	1/8-27NPTF
03-020-535	1.500 in	0.875 in	1.44 in	100 PSI	BF	30-020-089	32-570-005	Yes	1/8-27NPTF
● 03-020-610	1.500 in	0.875 in	1.44 in	90 PSI	HO	None	32-570-004	Yes	1/2-20UNF-2B
03-021-396	1.500 in	0.875 in	1.44 in	125 PSI	HO	None	32-570-004	No	1/2-20UNF-2B
03-021-411	1.500 in	0.750 in	1.44 in	75 PSI	BF	None	32-570-004	No	1/2-20UNF-2B
03-021-420	1.500 in	0.750 in	1.44 in	115 PSI	HO	None	32-570-004	No	1/8-27NPTF
03-021-421	1.500 in	0.750 in	1.44 in	90 PSI	BF	None	32-570-004	No	1/8-27NPTF
03-021-461	1.500 in	0.875 in	1.44 in	150 PSI	BF	None	None	No	1/2-20UNF-2B
03-021-533	1.500 in	0.875 in	1.44 in	100 PSI	BF	None	32-570-004	No	1/8-27NPTF
03-021-535	1.500 in	0.875 in	1.44 in	100 PSI	BF	30-020-089	32-570-005	No	1/8-27NPTF
● 03-021-610	1.500 in	0.875 in	1.44 in	90 PSI	HO	None	32-570-004	No	1/2-20UNF-2B

HO = mineral base hydraulic oil. BF = DOT 3, 4, 5 and 5.1 brake fluid.

* Has a special standpipe filler cap with air filter.

+ Includes outlet port adapter 7/16-24 inverted flare.

■ Has fitting block with a second outlet port 7/16-24 inverted flare.

● Has one filler cap tapped (1/4-18NPTF) for remote reservoir.

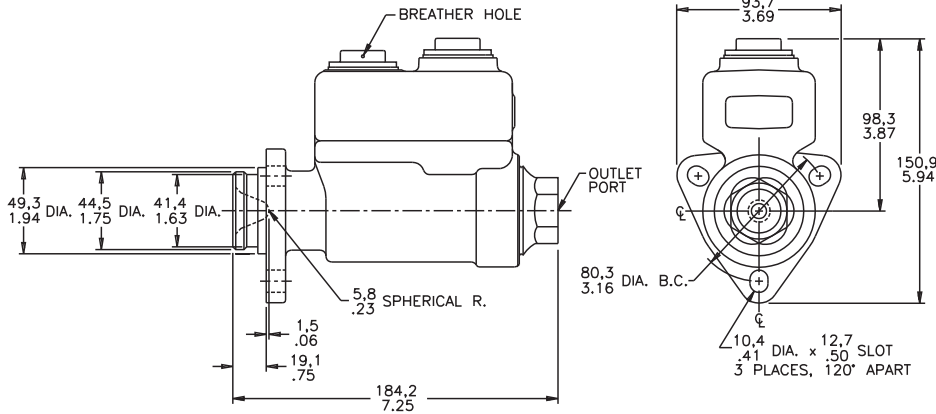
* Contact ZF Off-Highway Solutions Minnesota Inc. for available outlet port adapters.

Two-stage Master Cylinders

Low Pressure Relief Valve



Typical model show. Dimensions may vary slightly between units.



Bore Combinations:

- 1 3/4 inch over 7/8 inch
- 1 3/4 inch over 1 inch
- 1 3/4 inch over 1 1/8 inch

millimeters
inches

SPECIFICATIONS

Model Number	Large Bore Diameter	Small Bore Diameter	Effective Stroke	Relief Valve Pressure Setting	Fluid Type	Push Rod (refer to page 34)	Boot (refer to page 33)	Residual Check Valve	*Outlet Port
03-020-419	1.750 in	1.000 in	1.44 in	100 PSI	BF	None	None	Yes	1/8-27NPTF
03-020-422	1.750 in	1.000 in	1.44 in	100 PSI	HO	None	None	Yes	1/2-20UNF-2B
03-020-425	1.750 in	1.000 in	1.44 in	200 PSI	BF	None	32-570-006	Yes	1/2-20UNF-2B
03-020-427	1.750 in	1.125 in	1.44 in	100 PSI	BF	None	None	Yes	1/2-20UNF-2B
03-020-428	1.750 in	0.875 in	1.44 in	175 PSI	HO	None	None	Yes	1/8-27NPTF
03-020-429	1.750 in	0.875 in	1.44 in	175 PSI	BF	None	None	Yes	1/8-27NPTF
03-020-430	1.750 in	0.875 in	1.44 in	75 PSI	HO	None	None	No	1/8-27NPTF
03-020-466	1.750 in	1.000 in	1.44 in	190 PSI	HO	30-020-020	32-570-065	Yes	1/2-20UNF-2B
* 03-020-468	1.750 in	1.000 in	1.44 in	265 PSI	HO	30-020-020	32-570-065	No	1/8-27NPTF
03-020-471	1.750 in	1.000 in	1.44 in	150 PSI	BF	30-020-020	32-570-005	Yes	1/2-20UNF-2B
03-020-478	1.750 in	1.125 in	1.44 in	190 PSI	HO	30-020-020	32-570-065	No	1/2-20UNF-2B
03-020-515	1.750 in	1.125 in	1.44 in	200 PSI	BF	None	32-570-005	Yes	+ 1/8-27NPTF - 3 Places
03-020-557	1.750 in	1.125 in	1.44 in	75 PSI	BF	30-020-019	32-570-005	Yes	7/16-24 inverted flare
03-021-419	1.750 in	1.000 in	1.44 in	100 PSI	BF	None	None	No	1/8-27NPTF
03-021-422	1.750 in	1.000 in	1.44 in	100 PSI	HO	None	None	No	1/2-20UNF-2B
03-021-425	1.750 in	1.000 in	1.44 in	200 PSI	BF	None	32-570-006	No	1/2-20UNF-2B
03-021-427	1.750 in	1.125 in	1.44 in	100 PSI	BF	None	None	No	1/2-20UNF-2B
03-021-428	1.750 in	0.875 in	1.44 in	175 PSI	HO	None	None	No	1/8-27NPTF
03-021-429	1.750 in	0.875 in	1.44 in	175 PSI	BF	None	None	No	1/8-27NPTF
03-021-466	1.750 in	1.000 in	1.44 in	190 PSI	HO	30-020-020	32-570-065	No	1/2-20UNF-2B
03-021-557	1.750 in	1.125 in	1.44 in	75 PSI	BF	30-020-019	32-570-005	No	7/16-24 inverted flare

