Eaton VSQ Vane Pumps

Single-40 (2.44) to 90 cm³/r (5.49 in³/r)
Double-80 (4.88) to 180 cm³/r (10.98 in³/r)
Fixed displacement industrial

Powering Business Worldwide

Table of Contents

The new VSQ Vane pump is built to combine the best features of Vane pumps with 0 RPM low speed capable architecture to support efficiency and energy savings. Combined with high speed and high operating pressure features, this pump is an optimal choice over internal gear and piston pumps for industrial applications.

Eaton's VSQ pumps provide continuous pressure ratings up to 280 bar (4060 psi) for the 25 frame size and displacements up to 180 cm³/r (10.98 in³/r) in the double pump configuration. In addition, further reductions in noise levels on an already quiet design offers real possibilities in traditional internal gear pump applications.

Performance

Eaton's VSQ pumps meet global SAE and ISO standards. Currently available in 7 displacements, ranging from 40 cm³/r (2.44 in³/r) to 90 cm³/r (5.49 in³/r), with additional sizes to come soon. One double-pump configuration offer combined displacements from 80 cm³/r (4.88 in³/r) up to 180 cm³/r (10.98 in³/r).

Continuous outlet pressure ratings reach 280 bar (4060 psi), with permissible peak pressures up to 310 bar (4500 psi).

Features and benefits

- Hydraulically balanced design (no internal radial forces) gives almost limitless shaft and bearing life.
- Outstanding speed features from 0 up to 3000RPM speed.
- Two quadrant operation.
- Extremely low noise levels enhance operator comfort.
- Shafts easily handle maximum pressures, ensuring exceptionally long shaft life.
- Efficient design means pumps perform under the harshest speed, temperature and cyclical loading conditions.
- Removable cartridges facilitate easy maintenance and changes to flow direction or rate all while remaining on-line.
- Increased power density.
- Common inlet allowing for fewer ports and reducing the cost of redundant hose and fittings.
- Multiple displacements allow selection of the best flow output for optimum use of energy.
- Interchangeable cartridges between single, double, and thru-drives, simplify cartridge selection and reduce inventory.
- High volumetric efficiencies, which increase productivity and reduce energy and operating costs.
- Compatible with a wide variety of fluids, including fire resistant and biodegradable fluids.
- Shaft seal options: single seal design for "dry mount" applications, or double seal design for fluid separation in "wet mount" applications such as gearboxes or where lubricant is always present. (Wet mount applications extend shaft life.)

Applications

- Plastic injection molding
- Die-Casting
- Press-Brake
- General Industrial applications
- Variable Frequency Drives

Pump characteristics.

Rated pressure

Pumps should not be operated at or near rated pressures at idle speeds for extended periods. Localized overheating and damage can result.

Never assume pumps in a double, triple or thru-drive pump assembly can be simultaneously loaded to rated pressure. Shaft loading must be checked for excessive torque. **Never load or unload a VSQ pump at rates greater than 10,342 bar/sec (150,000 psig/sec), because pump instability could occur. If unloading pump at rates over 5,171 bar/sec (75,000 psig/sec), make sure inlet pressure does not fall below 0.83 bar (12 psi) absolute.**

Drive alignment

Concentricity and angular alignment of shafts are important to pump life. Misalignment can induce heavy loads on bearings, causing premature failure. Flexible coupling halves must be aligned according to the coupling manufacturer's recommendations.

Mounting dimensions requirements

Dimensional control requirements of the customer's mounting pad to which the pump or motor is affixed are as follows.

Pilot diameter

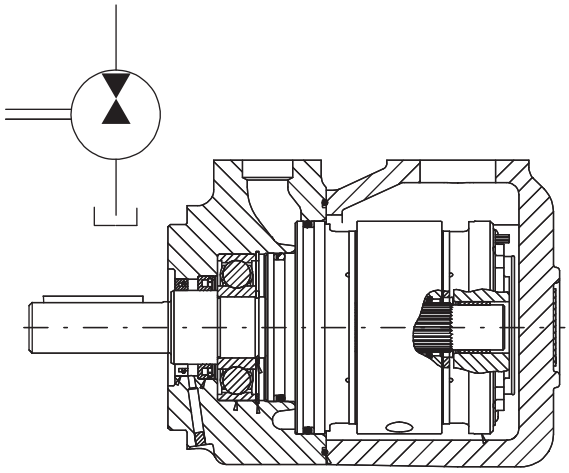
Concentricity of the customer's female pilot diameter relative to the effective axis of the female drive must be within 0,10 mm (0.004 in.) total indicator reading. The clearance between the male and female pilot diameters must be +0,01 to +0,05 mm (+0.0005 to +0.0020 in.).

Mounting face

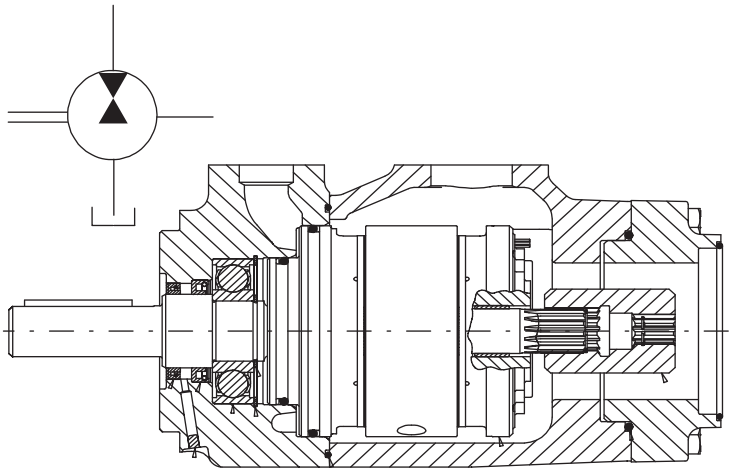
The customer's mounting face to which the pump or motor is affixed must be square to the axis of the female drive within 0,0381 mm per mm (0.0015 inch per inch).

Shafts

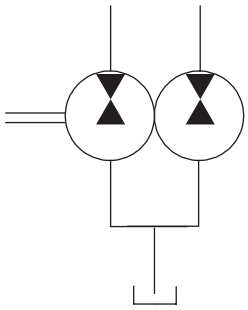
Dimensions of keyed shaft receivers must be between +0,003 and +0,03 mm (+0.0001 and +0.0010 in.) of the maximum shaft diameter shown on page 20.

