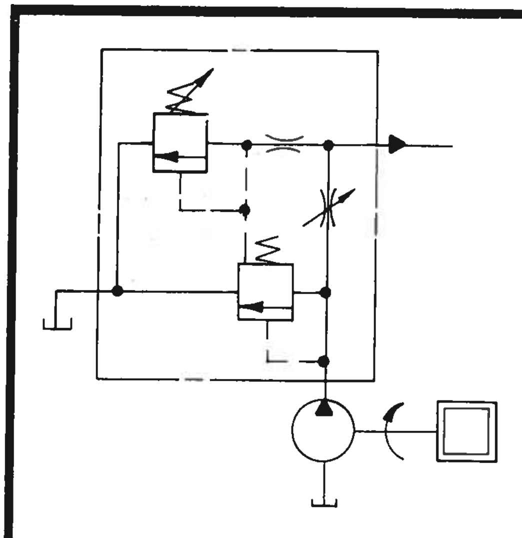
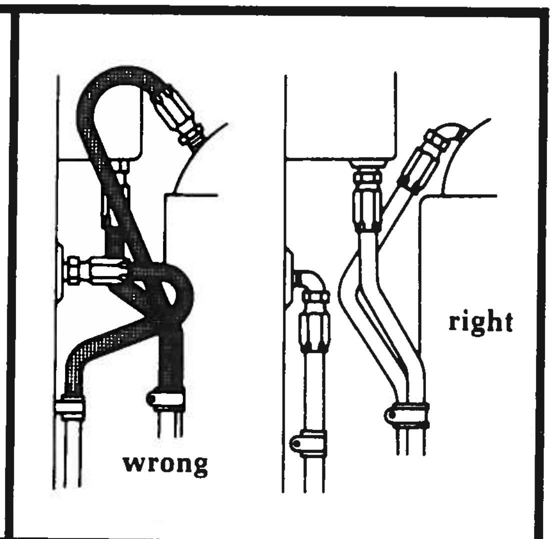
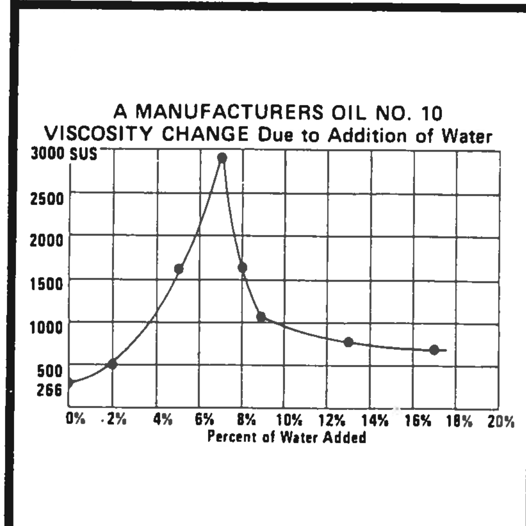
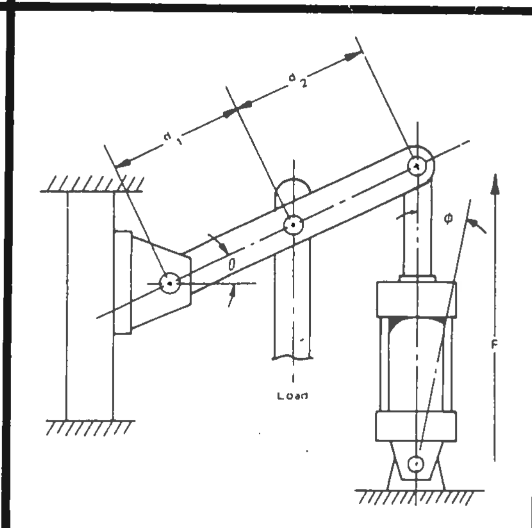
Design Engineers Handbook

Bulletin 0224-B1









Parker Fluidpower

theoretical push and pull forces for cylinders

CUSTOMARY U.S. UNITS

Cyl. Bore or Piston Rod. Dia. (in.)	Cyl. Bore Size (ϕ mm)	Area (sq. in.)	CYLINDER PUSH STROKE FORCE IN POUNDS AT VARIOUS PRESSURES (PSI)										Displacement per inch of Stroke (gallons)
			50	80	100	500	750	1000	1500	2000	2500	3000	
5/8	15.9	.307	15	25	31	154	230	307	461	614	768	921	.0013
1	25.4	.785	39	65	79	392	588	785	1,177	1,570	1,962	2,355	.0034
1-3/8	34.9	1.490	75	119	149	745	1,118	1,490	2,235	2,980	3,725	4,470	.0065
1-1/2	38.1	1.767	88	142	177	885	1,325	1,770	2,651	3,540	4,425	5,310	.00765
1-3/4	44.5	2.410	121	193	241	1,205	1,808	2,410	3,615	4,820	6,025	7,230	.0104
2	50.8	3.140	157	251	314	1,570	2,357	3,140	4,713	6,280	7,850	9,420	.0136
2-1/2	63.5	4.910	245	393	491	2,455	3,682	4,910	7,364	9,820	12,275	14,730	.0213
3	76.2	7.070	354	566	707	3,535	3,502	7,070	10,604	14,140	17,675	21,210	.0306
3-1/4	82.6	8.300	415	664	830	4,150	6,225	8,300	12,450	16,600	20,750	24,900	.0359
3-1/2	88.9	9.620	481	770	962	4,810	7,215	9,620	14,430	19,240	24,050	28,860	.0416
4	101.6	12.570	628	1,006	1,257	6,285	9,428	12,570	18,856	25,140	31,425	37,710	.0544
5	127.0	19.640	982	1,571	1,964	9,820	14,730	19,640	29,460	39,280	49,100	58,920	.0850
5-1/2	139.7	23.760	1,188	1,901	2,376	11,880	17,820	23,760	35,640	47,520	59,400	71,280	.1028
6	152.4	28.270	1,414	2,262	2,827	14,135	21,203	28,270	42,406	56,540	70,675	84,810	.1224
7	177.8	38.490	1,924	3,079	3,849	19,245	28,868	38,490	57,736	76,980	96,225	115,470	.1666
8	203.2	50.270	2,513	4,022	5,027	25,135	37,703	50,270	75,406	100,540	125,675	150,810	.2176
8-1/2	215.9	56.750	2,838	4,540	5,675	28,375	42,563	56,750	85,125	113,500	142,875	170,250	.2455
10	254.0	78.540	3,927	6,283	7,854	39,270	58,905	78,540	117,810	157,080	196,350	235,620	.3400
12	304.8	113.100	5,655	9,048	11,310	56,550	84,825	113,100	169,650	226,200	282,750	339,300	.4896

table b-1

NOTE: Deduct Force of Poston Rod Size from Bore Size for Pull Applications.

SI (METRIC) UNITS

Cyl. Bore or Piston Rod Dia. (in.)	Size in MM	Area in Sq. MM	CYLINDER PUSH FORCE IN NEWTONS AT VARIOUS PRESSURES IN BARS										Displacement for 1 MM of Stroke (Cu. MM)
			4	6.3	10	16	25	40	63	100	160	200	
5/8	15.87	197.9	79	125	198	317	495	792	1247	1979	3167	3959	197.9
1	25.40	506.7	203	319	507	811	1267	2027	3192	5067	8107	10134	506.7
1-3/8	34.93	958.0	383	604	958	1533	2395	3832	6035	9580	15328	19160	958.0
1-1/2	38.10	1140.1	456	718	1140	1824	2850	4560	7183	11401	18242	22802	1140.1
1-3/4	44.45	1551.8	621	978	1552	2483	3879	6207	9776	15518	24829	31036	1551.8
2	50.80	2026.9	811	1277	2027	3243	5067	8107	12769	20268	32429	40537	2026.9
2-1/2	63.50	3166.9	1267	1995	3167	5067	7917	12668	19952	31669	50671	63339	3166.9
3	76.20	4560.4	1824	2873	4560	7297	11401	18242	28730	45604	72966	91208	4560.4
3-1/4	82.55	5352.1	2141	3372	5352	8563	13380	21408	33718	53521	85634	107042	5352.1
3-1/2	88.90	6207.2	2483	3911	6207	9931	15518	24829	39105	62072	99315	124144	6207.2
4	101.60	8107.3	3243	5108	8107	12972	20268	32429	51076	81073	129717	162147	8107.3
5	127.00	12667.7	5067	7981	12668	20268	31669	50671	79807	126677	202683	253354	12667.7
5-1/2	139.70	15327.9	6131	9657	15328	24525	38320	61312	96566	153279	245247	306559	15327.9
6	152.40	18241.5	7297	11492	18242	29186	45604	72966	114922	182415	291864	364830	18241.5
7	177.80	24828.1	9931	15642	24829	39726	62072	99315	156421	248287	397260	496574	24828.7
8	203.20	32429.4	12972	20430	32429	51887	81073	129717	204305	324294	518870	648587	32429.4
8-1/2	215.90	36609.7	14644	23064	36610	58576	91524	146439	230641	366097	585755	732194	36609.7
10	254.00	50670.9	20268	31923	50671	81073	126677	202683	319226	506709	810734	1013417	50670.9
12	304.80	72966.0	29186	45968	72966	116746	182415	291864	459686	729660	1167457	1459321	72966.0

table b-2

REF. 1 $\#_f$ = 4.448 NEWTONS (N)
1 BAR = 14.504 PSI

mounting styles

In addition to the standard mountings shown the following information covers other mountings and mounting ideas that may prove helpful in your applications. When needed, special heads, caps, flanges or intermediate mountings can be provided. Sketches of your requirements, together with specifications relative to the application and forces involved should be submitted to the manufacturer.

Clevis Mountings — Cylinders should be pivoted at both ends, with the customer's pin in the piston rod knuckle parallel to the pivot pin supplied with the clevis.

Flange Mountings — Cylinders can be located by centering from the pilot diameter of the gland, or the alin-a-groove on the body. The flanges may be drilled for pins or dowels to prevent shifting after alignment has been obtained.

Lug and Side Tapped Mountings — Cylinders should be fixed at one end using fitted bolts, pins in the mounting lugs or shear keys so located as to resist the major load, whether push or pull.

Thrust Key Mountings — Thrust key mountings, of the integral key type eliminate the need of using fitted bolts or external keys on side mounted cylinders.

