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HYDRAULIC FUNDAMENTALS - CYLINDERS

Main Category:	Mechanical Engineering
Sub Category:	Hydraulics
Course #:	MEC-124
Course Content:	53 pgs
PDH/CE Hours:	3

OFFICIAL COURSE/EXAM

(SEE INSTRUCTIONS ON NEXT PAGE)

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MEC-124 EXAM PREVIEW

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Instructions:

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Exam Preview:

1. According to the reference material, a cylinder will produce more force on the pull stroke, than on the push stroke.
    a. True
    b. False
2. Using the Push Force Estimation Table, if a cylinder has a bore of 6 inches, and the pressure of the operating medium is 750 PSI, what is the theoretical push stroke force in pounds?
    a. 19,635
    b. 21,206
    c. 28,274
    d. 38,485
3. According to the reference material, cylinder mounting options can be generally grouped in to these three types: Centerline, Foot and Pivot.
    a. True
    b. False
4. Using the Rod Deflection Table, if a piston rod with a 2-inch diameter is spanned across a 10-foot length, which of the options below is the indicated sag, in inches, for that rod?
    a. .066
    b. .101
    c. .148
    d. .212

5. Using the Cylinder Breakloose Pressure Table, if a cylinder bore is 2 ½ inches in diameter, and uses a viton STAR Bushing with standard piston seals, which of the below options is the breakloose pressure for this configuration?
    a. 12 PSI
    b. 15 PSI
    c. 10 PSI
    d. 20 PSI
6. Using the Oil Consumption Per Inch of Stroke chart, which of the following choices is the gallons displaced by a piston rod which is 4 1/2 inches in diameter?
    a. .0417
    b. .0544
    c. .0688
    d. .0850
7. The use of stop tubing is a generally accepted and preferred method for reducing piston and bearing loads on long stroke cylinders and additionally, for preventing jack-knifing or buckling of horizontally mounted, long push stroke cylinders. Stop tubes are less effective, less costly, and lighter in weight than oversize piston rods.
    a. True
    b. False
8. Which of the following is NOT an option for corrosion protection offered by Miller?
    a. Epoxy Paint
    b. Chrome Plating
    c. Stainless Steel Piston Rods
    d. Nickel- Cadmium Plating
9. Which of the following is NOT a type of End-of-Stroke Proximity switch?
    a. Weld Field Immune
    b. Rotatable
    c. Open Enclosure
    d. Short Circuit Protection
10. According to the reference material, when considering the effect of temperature on a cylinder, both heat and cold must be considered. The components impacted the most by extreme temperatures are seals.
    a. True
    b. False

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Cylinder Operating Principles

Basic Types and Operation

The term cylinder is commonly used to describe a device that gives linear force output and movement. A cylinder may also be referred to as a linear actuator.

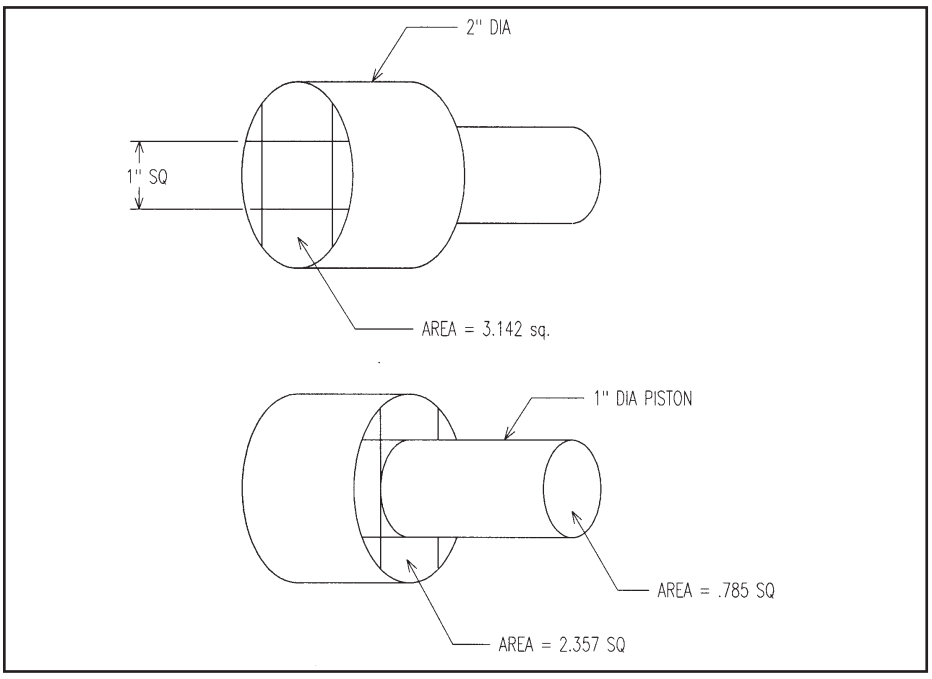
Cylinders are broken down into two main categories: pneumatic and hydraulic. Pneumatic cylinders can be operated by several types of gases; however, compressed air is by far the most common. Hydraulic cylinders can be operated with a wide range of fluids. By far the most common is petroleum base hydraulic fluid. Synthetic or water base fluids are also commonly used when fire resistance is required.

Cylinders can be broken down into two main subassemblies. The pressure-containing envelope consists of the head, cap, tie rods, tube and rod bearing. The other subassembly consists of the piston and piston rod. Typically, the pressure containing envelope is fixed on the machine and the piston and rod assembly is attached to the machine member on which motion and force needs to be applied. In rare instances, the opposite is done.

Force

The amount of force produced by the cylinder is the product of the internal fluid pressure against the piston, multiplied by the effective area of the piston. Most cylinders consist of a single piston rod. When the rod extends out of the cylinder it is operating on the “push” stroke. When the rod retracts into the cylinder, it is operating on the “pull” stroke. Assuming a constant fluid pressure, the cylinder will produce more force on the push stroke than on the pull stroke. The pull stroke force is reduced by the fluid pressure multiplied by the area of the piston rod.

For example a 2-inch bore cylinder with a 1-inch rod, operating at 1,000 psi will deliver 3,142 pounds of push force and 2,357 pounds of pull force.



A 2 inch bore piston has 3.142 square inches of area.
The 1 inch rod has .785 square inches of area, thereby reducing the rod end area of the piston, available to pressure, to 2.357 square inches.

Velocity

Cylinder piston and rod velocity is dependent on the rate that fluid or compressed air can be introduced into one end of the cylinder or exhausted from the other end.

Typical velocities range up to 24 inches per second. Miller recommends that cylinders be ordered with cushions when maximum velocities exceed 2 inches per second.

Selecting the Proper Bore Size

Basic Information Required

1. Determine the push or pull force (in pounds) required from the cylinder. Allowances must be made for cylinder packing friction.
    a) In pneumatic applications, 1 1/2 through 4 inch bore should be sized approximately 33% higher (multiply force by 1.33) than the force required. Cylinders larger than 4 inch bore should be sized 50% higher (multiply force by 1.50) than the force required. For dynamic applications where the load must be accelerated, additional allowances must be made.
    b) Hydraulic cylinders should be sized 5% higher (multiply force by 1.05) than the force required.

2. Determine the pressure that will be available at the cylinder. Be sure to allow for all pressure drops between the air compressor or hydraulic pump and the cylinder. Keep in mind that when the cylinder is not moving, pressure at the ports is equal to the relief valve setting in a hydraulic system or the pressure regulator setting in a pneumatic system. As soon as the piston begins to move and fluid flows through the piping, pressure is lost due to friction in long lengths of pipe, elbows, tees, fittings and valves. See the Pipe Size and Oil Flow Table to estimate pressure drop for your hydraulic application.

Push Applications

1. In the Push Force Estimation Table find the column headed by the pressure that will be available at the cylinder.

2. Move down that column to find the force value that is the same as (or greater than) that which the cylinder is required to deliver.

3. On the row with the required force, move to the first column on the left. The number shown here is most likely the bore size that will produce the required force.

Pull Applications - remember that pull forces are less than push forces by an amount equal to the operating pressure multiplied by the piston rod area.

1. In the Pull Force Estimation Table find the column headed by the pressure that will be available at the cylinder.

2. Move down that column to find the force value that is the same as (or greater than) that which the cylinder is required to deliver.

3. On the row with the required force, move to the first column on the left. The number shown here is most likely the bore and rod size combination that will produce the required force.

Note that approximately the same pull force can be achieved by more than one bore and rod combination. Selecting the smallest bore and rod combination that produces the required force will likely be the most economical.

Thrusts for operating pressures not shown in either table may be calculated by multiplying the operating pressure by the piston area or net rod end area.

Stroke

All Miller cylinders are made to order to customer specified stroke lengths. The standard stroke tolerance is ±.03 inch. Close stroke tolerance cylinders with a total tolerance as tight as .005 inch (e.g. +.002/-.003) are available as engineered customs.

Push Force Estimation Table

Cylinder Bores In Inches	Piston Area In Square Inches	Theoretical Push Stroke Force In Pounds														
		Pressures Of Operating Medium														
		50 PSI	60 PSI	80 PSI	100 PSI	200 PSI	250 PSI	500 PSI	750 PSI	1000 PSI	1500 PSI	2000 PSI	3000 PSI	4000 PSI	5000 PSI	6000 PSI
1 1/2	1.767	88	106	141	177	353	442	884	1,325	1,767	2,651	3,534	5,301	7,068	8,835	10,602
2	3.142	157	189	251	314	628	786	1,571	2,357	3,142	4,713	6,284	9,426	12,568	15,710	18,852
2 1/2	4.909	245	295	393	491	982	1,227	2,455	3,682	4,909	7,364	9,818	14,727	19,636	24,545	29,454
3 1/4	8.296	415	498	664	830	1,659	2,074	4,148	6,222	8,296	12,444	16,592	24,888	33,184	41,480	49,776
4	12.566	628	754	1,005	1,257	2,513	3,142	6,283	9,425	12,566	18,849	25,132	37,698	50,264	62,830	75,396
5	19.635	982	1,178	1,571	1,964	3,927	4,909	9,818	14,726	19,635	29,453	39,270	58,905	78,540	98,175	117,810
6	28.274	1,414	1,696	2,262	2,827	5,655	7,069	14,137	21,206	28,274	42,411	56,548	84,822	113,096	141,370	169,644
7	38.485	1,924	2,309	3,079	3,849	7,697	9,621	19,243	28,864	38,485	57,728	76,970	115,455	153,940	192,425	230,910
8	50.265	2,513	3,016	4,021	5,027	10,053	12,566	25,133	37,699	50,265	75,398	100,530	150,795	201,060	251,325	301,590
10	78.540	3,927	4,712	6,283	7,854	15,708	19,635	39,270	58,905	78,540	117,810	157,080	235,620	314,160	392,700	471,240
12	113.100	5,655	6,786	9,048	11,310	22,620	28,275	56,550	84,825	113,100	169,650	226,200	339,300	452,400	565,500	678,600
14	153.940	7,697	9,236	12,315	15,394	30,788	38,485	76,970	115,455	153,940	230,910	307,880	461,820	615,760	769,700	923,640
16	201.060	10,053	12,064	16,085	20,106	40,212	50,265	100,530	150,795	201,060	301,590	402,120	603,180	804,240	1,005,300	1,206,360
18	254.470	12,724	15,268	20,358	25,447	50,894	63,618	127,235	190,853	254,470	381,705	508,940	763,410	1,017,880	1,272,350	1,526,820
20	314.160	15,708	18,850	25,133	31,416	62,832	78,540	157,080	235,620	314,160	471,240	628,320	942,480	1,256,640	1,570,800	1,884,960

Pull Force Estimation Table

Cylinder Bores In Inches	Piston Rod Diameters In Inches	Net Rod End Area In Square Inches	Theoretical Pull Stroke Force In Pounds														
			Pressures Of Operating Medium														
			50 PSI	60 PSI	80 PSI	100 PSI	200 PSI	250 PSI	500 PSI	750 PSI	1000 PSI	1500 PSI	2000 PSI	3000 PSI	4000 PSI	5000 PSI	6000 PSI
1 1/2	5/8	1.460	73	88	117	146	292	365	730	1,095	1,460	2,190	2,920	4,380	5,840	7,300	8,760
	1	0.982	49	59	79	98	196	246	491	737	982	1,473	1,964	2,946	3,928	4,910	5,892
2	5/8 *	2.835	142	170	227	284	567	709	1,418	2,126	2,835	4,253	5,670	8,505	11,340	14,175	17,010
	1	2.357	118	141	189	236	471	589	1,179	1,768	2,357	3,536	4,714	7,071	9,428	11,785	14,142
	1 3/8	1.657	83	99	133	166	331	414	829	1,243	1,657	2,486	3,314	4,971	6,628	8,285	9,942
2 1/2	5/8 *	4.602	230	276	368	460	920	1,151	2,301	3,452	4,602	6,903	9,204	13,806	18,408	23,010	27,612
	1	4.124	206	247	330	412	825	1,031	2,062	3,093	4,124	6,186	8,248	12,372	16,496	20,620	24,744
	1 3/8	3.424	171	205	274	342	685	856	1,712	2,568	3,424	5,136	6,848	10,272	13,696	17,120	20,544
	1 3/4	2.504	125	150	200	250	501	626	1,252	1,878	2,504	3,756	5,008	7,512	10,016	12,520	15,024
3 1/4	1 *	7.511	376	451	601	751	1,502	1,878	3,756	5,633	7,511	11,267	15,022	22,533	30,044	37,555	45,066
	1 3/8	6.811	341	409	545	681	1,362	1,703	3,406	5,108	6,811	10,217	13,622	20,433	27,244	34,055	40,866
	1 3/4	5.891	295	353	471	589	1,178	1,473	2,946	4,418	5,891	8,837	11,782	17,673	23,564	29,455	35,346
	2	5.154	258	309	412	515	1,031	1,289	2,577	3,866	5,154	7,731	10,308	15,462	20,616	25,770	30,924
4	1*	11.781	589	707	942	1,178	2,356	2,945	5,891	8,836	11,781	17,672	23,562	35,343	47,124	58,905	70,686
	1 3/8 *	11.081	554	665	886	1,108	2,216	2,770	5,541	8,311	11,081	16,622	22,162	33,243	44,324	55,405	66,486
	1 3/4	10.161	508	610	813	1,016	2,032	2,540	5,081	7,621	10,161	15,242	20,322	30,483	40,644	50,805	60,966
	2	9.424	471	565	754	942	1,885	2,356	4,712	7,068	9,424	14,136	18,848	28,272	37,696	47,120	56,544
	2 1/2	7.657	383	459	613	766	1,531	1,914	3,829	5,743	7,657	11,486	15,314	22,971	30,628	38,285	45,942
5	1*	18.850	943	1,131	1,508	1,885	3,770	4,713	9,425	14,138	18,850	28,275	37,700	56,550	75,400	94,250	113,100
	1 3/8 *	18.150	908	1,089	1,452	1,815	3,630	4,538	9,075	13,613	18,150	27,225	36,300	54,450	72,600	90,750	108,900
	1 3/4 *	17.230	862	1,034	1,378	1,723	3,446	4,308	8,615	12,923	17,230	25,845	34,460	51,690	68,920	86,150	103,380
	2	16.493	825	990	1,319	1,649	3,299	4,123	8,247	12,370	16,493	24,740	32,986	49,479	65,972	82,465	98,958
	2 1/2	14.726	736	884	1,178	1,473	2,945	3,682	7,363	11,045	14,726	22,089	29,452	44,178	58,904	73,630	88,356
	3	12.566	628	754	1,005	1,257	2,513	3,142	6,283	9,425	12,566	18,849	25,132	37,698	50,264	62,830	75,396
	3 1/2	10.014	501	601	801	1,001	2,003	2,504	5,007	7,511	10,014	15,021	20,028	30,042	40,056	50,070	60,084
6	1 3/8 *	26.789	1,339	1,607	2,143	2,679	5,358	6,697	13,395	20,092	26,789	40,184	53,578	80,367	107,156	133,945	160,734
	1 3/4 *	25.869	1,293	1,552	2,070	2,587	5,174	6,467	12,935	19,402	25,869	38,804	51,738	77,607	103,476	129,345	155,214
	2 *	25.132	1,257	1,508	2,011	2,513	5,026	6,283	12,566	18,849	25,132	37,698	50,264	75,396	100,528	125,660	150,792
	2 1/2	23.365	1,168	1,402	1,869	2,337	4,673	5,841	11,683	17,524	23,365	35,048	46,730	70,095	93,460	116,825	140,190
	3	21.205	1,060	1,272	1,696	2,121	4,241	5,301	10,603	15,904	21,205	31,808	42,410	63,615	84,820	106,025	127,230
	3 1/2	18.653	933	1,119	1,492	1,865	3,731	4,663	9,327	13,990	18,653	27,980	37,306	55,959	74,612	93,265	111,918
	4	15.708	785	942	1,257	1,571	3,142	3,927	7,854	11,781	15,708	23,562	31,416	47,124	62,832	78,540	94,248
7	1 3/8 *	37.000	1,850	2,220	2,960	3,700	7,400	9,250	18,500	27,750	37,000	55,500	74,000	111,000	148,000	185,000	222,000
	1 3/4 *	36.080	1,804	2,165	2,886	3,608	7,216	9,020	18,040	27,060	36,080	54,120	72,160	108,240	144,320	180,400	216,480
	2 *	35.343	1,767	2,121	2,827	3,534	7,069	8,836	17,672	26,507	35,343	53,015	70,686	106,029	141,372	176,715	212,058
	2 1/2 *	33.576	1,679	2,015	2,686	3,358	6,715	8,394	16,788	25,182	33,576	50,364	67,152	100,728	134,304	167,880	201,456
	3	31.416	1,571	1,885	2,513	3,142	6,283	7,854	15,708	23,562	31,416	47,124	62,832	94,248	125,664	157,080	188,496
	3 1/2	28.864	1,443	1,732	2,309	2,886	5,773	7,216	14,432	21,648	28,864	43,296	57,728	86,592	115,456	144,320	173,184
	4	25.919	1,296	1,555	2,074	2,592	5,184	6,480	12,960	19,439	25,919	38,879	51,838	77,757	103,676	129,595	155,514
	4 1/2	22.581	1,129	1,355	1,806	2,258	4,516	5,645	11,291	16,936	22,581	33,872	45,162	67,743	90,324	112,905	135,486
	5	18.850	943	1,131	1,508	1,885	3,770	4,713	9,425	14,138	18,850	28,275	37,700	56,550	75,400	94,250	113,100