HO = mineral base hydraulic oil. BF = DOT 3, 4, 5 and 5.1 brake fluid.

* Has a special standpipe filler cap.

+ End plug has three outlet ports (1/8-27NPTF) equally spaced 120° apart.

* Contact ZF Off-Highway Solutions Minnesota Inc. for available outlet port adapters.

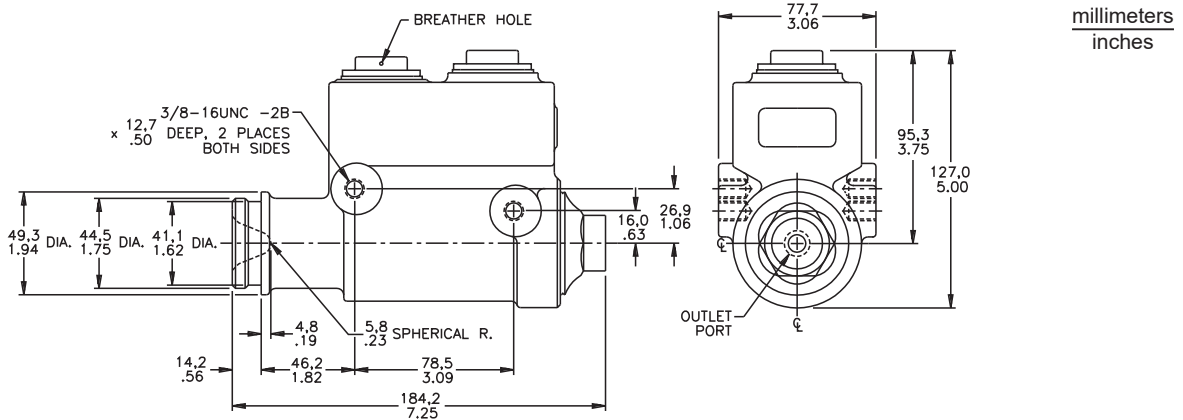
Two-stage Master Cylinders

Low Pressure Relief Valve



Typical model show. Dimensions may vary slightly between units.

- Bore Combinations:**
- 1 3/4 inch over 1 inch
 - 1 3/4 inch over 1 1/8 inch



SPECIFICATIONS

Model Number	Large Bore Diameter	Small Bore Diameter	Effective Stroke	Relief Valve Pressure Setting	Fluid Type	Push Rod (refer to page 33)	Boot (refer to page 33)	Residual Check Valve	*Outlet Port
02-020-303	1.750 in	1.000 in	1.44 in	100 PSI	BF	None	32-570-005	Yes	1/2-20UNF-2B
03-020-393	1.750 in	1.000 in	1.44 in	100 PSI	BF	None	None	Yes	+ 1/8-27NPTF - 3 Places
03-020-492	1.750 in	1.000 in	1.44 in	100 PSI	HO	None	32-570-065	Yes	1/2-20UNF-2B
03-020-495	1.750 in	1.125 in	1.44 in	100 PSI	BF	None	None	Yes	1/2-20UNF-2B
● 03-020-508	1.750 in	1.000 in	1.44 in	100 PSI	HO	None	32-570-065	Yes	#6 SAE o-ring boss
03-020-598	1.750 in	1.000 in	1.44 in	100 PSI	HO	None	None	Yes	+ 1/8-27NPTF - 3 Places
● 03-021-598	1.750 in	1.000 in	1.44 in	100 PSI	HO	None	None	No	+ 1/8-27NPTF - 3 Places

HO = mineral base hydraulic oil. BF = DOT 3, 4, 5 and 5.1 brake fluid.

● Has one filler cap tapped (#6 SAE o-ring boss) for remote reservoir.

+ End plug has three outlet ports (1/8-27NPTF) equally spaced 120° apart.

* Contact ZF Off-Highway Solutions Minnesota Inc. for available outlet port adapters.