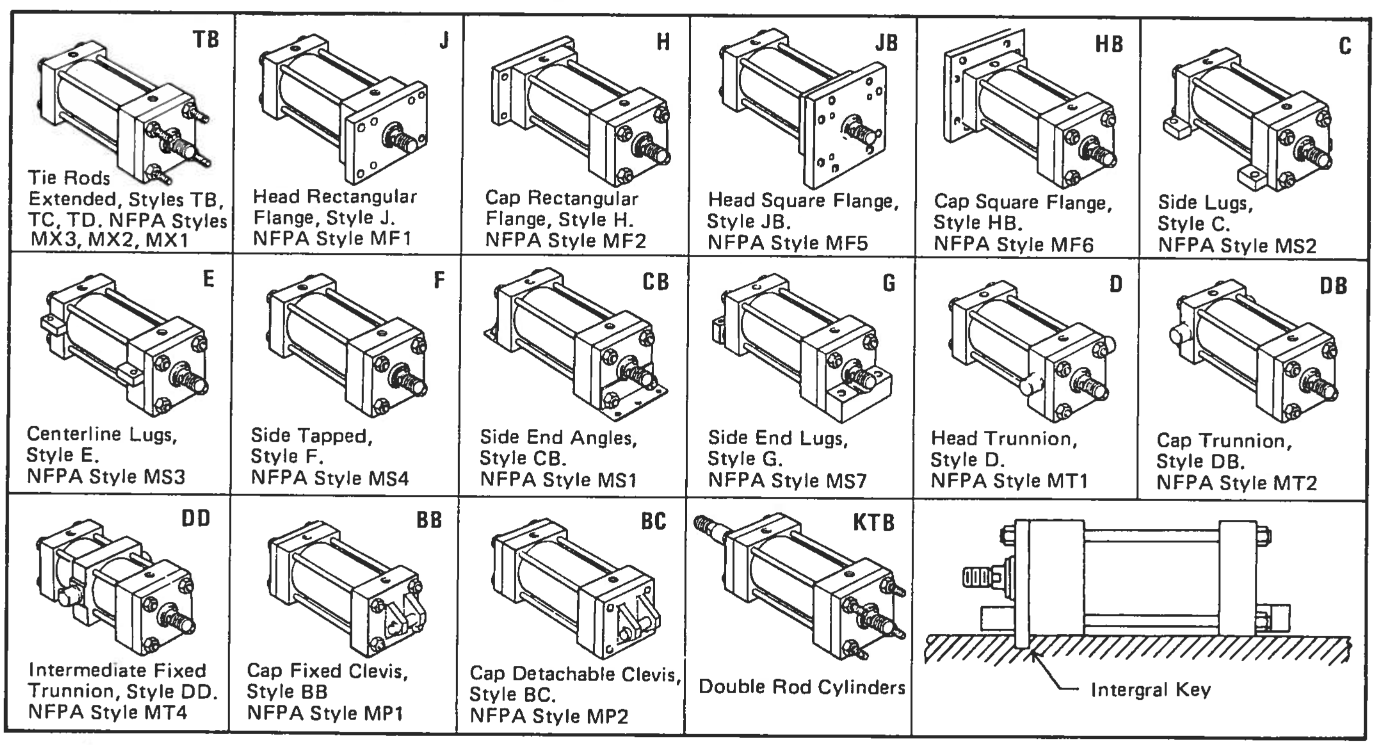
Tie Rod Mountings — Cylinders with tie rod mountings are recommended for applications where mounting space is limited.

Note: *If the tie rod nuts are removed during installation, be certain to retorque to manufacturer's specifications.*

In addition to the standard mountings shown the following information covers other mountings and mounting ideas that may prove helpful in your applications. When needed, special heads, caps, flanges or intermediate mountings can be provided. Sketches of your requirements, together with specifications relative to the application and forces involved should be submitted to the manufacturer.

Trunnion Mountings — Cylinders require lubricated pillow blocks with minimum bearing clearances. Pillow blocks should be carefully aligned and rigidly mounted so the trunnions will not be subjected to bending moments. The rod end connection should also be pivoted, with the customer's pin in the piston rod knuckle parallel to the trunnions. Trunnion pins are usually hard chrome plated.

Mounting Bolts — High tensile socket head screws are recommended for all mounting styles. Use 1/16" smaller than hole size.



Tie Rods Extended, Styles TB, TC, TD. NFPA Styles MX3, MX2, MX1

Head Rectangular Flange, Style J. NFPA Style MF1

Cap Rectangular Flange, Style H. NFPA Style MF2

Head Square Flange, Style JB. NFPA Style MF5

Cap Square Flange, Style HB. NFPA Style MF6

Side Lugs, Style C. NFPA Style MS2

Centerline Lugs, Style E. NFPA Style MS3

Side Tapped, Style F. NFPA Style MS4

Side End Angles, Style CB. NFPA Style MS1

Side End Lugs, Style G. NFPA Style MS7

Head Trunnion, Style D. NFPA Style MT1

Cap Trunnion, Style DB. NFPA Style MT2

Intermediate Fixed Trunnion, Style DD. NFPA Style MT4

Cap Fixed Clevis, Style BB NFPA Style MP1

Cap Detachable Clevis, Style BC. NFPA Style MP2

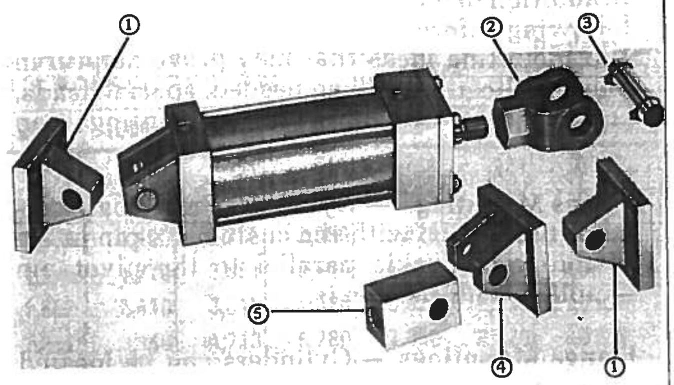
Double Rod Cylinders

illustration b-1

*NFPA Syles conform to ANSI Standard, 1393.15-1971

mounting accessories

A complete range of cylinder accessories are available from most manufacturers to give versatility to present or future cylinder applications. These include ① Eye Bracket, ② Rod Clevis, ③ Pivot Pins, ④ Clevis Bracket and ⑤Knuckle.



PH Industrial Cylinder with Accessories

illustration b-2

mounting classes

Standard mountings for power cylinders fall into two basic classes and three groups. The two classes can be summarized as follows:

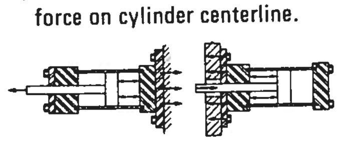
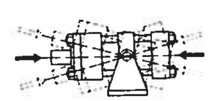
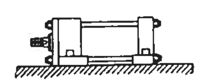
Class 1 — Straight Line Force Transfer (Group 1 and 3).

Class 2 — Pivot Force Transfer (Group 2). Pivot mountings permit a cylinder to change its alignment in one plane.

Because a cylinder's mounting directly affects the maximum pressure at which the cylinder can be used, **table b-3** (page b-4) should be helpful in the selection of the proper mounting for your application. Stroke length, piston rod connection to load, extra piston rod length over standard, etc., should be considered for thrust loads. Alloy steel mounting bolts are recommended for all mounting styles, and thrust keys are recommended for Group 3.

CYLINDER MOUNTING CLASSES

FOR CYLINDERS THAT ARE RECOMMENDED TO 3000 PSI WORKING AND 5000 PSI NON SHOCK SERVICE

	CLASS 1 – GROUP 1	CLASS 2 – GROUP 2	CLASS 1 – GROUP 3
	FIXED MOUNTS which absorb force on cylinder centerline.	PIVOT MOUNTS which absorb force on cylinder centerline.	FIXED MOUNTS which do not absorb force on the centerline.
			
HEAVY-DUTY SERVICE For Thrust Loads – For Tension Loads –	Mtg. Styles HB, TC, E Mtg. Styles JB, TB, E	Mtg. Styles DD, D, DB, BB Mtg. Styles BB, DD, D, DB	Mtg. Styles C, CP Mtg. Styles C, CP
MEDIUM-DUTY SERVICE For Thrust Loads – For Tension Loads –	Mtg. Styles H, JB Mtg. Styles J, HB	– –	Mtg. Styles G, GP, F, FP Mtg. Styles G, GP, F, FP
LIGHT-DUTY SERVICE For Thrust Loads – For Tension Loads –	Mtg. Style J Mtg. Style H	– –	Mtg. Styles CBP, CB * Mtg. Styles CBP, CB *

* Mounting style CB recommended for maximum pressure of 500 p.s.i. in short stroke applications (to 5"). Longer strokes permit higher pressures. The use of a thrust key is recommended with this mounting. For more detailed information see manufacturer's product catalog.

table b-3

cylinder stroke considerations

Long Strokes — When considering the use of long stroke cylinders, it is necessary that the rod diameter be of such dimension so as to provide the necessary column strength. For tension (pull) loads, a correct rod size is easily selected by specifying cylinders with standard rod diameters, and using them at rated or lower pressures.

For compression (push) loads, the column

cylinder stroke considerations continued

strength must be carefully considered. This involves the stroke length, the length of the piston rod extension, the support received from the rod end connection and gland and piston bearings, the style of mounting and the mounting attitude. It is also necessary to consider the bearing loads on pistons and glands, and to keep bearing pressures within proper limits by increasing the distance between piston and gland bearings. This is economically accomplished by various means. Commonly, separation of the bearings is effected with a stop tube on the piston rod much like a large diameter spacer sleeve. Other designs are provided according to the application requirements. The **Stroke Selection Graph b-1, page b-6,** printed in this handbook will guide you where requirements call for unusually long strokes, used in push applications.

When specifying cylinders with long stroke and stop tube, be sure to call out the net stroke and the length of the stop tube. Machine design can be continued without delay by laying in a cylinder equivalent in length to the **Net Stroke Plus Stop Tube Length,** which is referred to as **Gross Stroke.**

piston rod compared to stroke

How to Use the Table

The selection of a piston rod for thrust (push) conditions requires the following steps:

1. Determine the types of cylinder mounting style and rod end connection to be used. Then consult the **table 4** [page b-5] and find the "stroke factor" that corresponds to the conditions used.