*These rod diameters in these bore sizes are only available in A and J series

Pull Force Estimation Table

Cylinder Bores In Inches	Piston Rod Diameters In Inches	Net Rod End Area In Square Inches	Theoretical Pull Stroke Force In Pounds														
			Pressures Of Operating Medium														
			50 PSI	60 PSI	80 PSI	100 PSI	200 PSI	250 PSI	500 PSI	750 PSI	1000 PSI	1500 PSI	2000 PSI	3000 PSI	4000 PSI	5000 PSI	6000 PSI
8	1 3/8 *	48.780	2,439	2,927	3,902	4,878	9,756	12,195	24,390	36,585	48,780	73,170	97,560	146,340	195,120	243,900	292,680
	1 3/4 *	47.860	2,393	2,872	3,829	4,786	9,572	11,965	23,930	35,895	47,860	71,790	95,720	143,580	191,440	239,300	287,160
	2 *	47.123	2,356	2,827	3,770	4,712	9,425	11,781	23,562	35,342	47,123	70,685	94,246	141,369	188,492	235,615	282,738
	2 1/2 *	45.356	2,268	2,721	3,628	4,536	9,071	11,339	22,678	34,017	45,356	68,034	90,712	136,068	181,424	226,780	272,136
	3 *	43.196	2,160	2,592	3,456	4,320	8,639	10,799	21,598	32,397	43,196	64,794	86,392	129,588	172,784	215,980	259,176
	3 1/2	40.644	2,032	2,439	3,252	4,064	8,129	10,161	20,322	30,483	40,644	60,966	81,288	121,932	162,576	203,220	243,864
	4	37.699	1,885	2,262	3,016	3,770	7,540	9,425	18,850	28,274	37,699	56,549	75,398	113,097	150,796	188,495	226,194
	4 1/2	34.361	1,718	2,062	2,749	3,436	6,872	8,590	17,181	25,771	34,361	51,542	68,722	103,083	137,444	171,805	206,166
	5	30.630	1,532	1,838	2,450	3,063	6,126	7,658	15,315	22,973	30,630	45,945	61,260	91,890	122,520	153,150	183,780
	5 1/2	26.507	1,325	1,590	2,121	2,651	5,301	6,627	13,254	19,880	26,507	39,761	53,014	79,521	106,028	132,535	159,042
10	1 3/4 *	76.135	3,807	4,568	6,091	7,614	15,227	19,034	38,068	57,101	76,135	114,203	152,270	228,405	304,540	380,675	456,810
	2 *	75.398	3,770	4,524	6,032	7,540	15,080	18,850	37,699	56,549	75,398	113,097	150,796	226,194	301,592	376,990	452,388
	2 1/2 *	73.631	3,682	4,418	5,890	7,363	14,726	18,408	36,816	55,223	73,631	110,447	147,262	220,893	294,524	368,155	441,786
	3 *	71.471	3,574	4,288	5,718	7,147	14,294	17,868	35,736	53,603	71,471	107,207	142,942	214,413	285,884	357,355	428,826
	3 1/2 *	68.919	3,446	4,135	5,514	6,892	13,784	17,230	34,460	51,689	68,919	103,379	137,838	206,757	275,676	344,595	413,514
	4 *	65.974	3,299	3,958	5,278	6,597	13,195	16,494	32,987	49,481	65,974	98,961	131,948	197,922	263,896	329,870	395,844
	4 1/2	62.636	3,132	3,758	5,011	6,264	12,527	15,659	31,318	46,977	62,636	93,954	125,272	187,908	250,544	313,180	375,816
	5	58.905	2,945	3,534	4,712	5,891	11,781	14,726	29,453	44,179	58,905	88,358	117,810	176,715	235,620	294,525	353,430
	5 1/2	54.782	2,739	3,287	4,383	5,478	10,956	13,696	27,391	41,087	54,782	82,173	109,564	164,346	219,128	273,910	328,692
	7	40.055	2,003	2,403	3,204	4,006	8,011	10,014	20,028	30,041	40,055	60,083	80,110	120,165	160,220	200,275	240,330
12	2 *	109.958	5,498	6,597	8,797	10,996	21,992	27,490	54,979	82,469	109,958	164,937	219,916	329,874	439,832	549,790	659,748
	2 1/2 *	108.191	5,410	6,491	8,655	10,819	21,638	27,048	54,096	81,143	108,191	162,287	216,382	324,573	432,764	540,955	649,146
	3 *	106.031	5,302	6,362	8,482	10,603	21,206	26,508	53,016	79,523	106,031	159,047	212,062	318,093	424,124	530,155	636,186
	3 1/2 *	103.479	5,174	6,209	8,278	10,348	20,696	25,870	51,740	77,609	103,479	155,219	206,958	310,437	413,916	517,395	620,874
	4 *	100.534	5,027	6,032	8,043	10,053	20,107	25,134	50,267	75,401	100,534	150,801	201,068	301,602	402,136	502,670	603,204
	4 1/4 *	97.196	4,860	5,832	7,776	9,720	19,439	24,299	48,598	72,897	97,196	145,794	194,392	291,588	388,784	485,980	583,176
	5 *	93.465	4,673	5,608	7,477	9,347	18,693	23,366	46,733	70,099	93,465	140,198	186,930	280,395	373,860	467,325	560,790
	5 1/2	89.342	4,467	5,361	7,147	8,934	17,868	22,336	44,671	67,007	89,342	134,013	178,684	268,026	357,368	446,710	536,052
	7	74.615	3,731	4,477	5,969	7,462	14,923	18,654	37,308	55,961	74,615	111,923	149,230	223,845	298,460	373,075	447,690
	8	62.835	3,142	3,770	5,027	6,284	12,567	15,709	31,418	47,126	62,835	94,253	125,670	188,505	251,340	314,175	377,010
14	2 1/2 *	149.031	7,452	8,942	11,922	14,903	29,806	37,258	74,516	111,773	149,031	223,547	298,062	447,093	596,124	745,155	894,186
	3 *	146.871	7,344	8,812	11,750	14,687	29,374	36,718	73,436	110,153	146,871	220,307	293,742	440,613	587,484	734,355	881,226
	3 1/2 *	144.319	7,216	8,659	11,546	14,432	28,864	36,080	72,160	108,239	144,319	216,479	288,638	432,957	577,276	721,595	865,914
	4 *	141.374	7,069	8,482	11,310	14,137	28,275	35,344	70,687	106,031	141,374	212,061	282,748	424,122	565,496	706,870	848,244
	4 1/4 *	138.036	6,902	8,282	11,043	13,804	27,607	34,509	69,018	103,527	138,036	207,054	276,072	414,108	552,144	690,180	828,216
	5 *	134.305	6,715	8,058	10,744	13,431	26,861	33,576	67,153	100,729	134,305	201,458	268,610	402,915	537,220	671,525	805,830
	5 1/2 *	130.182	6,509	7,811	10,415	13,018	26,036	32,546	65,091	97,637	130,182	195,273	260,364	390,546	520,728	650,910	781,092
	7	115.455	5,773	6,927	9,236	11,546	23,091	28,864	57,728	86,591	115,455	173,183	230,910	346,365	461,820	577,275	692,730
	8	103.675	5,184	6,221	8,294	10,368	20,735	25,919	51,838	77,756	103,675	155,513	207,350	311,025	414,700	518,375	622,050
	9	90.323	4,516	5,419	7,226	9,032	18,065	22,581	45,162	67,742	90,323	135,485	180,646	270,969	361,292	451,615	541,938
	10	75.400	3,770	4,524	6,032	7,540	15,080	18,850	37,700	56,550	75,400	113,100	150,800	226,200	301,600	377,000	452,400
16	2 1/2 *	196.151	9,808	11,769	15,692	19,615	39,230	49,038	98,076	147,113	196,151	294,227	392,302	588,453	784,604	980,755	1,176,906
	3 *	193.991	9,700	11,639	15,519	19,399	38,798	48,498	96,996	145,493	193,991	290,987	387,982	581,973	775,964	969,955	1,163,946
	3 1/2 *	191.439	9,572	11,486	15,315	19,144	38,288	47,860	95,720	143,579	191,439	287,159	382,878	574,317	765,756	957,195	1,148,634
	4 *	188.494	9,425	11,310	15,080	18,849	37,699	47,124	94,247	141,371	188,494	282,741	376,988	565,482	753,976	942,470	1,130,964
	4 1/4 *	185.156	9,258	11,109	14,812	18,516	37,031	46,289	92,578	138,867	185,156	277,734	370,312	555,468	740,624	925,780	1,110,936
	5 *	181.425	9,071	10,886	14,514	18,143	36,285	45,356	90,713	136,069	181,425	272,138	362,850	544,275	725,700	907,125	1,088,550
	5 1/2 *	177.302	8,865	10,638	14,184	17,730	35,460	44,326	88,651	132,977	177,302	265,953	354,604	531,906	709,208	886,510	1,063,812
	7 *	162.575	8,129	9,755	13,006	16,258	32,515	40,644	81,288	121,931	162,575	243,863	325,150	487,725	650,300	812,875	975,450
	8	150.795	7,540	9,048	12,064	15,080	30,159	37,699	75,398	113,096	150,795	226,193	301,590	452,385	603,180	753,975	904,770
	9	137.443	6,872	8,247	10,995	13,744	27,489	34,361	68,722	103,082	137,443	206,165	274,886	412,329	549,772	687,215	824,658
	10	122.520	6,126	7,351	9,802	12,252	24,504	30,630	61,260	91,890	122,520	183,780	245,040	367,560	490,080	612,600	735,120
18	2 1/2 *	249.561	12,478	14,974	19,965	24,956	49,912	62,390	124,781	187,171	249,561	374,342	499,122	748,683	998,244	1,247,805	1,497,366
	3 *	247.401	12,370	14,844	19,792	24,740	49,480	61,850	123,701	185,551	247,401	371,102	494,802	742,203	989,604	1,237,005	1,484,406
	3 1/2 *	244.849	12,242	14,691	19,588	24,485	48,970	61,212	122,425	183,637	244,849	367,274	489,698	734,547	979,396	1,224,245	1,469,094
	4 *	241.904	12,095	14,514	19,352	24,190	48,381	60,476	120,952	181,428	241,904	362,856	483,808	725,712	967,616	1,209,520	1,451,424
	4 1/4 *	238.566	11,928	14,314	19,085	23,857	47,713	59,642	119,283	178,925	238,566	357,849	477,132	715,698	954,264	1,192,830	1,431,396
	5 *	234.835	11,742	14,090	18,787	23,484	46,967	58,709	117,418	176,126	234,835	352,253	469,670	704,505	939,340	1,174,175	1,409,010
	5 1/2 *	230.712	11,536	13,843	18,457	23,071	46,142	57,678	115,356	173,034	230,712	346,068	461,424	692,136	922,848	1,153,560	1,384,272
	7 *	215.985	10,799	12,959	17,279	21,599	43,197	53,996	107,993	161,989	215,985	323,978	431,970	647,955	863,940	1,079,925	1,295,910
	8 *	204.205	10,210	12,252	16,336	20,421	40,841	51,051	102,103	153,154	204,205	306,308	408,410	612,615	816,820	1,021,025	1,225,230
	9	190.853	9,543	11,451	15,268	19,085	38,171	47,713	95,427	143,140	190,853	286,280	381,706	572,559	763,412	954,265	1,145,118
	10	175.930	8,797	10,556	14,074	17,593	35,186	43,983	87,965	131,948	175,930	263,895	351,860	527,790	703,720	879,650	1,055,580
20	3 *	307.091	15,355	18,425	24,567	30,709	61,418	76,773	153,546	230,318	307,091	460,637	614,182	921,273	1,228,364	1,535,455	1,842,546
	3 1/2 *	304.539	15,227	18,272	24,363	30,454	60,908	76,135	152,270	228,404	304,539	456,809	609,078	913,617	1,218,156	1,522,695	1,827,234
	4 *	301.594	15,080	18,096	24,128	30,159	60,319	75,399	150,797	226,196	301,594	452,391	603,188	904,782	1,206,376	1,507,970	1,809,564
	4 1/4 *	298.256	14,913	17,895	23,860	29,826	59,651	74,564	149,128	223,692	298,256	447,384	596,512	894,768	1,193,024	1,491,280	1,789,536
	5 *	294.525	14,726	17,672	23,562	29,453	58,905	73,631	147,263	220,894	294,525	441,788	589,050	883,575	1,178,100	1,472,625	1,767,150
	5 1/2 *	290.402	14,520	17,424	23,232	29,040	58,080	72,601	145,201	217,802	290,402	435,603	580,804	871,206	1,161,608	1,452,010	1,742,412
	7 *	275.675	13,784	16,541	22,054	27,568	55,135	68,919	137,838	206,756	275,675	413,513	551,350	827,025	1,102,700	1,378,375	1,654,050
	8 *	263.895	13,195	15,834	21,112	26,390	52,779	65,974	131,948	197,921	263,895	395,843	527,790	791,685	1,055,580	1,319,475	1,583,370
	9 *	250.543	12,527	15,033	20,043	25,054	50,109	62,636	125,272	187,907	250,543	375,815	501,086	751,629	1,002,172	1,252,715	1,503,258
	10	235.620	11,781	14,137	18,850	23,562	47,124	58,905	117,810	176,715	235,620	353,430	471,240	706,860	942,480	1,178,100	1,413,720

*These rod diameters in these bore sizes are only available in A and J series cylinders.

Choosing the Cylinder Mounting

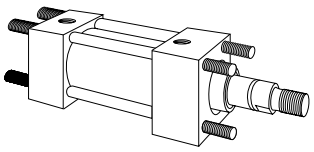
Miller pneumatic and hydraulic cylinders are offered in 23 standard mounting styles to suit a variety of applications. Many mountings (all odd numbered models, e.g. 51, 53, 61, 65, etc.) are also available in a double rod end configuration. In addition to cataloged mountings, Miller can produce custom mountings to fit special requirements. Request a copy of our Custom Cylinder Specification form (file number 5544), complete it, and return it to Miller for prompt consideration. A copy of this form is also available on page 55 of this guide.

Cylinder mountings can be generally grouped into three categories:

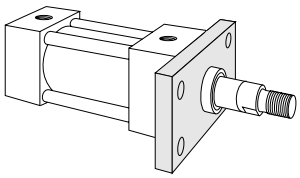
1. Centerline mountings that are fixed and absorb force on the centerline of the cylinder.
2. Foot mountings that are fixed and absorb force eccentric to the cylinder centerline.
3. Pivot mountings, that allow the cylinder body to move while the piston rod is in motion, and absorb force on the centerline of the cylinder.

Miller cylinders are designed to be linear actuators and should not be used to guide a moving load. An external guide that ensures the load remains aligned with the cylinder must be in place.

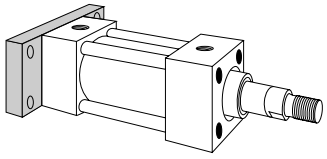
Centerline Mountings



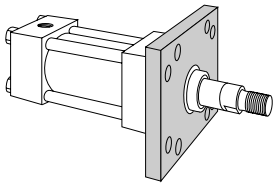
Models 51(shown),52 , 53



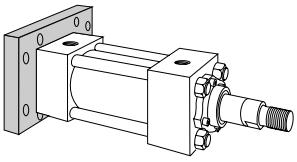
Model 61



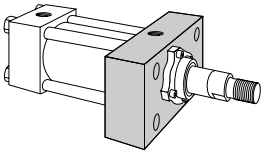
Model 62



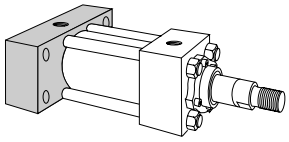
Model 65



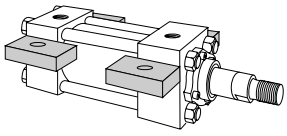
Model 66



Model 67



Model 68



Model 73

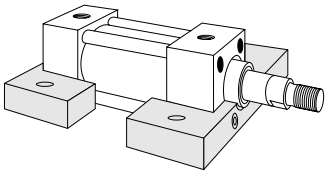
Centerline mounts are the preferred mounting method. These mountings put the mounting bolts only in simple tension or shear (model 73). See section 16 - Installation Advice, for recommended fastener torque values. Centerline mounts are rigid and thus require precise alignment with the load. A properly aligned centerline mount cylinder will have minimal piston and rod bearing loads, thus prolonging cylinder life.

- Mountings on the head or piston rod end of the cylinder are recommended for pull stroke applications. These mountings are models 53, 61, 65, & 67.

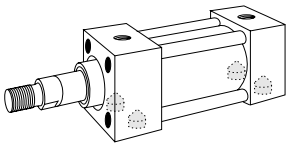
- Mountings on the cap or opposite the piston rod end of the cylinder are recommended for push stroke applications. These mountings are models 52, 62, 66, 68.

- Centerline lug mount, model 73, is recommended for both push and pull stroke application. Mounting lugs should be pinned as described in the section on foot mountings.

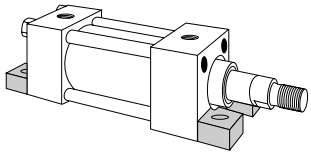
Foot Mountings



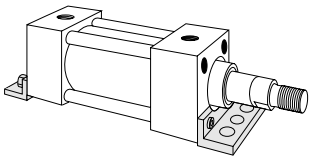
Model 72



Model 74



Model 77



Model 71

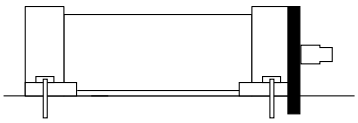
Foot mounting secures the cylinder along its side. Since the mounting surface plane is eccentric to the line of force, mounting bolts are subjected to a significant amount of shear stress. The cylinder should be pinned or keyed to absorb the stress of shear loads and allow the mounting bolts to remain in simple tension.

Cylinders with integral key mounts may be used where keyways can be cut in a machine member. This type of mounting accommodates shear loads, provides accurate alignment of the cylinder, and simplifies installation and servicing.

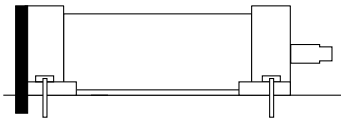
Only one end of a cylinder should be keyed to the machine. If both ends are keyed, there will be unequal distribution of internal stress and deformation. This is especially true for long stroke cylinders, where performance and life may be dramatically reduced.

Locating pins may be used instead of shear keys on side lug models 72 & 73. As with keys, cylinders should be pinned at either end (but not both ends). Contrary to common die design practices, cylinders should never be pinned across corners. To do so can result in severe warping under operating pressures and temperatures.

Keying a cylinder

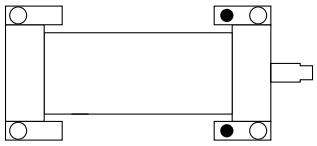


Key location for pull loads

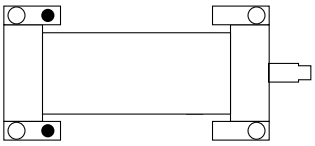


Key location for push loads

Pinning a cylinder



Pin location for pull loads



Pin location for push loads

'K' retainer key extension plates are an available option on foot mounted cylinders. The key thickness is dimension "F" from the respective cylinder catalog. The thickness tolerance is -0.0140/-0.0145; the extension is F/2.

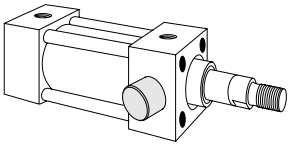
Locating Mounting Holes in Machinery For Foot Mounted Cylinders

Spacing of mounting holes from head to cap is stroke dependent. Miller cylinder stroke tolerance is ±.03, therefore hole spacing on the mating part should compensate for this tolerance.

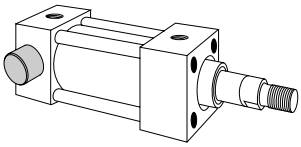
- Holes for mounting the cylinder on the end that is keyed or pinned should be 1/16 inch diameter larger than the bolt size specified in the catalog for the model and bore being applied. These holes should be drilled round.
- The center of the holes opposite the keyed or pinned end should be located to the catalog "Stroke Plus" (SS dimension models 72 & 73, SN dimension model 74, SE dimension model 77) dimension for the model being applied.

To compensate for the stroke tolerance and the movement of head or cap due to cylinder internal pressure, the holes should be elongated a total of .125 inches (.062 inches in each direction toward the cylinder head and cap).

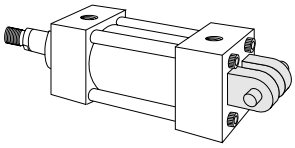
Pivot Mountings



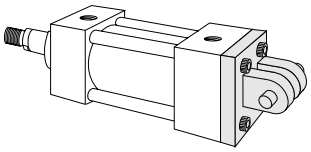
Model 81



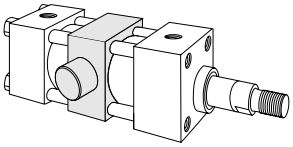
Model 82



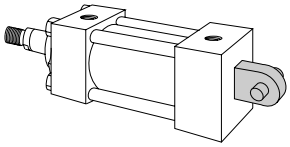
Model 84



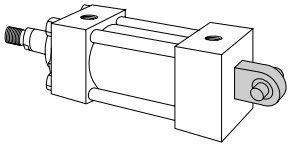
Model 86



Model 89



Model 90



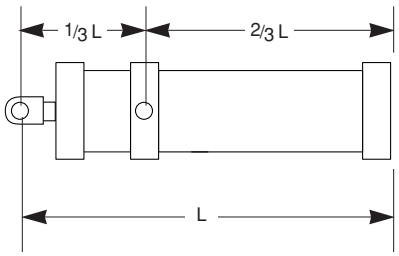
Spherical Bearing Mount
Model 94

Pivot mounting is used when the application requires the load to travel in a curved path. Clevis and trunnion mounts are the two methods used to allow this motion.

Pivot mounts will also absorb some misalignment of the load. Models 81, 82, 84, 86, 89, & 90 will only compensate in one plane. Spherical bearing mount, model 94 will compensate in all axes (if a spherical bearing attachment is also made at the piston rod end).

Trunnion pins are designed for shear loads only. Therefore, trunnion bearings that have a close fit and support the entire pin length should be used. Alignment of the bearings must also be held very tightly. The bearing support structure must be rigid so bending moments are not imposed on the pins.

Intermediate trunnion mounting model 89 requires that the customer specify the XI dimension (pin centerline to piston rod shoulder). This allows positioning the trunnion anywhere along the tube length. In horizontal applications positioning the trunnion at the cylinder center of gravity with the piston rod extended can minimize the effect of cylinder and oil weight on internal bearings. This distance can be approximated at 1/3 of total cylinder length back from the piston rod pivot point.



Piston Rod Diameter Sizing

It is important that the piston rod column strength be appropriate for your application. High force or long push stroke cylinders may require an oversize piston rod.

However, Miller Fluid Power cautions against depending upon the higher rigidity of oversize rods to absorb or reduce side loading. Actually, the greater flexibility of smaller diameter rods absorbs some side loading and transmits less side loading back to the bushing. Oversize rods, when not needed, merely add to the cylinder price and require longer delivery.

Standard rod diameters are recommended for all PULL STROKE applications. To determine the correct rod diameter for a PUSH STROKE application, follow these simple steps.

1. Determine the value of 'L' from the Group A through C illustration in Figure 1 that corresponds to your cylinder application. Or, if your cylinder requires stop tubing, use the 'Adjusted L Dimension' calculated in step 4 of the stop tube sizing procedure.

2. In the first column of the Piston Rod Sizing Table (Figure 2), locate the force value that is the same as (or greater than) that which the cylinder is required to deliver.

3. Move across the table to the right in the same row and locate your 'L' or 'Adjusted L Dimension'. If the exact value is not shown, continue to the next higher number.

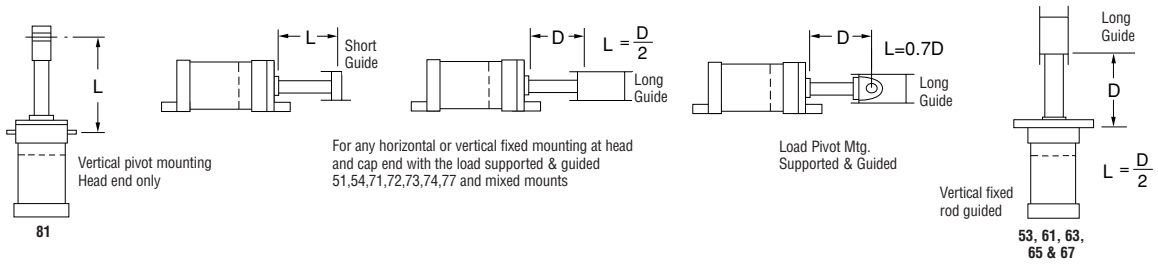
4. Go to the top of the column and you will find the correct rod diameter for your cylinder application.