Two-stage Master Cylinders

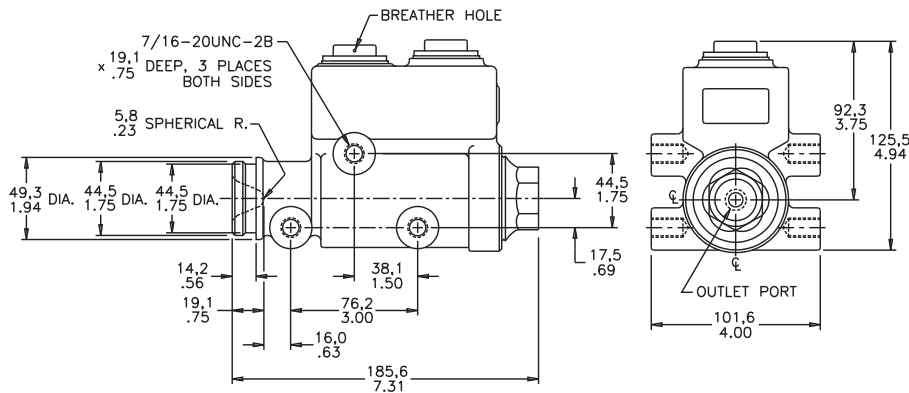
Low Pressure Relief Valve



Typical model show. Dimensions may vary slightly between units.

Bore Combinations:

- 1 3/4 inch over 1 inch
- 1 3/4 inch over 1 1/8 inch



millimeters
inches

SPECIFICATIONS

Model Number	Large Bore Diameter	Small Bore Diameter	Effective Stroke	Relief Valve Pressure Setting	Fluid Type	Push Rod (refer to page 34)	Boot (refer to page 33)	Residual Check Valve	* Outlet Port
03-020-363	1.750 in	1.125 in	1.44 in	100 PSI	BF	None	None	Yes	1/8-27NPTF
03-020-367	1.750 in	1.000 in	1.44 in	100 PSI	BF	None	None	Yes	1/2-20UNF-2B
03-020-469	1.750 in	1.125 in	1.44 in	300 PSI	BF	30-020-020	32-570-005	Yes	1/2-20UNF-2B
03-020-569	1.750 in	1.125 in	1.44 in	225 PSI	BF	None	32-570-006	Yes	1/2-20UNF-2B
03-021-367	1.750 in	1.000 in	1.44 in	100 PSI	BF	None	None	No	1/2-20UNF-2B

BF = DOT 3, 4, 5 and 5.1 brake fluid.

* Contact ZF Off-Highway Solutions Minnesota Inc. for available outlet port adapters.

Two-stage Master Cylinders

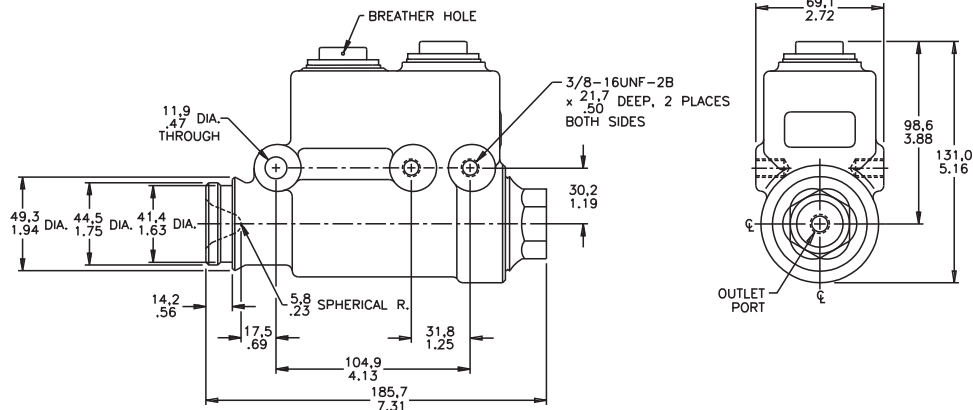
Low Pressure Relief Valve



Typical model show. Dimensions may vary slightly between units.

Bore Combinations:

- 1 3/4 inch over 1 inch
- 1 3/4 inch over 1 1/8 inch



SPECIFICATIONS

Model Number	Large Bore Diameter	Small Bore Diameter	Effective Stroke	Relief Valve Pressure Setting	Fluid Type	Push Rod (refer to page 34)	Boot (refer to page 33)	Residual Check Valve	*Outlet Port
02-020-321	1.750 in	1.000 in	1.44 in	100 PSI	BF	None	32-570-006	Yes	1/2-20UNF-2B
● 02-020-332	1.750 in	1.000 in	1.44 in	100 PSI	HO	30-020-083	32-570-065	Yes	+ 1/2-20UNF-2B
02-021-321	1.750 in	1.000 in	1.44 in	100 PSI	BF	None	32-570-006	No	1/2-20UNF-2B
● 02-021-332	1.750 in	1.000 in	1.44 in	100 PSI	HO	30-020-083	32-570-065	No	+ 1/2-20UNF-2B
03-020-551	1.750 in	1.125 in	1.44 in	175 PSI	BF	None	None	Yes	1/2-20UNF-2B
03-020-554	1.750 in	1.125 in	1.44 in	175 PSI	HO	None	32-570-006	Yes	+ 1/2-20UNF-2B
03-020-555	1.750 in	1.125 in	1.44 in	100 PSI	BF	None	32-570-006	Yes	+ 1/2-20UNF-2B
03-021-551	1.750 in	1.125 in	1.44 in	175 PSI	BF	None	None	No	1/2-20UNF-2B
03-021-554	1.750 in	1.125 in	1.44 in	175 PSI	HO	None	32-570-006	No	+ 1/2-20UNF-2B
03-021-555	1.750 in	1.125 in	1.44 in	100 PSI	BF	None	32-570-006	No	+ 1/2-20UNF-2B

HO = mineral base hydraulic oil. BF = DOT 3, 4, 5 and 5.1 brake fluid.