2. Using this stroke factor, determine the "basic length" from the equation:

$$\text{Basic Length} = \text{Actual Stroke} \times \text{Stroke Factor}$$

piston rod — stroke selection table

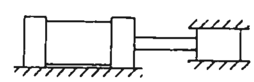
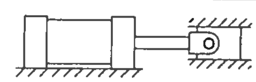
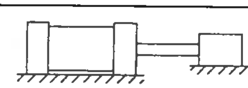
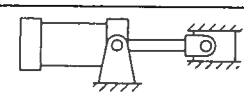
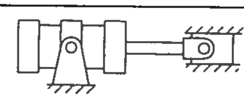
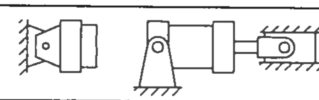
RECOMMENDED MOUNTING STYLES FOR MAXIMUM STROKE AND THRUST LOADS	ROD END CONNECTION	CASE		STROKE FACTOR
CLASS 1 – GROUPS 1 OR 3 Long stroke cylinders for thrust loads should be mounted using a heavy-duty mounting style at one end, firmly fixed and aligned to take the principle force. Additional mounting should be specified at the opposite end, which should be used for alignment and support. An intermediate support may also be desirable for long stroke cylinders mounted horizontally. Machine mounting pads can be adjustable for support mountings to achieve proper alignment.	FIXED AND RIGIDLY GUIDED.	I		.50
	PIVOTED AND RIGIDLY GUIDED	II		.70
	SUPPORTED BUT NOT RIGIDLY GUIDED	III		2.00
CLASS 2 – GROUP 2 Style – Trunnion on Head	PIVOTED AND RIGIDLY GUIDED	IV		1.00
Style – Intermediate Trunnion	PIVOTED AND RIGIDLY GUIDED	V		1.50
Style – Trunnion on Cap or Style – Clevis on Cap	PIVOTED AND RIGIDLY GUIDED	VI		2.00

table b-4

Graph b-1, page b-6, is prepared for standard rod extensions beyond the face of the gland retainers. For rod extensions greater than standard, add the increase to the actual stroke in arriving at the "basic length."

3. Find the load imposed for the thrust application by multiplying the full bore area of the cylinder by the system pressure.

4. Enter the graph along the values of "basic length" and "thrust" as found above and note the point of intersection:

a. The correct piston rod size is read from the diagonally curved line labeled "Rod Diameter" next **above** the point of intersection.

b. The required length of stop tube is read from the right of the graph by following the shaded band in which the point of intersection lies.

cylinder stroke considerations continued

5. If required length of stop tube is in the region labeled "consult factory," submit the following information for an individual analysis:

   a. Cylinder mounting style.

   b. Rod end connection and method of guiding load.

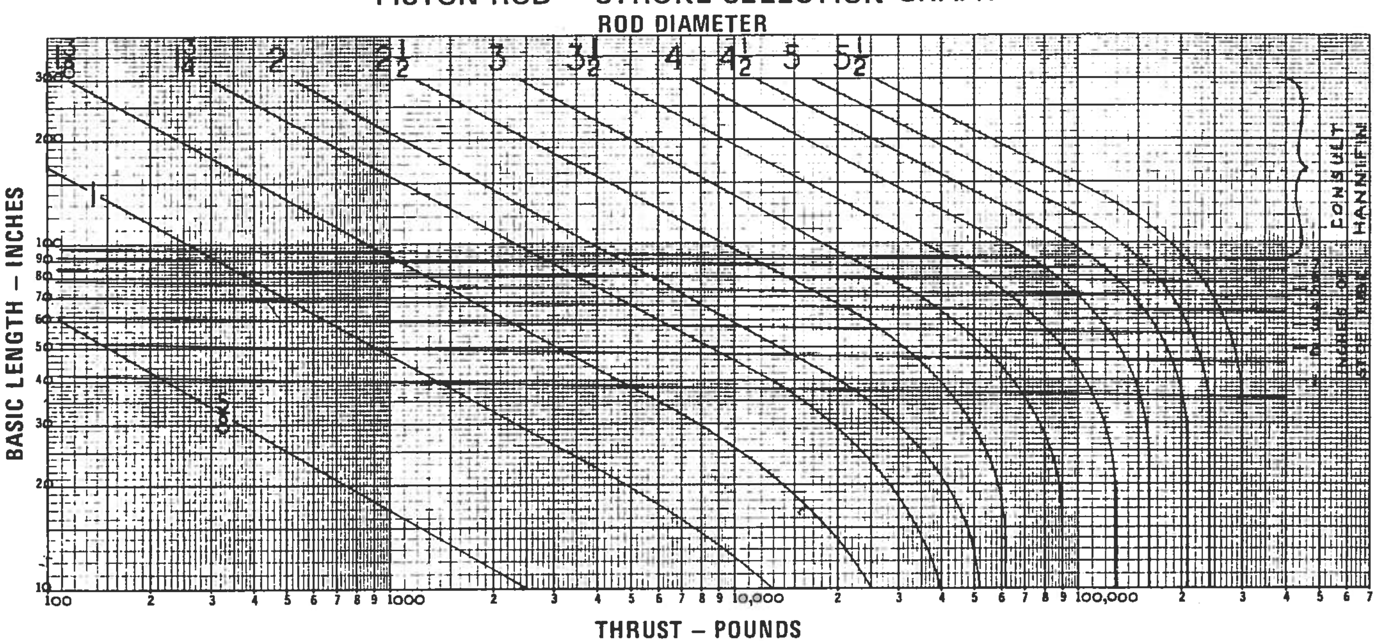
   c. Bore, required stroke, length of rod extension if greater than standard, and series of cylinder used.

   d. Mounting position of cylinder.

   Note: *If at an angle or vertical, specify direction of piston rod.*

   e. Operating pressure of cylinder.

PISTON ROD – STROKE SELECTION GRAPH



graph b-1

determining acceleration and deceleration force for hydraulic cylinders

The **Uniform Acceleration Force Factor Graph** and the accompanying formula can be used to rapidly determine the forces required to accelerate and decelerate a cylinder load. To determine these forces, the following factors must be known; total weight to be moved, maximum piston speed, distance available to start or stop the weight (load), direction of movement i.e. horizontal or vertical, and load friction. By use of the known factors and the "g" factor from **graph 2**, the force necessary to accelerate or decelerate a cylinder load may be found by solving the formula (as shown in graph on page b-7) applicable to given set of conditions.

Nomenclature

- V = Velocity in feet per minute
- S = Distance in inches
- F = Force in pounds
- W = Weight of load in pounds
- g = Force factor
- f = Friction of load on machine ways in pounds

To determine the force factor "g" from the graph, locate the intersection of the maximum piston velocity line and the line representing the available distance. Project downward to locate "g" on the horizontal axis. To calculate the "g" factor for distances and velocities exceeding those shown on the chart, this formula can be used:

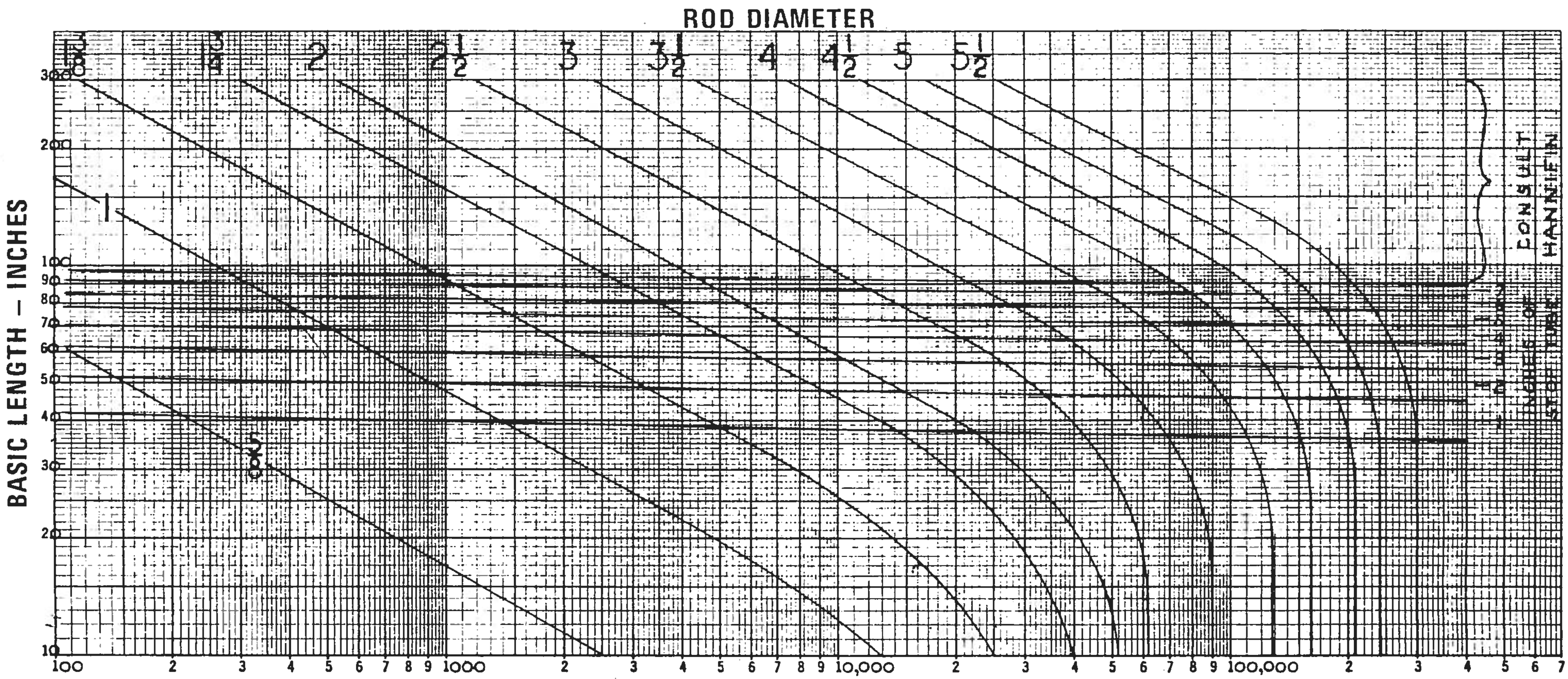
$$g = \frac{V^2}{S} \times .0000517$$

Example: *Horizontal motion of a free moving 6,000 pound load is required with a distance of 1/2" to a maximum speed of 120 feet per minute. Formula (1) F = Wg should be used.*

F = 6,000 pounds X1.50 (from table)= 9,000 pounds (page b-7)

Assuming a maximum available pump pressure of 1,000 p.s.i., a 4" bore cylinder should be selected, operating on push stroke at approximately 750 p.s.i. pressure at the cylinder to allow for pressure losses from the pump to the cylinder.

