AIT®

APPLIED
Industrial Technologies®

PRODUCT CATALOG
25/26

Metric/Decimal Equivalents

			Inches	Millimeters				Inches	Millimeters
		1/64	.015625	0.3969			33/64	.515625	13.0969
	1/32		.031250	0.7938		17/32		.531250	13.4938
			.039370	— 1			35/64	.546875	13.8906
		3/64	.046875	1.1906				.551181	— 14
1/16			.062500	1.5875	9/16			.562500	14.2875
		5/64	.078125	1.9844			37/64	.578125	14.6844
			.078740	— 2				.590551	— 15
	3/32		.093750	2.3812		19/32		.593750	15.0812
		7/64	.109375	2.7781			39/64	.609375	15.4781
			.118110	— 3	5/8			.625000	15.8750
1/8			.125000	3.1750				.629921	— 16
		9/64	.140625	3.5719			41/64	.640625	16.2719
	5/32		.156250	3.9688		21/32		.656250	16.6688
			.157480	— 4				.669291	— 17
		11/64	.171875	4.3656			43/64	.671875	17.0656
3/16			.187500	4.7625	11/16			.687500	17.4625
			.196850	— 5			45/64	.703125	17.8594
		13/64	.203125	5.1594				.708661	— 18
	7/32		.218750	5.5562		23/32		.718750	18.2562
		15/64	.234375	5.9531			47/64	.734375	18.6531
			.236220	— 6				.748031	— 19
1/4			.250000	6.3500	3/4			.750000	19.0500
		17/64	.265625	6.7469			49/64	.765625	19.4469
			.275591	— 7		25/32		.781250	19.8438
	9/32		.281250	7.1438				.787402	— 20
		19/64	.296875	7.5406			51/64	.796875	20.2406
5/16			.312500	7.9375	13/16			.812500	20.6375
			.314961	— 8				.826775	— 21
		21/64	.328125	8.3344			53/64	.828125	21.0344
	11/32		.343750	8.7312		27/32		.843750	21.4312
			.354331	— 9			55/64	.859375	21.8281
		23/64	.359375	9.1281				.866142	— 22
3/8			.375000	9.5250	7/8			.875000	22.2250
		25/64	.390625	9.9219			57/64	.890625	22.6219
			.393701	— 10				.905512	— 23
	13/32		.406250	10.3188		29/32		.906250	23.0188
		27/64	.421875	10.7156			59/64	.921875	23.4156
			.433071	— 11	15/16			.937500	23.8125
7/16			.437500	11.1125				.944882	— 24
		29/64	.453125	11.5094			61/64	.953125	24.2094
	15/32		.468750	11.9062		31/32		.968750	24.6062
			.472441	— 12				.984252	— 25
		31/64	.484375	12.3031			63/64	.984375	25.0031
1/2			.500000	12.7000	1			1.00000	25.4000
			.511811	— 13					

Decimal Equivalents of Millimeters

mm	Inches	mm	Inches	mm	Inches	mm	Inches	mm	Inches	mm	Inches
25	0.98425	38	1.49606	51	2.00787	64	2.51968	77	3.03149	90	3.54330
26	1.02362	39	1.53543	52	2.04724	65	2.55905	78	3.07086	91	3.58267
27	1.06299	40	1.57480	53	2.08661	66	2.59842	79	3.11023	92	3.62204
28	1.10236	41	1.61417	54	2.12598	67	2.63779	80	3.14960	93	3.66141
29	1.14173	42	1.65354	55	2.16535	68	2.67716	81	3.18897	94	3.70078
30	1.18110	43	1.69291	56	2.20472	69	2.71653	82	3.22834	95	3.74015
31	1.22047	44	1.73228	57	2.24409	70	2.75590	83	3.26771	96	3.77952
32	1.25984	45	1.77165	58	2.28346	71	2.79527	84	3.30708	97	3.81889
33	1.29921	46	1.81102	59	2.32283	72	2.83464	85	3.34645	98	3.85826
34	1.33858	47	1.85039	60	2.36220	73	2.87401	86	3.38582	99	3.89763
35	1.37795	48	1.88976	61	2.40157	74	2.91338	87	3.42519	100	3.93700
36	1.41732	49	1.92913	62	2.44094	75	2.95275	88	3.46456		
37	1.45669	50	1.96850	63	2.48031	76	2.99212	89	3.50393		

1 Inch = 25.400 mm

Temperature Conversions

°C – °F 0 to 40				°C – °F 41 to 80				°C – °F 81 to 250				°C – °F 260 to 600		
C	C or F	F		C	C or F	F		C	C or F	F		C	C or F	F
-17.80	0	32.0		5.00	41	105.8		27.2	81	177.8		127	260	500
-17.20	1	33.8		5.56	42	107.6		27.8	82	179.6		132	270	518
-16.70	2	35.6		6.11	43	109.4		28.3	83	181.4		138	280	536
-16.10	3	37.4		6.67	44	111.2		28.9	84	183.2		143	290	554
-15.60	4	39.2		7.22	45	113.0		29.4	85	185.0		149	300	572
-15.00	5	41.0		7.78	46	114.8		30.0	86	186.8		154	310	590
-14.40	6	42.8		8.33	47	116.6		30.6	87	188.6		160	320	608
-13.90	7	44.6		8.89	48	118.4		31.1	88	190.4		166	330	626
-13.30	8	46.4		9.44	49	120.2		31.7	89	192.2		171	340	644
-12.80	9	48.2		10.00	50	122.0		32.2	90	194.0		177	350	662
-12.20	10	50.0		10.60	51	123.8		32.8	91	195.8		182	360	680
-11.70	11	51.8		11.10	52	125.6		33.3	92	197.6		188	370	698
-11.10	12	53.6		11.70	53	127.4		33.9	93	199.4		193	380	716
-10.60	13	55.4		12.20	54	129.2		34.4	94	201.2		199	390	734
-10.00	14	57.2		12.80	55	131.0		35.0	95	203.0		204	400	752
-9.44	15	59.0		13.30	56	132.8		35.6	96	204.8		210	410	770
-8.89	16	60.8		13.90	57	134.6		36.1	97	206.6		216	420	788
-8.33	17	62.6		14.40	58	136.4		36.7	98	208.4		221	430	806
-7.78	18	64.4		15.00	59	138.2		37.2	99	210.2		227	440	824
-7.22	19	66.2		15.60	60	140.0		37.8	100	212.0		232	450	842
-6.67	20	68.0		16.10	61	141.8		43.0	110	230.0		238	460	860
-6.11	21	69.8		16.70	62	143.6		49.0	120	248.0		243	470	878
-5.56	22	71.6		17.20	63	145.4		54.0	130	266.0		249	480	896
-5.00	23	73.4		17.80	64	147.2		60.0	140	284.0		254	490	914
-4.44	24	75.2		18.30	65	149.0		66.0	150	302.0		260	500	932
-3.89	25	77.0		18.90	66	150.8		71.0	160	320.0		266	510	950
-3.33	26	78.8		19.40	67	152.6		77.0	170	338.0		271	520	968
-2.78	27	80.6		20.00	68	154.4		82.0	180	356.0		277	530	986
-2.22	28	82.4		20.60	69	156.2		88.0	190	374.0		282	540	1004
-1.67	29	84.2		21.10	70	158.0		93.0	200	392.0		288	550	1022
-1.11	30	86.0		21.70	71	159.8		99.0	210	410.0		293	560	1040
-0.56	31	87.8		22.20	72	161.6		100.0	212	413.0		299	570	1058
0.00	32	89.6		22.80	73	163.4		104.0	220	428.0		304	580	1076
0.56	33	91.4		23.30	74	165.2		110.0	230	446.0		310	590	1094
1.11	34	93.2		23.90	75	167.0		116.0	240	464.0		316	600	1112
1.67	35	95.0		24.40	76	168.8		121.0	250	482.0				
2.22	36	96.8		25.00	77	170.6								
2.78	37	98.6		25.60	78	172.4								
3.33	38	100.4		26.10	79	174.2								
3.89	39	102.2		26.70	80	176.0								
4.44	40	104.0												

Temperature Conversion Formulas

NEED TO FIND	FORMULA
DEGREES (IN CELSIUS)	.56 X (DEGREES F – 32)
DEGREES (IN FAHRENHEIT)	(1.8 X DEGREES C) + 32

General Formulas

Drive System Mechanical Formulas

NEED TO FIND:	FORMULA:
CIRCUMFERENCE OF A CIRCLE	3.1416 X DIAMETER
DIAMETER OF A CIRCLE	$\dfrac{\text{CIRCUMFERENCE}}{(3.1416)}$
VELOCITY IN FEET PER MINUTE	FPM = .262 X DIAMETER X RPM
RPM REVOLUTIONS PER MINUTE	$\dfrac{\text{FEET PER MINUTE}}{(.262 \times \text{DIAMETER})}$
TORQUE IN/LBS	$\dfrac{\text{HP X 63,025}}{\text{RPM}}$
TORQUE IN/LBS	FORCE (LBS) X RADIUS (IN)
HORSEPOWER	$\dfrac{\text{TORQUE (IN.LBS) X RPM}}{63,025}$
HORSEPOWER	$\dfrac{\text{FORCE X FPM}}{33,000}$
BELT LENGTH	[1.57 X (DIA + DIA)] +(2 X CENTER DIST)
MOTOR RPM SYNCHRONOUS	$\dfrac{120 \times 60 \text{ (HZ)}}{\text{NUMBER OF MOTOR POLES}}$
PUMP MOTOR HP	$\dfrac{\text{GPM X HEAD IN FEET X SPEC GRAVITY}}{3960 \times \text{EFFICIENCY OF PUMP}}$
FAN MOTOR HP	$\dfrac{\text{CFM X PRESSURE (LB/SQ FT)}}{33000 \times \text{EFFICIENCY}}$

(left sidebar label: Mechanical)

Formulas and Constants

1 hp = 33,000 / Foot-pounds of work per minute.

1 hp = .746 K.W. = K.W. ÷ 1.341.

1 hp = 2,547 B.T.U. per hour.

1 B.T.U. = Heat required to raise 1 lb. water 1 °F.

1 B.T.U. = 777.6 / Foot-pounds work.

1 Kilowatt Hour = 3,415 B.T.U.

Heat Value of Carbon = 14,600 B.T.U. per pound.

Latent Heat of Fusion of Ice = 143.15 B.T.U per pound.

Latent Heat of Evaporation of Water at 212 °F.
= 970.4 B.T.U. per pound.

Total Heat of Saturated Steam at Atmospheric Pressure
= 1,150.4 B.T.U. per pound.

1 Ton of Refrigeration = 288,000 B.T.U. per 24 hours.

g = Acceleration of Gravity
(commonly taken as 32.16 feet per second per second).

1 Radian = 57.296 degrees.

1 Meter = 100 cm. = 39.37 inches.

1 Kilometer = .62137 miles.

1 Gallon = 231 cubic inches.

1 Barrel = 42 gallons.

Atmospheric Pressure = 14.7 pounds per sq. in.
= 29.92 inches mercury at 32 °F.

1 Lb. Per Sq. In. Pressure = 2.3095 feet fresh water at 62 °F.
= 2.0355 inches mercury at 32 °F.
= 2.0416 inches mercury at 62 °F.

Water Pressure (pounds per sq. in.)
= .433 X height of water in feet (Fresh water at 62 °F).

Weight of 1 cu. ft. Fresh Water
= 62.355 lbs. at 62 °F. = 59.76 lbs. at 212 °F.

Weight of 1 cu. ft. Air at 14.7 lbs. per sq. in. Pressure
= .07608 lbs. at 62 °F = .08073 lbs. at 32 °F.

APPLIED Industrial Technologies®

Horsepower

SPEED, in the science of bearing application and power transmission, is expressed in terms of the revolutions per minute (rpms) of a rotating object.

**VELOCITY** is speed in a designated direction and is usually expressed in terms of feet per minute (fpm).

FORCE is the element that produces a change in the velocity of an object. It is usually expressed in pounds.

WORK occurs when a force moves an object through a distance. It is usually expressed in foot-pounds or inch-pounds.

POWER is the rate of doing work. It is usually expressed in foot-pounds per minute (fppm).

HORSEPOWER is the unit of power. It is the power required to lift 33,000 pounds one foot in one minute.

Illustration of Horsepower

$$\frac{33,000\# \times 1}{33,000} = 1\ hp \qquad \frac{1,000\# \times 33}{33,000} = 1\ hp$$
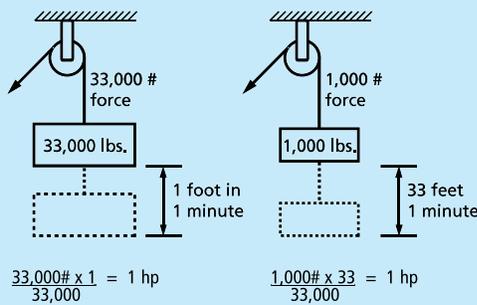
A **POUND-FOOT** is the moment created by a force of one pound applied to the end of a lever arm one foot long. Pound-feet indicate torque.

Example:
25 hp at 150 rpm = 10,504 Pound-Inches Torque
25 hp at 1.50 rpm = 1,050,400 Pound-Inches Torque
2.5 hp at 1.50 rpm = 105,040 Pound-Inches Torque

$$HORSEPOWER\ (hp) = \frac{pounds\ (\#) \times feet}{33,000 \times no.\ minutes}$$

$$hp = \frac{Force\ (lb\text{-}in) \times fpm}{33,000}$$

$$hp = \frac{Torque\ (in\ lb\text{-}in) \times rpm}{63,025}$$

$$hp = \frac{Torque\ (in\ lb\text{-}ft) \times rpm}{5,252}$$

Torque

TORQUE is the turning moment or twisting effort in a shaft or an object that tends to cause rotation. It is the measure of rotational force and is expressed in foot-pounds.

Torque = force in pounds x radius in inch or foot

$$Torque\ (pound\text{-}inch) = \frac{63,025 \times hp}{rpm}$$

$$Torque\ (pound\text{-}foot) = \frac{5,252 \times hp}{rpm}$$

$$Horsepower = \frac{TORQUE\ (lb\text{-}in) \times rpm}{63,025}$$

$$Horsepower = \frac{TORQUE\ (lb\text{-}ft) \times rpm}{5,252}$$

HORSEPOWER TO TORQUE CONVERSION TABLE
Torque lb-in @ 1 hp

rpm	LB-IN	rpm	LB-IN	rpm	LB-IN	rpm	LB-IN
3450	18	580	109	68	927	7.5	8,403
3000	21	520	121	56	1,125	6	10,504
2500	25	420	150	45	1,401	4.7	13,410
2000	32	350	180	37	1,703	4	15,756
1750	36	280	225	30	2,101	3.2	19,695
1430	44	230	274	25	2,521	2.7	23,343
1170	54	190	332	20	3,151	2.2	28,648
950	66	155	407	16.5	3,820	1.8	35,014
870	72	125	504	13.5	4,669	1.5	42,017
780	81	100	630	11	5,730	1.2	52,521
640	98	84	750	9	7,003	1	63,025

To compute torque at any horsepower, multiply torque values above by horsepower required.

Example:
10 hp @ 580 rpm, torque = 10 x 109, or 1,090 lb-ins
1/2 hp @ 100 rpm, torque = 1/2 x 630, or 315 lb-ins

For intermediate speeds, approximate the torque from table, or apply standard torque formula above.

Electrical Formulas

Drive System Electrical Formulas

NEED TO FIND	FORMULA
HORSEPOWER – DC	$\dfrac{\text{VOLTS X AMPS X EFFICIENCY}}{746}$
HORSEPOWER – AC	$\dfrac{\text{VOLTS X AMPS X 1.732 X EFF X PF}}{746}$
WATTS-DC	VOLTS X AMPS
WATTS-AC	VOLTS X AMPS X PF X 1.732
KILOWATTS	$\dfrac{\text{VOLTS X AMPS X PF X 1.732}}{1000}$
AMPERES (DC)	$\dfrac{\text{WATTS}}{\text{VOLTS}}$
AMPERES (AC)	$\dfrac{\text{746 X HORSEPOWER}}{\text{VOLTS X EFF X PF X 1.732}}$
KVA	$\dfrac{\text{VOLTS X AMPS X 1.732}}{1000}$
PUMP MOTOR HP	$\dfrac{\text{GPM X HEAD IN FEET X SPEC GRAVITY}}{\text{3960 X EFFICIENCY OF PUMP}}$
FAN MOTOR HP	$\dfrac{\text{CFM X PRESSURE (LB/SQ FT)}}{\text{33000 X EFFICIENCY}}$

(ELECTRICAL)

To Find	Alternating Current		Direct Current
	Single-Phase	Three-Phase	
Amperes when horsepower is known	$\dfrac{\text{hp X 764}}{\text{E X Eff X pf}}$	$\dfrac{\text{hp X 746}}{\text{1.73 X E X Eff = pf}}$	$\dfrac{\text{hp X 746}}{\text{E X Eff}}$
Amperes when kilowatts are known	$\dfrac{\text{Kw X 1000}}{\text{E X pf}}$	$\dfrac{\text{Kw X 1000}}{\text{1.73 X E X pf}}$	$\dfrac{\text{Kw X 1000}}{\text{E}}$
Amperes when Kva are known	$\dfrac{\text{Kva X 1000}}{\text{E}}$	$\dfrac{\text{Kva X 1000}}{\text{1.73 X E}}$	-
Kilowatts	$\dfrac{\text{I X E X pf}}{1000}$	$\dfrac{\text{1.73 X I X E X pf}}{1000}$	$\dfrac{\text{I X E}}{1000}$
Kva	$\dfrac{\text{I X E}}{1000}$	$\dfrac{\text{1.73 X I X E}}{1000}$	-
Horsepower = (Output)	$\dfrac{\text{I X E X Eff X pf}}{746}$	$\dfrac{\text{1.73 X I X E X Eff X pf}}{746}$	$\dfrac{\text{I X E X Eff}}{746}$

I = Amperes; E = Volts; Eff = Efficiency; pf = power factor;
Kva = Kilovolt Amperes; Kw = Kilowatts; R = Ohms.

To Find	Alternating or Direct Current
Amperes when voltage and resistance are known	$\dfrac{E}{R}$
Voltage when resistance and current are known	I R
Resistance when voltage and current are known	$\dfrac{E}{I}$

RULES OF THUMB

All Values At 100 % Load

1 hp = 746 Watts or (.746 Kilowatts)

At 3,600 rpm, a motor develops 18 lb.-in. per hp
At 1,800 rpm, a motor develops 36 lb.-in. per hp
At 1,200 rpm, a motor develops 54 lb.-in. per hp

At 575 volts, a 3-phase motor draws 1 amp per hp
At 460 volts, a 3-phase motor draws 1.25 amp per hp
At 230 volts, a 3-phase motor draws 2.5 amp per hp
At 230 volts, a single-phase motor draws 5 amp per hp
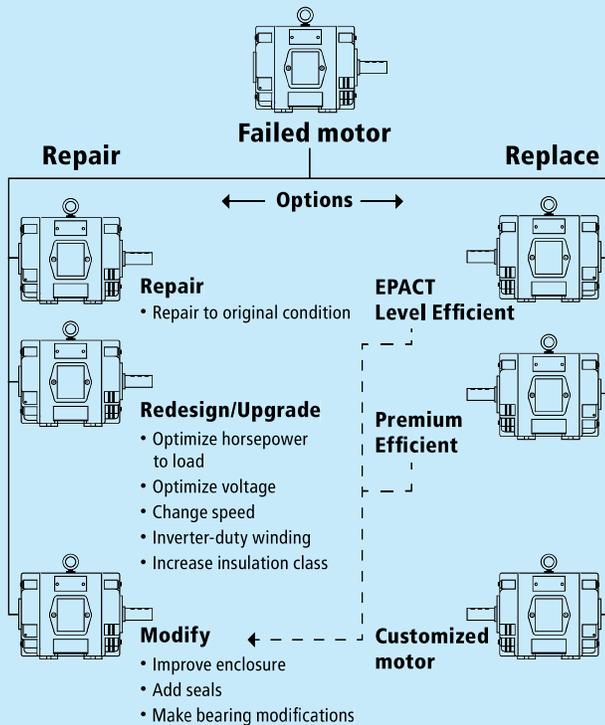At 115 volts, a single-phase motor draws 10 amp per hp

REPAIR OR REPLACE MOTOR DECISION PROCESS

Failed motor

Is the motor suitable for the application? — No → Investigate replacement with suitable motor (size/enclosure).

Yes ↓

What is the condition of the stator core? — Significant damage or high losses

OK ↓

Special cases (e.g., very expensive motors)

Has catastrophic failure occurred, or is there evidence of prior catastrophic failure? — Yes

No ↓

Is the cost of repair greater than the cost to replace the motor? — Yes

Is the rotor damaged, or is there severe damage to other mechanical parts? — Yes

No

No → Are replacement funds available?

No ↓

Yes ↓

Is it an EPACT motor? — Yes

No → Is replacement motor available?

No ↓

Yes ↓

Is return on investment of EPACT motor acceptable? — Yes

No → Is lead time of replacement motor acceptable?

No ↓

Yes ↓

Repair motor

Replace motor

• Additional considerations include increased reliability, life expectancy and benefits of additional features, upgrades or modifications.

REPAIR OR REPLACE MOTOR OPTIONS

Repair

Failed motor

Replace

← **Options** →

Repair
• Repair to original condition

EPACT Level Efficient

Redesign/Upgrade
• Optimize horsepower to load
• Optimize voltage
• Change speed
• Inverter-duty winding
• Increase insulation class

Premium Efficient

Modify
• Improve enclosure
• Add seals
• Make bearing modifications

Customized motor

Motor Amps @ Full Load*

hp	Alternating Current		DC	hp	Alternating Current		DC
	Single-Phase	3-Phase			Single-Phase	3-Phase	
1/2	4.9	2.0	2.7	25	-	60	92
1	8.0	3.4	4.8	30	-	75	110
1-1/2	10.0	4.8	6.6	40	-	100	146
2	12.0	6.2	8.5	50	-	120	180
3	17.0	8.6	12.5	60	-	150	215
5	28	14.4	20	75	-	180	268
7-1/2	40	21.0	29	100	-	240	355
10	50	26.0	38	125	-	300	443
15	-	38.0	56	150	-	360	534
20	-	50.0	74	200	-	480	712

* Baseline only; varies by manufacturer.

Values are for all speeds and frequencies @ 230 volts. Amperage other than 230 volts can be figured:

$$A = \frac{230 \times \text{Amp from Table}}{\text{New Voltage}}$$

Example:

For 60 hp, 3 phase @ 550 volts: $\frac{(230 \times 150)}{550}$ = 62 amps.

Power Factor estimated @ 80% for most motors. Efficiency is usually 80-90%.