Figure 1

Group A

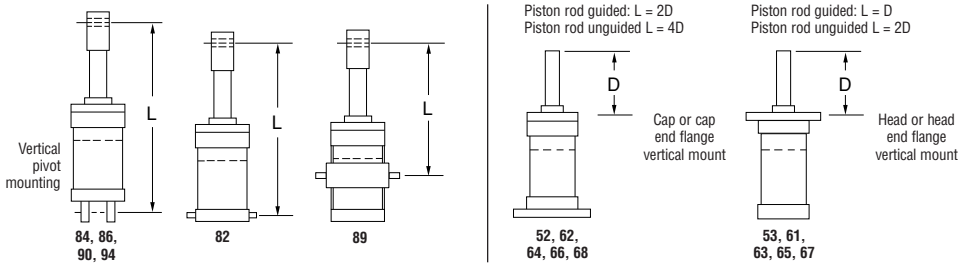
With piston rod extended. To be checked for rod diameter only. Stop tube required only for pivoting Model 81 See page 20.

Note: 'L' or 'D' are calculated from mounting point with rod extended.



Group B

To avoid rod buckling or cylinder jackknifing, check for stop tube and rod diameter requirements with piston rod extended. Use cylinder dimensional charts. No stop tube required if cylinder operates on pull stroke only. (Except cylinders pivoting up to 45° from vertical). See page 20



Group C

To be checked for stop tube length (see page 20 & 21) and piston rod diameter to eliminate buckling or jackknifing with piston rod extended.

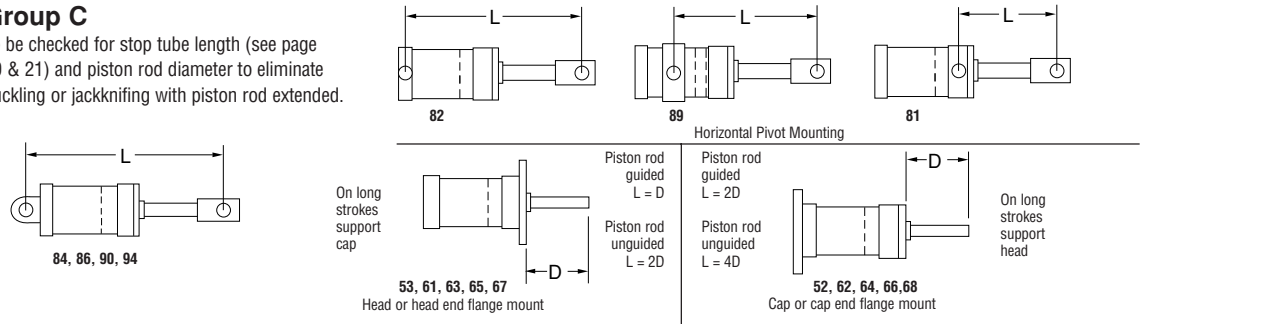


Figure 2

Cylinder Force in lbs.	PISTON ROD DIAMETER in inches															
	5/8	1	1 3/8	1 3/4	2	2 1/2	3	3 1/2	4	4 1/2	5	5 1/2	7	8	9	10
250	43	94	146													
400	37	83	134	186												
700	30	68	118	168	202	275										
1,000	27	60	105	155	190	257	330									
1,400	24	53	92	142	174	244	308	385								
1,800	23	48	82	127	160	230	296	366	440							
2,400	19	45	75	114	145	213	281	347	415	488						
3,200	16	41	67	103	130	194	261	329	400	461						
4,000	13	38	63	94	119	175	240	310	378	446						
5,000	9	34	60	87	110	163	225	289	360	426	494					
6,000	5	30	56	82	102	152	208	274	342	410	476					
8,000	5	26	50	76	93	137	188	245	310	375	447					
10,000	4	21	45	70	89	125	172	222	279	349	412	482				
12,000	3	17	41	65	84	118	155	210	269	326	388	454				
16,000		9	34	57	75	110	142	188	235	292	350	420				
20,000		8	28	52	68	103	136	172	218	270	326	385				
30,000		6	12	39	55	87	120	156	189	230	285	330				
40,000			11	22	43	74	108	142	177	210	248	294				
50,000			9	15	30	66	96	130	165	200	234	269	408			
60,000				14	18	57	88	119	154	190	225	256	384			
80,000				12	16	36	71	104	137	170	204	240	336			
100,000					14	22	57	90	120	154	189	222	324	400		
120,000					12	21	45	77	108	140	175	207	313	377		
140,000						19	27	64	98	128	160	194	301	365		
160,000						17	26	47	86	118	148	182	279	350	421	
200,000						14	23	31	67	98	131	161	260	330	402	
250,000							19	28	36	72	109	141	236	301	375	
300,000								25	34	42	86	120	212	281	351	420
350,000								22	31	39	52	100	195	261	328	396
400,000								19		37	45	77	182	241	309	374
500,000										32	41	49	152	212	274	341
600,000											37	45	114	183	247	310
700,000											32	41	70	162	221	280
800,000												37	63	118	197	260
900,000													60	82	168	237
1,000,000													57	73	115	212
1,200,000													51	68	84	170
1,400,000													45	62	79	105
1,600,000														57	74	91
1,800,000															70	86
2,000,000															65	82

Values of (L) for slenderness ratios (slenderness ratio = length ÷ radius of gyration = 4 x length ÷ piston rod diameter) greater than 50 have a safety factor of 5 to 1. Values of (L) for slenderness ratios less than 50 are based on compressive strength only (S = thrust ÷ rod area) and have safety factors between 2.4-1 and 5-1 which are directly proportional to (L). (i.e. the greater the value of (L) the greater the safety factor).

Non-sag piston rods for long stroke, horizontally mounted cylinders

Miller patented non-sag piston rods reduce bushing wear on long stroke, horizontally mounted cylinders. Keyed in your machinery in their prestressed position, to prevent rotation non-sag piston rods remain straight without the deflections or sag of ordinary rods. Using non-sag piston rods on long stroke cylinders prevents overloading of rod bushing and piston and the resulting costly damage.

Determining If Your Cylinder Requires A Non-Sag Rod

Miller cylinders have a commercial straightness of 0.002 inches per foot of length. The gravity-induced rod sag for horizontally mounted cylinders is given in the Rod Deflection Table. To determine if this sag is excessive, follow these simple directions.

1. After having checked the rod for column strength on the previous page, find your rod diameter in the first column of the table.

2. Read across the table to the column headed by the length of the rod between supports when rod is fully extended, and find the sag in inches which can be expected with a standard rod.

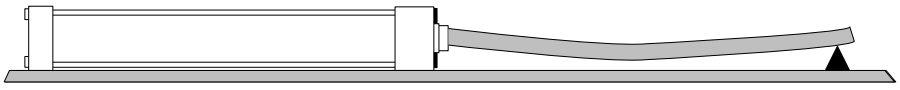
3. If this figure lies within the shaded area of the table, you should specify a non-sag rod.

Rod Deflection Table

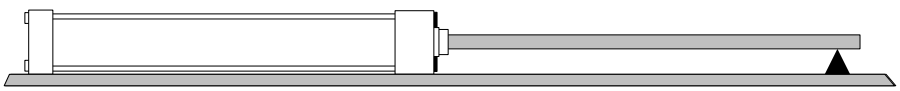
This table shows the deflections in inches of ordinary piston rods at center of span. Length of piston rod between supports is in feet. Rod diameter and sag are in inches.

Dia. Piston Rod	Weight In Lbs. PER FT.	LENGTH OF PISTON RODS (IN FEET) BETWEEN SUPPORTS WITH RODS EITHER EXTENDED OR RETRACTED																			
		5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
											⅝" rod not available in non-sag										
⅝	1.043	.065	.134	.255	.425	.675	1.020	1.500													
1	2.670	.030	.053	.099	.166	.265	.385	.580	.850	1.160	1.570										
1⅜	5.049	.013	.028	.053	.088	.136	.212	.310	.450	.617	.830	1.100	1.418								
1¾	8.178	.008	.017	.033	.054	.086	.130	.192	.278	.380	.515	.680	.870	1.115	1.400						
2	10.680	.006	.013	.025	.042	.066	.101	.148	.212	.290	.390	.525	.670	.850	1.072	1.330					
2½	16.690	.004	.0085	.016	.027	.042	.064	.094	.136	.186	.240	.335	.430	.545	.685	.856	1.040	1.286	1.520		
3	24.030		.006	.011	.018	.029	.045	.065	.094	.129	.175	.231	.296	.380	.475	.590	.722	.884	1.060	1.270	1.500
3½	32.710		.0043	.008	.014	.022	.033	.048	.069	.095	.128	.170	.218	.278	.350	.435	.530	.650	.780	.930	1.100
4	42.730			.006	.010	.016	.025	.037	.053	.073	.098	.130	.166	.213	.267	.333	.405	.500	.595	.715	.844
4½	54.070			.005	.0082	.013	.020	.029	.043	.057	.078	.103	.132	.168	.212	.262	.320	.395	.470	.565	.670
5	66.760				.0066	.0106	.016	.023	.034	.046	.063	.083	.107	.136	.171	.213	.260	.320	.380	.460	.545
5½	80.780				.0055	.0087	.013	.019	.028	.038	.052	.068	.088	.122	.142	.176	.215	.263	.315	.390	.450
7	130.8					.054	.0083	.0121	.172	.0237	.0319	.0421	.0545	.0695	.0873	.1084	.1331	.1618	.1949	.2329	.2761
8	170.9						.0063	.0093	.0132	.0182	.0244	.0322	.0417	.0532	.0669	.0830	.1019	.1239	.1493	.1783	.2114
9	216.3						.0050	.0073	.0104	.0143	.0193	.0254	.0330	.0420	.0528	.656	.0805	.0979	.1179	.1409	.1670
10	267.0							.0059	.0084	.0116	.0156	.0206	.0267	.0340	.0428	.0531	.0652	.0793	.0955	.1141	.1353

Standard Cylinder



Non-Sag Rod Miller Cylinder



Pressure Rating Tables

Pneumatic

Pneumatic cylinders have a single maximum operating pressure by product series. This pressure does not vary by bore, rod diameter, or mounting style. Maximum **pneumatic** operating pressures are as follows:

Series	Maximum Pressure (psi)
A	250
AL	200
C	250
LA	150

Hydraulic

Hydraulic cylinders are rated for Moderate (non-shock) and Severe (shock loaded) service. A cylinder in a non-shock application must never be exposed to a pressure exceeding the Moderate rating. In other words, there are no pressure spikes in the system. The most common non-shock application is air/oil booster system.

A cylinder in a shock loaded application is exposed to pressure spikes (in many cases spikes can only be detected with a pressure transducer). Cylinders driven by a hydraulic power unit will be exposed to shock pressures unless the circuit has provisions to eliminate them. Therefore, the preponderance of hydraulic cylinder applications are Severe and cylinders should be selected on the basis of the Severe rating.

Due to the much higher forces achieved in hydraulic cylinders, some mountings have reduced ratings. For example, flange mountings (models 61, 62, 65, 66) have a reduced rating because the flange may deflect at higher pressures. Base mount cylinders (models 72,74,77) have a reduced rating because when the cylinder is bolted down, the top two tie rods are resisting the majority of internal pressure. Trunnion mounted cylinders (models 81, 82, 89) have reduced ratings due to pin shear and bending load resistance. Spherical mounting model 94 has a reduced rating based on the dynamic load rating of the spherical bearing.

Following are Moderate pressure rating tables for J, H, and HV series hydraulic cylinders. Severe ratings are 60% of the Moderate rating (multiply the Moderate rating by .6). The 61 B indicates bolted bushing. The 61R indicates retainer or flange held bushing.

J Series Cylinders • **Moderate Pressure Ratings In PSI**

Bore Dia.	Rod Dia.	Mounting								
		61B	61R	62	72	74 & 77	81 & 82	83 & 89	94	All Other
1 1/2	5/8	N/A	2,500	2,500	2,500	2,100	2,500	2,500	1,520	2,500
	1	N/A	1,470	2,500	2,500	2,100	2,500	2,500	1,520	2,500
2	5/8	770	1,930	1,930	1,760	2,050	2,500	2,500	850	2,500
	1	N/A	1,430	1,930	1,760	2,050	2,500	2,500	850	2,500
	1 3/8	N/A	770	1,930	1,760	2,050	2,500	2,500	850	2,500
2 1/2	5/8	950	1,500	1,500	1,090	1,150	1,500	1,500	550	1,500
	1	470	1,340	1,500	1,090	1,150	1,500	1,500	550	1,500
	1 3/8	N/A	950	1,500	1,090	1,150	1,500	1,500	550	1,500
	1 3/4	N/A	660	1,500	1,090	1,150	1,500	1,500	550	1,500
3 1/4	1	1,670	2,500	2,500	1,380	1,750	1,770	1,550	730	2,500
	1 3/8	1,100	2,380	2,500	1,380	1,750	1,770	1,550	730	2,500
	1 3/4	N/A	1,950	2,500	1,380	1,750	1,770	1,550	730	2,500
	2	N/A	1,670	2,500	1,380	1,750	1,770	1,550	730	2,500
4	1	1,500	1,500	1,500	920	900	1,170	1,030	480	1,500
	1 3/8	1,340	1,500	1,500	920	900	1,170	1,030	480	1,500
	1 3/4	990	1,500	1,500	920	900	1,170	1,030	480	1,500
	2	910	1,500	1,500	920	900	1,170	1,030	480	1,500
	2 1/2	N/A	1,340	1,500	920	900	1,170	1,030	480	1,500
5	1	1,200	1,200	1,200	880	800	750	660	310	1,200
	1 3/8	1,110	1,200	1,200	880	800	750	660	310	1,200
	1 3/4	930	1,200	1,200	880	800	750	660	310	1,200
	2	880	1,200	1,200	880	800	750	660	310	1,200
	2 1/2	680	1,110	1,200	880	800	750	660	310	1,200
	3	490	880	1,200	880	800	750	660	310	1,200
	3 1/2	N/A	690	1,200	880	800	750	660	310	1,200
6	1 3/8	1,200	1,200	1,200	770	800	1,030	800	380	1,200
	1 3/4	1,200	1,200	1,200	770	800	1,030	800	380	1,200
	2	1,200	1,200	1,200	770	800	1,030	800	380	1,200
	2 1/2	1,070	1,200	1,200	770	800	1,030	800	380	1,200
	3	900	1,200	1,200	770	800	1,030	800	380	1,200
	3 1/2	730	1,090	1,200	770	800	1,030	800	380	1,200
	4	N/A	920	1,200	770	800	1,030	800	380	1,200
7	1 3/8	N/A	N/A	N/A	620	500	750	660	N/A	800
	1 3/4	N/A	N/A	N/A	620	500	750	660	N/A	800
	2	N/A	N/A	N/A	620	500	750	660	N/A	800
	2 1/2	N/A	N/A	N/A	620	500	750	660	N/A	800
	3	N/A	N/A	N/A	620	500	750	660	N/A	800
	3 1/2	N/A	N/A	N/A	620	500	750	660	N/A	800
	4	N/A	N/A	N/A	620	500	750	660	N/A	800
	4 1/2	N/A	N/A	N/A	620	500	750	660	N/A	800
	5	N/A	N/A	N/A	620	500	750	660	N/A	800

J Series Cylinders • **Moderate Pressure Ratings In PSI**

Bore Dia.	Rod Dia.	Mounting								
		61B	61R	62	72	74 & 77	81 & 82	83 & 89	94	All Other
8	1 3/8	N/A	N/A	N/A	520	500	580	500	380	800
	1 3/4	N/A	N/A	N/A	520	500	580	500	380	800
	2	N/A	N/A	N/A	520	500	580	500	380	800
	2 1/2	N/A	N/A	N/A	520	500	580	500	380	800
	3	N/A	N/A	N/A	520	500	580	500	380	800
	3 1/2	N/A	N/A	N/A	520	500	580	500	380	800
	4	N/A	N/A	N/A	520	500	580	500	380	800
	4 1/2	N/A	N/A	N/A	520	500	580	500	380	800
	5	N/A	N/A	N/A	520	500	580	500	380	800
	5 1/2	N/A	N/A	N/A	520	500	580	500	380	800
10	1 3/4	N/A	N/A	N/A	590	500	600	440	N/A	800
	2	N/A	N/A	N/A	590	500	600	440	N/A	800
	2 1/2	N/A	N/A	N/A	590	500	600	440	N/A	800
	3	N/A	N/A	N/A	590	500	600	440	N/A	800
	3 1/2	N/A	N/A	N/A	590	500	600	440	N/A	800
	4	N/A	N/A	N/A	590	500	600	440	N/A	800
	4 1/2	N/A	N/A	N/A	590	500	600	440	N/A	800
	5	N/A	N/A	N/A	590	500	600	440	N/A	800
	5 1/2	N/A	N/A	N/A	590	500	600	440	N/A	800
12	2	N/A	N/A	N/A	530	470	420	310	N/A	800
	2 1/2	N/A	N/A	N/A	530	470	420	310	N/A	800
	3	N/A	N/A	N/A	530	470	420	310	N/A	800
	3 1/2	N/A	N/A	N/A	530	470	420	310	N/A	800
	4	N/A	N/A	N/A	530	470	420	310	N/A	800
	4 1/2	N/A	N/A	N/A	530	470	420	310	N/A	800
	5	N/A	N/A	N/A	530	470	420	310	N/A	800
	5 1/2	N/A	N/A	N/A	530	470	420	310	N/A	800
14	2 1/2	N/A	N/A	N/A	480	370	370	330	N/A	800
	3	N/A	N/A	N/A	480	370	370	330	N/A	800
	3 1/2	N/A	N/A	N/A	480	370	370	330	N/A	800
	4	N/A	N/A	N/A	480	370	370	330	N/A	800
	4 1/2	N/A	N/A	N/A	480	370	370	330	N/A	800
	5	N/A	N/A	N/A	480	370	370	330	N/A	800
	5 1/2	N/A	N/A	N/A	480	370	370	330	N/A	800
16	2 1/2	N/A	N/A	N/A	500	190	180	N/A	N/A	500
	3	N/A	N/A	N/A	500	190	180	N/A	N/A	500
	3 1/2	N/A	N/A	N/A	500	190	180	N/A	N/A	500
	4	N/A	N/A	N/A	500	190	180	N/A	N/A	500
	4 1/2	N/A	N/A	N/A	500	190	180	N/A	N/A	500
	5	N/A	N/A	N/A	500	190	180	N/A	N/A	500
	5 1/2	N/A	N/A	N/A	500	190	180	N/A	N/A	500
18	3	N/A	N/A	N/A	430	120	220	N/A	N/A	500
	3 1/2	N/A	N/A	N/A	430	120	220	N/A	N/A	500
	4	N/A	N/A	N/A	430	120	220	N/A	N/A	500
	4 1/2	N/A	N/A	N/A	430	120	220	N/A	N/A	500
	5	N/A	N/A	N/A	430	120	220	N/A	N/A	500
	5 1/2	N/A	N/A	N/A	430	120	220	N/A	N/A	500
20	3	N/A	N/A	N/A	350	80	180	N/A	N/A	500
	3 1/2	N/A	N/A	N/A	350	80	180	N/A	N/A	500
	4	N/A	N/A	N/A	350	80	180	N/A	N/A	500
	4 1/2	N/A	N/A	N/A	350	80	180	N/A	N/A	500
	5	N/A	N/A	N/A	350	80	180	N/A	N/A	500
	5 1/2	N/A	N/A	N/A	350	80	180	N/A	N/A	500