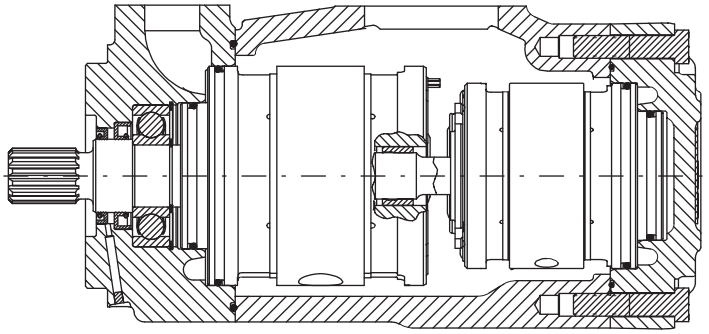


Single pump example



Thru-drive pump example





Double pump example

Typical performance data - industrial

49°C (120°F), SAE 10W oil, 26 cSt (128 SUS)

Conversion factors

Frame size	Displacement		Pressure rating (Maximum) Continuous		Peak ■		Minimum speed rating*	Maximum speed rating at 0 bar (0 psig) inlet	Outlet flow at 1800 r/min 210 bar (3000 psi)		Input power at 1800 r/min 210 bar (3000 psi)	
	cm³/r	(in³/r)	bar	(psi)	bar	(psi)	r/min	r/min	l/min	(USgpm)	kW	(hp)
25	40	(2.44)	280	(4060)	310	(4500)	0	2600	61,6	(15.9)	25,8	(34.4)
	45	(2.75)	280	(4060)	310	(4500)	0	2600	71,0	(18.3)	29,1	(38.8)
	50	(3.05)	280	(4060)	310	(4500)	0	2600	80,0	(20.6)	32,2	(43.0)
	63	(3.84)	280	(4060)	310	(4500)	0	2600	103,9	(26.8)	40,6	(54.1)
	71	(4.33)	280	(4060)	310	(4500)	0	2600	118,7	(30.6)	45,8	(61.0)
	80	(4.88)	280	(4060)	310	(4500)	0	2600	136,1	(35.1)	51,6	(68.8)
	90	(5.49)	248	(3600)	276	(4000)	0	2200	153,9	(40.65)	71,9	(96.5)

■ Peak pressure < 0.5 seconds

* The speed range 0-400 RPM depends on the pressure

Moments of Inertia

Pump	Moment of inertia N*M*SEC2	(LB*IN*SEC2)
VSQ125 (40-80 cm³/r)	0,00103	(0.0091)

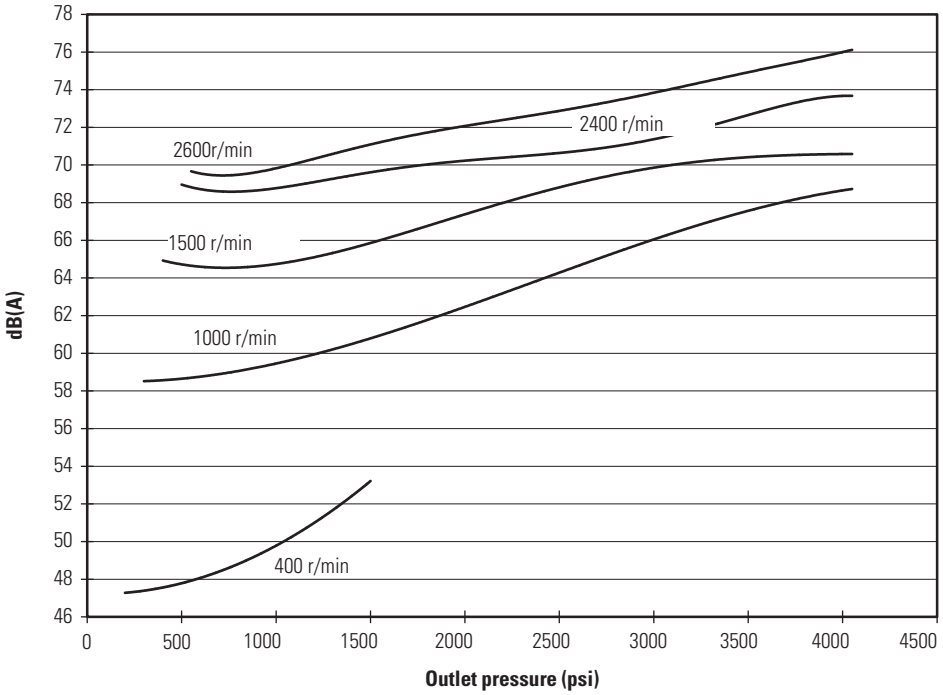
Weights

Frame size	KG	(LB)
25	20,4	(45)

Typical sound data

49°C (120°F), SAE 10W oil, 0 bar (0 psig) inlet

Frame size 25



Model code - single and thru-drive pumps

VSQ1	**	*	***	*	*	**	**	*	*	*	*	*	*	00	*	0	0A
1 2 3 4	5 6	7	8 9 10	11	12	13 14	15 16	17	18	19	20	21	22	23 24	25	26	27 28

1 2 3 4 Series designation

VSQ1 Vane Pump Single Series

5 6 Frame size

25 40-90 cm³/r (2.44-5.49 in³/r)

7 Pump type

S Single

T Thru-drive

(Options at model codes 12 and 15 16 must be specified for thru-drive units)

8 9 10 Displacement

040 40 cm³/r (2.44 in³/r)

045 45 cm³/r (2.75 in³/r)

050 50 cm³/r (3.05 in³/r)

063 63 cm³/r (3.84 in³/r)

071 71 cm³/r (4.33 in³/r)

080 80 cm³/r (4.88 in³/r)

090 90 cm³/r (5.49 in³/r)

*Additional displacements available soon

11 Front flange mounting style

A SAE B 2-bolt
101,60 (4.000) x 9,4 (0.37) pilot
14,4 (0.57) slots on 146,0 (5.75) bolt circle

B SAE C 2-bolt
127,00 (5.000) x 12,4 (0.49) pilot
17,6 (0.69) slots on 181,0 (7.13) bolt circle

12 Rear mounting flange and orientation

Viewed from cover end of pump (Adapter end for thru-drive units, model code 7 = T)

0 None (non thru-drive)

SAE A

A In-line with mounting flange

B 90° to mounting flange

SAE B

C In-line with mounting flange

D 90° to mounting flange

13 14 Input shaft type*

01 SAE J744 keyed: 25,40 (1.000)

02 SAE J744 splined-B-B

05 SAE J744 keyed: 31,75 (1.250)

09 SAE J744 splined: B

15 16 Output shaft coupling

Thru-drive units, model code 7 = T

00 None (non thru-drive)

22 SAE J744 22-4 B-spline shaft

25 SAE J744 25-4 B-B-spline shaft

17 Inlet port type

A SAE J518 4-bolt split flange

18 Outlet Port Type

A SAE J518 4-bolt flange

19 Outlet port position

Viewed from cover end of pump
(Adapter end for thru-drive units)

A Opposite inlet port

B 90° CCW to inlet port

C In-line with inlet port

D 90° CW to inlet port

20 Shaft seal

A Single, primary

B Double, secondary (spring side out)
Recommended for wet mount applications

21 Seal type

N Buna N

V Viton

22 Shaft rotation

Viewed from shaft end of pump

L Left hand (CCW)

R Right hand (CW)

23 24 Special features

00 None

25 Paint

0 None

A Blue

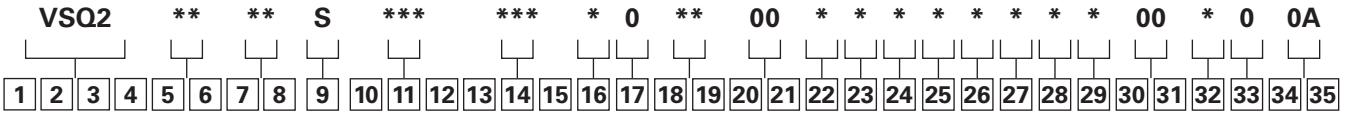
26 Customer identification

0 None

27 28 Design code

0A Design Code A

Model code - double pumps



1 2 3 4 Series designation

VSQ2 Vane Pump Double Series

5 6 Frame size (front section)