NEMA Electrical Enclosure Types

| Type	Description
NEMA Type 1 (General Purpose)	For indoor use wherever oil, dust or water is not a problem.
NEMA Type 2 (Driptight)	Used indoors to exclude falling moisture and dirt.
NEMA Type 3 (Weatherproof)	Provides protection against rain, sleet and snow.
NEMA Type 4 (Watertight)*	Needed when subject to great amounts of water from any angle—such as areas which are repeatedly hosed down.
NEMA Type 4x (Corrosion Resistant)	Needed when subject to great amounts of water from any angle—such as areas which are repeatedly hosed down; corrosion resistant.
NEMA Type 5 Dust Tight (Non-Hazardous)	Used for excluding dust. (All NEMA 12 enclosures are usually suitable for NEMA 5 use.)
NEMA Type 9 Dust Tight (Hazardous)**	For locations where combustible dusts are present.
NEMA Type 12 (Industrial Use)	Used for excluding oil, coolant, flying dust, lint, etc.

* Not designed to be submerged.
** Class II Groups E, F and G.

Information used with permission of ABB Motors and Mechanical Inc.

## AC Critical Motor Mounting Dimensions

48-449T FRAMES
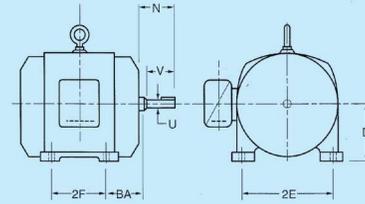
Frame Size	2F	BA	N		V	U	2E	D
			TEFC/TENV	XP				
48	2.75	2.50	1.56	1.56	1.50	0.500	4.24	3.00
56	3.00	2.75	1.94	1.94	1.88	0.625	4.88	3.50
143T	4.00	2.25	2.31	2.31	2.25	0.875	5.50	3.50
145T	5.00	2.75	2.31	2.31	2.25	0.875	5.50	3.50
182T	4.50	2.75	3.00	2.81	2.50	1.125	7.50	4.50
184T	5.50	2.75	3.00	2.81	2.50	1.125	7.50	4.50
213T	5.50	3.50	3.62	3.44	3.12	1.375	8.50	5.25
215T	7.00	3.50	3.62	3.44	3.12	1.375	8.50	5.25
254T	8.25	4.25	4.12	4.06	3.75	1.625	10.00	6.25
256T	10.00	4.25	4.12	4.06	3.75	1.625	10.00	6.25
284T	9.50	4.75	5.00	4.69	4.38	1.875	11.00	7.00
284TS	9.50	4.75	3.62	3.31	3.00	1.625	11.00	7.00
286T	11.00	4.75	5.00	4.69	4.38	1.875	11.00	7.00
286TS	11.00	4.75	3.62	3.31	3.00	1.625	11.00	7.00
324T	10.50	5.25	5.62	5.62	5.00	2.125	12.50	8.00
324TS	10.50	5.25	4.12	4.12	3.50	1.875	12.50	8.00
326T	12.00	5.25	5.62	5.62	5.00	2.125	12.50	8.00
326TS	12.00	5.25	4.12	4.12	3.50	1.875	12.50	8.00
364T	11.25	5.88	6.25	6.00	5.62	2.375	14.00	9.00
364TS	11.25	5.88	4.12	3.88	3.50	1.875	14.00	9.00
365T	12.25	5.88	6.25	6.00	5.62	2.375	14.00	9.00
365TS	12.25	5.88	4.12	3.88	3.50	1.875	14.00	9.00
404T	12.25	6.63	7.50	7.50	7.00	2.875	16.00	10.00
404TS	12.25	6.63	4.50	4.50	4.00	2.125	16.00	10.00
405T	13.75	6.63	7.50	7.50	7.00	2.875	16.00	10.00
405TS	13.75	6.63	4.50	3.50	4.00	2.125	16.00	10.00
444T	14.50	7.50	8.94	8.94	8.25	3.375	18.00	11.00
444TS	14.50	7.50	5.19	5.19	4.50	2.375	18.00	11.00
445T	16.50	7.50	8.94	8.94	8.25	3.375	18.00	11.00
445TS	16.50	7.50	5.19	5.19	4.50	2.375	18.00	11.00
447T	20.00	7.50	8.50	8.50	8.25	3.375	18.00	11.00
447TS	20.00	7.50	4.75	4.75	4.50	2.375	18.00	11.00
449T	25.00	7.50	8.50	8.50	8.25	3.375	18.00	11.00
449TS	25.00	7.33	4.75	4.75	4.50	2.375	18.00	11.00

Note: Dimensions are for estimating purposes only.

C-FACE 56C-365TC
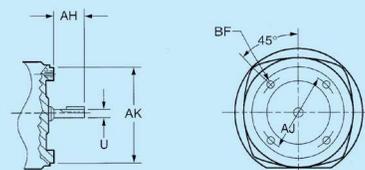
Frame Size	AH	AJ	AK	BF	No.	Depth	U	Key Sq.	Key Length
56C	2.06	5.88	4.500	3/8-16	4	0.56	0.625	0.188	1.25
143-145TC	2.12	5.88	4.500	3/8-16	4	0.56	0.875	0.188	1.25
182-184TC	2.62	7.25	8.500	1/2-13	4	0.75	1.125	0.250	1.75
213-215TC	3.12	7.25	8.500	1/2-13	4	0.75	1.375	0.312	2.38
254-256TC	3.75	7.25	8.500	1/2-13	4	0.75	1.625	0.375	2.88
284-286TC	4.38	9.00	10.500	1/2-13	4	0.75	1.875	0.500	3.25
324-326TC	5.00	11.00	12.500	5/8-11	4	0.94	2.125	0.500	3.88
364-365TC	5.62	11.00	12.500	5/8-11	4	0.94	2.375	0.625	4.25

Note: Dimensions are for estimating purposes only.

Information used with permission of ABB Motors and Mechanical Inc.
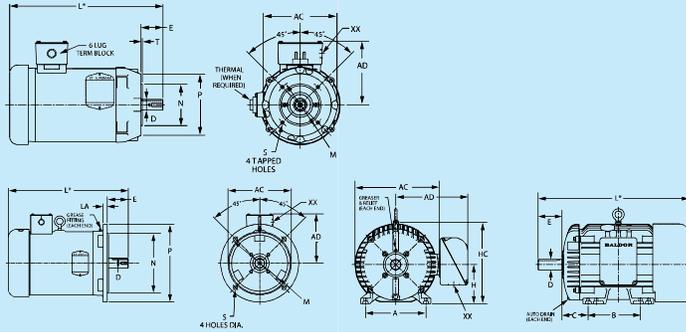
Key and Keyseat Dimensions

Frame	D	G	F	GD	Frame	D	G	F	GD
63	11	8.5	4	4	180	48	42.5	14	9
71	14	11	5	5	200	55	49	16	10
80	19	15.5	6	6	225	60	53	18	11
90	24	20	8	7	250	70	67.5	20	12
100	28	24	8	7	280	80	71	22	14
112	28	24	8	7	315	85	76	22	14
132	38	33	10	8	355	85	76	22	14
160	42	37	12	8					

Drawings represent standard TEFC general purpose motors.

*Dimensions are for reference only.

L dimension not designated by IEC

IEC QUICK REFERENCE CHART

IEC Frame	Type	A	B	C	H	D	E	LA	M	N	P	S	T	M	N	P	S	T	L	AC	AD	HC	XX
63	300	100 3.937	80 3.150	40 1.570	63 2.480	11 .433	23 .906	8 .313	115 4.528	95 3.740	140 5.512	9 .354	3 .118	75 2.953	60 2.362	90 3.540	M5	2.5 0.98	*	119 4.690	102 4 116d 4.567d	121 4.760 136d 5.375d	13 .500 22d .880d
71	300 400	112 4.409	90 3.543	45 1.770	71 2.800	14 .551	30 1.181	8 .313	130 5.118	110 4.331	160 6.299	10 .393	3.5 .138	85 3.347	70 2.756	105 4.130	M6	2.5 .098	*	119 4.690 145d 5.690d	102 4	131 5.140 149d 5.880d	18 .690 21d .844d
80	400 500	125 4.921	100 3.937	50 1.969	80 3.150	19 .748	40 1.575	13 .500	165 6.496	130 5.118	200 7.874	11 .430	3.5 .138	100 3.937	80 3.150	120 4.724	M6	3 .118	*	145 5.690 168d 6.614d	116 4.510 130 5.120	152 6 162d 6.380d	22 .880 21d .844d
90	S L	140 5.511	100 3.937 125 4.921	56 2.205	90 3.543	24 .945	50 1.969	13 .500	165 6.496	130 5.118	200 7.874	12 .472	3.5 .138	115 4.530	95 3.740	140 5.512	M8	3 .118	*	168 6.614 144d 5.687d	130 5.120 107d 4.250d	173 6.810 165d 6.531d	22 .880 21d .844d
100	S L	160 6.300	112 4.409 140 5.512	63 2.480	100 3.937	28 1.102	60 2.362	14 .562	215 8.465	180 7.087	250 9.840	14 .560	4 .160	130 5.108	110 4.331	160 6.299	M8	3.5 .138	*	200 7.875	149 5.875 153d 6.060d	180 7.906 239d 9.440d	27 1.062
112	S M	190 7.480	114 4.488 140 5.512	70 2.760	112 4.409	28 1.102	60 2.362	14 .562	215 8.465	180 7.087	250 9.840	14 .560	4 .160	130 5.108	110 4.331	160 6.299	M8	3.5 .138	*	243 7.875	149 5.875	214 8.437	27 1.062
132	S M	216 8.504	140 5.512 178 7.008	89 3.504	132 5.197	38 1.496	80 3.150	14 .562	265 10.433	230 9.055	300 11.811	14 .560	4 .160	165 6.496	130 5.118	200 7.874	M8	3.5 .138	*	243 9.562	187 7.375	256 10.062	27 1.062
160	M L	254 10	210 8.268 254 10	108 4.252	160 6.299	42 1.654	110 4.331	20 .787	300 11.811	250 9.842	350 13.780	19 .748	5 .200	215 8.465	180 7.087	250 9.840	M12	4 .160	*	329 12.940	242 9.510	329 12.940	35 1.375
180	M L	279 10.984	241 9.488 279 10.984	121 4.764	180 7.087	48 1.890	110 4.331	20 .787	300 11.811	250 9.842	350 13.780	19 .748	5 .200						*	395 15.560	333 13.120	372 14.640	51 2.008
200	L M	318 12.520	267 10.512 305 12.008	133 5.236	200 7.874	55 2.165	110 4.331	27 1.062	350 13.780	300 11.811	400 15.748	19 .748	5 .200						*	441 17.375	359 14.125	416 16.375	63 2.500
225	S M	356 14.016	286 11.260 311 12.244	149 5.866	225 8.858	60 2.362	140 5.512	19 .748	400 15.748	350 13.780	450 17.716	19 .748	6 .236						*	495 19.488	383 15.079	483 19.016	63 2.500
250	S M	406 15.984	311 12.244 349 13.740	168 6.614	250 9.843	70 2.756	140 5.512												*	520 20.472	457 17.992	513 20.197	63 2.500
280	S M	457 17.992	368 14.488 419 16.496	190 7.485	280 11.025	80 3.150	170 6.693												*	616 24.252	497 19.567	581 22.874	63 2.500
315	S M	508 20	406 16 457 18	216 8.500	315 12.400	85 3.346	170 6.693												*	759 29.900	683 26.880	682 26.840	102 4
355	S L	610 24	500 19.690 630 24.800	254 10	355 13.980	85 3.346	170 6.693												*	759 29.900	683 26.880	719 28.320	102 4

Foot Mounting: A, B, C, H — Shaft: D, E — B5 Flange: LA, M, N, P, S, T — B14 Face: M, N, P, S, T — General: L, AC, AD, HC, XX

LEGEND
Metric (MM) Dimensions in Black
Inch Dimensions in Gray
d = DC Motors
1 mm = .03937" 1" = 25.40 mm

Horizontal Shaft Arrangements

B3 FOOT MOUNTED.
B5 "D" TYPE FLANGE AT DRIVE END, NO FEET.
B6 FOOT WALL MOUNT WITH FEET ON LEFT HAND SIDE WHEN VIEWED FROM DRIVE END.
B7 FOOT WALL MOUNT WITH FEET ON RIGHT HAND SIDE WHEN VIEWED FROM DRIVE END.
B8 CEILING MOUNTED WITH FEET ABOVE MOTOR.
B14 "C" TYPE FACE AT DRIVE END, NO FEET.
B17 2 "C" OR "D" TYPE FLANGES, FOOT MOUNTED.
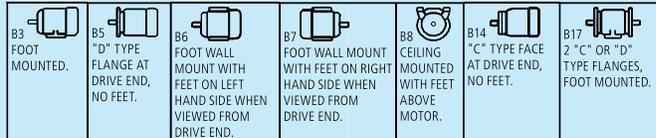
Vertical Shaft Arrangements

V1 "D" TYPE FLANGE AT DRIVE END, SHAFT DOWN, NO FEET.
V3 "D" TYPE FLANGE AT DRIVE END, SHAFT UP, NO FEET.
V5 VERTICAL FOOT, WALL MOUNTED, SHAFT DOWN.
V6 VERTICAL FOOT, WALL MOUNTED, SHAFT UP.
V18 "C" TYPE FACE AT DRIVE END, SHAFT DOWN, NO FEET.
V19 "C" TYPE FACE AT DRIVE END, SHAFT UP, NO FEET.
V22 SKIRT MOUNTING, SHAFT DOWN, NO FEET.

Reference chart courtesy of ABB Motors and Mechanical Inc.

IP Protection

IP22 = Open Drip Proof AC or DC Motors.
IP54 = All standard TEFC AC and DC Motors.
IP55 = All TEFC Chemical Processing, Dirty Duty, and Washdown Duty Motors.

SUMMARY OF IP PROTECTION NUMBERS

First # Protection Against Solid Objects
IP TESTS
0 NO PROTECTION
1 Protection against solid objects up to 50 mm. (E.G. Accidental touch by hands.)
2 Protection against solid objects up to 12 mm. (E.G. Fingers)
3 Protection against solid objects over 2.5 mm. (E.G. Tools,Wires)
4 Protection against solid objects over 1 mm. (E.G. Tools, Wires, and Small Wires)
5 Protection against dust - limited ingress (No harmful deposits).
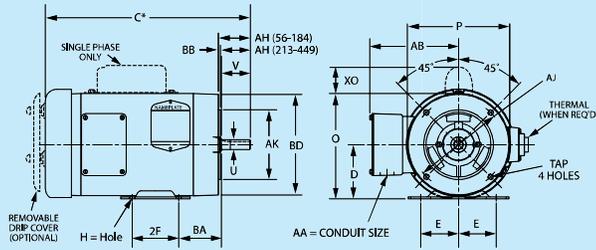6 Totally protected against all dust.

Second # Protection Against Liquids
0 NO PROTECTION
1 Protection against vertical drops of water. (E.G. Condensation).
2 Protection against falling water up to 15 degrees from the vertical.
3 Protection against falling water up to 60 degrees from the vertical.
4 Protection against splashing water from all directions, limited ingress.
5 Protection against low pressure jets of water from all directions, limited ingress.
6 Protection against strong jets of water. (E.G. Use on ship decks, limited ingress.)
7 Protection against immersion.
8 Protection against submersion.

NEMA Quick Reference

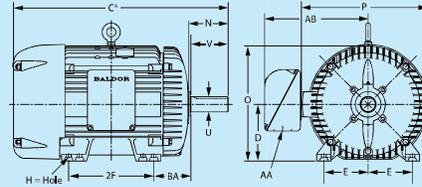Drawings represent standard TEFC general purpose motors.

C dimension not designated by NEMA.

* Dimensions are for reference only.

NEMA Shaft	Keyseat Dimensions		NEMA Shaft	Keyseat Dimensions	
(U)	(R)	(S)	(U)	(R)	(S)
3/8	21/64	FLAT	1-7/8	1-19/32	1/2
1/2	29/64	FLAT	2-1/8	1-27/32	1/2
5/8	33/64	3/16	2-3/8	2-1/64	5/8
7/8	49/64	3/16	2-1/2	2-3/16	5/8
1-1/8	63/64	1/4	2-7/8	2-29/64	3/4
1-3/8	1-13/64	5/16	3-3/8	2-7/8	7/8
1-5/8	1-13/32	3/8	3-7/8	3-5/16	1

Inch Dimensions

NEMA FRAME	D	E	2F	H	N	O	P	U	V	AA	AB	AH	AJ	AK	BA	BB	BD	XO	TAP
42	2-5/8	1-3/4	1-11/16	9/32 SLOT	1-1/2	5	4-11/16	3/8	1-1/8	3/8	4-1/32	1-5/16	3-3/4	3	2-1/16	1/8	4-5/8	1-9/16	1/4-20
48	3	2-1/8	2-3/4	11/32 SLOT	1-7/8	5-7/8	5-11/16	1/2	1-1/2	1/2	4-3/8	1-11/16	3-3/4	3	2-1/2	1/8	5-5/8	2-1/4	1/4-20
56 56H	3-1/2	2-7/16	3 5	11/32 SLOT	2-7/16 2-1/8	6-7/8	6-5/8	5/8	1-7/8	1/2	5	2-1/16	5-7/8	4-1/2	2-3/4	1/8	6-1/2	2-1/4	3/8-16
143T 145T	3-1/2	2-3/4	4 5	11/32	2-1/2	6-7/8	6-5/8	7/8	2-1/4	3/4	5-1/4	2-1/8	5-7/8	4-1/2	2-1/4	1/8	6-1/2	2-1/4	3/8-16
182 184 182T 184T	4-1/2	3-3/4	4-1/2 5-1/2 4-1/2 5-1/2	13/32	2-11/16 2-11/16 3-9/16 3-9/16	8-11/16	7-7/8	7/8 7/8 1-1/8 1-1/8	2-1/4 2-1/4 2-3/4 2-3/4	3/4	5-7/8	2-1/8 2-1/8 2-5/8 2-5/8	5-7/8 5-7/8 7-1/4 7-1/4	4-1/2 4-1/2 8-1/2 8-1/2	2-3/4	1/8 1/8 1/4 1/4	6-1/2 6-1/2 9 9	2-3/8	3/8-16 3/8-16 1/2-13 1/2-13
213 215 213T 215T	5-1/4	4-1/4	5-1/2 7 5-1/2 7	13/32	3-1/2 3-1/2 3-7/8 3-7/8	10-1/4	9-9/16	1-1/8 1-1/8 1-3/8 1-3/8	3 3 3-3/8 3-3/8	3/4	7-3/8	2-3/4 2-3/4 3-1/8 3-1/8	7-1/4	8-1/2	3-1/2	1/4	9	2-3/4	1/2-13
254U 256U 254T 256T	6-1/4	5	8-1/4 10 8-1/4 10	17/32	4-1/16 4-1/16 4-5/16 4-5/16	12-7/8	12-15/16	1-3/8 1-3/8 1-5/8 1-5/8	3-3/4 3-3/4 4 4	1	9-5/8	3-1/2 3-1/2 3-3/4 3-3/4	7-1/4	8-1/2	4-1/4	1/4	10	—	1/2-13
284U 286U 284T 286T 284TS 286TS	7	5-1/2	9-1/2 11 9-1/2 11 9-1/2 11	17/32	5-1/8 5-1/8 4-7/8 4-7/8 3-3/8 3-3/8	14-5/8	14-5/8	1-5/8 1-5/8 1-7/8 1-7/8 1-5/8 1-5/8	4-7/8 4-7/8 4-5/8 4-5/8 3-1/4 3-1/4	1-1/2	13-1/8	4-5/8 4-5/8 4-3/8 4-3/8 3 3	9	10-1/2	4-3/4	1/4	11-1/4	—	1/2-13
324U 326U 324T 326T 324TS 326TS	8	6-1/4	10-1/2 12 10-1/2 12 10-1/2 12	21/32	5-7/8 5-7/8 5-1/2 5-1/2 3-15/16 3-15/16	16-1/2	16-1/2	1-7/8 1-7/8 2-1/8 2-1/8 1-7/8 1-7/8	5-5/8 5-5/8 5-1/4 5-1/4 3-3/4 3-3/4	2	14-1/8	5-3/8 5-3/8 5 5 3-1/2 3-1/2	11	12-1/2	5-1/4	1/4	13-3/8	—	5/8-11
364U 365U 364T 365T 364TS 365TS	9	7	11-1/4 12-1/4 11-1/4 12-1/4 11-1/4 12-1/4	21/32	6-3/4 6-3/4 6-1/4 6-1/4 4 4	18-1/2	18-1/4	2-1/8 2-1/8 2-3/8 2-3/8 1-7/8 1-7/8	6-3/8 6-3/8 5-7/8 5-7/8 3-3/4 3-3/4	2-1/2	15-1/16	6-1/8 6-1/8 5-5/8 5-5/8 3-1/2 3-1/2	11	12-1/2	5-7/8	/4	13-3/8	—	5/8-11
404U 405U 404T 405T 404TS 405TS	10	8	12-1/4 13-3/4 12-1/4 13-3/4 12-1/4 13-3/4	13/16	7-3/16 7-3/16 7-5/16 7-5/16 4-1/2 4-1/2	20-5/16	20-1/8	2-3/8 2-3/8 2-7/8 2-7/8 2-1/8 2-1/8	7-1/8 7-1/8 7-1/4 7-1/4 4-1/4 4-1/4	3	18	6-7/8 6-7/8 7 7 4 4	11	12-1/2	6-5/8	1/4	13-7/8	—	5/8-11
444U 445U 444T 445T 447T 449T 444TS 445TS 447TS 449TS	11	9	14-1/2 16-1/2 14-1/2 16-1/2 20 25 14-1/2 16-1/2 20 25	13/16	8-5/8 8-5/8 8-1/2 8-1/2 8-15/16 8-15/16 5-3/16 5-3/16 4-15/16 4-15/16	22-7/8 22-7/8 22-7/8 22-7/8 22-15/16 22-15/16 22-7/8 22-7/8 22-15/16 22-15/16	22-3/8 22-3/8 22-3/8 22-3/8 23-3/4 23-3/4 22-3/8 22-3/8 23-3/4 23-3/4	2-7/8 2-7/8 3-3/8 3-3/8 3-3/8 3-3/8 2-3/8 2-3/8 2-3/8 2-3/8	8-5/8 8-5/8 8-1/2 8-1/2 8-1/2 8-1/2 4-3/4 4-3/4 4-3/4 4-3/4	3 4NPT 4NPT	19-9/16 19-9/16 19-9/16 19-9/16 21-11/16 21-11/16 19-9/16 19-9/16 21-11/16 21-11/16	8-3/8 8-3/8 8-1/4 8-1/4 8-1/4 8-1/4 4-1/2 4-1/2 4-1/2 4-1/2	14	16	7-1/2	1/4	16-3/4	—	5/8-11

Slight differences may exist between suppliers.

5000 FRAME	D	E	2F	H	O	P	U	V	AA	AB	BA
5007S	12-1/2	10	22	15/16	26-27/32	30	2-1/2	6-1/2	4-NPT	26-7/8	8-1/2
5007L	12-1/2	10	22	15/16	26-27/32	30	3-7/8	11-1/8	4-NPT	26-7/8	8-1/2
5009S	12-1/2	10	28	15/16	26-27/32	30	2-1/2	6-1/2	4-NPT	26-7/8	8-1/2
5009L	12-1/2	10	28	15/16	26-27/32	30	3-7/8	11-1/8	4-NPT	26-7/8	8-1/2
5011S	12-1/2	10	36	15/16	26-27/32	30	2-1/2	6-1/2	4-NPT	26-7/8	8-1/2
5011L	12-1/2	10	36	15/16	26-27/32	30	3-7/8	11-1/8	4-NPT	26-7/8	8-1/2

Reference chart courtesy of ABB Motors and Mechanical Inc.