- Has one filler cap tapped (#6 SAE o-ring boss) for remote reservoir.
- + Includes outlet port adapter 7/16-24 inverted flare.
- * Contact ZF Off-Highway Solutions Minnesota Inc. for available outlet port adapters.

Two-stage Master Cylinders

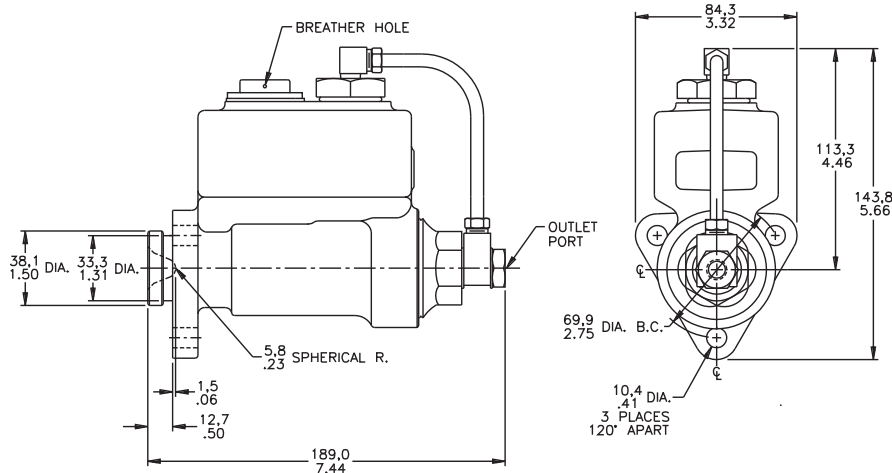
High Pressure Relief Valve



Typical model show. Dimensions may vary slightly between units.

Bore Combinations:

- 1 1/2 inch over 3/4 inch
- 1 1/2 inch over 7/8 inch



SPECIFICATIONS

Model Number	Large Bore Diameter	Small Bore Diameter	Effective Stroke	Relief Valve Pressure Setting	Fluid Type	Push Rod (refer to page 34)	Boot (refer to page 33)	Residual Check Valve	*Outlet Port
03-020-365	1.500 in	0.750 in	1.44 in	125 PSI	BF	None	32-570-005	Yes	■ 1/8-27NPTF
03-020-381	1.500 in	0.750 in	1.44 in	180 PSI	BF	30-020-083	32-570-005	No	1/2-20 inverted flare
03-020-384	1.500 in	0.750 in	1.44 in	125 PSI	HO	30-020-020	32-570-065	No	■ 1/8-27NPTF
03-020-397	1.500 in	0.875 in	1.44 in	155 PSI	BF	30-020-057	32-570-004	Yes	7/16-24 inverted flare
03-020-399	1.500 in	0.875 in	1.44 in	125 PSI	BF	None	None	Yes	1/8-27NPTF
● 03-020-402	1.500 in	0.875 in	1.44 in	180 PSI	HO	30-020-020	32-570-065	No	1/8-27NPTF
03-020-413	1.500 in	0.875 in	1.44 in	180 PSI	BF	None	32-570-004	Yes	1/8-27NPTF
03-020-434	1.500 in	0.750 in	1.44 in	180 PSI	HO	30-020-020	32-570-065	No	7/16-24 inverted flare
* 03-020-438	1.500 in	0.750 in	1.44 in	180 PSI	HO	30-020-020	32-570-065	No	1/8-27NPTF
03-020-440	1.500 in	0.750 in	1.44 in	180 PSI	HO	30-020-020	32-570-065	Yes	1/8-27NPTF
03-021-365	1.500 in	0.750 in	1.44 in	125 PSI	BF	None	32-570-005	No	■ 1/8-27NPTF
03-021-399	1.500 in	0.875 in	1.44 in	125 PSI	BF	None	None	No	1/8-27NPTF
03-021-440	1.500 in	0.750 in	1.44 in	180 PSI	HO	30-020-020	32-570-065	No	1/8-27NPTF

HO = mineral base hydraulic oil. BF = DOT 3, 4, 5 and 5.1 brake fluid.

* Has a special standpipe filler cap.

● Has one filler cap tapped (1/4-18NPTF) for remote reservoir.

■ Has fitting block with a second outlet port 7/16-24 inverted flare.