H Series Cylinders • Moderate Pressure Ratings In PSI

Bore Dia.	Rod Dia.	Mounting												
		61B	61R	62	65B	65R	66	72	73	74 & 77	81 & 82	83 & 89	94	All Other
1 1/2	5/8	N/A	2,480	2,480	N/A	5,000	5,000	5,000	5,000	4,700	5,000	5,000	1,520	5,000
	1	N/A	1,740	2,480	N/A	5,000	5,000	5,000	5,000	4,700	5,000	5,000	1,520	5,000
2	1	N/A	3,610	3,610	N/A	5,000	5,000	5,000	5,000	4,600	5,000	5,000	1,930	5,000
	1 3/8	N/A	2,220	3,610	N/A	5,000	5,000	5,000	5,000	4,600	5,000	5,000	1,930	5,000
2 1/2	1	1,560	3,560	3,560	5,000	5,000	5,000	4,400	5,000	4,300	5,000	5,000	1,230	5,000
	1 3/8	N/A	2,670	3,560	N/A	5,000	5,000	4,400	5,000	4,300	5,000	5,000	1,230	5,000
	1 3/4	N/A	2,000	3,560	N/A	5,000	5,000	4,400	5,000	4,300	5,000	5,000	1,230	5,000
3 1/4	1 3/8	1,720	3,080	3,080	5,000	5,000	5,000	3,800	5,000	4,300	5,000	4,220	1,300	5,000
	1 3/4	1,110	2,620	3,080	5,000	5,000	5,000	3,800	5,000	4,300	5,000	4,220	1,300	5,000
	2	N/A	2,320	3,080	N/A	5,000	5,000	3,800	5,000	4,300	5,000	4,220	1,300	5,000
4	1 3/4	1,850	3,240	3,240	4,000	4,000	4,000	2,520	5,000	4,000	3,760	2,780	1,600	5,000
	2	1,710	2,960	3,240	4,000	4,000	4,000	2,520	5,000	4,000	3,760	2,780	1,600	5,000
	2 1/2	1,080	2,400	3,240	4,000	4,000	4,000	2,520	5,000	4,000	3,760	2,780	1,600	5,000
5	2	1,700	2,330	2,330	4,000	4,000	4,000	2,400	5,000	4,000	2,410	1,780	1,680	5,000
	2 1/2	1,380	2,050	2,330	4,000	4,000	4,000	2,400	5,000	4,000	2,410	1,780	1,680	5,000
	3	1,100	1,700	2,330	3,780	3,780	4,000	2,400	5,000	4,000	2,410	1,780	1,680	5,000
	3 1/2	810	1,410	2,330	3,230	3,230	4,000	2,400	5,000	4,000	2,410	1,780	1,680	5,000
6	2 1/2	1,580	2,110	2,110	3,000	3,000	3,000	2,340	5,000	3,000	2,190	1,830	1,520	5,000
	3	1,350	1,830	2,110	3,000	3,000	3,000	2,340	5,000	3,000	2,190	1,830	1,520	5,000
	3 1/2	1,130	1,600	2,110	3,000	3,000	3,000	2,340	5,000	3,000	2,190	1,830	1,520	5,000
	4	820	1,380	2,110	3,000	3,000	3,000	2,340	5,000	3,000	2,190	1,830	1,520	5,000
7	3	1,240	N/A	1,240	3,000	N/A	3,000	2,470	5,000	3,000	2,100	2,100	N/A	5,000
	3 1/2	1,090	N/A	1,240	3,000	N/A	3,000	2,470	5,000	3,000	2,100	2,100	N/A	5,000
	4	750	N/A	1,240	2,580	N/A	3,000	2,470	5,000	3,000	2,100	2,100	N/A	5,000
	4 1/2	600	N/A	1,240	2,280	N/A	3,000	2,470	5,000	3,000	2,100	2,100	N/A	5,000
	5	450	N/A	1,240	1,980	N/A	3,000	2,470	5,000	3,000	2,100	2,100	N/A	5,000
8	3 1/2	1,030	N/A	1,030	2,890	N/A	2,890	2,370	5,000	3,000	2,770	1,380	N/A	5,000
	4	780	N/A	1,030	2,400	N/A	2,890	2,370	5,000	3,000	2,770	1,380	N/A	5,000
	4 1/2	680	N/A	1,030	2,180	N/A	2,890	2,370	5,000	3,000	2,770	1,380	N/A	5,000
	5	570	N/A	1,030	1,970	N/A	2,890	2,370	5,000	3,000	2,770	1,380	N/A	5,000
	5 1/2	460	N/A	1,030	1,750	N/A	2,890	2,370	5,000	3,000	2,770	1,380	N/A	5,000
10	4 1/2	N/A	N/A	N/A	N/A	N/A	N/A	2,060	2,210	N/A	1,500	900	N/A	5,000
	5	N/A	N/A	N/A	N/A	N/A	N/A	2,060	2,210	N/A	1,500	900	N/A	5,000
	5 1/2	N/A	N/A	N/A	N/A	N/A	N/A	2,060	2,210	N/A	1,500	900	N/A	5,000
	7	N/A	N/A	N/A	N/A	N/A	N/A	2,060	2,210	N/A	1,500	900	N/A	5,000
12	5 1/2	N/A	N/A	N/A	N/A	N/A	N/A	2,200	2,480	N/A	1,270	1,220	N/A	5,000
	7	N/A	N/A	N/A	N/A	N/A	N/A	2,200	2,480	N/A	1,270	1,220	N/A	5,000
	8	N/A	N/A	N/A	N/A	N/A	N/A	2,200	2,480	N/A	1,270	1,220	N/A	5,000
14	7	N/A	N/A	N/A	N/A	N/A	N/A	2,000	2,700	N/A	1,460	N/A	N/A	5,000
	8	N/A	N/A	N/A	N/A	N/A	N/A	2,000	2,700	N/A	1,460	N/A	N/A	5,000
	9	N/A	N/A	N/A	N/A	N/A	N/A	2,000	2,700	N/A	1,460	N/A	N/A	5,000
	10	N/A	N/A	N/A	N/A	N/A	N/A	2,000	2,700	N/A	1,460	N/A	N/A	5,000
16	8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	5,000
	9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	5,000
	10	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	5,000
18	9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	5,000
	10	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	5,000
20	10	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	5,000

HV Series Cylinders * Moderate Pressure Ratings In PSI

Bore Dia.	Rod Dia.	Mounting												
		61B	61R	62	65B	65R	66	72	73	74 & 77	81 & 82	83 & 89	94	All Other
1 1/2	5/8	N/A	2,480	2,480	N/A	5,000	5,000	5,000	5,000	4,700	5,000	5,000	1,520	5,000
	1	N/A	1,740	2,480	N/A	5,000	5,000	5,000	5,000	4,700	5,000	5,000	1,520	5,000
2	1	N/A	3,610	3,610	N/A	5,000	5,000	5,000	5,000	4,600	5,000	5,000	1,930	5,000
	1 3/8	N/A	2,220	3,610	N/A	5,000	5,000	5,000	5,000	4,600	5,000	5,000	1,930	5,000
2 1/2	1	1,560	3,560	3,560	5,000	5,000	5,000	4,400	5,000	4,300	5,000	5,000	1,230	5,000
	1 3/8	N/A	2,670	3,560	N/A	5,000	5,000	4,400	5,000	4,300	5,000	5,000	1,230	5,000
	1 3/4	N/A	2,000	3,560	N/A	5,000	5,000	4,400	5,000	4,300	5,000	5,000	1,230	5,000
3 1/4	1 3/8	1,720	3,080	3,080	5,000	5,000	5,000	3,800	5,000	4,300	5,000	4,220	1,300	5,000
	1 3/4	1,110	2,620	3,080	5,000	5,000	5,000	3,800	5,000	4,300	5,000	4,220	1,300	5,000
	2	N/A	2,320	3,080	N/A	5,000	5,000	3,800	5,000	4,300	5,000	4,220	1,300	5,000
4	1 3/4	1,850	3,240	3,240	4,000	4,000	4,000	2,520	5,000	4,000	3,760	2,780	1,600	5,000
	2	1,710	2,960	3,240	4,000	4,000	4,000	2,520	5,000	4,000	3,760	2,780	1,600	5,000
	2 1/2	1,080	2,400	3,240	4,000	4,000	4,000	2,520	5,000	4,000	3,760	2,780	1,600	5,000
5	2	1,700	2,330	2,330	4,000	4,000	4,000	2,400	5,000	4,000	2,410	1,780	1,680	5,000
	2 1/2	1,380	2,050	2,330	4,000	4,000	4,000	2,400	5,000	4,000	2,410	1,780	1,680	5,000
	3	1,100	1,700	2,330	3,780	3,780	4,000	2,400	5,000	4,000	2,410	1,780	1,680	5,000
	3 1/2	810	1,410	2,330	3,230	3,230	4,000	2,400	5,000	4,000	2,410	1,780	1,680	5,000
6	2 1/2	1,580	2,110	2,110	3,000	3,000	3,000	2,340	5,000	3,000	2,190	1,830	1,520	5,000
	3	1,350	1,830	2,110	3,000	3,000	3,000	2,340	5,000	3,000	2,190	1,830	1,520	5,000
	3 1/2	1,130	1,600	2,110	3,000	3,000	3,000	2,340	5,000	3,000	2,190	1,830	1,520	5,000
	4	820	1,380	2,110	3,000	3,000	3,000	2,340	5,000	3,000	2,190	1,830	1,520	5,000
7	3	1,240	N/A	1,240	3,000	N/A	3,000	2,470	5,000	3,000	2,100	2,100	N/A	5,000
	3 1/2	1,090	N/A	1,240	3,000	N/A	3,000	2,470	5,000	3,000	2,100	2,100	N/A	5,000
	4	750	N/A	1,240	2,580	N/A	3,000	2,470	5,000	3,000	2,100	2,100	N/A	5,000
	4 1/2	600	N/A	1,240	2,280	N/A	3,000	2,470	5,000	3,000	2,100	2,100	N/A	5,000
	5	450	N/A	1,240	1,980	N/A	3,000	2,470	5,000	3,000	2,100	2,100	N/A	5,000
8	3 1/2	1,030	N/A	1,030	2,890	N/A	2,890	2,370	5,000	3,000	2,770	1,380	N/A	5,000
	4	780	N/A	1,030	2,400	N/A	2,890	2,370	5,000	3,000	2,770	1,380	N/A	5,000
	4 1/2	680	N/A	1,030	2,180	N/A	2,890	2,370	5,000	3,000	2,770	1,380	N/A	5,000
	5	570	N/A	1,030	1,970	N/A	2,890	2,370	5,000	3,000	2,770	1,380	N/A	5,000
	5 1/2	460	N/A	1,030	1,750	N/A	2,890	2,370	5,000	3,000	2,770	1,380	N/A	5,000

* All HV cylinders with 5/8, 1, 1 3/8 inch rods and bolted bushing construction are limited to a maximum pressure of 3,000 psi moderate. Further limitations may apply by bore and mounting as indicated in the above table.

Piston & Rod Breakloose Pressures

The pressure at which a piston and rod begins to move, from the mid-stroke position of a horizontally mounted cylinder, is called the breakloose pressure. Factors that contribute to the breakloose pressure are:

- Bore diameter
- Seal material
- Seal type, e.g. STAR vs. Base-Lok
- Stroke length
- Piston rod diameter
- Double rod end cylinders

Following is a table of maximum allowable breakloose pressures by bore, cylinder series, and seal material/type. Below the table, note breakloose adders for other cylinder construction factors.

Note: Custom cylinder modifications, requested by the customer, may impact breakloose pressure.

Cylinder Breakloose Pressure (psi)
(For strokes less than 3 feet and standard piston seals)

Cylinder Bore	STAR Bushing (Polyurethane or viton) A, J, H Series with standard piston seals	Base-Lok Bushing (Buna-N) A Series with standard piston seals	HV Series Polyurethane or viton rod seal & piston seal	AL Series
1 1/2	20.0	7.0	75.0	7.0
2	15.0	4.5	65.0	7.0
2 1/2	12.0	4.0	45.0	7.0
3 1/4	10.0	3.0	30.0	7.0
4	8.0	2.5	30.0	7.0
5	6.0	2.0	30.0	7.0
6	5.0	2.0	30.0	7.0
7	4.5	2.0	30.0	N/A
8	4.0	2.0	30.0	7.0
10	3.5	2.0	N/A	N/A
12	3.0	2.0	N/A	N/A
14	3.0	2.0	N/A	N/A
16	3.0	2.0	N/A	N/A
18	3.0	2.0	N/A	N/A
20	3.0	2.0	N/A	N/A

Breakloose adders: adders are cumulative, and should be added in the sequence listed.
For cylinders with 3 to 6 foot strokes — add 50%.
For cylinders over 6 foot stroke — add 100%.
For cylinders with oversize rods — add 50%.
For cylinders with double rod ends — add 100%.

Cushions

Purpose and Application
Cushions are intended to absorb energy at the cylinder's stroke ends and can reduce or eliminate noise associated with the piston contacting head or cap. Cushions are effective during approximately the last 3/4" of stroke. They are built into the cylinder and do not increase the cylinder's overall length.

When piston maximum velocity exceeds 2 inches per second cushions are recommended. Cushions are available on the head, cap, or both ends of the cylinder, and they should be specified on the cylinder end(s) where the piston contacts the head and/or cap.

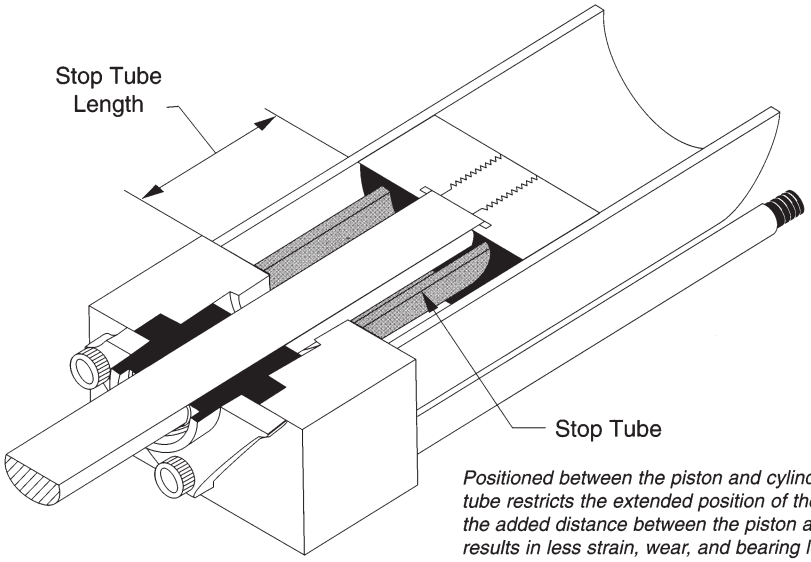
- Cushions are an available option on A, AL, J, H, and HV cylinders.
- Cushions should not be specified on the end of a cylinder where the piston bottoms on the load and not on the head or cap.
- Cushions should not be specified on cylinders with less than 2 inches of stroke.
- For piston velocities over 12 inches per second contact Miller Fluid Power Application Engineering. To determine cushion adequacy, supply the following application data: cylinder configuration, mounting orientation, load, velocity, pressure, etc. as requested on the Custom Cylinder Specification page in the back of this publication.

Self-Regulating Cushions
The standard cushion on J and H series cylinders is a self-regulating type. This cushion automatically compensates for varying pressures and loads and is not externally adjustable. It is a high-speed type cushion with built-in checking for fast out-of-cushion performance. Adjustable cushions are an available option on J and H series cylinders.

Adjustable Cushions
The standard cushion on A, AL, and HV cylinders is an adjustable type. A captive adjustment screw is supplied in the head and/or cap end of the cylinder that is cushioned. Turning the screw clockwise will slow the cylinder more while in cushion. This adjustment allows the user to manually vary the cushion rate to suit the application.

Stop Tubing

Purpose
The use of stop tubing is a generally accepted and preferred method for reducing piston and bearing loads on long stroke cylinders and additionally, for preventing jack-knifing or buckling of horizontally mounted, long push stroke cylinders. Stop tubes are more effective, less costly, and lighter in weight than oversize piston rods.



Positioned between the piston and cylinder head, a stop tube restricts the extended position of the rod so that the added distance between the piston and bushing results in less strain, wear, and bearing load.

Note: AL Cylinder stop tube design can be seen in AL Cylinder Catalog #8564.

Determining the Length and Need For Stop Tubing

Follow these steps to determine whether your cylinder requires stop tube, and, how long it should be.

1. Examine the groups of cylinders illustrated on Page 10 and determine which, if any, of the mounting configurations correspond to your cylinder application.

2A. If your cylinder mounting style corresponds to any of those in Group A (except a pivoting model 81) , then no stop tube is required.

If model 81 pivots up to 45 degrees, then proceed to step 3 and establish a stop tube length. Multiply the stop tube length established by .7 to determine the actual stop tube length for this mounting.

If the cylinder operates on push stroke, an oversize rod may be required. Check for this by determining an 'L' dimension as described in step 3 and then follow the instructions to determine oversize rod diameter requirements.

2B. If your cylinder mounting style is like one of those in Group B (including those pivoting up to 45 degrees from vertical), then a stop tube is recommended for push applications. For fixed mounts and pivot mounts operating on push stroke, proceed to Step 3. Stop tube requirements for cylinders pivoting up to 45 degrees from vertical, and operating on pull stroke, is calculated by multiplying the length determined in step 3 by .7

2C. If your cylinder is A or AL series operating with air and similar to one of the Group C illustrations, proceed to step 3.

2D. If your cylinder is J, H, or HV series and is one of Group C models 81, 82, 84, 86, 89, 90, or 94 contact Miller Fluid Power Application Engineering for stop tube and rod diameter recommendations. Cylinder and fluid weight must be considered in determining turning moments and bearing loads for these conditions.

2E. If your cylinder is J, H, or HV series and is one of Group C models 52, 53, 61, 62, 63, 64, 65, 66, 67, or 68, proceed to step 3.

3. Referring to the illustration that corresponds to your cylinder application, determine the value of 'L'. For pivoting cylinders, be certain to include the thickness of the cylinder head, cap and piston assembly plus twice the length of the cylinder stroke. Then go down the first column of the Stop Tube Table and find the range that encompasses that value of 'L'. The number shown to the right in the second column is the length of stop tube your cylinder requires.

When eccentric or side loads will be imparted to the cylinder, additional stop tube length may be required. Contact Miller Application Engineering for stop tube sizing assistance.

4. Add the stop tube length to your 'L' dimension to obtain an 'Adjusted L Dimension'. This dimension will be used in the procedures to determine whether your cylinder requires an oversize piston rod in addition to the stop tube. Do not add the stop tube length to 'L' for models 53, 61, 63, 67, 81, 83, & 89.

Group A

Horizontally mounted models 51, 54, 71, 72, 73, 74, 77, and mixed mounts.
Vertically mounted models 53, 61, 63, 65, 67, & 81.
(Stop tube requirements for model 81 cylinders pivoting up to 45 degrees from vertical, and operating either on push or pull stroke, is calculated by multiplying the length determined in Step 3 by .7)
With piston rod extended. Check for rod diameter only. Stop tube not required (except pivoting model 81).

Group B

Vertically mounted models 52, 62, 64, 66, 68, 82, 84, 86, 89, 90, & 94.
(Stop tube requirements for cylinders pivoting up to 45 degrees from vertical, and operating either on push or pull stroke, is calculated by multiplying the length determined in Step 3 by .7)
To avoid rod buckling or cylinder jackknifing, check for stop tube and rod diameter requirements with piston rod extended. Use cylinder dimensional charts. No stop tube required if cylinder operates on pull stroke only.

Group C

Horizontally mounted pivoting models 81, 82, 84, 86, 89, 90, 94. Contact Miller Fluid Power Application Engineering for assistance in sizing stop tubing for these models in J, H, and HV series.
Horizontally mounted fixed models 52, 53, 61, 62, 63, 64, 65, 66, 67, 68.
To eliminate buckling or jackknifing with piston rod extended. Check for stop tube length and rod diameter on push stroke applications. Check for stop tube only on pull stroke applications.

Stop Tube Table

"L" (inches)	Stop Tube Length (inches)	"L" (inches)	Stop Tube Length (inches)
0-40	0	171-180	14
41-50	1	181-190	15
51-60	2	191-200	16
61-70	3	201-210	17
71-80	4	211-220	18
81-90	5	221-230	19
91-100	6	231-240	20
101-110	7	241-250	21
111-120	8	251-260	22
121-130	9	261-270	23
131-140	10	271-280	24
141-150	11	281-290	25
151-160	12	291-300	26
161-170	13	301-310	27

Note: 'L' or 'D' are calculated from mounting point with rod extended.

Ports

Ports are the means by which fluid or compressed air is input to or exhausted from the cylinder. Several aspects of ports must be considered when specifying them for a cylinder.

- Port sizing
- Piping connection method (threaded or flanged) and type
- Port location

Port Sizing

Cylinder piston and rod velocity is dependent on the rate that fluid or compressed air can be introduced into one end of the cylinder or exhausted from the other end. One factor that contributes to a cylinder's ability to accept and exhaust fluid or compressed air is the port size and its flow area.

To determine whether the standard 'EE' port size will flow enough fluid to achieve the piston and rod velocity required for your application, follow these simple steps. Assume that NPT and SAE ports with the same thread size have flow equivalent volumes.

Hydraulic Cylinders

1. Divide your cylinder stroke length (in inches) by the length of time (in seconds) required for the cylinder stroke to take place. Multiply the result by 60 to obtain the stroke speed in inches per minute.

Example: 20-inch stroke, 2 seconds
20 ÷ 2 = 10 inches/second
10 x 60 = 600 inches/minute

2. In the table following, find the oil consumption per inch of stroke for the cylinder bore you have chosen. Multiply the stroke speed calculated in Step 1 by the oil consumption per inch of stroke. This will give you the oil consumption per minute.

Oil Consumption Per Inch of Stroke

Cylinder Bore In Inches	Gallons Displaced	Piston Rod Diameter In Inches	Gallons Displaced
1 ½	.00765	⅝	.00133
2	.01360	1	.0034
2 ½	.0213	1 ⅜	.00673
3 ¼	.0359	1 ¾	.01041
4	.0455	2	.01360
5	.0850	2 ½	.0213
6	.1224	3	.0306
7	.1666	3 ½	.0417
8	.2176	4	.0544
10	.3400	4 ½	.0688
12	.4896	5	.0850
14	.6664	5 ½	.1028
16	.8704	7	.1666
18	1.1016	8	.2176
20	1.3600	9	.2754
		10	.3400

Example: 3 ¼ inch bore, push stroke cylinder
600 x 0.0359 = 21.54 gallons per minute

3. Find the standard port size for the cylinder you have chosen in the Port Size Availability table (page 23).

Example: 3 ¼-inch bore, H Series Cylinder
Standard port is -12 SAE or ¾-14 NPT equivalent.

4. Determine whether flow through the standard port exceeds the maximum recommended velocity of 15 feet per second. Oil velocities above of 15 feet per second might result in excessive shock loading. In the “Pipe Size and Oil Flow” table find your port size row and follow it right to the “Gallons Per Minute” column under “Velocity = 15 ft. per sec.”