NEMA C-Face	BA Dimensions
143-5TC	2-3/4
182-4TC	3-1/2
213-5TC	4-1/4
254-6TC	4-3/4

Frame	NEMA FRAMES PRIOR TO 1953						
	D	E	F	N	U	V	BA
66	4-1/8	2-15/16	2-1/2	2-1/4	3/4	2-1/4	3-1/8
203 204	5	4	2-3/4 3-1/4	2-7/16	3/4	2	3-1/8
224 225	5-1/2	4-1/2	3-3/8 3-3/4	3-1/4	1	3	3-1/2
254	6-1/4	5	4-1/8	3-7/16	1-1/8	3-3/8	4-1/4
284	7	5-1/2	4-3/4	4-1/4	1-1/4	3-3/4	4-3/4
324 326	8	6-1/4	5-1/4 6	5-3/8	1-5/8	4-7/8	5-1/4
364 365	9	7	5-5/8 6-1/8	5-5/8	1-78/8	5-3/8	5-7/8
404 405	10	8	6-1/8 6-7/8	6-3/8	2-1/8	6-1/8	6-5/8
444 445	11	9	7-1/4 8-1/4	7-1/8	2-3/8	6-7/8	7-1/2
504 505	12-1/2	10	8 9	8-5/8	2-7/8	8-3/8	8-1/2

Motor Frame Dimensions

Frame Size	D	E	2F	H Dia. (4) Holes	U Dia.	BA	V Min.	Key
48	3	2-1/8	2-3/4	11/32	1/2	2-1/2	-	3/64 Flat
56	3-1/2	2-7/16	3	11/32	5/8	2-3/4	-	3/16 x 3/16 x 1-3/8
143T	3-1/2	2-3/4	4	11/32	7/8	2-1/4	2	3/16 x 3/16 x 1-3/8
145T	3-1/2	2-3/4	5	11/32	7/8	2-1/4	2	3/16 x 3/16 x 1-3/8
182T	4-1/2	3-3/4	4-1/2	13/32	1-1/8	2-3/4	2-1/2	1/4 x 1/4 x 1-3/4
184T	4-1/2	3-3/4	5-1/2	13/32	1-1/8	2-3/4	2-1/2	1/4 x 1/4 x 1-3/4
213T	5-1/4	4-1/4	5-1/2	13/32	1-3/8	3-1/2	3-1/8	5/16 x 5/16 x 2-3/8
215T	5-1/4	4-1/4	7	13/32	1-3/8	3-1/2	3-1/8	5/16 x 5/16 x 2-3/8
254U	6-1/4	5	8-1/4	17/32	1-3/8	4-1/4	3-1/2	5/16 x 5/16 x 2-3/4
254T	6-1/4	5	8-1/4	17/32	1-5/8	4-1/4	3-3/4	3/8 x 3/8 x 2-7/8
256U	6-1/4	5	10	17/32	1-3/8	4-1/4	3-1/2	5/16 x 5/16 x 2-3/4
256T	6-1/4	5	10	17/32	1-5/8	4-1/4	3-3/4	3/8 x 3/8 x 2-7/8
284U	7	5-1/2	9-1/2	17/32	1-5/8	4-3/4	4-5/8	3/8 x 3/8 x 3-3/4
284T	7	5-1/2	9-1/2	17/32	1-7/8	4-3/4	4-3/8	1/2 x 1/2 x 3-1/4
284TS	7	5-1/2	9-1/2	17/32	1-5/8	4-3/4	3	3/8 x 3/8 x 1-7/8
286U	7	5-1/2	11	17/32	1-5/8	4-3/4	4-5/8	3/8 x 3/8 x 3-3/4
286T	7	5-1/2	11	17/32	1-7/8	4-3/4	4-3/8	1/2 x 1/2 x 3-1/4
286TS	7	5-1/2	11	17/32	1-5/8	4-3/4	3	3/8 x 3/8 x 1-7/8
324U	8	6-1/4	10-1/2	21/32	1-7/8	5-1/4	5-3/8	1/2 x 1/2 x 4-1/4
324T	8	6-1/4	10-1/2	21/32	2-1/8	5-1/4	5	1/2 x 1/2 x 3-7/8
324TS	8	6-1/4	10-1/2	21/32	1-7/8	5-1/4	3-1/2	1/2 x 1/2 x 2
326U	8	6-1/4	12	21/32	1-7/8	5-1/4	5-3/8	1/2 x 1/2 x 4-1/4
326T	8	6-1/4	12	21/32	2-1/8	5-1/4	5	1/2 x 1/2 x 3-7/8
326TS	8	6-1/4	12	21/32	1-7/8	5-1/4	3-1/2	1/2 x 1/2 x 2
364U	9	7	11-1/4	21/32	2-1/8	5-7/8	6-1/8	1/2 x 1/2 x 5
364US	9	7	11-1/4	21/32	1-7/8	5-7/8	3-1/2	1/2 x 1/2 x 2
364T	9	7	11-1/4	21/32	2-3/8	5-7/8	5-5/8	5/8 x 5/8 x 4-1/4
364TS	9	7	11-1/4	21/32	1-7/8	5-7/8	3-1/2	1/2 x 1/2 x 2
365U	9	7	12-1/4	21/32	2-1/8	5-7/8	6-1/8	1/2 x 1/2 x 5
365US	9	7	12-1/4	21/32	1-7/8	5-7/8	3-1/2	1/2 x 1/2 x 2
365T	9	7	12-1/4	21/32	2-3/8	5-7/8	5-5/8	5/8 x 5/8 x 4-1/4
365TS	9	7	12-1/4	21/32	1-7/8	5-7/8	3-1/2	1/2 x 1/2 x 2
404U	10	8	12-1/4	13/16	2-3/8	6-5/8	6-7/8	5/8 x 5/8 x 5-1/2
404US	10	8	12-1/4	13/16	2-1/8	6-5/8	4	1/2 x 1/2 x 2-3/4
404T	10	8	12-1/4	13/16	2-7/8	6-5/8	7	3/4 x 3/4 x 5-5/8
404TS	10	8	12-1/4	13/16	2-1/8	6-5/8	4	1/2 x 1/2 x 2-3/4
405U	10	8	13-3/4	13/16	2-3/8	6-5/8	6-7/8	5/8 x 5/8 x 5-1/2
405US	10	8	13-3/4	13/16	2-1/8	6-5/8	4	1/2 x 1/2 x 2-3/4
405T	10	8	13-3/4	13/16	2-7/8	6-5/8	7	3/4 x 3/4 x 5-5/8
405TS	10	8	13-3/4	13/16	2-1/8	6-5/8	4	1/2 x 1/2 x 2-3/4
444U	11	9	14-1/2	13/16	2-7/8	7-1/2	8-3/8	3/4 x 3/4 x 7
444US	11	9	14-1/2	13/16	2-1/8	7-1/2	4	1/2 x 1/2 x 2-3/4
444T	11	9	14-1/2	13/16	3-3/8	7-1/2	8-1/4	7/8 x 7/8 x 6-7/8
444TS	11	9	14-1/2	13/16	2-3/8	7-1/2	4-1/2	5/8 x 5/8 x 3
445U	11	9	16-1/2	13/16	2-7/8	7-1/2	8-3/8	3/4 x 3/4 x 7
445US	11	9	16-1/2	13/16	2-1/8	7-1/2	4	1/2 x 1/2 x 2-3/4
445T	11	9	16-1/2	13/16	3-3/8	7-1/2	8-1/4	7/8 x 7/8 x 6-7/8
445TS	11	9	16-1/2	13/16	2-3/8	7-1/2	4-1/2	5/8 x 5/8 x 3
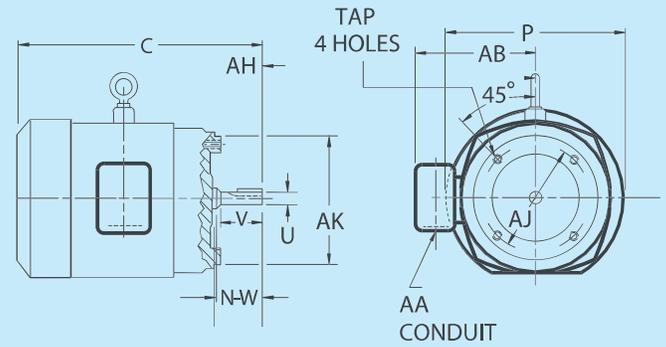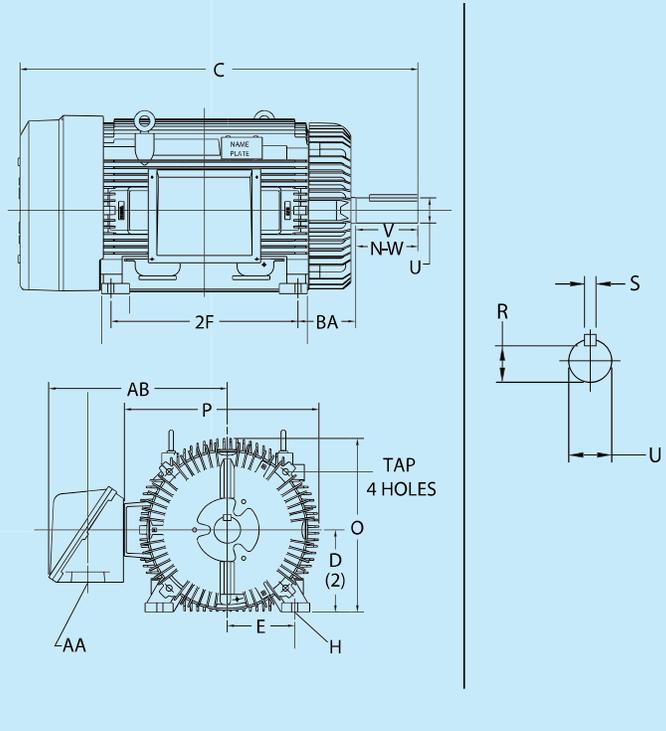
Information used with permission of ABB Motors and Mechanical Inc.

Frame Assignments

hp	Motor Speed, rpm				hp	Motor Speed, rpm			
	3600	1800	1200	900		3600	1800	1200	900
1/8	-	48	-	-	15	254T,256U	254T,284U	284T,284TS,324U	286T,326U
1/6	-	48	-	-	20	256T,286U	256T,286U	286T,286TS,326U	324T,364U
1/4	48	48	48	56	25	284TS,324US	284T,284TS,324U	324T,324TS,364U	326T,365U
1/3	48	48,56	56	56	30	286TS,326US	286T,284TS,326U	326T,326TS,365U	364T,404U
1/2	48,56	48,56	56	56	40	324TS,364US	324T,324TS,364U	354T,404U	365T,405
3/4	56	56	56,143T, 182U	56,145T	50	326TS,365US	326T,326TS,365U	365T,405U	404T
1	56,143T,182U	56,143T,182U	56, 143T, 184U	182T	60	364TS	364T,364TS	404T	405T
1-1/2	56,143T,182U	56,145T,184U	145T, 184U	184T	75	365TS	365T,365TS	405T	444T
2	56,145T,184U	56,145T,184U	184T, 213U	213T	100	405TS	405T,405TS	444T	445T
3	56,145T,182T,184U	182T,213U	213T, 215U	215T,254U	125	444TS	444T,444TS	445T	-
5	184T,213U	184T,215U	215T,254U	254T,256U	150	445TS	445T,445TS	-	-
7-1/2	213T,215U	213T,254U	254T,256U	256T,284U	200	445	445T,445TS	-	-
10	215T,254U	215T,256U	256T,284U	284T,286U	250	447TS	447T,447TS	-	-

AC Motor Selection Guide

Date:_____

Service Center:_____ Service Center Contact:_____

Customer:_____

Address:_____

City:_____ State:_____ Zip:_____

Contact:_____ Phone:_____

Fax:_____

E-mail:_____

Application Information

Please describe the application in detail:_____

_____

Application: _____New _____Replacement Why?_____

Speed Required: _____rpm

Torque Required: _____#/in. (if known)

Starting Torque Required: _____#/in. (if known)

Ambient Temp Range: _____°F to _____°F

Environment: _____Wet _____Humid _____Dusty/Dirty _____Clean

Chemical Stress: _____No _____Yes Explain_____

Operating Time: _____Hours per Day

Starting Methods: _____Starter _____VFD _____Other Explain_____

Starts/Stops: _____per Hour

Reversing: _____Times per Hour

Brake Required: _____No _____Yes Torque?_____#/ft Where?_____

Size/Space/Weight Limitations: _____No _____Yes Explain_____

Motor Specifications

Electric Motor: _____hp _____rpm _____Frame _____Foot Mount or _____C-Face (check one)

_____Voltage _____Phase _____Full Load Amps

Enclosure: (check one) _____Open Dripproof _____Totally Enclosed-Fan Cooled

_____X-proof (Class & Group?) _____

Spec. Paint or Coating: _____No _____Yes Explain_____

Spec. Lubricant: _____No _____Yes Explain_____

Other Considerations:_____

_____

Date:_____

Service Center:_____ Service Center Contact:_____

Customer:_____

Address:_____

City:_____State:_____Zip:_____

Contact:_____Phone:_____

Fax:_____

E-mail:_____

Application Information

Please describe the application in detail:_____

_____

_____

_____

Application:	_____New	_____Replacement	Why?_____	
Speed Required:	_____rpm			
Torque Required:	_____#/in.	(if known)		
Starting Torque Required:	_____#/in.	(if known)		
Ambient Temp Range:	_____°F to _____°F			
Environment:	_____Wet	_____Humid	_____Dusty/Dirty	_____Clean
Chemical Stress:	_____No	_____Yes	Explain_____	
Operating Time:	_____Hours per Day			
Starts/Stops:	_____per Hour			
Reversing:	_____Times per Hour			
Brake Required:	_____No	_____Yes	Torque?_____#/ft	Where?_____
Size/Space/Weight Limitations:	_____No	_____Yes	Explain_____	

Prime Mover

Electric Motor: _____hp _____rpm _____Frame _____Foot Mount or _____C-Face (check one)

_____Voltage _____Phase _____Full Load Amps

Internal Combustion Engine: _____hp or _____Torque _____rpm _____No. of Cylinders

Other: _____hp or _____Torque _____rpm

Speed Reducer / Gearmotor Selection Guide

Reducer Information

Ratio:_____

Configuration: (check one)   _____Concentric (in-line)   _____Right Angle   _____Offset Parallel

Mounting Style: (check one)   _____Base (foot)   _____Flanged Output   _____Shaft Mount

_____Screw Conveyor Drive

Input Style: (check one)   _____C-Face   _____Input Shaft   _____Integral Motor

Output Style: (check one)   _____Solid Shaft   _____Hollow Shaft   _____Double Extended

Motor Mount: (check one)   _____None Req'd   _____Scoop   _____Top Mount

_____Motorbase

Backstop: _____No_____Yes   Rotation viewing end of L.S. shaft _____CW____CCW

Spec. Paint or Coating: _____No_____Yes   Explain_____

Spec. Lubricant: _____No_____Yes   Explain_____

Other Considerations: _____

_____

Sketch existing drive:

Rectangular Keyways

Metric:
W x H Key
W x T2 Keyway

ISO Standard — mm

Shaft Diameter D		Groove Width			
≤	>	W	H	T1	T2*
6	8	2	2	1.2	1
8	10	3	3	1.8	1.4
10	12	4	4	2.5	1.8
12	17	5	5	3.0	2.3
17	22	6	6	3.5	2.8
22	30	8	7	4.0	3.3
30	38	10	8	5.0	3.3
38	44	12	8	5.0	3.3
44	50	14	9	5.5	3.8
50	58	16	10	6.0	4.3
58	65	18	11	7.0	4.4
65	75	20	12	7.5	4.9
75	85	22	14	9.0	5.4
85	95	25	14	9.0	5.4
95	110	28	16	10.0	6.4
110	130	32	18	11.0	7.4
130	150	36	20	12.0	8.4
150	170	40	22	13.0	9.4
170	200	45	25	15.0	10.4
200	230	50	28	17.0	11.4
230	260	56	32	20.0	12.4
260	290	63	32	20.0	12.4
290	330	70	36	22.0	14.4
330	380	80	40	25.0	15.4
380	440	90	45	28.0	17.4
440	500	100	50	31.0	19.5

* Groove dimensions for woodruff keys DIN 6888 in
  accordance with DIN 6885 Sheet 1 (with black clearance).

BS 4235 Pt. 1 - 1972

In the absence of specific details, manufacturing will be based upon DIN 6885 - T1

Information used with permission of Martin.

Shaft Keyseats/Hub Keyways

Standard Keyseats/Keyways

Shaft Size	W width	D,d Depth		R R Cutter Run-out
		Regular	Shallow	
5/16 to 7/16	3/32	3/64	-	1/2
1/2 to 3/16	1/8	1/16	-	9/16
5/8 to 7/8	3/16	3/32	-	11/16
13/16 to 1-1/4	1/4	1/8	-	13/16
1-5/16 to 1-3/8	5/16	3/32	-	15/16
1-7/16 to 1-3/4	3/8	3/16	-	1-1/16
1-13/16 to 2-1/4	1/2	1/4	1/8	1-3/16
2-5/16 to 2-3/4	5/8	5/16	3/16	1-5/16
2-15/16 to 3-1/4	3/4	3/8	3/16	1-9/16
3-5/16 to 3-3/4	7/8	7/16	1/4	1-11/16
3-13/16 to 4-1/2	1	1/2	1/4	1-3/4
4-9/16 to 5-1/2	1-1/4	5/8	1/4	1-15/16
5-9/16 to 6-1/2	1-1/2	3/4	1/4	2-1/8
6-9/16 to 7-1/2	1-3/4	3/4	1/4	2-1/8
7-9/16 to 9	2	3/4	3/8	2-1/8
9-1/16 to 11	2-1/2	7/8	3/8	2-5/16
11-1/16 to 13	3	1	3/8	2-7/16

Square Keyways
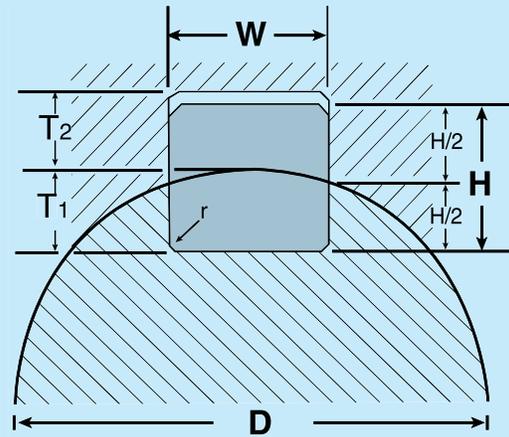
Metric:
W x H Key
W x T2 Keyway

American Standard — Inches

Shaft Diameter D		Groove Width W	H	T1#	T2#
7/16	9/16	1/8	1/8	–	–
9/16	7/8	3/16	3/16	–	–
7/8	1-1/4	1/4	1/4	–	–
1-1/4	1-3/8	5/16	5/16	–	–
1-3/8	1-3/4	3/8	3/8	–	–
1-3/4	2-1/4	1/2	1/2	–	–
2-1/4	2-3/4	5/8	5/8	–	–
2-3/4	3-1/4	3/4	3/4	–	–
3-1/4	3-3/4	7/8	7/8	–	–
3-3/4	4-1/2	1	1	–	–
4-1/2	5-1/2	1-/14	1-1/4	–	–
5-1/2	6-1/2	1-1/2	1-1/2	–	–
6-1/2	7-1/2	1-3/4	1-1/2	–	–
7-1/2	9	2	1-1/2	–	–
9	11	2-1/2	1-3/4	–	–
11	13	3	2	–	–
13	15	3-1/2	2-1/2	–	–
15	18	4	3	–	–
18	22	5	3-1/2	–	–
22	26	6	4	–	–
26	30	7	5	–	–

Tolerance each on T1 and T2 is -.000/+.010.

$$T1 = \frac{D-\sqrt{D^2 - W^2}}{2} - \frac{H}{2}$$

$$T2 = \frac{H}{2} - \frac{D-\sqrt{D^2 - W^2}}{2}$$

Keyway & Key Dimensions / Tap & Drill Sizes

STANDARD KEYWAY AND KEY DIMENSIONS

Bores	Keyway	Key
$7/8$″	$3/16$″ x $3/32$″	$3/16$″ x $3/16$″
$15/16$″ – $1\,1/4$″	$1/4$″ x $1/8$″	$1/4$″ x $1/4$″
$1\,5/16$″ – $1\,3/8$″	$5/16$″ x $5/32$″	$5/16$″ x $5/16$″
$1\,7/16$″ – $1\,3/4$″	$3/8$″ x $3/16$″	$3/8$″ x $3/8$″
$1\,13/16$″ – $2\,1/4$″	$1/2$″ x $1/4$″	$1/2$″ x $1/2$″
$2\,5/16$″ – $2\,3/4$″	$5/8$″ x $5/16$″	$5/8$″ x $5/8$″
$2\,13/16$″ – $3\,1/4$″	$3/4$″ x $3/8$″	$3/4$″ x $3/4$″
$3\,5/16$″ – $3\,3/4$″	$7/8$″ x $7/16$″	$7/8$″ x $7/8$″
$3\,13/16$″ – $4\,1/2$″	1″ x $1/2$″	1″ x 1″
$4\,9/16$″ – $5\,1/2$″	$1\,1/4$″ x $5/8$″	$1\,1/4$″ x $1\,1/4$″
$5\,9/16$″ – $6\,1/2$″	$1\,1/2$″ x $3/4$″	$1\,1/2$″ x $1\,1/2$″
$6\,9/16$″ – $7\,1/2$″	$1\,3/4$″ x $3/4$″	$1\,3/4$″ x $1\,1/2$″
$7\,9/16$″ – 9″	2″ x $3/4$″	2″ x $1\,1/2$″
$9\,1/16$″ – 11″	$2\,1/2$″ x $7/8$″	- - -
$11\,1/16$″ – 13″	3″ x 1″	- - -