25 40-90 cm³/r (2.44-5.49 in³/r)

7 8 Frame size (rear section)

25 40-90 cm³/r (2.44-5.49 in³/r)

9 Pump type

S Standard

10 11 12 Displacement (front section)

040 40 cm³/r (2.44 in³/r)
045 45 cm³/r (2.75 in³/r)
050 50 cm³/r (3.05 in³/r)
063 63 cm³/r (3.84 in³/r)
071 71 cm³/r (4.33 in³/r)
080 80 cm³/r (4.88 in³/r)
090 90 cm³/r (5.49 in³/r)
*Additional displacements available soon

13 14 15 Displacement (rear section)

040 40 cm³/r (2.44 in³/r)
045 45 cm³/r (2.75 in³/r)
050 50 cm³/r (3.05 in³/r)
063 63 cm³/r (3.84 in³/r)
071 71 cm³/r (4.33 in³/r)
080 80 cm³/r (4.88 in³/r)
090 90 cm³/r (5.49 in³/r)
*Additional displacements available soon

16 Front flange mounting style

A SAE B 2-bolt 101,60 (4.000) x 9,4 (0.37) pilot 14,4 (0.57) slots on 146,0 (5.75) bolt circle

B SAE C 2-bolt 127,00 (5.000) x 12,4 (0.49) pilot 17,6 (0.69) slots on 181,0 (7.13) bolt circle

17 Adapter flange

0 None (standard double pump)

18 19 Input shaft type*

01 SAE J744 Keyed: 25,40 (1.000)
02 SAE J744 Splined: B-B
05 SAE J744 Keyed: 31,75 (1.250)
09 SAE J744 Spline: B

20 21 Output shaft coupling

00 None (standard double pump)

22 Inlet port type

A SAE J518 4-split flange

23 Front outlet port type

A SAE J518 4-bolt flange

24 Rear outlet port type

A SAE J518 4-bolt flange

25 Front outlet port position

A Opposite inlet port
B 90° CCW to inlet port
C In-Line with front inlet port
D 90° CW to inlet port

26 Rear outlet port position

Viewed from cover end of pump
E Opposite inlet port
F 90° CCW to inlet port
G In-line with inlet port
H 90° CW to inlet port

27 Shaft seal

A Single, primary
B Double, secondary (spring side out) Recommended for wet mount applications

28 Seal type

N Buna-N
V Viton

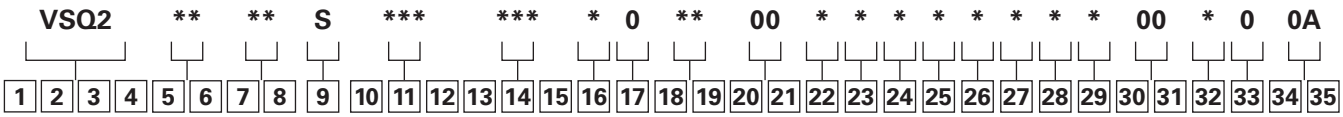
29 Shaft rotation

Viewed from shaft end of pump
L Left Hand (CCW)
R Right Hand (CW)

30 31 Special features

00 None

Model code - double pumps



32 **Paint**

O	None
A	Blue

33 **Customer Identification**

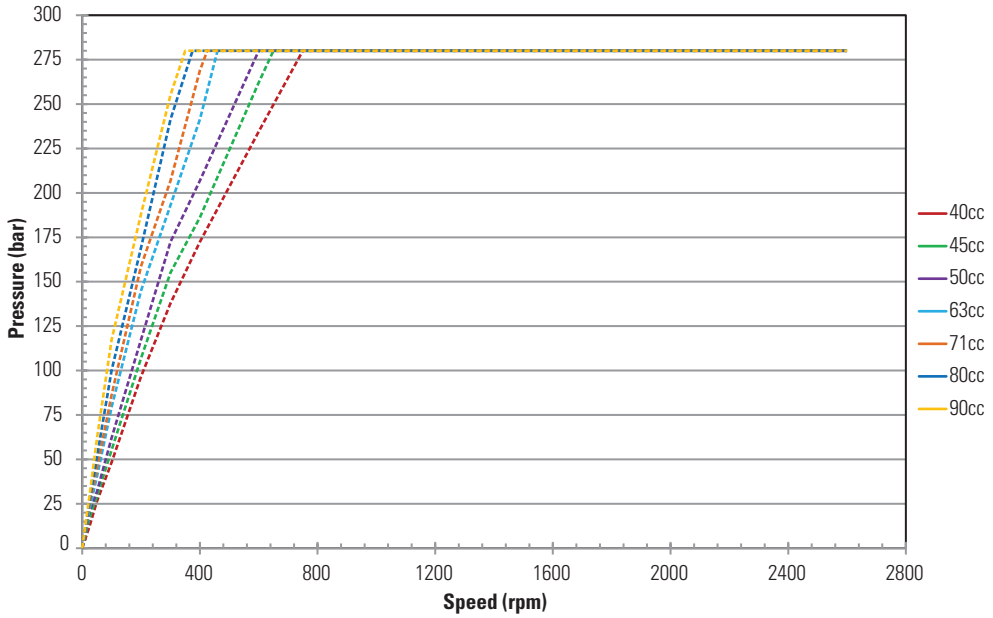
0	None

34 35 **Design code**

0A	Design code A

* Verify shaft torque ratings meet or exceed input torque requirements (see page 22).

25VSQ (40 to 90cc) **Continuous pressure depending on the speed**

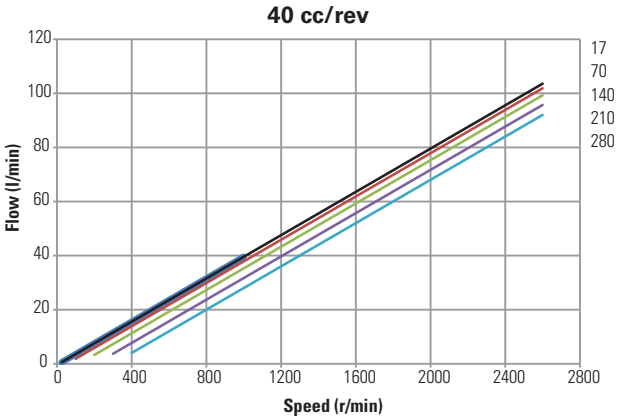


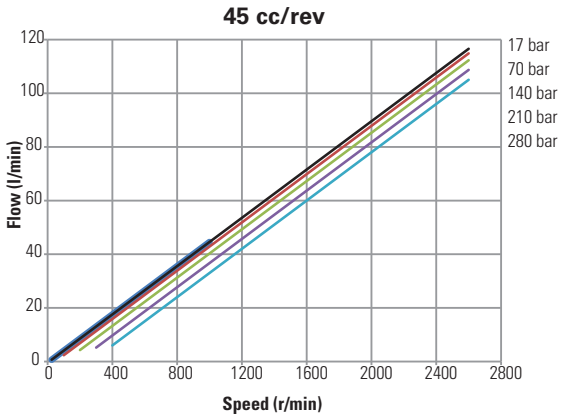
Mineral oil SAE 10W, oil temperature 49° C (120° F), 1 bar absolute inlet pressure