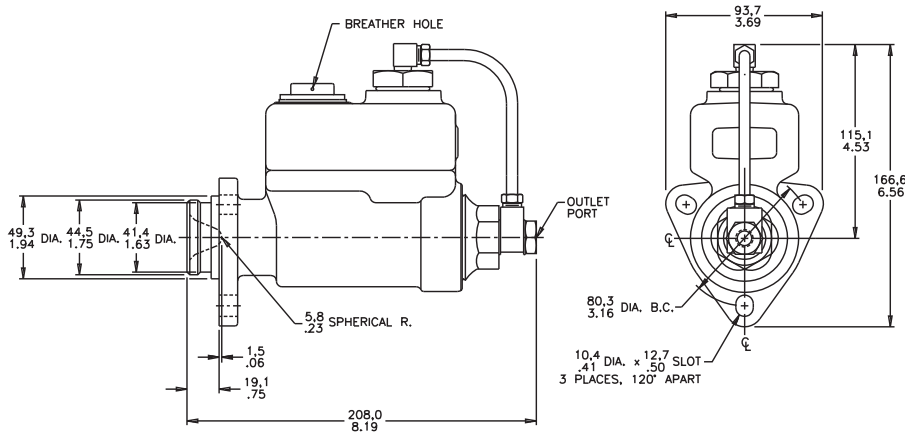
* Contact ZF Off-Highway Solutions Minnesota Inc. for available outlet port adapters.

Two-stage Master Cylinders

High Pressure Relief Valve



Typical model show. Dimensions may vary slightly between units.



Bore Combinations:

- 1 3/4 inch over 1 inch
- 1 3/4 inch over 1 1/8 inch

millimeters
inches

SPECIFICATIONS

Model Number	Large Bore Diameter	Small Bore Diameter	Effective Stroke	Relief Valve Pressure Setting	Fluid Type	Push Rod (refer to page 34)	Boot (refer to page 33)	Residual Check Valve	*Outlet Port
03-020-107	1.750 in	1.125 in	1.44 in	125 PSI	BF	30-020-083	32-570-005	Yes	7/16-24 inverted flare
03-020-119	1.750 in	1.125 in	1.44 in	180 PSI	BF	None	None	No	7/16-24 inverted flare
03-020-467	1.750 in	1.000 in	1.44 in	90 PSI	BF	None	None	Yes	+ 1/8-27NPTF
03-020-485	1.750 in	1.125 in	1.44 in	90 PSI	BF	None	None	Yes	1/8-27NPTF
03-020-597	1.750 in	1.000 in	1.44 in	125 PSI	BF	None	32-570-005	Yes	1/8-27NPTF
03-021-107	1.750 in	1.125 in	1.44 in	125 PSI	BF	30-020-083	32-570-005	No	7/16-24 inverted flare
03-021-467	1.750 in	1.000 in	1.44 in	90 PSI	BF	None	None	No	+ 1/8-27NPTF
03-021-485	1.750 in	1.125 in	1.44 in	90 PSI	BF	None	None	No	1/8-27NPTF

BF = DOT 3, 4, 5 and 5.1 brake fluid.

+ Includes outlet port adapter tee for two outlet ports 3/8-24 inverted flare.

* Contact ZF Off-Highway Solutions Minnesota Inc. for available outlet port adapters.

Two-stage Master Cylinders

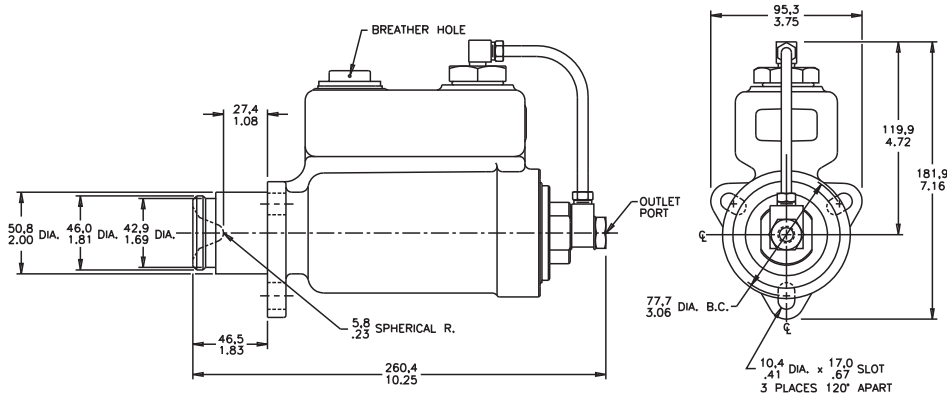
High Pressure Relief Valve



Typical model show. Dimensions may vary slightly between units.

Bore Combinations:

- 2 1/4 inch over 1 inch
- 2 1/4 inch over 1 1/8 inch



millimeters
inches

SPECIFICATIONS

Model Number	Large Bore Diameter	Small Bore Diameter	Effective Stroke	Relief Valve Pressure Setting	Fluid Type	Push Rod (refer to page 34)	Boot (refer to page 33)	Residual Check Valve	*Outlet Port
02-020-132	2.250 in	1.125 in	2.00 in	90 PSI	BF	None	32-570-005	Yes	1/8-27NPTF
02-020-137	2.250 in	1.000 in	2.00 in	90 PSI	BF	30-020-072	32-570-005	Yes	1/8-27NPTF
02-021-137	2.250 in	1.000 in	2.00 in	90 PSI	BF	30-020-072	32-570-005	No	1/8-27NPTF
03-020-232	2.250 in	1.125 in	2.00 in	90 PSI	HO	30-020-072	32-570-065	Yes	1/8-27NPTF
03-020-233	2.250 in	1.125 in	2.00 in	125 PSI	BF	30-020-020	32-570-005	Yes	1/8-27NPTF
03-020-241	2.250 in	1.000 in	2.00 in	180 PSI	BF	None	32-570-005	Yes	1/8-27NPTF
03-020-242	2.250 in	1.000 in	2.00 in	90 PSI	HO	None	32-570-065	Yes	1/8-27NPTF
03-021-232	2.250 in	1.125 in	2.00 in	90 PSI	HO	30-020-072	32-570-065	No	1/8-27NPTF
03-021-233	2.250 in	1.125 in	2.00 in	125 PSI	BF	30-020-020	32-570-005	No	1/8-27NPTF
03-021-242	2.250 in	1.000 in	2.00 in	90 PSI	HO	None	32-570-065	No	1/8-27NPTF

HO = mineral base hydraulic oil. BF = DOT 3, 4, 5 and 5.1 brake fluid.

* Contact ZF Off-Highway Solutions Minnesota Inc. for available outlet port adapters.



BRAKES



**HYDRAULIC OVER AIR
RELAY VALVES**



**ELECTROHYDRAULIC
VALVES**



**ACCUMULATOR
CHARGING VALVES**



**MODULATING BRAKE
VALVES**



QUADRIGAGE™



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ELECTRONIC PEDALS



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Learn more about our hydraulic products at:
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Hystat/Master Cylinder



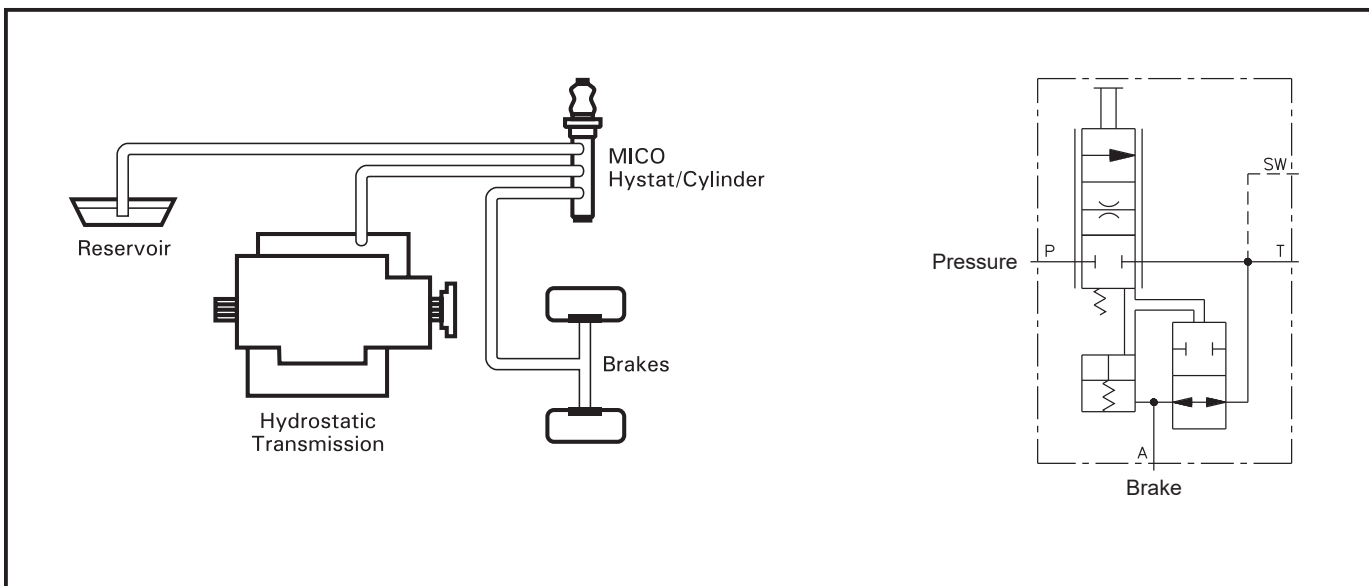
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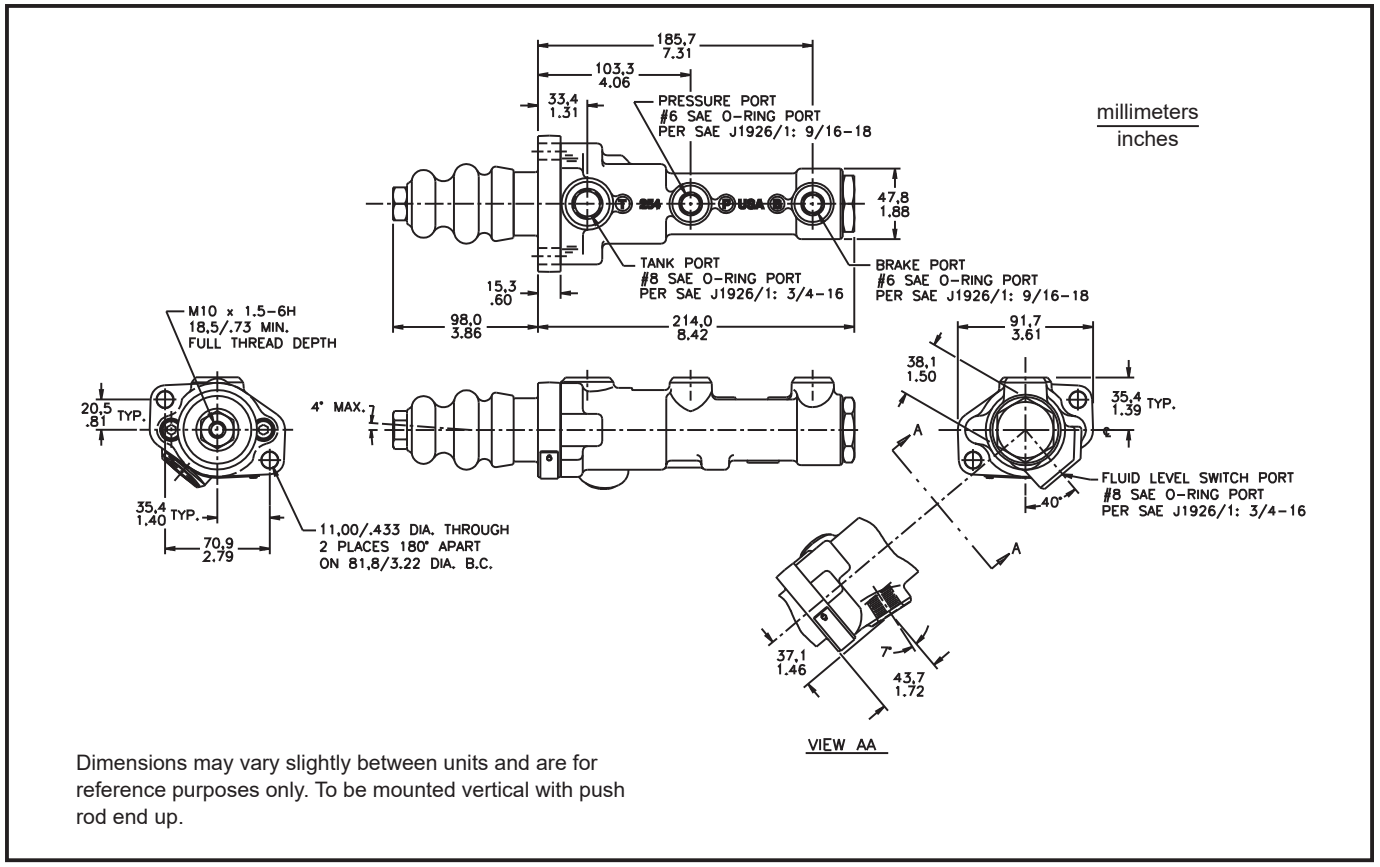
The Hystat/Master Cylinder was developed to de-stroke the hydrostatic transmission then apply the vehicle brakes. This function is normally described as inching. As you release the cylinder the brakes release and the hydrostatic transmission re-engages. It is application specific and must be carefully sized. Please contact the ZF Off-Highway Solutions Minnesota Inc. Applications Department with your questions.