PISTON ROD — STROKE SELECTION GRAPH



graph b-1

determining forces continued

Assume the same load to be sliding on ways with a coefficient of friction of 0.15. The resultant friction load would be 6,000 × 0.15 = 900 pounds. Formula (2) F = Wg + f should be used.

F =6,000 lbs. X1.5 (from table)+ 900 =9,900 lbs. (page b-7)

Again allowing 750 p.s.i. pressure at the cylinder, a 5" bore cylinder is indicated.

Example: *Horizontal deceleration of a 6,000 pound load is required by using a 1" long cushion in a 5" bore cylinder having a 2" diameter piston rod. Cylinder bore area (19.64 Sq. In.) minus the rod area (3.14 Sq. In.) results in a minor area of 16.5 Sq. In. at head end of cylinder. A 1,000 p.s.i. pump delivering 750 p.s.i. at the cylinder is being used to push the load at 120 feet per minute. Friction coefficient is 0.15 or 900 pounds.*

In this example, the total deceleration force is the sum of the force needed to decelerate 6,000 pound load, and the force required to counteract the thrust produced by the pump.

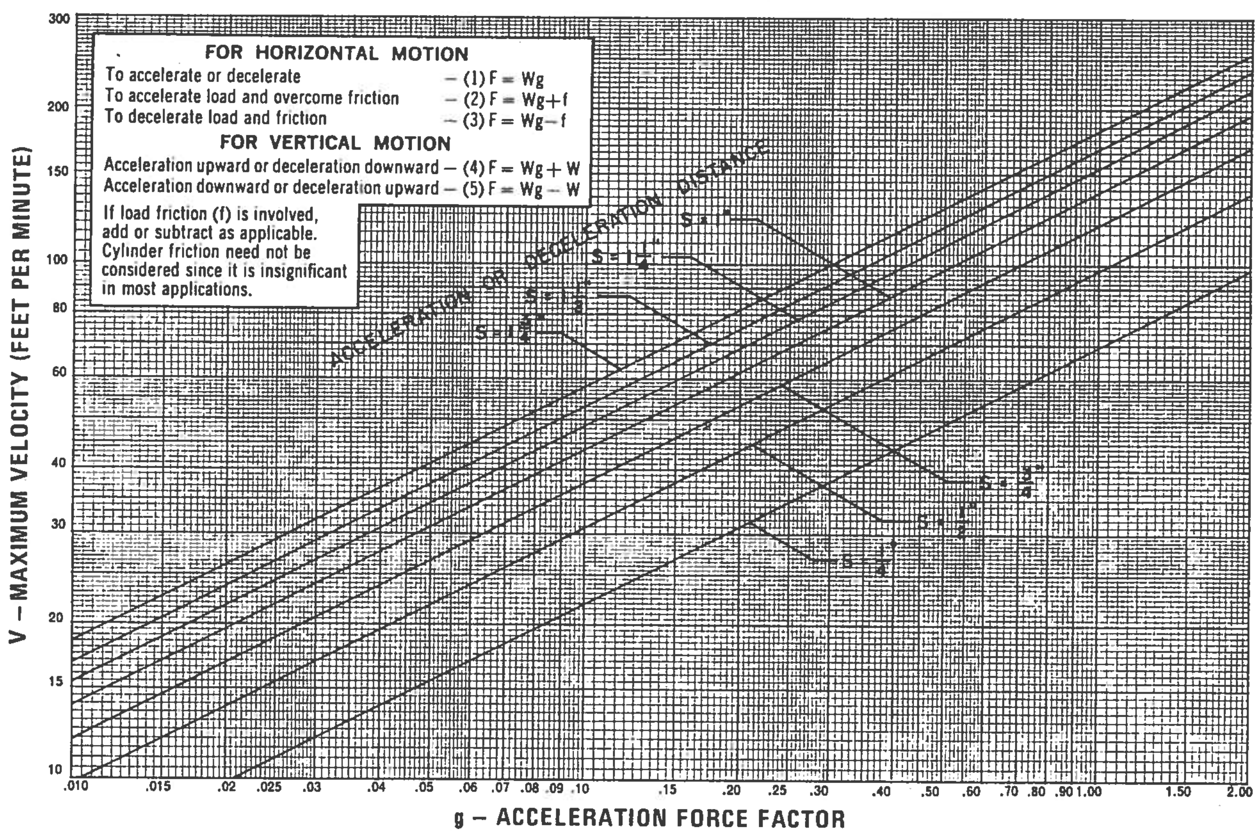
W = Load in pounds = 6,000
S = Deceleration distance in inches = 1"
V = Maximum piston speed in feet per minute = 120
g = .74 (from table)
f = 900 pounds

Use formula (3) F = Wg - f

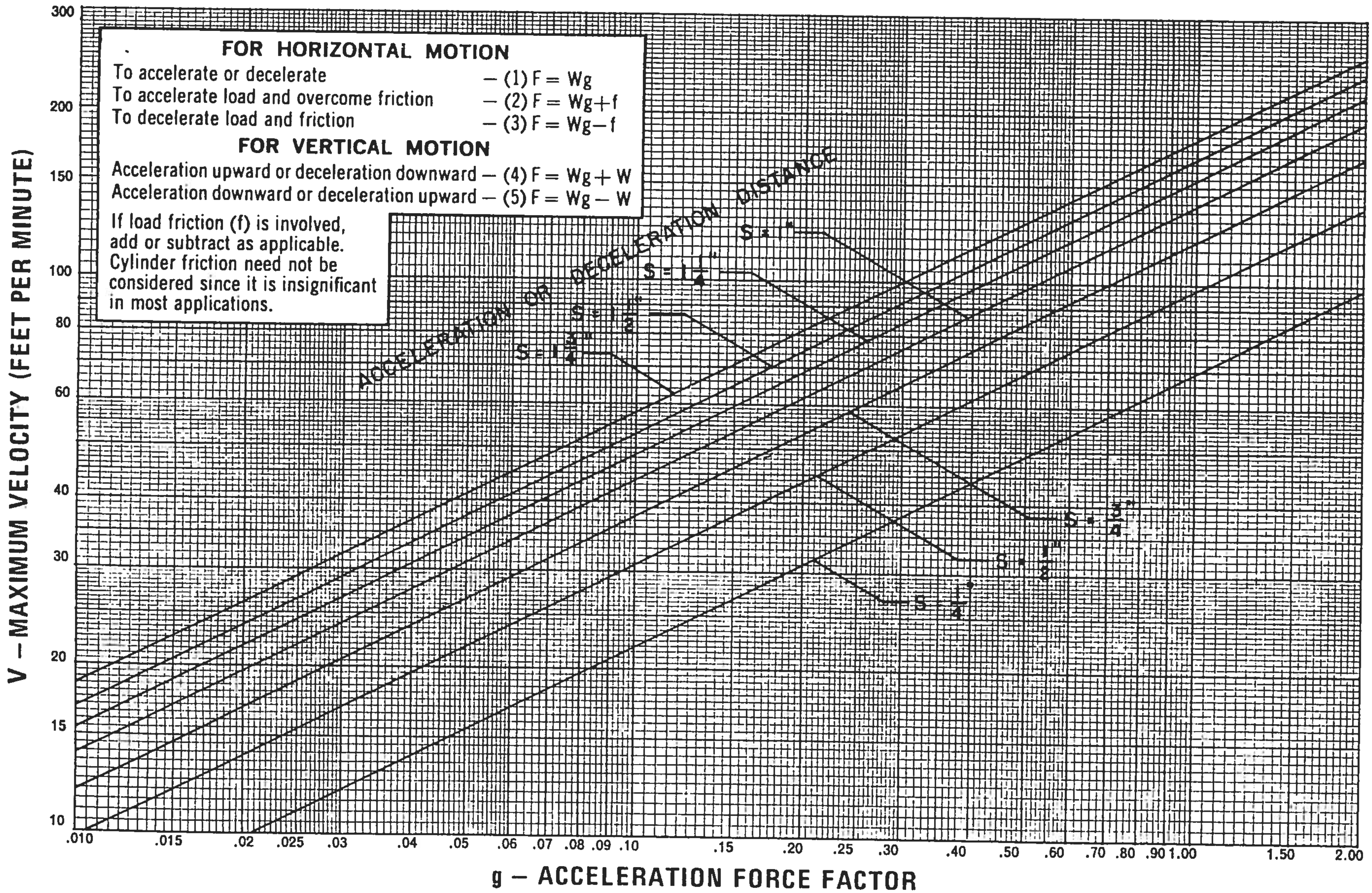
(F = Wg - f) = (F = 6,000 X .74 - 900) = 3,540 lbs.

The pump is delivering 750 p.s.i. acting on the 19.64 Sq. In. piston area producing a force (F_2) of 14,730 pounds. This force must be included in our calculations. Thus F + F_2 = 3,540 + 14,730 = 18,270 pounds total force to be decelerated.

The total deceleration force is developed by the fluid trapped between the piston and the head. The fluid pressure is equal to the force (18,270 pounds) divided by the minor area (16.5 Sq. In.) equals 1107 p.s.i. This pressure should not exceed the non-shock rating of the cylinder.



graph b-2


FOR HORIZONTAL MOTION
To accelerate or decelerate — (1) F = Wg
To accelerate load and overcome friction — (2) F = Wg+f
To decelerate load and friction — (3) F = Wg−f
FOR VERTICAL MOTION
Acceleration upward or deceleration downward — (4) F = Wg + W
Acceleration downward or deceleration upward — (5) F = Wg − W
If load friction (f) is involved, add or subtract as applicable. Cylinder friction need not be considered since it is insignificant in most applications.
ACCELERATION OR DECELERATION DISTANCE
S = 1"
S = 1 1/4"
S = 1 1/2"
S = 1 3/4"
S = 3/4"
S = 1/2"
S = 1/4"
V – MAXIMUM VELOCITY (FEET PER MINUTE)
300
200
150
100
80
60
40
30
20
15
10
.010
.015
.02
.025
.03
.04
.05
.06
.07
.08
.09
.10
.15
.20
.25
.30
.40
.50
.60
.70
.80
.90
1.00
1.50
2.00
g – ACCELERATION FORCE FACTOR

graph b-2

hydraulic cylinder port sizes and piston speed

One of the factors involved in determining the speed of a hydraulic cylinder piston is fluid flow in connecting lines, generally measured in gallons per minute, introduced to, or expelled from, cap end cylinder port. (Due to piston rod displacement, the flow at head end port will be less than at cap end.) Fluid velocity, however, is measured in feet per second. In connecting lines this velocity should generally be limited to 15 feet per second to minimize fluid turbulence, pressure loss and hydraulic shock.