STANDARD ANSI TAP/DRILL SIZES

Tap Size	Drill Size	Tap Size	Drill Size
# 0 - 80	$3/64$	# 1 - 72	# 53
# 1 - 64	# 53	# 2 - 64	# 50
# 2 - 56	# 51	# 3 - 56	# 46
# 3 - 48	$5/64$″	# 4 - 48	# 42
# 4 - 40	# 43	# 5 - 44	# 37
# 5 - 40	# 39	# 6 - 40	# 33
# 6 - 32	# 36	# 8 - 36	# 29
# 8 - 32	# 29	# 10 - 32	# 21
# 10 - 24	# 25	# 12 - 28	# 15
# 12 - 24	# 17	$1/4$″ - 28	# 3
$1/4$″ - 20	# 7	$5/16$″ - 24	I
$5/16$″ - 18	F	$3/8$″ - 24	Q
$3/8$″ - 16	$5/16$″	$7/16$″ - 20	W
$7/16$″ - 14	U	$1/2$″ - 20	$29/64$″
$1/2$″ - 13	$27/64$″	$9/16$″ - 18	$33/64$″
$9/16$″ - 12	$31/64$″	$5/8$″ - 18	$37/64$″
$5/8$″ - 11	$17/32$″	$3/4$″ - 16	$11/16$″
$3/4$″ - 10	$21/32$″	$7/8$″ - 14	$13/16$″
$7/8$″ - 9	$49/64$″	1″ - 12	$15/16$″
1″ - 8	$7/8$″	$1\,1/8$″ - 12	$13/64$″
$1\,1/8$″ - 7	$63/64$″	$1\,1/4$″ - 12	$1\,11/64$″
$1\,1/4$″ - 7	$1\,7/64$″	$1\,1/2$″ - 12	$1\,27/64$″
$1\,1/2$″ - 6	$1\,11/32$″	$1\,3/4$″ - 12	$1\,43/64$″
$1\,3/4$″ - 5	$1\,35/64$″	2″ - 12	$1\,59/64$″
2″ - $4\,1/2$	$1\,25/32$″	—	—

STANDARD METRIC ISO TAP/DRILL SIZES

Tap Size	Drill Size	Tap Size	Drill Size
1 mm X .25	.75 mm	4 mm x .35	3.6 mm
1.1 x .25	.85	4 x .5	3.5
1.2 x .25	.95	5 x .5	4.5
1.4 x .3	1.1	6 x .5	5.5
1.6 x .35	1.25	6 x .75	5.25
1.7 x .35	1.3	7 x .75	6.25
1.8 x .35	1.45	8 x .5	7.5
2 x .4	1.6	8 x .75	7.25
2.2 x .45	1.75	8 x 1	7
2.5 x .45	2.05	9 x 1	8
3 x .5	2.5	10 x .75	9.25
3.5 x .6	2.9	10 x 1	9
4 x .7	3.3	10 x 1.25	8.8
4.5 x .75	3.7	11 x 1	10
5 x .8	4.2	12 x .75	11.25
6 x 1	5	12 x 1	11
7 x 1	6	12 x 1.5	10.5
8 x 1.25	6.8	14 x 1	13
9 x 1.25	7.8	14 x 1.25	12.8
10 x 1.5	8.5	14 x 1.5	12.5
11 x 1.5	9.5	16 x 1	15
12 x 1.75	10.2	16 x 1.5	14.5
14 x 2	12	18 x 1	17
16 x 2	14	18 x 2	16
18 x 2.5	15.5	20 x 1	19
20 x 2.5	17.5	20 x 1.5	18.5
22 x 2.5	19.5	20 x 2	18
24 x 3	21	22 x 1	21

NOMINAL V-BELT CROSS SECTIONS
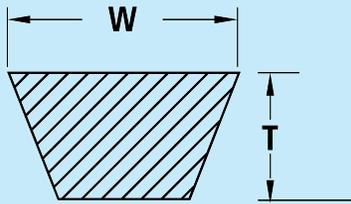
Belt Section	Industry Standard Description	Width W, in Inches	Thickness T, in Inches
3L	FHP	3/8	7/32
4L		1/2	5/16
5L		21/32	3/8
3V	Narrow	3/8	5/16
5V		5/8	17/32
8V		1	29/32
A	Classical	1/2	5/16
B		21/32	13/32
C		7/8	17/32
D		1-1/4	3/4

V-BELTS: WHAT TO LISTEN FOR
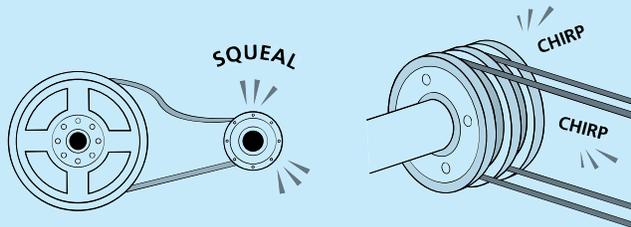
SQUEAL

CHIRP

CHIRP

Squeal is usually a result of insufficient belt tension and requires prompt investigation. If squeal persists after you have checked all belts and adjusted tension, examine the drive itself for overloading.

Chirp, a sound like that of a chirping bird, can occur on all types of belt drives. Never apply dressing or oil to a belt in an effort to eliminate chirps or squeaks. Realignments of an idler may help. Chirps or squeaks are often annoying, but will not harm belts.

Information used with permission of Continental.

V-BELT TENSIONING

P. Span Length
D. Diameter (in)
F. Force (lbs)
Q. Deflection (in)
d. Diameter (in)
C. Center Distance (in)
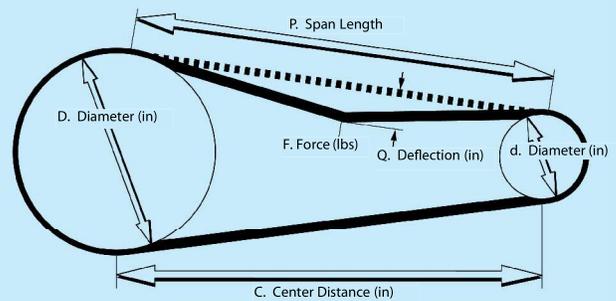
$$P = \sqrt{C^2 - \left(\frac{D-d}{2}\right)^2}$$

F = Deflection Force
q = Deflection, 1/64" per inch of span length
C = Center Distance
D = Large Sprocket Pitch Diameter
d = Small Sprocket Pitch Diameter
P = Span Length

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CONVEYOR BELT FPM TO RPM

Pulley Dia. Inches	FPM												
	100	150	200	250	300	350	400	500	600	700	800	900	1000
6	64	95	127	159	191	223	254	318	382	445	509	573	636
8	48	72	95	119	143	167	191	239	286	334	382	429	477
10	38	57	76	95	115	134	153	191	229	267	305	344	382
12	32	48	64	80	95	111	127	159	191	223	254	286	318
14	27	41	55	68	82	95	109	136	164	191	218	245	273
16	24	36	48	60	72	83	95	119	143	167	191	215	239
18	21	32	42	53	64	74	85	106	127	148	170	191	212
20	19	29	38	48	57	67	76	95	115	134	153	172	191
24	16	24	32	40	48	56	64	80	95	111	127	143	159
30	13	19	25	32	38	45	51	64	76	89	102	115	127
36	11	16	21	27	32	37	42	53	64	74	85	95	106
42	9	14	18	23	27	32	36	45	55	64	73	82	91
48	8	12	16	20	24	28	32	40	48	56	64	72	80
54	7	11	14	18	21	25	28	35	42	49	57	64	71
60	6	10	13	16	19	22	25	32	38	45	51	57	64

For values not shown use formula: **SFM = .2618 x D x rpm**
SFM = Surface Feet Per Minute
D = Pulley Diameter, Inches
rpm = Revolutions Per Minute

V-Belt Systems

TYPE OF FAILURE												POSSIBLE CAUSE OF FAILURE	CORRECTIVE ACTION
Excessive edge wear	Excessive tooth wear	Uneven tooth wear	Apparent belt stretch	Cracks in backing	Tooth shear	Tensile failure	Excessive drive noise	Tooth skipping (ratcheting)	Belt tracking	Excessive sprocket/sheave wear	Excessive drive vibration		
■		▨					░				░	Belt hitting obstruction	Remove obstruction or use idler to reroute belt
	▨				■							Excessive load	Redesign drive
						░	▨			░		Belt overtensioned	Use tensioning gauge to set proper tension
	■	▨	░				▨	■				Belt undertensioned	Use tensioning gauge to set proper tension
	▨									░		Rough or damaged sprocket/sheave	Replace sprocket/sheave
	■				▨	■			■			Misalignment	Align shafts and sprockets/sheaves
						░		░				Worn sprocket/sheave	Replace sprocket/sheave
							░					Sprocket out of tolerance	Replace sprocket/sheave; never attempt to remachine
											■	Soft sprocket/sheave material	Use harder sprocket/sheave material
	▨						▨	▨	▨			Debris in sprocket/sheave or drive	Shield drive
			■									Center distance changed	Check lock down bolts on motors and shafts
			■				▨	▨			■	Weak drive structure	Reinforce drive structure
				■							░	Excessive low temperature	Moderate temperature especially at startup
			░	■								Excessive high temperature	Moderate temperature, shield drive
			▨	▨								Exposure to oil, solvents, chemicals	Shield drive, eliminate chemicals
			▨	░								Sprocket diameter sub minimum	Redesign drive to increased sprocket/sheave diameters
				▨								Back side idler	Redesign to reduce wrap on backside idler
					■	▨		▨				Shock loading	Eliminate shock loading or redesign drive to handle it
	░					▨						Less than six teeth in mesh	Increase wrap on sprocket/sheave
											▨	Excessive sprocket/sheave runout	Replace sprocket/sheave
					■							Damage due to handling	Replace product, don't crimp belt or drop sprockets/sheaves
											▨	Vibrating bearings/mountings	Replace bearings or reinforce mountings
									▨			Center distance greater than 8x small sprocket/sheave diameter	Alignment is critical
							▨				■	Sprocket/sheave not properly balanced	Check sprocket/sheave balance

■ PRIMARY CAUSE ▨ POSSIBLE CAUSE ░ COULD CAUSE BUT NOT LIKELY

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PROBABLE CAUSES

PROBLEM	Excessive Oil	Exposure to Elements	Pried Over Sheaves	Contact w/ Obstruction	Insufficient Tension	Stalled Drive Sheaves	Constant Slippage	Rough Sheaves	Substandard Sheaves	Excessive Tension	Shock Load	Foreign Material	Excessive Dust	Drive Misalignment	Worn Sheaves	Excessive Vibration	High Ambient Temperature	Drive Underbelted	Damaged Tensile Member	Incorrect Belts	Incorrect Drive Setup	Insufficient Take Up	Improper Matching	Mixed Old & New Belts	Non Parallel Shafts	Different Manufacturers	Belt/Pulley Incompatible
Loose Cover & Swell	X																										
Weathering or "Craze" Cracks		X																									
Gouges			X	X																							
Spin Burn				X	X																						
Envelope Wear						X								X													
Uneven Envelope Wear								X							X												
Ply Separation										X																	
Side Split										X																	
Broken Belts			X								X																
Belts Turn Over														X	X												
Hardening & Premature Cracking		X															X										
Belt Squeal					X																						
Excessive Stretch																								X	X		X
Excessive Vibration																X											
Belts Too Long At Installation																				X	X	X					
Belts Too Short At Installation																						X					
Mismatched Belts At Installation															X											X	
Cut Thru on Top (Joined Belts)																X											X
Flange Wear (Synchronous Belts)														X													
Web Fabric Wear (Synchronous Belts)																											X
Tooth Shear (Synchronous Belts)											X							X									

SOLUTIONS

PROBLEM	Lubricate Properly	Clean Sheaves & Belt	Replace Belts	Provide Protection	Install Properly	Check for Belt Length	Remove Obstruction	Tension Properly	Free Sheaves	Replace Sheaves	File Smooth	Redesign Drive	Operate Properly	Align Drive	Provide Ventilation	Check for Proper Belt	Check Machinery	Use Only New Belts	Use Single Source	Check Fit	Replace Pulleys
Loose Cover & Swell	X	X																			
Weathering or "Craze" Cracks			X	X																	
Gouges					X	X	X														
Spin Burn	X							X	X												
Envelope Wear				X				X						X							
Uneven Envelope Wear										X	X										
Ply Separation						X															
Side Split												X									
Broken Belts				X	X								X			X					
Belts Turn Over								X						X							
Belt Squeal								X													
Excessive Stretch										X											
Excessive Vibration			X		X																
Belts Too Long At Installation																X	X				
Belts Too Short At Installation																X	X				
Mismatched Belts At Installation			X							X								X	X		
Cut Thru on Top (Joined Belts)								X													
Flange Wear (Synchronous Belts)														X							
Web Fabric Wear (Synchronous Belts)								X											X	X	X
Tooth Shear (Synchronous Belts)								X													

Information used with permission of Continental.

Coefficients of Friction

Coefficients of Friction "F"

Material	Static		Sliding	
	Dry	Lubricated	Dry	Lubricated
Aluminum on aluminum	1.35	-	-	-
Canvas belt on rubber lagging	0.30	-	-	-
Canvas belt, stitched, on steel	-	-	0.20	0.10
Canvas belt, woven, on steel	-	-	0.22	0.10
Cast iron on asbestos, fabric brake material	-	-	0.35-0.40	-
Cast iron on brass	-	-	0.30	-
Cast iron on bronze	-	-	0.22	0.07-0.08
Cast iron on cast iron	1.10	-	0.15	0.06-0.10
Cast iron on copper	1.05	-	0.29	-
Cast iron on lead	-	-	0.43	0.13-0.36
Cast iron on leather	.6	-	-	0.07-0.20
Cast iron on oak (parallel)	-	-	0.30-0.50	-
Cast iron on magnesium	-	-	0.25	0.133
Cast iron on steel, mild	-	0.18	0.23	-
Cast iron on tin	-	-	0.32	-
Cast iron on zinc	0.85	-	0.21	-
Earth on earth	0.25-1.0	-	-	-
Glass on glass	0.94	-	0.40	-
Hemp rope on wood	0.50-0.80	-	0.40-0.70	-
Nickel on nickel	1.10	-	0.53	0.12
Oak on leather (parallel)	0.50-0.60	-	0.30-0.50	-
Oak on oak (parallel)	0.62	-	0.48	0.16
Oak on oak (perpendicular)	0.54	-	0.32	0.07
Rubber tire on pavement	0.8-0.9	0.6-0.7*	0.75-0.85	0.5-0.7*
Steel on ice	0.03	-	0.01	-
Steel, hard, on babbit	0.42-0.70	0.08-0.25	0.33-0.35	0.05-0.16
Steel, hard, on steel, hard	0.78	0.11-0.23	0.42	0.03-0.12
Steel, mild, on aluminum	0.61	-	0.47	-
Steel, mild, on brass	0.51	-	0.44	-
Steel, mild, on bronze	-	-	0.34	0.17
Steel, mild, on copper	0.53	-	0.36	0.18
Steel, mild, on steel, mild	0.74	-	0.57	0.09-0.19
Stone masonry on concrete	0.76	-	-	-
Stone masonry on ground	0.65	-	-	-
Wrought iron in bronze	0.19	0.07-0.08	0.18	-
Wrought iron on wrought iron	-	0.11	0.44	0.08-0.10

* Wet pavement.

Bearing Facts

Improper lubrication and contamination are responsible for 70% of all early bearing failures.

Dirt is responsible for more than 90% of all bearing troubles.

Bearing life is reduced by approximately 20% with outer race rotation.

When a bearing is press fitted onto a steel shaft or press fitted into steel or cast iron housings, the **internal clearance is reduced by 80%** of fit interference.

Deep groove ball bearings (Conrad) are ideally designed to permit radial loading and thrust loading from either direction (the combined load should not exceed 100% of radial load rating).

Maximum type ball bearings (with precision ground filling slots) have a radial capacity of 10-15% more than the Conrad type. Thrust is limited to approximately 10% of radial capacity.

The angular contact design permits this bearing to carry high thrust in ONE DIRECTION ... Equal to 150% of its radial load capacity.

Double row ball bearings combine the features of two single row angular contact bearings mounted in duplex.

Always check bearing fit-up after assembly.

Recommended shaft finishes for Grade 1 bearings under 2" - max. 32 rms; over 2" - max. 64 rms; housing bores - 125 rms max.

High points of eccentricity of inner and outer races of high precision bearings are marked with a burnished spot on one face.

It is desirable to press needle bearings from the lettered end.

Do not check O.D. of a drawn cup needle bearing unmounted.

Bearings lubricated with petroleum greases have a shelf life of approximately seven years.

If you double the speed of a bearing, you cut its life in half. If you double the load on a ball bearing, you cut its life to 1/8 of its original life.

Coefficient of thermal expansion for steel is .000007 inch per °F and .0000063 inch per °F for carbon steel.

Common Causes of Bearing Failures

FOREIGN MATERIAL
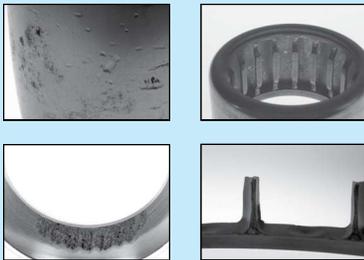
Typical causes include improper cleaning methods, poor oil filtration, or seal wear.
• Hard particle contamination
• Contamination bruising
• Fine particle contamination
• Internal cage wear from fine particle contamination

CORROSION/ETCHING

Typical causes include damaged packaging, improper storage, and worn or damaged seals.
• Roller-spaced spalling
• Corrosion on the outer ring race
• Etching and corrosion
• Advanced corrosion and spalling

INADEQUATE LUBRICATION

Typical causes include improper grease or oil viscosity, low flow rate, and high operation temperatures.
• Race deformation from excessive heat generation
• Peeling/Scoring damage on roller end
• Complete bearing lockup
• Rib and roller end scoring

FATIGUE SPALLING
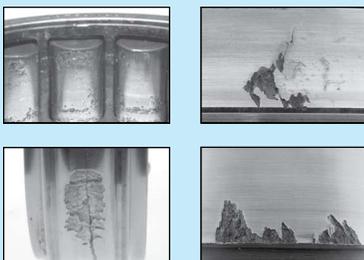
Typical causes include high load, misalignment, and stress concentration.
• Fatigue spalling on a cylindrical roller bearing
• Point Surface Origin (PSO) spalling
• Fatigue spalling on ball bearing inner ring
• Geometric Stress Concentration (GSC) spalling

EXCESSIVE PRELOAD, OVERLOAD AND ROLLOUT

Typical causes include excessive load, and/or misalignment, and improper mounting procedure.
• Roller fracture
• Peeling
• Rollout in bearing outer ring
• Outer ring subcase fracture

MISALIGNMENT
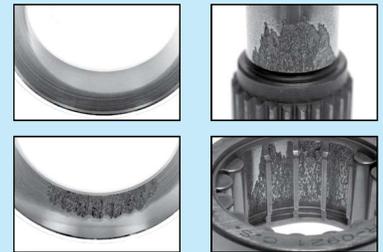
Typical causes include high load, shaft or housing deflection, inaccurate housing, or shaft machining.
• Irregular roller path caused by deflection
• Geometric Stress Concentration (GSC) spalling
• Irregular roller path (180 degree opposite of above)
• Geometric Stress Concentration (GSC) spalling on bearing outer ring

Photos courtesy of The Timken Company.
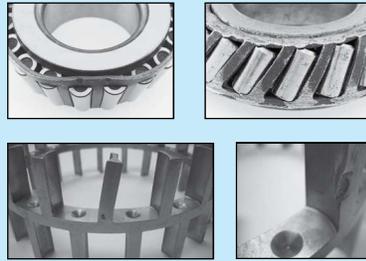
Bearings
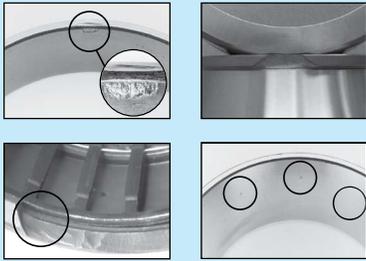
HANDLING DAMAGE

Typical causes include improper tool selection (hardened drivers), and poor handling practices.

- Outer ring denting
- Fractured inner ring rib
- Broken rib on outer race
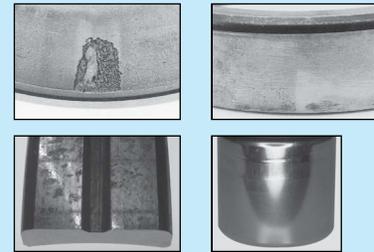- Roller spaced nicking

CAGE DAMAGE

Typical causes include improper handling, tools, and procedures.

- Cage deformation
- Roller binding and skewing
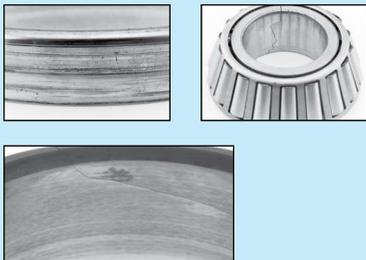- Bent bridge
- Deep dent on cage

HIGH SPOTS AND FITTING PRACTICES

Typical causes include improper machining, grinding, or repair methods.

- Localized spalling
- Marks from high spot on the housing
- Metal tearing and wear
- Pinch point

IMPROPER FIT IN HOUSING OR SHAFTS

Typical causes include wrong size and poor form, shaft or housing stress riser, and inaccurate machining.

- Loose outer ring fit in a wheel hub
- Fracture on inner ring
- Metal contaminant

BRINELL AND IMPACT DAMAGE
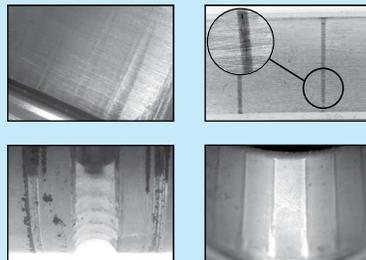
Typical causes include rough handling, and shock loads exceeding the material's limits.

- Roller impact damage
- True metal deformation
- Shock loading
- True brinell on needle bearing drawn cup race

FALSE BRINELLING
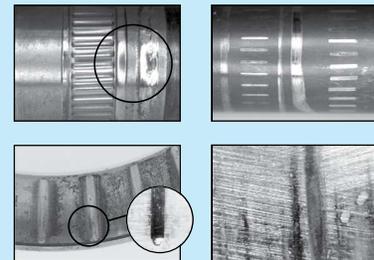
Typical causes include excessive vibration during shipment, or when the shaft is stationary.

- Extreme vibration
- False brinell on a shaft where a cylindrical bearing was mounted
- Wear caused by vibration
- False brinell on outer race

BURNS FROM ELECTRIC CURRENT
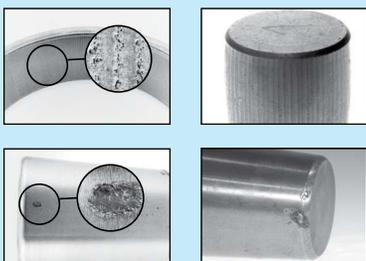
Typical causes include improper electrical grounding of equipment, welding damage, or static discharge.

- Electric arc fluting
- Fluting caused by electric current
- Electric arc pitting
- Roller with electric arc burns

ADHESIVE WEAR
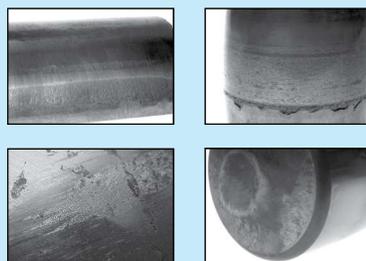
Typical causes include improper oil film, excess cage friction, and gross roller sliding.

- Roller flats and adhesive wear
- Spherical roller bearing with adhesive wear
- Skidding, raceway surface
- Cylindrical roller end with adhesive wear

NEEDLE BEARING INSTALLATION DAMAGE
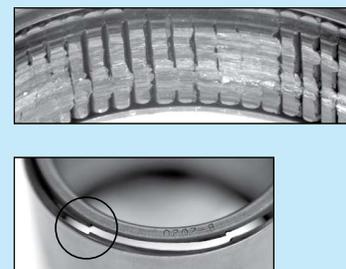
Typical causes include improper tool design, tool positioning, poor roller alignment, and excessive force.