Pipe Size and Oil Flow

Schedule 40 Butt Welded Steel Pipe				Velocity = 10 ft. per sec.		Velocity = 15 ft. per sec.	
Pipe Size	Burst Press. PSI	Internal Dia. Inches	Internal Area Sq. Inches	Gallons Per Minute	Pressure Drop In PSI	Gallons Per Minute	Pressure Drop In PSI
⅜	10,574	.493	.191	5.98	1.66	8.97	2.35
½	10,784	.622	.304	9.48	.82	14.31	1.65
¾	8,608	.824	.533	16.78	.59	25.17	1.17
1	8,088	1.049	.864	27.18	.43	40.77	.85
1¼	6,744	1.380	1.495	46.96	.31	70.44	.60
1 ½	6,104	1.610	2.036	63.36	.25	95.04	.48
2	5,184	2.067	3.355	104.72	.17	157.08	.32
2 ½	5,648	2.469	4.788	149.50	.14	224.25	.26
3	4,936	3.068	7.393	229.78	.10	344.67	.19

Example: ¾-inch port
Table row 3/4 under “15 ft. per sec.” shows
25.17 gallons per minute

5. If the flow rate found in Step 4 is greater than or equal to that calculated in Step 2, then the standard port size is adequate. If the Step 4 rate is less than the Step 2 rate, then return to the Pipe Size and Oil Flow table and find the flow rate value in the "15 ft. per sec." column which is equal to (or larger but closest to) the Step 2 flow rate. In the same row, move left across the table to the first column and find the proper oversize port.

Example: 25.17 is the number shown in the "15 ft. per sec." column, which is larger than 21.54.
The ¾ inch standard port is adequate.

Port Size Availability

H & HV Series
SAE Ports Standard - NPT Ports Optional

Cylinder Bore Dia. (Inches)	Standard SAE Port					Optional NPT Port		4 Bolt SAE CODE 61 5000psi
	NFPA Standard	** Maximum Oversize						
		H Head	**H** Cap	**HV** Head	**HV** Cap	Standard	** Maximum Oversize	
1½	(-8)	(-14)	(-14)	(-12)	(-12)	½-14	¾-14	N/A
2	(-8)	(-14)	(-14)	(-12)	(-12)	½-14	¾-14	N/A
2½	(-8)	(-14)	(-14)	(-12)	(-12)	½-14	¾-14	½
3¼	(-12)	(-20)	(-16)	(-16)	(-16)	¾-14	1-11½	¾
4	(-12)	(-20)	(-16)	(-16)	(-16)	¾-14	1-11½	¾
5	(-12)	(-16)	(-16)	(-16)	(-16)	¾-14	1-11½	¾
6	(-16)	(-20)	(-20)	(-24)	(-24)	1-11½	1¼-11½	1
7	(-20)	(-24)	(-24)	(-32)	(-32)	1¼-11½	1½-11½	1¼ (4000 psi)
8	(-24)	(-32)	(-32)	N/A	N/A	1½-11½	2-11½	1½ (3000 psi)

** Welded coupling
Note: All optional maximum oversize SAE and NPT ports are welded. For intermediate sizes consult Miller Application Engineering.

BSPP, BSPT, and ISO 6149-1 metric straight thread ports are available upon request. Consult Miller Application Engineering.

SAE Port Size Reference Chart

DASH Number	Tube OD (in.)	Thread Size (in.)
(6)	.38	.56-18
(8)	.50	.75-16
(10)	.62	.88-14
(12)	.75	1.06-12
(14)	.88	1.18-12
(16)	1.00	1.31-12
(20)	1.25	1.62-12
(24)	1.50	1.88-12
(32)	2.00	2.50-12

A&J Cylinders
NPT Ports Standard – SAE Ports Optional

Cylinder Bore Dia. (Inches)	Standard NPT Port		Optional SAE Port		
	NFPA Standard	** Maximum Oversize	Standard Size	** Maximum Oversize	
				Head	Cap
1½	⅜-18	½-14	* (-6)	(-12)	(-10)
2	⅜-18	½-14	* (-6)	(-12)	(-10)
2½	⅜-18	½-14	(-6)	(-12)	(-10)
3¼	½-14	¾-14	(-10)	(-14)	(-16)
4	½-14	¾-14	(-10)	(-14)	(-16)
5	½-14	¾-14	(-10)	(-14)	(-16)
6	¾-14	1-11½	(-12)	(-20)	(-16)
7	¾-14	1-11½	(-12)	(-20)	(-16)
8	¾-14	1-11½	(-12)	(-20)	(-16)

* Head end port of 1 1/2 inch bore x 1 inch rod and 2 inch bore x 1 3/8 inch rod is a welded coupling.
** Welded coupling
Note: All optional maximum oversize SAE and NPT ports are welded. For intermediate sizes consult Miller Application Engineering.

Pneumatic Cylinders

1. Divide your cylinder stroke length (in inches) by the length of time (in seconds) required for the cylinder stroke to take place. Multiply the result by 60 to obtain the stroke speed in inches per minute.

Example: 30-inch stroke, 4 seconds
30 ÷ 4 = 7.5 inches/second
7.5 x 60 = 450 inches/minute

2. In the table following, find the free air consumption per inch of stroke for the cylinder bore you have chosen. Multiply the stroke speed calculated in Step 1 by the free air (air volume at atmospheric pressure) consumption per inch of stroke. This will give you the free air consumption in cubic feet per minute. For your convenience, free air consumption at 80 psi has been calculated. To determine free air consumption at pressures other than 80 psi, use the following formula:

Free air consumption per inch of stroke =
Pressure Air Cu. Ft. Displaced x (Pressure + 14.7) ÷ 14.7

Free Air Consumption

Push stroke				Deduct the rod size consumption from push stroke figure to determine pull stroke consumption.			
		Consumption Per Inch of Stroke in One Direction				Consumption Per Inch of Stroke in One Direction	
Cylinder Bore In Inches	Piston Area Sq. Inches	Pressure Air Cu. Ft. Displaced	Free Air Cu. Ft. at 80 PSI	Standard Piston Rod Diameter In Inches	Piston Rod Area Sq. In.	Pressure Air Cu. Ft. Displaced	Free Air Cu. Ft. at 80 PSI
1½	1.767	.00102	.00657	⅝	.307	.0001778	.00115
2	3.142	.00184	.01185	1	.785	.000454	.0002925
2½	4.909	.00289	.01863	1 ⅜	1.485	.00086	.00554
3¼	8.296	.00481	.0310	1 ¾	2.405	.001393	.00897
4	12.566	.00726	.04675	2	3.142	.00189	.01219
5	19.635	.01137	.0732	2 ½	4.909	.00284	.0183
6	28.274	.01638	.1056	3	7.069	.00409	.02638
7	38.485	.02230	.1435	3 ½	9.621	.00556	.0358
8	50.265	.02910	.1873	4	12.566	.00727	.0468
10	78.540	.04545	.2928	4 ½	15.904	.0092	.0593
12	113.100	.0656	.4226	5	19.635	.01136	.0732
14	153.940	.0891	.5740	5 ½	23.758	.013473	.0861
16	201.060	.1163	.7495				
18	254.470	.1473	.9489				
20	314.160	.1818	1.1711				

Example: A. 5 inch bore, push stroke cylinder,
80 psi operating pressure
450 inches/minute x 0.0732 = 32.9 SCFM free air

B. 5 inch bore, push stroke cylinder,
120 psi operating pressure
Free Air Cu. Ft. = .01137 x (120 + 14.7) ÷ 14.7 = Free Air Cu. Ft. = 0.1041
450 inches/minute x 0.1041 = 46.9 SCFM free air

3. Find the standard port size for the cylinder you have chosen in the Port Size Availability table.

Example: 5-inch bore, A Series Cylinder
Standard port is 1/2-14 NPT

4. In the Air Flow Chart, find the value for Maximum Recommended Flow in the column headed by the standard port size and row with your operating pressure.

Air Flow Chart

Maximum Recommended Flow Through Standard Weight Pipe To be used as a guide in determining size of equipment in compressed air circuits.								
Internal Area Of Pipe Sq. In.	Nominal Standard Pipe Size							
	⅛" .057	¼" .104	⅜" .191	½" .304	¾" .533	1" .864	1¼" 1.495	1½" 2.036
Initial Pressure psig.	MAXIMUM RECOMMENDED FLOW (SCFM – free air)							
10	5.5	9.2	18.6	30.2	51.1	84.0	139	186
20	6.5	11.0	22.0	35.7	60.6	100	165	220
30	7.4	12.5	25.0	40.7	68.4	112	187	250
40	8.2	13.3	27.6	44.9	76.0	125	207	276
50	8.9	15.0	30.0	48.8	82.2	135	226	301
60	9.6	16.1	32.2	52.3	89.0	146	242	323
70	10.4	17.7	34.3	56.0	94.0	154	258	345
80	10.8	18.2	36.3	59.0	100	165	273	364
90	11.3	19.1	38.2	62.2	105	172	286	382
100	12.0	20.0	40.0	65.0	110	180	300	400
110	12.5	20.8	41.8	67.7	114	188	312	417
120	12.8	21.6	43.4	70.4	119	195	325	434
130	13.3	22.4	45.0	73.0	123	202	337	450
140	13.8	23.2	46.5	75.5	127	209	348	465
150	14.2	23.9	48.0	77.7	132	218	360	479
PRESSURE DROP IN PSI PER 100 FEET OF PIPE								
Pressure Drop PSI/100'	54.0	31.7	25.4	19.0	12.4	9.2	5.94	4.68

Example: A. 5 inch bore, push stroke cylinder,
80 psi operating pressure
32.9 SCFM free air required, 1/2-14 port
Maximum recommended flow is 59.0 SCFM
Port size is adequate

B. 5 inch bore, push stroke cylinder,
120 psi operating pressure
46.9 SCFM air flow required, 1/2-14 NPT port
Maximum recommended flow is 59.0 SCFM
Port size is adequate

Piping Connection Method

Threaded Ports
The most common method of connecting fluid or compressed air lines to cylinders is with threaded ports. The most commonly specified port threads are as follows:

- SAE straight thread with o-ring boss - this port is recommended for hydraulic applications because it is least prone to leakage. This port thread is standard on Miller heavy-duty hydraulic series H and HV cylinders.
- NPT tapered pipe threads - this port is standard on A, AL, and J series cylinders and is a no cost option on H and HV cylinders.
- Oversize ports are available in both SAE and NPT thread forms. Some oversize SAE ports can be machined into standard thickness heads and caps. Contact Miller Application Engineering for availability. However, all maximum oversize SAE and NPT ports are supplied as welded couplings.

If ports larger than the maximum oversize thread listed in Port Availability tables are required, heads and caps must be made thicker to accommodate them. In these cases, supply information about speed, load, and pressure to Miller Application Engineering.

- Other port threads, such as BSPP, BSPT, and ISO 6149-1, are available on request. Contact Miller Application Engineering for availability.

Flange Ports
SAE Code 61 four bolt flange ports are available in H and HV series cylinders as listed in the table below.

SAE Four Bolt Flange Port (Code 61)

H & HV* Bore Size	Nominal SAE Flange Size	Max. Opoerating Pressure in PSI
2 1/2	1/2	5000
3 1/4	3/4	5000
4	3/4	5000
5	3/4	5000
6	1	5000
7	1 1/4	4000
8	1 1/2	3000
10	2	3000
12	2 1/2	2500
14	3	2000

*HV bore size through 8 inch

Port Location

Standard port location is at position #1 as viewed from the rod end of the cylinder. Typically, ports can be supplied at any position (#1, 2, 3, or 4) of the head or cap that is not occupied by mounting hardware or machining.

- Ports at position #2 or #4 of model 72 cylinders may interfere with mounting bolts. See the following tables for restrictions. Contact Miller Application Engineering for availability of oversize ports in this model.

A & J Series Cylinders
Model 72 with port at position #2 or #4

Bore Size	HEAD Standard **NPT** Port Size	CAP Standard **NPT** Port Size
1 1/2	CS-1	CS-1
2	NR	CS-2
2 1/2	NR	CS-2
3 1/4	CS-2	CS-2
4, 5, 6, 7	CS-2	CS-2
8	NR	CS-2
10	NR	NR
12 & 14	NR	NR

H & HV Cylinders
Model 72 with port at position #2 or #4

Bore Size	HEAD Standard **SAE** Port Size	CAP Standard **SAE** Port Size
1 1/2	CS-3	CS-3
2	CS-3	CS-3
2 1/2	CS-1	CS-1
3 1/4	CS-3	CS-3
4	CS-3	CS-3
5	CS-3	CS-3
6	CS-3	CS-3
7	CS-3	CS-3
8, 10, 12, 14	CS-3	CS-3

CS-1 - *Mounting lug is counterbored for socket head cap screw. Port is offset, from block centerline, toward position #1. Socket head cap screw must be installed from cylinder side of lug, before piping is installed.*

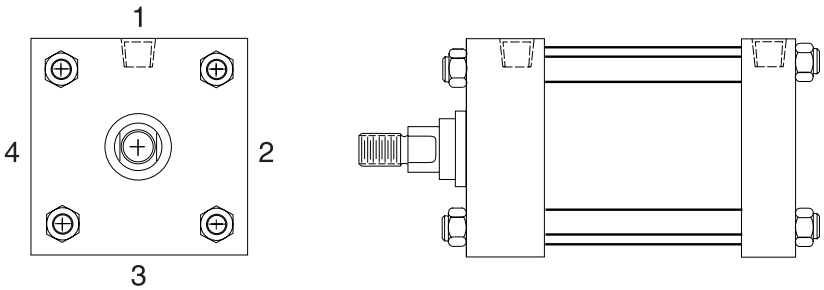
CS-2 - *Hex head bolt can be installed from cylinder or mounting side of lug, before piping is installed.*

CS-3 - *Port is offset, from block centerline, toward position #1. Socket head cap screw can be installed from cylinder side of lug, before piping is installed. Any type mounting screw can be installed from mounting side of lug, using a standard hex nut, after piping is installed.*

NR - *No restriction. Mounting screws can be installed with piping in place.*

• Ports can be supplied in the center rear face of a cap that is not occupied with mounting hardware or is a mounting surface. These ports are typically supplied as welded couplings.

• Ports may be supplied in a position normally occupied with a cushion adjusting screw or ball check on a cylinder with adjustable cushions. In that case, the cushion adjust or ball check is typically rotated clockwise to the next open position.



Seals

Miller A and AL series pneumatic cylinders are designed to operate with non-lubricated or lubricated compressed air. J, H, and HV hydraulic cylinders are designed for use with mineral-based hydraulic oil and water glycols below 160°F. See the table below for standard seal material and temperature resistance by cylinder series.

Standard Seal Compatibility

Cylinder Series	Rod Seal Material	Rod Wiper Material	Piston Seal Material	Tube End Seal Material	Cushion Seal Material	Fluid Compatibility	Temperature Range
A	Polyurethane	Nitrile	Nitrile	Teflon ®	Nitrile*	Compressed air – non-lubricated or lubricated.	-10° F to 200° F
AL	Nitrile	Nitrile	Nitrile	Nitrile	Nitrile and polyur-ethane	Compressed air – non-lubricated or lubricated.	-10° F to 200° F
J	Polyurethane	Nitrile	Teflon ®	Teflon ®	N/A	Mineral based hydraulic oil or water glycol	-20° F to 160° F
H	Polyurethane	Nitrile	Teflon ®	Teflon ®	N/A	Mineral based hydraulic oil or water glycol	-20° F to 160° F
HV	Polyurethane	Nitrile	Polyurethane	Teflon ®	N/A	Mineral based hydraulic oil or water glycol	-20° F to 160° F
LA	Nitrile	N/A	Nitrile	Nitrile	N/A	Compressed air – non-lubricated or lubricated.	-10° F to 200° F

* Cushion seal is supplied on rod end cushion plungers through 1 3/8" rod diameter and on cap end cushion plunger through 8" bore.

Applications outside the standard seal temperature range or operation with fluids other than mineral-based hydraulic oil or water glycol require specification of optional seal material. See the tables below for fluid and temperature compatibility of optional seal materials.

High Temperature Air Service

Cylinder Series	Rod Seal Material	Rod Wiper Material	Piston Seal Material	Tube End Seal Material	Cushion Seal Material	Fluid Compatibility	Temperature Range
A	Viton	Viton	Viton	Viton	Viton	Compressed air– non-lubricated or lubricated.	-10° F to 350° F
	Spring loaded Teflon (Base-Lok)	Teflon	Spring loaded Teflon	Teflon	Viton*	Compressed air– non-lubricated or lubricated.	-10° F to 450° F*
AL	Viton	Viton	Viton	Viton	Viton	Compressed air– non-lubricated or lubricated.	-10° F to 300° F
LA	Viton	N/A	Viton	Viton	N/A	Compressed air– non-lubricated or lubricated.	-10° F to 400° F

* 400° F if rod end cushioned through 1 3/8" rod diameter and cap end cushioned through 8" bore.

Special Fluid & Temperature

Operating Fluid***	Cylinder Series	Rod Seal Material	Rod Wiper Material	Piston Seal Material	Temperature Range
Water (up to 1500 psi)	J, H	Spring loaded nitrile (Base-Lok)	Teflon	Nitrile	200º F max.
	HV	Viton	Nitrile	Viton	200º F max.
Water Glycols	J, H	Polyurethane **or** Spring Loaded Teflon (Base-Lok)	Nitrile **or** Teflon	Teflon	160ºF max.
	HV	Viton	Nitrile	Viton	200º F max
Phosphate ester fluids	J, H	Viton **or** Spring Loaded Teflon (Base-Lok)	Viton **or** Teflon	Spring loaded teflon **or** cast iron piston rings*	400ºF max.
	HV	Viton	Viton	Viton **or** cast iron piston rings*	350º F max.**

* Piston rings are not recommended for holding applications where seal bypass is critical. A rule of thumb to use for estimating piston ring bypass is 1 ounce of oil per 1,000 psi operating pressure per inch of bore size per minute.

** 350° F temperature limitation with standard glass filled nylon piston wear band. Specify bronze piston wear band for 400° F maximum temperature.

*** For high temperature mineral base D oil applications use Viton or spring loaded teflon seals to a maximum operating temperature as recomended by the fluid supplier, up to 400°F.

Rod Wiper Option

Metallic Rod Scraper

In environments where foreign material may adhere to the piston rod a metallic rod scraper should be specified. The double brass rings will scrape the rod of sticking material before it can enter the bushing. Scrapers are available with either nitrile or Teflon back-up rings, which should be selected to suit the application's fluid or temperature conditions. This option is available in A, AL, J, H, and HV series cylinders.

Environment

Corrosion Protection

Standard Protection

Miller A, LA, J, H, and HV steel cylinders are protected from corrosion in typical machine tool applications. The cylinder body (head, cap, tube, tie rods, bushing, etc.) is washed and painted with one coat of oil resistant enamel.

Miller AL aluminum cylinders are also protected from corrosion. The aluminum head, cap, and tube OD are anodized; tie rods are painted (E-coat); mountings are painted; tie rod nuts and fasteners are black oxide coated; the bushing is tin plated.

All Miller piston rods are chrome plated .0003-.0005 inch thick for protection in typical machine tool applications. Machined piston rod surfaces are not plated.

Epoxy Paint

Miller offers two forms of epoxy paint to give cylinders enhanced corrosion protection.

- Single topcoat applied over bare metal. 24-hour cure time.
- Double topcoat applied over rust-inhibiting primer. Specify this option for cylinders used in sub-sea applications. 3-day cure time.

Chrome Plating

All Miller piston rods are chrome plated .0003-.0005 inch thick for protection in typical machine tool applications. Machined piston rod surfaces are not plated.

- Optional heavy chrome plating, .001-.002 inch thick, is available for additional corrosion protection and longer wear.

Steel tubing in model A series cylinders is plated on the ID .0003-.0005 inch thick to resist corrosion.

- Optional heavy chrome plating, .001-.002 inch thick on the I.D., can be supplied in A, J, H & HV series cylinders for additional corrosion protection and longer wear. Contact Miller Application Engineering for availability.

Stainless Steel Piston Rods

A standard Miller option for piston rods is chrome plated (.0003-.0005 inch thick) stainless steel material. Stainless steel provides the best protection against piston rod corrosion.

- 17-4 stainless steel is supplied in A, LA, J, H, and HV series cylinders due to its high strength.
- 316 stainless steel is supplied in AL cylinders.

Nickel-Teflon Plating

For improved corrosion protection, steel and iron cylinder components (head, cap, bushing, tube, tie rods, etc.) can be Nickel-Teflon plated. Co-deposition of Nickel and Teflon provides the corrosion resistance of Nickel plus the lubricity of Teflon. Unlike paint that can chip, Nickel-Teflon plating's hardness (41-45 Rc) resists scratching and chipping. And, Teflon on bearing surfaces (bushing and tube ID) contributes to improved stick-slip performance. Surfaces plated with Nickel-Teflon cannot be painted. This plating is not recommended for protection against steam washdown.

Temperature

When considering the effect of temperature on a cylinder, both heat and cold must be considered. The components impacted the most by extreme temperatures are seals. See the section titled "Seals" for recommendations of materials and their temperature resistance.

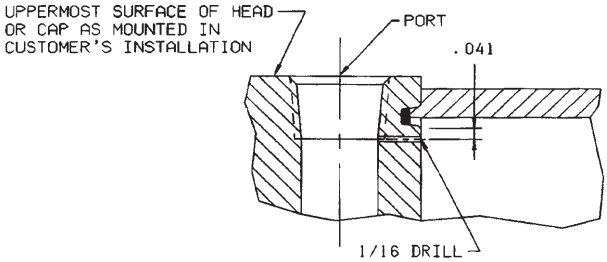
Cylinders intended for use where ambient fluid (gas) temperature approaches -20 degrees F are subject to failure due to the brittle nature of most common steels at these temperatures. If cycle rate and speed are low and there is no danger of shock in the system, then cylinders can be used at catalog pressure ratings to -20 degrees F. Contact Miller Application Engineering for applications below -20 degrees F.