Piston speed for cylinders can be calculated from data shown in **table b-5** and **b-6.** The table shows fluid velocity flow fo major cylinder area as well as for the net area at the rod end for cylinders 1" through 14" bore size.

If desired piston speed results in fluid flow in excess of 15 feet per second in connecting lines, consider the use of larger lines up to cylinder port, using either oversized ports or two ports per cap.

CYLINDER BORE-INCHES	PISTON ROD DIA.-INCHES	PISTON ROD AREA SQ. IN.	CYLINDER NET AREA SQ. IN.	FLUID DISPLACEMENT AT 10 FT. PER MINUTE PISTON VELOCITY G.P.M.	C.F.M.	FLUID VELOCITY (IN FEET PER SECOND) THROUGH EXTRA HEAVY PIPE AT 10 F.P.M. PISTON SPEED. 1/4	3/8	1/2	3/4	1	1-1/4	1-1/2	2	2-1/2
1	0	0	0.785	0.41	0.054	1.82	0.92	0.56	0.30	0.183	0.102	0.074	0.045	.....
	1/2	0.196	0.589	0.30	0.041	1.33	0.68	0.41	0.21	0.134	0.075	0.055	0.033	.....
	5/8	0.307	0.478	0.16	0.033	0.71	0.36	0.22	0.12	0.071	0.040	0.029	0.017	.....
1½	0	0	1.77	0.92	0.123	4.09	2.09	1.259	0.680	0.410	0.230	0.167	0.100	.....
	5/8	0.307	1.46	0.76	0.101	3.38	1.73	1.040	0.562	0.338	0.190	0.138	0.082	.....
	1	0.785	0.98	0.51	0.068	2.27	1.16	0.699	0.378	0.228	0.128	0.093	0.055	.....
2	0	0	3.14	1.63	0.218	7.27	3.71	2.238	1.209	0.728	0.408	0.296	0.177	.....
	5/8	0.307	2.84	1.48	0.197	6.56	3.35	2.019	1.091	0.657	0.368	0.267	0.160	.....
	1	0.785	2.36	1.23	0.164	5.45	2.79	1.678	0.907	0.546	0.306	0.222	0.133	.....
	1-3/8	1.485	1.66	0.86	0.115	3.84	1.96	1.180	0.638	0.384	0.215	0.156	0.094	.....
2½	0	0	4.91	2.55	0.341	11.36	5.80	3.496	1.890	1.138	0.638	0.463	0.277	.....
	5/8	0.307	4.60	2.39	0.319	10.65	5.44	3.278	1.771	1.067	0.598	0.434	0.260	.....
	1	0.785	4.12	2.14	0.286	9.54	4.87	2.937	1.587	0.956	0.536	0.389	0.233	.....
	1-3/8	1.485	3.42	1.78	0.237	7.93	4.05	2.439	1.318	0.794	0.445	0.323	0.193	.....
	1-3/4	2.405	2.50	1.30	0.174	5.96	2.96	1.783	0.963	0.580	0.325	0.236	0.141	.....
3¼	0	0	8.30	4.31	0.576	19.20	9.81	5.909	3.193	1.923	1.078	0.783	0.468	.....
	1	0.785	7.51	3.90	0.521	17.38	8.88	5.349	2.891	1.741	0.976	0.708	0.424	.....
	1-3/8	1.485	6.81	3.54	0.473	15.77	8.05	4.851	2.622	1.579	0.885	0.642	0.384	.....
	1-3/4	2.405	5.89	3.06	0.409	13.64	6.96	4.196	2.268	1.366	0.765	0.556	0.333	.....
	2	3.142	5.15	2.68	0.357	11.93	6.09	3.671	1.984	1.195	0.670	0.486	0.291	.....
4	0	0	12.57	6.53	0.872	29.09	14.85	8.95	4.84	2.91	1.63	1.19	0.709	.....
	1	0.785	11.78	6.12	0.818	27.27	13.93	8.39	4.54	2.73	1.53	1.11	0.665	.....
	1-3/8	1.485	11.08	5.76	0.769	25.65	13.10	7.89	4.27	2.57	1.44	1.05	0.625	.....
	1-3/4	2.405	10.16	5.28	0.705	23.52	12.01	7.24	3.91	2.36	1.32	0.96	0.574	.....
	2	3.142	9.42	4.89	0.654	21.82	11.14	6.71	3.63	2.19	1.22	0.89	0.532	.....
	2-1/2	4.909	7.66	3.98	0.532	17.73	9.05	5.45	2.95	1.78	1.00	0.72	0.432	.....
5	0	0	19.64	10.20	1.363	45.45	23.21	13.99	7.56	4.55	2.55	1.85	1.108	.....
	1	0.785	18.85	9.79	1.308	43.64	22.28	13.43	7.26	4.37	2.45	1.78	1.064	.....
	1-3/8	1.485	18.15	9.43	1.260	42.01	21.45	12.93	6.99	4.21	2.36	1.71	1.024	.....
	1-3/4	2.405	17.23	8.95	1.196	39.88	20.37	12.27	6.63	3.99	2.24	1.63	0.973	.....
	2	3.142	16.49	8.57	1.144	38.18	19.50	11.75	6.35	3.82	2.14	1.56	0.931	.....
	2-1/2	4.909	14.73	7.65	1.022	34.09	17.41	10.49	5.67	3.41	1.91	1.39	0.831	.....
	3	7.069	12.57	6.53	0.872	29.09	14.85	8.95	4.84	2.91	1.63	1.19	0.709	.....
	3-1/2	9.621	10.01	5.21	0.695	23.18	11.84	7.13	3.86	2.32	1.30	0.95	0.565	.....
6	0	0	28.27	14.69	1.962	65.45	33.42	20.14	10.88	6.55	3.67	2.67	1.596	.....
	1-3/8	1.485	26.79	13.92	1.859	62.01	31.67	19.08	10.31	6.21	3.48	2.53	1.512	.....
	1-3/4	2.405	25.87	13.44	1.795	59.88	30.58	18.43	9.96	5.60	3.36	2.44	1.460	.....
	2	3.142	25.13	13.06	1.744	58.18	29.71	17.90	9.67	5.83	3.27	2.37	1.418	.....
	2-1/2	4.909	23.37	12.14	1.622	54.1	27.6	16.64	8.99	5.42	3.04	2.20	1.32	.....
	3	7.069	21.21	11.02	1.472	49.1	25.1	15.10	8.16	4.92	2.76	2.00	1.20	.....
	3-1/2	9.621	18.65	9.69	1.294	43.2	22.1	13.29	7.18	4.32	2.42	1.76	1.05	.....
	4	12.566	15.71	8.16	1.090	36.4	18.6	11.19	6.05	3.64	2.04	1.48	0.89	.....