FEATURES

- For use with mineral base hydraulic oil only
- Compact size
- #8 SAE o-ring port for a customer supplied, liquid switch to monitor reservoir oil height

Typical Circuit Schematic





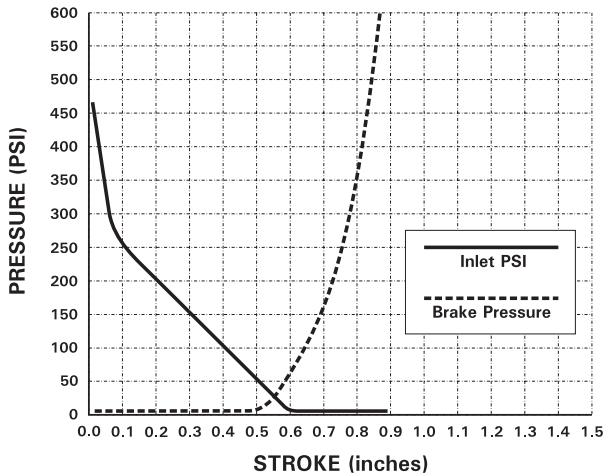
SPECIFICATIONS

Consult ZF Off-Highway Solutions Minnesota Inc
Applications Department for available models

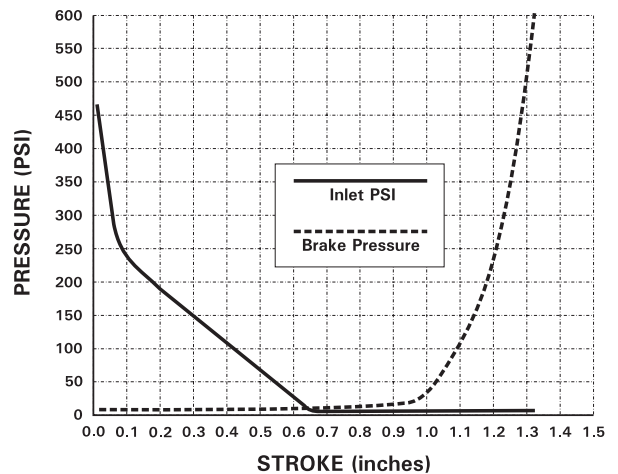
PERFORMANCE DATA

Available in two bore sizes	0.875 inch diameter
	1.063 inch diameter
Stroke with internal stop	1.500 inch maximum
Displacement	0.60 in ³ (0.875 bore model)
	1.24 in ³ (1.063 bore model)
Rated pressures	1500 PSI (working)