Typical output flow - industrial

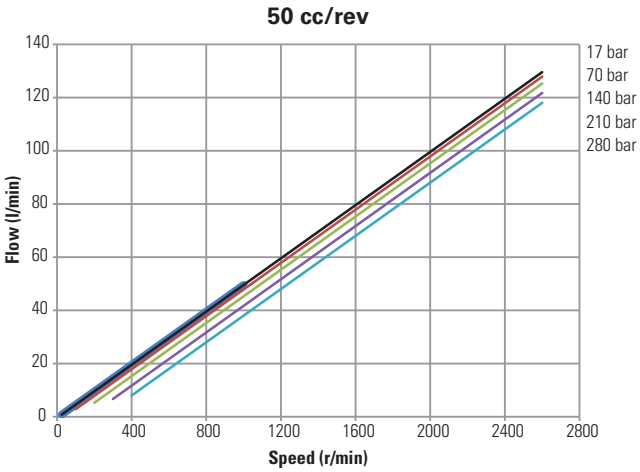
Performance data

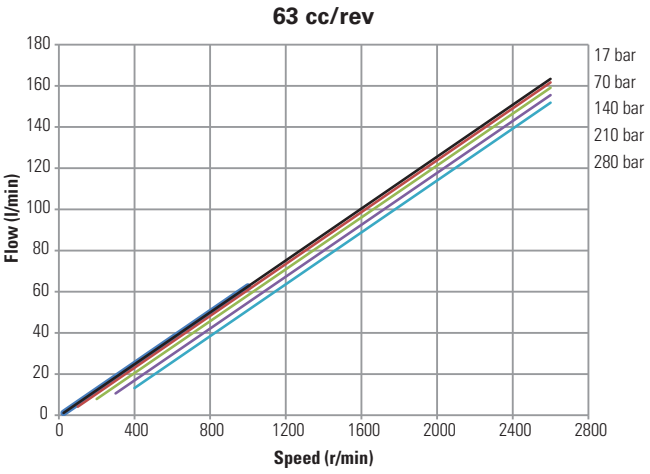
Frame size 25: 40 and 45 cm³/r



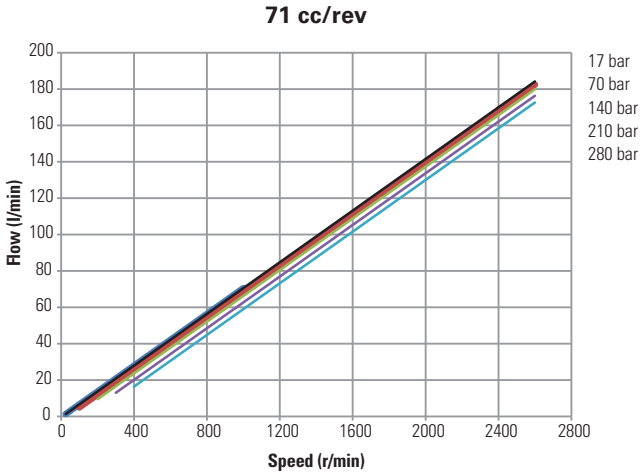


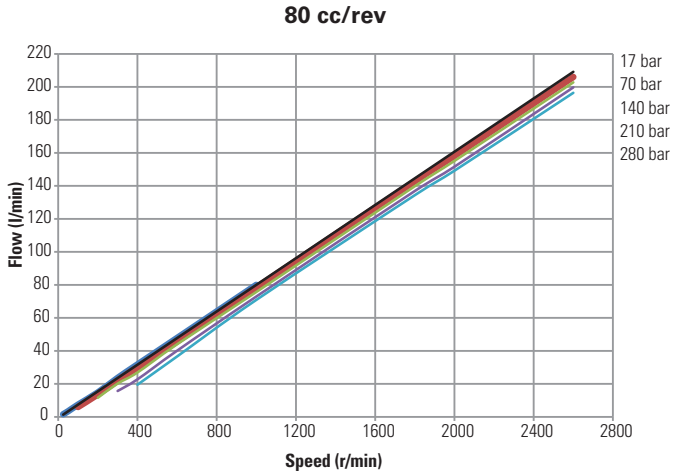
Frame size 25: 50 and 63 cm³/r



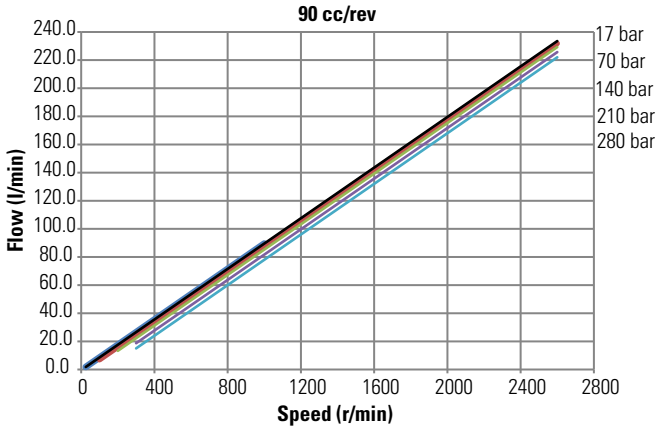


Frame size 25: 71 and 80 cm³/r





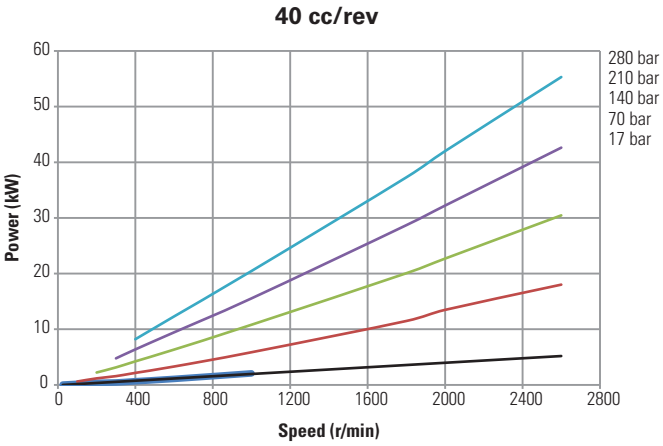
Frame size 25: 90 cm³/r

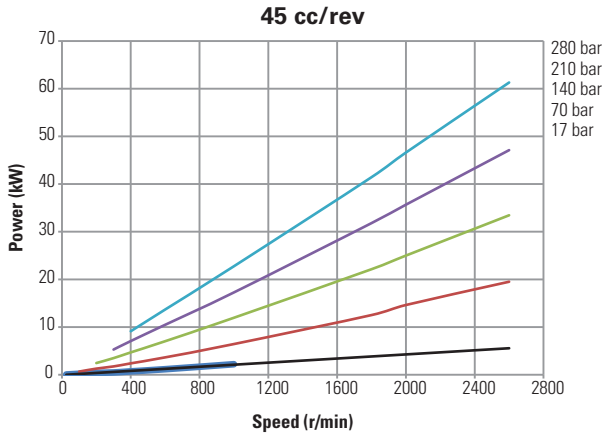


Typical input power - industrial

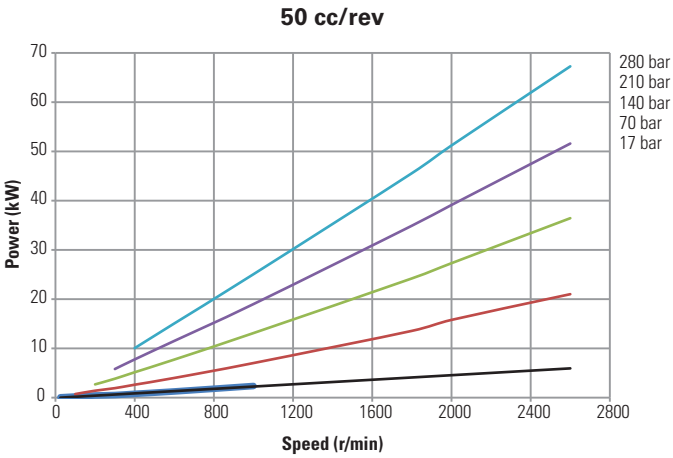