- Roller lock-up
- Bearing stamping lip fracture

WARNING

Photos courtesy of The Timken Company.

		SHAFT FITS Standard Bearings							
		BEARING BORE		SHAFT ROTATING			SHAFT STATIONARY		
Types	Basic Number			SHAFT DIAMETER		MEAN FIT TIGHT	SHAFT DIAMETER		MEAN FIT LOOSE
		Max	Min	Max	Min		Max	Min	
Single Row	00	0.3937	0.3934	0.3939	0.3936	0.00020	0.3935	0.3931	0.00025
Extra Light	01	0.4724	0.4721	0.4726	0.4723	0.00020	0.4722	0.4717	0.00030
200 Light	02	0.5906	0.5903	0.5908	0.5905	0.00020	0.5904	0.5899	0.00030
300 Medium	03	0.6693	0.6690	0.6695	0.6692	0.00020	0.6691	0.6686	0.00030
400 Heavy	04	0.7874	0.7870	0.7878	0.7875	0.00045	0.7871	0.7866	0.00035
	05	0.9843	0.9839	0.9847	0.9844	0.00045	0.9840	0.9835	0.00035
	06	1.1811	1.1807	1.1815	1.1812	0.00045	1.1808	1.1803	0.00035
	07	1.3780	1.3775	1.3785	1.3781	0.00055	1.3776	1.3770	0.00045
	08	1.5748	1.5743	1.5753	1.5749	0.00055	1.5744	1.5738	0.00045
	09	1.7717	1.7712	1.7722	1.7718	0.00055	1.7713	1.7707	0.00045
Radial-Thrust	10	1.9685	1.9680	1.9690	1.9686	0.00055	1.9681	1.9675	0.00045
7200 Light	11	2.1654	2.1648	2.1660	2.1655	0.00065	2.1650	2.1643	0.00045
7300 Medium	12	2.3622	2.3616	2.3628	2.3623	0.00065	2.3618	2.3611	0.00045
7400 Heavy	13	2.5591	2.5585	2.5597	2.5592	0.00065	2.5587	2.5580	0.00045
	14	2.7559	2.7553	2.7565	2.7560	0.00065	2.7555	2.7548	0.00045
	15	2.9528	2.9522	2.9534	2.9529	0.00065	2.9524	2.9517	0.00045
	16	3.1496	3.1490	3.1502	3.1497	0.00065	3.1492	3.1485	0.00045
	17	3.3465	3.3457	3.3472	3.3466	0.00080	3.3460	3.3452	0.00050
	18	3.5433	3.5425	3.5440	3.5434	0.00080	3.5428	3.5420	0.00050
Double Row	19	3.7402	3.7394	3.7409	3.7403	0.00080	3.7397	3.7389	0.00050
5200 Light	20	3.9370	3.9362	3.9377	3.9371	0.00080	3.9365	3.9357	0.00050
5300 Medium	21	4.1339	4.1331	4.1346	4.1340	0.00080	4.1334	4.1326	0.00050
5400 Heavy	22	4.3307	4.3299	4.3314	4.3308	0.00080	4.3302	4.3924	0.00050

Fretting corrosion on a shaft caused by improper housing and shaft fits. Fretting corrosion will look the same on ID/OD of bearing.

Photo courtesy of The Timken Company.

	HOUSING FITS Standard Bearings										
	Basic Number				BEARING O.D.		HOUSING STATIONARY HOUSING BORE			HOUSING ROTATING HOUSING BORE	
Types	EXTRA LIGHT	LIGHT	MEDIUM	HEAVY	Max	Min	Min	Max	MEAN FIT LOOSE	Min	Max	MEAN FIT TIGHT
Single Row Extra Light 200 Light 300 Medium 400 Heavy	00				1.0236	1.0232	1.0236	1.0241	0.00055	1.0228	1.0236	0.0002
	01				1.1024	1.1020	1.1024	1.1029	0.00055	1.1016	1.1024	0.0002
		200			1.1811	1.1807	1.1811	1.1816	0.00055	1.1803	1.1811	0.0002
	02	201			1.2598	1.2593	1.2598	1.2604	0.00055	1.2588	1.2598	0.00025
	03	202	300		1.3780	1.3775	1.3780	1.3786	0.00055	1.3770	1.3780	0.00025
			301		1.4567	1.4562	1.4567	1.4573	0.00055	1.4557	1.4567	0.00025
		203			1.5748	1.5743	1.5748	1.5754	0.00055	1.5738	1.5748	0.00025
	04		302		1.6535	1.6530	1.6535	1.6541	0.00055	1.6525	1.6535	0.00025
	05	204	303		1.8504	1.8499	1.8504	1.8510	0.00055	1.8494	1.8504	0.00025
		205	304		2.0472	2.0467	2.0472	2.0479	0.00060	2.0460	2.0472	0.00035
	06				2.1654	2.1649	2.1654	2.1661	0.00060	2.1642	2.1654	0.00035
	07	206	305	403	2.4409	2.4404	2.4409	2.4416	0.00060	2.4397	2.4409	0.00035
	08				2.6772	2.6767	2.6772	2.6779	0.00060	2.6760	2.6772	0.00035
		207	306	404	2.8346	2.8341	2.8346	2.8353	0.00060	2.8334	2.8346	0.00035
	09				2.9528	2.9523	2.9528	2.9535	0.00060	2.9516	2.9528	0.00035
Radial-Thrust 7200 Light 7300 Medium 7400 Heavy	10	208	307	405	3.1496	3.1491	3.1496	3.1503	0.00060	3.1484	3.1496	0.00035
		209			3.3465	3.3459	3.3465	3.3474	0.00075	3.3451	3.3465	0.0004
	11	210	308	406	3.5433	3.5427	3.5433	3.5442	0.00075	3.5419	3.5433	0.0004
	12				3.7402	3.7396	3.7402	3.7411	0.00075	3.7388	3.7402	0.0004
	13	211	309	407	3.9370	3.9364	3.9370	3.9379	0.00075	3.9356	3.9370	0.0004
	14	212	310	408	4.3307	4.3301	4.3307	4.3316	0.00075	4.3293	4.3307	0.0004
		213	311	409	4.7244	4.7238	4.7244	4.7253	0.00075	4.7230	4.7244	0.0004
		214			4.9213	4.9205	4.9213	4.9223	0.00090	4.9197	4.9213	0.0004
	17	215	312	410	5.1181	5.1173	5.1181	5.1191	0.00090	5.1165	5.1181	0.0004
	18	216	313	411	5.5118	5.5110	5.5118	5.5128	0.00090	5.5102	5.5118	0.0004
	20	217	314	412	5.9055	5.9047	5.9055	5.9065	0.00090	5.9039	5.9055	0.0004
Double Row 5200 Light 5300 Medium 5300 Heavy		218	315		6.2992	6.2982	6.2992	6.3002	0.00100	6.2976	6.2992	0.0003
	21			413	6.2992	6.2982	6.2992	6.3002	0.00100	6.2976	6.2992	0.0003
	22	219	316		6.6929	6.6919	6.6929	6.6939	0.00100	6.6913	6.6929	0.0003
	24	220	317	414	7.0866	7.0856	7.0866	7.0876	0.00100	7.0850	7.0866	0.0003
		221	318	415	7.4803	7.4791	7.4803	7.4814	0.00115	7.4785	7.4803	0.0003
	26	222	319	416	7.8740	7.8728	7.8740	7.8751	0.00115	7.8722	7.8740	0.0003
				417	8.2677	8.2665	8.2677	8.2688	0.00115	8.2659	8.2677	0.0003
		224	320		8.4646	8.4634	8.4646	8.4657	0.00115	8.4628	8.4646	0.0003
			321	418	8.8583	8.8571	8.8583	8.8594	0.00115	8.8565	8.8583	0.0003
		226			9.0551	9.0539	9.0551	9.0562	0.00115	9.0533	9.0551	0.0003
			322		9.4488	9.4476	9.4488	9.4499	0.00115	9.4470	9.4488	0.0003

* Dimensions to which shafts and housings should be machined to produce a satisfactory operating assembly of the bearings with these units. Standards were arrived by the Bearings Engineer Committee.

Hose Selection

Just Remember the acronym **STAMPED**:

Size – Hose ID and length
Temperature – Environment and product temperature
Application – How is the product being used?
Material – What is going through the hose?
Pressure – PSI or suction?
Ends – What fittings do you need?
Delivery – How soon do you need it?

STAMPED form – To determine the proper hose assembly, fill out this form and send it to your local Applied Industrial Technologies service center.

Date:_____

Customer: _____

Address:_____

City: _____ State: _____ Zip: _____

Contact: _____ Phone: _____

E-mail: _____ Fax: _____

SIZE	
I.D.	
O.D.	
Hose Length (OAL or uncpld. length)	
Tolerances	

TEMPERATURE	
Of Material Being Conveyed (high, low, ambient)	
Of Outside Exposure (high, low, ambient)	
Intermittent?	
Constant?	
Sub-Zero Exposure	

APPLICATION(S)	
Indoor and/or Outdoor Use	
Intermittent or Continuous Use	
Flexing Required (min. bend radius)	
Movement (static, vibrations, flexing)	

EXTERNAL CONDITIONS	
Abrasion	
Oil	
Solvents	
Acid	
Ozone	
Electrical/Static Conductive	

OIL RESISTANCE	
Tube	
Cover	
Flame Resistance	
Noncontaminating Materials	
Hose Currently in Use	
Current Hose Service Life/ Failure Description	
Service Life Desired	

MATERIAL(S) BEING CONVEYED	
Solids (size, description)	
Gaseous (volatility, inert)	
Liquids (flammability, causticity, acid/alkaline, solution/concentration)	
Chemical Names (generic)	

PRESSURE(S)	
Working Pressure (including surges)	
Burst Pressure	
Suction or Vacuum Requirements	
Velocity	
Impulse	

ENDS & FITTINGS	
Type of Threads	
Male/Female	
Reusable/Nonreusable	
Material for Fittings	
Swivel or Non-Swivel	
Straight or Bent Tube	
Fitting 1 & 2 Orientation	
Other	
Cut to Length	
Crimp Specs or Crimper Used	

DELIVERY	
Required Date	
Quantity	

OTHER INFORMATION	
Special Print	
Special Packaging	

Information used with permission of Continental.

Defining Hose & Assembly Length

Identifying Overall Assembly Length

Unless otherwise specified, the assembly's overall length is measured from the extreme end of one fitting to the extreme of the other; except for the O-ring face seal fittings which shall be measured from the sealing face. Where elbow fittings are used, measurement shall be to the centerline of the sealing surface of the elbow end.

Assembly Length Measurements

Overall Assembly Length

Male Ends

Female Swivel Ends (except O-Ring Face Seal)

L

Bent Stem Swivel Female Ends

L

Flange Ends

L

Swivel O-Ring Face Seal Ends

Measure to seat face

L
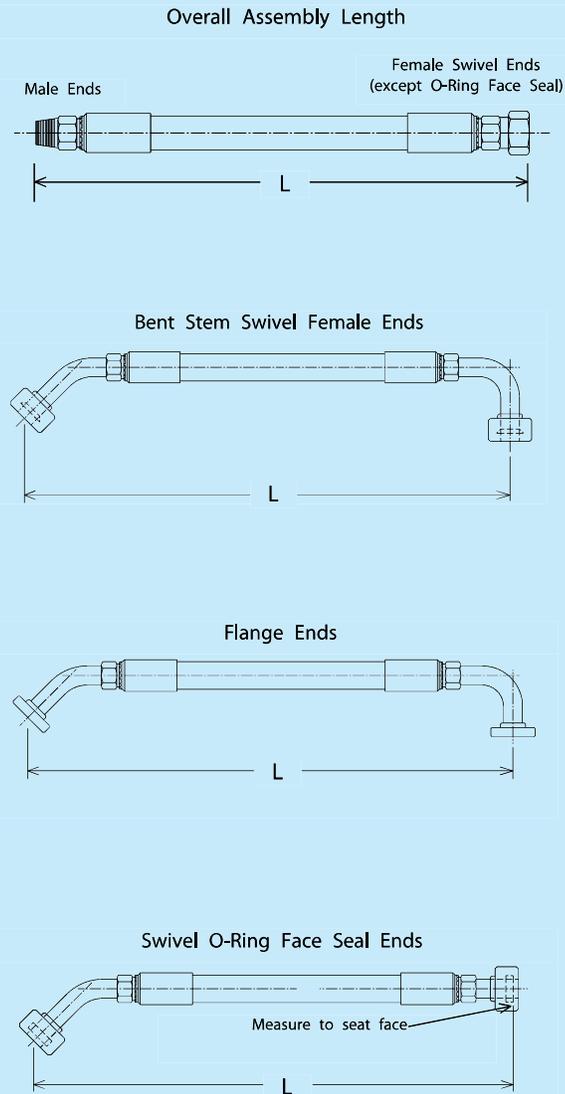
Measuring the Offset Angle

The offset angle between two fittings is the number of degrees measured in a clockwise direction, between the fitting nearest the viewer and the farthest end fitting. Tolerance on the offset angle is +/- 3 degrees for assemblies up to 24 inches long and +/- 5 degrees for assemblies 24 inches and longer.

The following illustration shows the clockwise angle separation between a "close" fitting and a "far" fitting. The "close" fitting would be defined as the fitting closest when looking at an assembly end to end. The "far" fitting would be defined as the fitting on the far of the assembly when looking at an assembly end to end. The far end is used as the reference point and the "close" end establishes the angular difference.

0°
315°
45°
270°
90°
225°
135°
180°
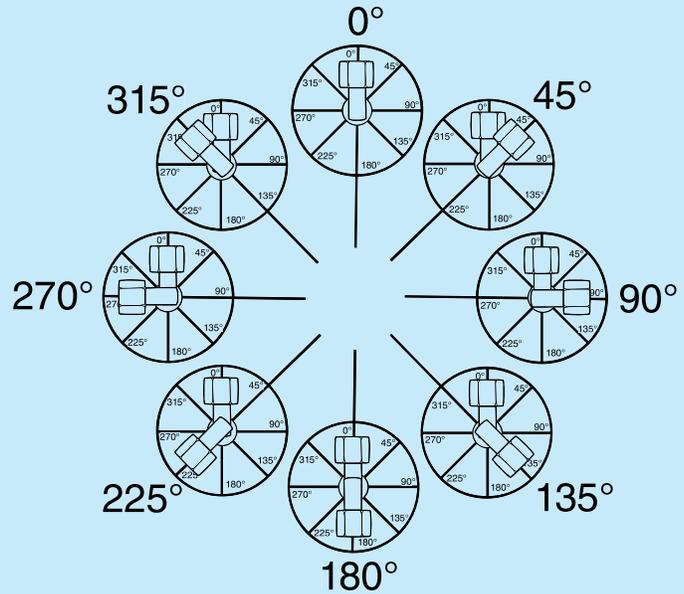
Far End Reference Measuring Clockwise

Close End

Far End

Clockwise Measurement (Degrees)

■ General Fluid Power Troubleshooting Charts

Use the charts on the following pages to help in listing all the possible causes of trouble when you begin diagnosing and testing a machine. Once you have located the cause, check the item in the chart again for the possible remedy. The technical manual for each machine supplements these charts by giving more detailed and specific causes and remedies.

System Inoperative

Possible Causes:	Remedy:
No oil in system.	Fill to full mark. Check system for leaks.
Oil low in reservoir.	Check level and fill to full mark. Check system for leaks.
Oil of wrong viscosity.	Refer to specifications for proper viscosity.
Filter dirty or plugged.	Drain oil and replace filters. Try to find source of contamination.
Restriction in system.	Oil lines could be dirty or have inner walls that are collapsing, cutting off oil supply. Clean or replace lines. Clean orifices.
Air leaks in suction line.	Repair or replace lines.
Dirt in pump.	Clean and repair pump. If necessary, drain and flush hydraulic system. Try to find source of contamination.
Badly worn pump.	Repair or replace pump. Check for problems causing pump wear such as misalignment or contaminated oil.
Badly worn components.	Examine and test valves, motors, cylinders, etc. for external and internal leaks. If wear is abnormal, try to locate the cause.
Oil leak in pressure lines.	Tighten fittings or replace defective lines. Examine mating surfaces on couplers for irregularities.
Components not properly adjusted.	Refer to machine technical manual for proper adjustment of components.
Relief valve defective.	Test relief valves to make sure they are opening at their rated pressure. Examine seals for damage that could cause leaks. Clean relief valves and check for broken springs, etc.
Pump rotating in wrong direction.	Reverse to prevent damage.
Excessive load on system.	Check specification of unit for load limits.
Hoses attached improperly.	Attach properly and tighten securely.
Slipping or broken pump drive.	Replace couplers or belts if necessary. Align them and adjust tension.
Pump not operating.	Check for shut-off device on pump or pump drive.

System Operates Erratically

Possible Causes:	Remedy:
Air in system.	Examine suction side of system for leaks. Make sure oil level is correct. Oil leaks on the pressure side of system could account for loss of oil.
Cold oil.	Viscosity of oil may be too high at start of warm-up period. Allow oil to warm up to operating temperature before using hydraulic functions.
Components sticking or binding.	Check for dirt or gummy deposits. If contaminated, try to find the source of contamination. Check for worn or bent parts.
Pump damaged.	Check for broken or worn parts. Determine cause of pump damage.
Dirt in relief valves.	Clean relief valves or replace.
Restriction in filter or suction line.	Suction line could be dirty or have inner walls that are collapsing, cutting off oil supply. Clean or replace suction line. Also, check filter line for restrictions.

Fluid Power General Troubleshooting

Overheating of Oil in System

Possible Causes:	Remedy:
Operator holds control valves in power position too long, causing relief valve to open.	Return control lever to neutral position when not in use.
Using incorrect oil.	Use oil recommended by manufacturer. Be sure oil viscosity is correct.
Low oil level.	Fill reservoir. Look for leaks.
Dirty oil.	Drain and refill with clean oil. Look for source of contamination and replace filters.
Engine running too fast.	Reset governor or reduce throttle.
Incorrect relief valve pressure.	Check pressure and clean or replace relief valves.
Internal component oil leakage.	Examine and test valves, cylinders, motors, etc. for external and internal leaks. If wear is abnormal, try to locate cause.
Restriction in pump suction line.	Clean or replace.
Dented, obstructed or undersized oil lines.	Replace defective or undersized oil lines. Remove obstructions.
Oil cooler malfunctioning.	Clean or repair.
Control valve stuck open.	Free all spools so that they return to neutral position.
Heat not radiating properly.	Clean dirt and mud from reservoir, oil lines, coolers, and other components.
Automatic unloading control inoperative (if equipped).	Repair valve.

System Operates Slowly

Possible Causes:	Remedy:
Cold oil.	Allow oil to warm up before operating machine.
Oil viscosity too heavy.	Use oil recommended by the manufacturer.
Insufficient engine speed.	Refer to operator's manual for recommended speed. If machine has a governor, it may need adjustment.
Low oil supply.	Check reservoir and add oil if necessary. Check system for leaks that could cause loss of oil.
Adjustable orifice restricted too much.	Back out orifice and adjust it. Check machine specifications for proper setting.
Air in system.	Check suction side of the system for leaks.
Badly worn pump.	Repair or replace pump. Check for problems causing pump wear such as misalignment or contaminated oil.
Restriction in suction line or filter.	Suction line could be dirty or have inner walls that are collapsing to cut off oil supply. Clean or replace suction line. Examine filter for plugging.
Relief valves not properly set or leaking.	Test relief valves to make sure they are opening at their rated pressure. Examine valves for damaged seats that could leak.
Badly worn components.	Examine and test valves, motors, cylinders, etc. for external and internal leaks. If wear is abnormal, try to locate the cause.
Valve or regulators plugged.	Clean dirt from components. Clean orifices. Check for source of dirt and correct.
Oil leak in pressure lines.	Tighten fittings or replace defective lines. Examine mating surfaces on couplers for irregularities.
Components not properly adjusted.	Refer to machine technical manual for proper adjustment of components.

System Operates Too Fast

Possible Causes:	Remedy:
Adjustable orifice installed backward or not installed.	Install orifice parts correctly and adjust.
Obstruction or dirt under seat of orifice.	Remove foreign material. Readjust orifice.
Overspeeding of engine.	Refer to operator's manual for recommended speed. If machine has a governor, it may need adjustment.

Foaming of Oil in System

Possible Causes:	Remedy:
Low oil level.	Fill reservoir. Look for leaks. Drain and replace oil.
Water in oil.	Check filler breather on reservoir. Heat exchanger may be cracked.
Wrong kind of oil being used.	Use oil recommended by manufacturer.
Air leak in line from reservoir to pump.	Tighten or replace suction line.
Kink or dent in oil lines.	Replace oil lines.
Worn pump shaft seal.	Clean sealing area and replace seal. Check oil for contamination or pump for misalignment.

Pump Makes Noise

Possible Causes:	Remedy:
Low oil level.	Fill reservoir. Check system for leaks.
Oil viscosity too high.	Change to lighter oil.
Pump speed too fast.	Operate pump at recommended speed.
Suction line plugged or pinched.	Clean or replace line between reservoir and pump.
Sludge and dirt in pump.	Disassemble and inspect pump and lines. Clean hydraulic system. Determine cause of dirt.
Reservoir air vent plugged.	Remove breather cap, flush, and clean air vent.
Air in oil.	Tighten or replace suction line. Check system for leaks. Replace pump shaft seal.
Worn or scored pump bearings or shafts.	Replace worn parts or complete pump if parts are badly worn or scored. Determine cause of scoring.
Inlet screen plugged.	Clean screen.
Broken or damaged pump parts.	Repair pump. Look for cause of damage such as contamination or too much pressure.
Sticking or binding parts.	Repair binding parts. Clean parts and change oil if necessary.

Pump Leaks Oil

Possible Causes:	Remedy:
Damaged seal around drive shaft.	Tighten packing or replace seal. Trouble may be caused by contaminated oil. Check oil for abrasives and clean entire hydraulic system. Try to locate source of contamination. Check the pump drive shaft. Misalignment could cause the seal to wear. If shaft is not aligned, check the pump for other damage.
Loose or broken pump parts.	Make sure all bolts and fittings are tight. Check gaskets. Examine pump castings for cracks. If pump is cracked, look for a cause like too much pressure or hoses that are attached incorrectly.

Fluid Power General Troubleshooting

Load Drops with Control Valve in Neutral Position

Possible Causes:	Remedy:
Leaking or broken oil lines from control valve to cylinder.	Check for leaks. Tighten or replace lines. Examine mating surfaces on couplers for irregularities.
Oil leaking past cylinder packings or O-rings.	Replace worn parts. If wear is caused by contamination, clean hydraulic system and determine the contamination source.
Oil leaking past control valve or relief valves.	Clean or replace valves. Wear may be caused by contamination. Clean hydraulic system and determine the contamination source.
Oil leaking past load holding valve.	Check for proper adjustment. Remove and replace cartridge with spare. (Support boom before removing cartridge.) Do not attempt to repair.
Control lever not centering when released.	Check linkage for binding. Make sure valve is properly adjusted and has no broken or binding parts.