table b-5

hydraulic cylinder port sizes and piston speed

	0	0	38.49	20.00	2.671	89.1	45.5	27.41	14.81	8.92	5.00	3.63	2.17	.....
	1-3/8	1.485	37.00	19.22	2.568	85.7	43.7	26.35	14.24	8.58	4.81	3.49	2.09	.....
	1-3/4	2.405	36.08	18.74	2.504	83.5	42.7	25.70	13.89	8.36	4.69	3.40	2.04	.....
	2	3.142	35.34	18.36	2.453	81.8	41.8	25.17	13.60	8.19	4.59	3.33	2.00	.....
	2-1/2	4.909	33.58	17.44	2.330	77.7	39.7	23.92	12.92	7.78	4.36	3.17	1.90	.....
7	3	7.069	31.42	16.32	2.181	72.7	37.1	22.38	12.09	7.28	4.08	2.96	1.77	.....
	3-1/2	9.621	28.86	14.99	2.003	66.8	34.1	20.56	11.11	6.69	3.75	2.72	1.63	.....
	4	12.566	25.92	13.47	1.799	60.0	30.6	18.46	9.98	6.01	3.37	2.45	1.46	.....
	4-1/2	15.904	22.58	11.73	1.567	52.3	26.7	16.08	8.69	5.23	2.93	2.12	1.28	.....
	5	19.635	18.85	9.79	1.308	43.6	22.3	13.43	7.26	4.37	2.45	1.78	1.06	.....
	0	0	50.27	26.12	3.489	116.4	59.4	35.80	19.35	11.65	6.53	4.74	2.84	1.977
	1-3/8	1.485	48.78	25.34	3.385	112.9	57.7	34.74	18.78	11.31	6.34	4.60	2.75	1.918
	1-3/4	2.405	47.86	24.86	3.321	110.8	56.6	34.09	18.42	11.09	6.22	4.51	2.70	1.882
	2	3.142	47.12	24.48	3.270	109.1	55.7	33.56	18.14	10.92	6.12	4.45	2.66	1.853
	2-1/2	4.909	45.36	23.57	3.149	105.0	53.61	32.31	17.46	10.51	5.892	4.278	2.560	1.784
8	3	7.069	43.20	22.44	2.998	100.0	51.06	30.77	16.63	10.01	5.612	4.074	2.438	1.699
	3-1/2	9.621	40.65	21.12	2.821	94.1	48.04	28.95	15.65	9.42	5.279	3.834	2.294	1.598
	4	12.566	37.70	19.59	2.616	87.3	44.56	26.85	14.51	8.74	4.897	3.556	2.128	1.483
	4-1/2	15.904	34.36	17.85	2.385	79.5	40.62	24.47	13.23	8.20	4.464	3.241	1.939	1.351
	5	19.635	30.63	15.91	2.126	70.9	36.21	21.82	11.79	7.10	3.979	2.889	1.729	1.205
	5-1/2	23.758	26.51	13.77	1.840	61.4	31.33	18.88	10.20	6.15	3.444	2.500	1.496	1.043
	0	0	78.54	40.80	5.451	181.8	92.84	55.94	30.23	18.21	10.203	7.408	4.433	3.089
	1-3/4	2.405	76.14	39.56	5.284	176.2	89.99	54.23	29.31	17.65	9.890	7.181	4.297	2.994
	2	3.142	75.40	39.17	5.233	174.5	89.12	53.70	29.02	17.48	9.795	7.112	4.255	2.965
	2-1/2	4.909	73.63	38.25	5.110	170.4	87.03	52.44	28.34	17.07	9.565	6.945	4.156	2.896
	3	7.069	71.47	37.13	4.960	165.4	84.48	50.91	27.51	16.57	9.284	6.741	4.034	2.811
	3-1/2	9.621	68.92	35.80	4.783	159.5	81.47	49.09	26.53	15.98	8.953	6.501	3.890	2.710
10	4	12.566	65.97	34.27	4.578	152.7	77.98	46.99	25.39	15.29	8.570	6.223	3.724	2.595
	4-1/2	15.904	62.64	32.54	4.347	145.0	74.04	44.61	24.11	14.52	8.137	5.908	3.535	2.463
	5	19.635	58.91	30.60	4.088	136.4	69.63	41.96	22.67	13.65	7.652	5.556	3.325	2.317
	5-1/2	23.758	54.78	28.46	3.802	126.8	64.75	39.02	21.09	12.70	7.116	5.167	3.092	2.154
	6	28.274	50.27	26.12	3.489	116.4	59.42	35.80	19.35	11.65	6.530	4.741	2.837	1.977
	6-1/2	33.183	45.36	23.57	3.148	105.0	53.6	32.31	17.46	10.52	5.89	4.278	2.560	1.784
	7	38.485	40.06	20.81	2.780	92.7	47.4	28.53	15.42	9.29	5.20	3.778	2.261	1.575
	0	0	113.10	58.76	7.849	261.8	133.7	80.55	43.53	26.22	14.69	10.668	6.383	4.448
	2	3.142	109.96	57.12	7.631	254.5	130.0	78.32	42.32	25.49	14.28	10.371	6.206	4.324
	2-1/2	4.909	108.19	56.21	7.508	250.4	127.9	77.06	41.64	25.08	14.05	10.205	6.106	4.255
	3	7.069	106.03	55.08	7.359	245.4	125.3	75.52	40.81	24.58	13.77	10.001	5.984	4.170
	3-1/2	9.621	103.48	53.76	7.182	239.5	122.3	73.70	39.83	23.99	13.44	9.760	5.840	4.069
	4	12.566	100.53	52.23	6.977	232.7	118.8	71.60	38.70	23.30	13.06	9.482	5.674	3.954
	4-1/2	15.904	97.19	50.49	6.745	225.0	114.9	69.23	37.41	22.53	12.63	9.168	5.486	3.822
12	5	19.635	93.46	48.55	6.486	216.4	110.5	66.57	35.98	21.67	12.14	8.816	5.275	3.676
	5-1/2	23.758	89.34	46.41	6.200	206.8	105.6	63.63	34.39	20.71	11.61	8.427	5.042	3.513
	6	28.274	84.82	44.06	5.887	196.4	100.3	60.42	32.65	19.66	11.02	8.001	4.787	3.336
	6-1/2	33.183	79.92	41.52	5.547	185.0	94.5	56.92	30.76	18.53	10.38	7.538	4.510	3.143
	7	38.485	74.61	38.77	5.179	172.7	88.2	53.14	28.72	17.30	9.69	7.038	4.211	2.934
	7-1/2	44.179	68.92	35.80	4.783	159.5	81.5	49.09	26.53	15.98	8.95	6.501	3.890	2.710
	8	50.266	62.83	32.64	4.360	145.4	74.3	44.75	24.19	14.57	8.16	5.926	3.546	2.471
	8-1/2	56.745	56.35	29.27	3.911	130.5	66.6	40.14	21.69	13.06	7.32	5.315	3.181	2.216
	0	0	153.94	79.97	10.683	356.3	182.0	109.6	59.25	35.68	20.00	14.52	8.688	6.054
	2-1/2	4.909	149.03	77.42	10.343	345.0	176.2	106.2	57.36	34.55	19.36	14.06	8.411	5.861
	3	7.069	146.87	76.30	10.193	340.0	173.6	104.6	56.53	34.05	19.08	13.85	8.289	5.776
14	3-1/2	9.621	144.32	74.97	10.016	334.1	170.6	102.8	55.55	33.45	18.75	13.61	8.145	5.676
	4	12.566	141.37	73.44	9.811	327.3	167.1	100.7	54.42	32.77	18.37	13.33	7.979	5.560
	4-1/2	15.904	138.03	71.71	9.579	319.5	163.2	98.3	53.13	32.00	17.93	13.02	7.791	5.428
	5	19.635	134.30	69.77	9.320	310.9	158.8	95.7	51.70	31.13	17.45	12.67	7.580	5.282
	5-1/2	23.758	130.18	67.63	9.035	301.3	153.9	92.7	50.11	30.18	16.91	12.28	7.347	5.120

table b-5 (cont.)

applications of cylinders
for providing a variety of fundamental mechanical motions.

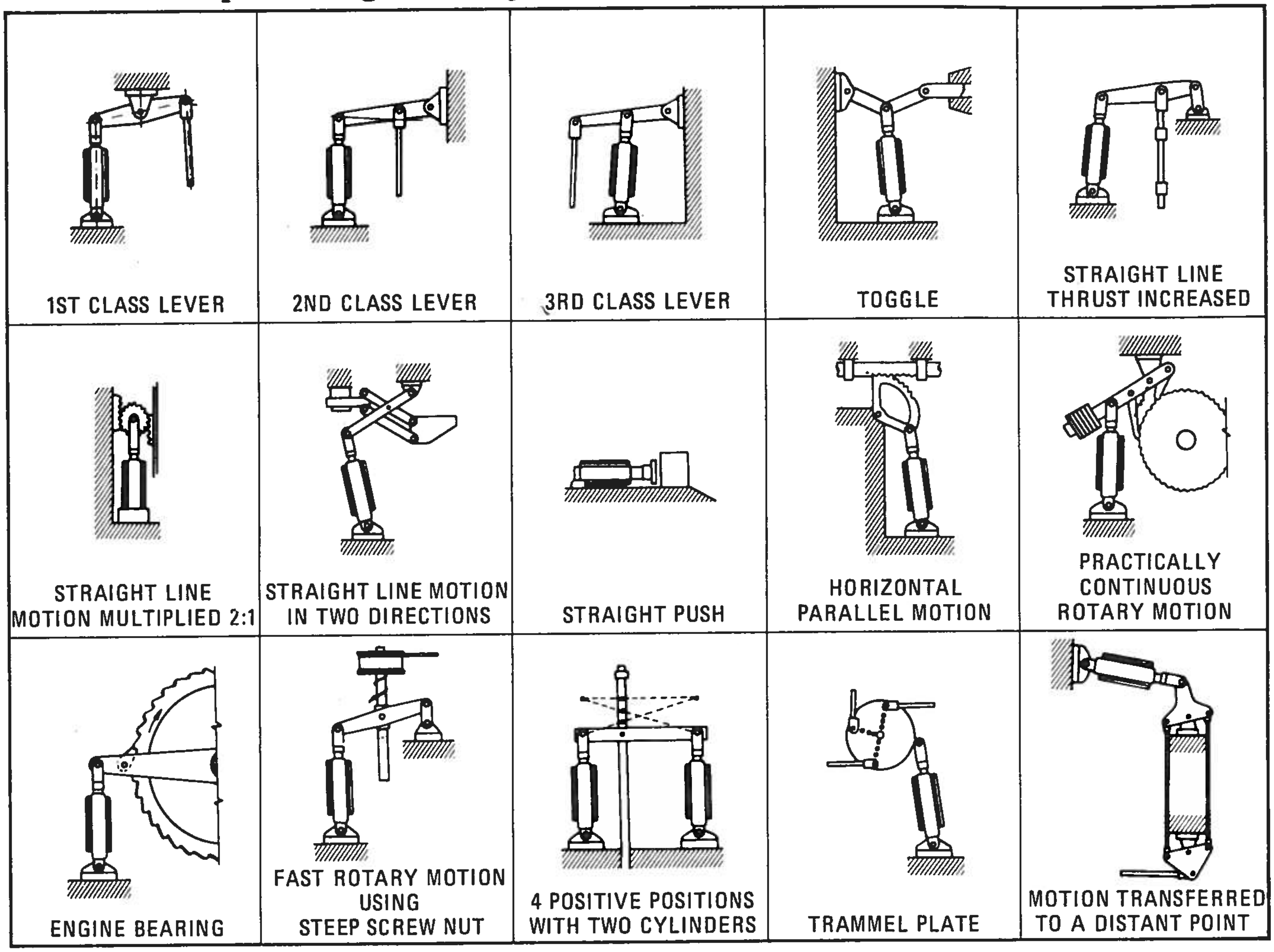


illustration b-10

Toggle Mechanism

For operations such as coining and marking requiring exact depth control, and requiring extremely high force for a very short distance, the toggle lever system can be useful.

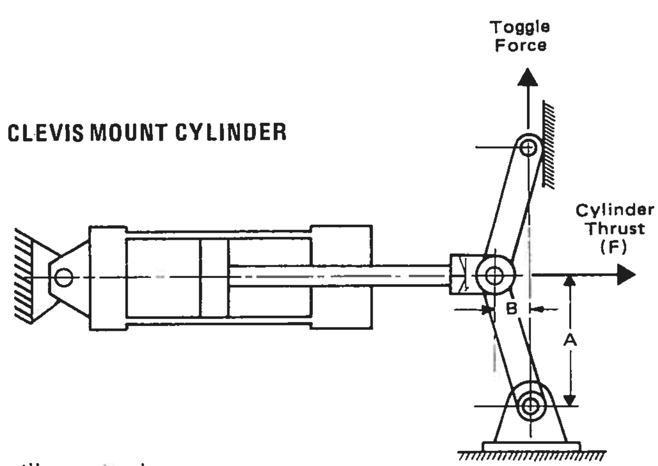


illustration b-11

In **illustration b-11,** cylinder thrust is horizontal and toggle force is taken off vertically. Bearings at each end of the toggle lever must be closely fitted and heavy enough to carry the full toggle thrust.