Performance data

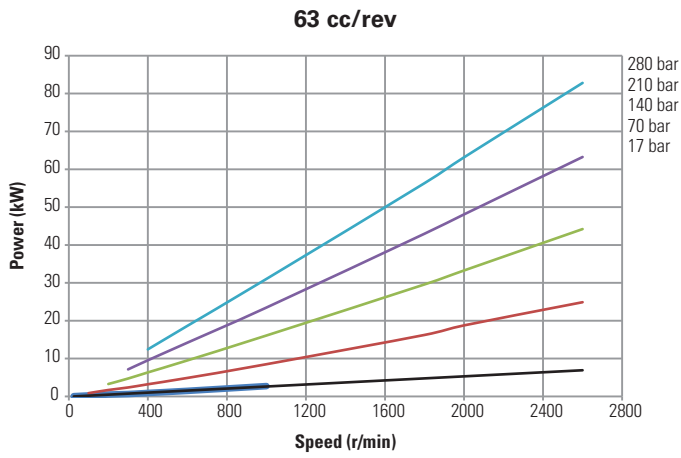
Frame size 25: 40 and 45 cm³/r



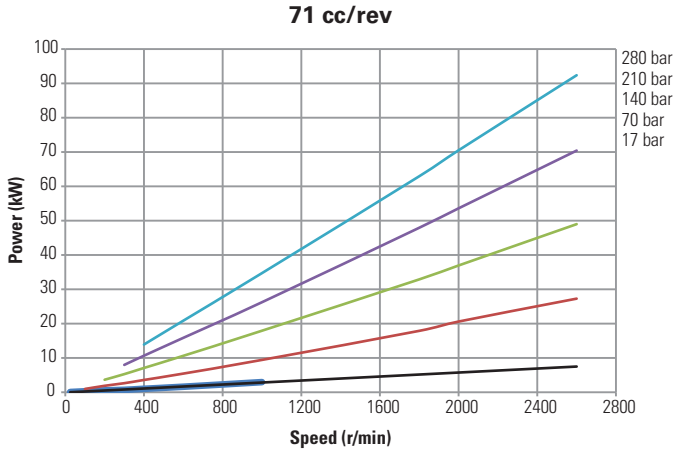


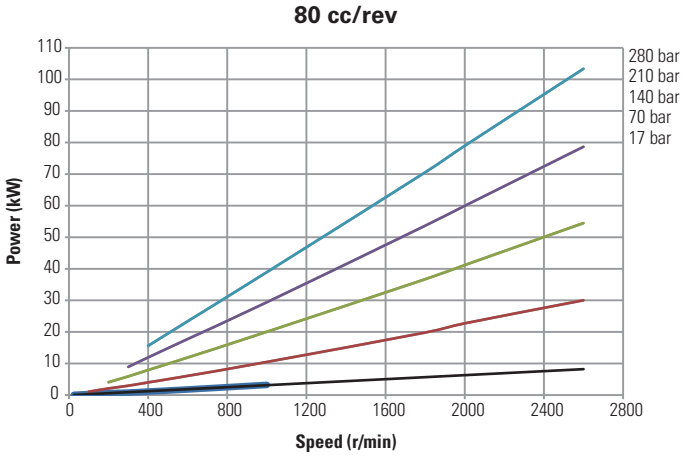
Frame size 25: 50 and 63 cm³/r



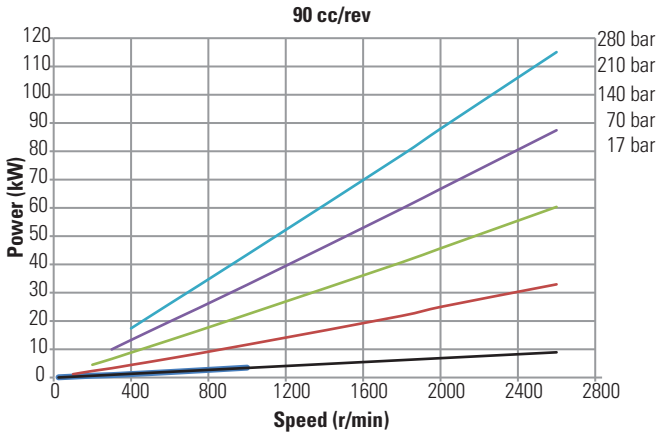


Frame size 25: 71 and 80 cm³/r





Frame size 25: 90 cm³/r



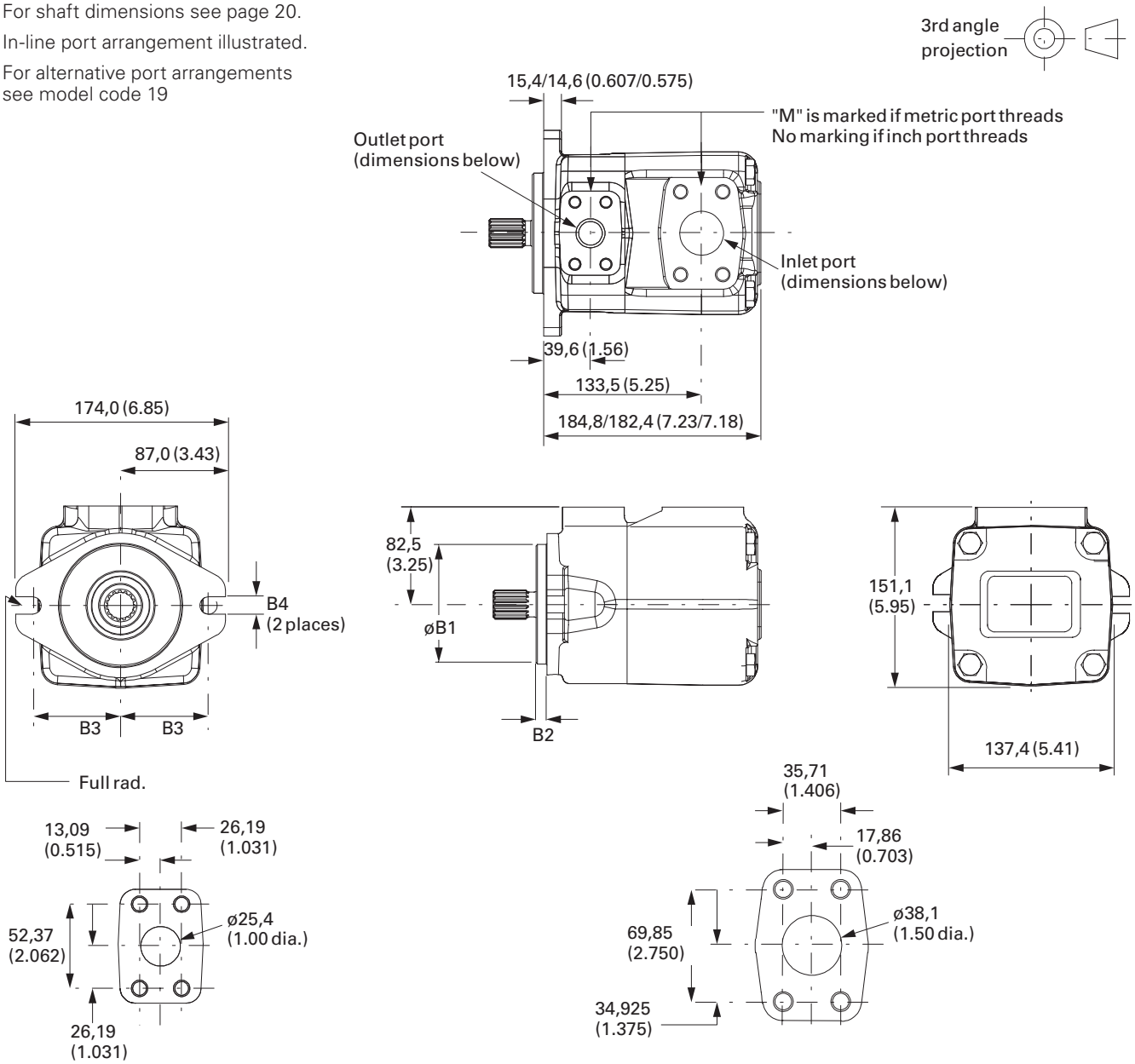
VSQ1 25 Single pumps

Installation dimensions in mm (in)

For shaft dimensions see page 20.

In-line port arrangement illustrated.

For alternative port arrangements see model code 19