Control Valve Sticks or Works Hard

Possible Causes:	Remedy:
Misalignment or seizing of control linkage.	Correct misalignment. Lubricate linkage joints.
Tie bolts too tight (on valve stacks).	Use manufacturer's recommendation to adjust tie bolt torque.
Valve broken or scored internally.	Repair broken or scored parts. Locate source of contamination that caused scoring.

Control Valve Leaks Oil

Possible Causes:	Remedy:
Tie bolts too loose (on valve stacks).	Use manufacturer's recommendation to adjust tie bolt torque.
Worn or damaged O-rings.	Replace O-rings, especially between valve stacks. If contamination has caused O-rings to wear, clean system and look for source of contamination.
Broken valve parts.	If valve is cracked, look for a cause like too much pressure or pipe fittings that are over tightened.

Cylinders Leak Oil

Possible Causes:	Remedy:
Damaged cylinder barrel.	Replace cylinder barrel. Correct cause of barrel damage.
Rod seal leaking.	Replace seal. If contamination caused seal to wear, look for source. Wear may be caused by external as well as internal contaminants. Check piston rod for scratches or misalignment.
Loose parts.	Tighten parts until leakage has stopped.
Piston rod damaged.	Check rod for nicks or scratches that could cause seal damage or allow oil leakage. Replace defective rods.

Cylinders Lower when Control Valve is in "Slow Raise" Position

Possible Causes:	Remedy:
Damaged check valve in lift circuit.	Repair or replace check valve.
Leaking cylinder packing.	Replace packing. Check oil for contamination that could cause wear. Check alignment of cylinder.
Leaking lines or fittings to cylinder.	Check and tighten. Examine mating surfaces on couplers for irregularities.

■ Lines

	Line, Working (Main)
	Line, Pilot or Drain
	Flow Direction Hydraulic Pneumatic
	Lines Crossing
	Lines Joining
	Lines With Fixed Restriction
	Line, Flexible
	Station, Testing, Measurement or Power Take-Off
	Variable Component (run arrow through symbol at 45)
	Pressure Compensated Units (Arrow parallel to short side of symbol)
	Temperature Cause or Effect

Reservoir

	Vented
	Pressurized

Line, To Reservoir

	Above Fluid Level / Below Fluid Level
	Vented Manifold

■ Hydraulic Pumps

	Fixed Displacement
	Variable Displacement

■ Motors and Cylinders

Hydraulic

	Fixed Displacement
	Variable Displacement
	Cylinder, Single-Acting

Cylinder, Double-Acting

	Single End Rod
	Double End Rod
	Adjustable Cushion Advance Only
	Differential Piston

■ Miscellaneous Units

	Electric Motor
	Accumulator, Spring Loaded
	Accumulator, Gas Charged
	Heater

■ Miscellaneous Units

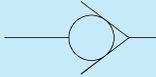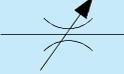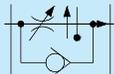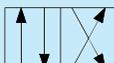|	
	Cooler
	Temperature Controller
	Filter, Strainer
	Pressure Switch
	Pressure Indicator
	Temperature Indicator
	Component Enclosure
	Direction of Shaft Rotation (assume arrow on near side of shaft)

■ Methods of Operation

	Spring
	Manual
	Push Button
	Push-Pull Lever
	Pedal or Treadle
	Mechanical
	Detent
	Pressure Compensated

Hydraulic Symbols

■ Methods of Operation
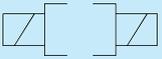
	Solenoid, Single Winding
	Servo Control
Pilot Pressure	
	Remote Supply
	Internal Supply
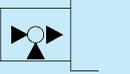
■ Valves

	Check
	On-Off (manual shut-off)
	Pressure Relief
	Pressure Reducing
	Flow Control, Adjustable - Non-Compensated
	Flow Control, Adjustable (Temperature and pressure compensated)
	Two-Position Two Way
	Two-Position Three Way
	Two-Position Four Way
	Two-Position In Transition
	Three-Position Four Way Closed Center
	Three Position Open Center Four Way
	Three Position Tandem Center Four Way
	Three Position Float Center Four Way
	Valves Capable of Infinite Positioning (Horizontal bars indicate infinite positioning ability)
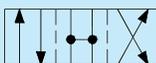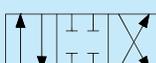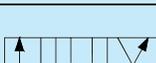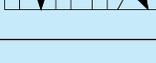
■ Color Code for Fluid Power Schematic Drawings

Black	Intensified Pressure
Red	Supply
Intermittent Red	Charging Pressure
Intermittent Red	Reduced Pressure
Intermittent Red	Pilot Pressure
Yellow	Metered Flow
Blue	Exhaust
Green	Intake
Green	Drain
Blank	Inactive

■ Air Prep Units

	Filter/Separator with manual drain
	Filter/Separator with automatic drain
	Oil Removal Filter
	Automatic Drain
	Lubricator less drain
	Lubricator with manual drain
	Lubricator with automatic filling
	Air Line Pressure Regulator adjustable, relieving
	Air Line Pressure Regulator pilot controlled, relieving
	Filter/Regulator (piggyback) Manual Drain Relieving (without gauge)
	Filter/Regulator (piggyback) Auto Drain Relieving
	Air Line Combo F-R-L simplified

■ Pneumatic Valves

	Check
	Flow Control
	Relief Valve
	2-Position, 2-Way
	2-Position, 3-Way
	2-Position, 4-Way 4-Ported
	2-Position, 4-Way 5-Ported
	3-Position, 4-Way ports closed, center position
	3-Position, 4-Way, 5-Ported cylinder ports open to pressure in center position
	Quick Exhaust
	Shuttle

■ Valve Actuators

|	
	Manual General Symbol
	Push Button
	Lever
	Pedal or Treadle
	Mechanical Cam, Toggle, etc.
	Spring
	Detent - Line indicates which detent is in use
	Solenoid
	Internal Pilot Supply
	Remote Pilot Supply
	And/or Composite solenoid and pilot or manual override
	And/or Composite solenoid and pilot or manual override and pilot

Pneumatic Symbols

|	Lines & Functions		Lines & Functions
———————	Main Line	→|←	Quick Disconnect without checks connected
– – – – –	Pilot Line	→| |←	Quick Disconnect without checks disconnected
- - - - - - -	Exhaust or Drain Line	–◯|◯–	Quick Disconnect with checks connected
– - – - –	Enclosure Line	–◯| |◯–	Quick Disconnect with checks disconnected
Lines Crossing	Lines Crossing	–◯|←	Quick Disconnect with one check connected
Lines Joining	Lines Joining	–◯| |←	Quick Disconnect with one check disconnected
▶	Flow Direction Hydraulic Medium		
▷	Flow Direction Gaseous Medium		
Energy Source	Energy Source		
Line with Fixed Restriction	Line with Fixed Restriction		
Line with Adjustable Restriction	Line with Adjustable Restriction		
Flexible Line	Flexible Line		
✕	Plugged Port, Test Station, Power Take-Off		

Standard Double-Acting
Power stroke is in both directions and is used in the majority of applications.
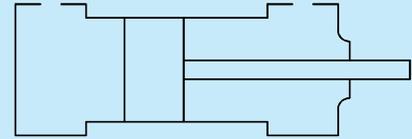
Single-Acting
When thrust is needed in only one direction, a single-acting cylinder may be used. The inactive end is vented into the atmosphere through a breather filter for pneumatic applications, or vented to a resevoir below the oil level in hydraulic applications.
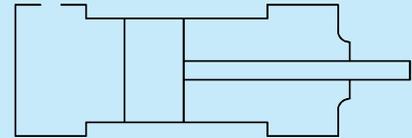
Double Rod
Used when equal displacement is needed on both sides of the piston, or when it is mechanically advantageous to couple a load to each end. The extra end can be used to mount cams for operating limit switches, etc.
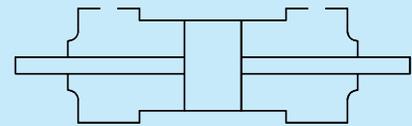
Spring Return, Single-Acting
Usually limited to very small, short stroke cylinders used for holding and clamping. The length needed to contain the return spring makes them undesirable when a long stroke is needed.
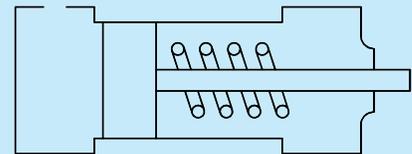
Ram Type, Single-Acting
Containing only one fluid chamber; this type of cylinder is usually mounted vertically. The weight of the load retracts the cylinder. They are sometimes known as "displacement cylinders", and are practical for long strokes.
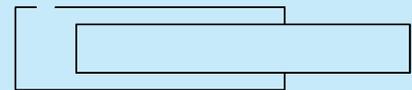
Telescoping
Available with up to 4 or 5 sleeves; collapsed length is shorter than standard cylinders. Available either as single or double-acting, they are relatively expensive compared to standard cylinders.
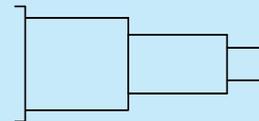
Tandem
A tandem cylinder is made up of two cylinders mounted in line with pistons connected by a common piston rod and rod seals installed between the cylinders to permit double acting operation of each. Tandem cylinders allow increased output force when mounting width or height are restricted.
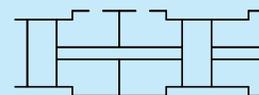
Duplex
A duplex cylinder is made up of two cylinders mounted in line with pistons not connected and with rod seals installed between the cylinders to permit double acting operation of each. Cylinders may be mounted with piston rod to piston (as shown) or back to back, and are generally used to provide three position operation.
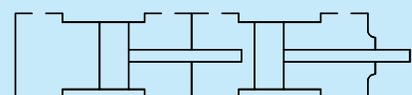
Cylinders

Hydraulic Cylinder Speeds — Inches/Minutes

This chart is based on the formula:

$$V \text{ (Velocity)} = \frac{231 \times GPM}{\text{Eff. Cyl. Area (Sq. In.)}}$$

Piston Diameter	Rod Diameter	Flow-GPM										
		1	2	3	5	10	12	15	20	25	50	75
1	-	298	596	849	149							
	1/2	392	784	1176	196							
1 1/2	-	130	260	392	654	1308						
	5/8	158	316	476	792	1584						
	1	235	470	706	1176	2352						
2	-	73	146	221	368	736	883	1120				
	3/4	85	170	257	428	956	1025	1283				
	1	97	184	294	490	980	1175	1465				
	1 3/8	139	278	418	697	1394	1673	2090				
2 1/2	-	47	94	141	235	470	565	675	940	1175		
	1	56	112	168	280	560	672	840	1120	1400		
	1 3/8	67	134	203	339	678	813	1015	1355	1695		
	1 3/4	92	184	277	463	926	1110	1385	1850	2310		
3	-	32	64	98	163	326	392	490	653	817		
	1	36	72	110	184	368	440	551	735	920		
	1 1/2	43	86	131	218	436	523	655	872	1090		
	2	58	116	176	294	588	705	882	1175	1470		
3 1/2	-	24	48	72	120	240	288	360	480	600	1200	
	1 1/4	27	54	82	137	274	330	411	548	685	1370	
	1 3/4	32	64	96	160	320	384	480	640	800	1600	
	2	35	70	107	178	356	428	534	712	890	1780	
4	-	18	36	55	92	184	220	276	368	460	920	
	1 1/4	20	40	61	102	240	244	306	408	510	1020	
	1 3/4	22	44	68	113	226	273	339	452	565	1130	
	2	24	48	73	122	244	294	366	488	610	1220	
	2 1/2	30	60	90	150	300	362	450	600	750	1500	
5	-	12	24	35	58	116	141	174	232	290	580	870
	1 1/2	13	26	39	64	128	155	193	258	320	640	960
	2	14	28	42	70	140	168	210	280	350	700	1050
	2 1/2	16	32	47	78	156	188	235	315	390	780	1170
	3	18	36	55	92	184	220	275	365	460	920	1380
	3 1/2	22	44	66	111	222	266	333	444	555	1110	1665
6	-	8	16	24	41	82	98	123	162	202	404	606
	1 3/4	9	18	27	45	90	107	135	180	225	450	675
	2 1/2	10	20	30	50	100	118	150	200	250	500	750
	3	11	22	33	54	108	130	165	206	270	540	810
	3 1/2	12	24	37	62	124	148	185	245	310	620	930
	4	15	30	44	73	146	176	220	295	365	730	1095
8	-	4	8	14	23	46	55	69	92	115	230	345
	3 1/2	5 1/2	11	17	28	56	68	85	115	140	280	420
	4	6	12	18	30	60	73	90	122	150	300	450
	5	7 1/2	15	22	38	76	90	114	150	185	375	555
	5 1/2	8 1/2	17	26	43	86	104	129	172	215	430	645
10	-	3	6	9	15	30	35	44	60	73	146	220
	4 1/2	3 1/2	7	11	18	36	44	55	75	92	184	275
	5	4	8	12	20	40	47	60	80	100	200	300
	5 1/2	4 1/2	9	13	21	42	50	63	84	105	210	315
	7	5 1/2	11	17	29	58	69	87	115	145	290	435

Theoretical Push and Pull Forces for Pneumatic and Hydraulic Cylinders

The cylinder output forces are derived from the formula:

$F = P \times A$

F = Force in pounds
P = Pressure at the cylinder in pounds per sq. inch, gauge
A = Effective area of cylinder piston in sq. inches

Free air refers to normal atmospheric conditions of the air at sea level (14.7 psi). Use cu. ft. free air required data (see chart below) to compute CFM required from a compressor at 80 cu. ft. of free air required. Other pressures can be calculated using the information below.

$$V_1 = \frac{(P_2 + 14.7)V_2}{14.7}$$

V_1 = Free air consumption per inch of stroke (cubic feet)
V_2 = Cubic feet displaced per inch of stroke
P_2 = Gauge pressure required to move maximum load

Push Force and Displacement													
Cyl. Bore Size (Inches)	Piston Area (Sq. In.)	Cylinder Push Stroke Force in Pounds at Various Pressures										Cu. Ft. Free Air at 80 Lbs. Pressure, Required to move Max. Load 1 Inch	Displace. Per Inch of Stroke (Gallons)
		25	50	65	80	100	250	500	1000	2000	3000		
1	0.785	20	39	51	65	79	196	392	785	1570	2355	.00293	.00340
1 1/2	1.767	44	88	115	142	177	443	885	1770	3540	5310	.00659	.00765
2	3.14	79	157	204	251	314	785	1570	3140	6280	9420	.01171	.0136
2 1/2	4.91	123	245	319	393	491	1228	2455	4910	9820	14730	.01830	.0213
3 1/4	8.30	208	415	540	664	830	2072	4150	8300	16600	24900	.03093	.0359
4	12.57	314	628	817	1006	1257	3143	6285	12570	25140	37710	.04685	.0544
5	19.64	491	982	1277	1571	1964	4910	9820	19640	39280	58920	.07320	.0850
6	28.27	707	1414	1838	2262	2827	7068	14135	28270	56540	84810	.10540	.1224
7	38.49	962	1924	2502	3079	3849	9623	19245	38490	76980	115470	.14347	.1666
8	50.27	1257	2513	3268	4022	5027	12568	25135	50270	100540	150810	.18740	.2176
10	78.54	1964	3927	5105	6283	7854	19635	39270	78540	157080	235620	.29280	.3400
12	113.10	2828	5655	7652	9048	11310	28275	56550	113100	226200	339300	.42164	.4896
14	153.94	3849	7697	10006	12315	15394	38485	76970	153940	307880	461820	.57389	.6664

Deductions for Pull Force and Displacement													
Piston Rod Dia. (Inches)	Piston Rod Area (Sq. In.)	Piston Rod Diameter Force in Pounds at Various Pressures To determine Cylinder Pull Force or Displacement, deduct the following Force or Displacement corresponding to Rod Size, from selected Push Stroke Force or Displacement corresponding to Bore Size in the table above										Cu. Ft. Free Air at 80 Lbs. Pressure, Required to move Max. Load 1 Inch	Displace. Per Inch of Stroke (Gallons)
		25	50	65	80	100	250	500	1000	2000	3000		
1/2	0.196	5	10	13	16	20	49	98	196	392	588	.00073	.0009
5/8	0.307	8	15	20	25	31	77	154	307	614	921	.00114	.0013
1	0.785	20	39	51	65	79	196	392	785	1570	2355	.00293	.0034
1 3/8	1.49	37	75	97	119	149	373	745	1490	2980	4470	.00554	.0065
1 3/4	2.41	60	121	157	193	241	603	1205	2410	4820	7230	.00897	.0104
2	3.14	79	157	204	251	314	785	1570	3140	6280	9420	.01171	.0136
2 1/2	4.91	123	245	319	393	491	1228	2455	4910	9820	14730	.01830	.0213
3	7.07	177	354	460	566	707	1767	3535	7070	14140	21210	.02635	.0306
3 1/2	9.62	241	481	625	770	962	2405	4810	9620	19240	28860	.03587	.0416
4	12.57	314	628	817	1006	1257	3143	6285	12570	25140	37710	.04685	.0544
4 1/2	15.90	398	795	1033	1272	1590	3975	7950	15900	31800	47708	.05929	.0688
5	19.64	491	982	1277	1571	1964	4910	9820	19640	39280	58920	.07320	.0850
5 1/2	23.76	594	1188	1544	1901	2376	5940	11880	23760	47520	71280	.08857	.1028
7	38.49	962	1924	2502	3079	3849	9623	19245	38490	76980	115470	.14347	.1666
8 1/2	56.75	1419	2838	3689	4540	5675	14187	28375	56750	113500	170250	.21157	.2455

Cylinders

How to Select a Hydraulic Cylinder and Power Unit

Selection of the proper components for a hydraulic system is quite simple when you use the accompanying table and chart. Here is an example to illustrate their use. Assume your requirements are: 20,000 lbs. of force, 28" stroke, and 7.5 seconds for full cylinder extension.

Step One:
The table below shows a 3" diameter cylinder will develop 21,204 lbs. of force with 3,000 psi pressure.

Step Two:
A line has been drawn on the chart from 3" diameter through 28" stroke.

Cylinder Bore	Cylinder push in pounds		
	@ 1000 psi	@ 2000 psi	@ 3000 psi
2	3141	6282	9423
2 ½	4908	9816	14724
3	7068	14136	21204
4	12566	25132	37698
5	19635	39270	58905
6	28274	56548	84822
7	38465	76930	115395

Step Three:
By continuing this line, it intersects 200 cubic inch displacement.

Step Four:
Another line drawn from 200 cubic inches through 7.5 seconds intersects 7 GPM.

Your Answer:
Using this example, the chart and table show that your components should be a 3" diameter 3,000 psi cylinder and a hydraulic power unit with approximately 7 GPM and 3,000 psi rating.

Theoretical horsepower for these values would be 12.25 hp. However, since most applications usually require maximum GPM and pressure for only a very short portion of each cycle, the electric motor of the hydraulic power unit will usually be considerably smaller (one half or less).

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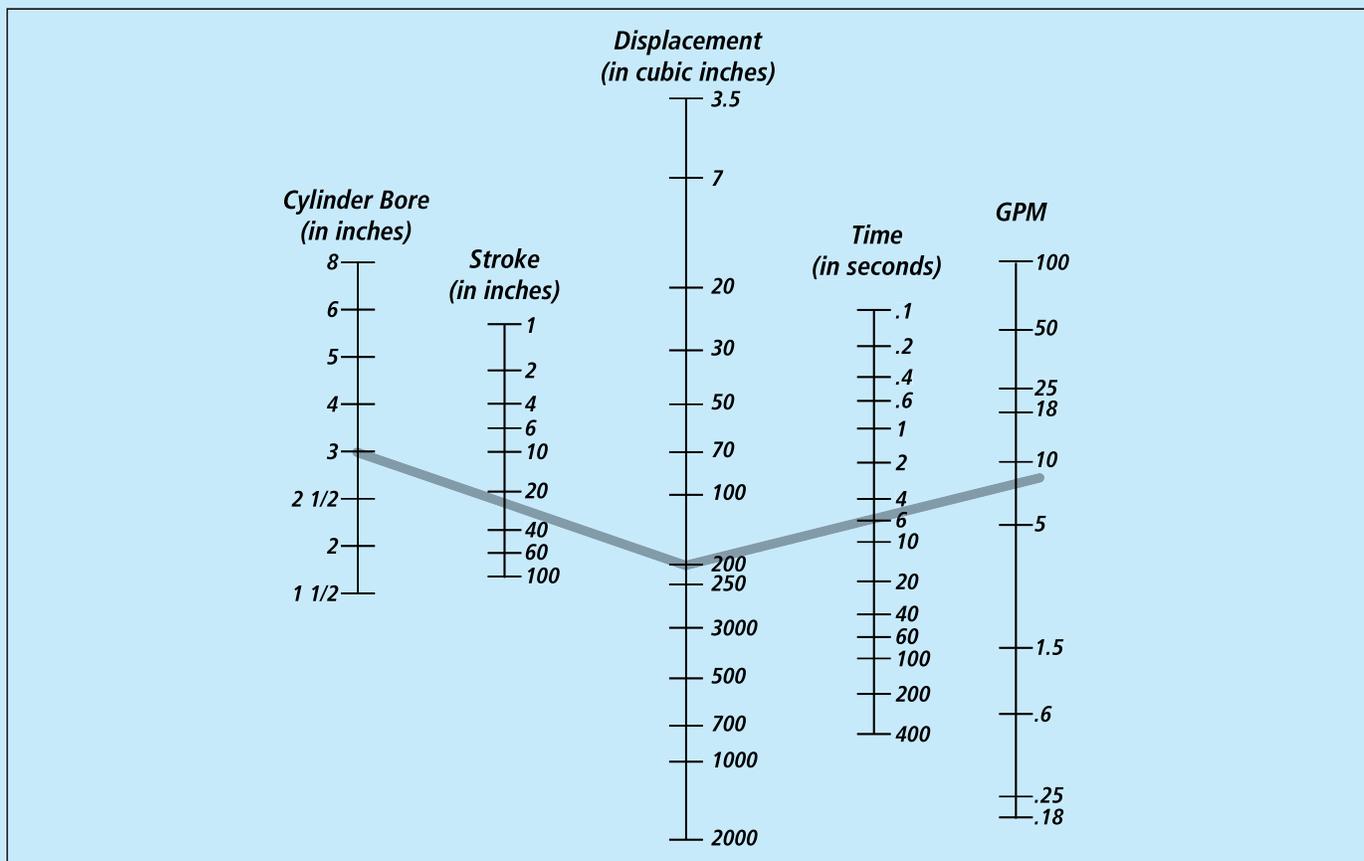
Cylinder Speed

This chart will help you calculate the time required for an Enerpac cylinder to lift a load when powered by a 10,000 psi Enerpac hydraulic pump. The Cylinder Speed Chart can also be used to determine the pump type and model best suited for an application when you know the plunger speed required.