A calculation of toggle force can be made with the following formula, with T and F in the same units, and A and B in the same units. Note that dimension A is not the lever length, but for high leverage toggle calculations it can be used for lever length, with only small error, since the lever is nearly vertical.

$$T \text{ (Toggle Force)} = \frac{F \text{ (Cylinder Thrust)} \times A}{2B}$$

Example: *Find the toggle force from a cylinder thrust of 8300 lbs., if the toggle lever is 14 inches long and is 1/2 inch from vertical (Distance B).*

electric motor horsepower

ELECTRIC MOTOR HORSEPOWER REQUIRED TO DRIVE A HYDRAULIC PUMP

GPM	100 PSI	200 PSI	250 PSI	300 PSI	400 PSI	500 PSI	750 PSI	1000 PSI	1250 PSI	1500 PSI	2000 PSI	2500 PSI	3000 PSI
1/2	.04	.07	.09	.11	.14	.18	.26	.35	.44	.53	.70	.88	1.10
1	.07	.14	.18	.21	.28	.35	.52	.70	.88	1.05	1.40	1.76	1.92
1-1/2	.10	.21	.26	.31	.41	.52	.77	1.03	1.29	1.55	2.06	2.58	3.09
2	.14	.28	.35	.42	.56	.70	1.04	1.40	1.76	2.10	2.80	3.53	4.20
2-1/2	.17	.34	.43	.51	.69	.86	1.29	1.72	2.15	2.58	3.44	4.30	5.14
3	.21	.42	.53	.63	.84	1.05	1.56	2.10	2.64	3.15	4.20	5.28	6.30
3-1/2	.24	.48	.60	.72	.96	1.20	1.80	2.40	3.00	3.60	4.80	6.00	7.20
4	.28	.56	.70	.84	1.12	1.40	2.08	2.80	3.52	4.20	5.60	7.04	8.40
5	.35	.70	.88	1.05	1.40	1.75	2.60	3.50	4.40	5.25	7.00	8.80	10.50
6	.42	.84	1.05	1.26	1.68	2.10	3.12	4.20	5.28	6.30	8.40	10.56	12.60
7	.49	.98	1.23	1.47	1.96	2.45	3.64	4.90	6.16	7.35	9.80	12.32	14.70
8	.56	1.12	1.40	1.68	2.24	2.80	4.16	5.60	7.04	8.40	11.20	14.08	16.80
9	.62	1.24	1.55	1.86	2.48	3.10	4.65	6.18	7.73	9.28	12.40	15.56	18.58
10	.70	1.40	1.75	2.10	2.80	3.50	5.20	7.00	8.80	10.50	14.00	17.60	21.00
11	.77	1.54	1.93	2.31	3.08	3.85	5.72	7.70	9.68	11.50	15.40	19.36	23.10
12	.84	1.68	2.10	2.52	3.36	4.20	6.24	8.40	10.50	12.60	16.80	21.00	25.20
13	.89	1.78	2.23	2.67	3.56	4.45	6.68	8.92	11.20	13.40	17.80	22.40	26.72
14	.96	1.92	2.40	2.88	3.84	4.80	7.20	9.60	12.00	14.40	19.20	24.00	28.80
15	1.05	2.10	2.63	3.15	4.20	5.25	7.80	10.50	13.20	15.70	21.00	26.40	31.50
16	1.10	2.20	2.75	3.30	4.40	5.50	8.25	11.00	13.80	16.50	22.00	27.60	33.00
17	1.17	2.34	2.93	3.51	4.68	5.85	8.78	11.70	14.60	17.60	23.40	29.20	35.10
18	1.26	2.52	3.15	3.78	5.04	6.30	9.35	12.60	15.80	18.90	25.20	31.60	37.80
19	1.30	2.60	3.25	3.90	5.20	6.50	9.75	13.00	16.30	19.50	26.00	32.60	39.00
20	1.40	2.80	3.50	4.20	5.60	7.00	10.40	14.00	17.60	21.00	28.00	35.20	42.00
25	1.75	3.50	4.38	5.25	7.00	8.75	13.10	17.50	21.90	26.20	35.00	43.80	52.50
30	2.10	4.20	5.25	6.30	8.40	10.50	15.60	21.00	26.40	31.50	42.00	52.80	63.00
35	2.45	4.90	6.13	7.35	9.80	12.20	18.40	24.50	30.60	36.70	49.00	61.20	73.50
40	2.80	5.60	7.00	8.40	11.20	14.00	20.80	28.00	35.20	42.00	56.00	70.40	84.00
45	3.15	6.30	7.87	9.45	12.60	15.80	23.60	31.50	39.40	47.30	63.00	78.80	94.50
50	3.50	7.00	8.75	10.50	14.00	17.50	26.00	35.00	44.00	52.50	70.00	88.00	105.00
55	3.85	7.70	9.63	11.60	15.40	19.30	28.60	38.50	48.40	57.80	77.00	96.80	115.50
60	4.20	8.40	10.50	12.60	16.80	21.00	31.20	42.00	52.80	63.00	84.00	105.60	126.00
65	4.55	9.10	11.40	13.60	18.20	22.80	33.80	45.50	57.20	68.20	90.00	114.40	136.50

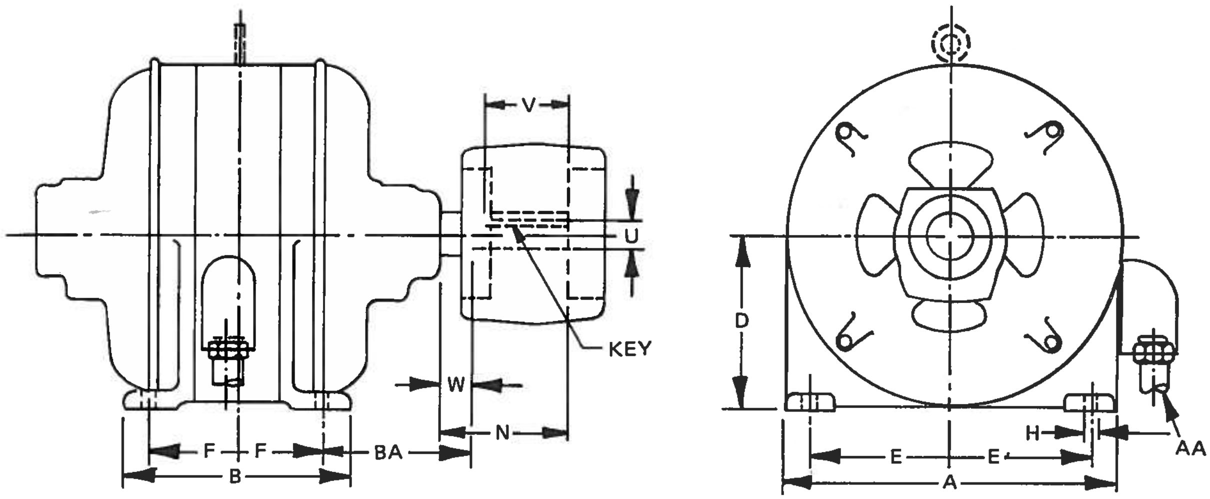
table c-1

The **table c-1,** above is based on a pump efficiency of 85%, and is calculated from the formula:

$$HP = GPM \times PSI \div (1714 \times .85)$$

As horsepower varies directly with flow or pressure, multiply proportionately to determine values not shown. For example, at 4000 PSI, multiply 2000 PSI values by 2.

DIMENSIONS FOR FOOT-MOUNTED A-C MOTORS WITH SINGLE STRAIGHT SHAFT EXTENSION



Frame Number	A Max.	B Max.	D*	E	F	BA	H	N-W	U	V Min.	Key Width	Key Thickness	Key Length	AA, Min. Conduit Size
42	....	....	2-5/8	1-3/4	27/32	2-1/16	9/32 slot	1-1/8	3/8	....	....	3/64 flat	....	....
48	....	....	3	2-1/8	1-3/8	2-1/2	11/32 slot	1-1/2	1/2	....	....	3/64 flat	....	....
56	....	....	3-1/2	2-7/16	1-1/2	2-3/4	11/32 slot	1-7/8	5/8	....	3/16	3/16	1-3/8†	....
66	....	....	4-1/8	2-15/16	2-1/2	3-1/8	13/32 slot	2-1/4	3/4	....	3/16	3/16	1-7/8†	....
182	9	6-1/2	4-1/2	3-3/4	2-1/4	2-3/4	13/32	2-1/4	7/8	2	3/16	3/16	1-3/8	3/4
184	9	7-1/2	4-1/2	3-3/4	2-3/4	2-3/4	13/32	2-1/4	7/8	2	3/16	3/16	1-3/8	3/4
213	10-1/2	7-1/2	5-1/4	4-1/4	2-3/4	3-1/2	13/32	3	1-1/8	2-3/4	1/4	1/4	2	3/4
215	10-1/2	9	5-1/4	4-1/4	3-1/4	3-1/2	13/32	3	1-1/8	2-3/4	1/4	1/4	2	3/4
254U	12-1/2	10-3/4	6-1/4	5	4-1/8	4-1/4	17/32	3-3/4	1-3/8	3-1/2	5/16	5/16	2-3/4	1
256U	12-1/2	12-1/2	6-1/4	5	5	4-1/4	17/32	3-3/4	1-3/8	3-1/2	5/16	5/16	2-3/4	1
284U	14	12-1/2	7	5-1/2	4-3/4	4-3/4	17/32	4-7/8	1-5/8	4-5/8	3/8	3/8	3-3/4	1-1/4
286U	14	14	7	5-1/2	5-1/2	4-3/4	17/32	4-7/8	1-5/8	4-5/8	3/8	3/8	3-3/4	1-1/4
324U	16	14	8	6-1/4	5-1/4	5-1/4	21/32	5-5/8	1-7/8	5-3/8	1/2	1/2	4-1/4	1-1/2
324S	16	14	8	6-1/4	5-1/4	5-1/4	21/32	3-1/4	1-5/8	3	3/8	3/8	1-7/8	1-1/2
326U	16	15-1/2	8	6-1/4	6	5-1/4	21/32	5-5/8	1-7/8	5-3/8	1/2	1/2	4-1/4	1-1/2
326S	16	15-1/2	8	6-1/4	6	5-1/4	21/32	3-1/4	1-5/8	3	3/8	3/8	1-7/8	1-1/2
364U	18	15-1/4	9	7	5-5/8	5-7/8	21/32	6-3/8	2-1/8	6-1/8	1/2	1/2	5	2
364US	18	15-1/4	9	7	5-5/8	5-7/8	21/32	3-3/4	1-7/8	3-1/2	1/2	1/2	2	2
365U	18	16-1/4	9	7	6-1/8	5-7/8	21/32	6-3/8	2-1/8	6-1/8	1/2	1/2	5	2
365US	18	16-1/4	9	7	6-1/8	5-7/8	21/32	3-3/4	1-7/8	3-1/2	1/2	1/2	2	2
404U	20	16-1/4	10	8	6-1/8	6-5/8	13/16	7-1/8	2-3/8	6-7/8	5/8	5/8	5-1/2	2
404US	20	16-1/4	10	8	6-1/8	6-5/8	13/16	4-1/4	2-1/8	4	1/2	1/2	2-3/4	2
405U	20	17-3/4	10	8	6-7/8	6-5/8	13/16	7-1/8	2-3/8	6-7/8	5/8	5/8	5-1/2	2
405US	20	17-3/4	10	8	6-7/8	6-5/8	13/16	4-1/4	2-1/8	4	1/2	1/2	2-3/4	2
444U	22	18-1/2	11	9	7-1/4	7-1/2	13/16	8-5/8	2-7/8	8-3/8	3/4	3/4	7	2-1/2
444US	22	18-1/2	11	9	7-1/4	7-1/2	13/16	4-1/4	2-1/8	4	1/2	1/2	2-3/4	2-1/2
445U	22	20-1/2	11	9	8-1/4	7-1/2	13/16	8-5/8	2-7/8	8-3/8	3/4	3/4	7	2-1/2
445US	22	20-1/2	11	9	8-1/4	7-1/2	13/16	4-1/4	2-1/8	4	1/2	1/2	2-3/4	2-1/2
504U	25	21	12-1/2	10	8	8-1/2	15/16	8-5/8	2-7/8	8-3/8	3/4	3/4	7-1/4	2-1/2
504S	25	21	12-1/2	10	8	8-1/2	15/16	4-1/4	2-1/8	4	1/2	1/2	2-3/4	2-1/2
505	25	23	12-1/2	10	8	8-1/2	15/16	8-5/8	2-7/8	8-3/8	3/4	3/4	7-1/4	2-1/2
505S	25	23	12-1/2	10	8	8-1/2	15/16	4-1/4	2-1/8	4	1/2	1/2	2-3/4	2-1/2

table c-2

Adapted from MG 1-11.31.