Outlet port

Code A: SAE J518 4-bolt flange

Threads:

Code A: 3/8"-16UNC-2B, 22,0 (0.87) min. depth

Inlet port

Code A: SAE J518 4-bolt flange

Threads:

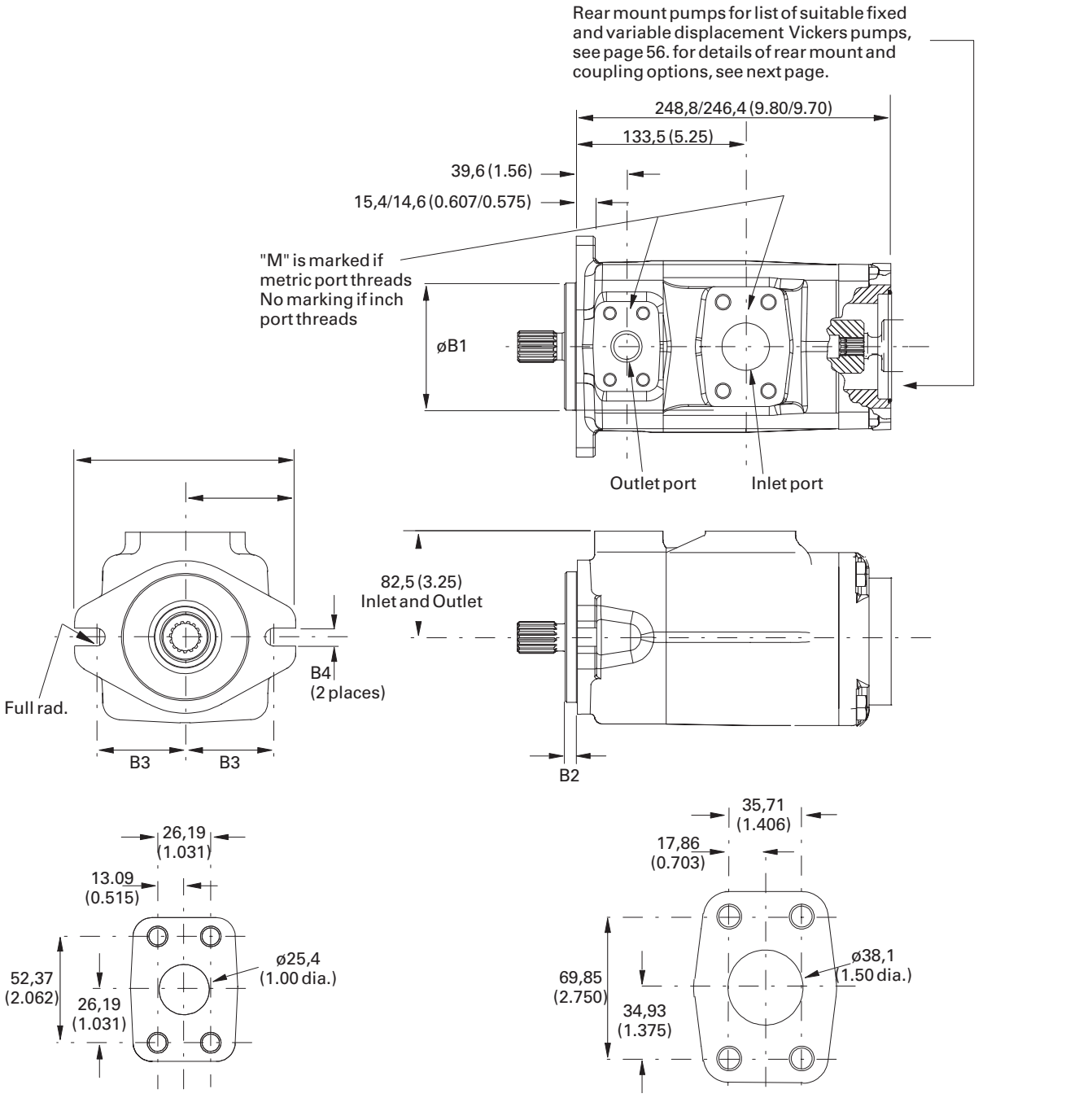
Code A: 1/2"-13UNC-2B, 27,0 (1.06) min. depth

Model code 11	Flange type	Ø B1	B2	B3	B4
A	SAE 101-2	101,55/101,6 (3.998/4.000)	9,19/9,70 0.362/0.382)	73,00 (2.874)	14,17/14,55 (0.558/0.573)

Illustration shows assembly with port configuration C (outlet in line with inlet) as per model code 19

For shaft dimensions see page 20.