**Pressure vs. Stroke Graph
for 0.875 inch bore**



**Pressure vs. Stroke Graph
for 1.063 inch bore**



Fluid Reservoirs

For Direct or Remote Mounting



POLYALLOMER RESERVOIR

- Translucent for easy view of fluid level
- Diaphragm seals out environmental contaminants
- Adaptable outlet fittings
- Sediment trap inherent to design
- Easy screw on and off filler cap
- 238 cm³ (14.5 in³) usable fluid capacity
- For use with hydraulic oil or brake fluid
(contact ZF Off-Highway regarding phosphate ester fluids)

METAL RESERVOIR

- Rugged anodized aluminum housing
- Easy screw on and off filler cap with baffle and breather
- 54 cm³ (3.3 in³) usable fluid capacity
- Compact design for ease of mounting
- Adaptable outlet fittings
- For use with hydraulic oil or brake fluid
(contact ZF Off-Highway regarding phosphate ester fluids)

SPECIFICATIONS

Poylallomer Reservoirs

Model Number	Fluid Type	Outlet Fitting	Mounting Bracket	Diaphragm Part Number
20-920-500	HO	9/16-18UNF-2A	Yes	32-490-009
20-920-520	HO	9/16-18UNF-2A	No	32-490-009
20-920-512	HO	1/4-18NPTF (internal)	Yes	32-490-009
20-920-514	HO	1/4-18NPTF (internal)	No	32-490-009
20-920-505	BF	9/16-18UNF-2A	Yes	32-490-010
20-920-509	BF	1/4-18NPTF (internal)	Yes	32-490-010
20-920-515	BF	1/4-18NPTF (internal)	No	32-490-010

HO = mineral base hydraulic oil.

BF = DOT 3, 4, 5 and 5.1 brake fluid.

SPECIFICATIONS

Metal Reservoirs

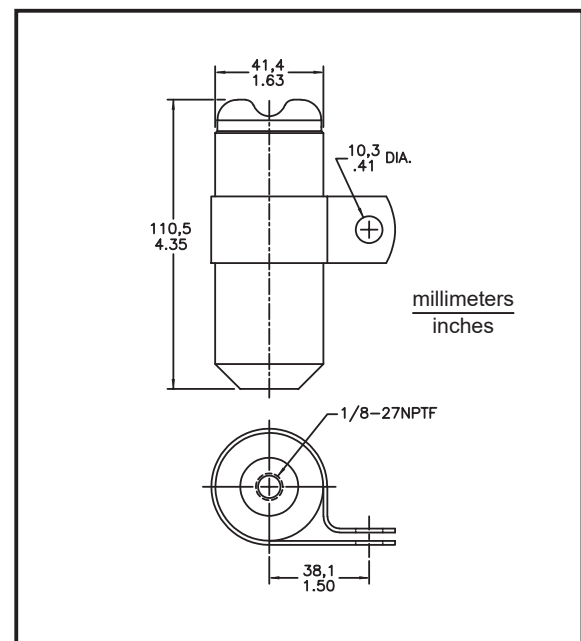
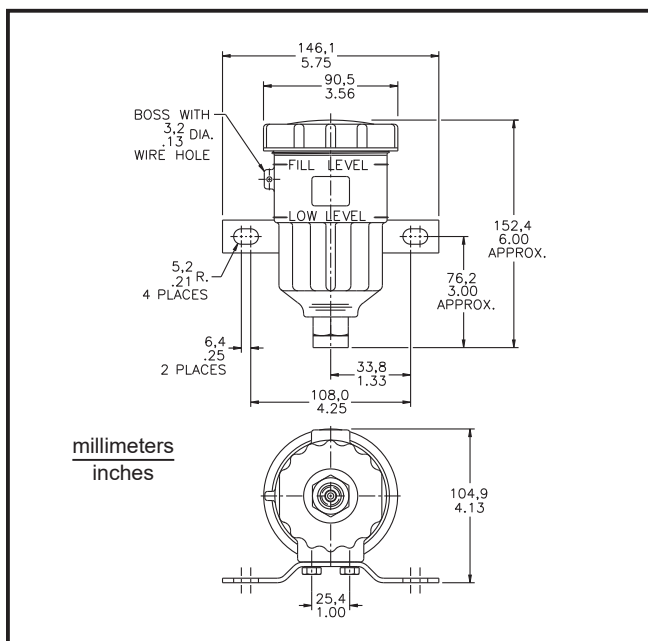
Model Number	Fluid Type	Mounting Bracket
* 20-920-002	BF or HO	No
** 20-920-006	BF or HO	Yes
20-920-009	BF or HO	Yes

* Includes 1/8-27NPTF male 90° elbow fitting.

** Includes two 1/4-27NPTF x 1/4 tube fittings.

HO = mineral base hydraulic oil.

BF = DOT 3, 4, 5 and 5.1 brake fluid.



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