General Cylinder Modifications

Air Bleeds

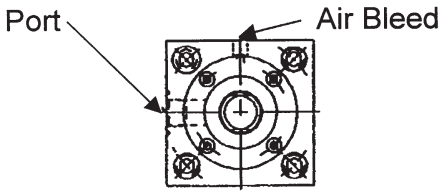
Miller J, H, and HV cylinders can be ordered with optional air bleeds. Both self-bleeding and manual air bleeds are available in the cylinder head and cap.

- Self-bleeding air bleeds should be specified when the port is the uppermost surface of the cylinder. Self-bleeding air bleeds are not available with cushioning.



For Air Bleed

- Manual air bleeds require an additional port. The Miller standard is 5/16 - 24" which is sealed with a plug and Tru-Seal nut. This bleed port must be on the uppermost face of the cylinder.



Spring Operated Cylinders

Miller cylinders can be supplied with internal springs that can extend or retract the piston and rod.

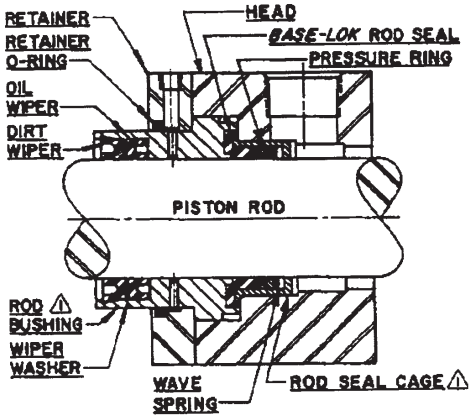
- A spring extend or retract option for A series cylinders is designed move the weight of the piston and rod assembly only (no load). This option is for 1 inch through 8-inch work strokes in 1 1/2 - 10" bores with standard rod diameters. The length of cylinders with this spring installed is approximately doubled.

- Special spring extend or retract cylinders can be supplied to fill a variety of load and stroke conditions. They are available in A, AL, LA, J, H, and HV series cylinders. Weight of oil, line size and length are important factors in sizing a spring for hydraulic cylinders. Complete the Custom Cylinder Specification sheet at the back of this guide and send it to our Application Engineering Department. Be sure to include all information requested in the "Spring Return" section of the form. E.g. load, work stroke, minimum available pressure, etc.

Bushing Modifications

External Drainback Bushing

In applications where fluid weepage from the rod bushing cannot be tolerated, an external drainback bushing should be specified. To accomplish the drainback function, a port is provided in either the bushing or bushing retainer to drain fluid that passes the rod seal, but is held in by the rod wiper. This port must be plumbed with an unobstructed line back to a reservoir. This option is available in J & H series cylinders with Base-Lok bushings, and in HV series cylinders.



Water Cooled Bushing

In high ambient heat applications where rod bushing temperatures are expected to exceed 400°, a water-cooled bushing can be supplied. This option provides two ports on the bushing retainer for connection to a water source and drain. Water flow around the bushing OD will remove excess heat. Available in A, J, H, and HV series cylinders.

DU® Lined Bushing

When cylinders "dither" in operation, the piston rod moves back and forth for a short distance at high frequency. This is common when the cylinder operates in a "closed loop" system with a transducer and servo valve. To minimize piston rod and bushing wear when this condition is present, specify a DU lined bushing.

DU lined bushings can also enhance a cylinder's ability to withstand side load. If side load is suspected in the application, contact Miller Application Engineering for construction recommendations.

The DU liner provides a Teflon impregnated bronze bearing surface for low friction and long wear. This option is available in J & H series cylinders with Base-Lok bushings, and in HV series cylinders. (Not available in STAR bushings.)

Position Sensing Cylinders
LDT (Linear Displacement Transducer)

Magnetostrictive Technology

Principle of operation:

An interrogation pulse is launched down a magnetostrictive waveguide creating an instantaneous magnetic field along the active length of the sensor. This magnetic field interacts with the magnetic field from the movable magnet mounted in the cylinder piston. The interaction between the two magnetic fields creates a torsional strain pulse, which travels through the waveguide at sonic speed towards the sensorís head electronics. The position of the piston and magnet is determined by measuring the elapsed time between the launching of the interrogation pulse and the detection of the strain pulse.

Analog

The "conditioned" output signal is available in either a voltage or current configuration. A voltage of 0 to 10 VDC and a current of 4 to 20 MA are most commonly utilized. The analog output (volts or current) is proportional to the stroke length of the cylinder. Example: A 10" stroke cylinder will produce 0.05 VDC when fully retracted and 10.00 VDC when fully extended. At 5" it will produce 5.00 VDC. With third generation Temposonics products, the output is only available in a positive value. If a negative output is required, you must select a Tempo II or Balluff product. True 0 VDC output is not obtainable, Typical minimum output is 0.050 VDC. Maximum recommended cable length between the cylinder and control electronics is 50 feet.

"L" Series and "LD" Series Analog

When ordering a "L" series analog, you must specify your output. When voltage is ordered, the standard option is 0 to 10 VDC and 10 to 0 VDC. We always refer to the swing of the output from the cylinder travelling from it's full retract position to it's full extend position. If current output is ordered, you must specify increasing or decreasing units. Unlike the voltage outputs, we do not offer both swings in one transducer. Resolution is infinite.

Field adjustments for offset (zero) and span (gain) for "L" and "LD" series are +/- 5%. If the "L" series electronics are housed in a protective cover with a rear pivot mount, you lose the ability for span and offset adjustment. Please refer to maintenance manual for adjustment instructions.

The stroke limitation for "L" and "LD" series Analog output transducers is 1 to 78 inches (25 to 1980 mm). Digital output strokes from 1 to 300 inches (25 to 7620 mm). If a longer stroke is required utilizing an analog format, select a TEMPO III or Balluff format.

TEMPO III Analog

When ordering a “III” series analog transducer, you must specify your output. When voltage is ordered, unlike the “L” series you only receive one output. However, with a Tempo III, you automatically receive the option for a velocity output. When ordering this type of transducer, you must specify the maximum speed at which you desire to measure. Example: 10-inches/sec maximum speed, the velocity output will produce 1 volt when the cylinder is traveling at 1 inch/sec. Note: This output is always positive and will not differentiate between the cylinder extending and retracting. Maximum measurable velocity range is 1 to 400 inches/second. Resolution is 16 bit or 0.001" whichever is greater.

Field adjustments for offset (zero) and span (gain) for a “III” series are 100%. If the electronics are housed in a protective cover with a rear pivot mount, you lose the ability for span and offset adjustment. Please refer to maintenance manual for adjustment instructions.

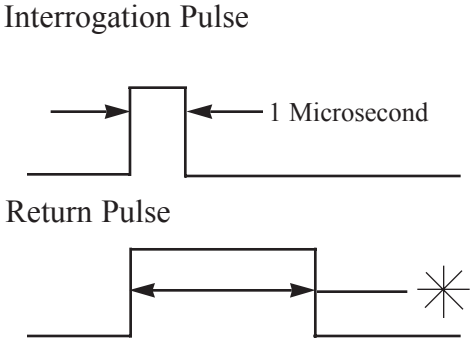
The stroke limitation for a “III” series transducer is 1 to 300 inches (25 to 7620 mm).

L Series and LD Series Digital

PWM (Pulse Width Modulation also known as “DPM”)

A host digital control system will ìtimeî the duration between the leading edge and trailing edge of the return pulse. Position is derived from a time gradient (Constant) located on the transducer label.

H" 9 µs/inch.



** Approximately a 9 microsecond time duration between the gate is equal to 1 cylinder travel from the cylinders cap end.*

This option requires a known number of recirculations (number of interrogation pulses sent) before ordering this type of transducer. These recirculations increase your resolution when incorporated with controllers with slower clock speeds.

You can utilize the following formula:

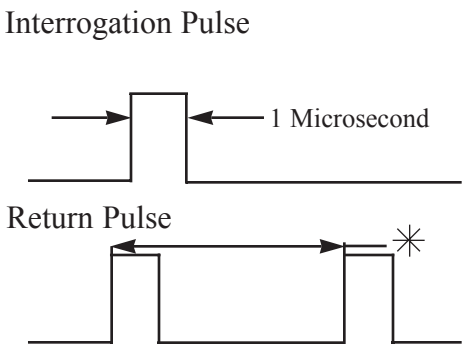
Recirculations Count = 1/(G X F X R)

G = Gradient (Located on the transducer label) For order purpose use 9 µs/inch.
F = Host Controller frequency (MHz) Must check Controller Manufacturer
R = Resolution Desired (inches)

Various controllers and dedicated PLC cards can take this data and process it for position and velocity indication. Commonly this is incorporated with a Motion Control card for closed loop position and velocity control.

RPM (Start Stop)

A host digital control system will "time" the duration between the returned 'start' signal and "stop" signal. This type of output is very similar to the "PWM" listed above, but has only one recirculation.



**Approximately a 9 microsecond time between the leading gate pulse to the next leading gate pulse is equal to 1" cylinder travel from the cylinder's cap end.*

Resolution may be calculated from the following formula:

Resolution (in inches) = 1/(G X F X C)

G = Gradient (Located on the transducer label) For order purpose use 9 µs/inch.
F = Host Controller frequency (MHz) Must check Controller Manufacturer
C = circulation count (number of recirculations)

Various controllers and dedicated PLC cards can take this data and process it for position and velocity indication. Commonly this is incorporated with a Motion Control card for closed loop position and velocity control.
Maximum recommended cable lengths for digital LDT is 100 feet.

VRVT (Variable Resistive Vector Transducer)

VRVT's are a non-contacting feedback device. The sensing element is a single layer coil wound on an insulated guide/pressure tube, wrapped in a screen and housed in a stainless steel case. A separate electronics card energizes the coil with a constant RMS current. A highly permeable nickel/iron core is passed through the coil changing the impedance of the coil, thus the voltage developed across it. Synchronously demodulating this voltage produces a dc signal, which is both proportional to the resistive vector and linear with respect to the cylinder piston movement.

The VRVT is available in all bore and rod configurations and is only limited by stroke length. For rod sizes: 5/8" and 1" maximum stroke is 14”, all other rod sizes maximum stroke length is 40".

There are several options available for signal conditioners. The conditioner is a loose item and is intended to be mounted on Din rail, in an electrical enclosure. Maximum recommended distance between the cylinder and the signal conditioner is 100’. The signal conditioner has a temperature stabilizing circuit to improve the VRVT’s performance.

Please note when the Signal conditioner is first excited (turned on) the outputs are saturated regardless of the cylinder’s position. After Approximately 3-5 minutes, the stabilization is complete and the outputs are relative to the cylinderís position. For this reason it is recommended that the signal conditioner be excited before enabling the hydraulic supply.

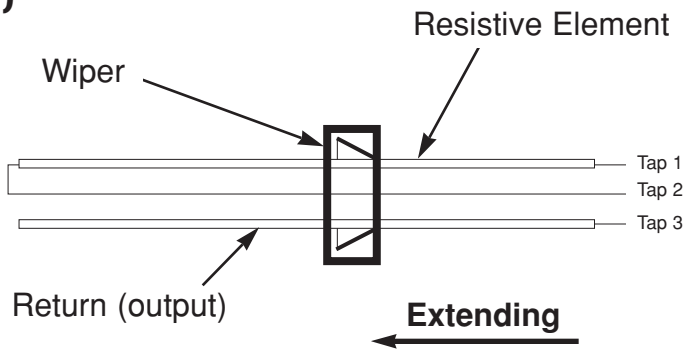
Outputs available are analog voltage or current.
Standard voltage ranges are: 0 to 10 VDC, 0 to 5 VDC, and -5 to +5 VDC. Standard current outputs are: 4 to 20 MA and 0 to 20 MA.

Signal Conditioners

Part Number	Excitation (Input Power)	Output
580-EM10V	**(+) 24 VDC**	**Voltage**
580-EM10I	**(+) & (-) 15 VDC**	**Voltage and Current**
580-EM9V	**(+) 24 VDC**	**Voltage**
580-EM9I	**(+) & (-) 15 VDC**	**Voltage and Current**

LRT (Linear Resistive Transducer)

The LRT is a linear potentiometer, which creates a voltage dividing circuit when used as a cylinder feedback device. An excitation (input) is applied to one end (tap) of the potentiometer, and the other end is connected to the excitation common. The wiper, which is mounted to the piston, slides up and down the resistive element and divides the voltage applied proportional to the wiper position.



The resistive element is constructed from a conductive plastic material. Plastic is selected for increased temperature stability. The resistance value per inch is aproximatly 1000 ohms. This conductive plastic is adhered to the base which is either a composite material or aluminum. This base is mounted stationary to the cap. The three wire output is terminated at a pressure connector and mates to the Brad Harrison three pin mini cable assembly.

The stroke limitation for the LRT is 120 inches.

Since the device is contacting; water based and synthetic fluids are not applicable. Petroelum based fluids with high levels of Zinc may produce premature failure. The LRT feedback device does not allow the user to make adjustments for zero or span. Listed below is the formula to calulate the approximate zero and span values.

$$Z = (E / H) * 0.5$$

$$S = E - Z$$

Where:

Z = Zero Voltage value (*Approximation)*
E = Excitation Voltage
H = Cylinder (Transducer) Stroke
S = Span Voltage Value (*Approximation*)

Proximity Switches

End-of-Stroke Inductive Type

- **Weld Field Immune** - Permits application within one inch of resistance welder tips carrying 20,000 Amperes.
- **Rotatable** - Switch body may be rotated in 30° increments up to 335° to position the quick disconnect.
- **Sealed Enclosure** - Housings meet NEMA 1, 4, & 13 requirements.
- **Short Circuit Protection (SCP)** - Protects the switch from shorts in the load or line. Upon sensing a short condition, both LED's will flash and the sensor will limit the current flow to about 2mA.

Operating Principal

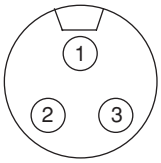
This solid state switch emits a small directional radio frequency field. When the cushion plunger enters the field, eddy current losses occur. When these losses exceed a set level, the switch output is energized.

The two-wire circuit will operate on AC or DC. It operates reliably as a programmable controller input or with a relay load. Off state current is factory set at 1.7mA. The 1.7mA type will generally allow direct connection to most P.C.'s without adding shunt resistors.

Specifications

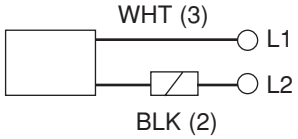
2-Wire AC Supply Voltage (50/60 Hz)-	20-230 VAC/DC
Pressure Rating -	3,000 psi non-shock.
Temperature Range -	-4°F to +158°F
Sensing Range -	.080±10%
Repeatability -	Less than ±1.25%
Hysteresis -	3% to 10%
Voltage Drop -	≤10V
Load Current -	5 to 500 mA
Current Consumption -	1.7mA AC; 4.5mA DC
Standard Indicating LED's -	1. Power on/load de-energized - red 2. Power on/load energized - green 3. SCP mode - both LED's flashing
Connector -	3 pin micro male.

COLOR CODE
1. Green
2. Black (Red)
3. White (Red)



(3) PIN RECEPTACLE (AC)

2-Wire AC/DC



INTERNALLY SHORT
CIRCUIT PROTECTED
PIN#1 NOT USED.

Switch Options

DC Sourcing with 4-pin mini connector
DC Sinking with 4-pin Euro connector

Stroke-To-Go

The Miller End-of-Stroke inductive switch option is engineered to give an electrical signal as close as possible to the cylinder stroke end while using standard components. The switch's fixed probe length and component tolerance (cushion plunger length, switch mounting machining, spacer thickness, etc.) stack-up make it impossible to locate the switch so that it signals exactly at the cylinder stroke end. Therefore, there will be some piston travel or stroke-to-go after the switch signals. Following are tables, by series, bore, and rod diameter, of approximate stroke-to-go. Note that cap end stroke-to-go is the same regardless of piston rod diameter.

A & J Series

		Stroke-To-Go In Inches			
		A Series		J Series	
Bore	Rod	Head	Cap	Head	Cap
1 1/2	.625	.219	.254	.215	.244
	1.000	.155		.169	
2	.625	.219	.253	.215	.244
	1.000	.218		.232	
	1.375	.149		.165	
2 1/2	.625	.219	.253	.215	.244
	1.000	.218		.232	
	1.375	.212		.228	
	1.750	.118		.180	
3 1/4	1.000	.124	.095	.107	.119
	1.375	.118		.103	
	1.750	.118		.118	
	2.000	.110		.100	
4	1.000	.124	.095	.138	.119
	1.375	.118		.134	
	1.750	.118		.180	
	2.000	.110		.100	
	2.500	.110		.100	
5	1.000	.124	.095	.107	.119
	1.375	.118		.103	
	1.750	.118		.118	
	2.000	.110		.100	
	2.500	.110		.100	
	3.000	.110		.132	
	3.500	.110		.119	
6	1.375	.118	.103	.134	.116
	1.750	.118		.180	
	2.000	.110		.100	
	2.500	.110		.100	
	3.000	.110		.132	
	3.500	.110		.119	
	4.000	.112		.064	
7	1.375	.118	.103	.134	.116
	1.750	.118		.180	
	2.000	.110		.100	
	2.500	.110		.100	
	3.000	.110		.132	
	3.500	.110		.119	
	4.000	.112		.094	
	4.500	.112		.064	
	5.000	.112		.112	
8	1.375	.118	.103	.134	.116
	1.750	.118		.180	
	2.000	.110		.100	
	2.500	.110		.100	
	3.000	.110		.132	
	3.500	.110		.119	
	4.000	.112		.064	
	4.500	.112		.064	
	5.000	.112		.112	
	5.500	.097		.118	

AL Series

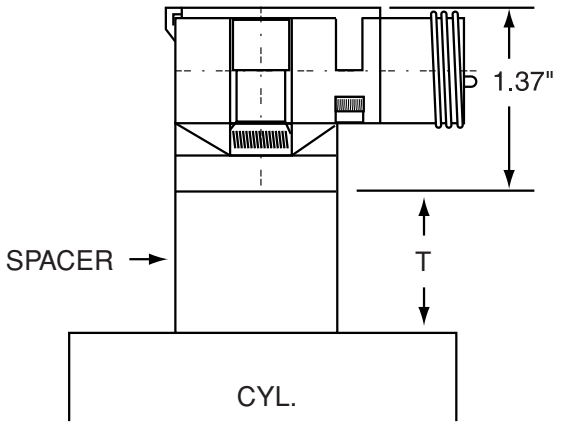
		Stroke-To-Go In Inches	
Bore	Rod	Head	Cap
1 1/2	.625	.187	.120
2	.625	.202	.120
	1.000	.202	
2 1/2	.625	.202	.120
	1.000	.202	
3 1/4	All	.120	.108
4	All	.120	.108
5	All	.120	.108
6	All	.112	.123
8	All	.112	.123

H & HV Series

		Stroke-To-Go In Inches			
		H Series		HV Series	
Bore	Rod	Head	Cap	Head	Cap
1 1/2	.625	.121	.119	.220	.124
	1.000	.107		.159	
2	1.000	.107	.096	.220	.124
	1.375	.103		.159	
2 1/2	1.000	.107	.096	.220	.124
	1.375	.103		.220	
	1.750	.118		.159	
3 1/4	1.375	.103	.123	.155	.106
	1.750	.118		.155	
	2.000	.100		.155	
4	1.750	.118	.116	.155	.106
	2.000	.100		.155	
	2.500	.100		.155	
5	2.000	.100	.100	.155	.106
	2.500	.100		.155	
	3.000	.101		.155	
	3.500	.119		.155	
6	2.500	.100	.100	.114	.109
	3.000	.101		.145	
	3.500	.119		.145	
	4.000	.095		.155	
7	3.000	.101	.112	.100	.100
	3.500	.119		.100	
	4.000	.095		.145	
	4.500	.095		.145	
	5.000	.096		.145	
8	3.500	.119	.112	.100	.101
	4.000	.095		.100	
	4.500	.095		.083	
	5.000	.096		.083	
	5.500	.118		.115	

Switch and Spacer Heights

Spacers are installed between the switch and cylinder end cover. They are required to achieve the proper air gap between the fixed length probe end and cushion plunger. Following are tables giving spacer thickness by cylinder series, bore, and rod diameter.