3rd angle projection



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Code A: SAE J518 4-bolt flange

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Code A: SAE J518 4-bolt flange

Threads:

Code A: 1/2"-13UNC-2B, 27,0 (1.06) min. depth

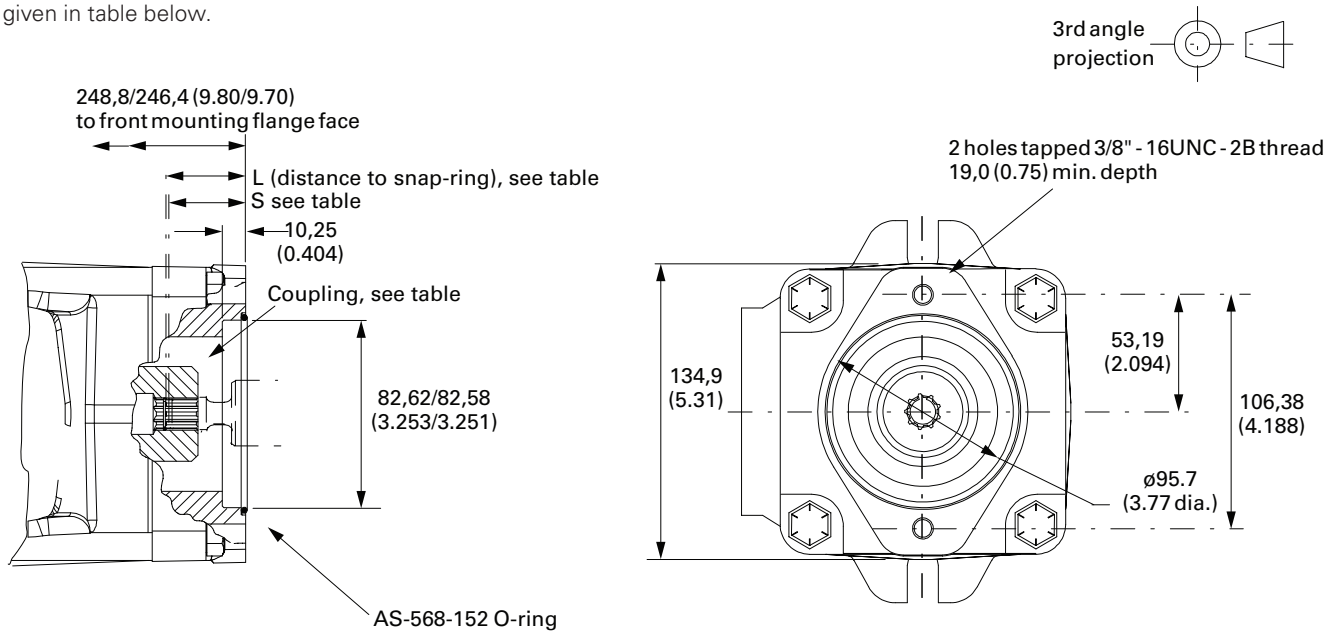
Model code 11	Flange type	Ø B1	B2	B3	B4
A	SAE 101-2	101,55/101,6 (3.998/4.000)	9,19/9,70 0.362/0.382)	73,00 (2.874)	14,17/14,55 (0.558/0.573)

VSQ1 25T Thru-drive pumps rear mount/coupling details

Installation dimensions in mm (in)

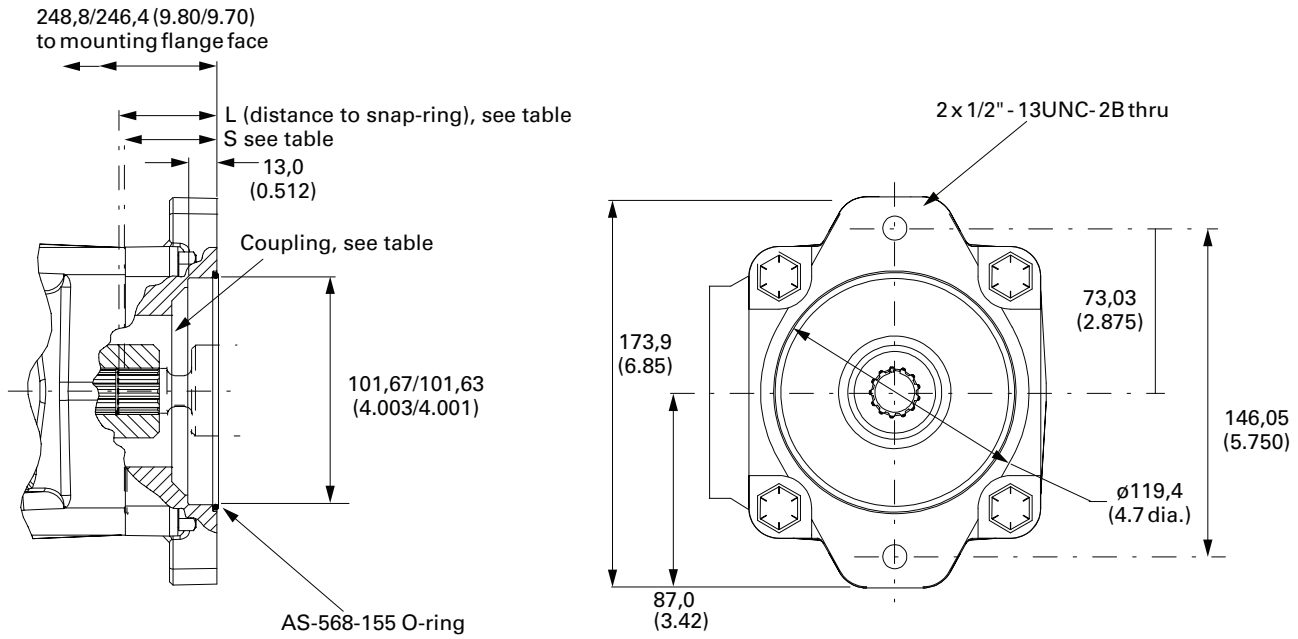
Detail of SAE A flange per model code 12 = C
(SAE flange in line with mounting flange.)

Coupling options per model code 15 16 and details are given in table below.



Detail of SAE B flange per model code 12 = C
(SAE B flange in line with mounting flange.)

Coupling options per model code 15 16 and details are given in table below.