To determine:

Cylinder plunger speed

30 ton		50 ton		75 ton		100 ton		
No Load	Load	No Load	Load	No Load	Load	No Load	Load	Pump Type
1.9	19.5	3.3	33.2	4.8	47.7	6.2	61.9	.5 hp Economy
.63	6.5	1.1	11.1	1.6	15.9	2.0	20.6	Titan
2.6	19.5	4.4	33.2	6.4	47.7	8.3	61.9	.5 hp Submerged
1.6	9.3	2.8	15.8	4.0	22.7	5.2	29.5	20-Series
.61	6.5	1.0	11.1	1.5	15.9	1.9	20.6	3-Series Hushh
.61	3.2	1.0	5.5	1.5	8.0	1.9	10.3	5-Series Hushh
.38	.84	.65	1.4	.94	2.1	1.2	2.7	8000-Series
6.5	39.0	11.0	66.3	15.9	95.5	20.6	123.9	Turbo II Pump
7.8	48.7	13.3	82.9	19.1	119.3	24.8	154.7	PA-133
.60	43.3	1.0	73.7	1.5	106.0	1.9	137.5	10-Series
.46	13.0	.80	22.1	1.1	31.8	1.5	41.3	Modular Air

Your 30 ton cylinder needs to move a load at a speed of 6.50 sec/in. Simply go down from the top of the chart, to the value of 6.50 sec/in. Then follow the chart to the right to find that the 3-Series Hushh pump or Titan most suitable for your application.

To determine:

Cylinder plunger speed

30 ton		50 ton		75 ton		100 ton		
No Load	Load	No Load	Load	No Load	Load	No Load	Load	Pump Type
1.9	19.5	3.3	33.2	4.8	47.7	6.2	61.9	.5 hp Economy
.63	6.5	1.1	11.1	1.6	15.9	2.0	20.6	Titan
2.6	19.5	4.4	33.2	6.4	47.7	8.3	61.9	.5 hp Submerged
1.6	9.3	2.8	15.8	4.0	22.7	5.2	29.5	20-Series
.61	6.5	1.0	11.1	1.5	15.9	1.9	20.6	3-Series Hushh
.61	3.2	1.0	5.5	1.5	8.0	1.9	10.3	5-Series Hushh
.38	.84	.65	1.4	.94	2.1	1.2	2.7	8000-Series
6.5	39.0	11.0	66.3	15.9	95.5	20.6	123.9	Turbo II Pump
7.8	48.7	13.3	82.9	19.1	119.3	24.8	154.7	PA-133
.60	43.3	1.0	73.7	1.5	106.0	1.9	137.5	10-Series
.46	13.0	.80	22.1	1.1	31.8	1.5	41.3	Modular Air
1.9	9.7	3.3	16.6	4.8	23.9	6.2	30.9	Atlas Pump 2.5 hp
.81	7.1	1.4	12.1	2.0	17.3	2.6	22.5	Atlas Pump 5.0 hp

An RC-308 cylinder (30 ton) is powered by a 5-Series Hushh pump. While lifting the load, the cylinder plunger will require 3.2 seconds to travel 1 inch. While extending towards the load, the cylinder plunger travels at .61 sec/in.

Number of Pump Handle Strokes per Inch of Cylinder Plunger Travel

Cyl. Capacity ▶	5 ton		10 ton		15 ton		25 ton		30 ton		50 ton		75 ton		100 ton		
Power Source ▼	No Load	Load	No Load	Load	No Load	Load	No Load	Load	No Load	Load	No Load	Load	No Load	Load	No Load	Load	Pump Type
Manual	7	7	15	15	21	21	34	34	43	43	73	73	105	105	137	137	P-391
	2	7	4	15	5	21	8	34	10	43	16	73	24	105	30	137	P-392
	1	7	2	15	3	21	5	34	7	43	11	73	16	105	21	137	P-80/84/801
	1	7	1	15	1	21	2	34	3	43	5	73	7	105	9	137	P-802/842
	1	3	1	8	1	11	1	18	1	23	2	38	2	55	3	71	P-462/464

Seconds per Inch of Cylinder Plunger Travel

Cyl. Capacity ▶	5 ton		10 ton		15 ton		25 ton		30 ton		50 ton		75 ton		100 ton		
Power Source ▼	No Load	Load	No Load	Load	No Load	Load	No Load	Load	No Load	Load	No Load	Load	No Load	Load	No Load	Load	Pump Type
Electric (speed based on 60 Hz)	.30	3.0	.67	6.7	.94	9.4	1.5	15.5	1.9	19.5	3.3	33.2	4.8	47.7	6.2	61.9	0.5 hp Economy
	.09	1.0	.22	2.2	.31	3.1	.50	5.2	.63	6.5	1.1	11.1	1.6	15.9	2.0	20.6	Titan
	.40	3.0	.90	6.7	1.3	9.4	2.1	15.5	2.6	19.5	4.4	33.2	6.4	47.7	8.3	61.9	0.5 hp Submerged
	.25	1.4	.56	3.2	.79	4.5	1.3	7.4	1.6	9.3	2.8	15.8	4.0	22.7	5.2	29.5	20-Series
	.09	1.0	.21	2.2	.29	3.1	.48	5.2	.61	6.5	1.0	11.1	1.5	15.9	1.9	20.6	3-Series Hushh
	.09	.50	.21	1.1	.29	1.6	.48	2.6	.61	3.2	1.0	5.5	1.5	8.0	1.9	10.3	5-Series Hushh
	.06	.13	.13	.29	.19	.41	.30	.67	.38	.84	.65	1.4	.94	2.1	1.2	2.7	8000-Series
Air (speed based on 100 psi air pressure)	1.0	5.9	2.2	13.4	3.1	18.8	5.2	30.9	6.5	39.0	11.0	66.3	15.9	95.5	20.6	123.9	Turbo II Pump
	1.2	7.4	2.7	16.8	3.8	23.6	6.2	38.6	7.8	48.7	13.3	82.9	19.1	119.3	24.8	154.7	PA-133
	.09	6.6	.21	14.9	.29	20.9	.48	34.3	.60	43.3	1.0	73.7	1.5	106.0	1.9	137.5	10-Series
	.07	2.0	.16	4.5	.22	6.3	.36	10.3	.46	13.0	.80	22.1	1.1	31.8	1.5	41.3	Modular Air
Gasoline	.30	1.5	.67	3.4	.94	4.7	1.5	7.7	1.9	9.7	3.3	16.6	4.8	23.9	6.2	30.9	Atlas Pump 2.5 hp
	.12	1.1	.28	2.4	.39	3.4	.64	5.6	.81	7.1	1.4	12.1	2.0	17.3	2.6	22.5	Atlas Pump 5.0 hp
	.12	.59	.28	1.3	.39	1.9	.64	3.1	.81	3.9	1.4	6.6	2.0	9.5	2.6	12.4	Atlas Pump 5.5 hp
	.06	.30	.13	.67	.19	.94	.31	1.5	.39	1.9	.66	3.3	.95	4.7	1.2	6.2	Atlas Pump 13 hp

No Load indicates the plunger speed as the plunger extends toward the load (1st stage).
Load indicates the plunger speed as the load is lifted at a system pressure of 10,000 psi (2nd stage).

Formula V = A ÷ Q

V (sec/in) = A (in^2) ÷ Q (in^3/min)
V = Cylinder plunger speed in seconds per inch
A = Cylinder effective area in square inches
Q = Pump oil flow in cubic inches

Example
At what speed (V) will the RC-308 (30 ton) cylinder move when powered by a 20-Series electric driven pump?
20-Series pump:
Oil flow Q, (no load) is 240 in^3/min
RC-308 cylinder:
Effective area A is 6.50 in^2
V = 6.50 in^2 ÷ 240 in^3/min x 60 = 1.60 sec/in

$$\text{Cylinder Plunger Speed (sec/in)} = \frac{\text{Cylinder Effective Area (in}^2\text{)}}{\text{Pump Flow Rate (in}^3\text{/min)}} = \frac{60 \text{ sec}}{1}$$

Source: Enerpac

Electric Motor Horsepower

Required to Drive a Hydraulic Pump

This chart is based on the formula:

$$hp = \frac{GPM \times psi}{1714 \times Efficiency}$$

For the purposes of this chart, pump efficiency was assumed to be 85%.

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

GPM	Pump Pressure psi										
	100	200	250	300	400	500	750	1000	1250	1500	2000
1/2	0.04	0.07	0.09	0.10	0.14	0.17	0.26	0.34	0.43	0.52	0.69
1	0.07	0.14	0.17	0.21	0.28	0.34	0.52	0.69	0.86	1.03	1.37
1 1/2	0.10	0.21	0.26	0.31	0.41	0.52	0.77	1.03	1.29	1.54	2.06
2	0.14	0.28	0.34	0.41	0.55	0.69	1.03	1.37	1.72	2.06	2.75
2 1/2	0.17	0.34	0.43	0.52	0.69	0.86	1.29	1.72	2.15	2.58	3.43
3	0.21	0.41	0.52	0.62	0.83	1.03	1.54	2.06	2.57	3.09	4.12
3 1/2	0.24	0.48	0.60	0.72	0.96	1.20	1.80	2.40	3.00	3.60	4.81
4	0.28	0.55	0.69	0.82	1.10	1.37	2.06	2.75	3.43	4.12	5.49
5	0.34	0.69	0.86	1.03	1.32	1.72	2.57	3.43	4.29	5.15	6.86
6	0.41	0.82	1.03	1.24	1.65	2.06	3.09	4.12	5.15	6.18	8.24
7	0.48	0.96	1.20	1.44	1.92	2.40	3.60	4.81	6.01	7.21	9.61
8	0.55	1.10	1.37	1.65	2.20	2.75	4.12	5.49	6.86	8.24	11.00
9	0.62	1.24	1.55	1.85	2.47	3.09	4.63	6.18	7.72	9.27	12.40
10	0.69	1.37	1.62	2.06	2.75	3.43	5.15	6.86	8.58	10.30	13.80
11	0.76	1.51	1.89	2.27	3.02	3.78	5.66	7.55	9.44	11.30	15.10
12	0.83	1.65	2.06	2.47	3.30	4.12	6.18	8.24	10.30	12.40	16.50
13	0.89	1.79	2.23	2.68	3.57	4.46	6.69	8.92	11.20	13.40	17.80
14	0.96	1.92	2.40	2.88	3.84	4.81	7.21	9.61	12.00	14.40	19.20
15	1.03	2.06	2.57	3.09	4.12	5.15	7.72	10.30	12.90	15.40	20.60
16	1.10	2.20	2.75	3.30	4.39	5.49	8.24	11.00	13.70	16.50	22.00
17	1.17	2.33	2.92	3.50	4.68	5.83	8.75	11.70	14.60	17.50	23.30
18	1.24	2.47	3.09	3.71	4.94	6.18	9.27	12.40	15.40	18.50	24.70
19	1.30	2.61	3.26	3.91	5.22	6.52	9.78	13.00	16.30	19.60	26.10
20	1.37	2.75	3.43	4.12	5.49	6.86	10.30	13.70	17.20	21.60	27.50
25	1.72	3.43	4.29	5.15	6.86	8.58	12.90	17.20	21.50	25.80	34.30
30	2.06	4.12	5.15	6.18	8.24	10.30	15.40	20.6	25.70	30.90	41.20
35	2.40	4.81	6.01	7.21	9.61	12.00	18.00	24.00	30.00	36.00	48.00
40	2.75	5.49	6.86	8.24	11.00	13.70	20.60	27.50	34.30	41.20	54.90
45	3.09	6.18	7.72	9.27	12.40	15.40	23.20	31.00	38.60	46.30	61.80
50	3.43	6.86	8.58	10.30	13.70	17.20	25.70	34.30	42.90	51.50	68.60
55	3.78	7.55	9.44	11.30	15.10	18.90	28.30	37.80	47.20	56.60	75.50
60	4.12	8.24	10.30	12.40	16.50	20.60	30.90	41.20	51.50	61.80	83.40
65	4.46	8.92	11.20	13.40	17.80	22.30	33.50	44.60	55.80	66.90	89.20
70	4.81	9.61	12.00	14.40	19.20	24.00	36.00	48.00	60.10	72.10	96.10
75	5.15	10.30	12.90	15.40	2.60	25.70	38.60	51.40	64.30	77.20	103.00
80	5.49	11.00	13.70	16.50	22.00	27.50	41.20	54.90	68.60	82.40	109.80
90	6.18	12.40	15.40	18.50	24.70	30.90	46.30	61.80	77.20	92.70	123.60
100	6.86	13.70	17.20	20.60	27.50	34.40	51.50	68.60	85.80	103.00	137.30

How to Determine Proper Air Valve Size

Most manufacturers' catalogs provide flow ratings for valves in Cv, based on National Fluid Power Association (NFPA) standard T3.21.3. The following tables and formulas will enable you to quickly size a valve properly. The traditional, often-used approach of using the valve size equivalent to the port in the cylinder can be very costly. Cylinder speed, not port size, should be the determining factor.

The following Cv calculations are based upon simplified formulas which yield results with acceptable accuracy under the following standard condition:

Air at a temperature of 68 °F (20 °C)

Absolute downstream or secondary pressure must be 53% of absolute inlet or primary pressure or greater. Below 53%, the air velocity may become sonic and the Cv formula does not apply.

Nomenclature:

B	Pressure drop factor	
C	Compression factor	
Cv	Flow factor	
D	Cylinder Diameter	(I N)
F	Cylinder Area	(SQ IN)
L	Cylinder Stroke	(I N)
p1	Inlet or Primary Pressure	(PS I G)
p2	Outlet or Secondary Pressure	(PS I G)
Δp	Pressure differential (p1- p2)	(psiD)
q	Air flow at actual condition	(CFM)
Q	Air flow of free air	(SCFM)
t	Time to complete one cylinder stroke	(SEC)
T	Absolute temperature at operating pressure. Deg R = Deg F + 460	(°R)

Valve Sizing for Cylinder Actuation Direct Formula

$$Cv = \frac{\text{Cylinder Area (F) (Sq. In.) (See Table 1)} \times \text{Cylinder Stroke (L) (In.)} \times \text{Compression (C) Factor (See Table 2)}}{\text{Pressure Drop (B) Factor (See Table 2)} \times \text{Time to Complete Cylinder Stroke (Sec)} \times 28.8}$$

Example: Cylinder size 4" Dia. x 10" stroke. Time to extend: 2 seconds. Inlet pressure 90 psiG. Allowable pressure drop 5 psiD. Determine Cv.

Solution:
F = 12.57 Sq. In. (Table 1)
C = 7.1 (Table 2)   B = 21.6

$$Cv = \frac{12.57 \times 10 \times 7.1}{21.6 \times 2 \times 28.8} = 0.7$$

Select a valve that has a Cv factor of .7 or higher. In most cases, a 1/4" valve would be sufficient.

It is considered good engineering practice to limit the pressure drop Dp to approximately 10% of primary pressure P1. The smaller the allowable pressure drop, the larger the required valve will become.

After the minimum required Cv has been calculated, the proper size valve can be selected from the catalog.

Table 1:

Cylinder push bore area F for standard size cylinders			
Bore Size D (In.)	Cylinder Area F (Sq. In)	Bore Size D (In.)	Cylinder Area F (Sq. In)
3/4	0.44	4	12.57
1	0.79	4 1/2	15.90
1 1/8	0.99	5	19.64
1 1/4	1.23	6	28.27
1 1/2	1.77	7	38.48
1 3/4	2.41	8	50.27
2	3.14	10	78.54
2 1/2	4.91	12	113.10
3 1/4	8.30	14	153.94

Table 2:

Compression factor C and pressure drop factor B						
Inlet Pressure (psiG)	Compr. Factor C	Pressure Drop Factor B for Various Pressure Drops Δ p				
		2 psiD	5 psiD	10 psiD	15 psiD	20 psiD
10	1.7	6.5	-	-	-	-
20	2.4	7.8	11.8	-	-	-
30	3.0	8.9	13.6	18.0	-	-
40	3.7	9.9	15.3	20.5	23.6	-
50	4.4	10.8	16.7	22.6	26.4	29.0
60	5.1	11.7	18.1	24.6	29	32.0
70	5.8	12.5	19.3	26.5	31.3	34.8
80	6.4	13.2	20.5	28.2	33.5	37.4
90	7.1	13.9	21.6	29.8	35.5	39.9
100	7.8	14.5	22.7	31.3	37.4	42.1
110	8.5	15.2	23.7	32.8	39.3	44.3
120	9.2	15.8	24.7	34.2	41.0	46.4
130	9.8	16.4	25.6	35.5	42.7	48.4
140	10.5	16.9	26.5	36.8	44.3	50.3
150	11.2	17.5	27.4	38.1	45.9	52.1
160	11.9	18.0	28.2	39.3	47.4	53.9
170	12.6	18.5	29.0	40.5	48.9	55.6
180	13.2	19.0	29.8	41.6	50.3	57.2
190	13.9	19.5	30.6	42.7	51.7	58.9
200	14.6	20.0	31.4	43.8	53.0	60.4
210	15.3	20.4	32.1	44.9	54.3	62.0
220	16.0	20.9	32.8	45.9	55.6	63.5
230	16.7	21.3	33.5	46.9	56.8	64.9
240	17.3	21.8	34.2	47.9	58.1	66.3
250	18.0	22.2	34.9	48.9	59.3	67.7

Fluid Power Formulas

Basic Formulas

Formula For:	Word Formula:	Letter Formula:
FLUID PRESSURE In Pounds/Square Inch	$\text{Pressure} = \dfrac{\text{Force (Pounds)}}{\text{Unit Area (Square Inches)}}$	P = F/A or psi = F/A
FLUID FLOW RATE In Gallons/Minute	$\text{Flow Rate} = \dfrac{\text{Volume (Gallons)}}{\text{Unit Time (Minute)}}$	Q = V/T
FLUID POWER In Horsepower	$\text{Horsepower} = \dfrac{\text{Pressure (psi) x Flow (GPM)}}{1714}$	hp = PQ/1714

Fluid Formulas

Formula For:	Word Formula:	Letter Formula:
VELOCITY THROUGH PIPING In Feet/Second Velocity	$\text{Velocity} = \dfrac{.3208 \text{ x Flow Rate through I.D. (GPM)}}{\text{Internal Area (Square Inches)}}$	V = .3208Q/A
COMPRESSIBILITY OF OIL In Additional Required Oil to Reach Pressure	$\text{Additional Volume} = \dfrac{\text{Pressure (psi) x Volume of Oil under Pressure}}{250{,}000 \text{ (approx.)}}$	V_A = PV/250,000 (approx.)
COMPRESSIBILITY OF A FLUID	$\text{Compressibility} = \dfrac{1}{\text{Bulk Modulus of the Fluid}}$	C(ß) = 1/BM
SPECIFIC GRAVITY OF A FLUID	$\text{Specific Gravity} = \dfrac{\text{Weight of One Cubic Foot of Fluid}}{\text{Weight of One Cubic Foot of Water}}$	SG = W/62.4283
VALVE (Cv) FLOW FACTOR	$\text{Valve Factor} = \dfrac{\text{Flow Rate (GPM)}\sqrt{\text{Specific Gravity}}}{\sqrt{\text{Pressure Drop (psi)}}}$	$Cv = (Q\sqrt{SG})/(\sqrt{\Delta p})$
VISCOSITY IN CENTISTOKES	For Viscosities of 32 to 100 Saybolt Universal Seconds: $\text{Centistokes} = .2253 \text{ x SUS} - \left(\dfrac{194.4}{\text{SUS}}\right)$	CS = .2253 SUS - (194.4/SUS)
	For Viscosities of 100 to 240 Saybolt Universal Seconds: $\text{Centistokes} = .2193 \text{ x SUS} - \left(\dfrac{134.6}{\text{SUS}}\right)$	CS = .2193 SUS - (134.6/SUS)
	For Viscosities greater than 240 Saybolt Universal Seconds: $\text{Centistokes} = \left(\dfrac{\text{SUS}}{4.635}\right)$	CS = SUS/4.635

Note: Saybolt Universal Seconds can also be abbreviated as SUS.

Pump Formulas

Formula For:	Word Formula:	Letter Formula:
PUMP OUTLET FLOW In Gallons/Minute	$\text{Flow} = \dfrac{\text{rpm} \times \text{Pump Displacement (Cu. In./Ref.)}}{231}$	$Q = nd/231$
PUMP INPUT POWER In Horsepower Required	$\text{Horsepower Input} = \dfrac{\text{Flow Rate Output (GPM)} \times \text{Pressure (psi)}}{1714 \text{ Efficiency (Overall)}}$	$Hp_{in} = QP/1714Eff.$ or $(GPM \times psi)/1714Eff.$
PUMP EFFICIENCY Overall in Percent	$\text{Overall Efficiency} = \left(\dfrac{\text{Output Horsepower}}{\text{Input Horsepower}}\right) \times 100$	$Eff_{OV} = (HP_{out}/HP_{in}) \times 100$
	Overall Efficiency = Volumetric Eff. x Mechanical Eff.	$Eff_{ov} = Eff_{vol} \times Eff_{mech}$
PUMP EFFICIENCY Volumetric in Percent	$\text{Volumetric Efficiency} = \dfrac{\text{Actual Flow Rate Output (GPM)}}{\text{Theoretical Flow Rate Output (GPM)}} \times 100$	$Eff_{vol} = (Q_{act}/Q_{theo}) \times 100$
PUMP EFFICIENCY Mechanical in Percent	$\text{Mechanical Efficiency} = \dfrac{\text{Theoretical Torque to Drive}}{\text{Actual Torque to Drive}} \times 100$	$Eff_{mech} = (T_{theo}/T_{act}) \times 100$
PUMP LIFE B_{10} Bearing Life	$B_{10}\text{ Hrs. Bearing Life} = \text{Rated Life Hrs.} \times \dfrac{\text{Rated Speed (rpm)}}{\text{New Speed (rpm)}} \times \dfrac{\text{Rated Pressure (psi)}}{\text{New Pressure (psi)}}$	$B_{10} = \text{Rated Hrs} \times (RPM_r/RPM_n) \times (P_r/P_n)^3$

Actuator Formulas

Formula For:	Word Formula:	Letter Formula:
CYLINDER AREA In Square Inches	$\text{Area} = \prod \times \text{Radius}^2 \text{ (Inches)}$	$A = \prod r^2$
	$\text{Area} = (P/4) \times \text{Diameter}^2 \text{ (Inches)}$	$A = (\prod D^2)/4$ or $A = .785D^2$
CYLINDER FORCE In Pounds, Push or Pull	Area = Pressure (psi) x Net Area (sq in.)	$F = psi \times A$ or $F = PA$
CYLINDER VELOCITY or SPEED In Feet/Second	$\text{Velocity} = \dfrac{231 \times \text{Flow Rate (GPM)}}{12 \times 60 \times \text{Net Area (sq in.)}}$	$v = 231Q/720A$ or $v = .3208Q/A$
CYLINDER VOLUME CAPACITY In Gallons of Fluid	$\text{Volume} = \dfrac{\prod \times \text{Radius}^2 \text{ (in.)} \times \text{Stroke (in.)}}{231}$	$V = (\prod r^2 L)/231$
	$\text{Volume} = \dfrac{\text{Net Area (sq. in.)} \times \text{Stroke (in.)}}{231}$	$V = (A L)/231$
CYLINDER FLOW RATE In Gallons/Minute	$\text{Flow Rate} = \dfrac{12 \times 60 \times \text{Velocity (Ft/Sec)} \times \text{Net Area (sq. in.)}}{231}$	$Q = (720vA)231$ or $Q = 3.117vA$
FLUID MOTOR TORQUE In Inch Pounds	$\text{Torque} = \dfrac{\text{Pressure (psi)} \times \text{F.M. Displacement (Cu. In./Rev.)}}{2\prod}$	$T = psi\ d/2\prod$ or $T = Pd/2\prod$
	$\text{Torque} = \dfrac{\text{Horsepower} \times 63025}{\text{rpm}}$	$T = 63025\ hp/n$
	$\text{Torque} = \dfrac{\text{Flow Rate (GPM)} \times \text{Pressure (psi)} \times 36.77}{\text{rpm}}$	$T = 36.77QP/n$ or $T = 36.77Qpsi/n$
FLUID MOTOR TORQUE/100 psi In Inch Pounds	$\dfrac{\text{Torque}}{100} = \dfrac{\text{F.M. Displacement (Cu. In./Rev.)}}{.0628}$	$T_{100psi} = d/.0628$
FLUID MOTOR SPEED In Revolutions/Minute	$\text{Speed} = \dfrac{231\ \text{Flow Rate (GPM)}}{\text{F.M. Displacement (Cu. In./Rev.)}}$	$n = 231\ Q/d$
FLUID MOTOR POWER In Horsepower Output	$\text{Horsepower} = \dfrac{\text{Torque Output (Inch Pounds)} \times \text{rpm}}{63025}$	$hp = Tn/63025$

Fluid Power Formulas

Thermal Formulas

Formula For:	Word Formula:	Letter Formula:
RESERVOIR COOLING CAPACITY Based on Adequate Air Circulation	Heat (BTU/Hr) = 2 x Temperature Difference Between Reservoir Walls and Air (F°) x Area of Reservoir (Sq. Ft.)	BTU/Hr = 2.0 x DT x A
HEAT IN HYDRAULIC OIL Due to System Inefficiency (SG=.89-.92)	Heat (BTU/Hr) = Flow Rate (GPM) x 210 x Temp. Difference (F°)	BTU/Hr = Q x 210 x DT
HEAT IN FRESH WATER	Heat (BTU/Hr) = Flow Rate (GPM) x 500 x Temp. Difference (F°)	BTU/Hr = Q x 500 x DT

Note: One British Thermal Unit (BTU) is the amount of heat required to raise the temperature of one pound of water one degree Fahrenheit. One Horsepower = 2545 BTU/Hr.