A & J Series

		Spacer 'T' Dimension In Inches	
		All Except Model 67/68 @ Pos. 2 or 4	Model 67/68 @ Pos. 2 or 4
Bore	Rod	T	T
1 1/2	.625	.712	1.149
	1.000	.675	1.336
	Cap	.712	1.149
2	.625	1.274	.836
	1.000	.654	1.024
	1.375	.612	1.212
	Cap	1.274	.836
2 1/2	.625	.212	.649
	1.000	.175	.836
	1.375	.363	.212
	1.750	.550	.175
	Cap	.212	.649
3 1/4	1.000	.836	.400
	1.375	.212	.587
	1.750	.175	.774
	2.000	.300	.900
	Cap	.649	.212
4	1.000	.462	.154
	1.375	.649	.336
	1.750	.836	.524
	2.000	.154	.649
	2.500	.175	.900
	Cap	.275	.774
5	1.000	774	.300
	1.375	.154	.491
	1.750	.336	.674
	2.000	.462	.803
	2.500	.712	.250
	3.000	.154	.491
	3.500	.181	.134
	Cap	.587	.122
6	1.375	.462	.988
	1.750	.649	.275
	2.000	.774	.400
	2.500	.212	.649
	3.000	.462	.900
	3.500	.102	.540
	4.000	.175	.836
	Cap	.275	.803
7	1.375	.860	.300
	1.750	.154	.491
	2.000	.275	.611
	2.500	.524	.860
	3.000	.774	.212
	3.500	.415	.674
	4.000	.712	.154
	4.500	.197	.443
	5.000	.275	.750
	Cap	.674	.112
8	1.375	.363	
	1.750	.550	
	2.000	.674	
	2.500	.925	
	3.000	.275	Not
	3.500	.728	Available
	4.000	.212	
	4.500	.509	
	5.000	0	
	5.500	.300	
	Cap	.175	

H & HV Series

		Spacer 'T' Dimension In Inches			
		All Except Model 67/68 @ Pos. 2 or 4		Model 67/68 @ Pos. 2 or 4	
Bore	Rod	H Series	HV Series	H Series	HV Series
1 1/2	.625	1.274	1.274	1.212	1.212
	1.000	.654	1.425	1.400	1.360
	Cap	1.274	1.024	1.212	.962
2	1.000	.175	.175	.154	.154
	1.375	.363	.314	.336	.300
	Cap	.212	.900	.774	.649
2 1/2	1.000	.154	.154	.712	.712
	1.375	.112	.112	.900	.900
	1.750	.348	.250	.314	.232
	Cap	.774	.649	.524	.400
3 1/4	1.375	.649	.649	.154	.154
	1.750	.884	.884	.381	.381
	2.000	.212	.212	.524	.524
	Cap	.275	.275	.674	.674
4	1.750	.630	.630	.134	.134
	2.000	.774	.774	.275	.275
	2.500	.275	.275	.587	.587
	Cap	.212	.836	.611	.425
5	2.000	.836	.836	.112	.112
	2.500	.336	.336	.425	.425
	3.000	.630	.649	.712	.737
	3.500	.102	.774	.102	.860
	Cap	.462	.275	.524	.336
6	2.500	.649	.649	.462	.462
	3.000	.122	.154	.750	.774
	3.500	.415	.275	.250	.112
	4.000	.712	.462	.550	.300
	Cap	.154	.674	N/A	N/A
7	3.000	.443	.462	N/A	N/A
	3.500	.728	.649	.348	.275
	4.000	.212	.900	.649	.524
	4.500	.509	.336	.154	.774
	5.000	0	.587	.462	.232
	Cap	.737	.363	N/A	N/A
8	3.500	.232	.154	N/A	N/A
	4.000	.524	.400	N/A	N/A
	4.500	0	.649	.250	N/A
	5.000	.314	.900	.560	.336
	5.500	.611	.336	.860	.587
	Cap	.232	.836	N/A	N/A

AL Series

Bore	Rod	Spacer 'T' Dimension In Inches
1 1/2	.625	N/A
	Cap	1.274
2	.625	1.274
	1.000	.654
	Cap	1.024
2 1/2	.625	.212
	1.000	.175
	Cap	.774
3 1/4	1.000	.212
	1.375	.212
	Cap	.524
4	1.000	.674
	1.375	.674
	Cap	.154
5	1.000	.154
	1.375	.154
	Cap	.462
6	1.375	.774
	1.750	.774
	Cap	.988
8	1.375	.674
	1.750	.674
	Cap	.774

Inductive proximity switches are available in A, AL, J, H, and HV series cylinders. Cylinders must be cushioned on end where switch is mounted. Specify "Inductive Proximity Switch" and mounting location when ordering.

End-Of-Stroke Magnetic Type

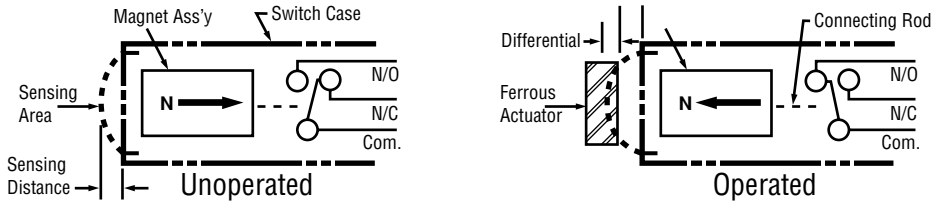
- **Reliable** - Proximity type sensor never contacts cylinder moving parts; eliminating wear and adjustments.
- **Positive action** - Multiple magnet design provides "snap action". Eliminates creep and false signals.
- **Versatile** - Sealed stainless steel switch body can be used with any operating fluid and is impervious to most environmental conditions.

Operating Principal

As shown in the diagrams following, the switches are magnetically operated. Dual magnets provide a dependable "snap action" for positive position sensing.

In the **unoperated** position, the magnet assembly is attracted in the direction of the arrow, causing a finely ground stainless steel connecting rod to hold the contacts open.

In the **operated** position a ferrous part (cylinder cushion plunger or piston) enters the sensing area and attracts the magnet assembly, which causes the rod to draw the contacts closed.



Specifications

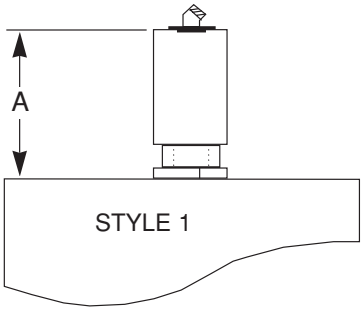
Approved switches are in compliance with current bulletins 1243, 1273 and 1308.

Contacts - Single pole - Double Throw; can be wired as normally closed or normally open.
Contact Rating*: - 2 Amp at 110-240 VAC (UL & CSA); 100MA at 12 VDC 50 MA at 24 VDC (CSA).
Note: Check current draw of solenoid valves.
* UL and CSA approved for industrial control, general-purpose use. If Class 1, Division 1 or 2 is required, please specify.
Leads - 18" long, 3 wire, potted in cable. Leads are tagged 'Com', 'N/O', 'N/C'.
Pressure Rating - 3,000 psi non-shock.
Temperature Range - -20°F to +200°F (UL 104°F max.)
Sensing Gap - .030 to .060 inch.
Trip Pont - Factory set with piston bottomed out.
Release Point - Approximately 1/4" piston travel. Minimum stroke $\frac{1}{2}$" on $1\frac{1}{2}$" & 2" bore, $\frac{3}{4}$" stroke on $2\frac{1}{2}$" and up.

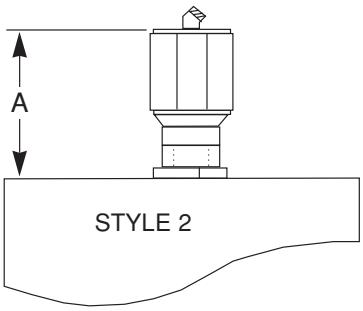
Switch Options:

Pressure ratings to 5,000 psi
Quick disconnect
Explosion proof
Sub sea, to 2,000 foot depths
Extra-long leads

Switch Extension for Standard Side Position Installation*



Standard location for switch mounting is any available side position. Please specify side location (1,2,3 or 4) desired. Cylinders are standardized. Models 67/68 in position #2 & #4 require special machining.



End-of-Stroke Magnetic Type Switch

A & J Series

		Switch Extension In Inches							
		All Except Model 67/68 @ Pos. 2 or 4				Model 67/68 @ Pos. 2 or 4			
		Head		Cap		Head		Cap	
Bore	Rod	A	Style	A	Style	A	Style	A	Style
1 1/2	.625	2.83	1	2.83	1	2.45	1	2.45	1
	1.000	3.02	1	2.83	1	N/A	N/A	2.45	1
2	.625	2.58	1	2.58	1	3.09	2	3.09	2
	1.000	2.77	1	2.58	1	2.33	1	3.09	2
	1.375	2.95	1	2.58	1	N/A	N/A	3.09	2
2 1/2	.625	2.33	1	2.33	1	2.90	2	2.90	2
	1.000	2.52	1	2.33	1	3.09	2	2.90	2
	1.375	2.70	1	2.33	1	2.33	1	2.90	2
	1.750	2.89	1	2.33	1	N/A	N/A	2.90	2
3 1/4	1.000	3.09	2	2.90	2	2.65	2	2.46	2
	1.375	3.28	2	2.90	2	2.84	2	2.46	2
	1.750	3.46	2	2.90	2	3.03	2	2.46	2
	2.000	3.59	2	2.90	2	3.15	2	2.46	2
4	1.000	2.71	2	2.53	2	2.40	2	2.21	2
	1.375	2.90	2	2.53	2	2.59	2	2.21	2
	1.750	3.09	2	2.53	2	2.78	2	2.21	2
	2.000	3.21	2	2.53	2	2.90	2	2.21	2
	2.500	3.46	2	2.53	2	3.15	2	2.21	2
5	1.000	2.21	2	2.03	2	3.25	2	3.06	2
	1.375	2.40	2	2.03	2	1.93	2	3.06	2
	1.750	2.59	2	2.03	2	2.12	2	3.06	2
	2.000	2.71	2	2.03	2	2.24	2	3.06	2
	2.500	2.96	2	2.03	2	2.49	2	3.06	2
	3.000	3.21	2	2.03	2	2.74	2	3.06	2
	3.500	3.67	2	2.03	2	3.20	2	3.06	2
6	1.375	1.90	2	3.22	2	3.03	2	2.84	2
	1.750	2.09	2	3.22	2	3.22	2	2.84	2
	2.000	2.21	2	3.22	2	1.84	2	2.84	2
	2.500	2.46	2	3.22	2	2.09	2	2.84	2
	3.000	2.71	2	3.22	2	2.34	2	2.84	2
	3.500	3.17	2	3.22	2	2.79	2	2.84	2
	4.000	3.46	2	3.22	2	3.09	2	2.84	2
7	1.375	2.90	2	2.72	2	2.34	2	2.15	2
	1.750	3.09	2	2.72	2	2.53	2	2.15	2
	2.000	3.22	2	2.72	2	2.65	2	2.15	2
	2.500	1.96	2	2.72	2	2.90	2	2.15	2
	3.000	2.21	2	2.72	2	3.15	2	2.15	2
	3.500	2.67	2	2.72	2	2.10	2	2.15	2
	4.000	2.96	2	2.72	2	2.40	2	2.15	2
	4.500	3.26	2	2.72	2	2.70	2	2.15	2
	5.000	3.56	2	2.72	2	3.00	2	2.15	2
8	1.375	2.40	2	2.22	2				
	1.750	2.59	2	2.22	2				
	2.000	2.72	2	2.22	2				
	2.500	2.97	2	2.22	2				
	3.000	3.22	2	2.22	2	N/A		N/A	
	3.500	2.17	2	2.22	2				
	4.000	2.46	2	2.22	2				
	4.500	2.76	2	2.22	2				
	5.000	3.06	2	2.22	2				
	5.500	3.36	2	2.22	2				

End-of-Stroke Magnetic Type Switch

H Series

		Switch Extension In Inches							
		All Except Model 67/68 @ Pos. 2 or 4				Model 67/68 @ Pos. 2 or 4			
		Head		Cap		Head		Cap	
Bore	Rod	A	Style	A	Style	A	Style	A	Style
1 1/2	.625	2.58	1	2.58	1	2.65	2	2.65	2
	1.000	2.77	1	2.58	1	2.84	2	2.65	2
2	1.000	2.52	1	2.33	1	2.40	2	2.21	2
	1.375	2.70	1	2.33	1	2.59	2	2.21	2
2 1/2	1.000	3.21	2	3.03	2	2.15	2	1.96	2
	1.375	3.40	2	3.03	2	2.34	2	1.96	2
	1.750	3.63	2	3.03	2	2.57	2	1.96	2
3 1/4	1.375	2.90	2	2.53	2	3.09	2	2.72	2
	1.750	3.13	2	2.53	2	3.33	2	2.72	2
	2.000	3.28	2	2.53	2	1.96	2	2.72	2
4	1.750	2.88	2	2.46	2	3.08	2	2.65	2
	2.000	3.03	2	2.46	2	3.22	2	2.65	2
	2.500	3.34	2	2.46	2	2.03	2	2.65	2
5	2.000	2.28	2	1.90	2	2.15	2	1.78	2
	2.500	2.59	2	1.90	2	2.47	2	1.78	2
	3.000	2.88	2	1.90	2	2.76	2	1.78	2
	3.500	3.17	2	1.90	2	3.04	2	1.78	2
6	2.500	2.09	2	3.14	2				
	3.000	2.38	2	3.14	2	N/A		N/A	
	3.500	2.67	2	3.14	2				
	4.000	2.96	2	3.14	2				
7	3.000	1.88	2	2.78	2				
	3.500	2.17	2	2.78	2	N/A		N/A	
	4.000	2.46	2	2.78	2				
	4.500	2.76	2	2.78	2				
	5.000	3.06	2	2.78	2				
8	3.500	3.17	2	2.28	2				
	4.000	1.96	2	2.28	2				
	4.500	2.26	2	2.28	2	N/A		N/A	
	5.000	2.56	2	2.28	2				
	5.500	2.86	2	2.28	2				

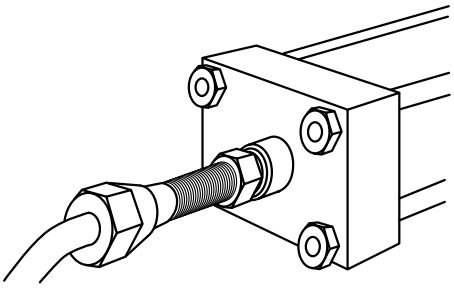
End-of-Stroke Magnetic Type Switch

HV Series

		Switch Extension In Inches							
		All Except Model 67/68 @ Pos. 2 or 4				Model 67/68 @ Pos. 2 or 4			
		Head		Cap		Head		Cap	
Bore	Rod	A	Style	A	Style	A	Style	A	Style
1½	.625	2.58	1	2.33	1	2.65	2	2.40	2
	1.000	2.70	1	2.33	1	2.78	2	2.40	2
2	1.000	2.52	1	2.20	1	2.40	2	3.59	2
	1.375	2.64	1	2.20	1	2.53	2	3.59	2
2½	1.000	2.27	2	2.90	2	3.65	2	3.34	2
	1.375	2.45	2	2.90	2	2.34	2	3.34	2
	1.750	2.58	2	2.90	2	2.46	2	3.34	2
3¼	1.375	2.90	2	2.53	2	3.09	2	2.72	2
	1.750	3.13	2	2.53	2	3.33	2	2.72	2
	2.000	2.33	2	2.53	2	3.47	2	2.72	2
4	1.750	2.88	2	2.28	2	3.08	2	2.47	2
	2.000	3.03	2	2.28	2	3.22	2	2.47	2
	2.500	2.39	2	2.28	2	3.53	2	2.47	2
5	2.000	2.28	2	3.22	2	2.15	2		
	2.500	2.59	2	3.22	2	2.47	2	N/A	
	3.000	2.90	2	3.22	2	2.78	2		
	3.500	3.03	2	3.22	2	2.90	2		
6	2.500	3.59	2	2.72	2				
	3.000	2.40	2	2.72	2	N/A		N/A	
	3.500	2.53	2	2.72	2				
	4.000	2.71	2	2.72	2				
7	3.000	3.40	2	2.40	2				
	3.500	3.59	2	2.40	2	N/A		N/A	
	4.000	2.34	2	2.40	2				
	4.500	2.59	2	2.40	2				
	5.000	2.84	2	2.40	2				
8	3.500	3.09	2	2.09	2				
	4.000	3.34	2	2.09	2				
	4.500	3.59	2	2.09	2	N/A		N/A	
	5.000	2.34	2	2.09	2				
	5.500	2.59	2	2.09	2				

* The depth to which a switch is installed may vary and still be in sensing range. Therefore, the calculated extension of the switch is approximate.

Switches can be optionally mounted in the cap rear face. Cushioning is not required to operate a switch mounted in this location.



Magnetic principle proximity switches are available in A, AL, J, H, and HV series cylinders. Cylinders must be cushioned on end where switch is mounted in a side position. Specify “Magnetic Principle Proximity Switch” and mounting location when ordering.

Reed and Hall Effect Switches

Provides high quality accuracy in detection of piston position.

Single-color and Bi-color-Proximity switches available to meet your production needs.

Adjustable position, external reed and Hall Effect switches are an available option for AL Series aluminum pneumatic cylinders. Miller limit switches are compact and reliable. Because of their low profile, and secure mounting brackets, the chance of damage by in advertent physical contact is remote. They have been thoroughly tested and proven to provide years of trouble-free service.

The piston contains a ring magnet that is sensed through the aluminum cylinder tube and “closes” the switch as the magnet passes. These switches are hermetically sealed and all electrical components are epoxy encapsulated.

These limit switches can be used, in almost any number, with a Miller AL Series cylinder equipped with a magnetic piston. The switches are easily attached to the tie rods. Switches require magnet output of 100-150 gauss at the tube OD for reliable operation. Specify a piston magnet when ordering a cylinder that is to operate switches.

Single or bi-color indicating lights are available on switches to help improve mounting position accuracy. Hall effect switches can be wired to provide either ‘sink’ or ‘source’ type output. See AL series catalog (bulletin number 8564) for detailed Switch Specifications, switch operation, and wiring options.

Cylinder Valve Packages

Integrally mounted valves offer faster response characteristics, improved system stiffness, and protection against hose failure.

Servo and Proportional Control
It is recommended that servo valve packages be mounted directly to the cylinder to provide the smallest column of fluid between the cylinder and the valve. Any additional volume of fluid introduces elasticity, which results in reduced response and accuracy.

Relief
Relief valve packages, pressure limiting and regulating devices directly mounted to the cylinder improve system response.

Load Holding Pilot Operated Check
Load holding pilot check valves can lock loads with zero or near zero leakage for extended periods (typically 30 minutes or more). Pilot operated check valves are on/off devices that allow free flow through a check valve in one direction and then block reverse flow until a pilot pressure is introduced, opening the check seat releasing the load.

Motion Control Counterbalance
Motion control counterbalance valves are modulating devices that allow free flow in one direction and then block reverse flow until a pilot pressure is introduced, opening a relief to control flow of overrunning loads.

Pre-Fill
Pre-fill valves provide leak-free closure in the checked direction and reverse free flow in the other direction. Pre-fill valves are large ported valves that allow higher flow with very low pressure drops. Pre-fill valves permit large bore, long stroke cylinders to stroke rapidly and gravity fill with oil. This may eliminate the need for very large displacement pumps.

Installation Advice

Mounting Fasteners and Accessories
It is very important that cylinders be properly secured to the equipment. To achieve this, bolts must be of appropriate strength and torqued to withstand the forces imparted by the cylinder.

- Fasteners should be minimum SAE Grade 8 (150,000 psi minimum tensile, 130,000 minimum yield).
- Miller recommends that cylinder and mounting accessory bolts be torqued to the foot-pound values listed in the tables following.

A & J Series

Cylinder Bore	Mounting Bolt (or nut) Torque in foot-pounds (Dry)							
	Models 51, 52, 53, 54	Models 61, 62, 67, 68	Models 65, 66	Models 72, 73	Model 74	Model 77	Eye Bracket (Models 84, 86)	Clevis Bracket (Model 90)
1½	6	5	3	22	10	4	7	7
2	11	11	6	22	20	11	14	14
2½	11	11	6	22	36	11	13	13
3¼	42	32	20	62	88	22	49	49
4	42	32	13	62	88	22	46	46
5	60	78	31	242	174	62	49	59
6	72	84	44	242	336	62	105	105
7	72	N/A	N/A	242	336	133	96	96
8	112	N/A	N/A	242	336	133	127	127
10	375	N/A	N/A	750	726	242	196	198
12	300	N/A	N/A	750	726	242	401	401
14	445	N/A	N/A	1200	1200	398	621	621
16	352	N/A	N/A	1200	1200	610	511	511
18	510	N/A	N/A	1200	1200	886	725	725
20	637	N/A	N/A	1200	1200	1200	900	900

H & HV Series

Cylinder Bore	Mounting Bolt (or nut) Torque in Foot-Pounds (Dry)								
	Models 51, 52, 53, 54	Models 61, 62	Models 65, 66	Models 67, 68	Models 72, 73	Model 74	Model 77	Eye Bracket (Models 84, 86)	Clevis Bracket (Model 90)
1 1/2	16	8	9	15	22	22	22	7	10
2	16	26	20	36	62	62	62	30	30
2 1/2	25	18	32	56	242	242	62	30	30
3 1/4	45	41	68	119	242	242	133	55	55
4	73	67	82	180	610	610	133	70	100
5	135	134	179	394	610	610	398	235	245
6	188	205	221	648	1200	1200	610	400	395
7	295	246	338	992	2100	2100	886	555	445
8	450	297	473	1440	2100	2100	1237	810	745

H Series

Cylinder Bore	Mounting Bolt Torque in Foot-Pounds (Dry)			
	Models 63, 64	Models 72, 73	Eye Bracket (Models 84, 86)	Clevis Bracket (Model 90)
10	900	2100	1280	1395
12	864	2100	1875	2345
14	882	2100	3430	N/A
16	768	N/A	5080	N/A
18	972	N/A	7105	N/A
20	800	N/A	10400	N/A

Piston Rod Attachment & Rod Accessories

When attaching machinery components or rod clevises, rod eyes, etc. to Miller Style 2 (threaded on turndown section) or Style 4 (internally threaded) piston rod ends, the attachments should be tightened to the torques given in Piston Rod Torque Chart. This torque or pre-stress triples the fatigue strength of the rod's threaded section and makes a stronger assembly than attaching the machinery component to a full diameter threaded rod (Style 1) and torquing it against a lock nut.