*Dimension D will never be greater than the values listed, but it may be less so that shims are usually required for coupled or geared machines. When exact dimension is required, shims up to 1/32 in. may be necessary on frame sizes whose dimension D is 8 in. and less; on larger frames, shims up to 1/16 in. may be necessary.

†Effective length of keyway.

standard enclosures for electric motors

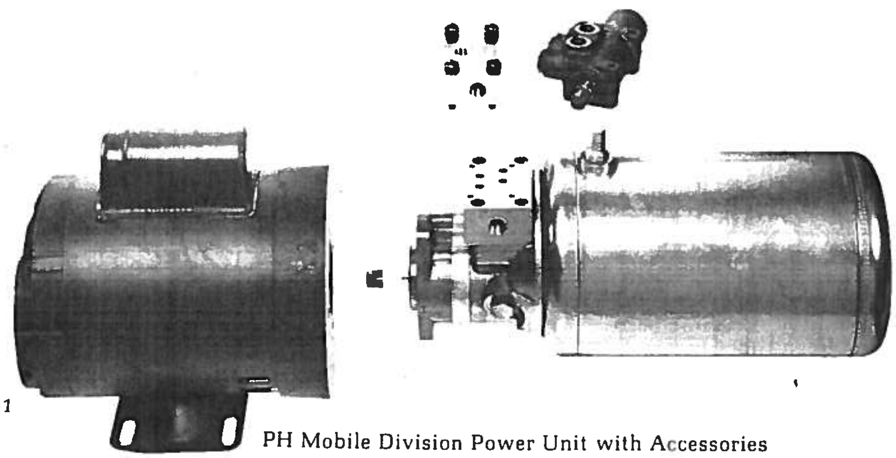


illustration c-1

PH Mobile Division Power Unit with Accessories

Open
The open motor is one having ventilating openings which permit passage of external cooling air over and around the windings.

Drip-Proof
The drip-proof motor is an open motor in which ventilating openings are so constructed that drops of liquid or solids falling on the machine at any angle not greater than 15 degrees from the vertical cannot enter the machine.

Guarded
A guarded motor is an open motor in which ventilating openings are limited to specified size and shape to prevent insertion of fingers or rods to avoid accidental contact with rotating or electrical parts.

Splash-Proof
A splash-proof motor is an open motor in which ventilating openings are so constructed that drops of liquid or solid particles falling on the machine or coming toward the machine in a straight line at any angle not greater than 100 degrees from the vertical cannot enter the machine.

Totally-Enclosed
A totally-enclosed motor is a motor so enclosed as to prevent the free exchange of air between the inside and outside of the case, but not air-tight.

Totally-Enclosed Nonventilated (TENV)
A totally-enclosed nonventilated (TENV) motor is a totally-enclosed motor which is not equipped for cooling by means external to the enclosing parts.

Totally-Enclosed Fan-Cooled (TEFC)
A totally-enclosed fan-cooled (TEFC) motor is a totally enclosed motor with a fan to blow cooling air across the external frame. It is a popular motor for use in dusty, dirty, and corrosive atmospheres.

Encapsulated
Encapsulated motor is an open motor in which the windings are covered with a heavy coating of material to protect them from moisture, dirt, abrasion, etc. Some encapsulated motors have only the coil noses coated. In others, the encapsulation material impregnates the windings even in the coil slots. With this complete protection, the motors can often be used in applications which formerly demand totally enclosed motors.

Explosion-Proof
An explosion-proof motor is a totally enclosed motor designed and built to withstand an explosion of gas or vapor within it, and to prevent ignition of gas or vapor surrounding the machine by sparks, flashes or explosions which may occur within the machine casing.

three-phase motor design

Design "B" — A Design "B" motor is a 3-phase squirrel-cage motor designed to withstand full-voltage starting and developing lock-rotor and breakdown torques adequate for general application.

Design "C" — A Design "C" motor is a 3-phase squirrel-cage motor designed to withstand full-voltage starting, developing locked-rotor torque for special high torque applications.

Design "D" — A Design "D" motor is a 3-phase squirrel-cage motor designed to withstand full-voltage starting, developing 275 percent locked-rotor torque (generally referred to as a "high slip" motor).

motor starter, conduit and wire size

3 PHASE MOTOR STARTERS

1/2 TO 20 H.P. MOTOR H.P. 3 ø	1/2		3/4		1		1-1/2		2		3		5		7-1/2		10		15		20	
VOLTAGE	220	440	220	440	220	440	220	440	220	440	220	440	220	440	220	440	220	440	220	440	220	440
Nema Starter Size	00	00	00	00	00	00	00	00	0	00	0	0	1	0	1	1	2	1	2	2	3	2
⊕ Full Load Current	2.0	1.0	2.8	1.4	3.5	1.8	5.0	2.5	6.5	3.3	9.0	4.5	15	7.5	22	11	28	14	40	20	52	26
Fuses – Amps: Std. N.E.C.	15	15	15	15	15	15	15	15	20	15	25	15	40	20	60	30	70	35	100	50	150	70
Fuses – Amps: Dual Element	5	4	5	4	8	4	8	5	12	8	15	10	25	15	30	20	45	25	60	30	80	40
Circuit Breaker Max. Amps.	15	15	15	15	15	15	15	15	15	15	20	15	30	15	50	20	50	30	70	40	100	50
Minimum Wire Sizes: R, RW, T, TW	14	14	14	14	14	14	14	14	14	14	14	14	12	14	10	14	8	12	6	10	4	8
Minimum Wire Sizes: RH	14	14	14	14	14	14	14	14	14	14	14	14	12	14	10	14	8·	12	6	10	6	8

Always specify voltage and frequency.

3 PHASE MOTOR STARTERS

25 TO 200 H.P. MOTOR H.P. 3 ø	25		30		40		50		60		75		100		125		150		200	
VOLTAGE	220	440	220	440	220	440	220	440	220	440	220	440	220	440	220	440	220	440	220	440
Nema Starter Size	3	2	3	3	4	3	4	3	5	4	5	4	5	4	6	5	6	5	6	5
⊕ Full Load Current	64	32	78	39	104	52	125	63	150	75	185	93	246	123	310	155	360	180	480	240
Fuses – Amps: Std. N.E.C.	175	80	200	100	300	150	350	175	400	200	500	250	600	350	–	400	–	450	–	600
Fuses – Amps: Dual Element	100	50	125	60	175	80	200	100	225	125	300	150	400	200	450	250	600	300	–	400
Circuit Breaker Max. Amps.	125	50	100	70	175	100	200	125	225	125	300	150	400	200	–	250	–	300	–	400
Minimum Wire Sizes: R, RW, T, TW	3	8	1	6	00	4	000	3	0000	2	300	0	500	000	–	0000	–	300	–	500
Minimum Wire Sizes: RH	4	8	3	6	1	6	00	4	000	3	0000	1	350	00	–	000	–	0000	–	350

Always specify voltage and frequency.

SINGLE PHASE MOTOR STARTERS

1/6 TO 5 H.P. MOTOR H.P. 1 ø	1/6		1/4		1/3		1/2		3/4		1		1-1/2		2		3		5	
VOLTAGE	115	230	115	230	115	230	115	230	115	230	115	230	115	230	115	230	115	230	115	230
⊕ Full Load Current	4.4	2.2	5.8	2.9	7.2	3.6	9.8	4.9	13.8	6.9	16	8	20	10	24	12	34	17	56	28
Fuses – Amps. Std. N.E.C.	15	15	20	15	25	15	30	15	45	25	50	25	60	30	80	40	100	60	–	90
Circuit Breaker Max. Amps.	15	15	15	15	15	15	30	15	40	20	40	20	50	30	70	30	100	50	–	70
Min. Wire Sizes – R, RH, RW, T, TW	14	14	14	14	14	14	14	14	12	14	12	14	10	14	10	14	6	10	–	8

WIRE & CONDUIT SIZES

WIRE SIZE AWG or MCM	14	12	10	8	6	4	3	2	1	0	00	000	0000	250	300	350	400	500	750	1000
MAXIMUM 3 WIRES IN CONDUIT – Wire Capacity: R-RW-T-TW Amps.	15	20	30	40	55	70	80	95	110	125	145	165	195	215	240	260	280	320	400	455
MAXIMUM 3 WIRES IN CONDUIT – Wire Capacity: RH Amps.	15	20	30	45	65	85	100	115	130	150	175	200	230	255	285	310	335	380	475	545
MAXIMUM 3 WIRES IN CONDUIT – CONDUIT SIZE – Inches	1/2	1/2	3/4	3/4	1	1-1/4	1-1/4	1-1/4	1-1/2	2	2	2	2-1/2	2-1/2	2-1/2	3	3	3	3-1/2	4
Volts Drop Per Ampere Per 100 Ft. – 80% P.F.: 1 Phase Volts	.4762	.3125	.1961	.1250	.0833	.0538	.0431	.0370	.0323	.0269	.0222	.0190	.0161	.0147	.0131	.0121	.0115	.0101	.0086	.0081
Volts Drop Per Ampere Per 100 Ft. – 80% P.F.: 3 Phase Volts	.4167	.2632	.1677	.1087	.0714	.0463	.0379	.0323	.0278	.0231	.0196	.0163	.0139	.0128	.0114	.0106	.0091	.0088	.0066	.0061

Capacity of conductors in conduit based on room temperature of 30° C. (86° F.)

⊕ The full load currents shown are average values.

table j (c-3)

electrical devices