Accumulator Formulas

Formula For:	Word Formula:	Letter Formula:
PRESSURE OR VOLUME With Constant T (Temperature)	Original Pressure x Original Volume = Final Pressure x Final Volume	$P_1V_1 = P_2V_2$ Isothermic
PRESSURE OR TEMPERATURE With Constant V (Volume)	Original Pressure x Final Temp. = Final Pressure x Original Temp.	$P_1T_2 = P_2T_1$ Isochoric
VOLUME OR TEMPERATURE With Constant P (Pressure)	Original Volume x Final Temp. = Final Volume x Original Temp.	$V_1T_2 = V_2T_1$ Isobaric
PRESSURE OR VOLUME With Temp. Change Due to Heat of Compression	Original Press. x Original Volume^n = Final Press. x Final Volume^n	$P_1V_1^n = P_2V_2^n$
	Final Temp./Orig. Temp. = (Orig. Vol./Final Vol.)$^{n-1}$ = (Final Press./Orig. Press.)$^{(n-1)/n}$	$T_2/T_1 = (V_1/V_2)^{n-1} = (P_2/P_1)^{(n-1)/n}$

Volume and Capacity Equivalents

	Cubic Inches	Cubic Feet	Cubic Centimeters	Liters	U.S. Gallons	Imperial Gallons	Water at Max Density	
							Pounds of Water	Kilograms of Water
Cubic Inches	1	0.0005787	16.384	0.016384	0.004329	0.0036065	0.361275	0.0163872
Cubic Feet	1,728	1	28,316.8	28.317	7.48052	6.23210	62.4283	28.3170
Cubic Centimeters	0.0610	0.0000353	1	0.001	0.000264	0.000220	0.002205	0.0001
Liters	61.0234	0.0353145	1,000	1	0.264170	0.220083	2.20462	1
U.S. Gallons	231	0.133681	3,785.41	3.78543	1	0.833111	8.34545	3.78543
Imperial Gallons	277.274	0.160459	4,546.09	4.54374	1.20032	1	10.0172	4.54373
Pounds of Water	27.6798	0.0160184	453.59	0.453592	0.119825	0.0998281	1	0.453593

ABSOLUTE – A measure having as its zero point or base the complete absence of the entity being measured.

ABSOLUTE PRESSURE (psia) – The pressure above absolute zero, the sum of atmospheric and gauge pressure.

ACCUMULATOR – A container in which fluid is stored under pressure as a source of fluid power. It also absorbs shocks and surges and smoothes out operation.

ACTUATOR – A device for converting hydraulic energy into mechanical energy. A motor or cylinder.

AERATION – Air in the hydraulic fluid. Excessive aeration causes the fluid to appear milky and components to operate erratically because of the compressibility of the air trapped in the fluid.

AMPLITUDE OF SOUND – The loudness of a sound.

ANNULAR AREA – A ring shaped area – often refers to the net effective area of the rod side of a cylinder piston, i.e., the piston area minus the rod area.

ASTM – American Society for Testing Materials.

ATMOSPHERE (ONE) – A pressure measure equal to 14.7 psi.

ATMOSPHERIC PRESSURE–Pressure on all objects in the atmosphere because of the weight of the surrounding air. At sea level, about 14.7 psi absolute.

BACK CONNECTED – A condition where port connections are on normally unexposed surfaces of hydraulic equipment. (Gasket mounted units are back connected.)

BACK PRESSURE – A pressure in series. Usually refers to pressure existing on the discharge side of a load. It adds to the pressure required to move the load.

BAFFLE – A device, usually a plate, installed in a reservoir to separate the pump inlet from return lines. The baffle also aids fluid cooling.

BAR – A unit of pressure based on 105 Newtons per square meter, equal to 100 kPa (kilopascals), approx. equal to 14.5 psig.

BERNOULLI PRINCIPLE – An increase in velocity causes a decrease in pressure.

BLEED-OFF – To divert a specific controllable portion of pump flow directly to a reservoir.

BREATHER – A device which permits air to move in and out of a container or component to maintain atmospheric pressure.

BSPP – British Standard Parallel Pipe.

BSPT – British Standard Pipe Thread.

BY-PASS – A secondary passage for fluid flow.

CARTRIDGE –
- The replaceable element of a fluid filter.
- The pumping unit from a vane pump, composed of the rotor, ring, vanes and one or both side plates.
- A removable valve element that fits into a cavity in a hydraulic component, e.g. manifold.

CASE DRAIN LINE – A line conducting fluid from a component housing to the reservoir.

CAVITATION – A localized gaseous condition within a liquid stream which occurs where the pressure is reduced to the vapor pressure.

CELSIUS – A temperature scale. 0° Celsius is the freezing point of water.

CENTISTOKES (cSt) – A unit of kinematic viscosity. 1 cSt = 10-2 square centimeters per second (cm^2/s).

CHAMBER – A compartment within a hydraulic unit. May contain elements to aid in operation or control of a unit. Examples: spring chamber, drain chamber, etc.

CHANNEL – A fluid passage, the length of which is large with respect to its cross-sectional dimension.

CHARGE (supercharge) –
- To replenish a hydraulic system above atmospheric pressure.
- To fill an accumulator with fluid under pressure (see pre-charge pressure).

CHARGE PRESSURE – The pressure at which replenishing fluid is forced into the hydraulic system (above atmospheric pressure).

CHECK VALVE – A valve which permits flow of fluid in one direction only.

CIRCUIT – The complete path of flow in a hydraulic system including the flow-generating device.

CLOSED CENTER – The condition where pump output is not unloaded to tank in the center or neutral operating condition.

CLOSED CIRCUIT – A piping arrangement in which pump delivery, after passing through other hydraulic components, bypasses the reservoir and returns directly to pump inlet.

COMPENSATOR CONTROL – A displacement control for variable pumps and motors which alters displacement in response to pressure changes in the system as related to its adjusted pressure setting.

COMPONENT – A single pneumatic or hydraulic unit.

COMPRESSIBILITY – The change in volume of a unit volume of a fluid when it is subjected to a unit change in pressure.

CONTROL – A device used to regulate the function of a unit (see Hydraulic Control, Manual Control, Mechanical Control and Compensator Control).

COOLER – A heat exchanger used to remove heat from the hydraulic fluid.

COUNTERBALANCE VALVE – A valve which maintains resistance to flow in one direction but permits free flow in the other. Usually connected to the outlet of a vertical double-acting cylinder to prevent uncontrolled falling, dropping or cavitation.

CRACKING PRESSURE – The pressure at which a pressure actuated valve begins to pass fluid.

CUSHION – A device sometimes built into the ends of a cylinder which restricts the flow of fluid at the outlet port, thereby slowing the motion of the piston rod.

CYLINDER – A device which converts fluid power into linear mechanical force and motion. It usually consists of a movable element such as a piston and piston rod, plunger rod, plunger or ram, operating within a cylindrical bore.

DELIVERY – The volume of fluid discharged by a pump in a given time, usually expressed in gallons per minute (gpm).

DELTA P (ΔP) – The change in pressure between two points in a system, such as in a passageway or between the inlet and outlet of a component.

DEMULSIFY – To separate water from oil.

DE-VENT – To close the vent connection of a pressure control valve permitting the valve to function at its adjusted pressure setting.

Fluid Power Glossary

DIRECTIONAL VALVE – A valve which selectively directs fluid to or prevents fluid from desired channels.

DISPLACEMENT – The quantity of fluid which can pass through a pump, motor or cylinder in a single revolution or stroke.

DOUBLE ACTING CYLINDER – A cylinder in which fluid force can be applied in either direction.

DRAIN – A passage in, or a line from, a hydraulic component which returns leakage fluid independently to a reservoir or to a vented manifold.

EFFICIENCY – The ratio of output to input. Volumetric efficiency of a pump is the actual output flow divided by the theoretical or design flow. The overall efficiency of a hydraulic system is the output power divided by the input power. Efficiency is usually expressed as a percent.

ELECTRO-HYDRAULIC SERVO VALVE – A directional type valve which receives a variable or controlled electrical signal and which controls or meters hydraulic flow.

EMULSION – A fluid formed by the suspension of one liquid in another.

ENERGY – The ability or capacity to do work. Measured in units of work.

FEEDBACK (or feedback signal) – The output signal from a feedback element.

FILTER – A device whose primary function is the retention of insoluble contaminants from a fluid by a porous media.

FLOODED – A condition where the pump inlet is charged by placing the reservoir oil level above the pump inlet port.

FLOW CONTROL VALVE – A valve which controls the rate of oil flow.

FLOW RATE – The volume, mass or weight of a fluid passing through a conductor per unit of time. Normally expressed in gallons per minute (gpm).

FLUID –
- A liquid or gas.
- A liquid that is specially compounded for use as a power transmitting medium in a hydraulic system.

FORCE – Any push or pull measured in units of weight. In hydraulics, total force is expressed by the product of pressure and the area of the surface on which the pressure acts. F = P x A.

FOUR-WAY VALVE – A directional valve having four flow paths.

FREQUENCY – The number of times an action occurs in a unit of time. Frequency is the basis of all sound. A pump or motor's basic frequency is equal to its speed in revolutions per second multiplied by the number of pumping chambers.

FRONT CONNECTED – A condition wherein piping connections are on normally exposed surfaces of hydraulic components.

FULL FLOW – In a filter, the condition where all the fluid must pass through the filter element.

GAUGE PRESSURE (psig) – A pressure scale which ignores atmospheric pressure. Its zero point is atmospheric pressure (14.7 psia at sea level).

gph (gallons per hour) - Unit of measure representing volume of liquid flow.

gpm (gallons per minute) - Unit of measure representing volume of liquid flow.

HEAD – The height of a column of fluid above a given point expressed in linear units. Head is often used to indicate gauge pressure. The pressure is equal to the height times the density of the fluid.

HEAT – The form of energy that has the capacity to create warmth or to increase the temperature of a substance. Any energy that is wasted or used to overcome friction is converted to heat. Heat is measured in calories or British Thermal Units (BTUs). One BTU is the amount of heat required to raise one pound of water one degree Fahrenheit.

HEAT EXCHANGER – A device which transfers heat through a conducting wall from one fluid to another.

HORSEPOWER (hp) – The power required to lift 550 pounds one foot in one second or 33,000 pounds one foot in one minute. A horsepower is equal to 746 watts or to 2544 BTUs per hour.

HYDRAULIC BALANCE – A condition of equal opposed hydraulic forces acting on a part in a hydraulic component.

HYDRAULIC CONTROL – A control which is actuated by hydraulically induced forces.

HYDRAULICS – Engineering science pertaining to liquid pressure and flow.

HYDRO – Greek word for water.

HYDRODYNAMICS – Engineering science pertaining to the energy of liquid pressure and flow.

HYDROSTATICS – Engineering science pertaining to the energy of liquids at rest.

INTENSIFIER – A device which converts low pressure fluid power to higher pressure fluid power.

JIC – Joint Industry Conference.

37° JIC – Refers to a JIC standard that establishes the 37° flare for use in plumbing with steel tubing. A 45° flare is commonly used for copper tube. This distinction assists in preventing the accidental use of low pressure fittings, designed for use with copper tubing, in hydraulic systems where pressures merit steel tubing and appropriate fittings.

KINETIC ENERGY – Energy that a substance or body has by virtue of its mass (weight) and velocity.

LAMINAR (flow) – A condition where the fluid particles move in continuous parallel paths. Streamline flow.

LEVERAGE – A gain in output force over input force by sacrificing the distance moved. Mechanical advantage or force multiplication.

LIFT – The height a body or column of fluid is raised; for instance, from the reservoir to the pump inlet. Lift is sometimes used to express a negative pressure or vacuum. The opposite of head.

LINE – A tube, pipe or hose which acts as a conductor of hydraulic fluid.

LINEAR ACTUATOR – A device for converting fluid power into linear motion. A piston or ram.

LOAD SENSING – A type of hydraulic circuit where the actual pressure required by the load is transmitted to the control elements such as valves and pumps. This typically allows the system to deliver only the pressure and flow required, usually saving energy.

MANIFOLD – A fluid conductor which provides multiple connection ports.

MANUAL CONTROL – A control actuated by the operator, regardless of the means of actuation. Example: Lever or foot pedal control for directional valves.

MANUAL OVERRIDE – A means of manually actuating an automatically-controlled device.

MECHANICAL CONTROL – Any control actuated by linkages, gears, screws, cams or other mechanical elements.

METER – To regulate the amount or rate of fluid flow.

METER-IN – To regulate the amount of fluid flow into an actuator or system.

METER-OUT – To regulate the flow of discharge fluid from an actuator or system.

MICRON (μ) – Size of a particle one millionth of a meter.

MICRON RATING – The size of the particles a filter will remove.

MOTOR – A rotary motion device which changes hydraulic energy into mechanical energy; a rotary actuator.

NEWTON METER (Nm) – Metric unit of measure representing force.

NPT – National Pipe Taper (requires pipe sealant).

NPTF – National Pipe Taper Fuel or Dry Seal Pipe Threads (may not require pipe sealant).

OPEN CENTER – A condition where pump delivery circulates freely to tank in the center or neutral position.

ORIFICE – A restriction, the length of which is small in respect to its cross-sectional dimensions.

OXIDATION – The chemical reaction of elements with oxygen which cause corrosion or deterioration.

PASCAL – Unit of pressure in metric system, usually expressed in kPa (kilopascals). 1 kPa = 0.01 bar = 0.145 psi.

PASSAGE – A fluid conducting path which lies within or passes through a component.

PI (¶) – Ratio of circumference of circle to diameter. Numerically expressed as approximately 3.1416.

PILOT PRESSURE – Auxiliary pressure used to actuate or control hydraulic or pneumatic components.

PILOT VALVE – An auxiliary valve to control the operation of another valve. The controlling stage of a 2-stage valve.

PISTON – A cylindrically shaped part which fits within a cylinder and transmits or receives motion by means of a connecting rod.

PLUNGER – A cylindrically shaped part with only one diameter that is used to transmit thrust (also called a ram).

POPPET – That part of certain valves which prevents flow when it closes against a seat.

PORT – An internal or external terminus of a passage in a component.

POSITIVE DISPLACEMENT – A characteristic of a pump or motor which has the inlet positively sealed from the outlet so that fluid cannot recirculate in the pump or motor.

POTENTIAL ENERGY – The energy level change which results when an object is raised to a new height.

POTENTIOMETER – A control element in the servo-system which measures and controls electrical potential.

POWER – Work per unit of time. Measured in horsepower (hp) or watts.

ppm (parts per million) - Unit of measure representing the number of particles in a given body.

PRECHARGE PRESSURE – The pressure of compressed gas in an accumulator prior to the admission of liquid.

PRESSURE – Force per unit area; usually expressed in psi, bar, or kPa.

PRESSURE DIFFERENTIAL (PRESSURE DROP) – The difference in pressure between any two points of a system or a component.

PRESSURE LINE – The line carrying the fluid from the pump outlet to the pressurized port of the actuator.

PRESSURE OVERRIDE – The difference between the cracking pressure and the full flow pressure of a valve.

PRESSURE REDUCING VALVE – A valve which limits the maximum pressure at its outlet regardless of the inlet pressure.

psia (pounds per square inch absolute) – See Absolute Pressure.

psig (pounds per square inch gauge) – See Gauge Pressure.

PUMP – A device which converts mechanical force and motion into hydraulic fluid flow.

RAM – A single acting cylinder with a plunger rather than a piston and rod. The plunger in a ram type cylinder.

RECIPROCATION – Back and forth straight line motion or oscillation.

RELIEF VALVE – A pressure operated valve which bypasses pump delivery to the reservoir, limiting system pressure to a predetermined maximum value.

REPLENISH – To add fluid to maintain a full hydraulic system.

RESERVOIR – A container for storage of liquid in a fluid power system.

RESTRICTION – A reduced cross-sectional area in a line or passage which produces a pressure drop.

RETURN LINE – A line used to carry exhaust fluid from the actuator back to a tank.

REVERSING VALVE – A four-way directional valve used to reverse a double acting cylinder or reversible motor.

ROTARY ACTUATOR – A device for converting hydraulic energy into rotary motion.

SAE – The Society of Automotive Engineers.

SAE O-Ring – Refers to a style of threaded connection that employs straight thread to secure the fitting and an o-ring to provide sealing. This style of connection is very popular for use in hydraulic systems and can be removed and reinstalled numerous times without damaging the sealing ability of the connection. Tapered pipe thread is actually damaged to make a fluid tight seal. Vibration and repeated connection of tapered pipe threaded connections will always result in leaks. An o-ring style or a 37° JIC flared connection are the best choices in preventing leaks.

scfm (standard cubic feet per minute) - Unit of measure representing volume of gas flow.

Fluid Power Glossary

SEQUENCE –
- The order of a series of operations or movements.
- To divert flow to accomplish a subsequent operation or movement.

SEQUENCE VALVE – A pressure operated valve which diverts flow to a secondary actuator while holding pressure on the primary actuator at a predetermined minimum value after the primary actuator completes its travel.

SERVO MECHANISM – A mechanism subjected to the action of a controlling device which will operate as if it were directly actuated by the controlling device, but capable of supplying power output many times that of the controlling device, this power being derived from an external and independent source.

SERVO VALVE –
- A valve which controls the direction and quantity of fluid flow in proportion to an input signal.
- A follow valve.

SIGNAL – A command or indication of a desired position or velocity.

SINGLE ACTING CYLINDER – A cylinder in which hydraulic energy can produce thrust or motion in only one direction. (Can be spring or gravity returned.)

SKIVING – Cutting, splitting or paring away the outer layer of a flexible hose.

SLIP – Internal leakage of hydraulic fluid.

SPOOL – A term loosely applied to almost any moving cylindrically shaped part of a hydraulic component which moves to direct flow through the component.

STRAINER – A coarse filter.

STROKE –
- The length of travel of a piston or plunger.
- To change the displacement of a variable displacement pump or motor.

SUBPLATE – An auxiliary mounting device for a hydraulic component providing a means of connecting piping to the component.

SUCTION LINE – The hydraulic line connecting the pump inlet port to the reservoir.

SUPERCHARGE – (See Charge).

SURGE – A momentary rise of pressure in a circuit.

SUS (Saybolt Universal Seconds) – A measure of viscosity, the time required for a given fluid to flow through a standard orifice.

SWASH PLATE – A stationary canted plate in an axial type piston pump or motor which causes the pistons to reciprocate as the cylinder barrel rotates.

TANK – The reservoir.

THROTTLE – To permit passing of a restricted flow. May control flow rate or create a deliberate pressure drop.

TORQUE – A rotary force. The output torque of a fluid motor is usually expressed in pound-inches (lb-in) or Newton-Meters (Nm).

TORQUE CONVERTER – A rotary fluid coupling that is capable of multiplying torque.

TORQUE MOTOR – An electromagnetic device consisting of coils and the proper magnetic circuit to provide actuation of a spring restrained armature, either rotary or translatory.

TURBINE – A rotary device that is actuated by the impact of moving fluid against blades or vanes.

TURBULENT FLOW (TURBULENCE) – A condition where the fluid particles move in random paths rather than in continuous parallel paths.

TWO-WAY VALVE – A directional control valve with two flow paths.

UNLOAD – To release flow (usually directly to the reservoir), to prevent pressure being imposed on the system or portion of the system.

UNLOADING VALVE – A valve which bypasses flow to a tank when a set pressure is maintained on its pilot port.

VACUUM – The absence of pressure. A perfect vacuum is the total absence of pressure; a partial vacuum is some condition less than atmospheric pressure. Measured in inches of Mercury (in.Hg) with the zero point equal to atmospheric pressure.

VALVE – A device which controls fluid flow direction pressure, or flow rate.

VAPOR PRESSURE – The pressure at which the liquid and gaseous phases of a fluid are in equilibrium.

VELOCITY –
- The speed of flow through a hydraulic line. Expressed in feet per second (fps) or meters per second (m/s).
- The speed of a rotating component measured in revolutions per minute (rpm or min-1).

VENT –
- To permit opening of a pressure control valve by opening its pilot port (vent connection) to atmospheric pressure.
- An air breathing device on a fluid reservoir.

VISCOSITY – A measure of the internal friction or the resistance of a fluid to flow.

VISCOSITY INDEX – A measure of the viscosity-temperature characteristics of a fluid as referred to that of two arbitrary reference fluids.

VOLUME –
- The size of a space or chamber in cubic units.
- Loosely applied to the output of a pump in gallons per minute (gpm).

WORK – Exerting a force through a definite distance. Work is measured in units of force multiplied by distance; for example, pound-feet or joule (1 J = 1 Nm).