Miller recommends the Style 2 (threaded on turndown section) rod for most applications. Its square shoulder design helps assure proper alignment of cylinder to mechanism, eliminates need for a jam nut, provides fixed point for more accurate cylinder positioning, and simplifies piloting to full rod diameter into mating part.

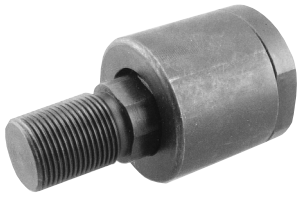
Piston Rod Torque

Thread Size	Torque In ft./lbs. *
7/16-20	36
3/4 -16	125
1-14	250
1 1/4 -12	460
1 1/2 -12	663
1 7/8-12	944
2 1/4 -12	1315
2 1/2 -12	5050
3-12	7070
3 1/4 -12	7940
3 1/2 -12	12760
4-12	12560

* Recommended torques (ft./lbs.) with MoS_2 (Molybdenum Disulfide) lubricant or equivalent.

Alignment

Rod End Couplers - Good machine design practice requires that proper alignment be maintained to avoid excessive bearing loads. The Miller linear alignment rod end coupler can reduce minor cylinder misalignment problems, within design limitations. These couplers can be used for both push and pull applications. Couplers allow 1/16-inch radial float and 10 degree total movement in sizes with 7/16-20 to 2-12 threads. See individual cylinder catalogs for part number and dimensional data.



Cautions

Welding on Machinery - When performing welding operations on equipment or machinery that has hydraulic or pneumatic cylinders attached, the piston rod attachment must be grounded to the cylinder to prevent internal arcing.

Spring Operated Cylinders - Some Miller cylinders are supplied with an internal spring to extend or retract the piston and rod. In these cases a warning label is affixed on the cylinder tube cautioning the user that a spring, under **HIGH** compression is installed within the cylinder. Improper disassembly can be extremely dangerous and may cause serious injury. Disassembly and reassembly should be done only in strict compliance with service procedure (File #7739) utilizing extended tie rods. File #7739 is available upon request.

Non-Rotating Cylinders - Miller cylinders supplied with a non-rotating option are identified with a yellow caution sticker on the tube OD. Hold the piston rod securely, at the wrench flats, to prevent it from rotating when threading onto its attachment. Rotation of the rod will cause damage to the cylinder's internal anti-rotation mechanism.

Cylinder Lifting - Care should be taken when lifting and moving a cylinder. Whenever possible the cylinder should be lifted and moved with the piston rod in a horizontal position. If a cylinder must be transported with the piston rod vertical, do so with the rod pointing up; do not lift the cylinder by the piston rod. To help retain the piston rod within the cylinder during transportation, leave the port shipping plugs in place.

Cylinder Weight Tables

Weights listed in tables following are intended for shipping purposes only and do not include packaging or fluids. Values shown represent the highest weight for the group of mountings at the top of the column. **All weights are expressed in pounds.**

For exact weights of individual models, contact Miller Application Engineering.

H & HV Series (Weights in Pounds)

Cylinder Bore	Piston Rod Diameter	Single Rod End Cylinder Models Weight @ Zero Stroke			Single Rod End Weight Per Inch Of Stroke	Double Rod End Cylinder Models Weight @ Zero Stroke		Double Rod End Weight Per Inch Of Stroke
		51, 52, 53, 74, 77, 81, 82, 84, 90, 94	61, 62, 67, 68, 72, 73, 86	65, 66, 89		51, 53, 61, 67, 72, 74, 77, 81	65, 89	
1 1/2	5/8	7.8	9.6	10.0	0.5	10.4	10.9	0.6
	1	8.3	10.1	10.5	0.6	11.4	11.8	0.8
2	5/8	12.4	14.4	16.3	0.8	16.0	17.4	1.0
	1	13.3	15.3	16.8	1.0	17.8	19.1	1.4
2 1/2	1	16.7	19.2	21.1	1.0	21.0	22.9	1.3
	1 3/8	17.6	20.1	22.0	1.2	22.8	24.7	1.6
	1 3/4	18.8	21.3	23.2	1.5	25.2	27.1	2.2
3 1/4	1 3/8	32.1	36.5	40.5	1.7	39.6	43.8	2.1
	1 3/4	33.3	37.7	41.7	2.0	42.1	46.2	2.6
	2	34.3	38.7	42.8	2.2	44.2	48.3	3.1
4	1 1/2	45.7	49.7	54.6	2.5	53.0	57.9	3.1
	2	46.7	50.7	55.7	2.7	54.8	59.7	3.5
	2 1/2	49.6	53.6	58.6	3.2	60.4	64.9	4.5
5	2	81.4	86.2	94.0	3.9	91.4	99.3	4.8
	2 1/2	84.3	89.1	96.9	4.4	96.6	104.5	5.8
	3	87.8	92.5	100.3	5.1	102.6	110.4	7.1
	3 1/2	90.6	95.3	103.2	5.8	110.2	115.2	8.5
6	2 1/2	126.2	136.2	148.1	5.1	140.4	152.4	6.5
	3	129.6	139.6	151.5	5.7	146.3	158.4	7.7
	3 1/2	132.4	142.4	154.3	6.4	151.0	164.0	9.1
	4	138.7	148.7	160.6	7.3	165.3	176.6	10.8
7	3	192.5	200.7	220.3	6.7	208.6	231.3	8.7
	3 1/2	195.4	203.6	223.2	7.5	214.4	237.1	10.2
	4	201.1	209.3	228.8	8.3	225.7	248.4	11.9
	4 1/2	206.1	214.3	233.9	9.2	235.9	258.5	13.7
	5	211.9	220.1	239.7	10.3	247.5	270.1	15.9
8	3 1/2	266.0	275.8	311.0	8.8	288.3	324.9	11.5
	4	271.7	281.4	316.7	9.6	299.6	336.2	13.2
	4 1/2	276.7	286.5	321.8	10.6	309.7	346.4	15.1
	5	282.5	292.3	327.5	11.6	321.3	357.9	17.2
	5 1/2	291.5	301.2	336.5	12.8	339.2	375.8	19.5

H Series – Large Bores (Weights in Pounds)

Cylinder Bore	Piston Rod Diameter	Single Rod End Cylinder Models Weight @ Zero Stroke		Weight Per Inch Of Stroke	Double Rod End Cylinder Models Weight @ Zero Stroke		Weight Per Inch Of Stroke
		63, 64, 72, 73, 81, 82,	84, 89, 90		63, 72, 81	89	
10	4 1/2	557.0	648.1	14.7	584.7	675.8	19.2
	5	564.9	656.0	15.8	600.5	691.6	21.3
	5 1/2	574.9	666.0	17.0	620.6	711.6	23.7
	7	622.5	713.5	21.1	715.7	806.7	32.0
12	5 1/2	968.3	1096.0	21.5	1014.0	1141.7	28.2
	7	1015.9	1143.6	25.7	1109.1	1236.8	36.6
	8	1040.2	1167.9	29.0	1157.7	1285.4	43.2
14	7	1465.9	1466.5	28.3	1559.1		39.1
	8	1490.2	1490.8	31.6	1607.8	N/A	45.8
	9	1530.1	1530.7	35.4	1687.5		53.4
	10	1570.1	1570.7	39.6	1767.6		61.8
16	8	2062.6	2324.3	37.0	2180.1		51.2
	9	2102.5	2364.2	40.8	2259.8	N/A	58.8
	10	2142.5	2404.3	45.0	2339.9		67.2
18	9	2937.5	3343.0	51.6	3094.9	N/A	69.6
	10	2977.5	3383.1	55.8	3175.0		78.1
20	10	4081.3	4642.4	59.8	4278.8	N/A	82.0

AL Series (Weights in Pounds)

Cylinder Bore	Piston Rod Diameter	Single Rod End Cylinder Models Weight @ Zero Stroke		Weight Per Inch Of Stroke	Double Rod End Cylinder Models Weight @ Zero Stroke		Weight Per Inch Of Stroke
		51, 52, 53, 71, 77, 81, 82	61, 62, 72, 84, 86, 89, 96		51, 53, 71, 77, 81	61, 72, 89	
1 1/2	5/8	2.4	3.1	0.2	2.0	2.7	0.3
2	5/8	3.2	4.0	0.2	2.6	3.4	0.4
	1	3.9	4.7	0.4	3.3	4.1	0.7
2 1/2	5/8	4.5	5.2	0.3	3.7	4.3	0.4
	1	5.2	5.9	0.4	4.4	5.0	0.7
3 1/4	1	8.3	10.6	0.5	6.6	8.3	0.7
	1 5/8	9.6	11.9	0.7	7.9	9.6	1.2
4	1	11.3	14.0	0.5	8.8	11.1	0.8
	1 3/8	12.6	15.3	0.7	10.1	12.4	1.2
5	1	17.4	20.9	0.6	13.7	17.2	0.9
	1 3/8	18.7	22.2	0.8	15.0	18.5	1.4
6	1 3/8	26.8	34.0	0.9	20.7	27.3	1.4
	1 3/4	28.6	35.7	1.1	22.5	29.0	2.0
8	1 3/8	45.9	61.0	1.2	35.4	40.8	1.7
	1 3/4	47.7	62.7	1.5	37.2	42.6	2.3

LA Cylinders (Weights in Pounds)

Cylinder Bore	Piston Rod Diameter	Single Rod End Cylinder Weight @ Zero Stroke	Weight Per Inch Of Stroke	Double Rod End Cylinder Weight @ Zero Stroke	Weight Per Inch Of Stroke
3 1/4	1	10.3	0.69	10.4	0.91
4	1	15.8	0.76	15.9	0.98
5	1	23.7	0.95	239	1.17
6	1	35.3	1.10	35.5	1.32
7	1	50.3	1.57	50.5	1.79
8	1	66.7	2.17	66.9	2.40
10	1	124.3	2.71	124.6	2.93
12	1 3/8	172.4	3.31	172.8	3.73
14	1 3/8	267.9	3.87	268.3	4.29
16	1 3/4	371.3	6.02	372.1	6.70
18	1 3/4	535.7	6.99	537.0	7.88
20	2	746.8	10.11	748.1	10.99

A & J Series (Weights in Pounds)

Cylinder Bore	Piston Rod Diameter	Single Rod End Cylinder Models Weight @ Zero Stroke			Single Rod End Weight Per Inch Of Stroke	Double Rod End Cylinder Models Weight @ Zero Stroke		Double Rod End Weight Per Inch Of Stroke
		51, 52, 53, 61, 67, 68, 72, 73, 74, 81, 82	62, 65, 66, 77, 86	89		51, 53, 61, 65, 67, 72, 73, 74, 77, 81	89	
1 1/2	5/8	4.9	5.2	6.0	0.3	5.9	6.9	0.4
	1	5.1	5.8	6.7	0.4	6.9	8.2	0.7
2	5/8	7.0	7.9	8.7	0.4	8.9	9.9	0.5
	1	7.4	8.7	9.3	0.5	9.9	11.1	0.7
	1 3/8	8.2	9.4	10.2	0.7	11.5	12.9	1.1
2 1/2	5/8	10.2	11.1	12.0	0.4	12.5	13.6	0.5
	1	10.5	11.8	12.6	0.6	13.5	14.9	0.8
	1 3/8	11.3	13.0	13.5	0.8	15.4	16.7	1.2
	1 3/4	12.3	13.9	14.8	1.0	17.6	19.1	1.7
3 1/4	1	19.5	21.8	22.9	0.7	24.3	25.9	0.9
	1 3/8	20.1	22.7	23.8	0.9	25.6	27.6	1.3
	1 3/4	20.9	23.9	25.0	1.2	27.7	30.1	1.8
	2	21.7	25.9	26.0	1.4	29.5	32.1	2.2
4	1	27.7	30.2	31.3	0.8	34.5	35.2	1.0
	1 3/8	28.2	31.1	32.2	1.0	35.6	36.9	1.4
	1 3/4	29.1	32.3	33.4	1.2	37.4	39.4	1.9
	2	29.9	33.3	34.5	1.4	39.0	41.4	2.3
	2 1/2	32.4	36.3	37.4	1.9	44.2	47.3	3.3
5	1	42.9	46.4	46.4	1.0	52.9	51.7	1.2
	1 3/8	43.5	47.2	47.3	1.2	54.1	53.5	1.6
	1 3/4	44.4	48.5	48.5	1.4	55.8	55.9	2.1
	2	45.2	49.5	49.6	1.6	57.4	57.9	2.5
	2 1/2	47.6	52.4	52.5	2.1	62.3	63.8	3.5
	3	50.4	55.8	55.9	2.7	68.0	70.6	4.7
	3 1/2	52.6	58.7	58.7	3.5	73.0	76.3	6.2
6	1 3/8	67.9	72.8	75.7	1.3	83.7	83.5	1.7
	1 3/4	68.7	74.0	76.9	1.6	85.4	85.9	2.2
	2	69.5	75.0	77.9	1.8	86.9	88.0	2.7
	2 1/2	71.9	78.0	80.8	2.3	91.6	93.8	3.7
	3	74.6	81.4	84.2	2.9	97.0	100.7	4.9
	3 1/2	76.7	84.2	87.1	3.6	101.2	106.3	6.3
	4	81.1	90.5	93.4	4.4	110.5	118.9	8.0
7	1 3/8	82.2	95.4	102.9	1.8	93.1	112.8	2.2
	1 3/4	83.4	96.6	104.2	2.0	95.5	115.2	2.7
	2	84.5	97.7	105.2	2.2	97.6	117.2	3.1
	2 1/2	87.4	100.6	108.1	2.7	103.5	123.1	4.1
	3	90.8	104.0	111.5	3.3	110.3	129.9	5.4
	3 1/2	93.6	106.9	114.4	4.1	115.9	135.6	6.8
	4	99.9	113.1	120.6	4.9	128.5	148.2	8.5
	4 1/2	105.0	118.2	125.7	5.9	138.6	158.3	10.4
	5	110.8	124.0	131.5	6.9	149.1	169.9	12.5
8	1 3/8	101.8	106.6	134.0	2.4	118.7	146.0	2.8
	1 3/4	103.0	107.8	135.2	2.6	121.1	148.4	3.3
	2	104.0	108.9	136.2	2.8	123.2	150.5	3.7
	2 1/2	106.9	111.8	139.1	3.3	129.1	156.4	4.7
	3	110.4	115.2	142.5	4.0	135.9	163.2	6.0
	3 1/2	113.2	118.1	145.4	4.7	141.5	168.9	7.4
	4	119.5	124.3	151.7	5.5	154.1	181.4	9.1
	4 1/2	124.5	129.4	156.7	6.5	164.2	191.5	11.0
	5	130.3	135.2	162.5	7.5	175.8	203.1	13.1
	5	139.3	144.4	171.4	8.7	193.7	221.0	15.4
10	1 3/4	196.6	202.5	251.4	3.2	205.6	254.5	3.9
	2	197.7	203.6	252.5	3.4	207.6	256.5	4.3
	2 1/2	200.6	206.5	255.4	3.9	213.5	262.4	5.3
	3	204.0	209.9	258.8	4.5	220.3	269.2	6.5
	3 1/2	206.8	212.7	261.6	5.2	226.0	274.9	7.9
	4	213.1	219.0	267.9	6.1	238.6	287.5	9.6
	4 1/2	218.2	224.1	273.0	7.0	248.7	297.6	11.5
	5	224.0	229.9	278.8	8.1	260.3	309.2	13.6
	5 1/2	232.9	238.8	287.7	9.2	278.1	327.0	15.9
12	2	300.6	305.2	375.0	3.8	309.3	379.1	4.7
	2 1/2	303.6	308.1	378.0	4.3	315.1	385.0	5.7
	3	307.0	311.5	381.4	4.9	322.0	391.8	6.9
	3 1/2	309.8	314.3	384.2	5.6	327.6	397.5	8.3
	4	316.1	320.6	390.5	6.5	340.2	410.0	10.0
	4 1/2	321.2	325.7	395.6	7.4	350.3	420.2	11.9
	5	327.0	331.5	401.3	8.5	361.9	431.7	14.0
	5 1/2	335.9	340.4	410.3	9.6	379.8	449.6	16.3
14	2 1/2	474.0	483.5	599.9	4.8	490.5	606.9	6.2
	3	477.4	486.9	603.3	5.5	497.3	613.7	7.5
	3 1/2	480.2	489.7	606.1	6.2	503.0	619.4	8.9
	4	486.5	496.0	612.4	7.0	515.5	632.0	10.6
	4 1/2	491.5	501.1	617.5	8.0	525.7	642.1	12.5
	5	497.3	506.9	623.3	9.0	537.3	653.7	14.6
	5 1/2	506.3	515.8	632.2	10.2	555.1	671.5	16.9
16	2 1/2	583.7	602.3		6.7	609.3		8.1
	3	587.1	605.7		7.3	616.1		9.3
	3 1/2	590.0	608.5		8.1	621.8		10.8
	4	596.2	614.8	N/A	8.9	634.3	N/A	12.5
	4 1/2	601.3	619.8		9.8	644.4		14.3
	5	607.1	625.6		10.9	656.0		16.5
	5 1/2	616.0	634.6		12.1	673.9		18.8
18	3	759.5	788.7		8.1	799.2		10.1
	3 1/2	762.3	791.6		8.8	804.8		11.6
	4	768.6	797.9	N/A	9.7	817.4	N/A	13.2
	4 1/2	773.7	802.9		10.6	827.5		15.1
	5	779.5	808.7		11.7	839.1		17.2
	5 1/2	788.4	817.7		12.8	857.0		19.6
20	3	967.0	1010.4		11.2	1020.8		13.2
	3 1/2	969.9	1013.2		11.9	1026.5		14.7
	4	976.1	1019.5	N/A	12.8	1039.1	N/A	16.3
	4 1/2	981.2	1024.6		13.7	1049.2		18.2
	5	987.0	1030.4		14.8	1060.8		20.3
	5 1/2	995.9	1039.3		15.9	1078.6		22.7

Universal Mounting Accessories (Weights in Pounds)

Rod Eye	Rod Clevis	Pivot Pin	Eye Bracket	Clevis Bracket	Rod End Coupler
057-RE001-44-20 0.3	057-RC001-44-20 0.5	057-PP001-50 0.1	057-EB001-50 0.9	170-MB86A-150-50 0.9	057-RCU01-44-20 0.5
057-RE001-75-16 1.1	057-RC001-75-16 1.4	057-PP001-75 0.4	057-EB001-75 3.0	170-MB86A-200-75 2.4	057-RCU01-63-18 0.5
057-RE001-100-14 2.4	057-RC001-100-14 2.8	057-PP001-100 0.8	057-EB001-100 5.9	170-MB86A-250-75 3.0	057-RCU01-75-16 1.3
057-RE001-125-12 5.5	057-RC001-125-12 6.8	057-PP001-138 2.0	057-EB001-138 10.3	170-MB86A-325-100 5.9	057-RCU01-100-14 3.4
057-RE001-150-12 10.5	057-RC001-150-12 12.0	057-PP001-175 3.9	057-EB001-175 19.2	170-MB86A-400-138 10.3	057-RCU01-125-12 3.3
057-RE001-188-12 14.0	057-RC001-188-12 16.2	057-PP001-200 5.1	057-EB001-200 33.2	170-MB86A-500-175 17.7	057-RCU01-150-12 8.5
057-RE001-225-12 24.9	057-RC001-225-12 27.9	057-PP001-250 9.4	057-EB001-250 47.6	170-MB86A-600-200 25.2	057-RCU01-188-12 8.5
057-RE001-250-12 32.3	057-RC001-250-12 31.3	057-PP001-300 13.7	057-EB001-300 70.3	170-MB86A-700-250 37.4	057-RCU02-225-12 35.3
057-RE001-325-12 60.8	057-RC001-325-12 69.8	057-PP001-350 24.4	057-EB001-350 172.3	170-MB86A-800-300 44.8	057-RCU02-250-12 45.3
057-RE001-350-12 89.4	057-RC001-350-12 N/A	057-PP001-400 35.4	057-EB001-400 280.4	170-MB86A-1000-350 118.7	057-RCU02-275-12 45.3
057-RE001-400-12 187.9	057-RC001-400-12 107.1			170-MB86A-1200-400 187.3	057-RCU01-300-12 45.3
					057-RCU01-325-12 115.0

Mounting Accessories for Spherical Bearing Models H94 & HV94 (Weights in Pounds)

Male Spherical Rod Eye	Pivot Pin	Clevis Bracket For Spherical Eye
057-SRE02-44-20 0.2	057-PP006-50 0.1	057-SMB01-50 2.5
057-SRE02-75-16 0.8	057-PP006-75 0.3	057-SMB01-75 4.9
057-SRE02-100-14 1.7	057-PP006-100 0.6	057-SMB01-100 10.2
057-SRE02-125-12 3.4	057-PP006-138 1.5	057-SMB01-138 17.3
057-SRE02-150-12 6.1	057-PP006-175 3.1	057-SMB01-175 36.5
057-SRE02-188-12 10.0	057-PP006-200 4.7	057-SMB01-200 62.6

Cylinder Storage Recommendations

1. Store cylinders in a clean, dry, protected area that has as little temperature variance as possible.
2. Store cylinders in a vertical position with the piston rod in an 'up' position.
3. Coat the entire cylinder inside with oil. Fill cylinders partially with oil, if practical.
4. Install protective plugs in all cylinder ports.
5. Apply a protective coating on any machined or critical mounting surfaces, including all threads and trunnions.

Cylinders which have been in storage over 30 days should be lubricated and cycled several times before they are installed on machines and subjected to actual loads. Should excessive breakloose and cycling pressure be noted, it may indicate the cylinder(s) had been damaged during shipment or storage.