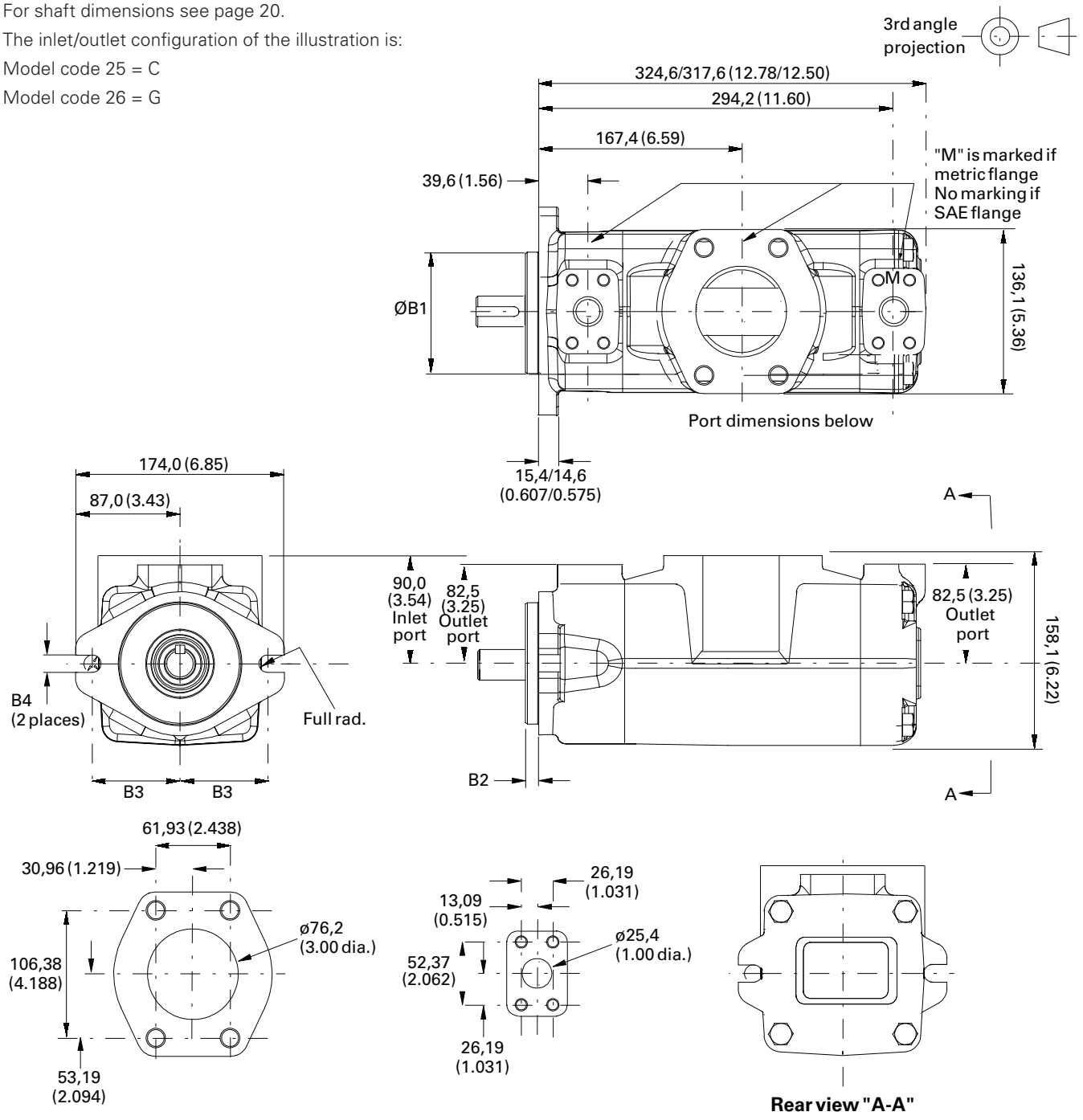
Coupling code	Description	Shaft extension S L	
22	For pump shaft of SAE "B" size with 30° involute splined shaft (per SAE std J744 JUL88) 13T 16/32 DP (per ANSI B92.1a 1976)	41,8/40,2 (1.64/1.58)	42,5 (1.67) min.
25	For pump shaft of SAE "B-B" size with 30°involute splined shaft (per SAE std J744 JUL88) 15T 16/32 DP (per ANSI B92.1a 1976)	46,8/45,2 (1.84/1.78)	47,4 (1.87) min.

For shaft dimensions see page 20.

The inlet/outlet configuration of the illustration is:

Model code 25 = C

Model code 26 = G



Inlet port

Code A: SAE J518 4-bolt flange

Threads:

Code A: 5/8"-11UNC-2B,30,2 (1.19) min. depth

Front and rear outlet ports

Code A: SAE J518 4-bolt flange

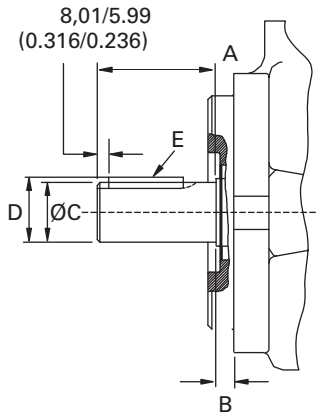
Threads:

Code A: 3/8"-16UNC-2B,22,0 (0.87)min. depth

Coupling code	Flange type	ØB1	B2	B3	B4
A	SAE 101-2	101,55/101,60 (3.998/4.000)	9,19/9,70 0.362/0.382)	73,00 (2.874)	14,17/14,55 (0.558/0.573)
C	ISO 3019/2 100A2HW	99,946/100,00 (3.935/3.937)	9,00/9.50 (0.354/0.374)	70,00 (2.756)	14,00/14,27 (0.551/0.562)

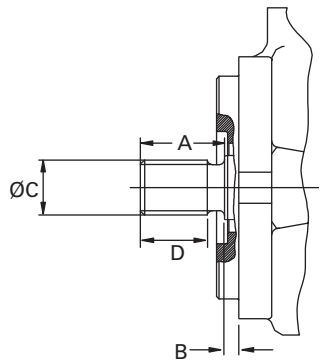
Shaft options

Straight, keyed shafts



Pump size	Shaft code	Shaft designation	A	B	ØC	D	E Key width X length
25(T)	01	SAE J744	70,00 (2.756)	8,84/7,22	25,40/25,36	28,23/27,99	6,363 (0.2505)
				(0.348/0.284)	(1.000/0.998)	(1.112/1.102)	x 49,23 (1.938)
	05	SAE J744	76,00 (2.992)	8,84/7,22	31,75/31,71	35,33/35,09	7,950 (0.3130)
				(0.348/0.284)	(1.250/1.248)	(1.391/1.381)	x50,80 (2.000)
2525	01	SAE J744	70,00 (2.756)	8,84/7,22	25,40/25,36	28,23/27,99	6,350 (0.2500)
				(0.348/0.284)	(1.000/0.999)	(1.112/1.102)	x 49,23 (1.938)
	05	SAE J744	76,00 (2.992)	8,84/7,22	31,75/31,71	35,33/35,09	7,938 (0.3125)
				(0.348/0.284)	(1.250/1.248)	(1.391/1.381)	x 50,80 (2.000)

Splined shafts



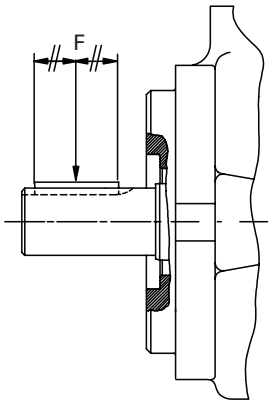
Pump size	Shaft code	Shaft type (refer spline data from below table)	A	B	ØC	D
25(T)	02	B-B	38,00	8,84/7,22	24,99	28,00
			(1.496)	(0.348/0.284)	(0.984)	(1.102)
	09	B	33,00	8,37/7,70	21,28	23,00
			(1.299)	(0.330/0.303)	(0.859)	(0.906)
2525	02	B-B	38,00	8,84/7,22	24,99	28,00
			(1.496)	(0.348/0.284)	(0.984)	(1.102)
	09	B	33,00	8,37/7,70	21,28	23,00
			(1.299)	(0.330/0.303)	(0.859)	(0.906)

Splined data

External involute spline tolerance class 7 ANSI B921A-1976 30˚ pressure angle, flat root, side fit.

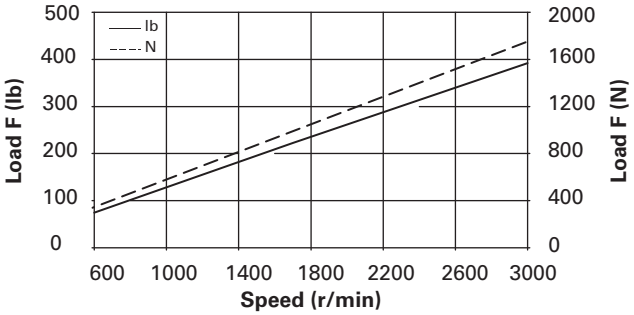
Shaft type	No.of teeth	Pitch	Pitch dia.	Major dia.	Form dia.	Minor dia. (Max)	Base dia.
B	13	16/32	20,637	22,23/22,17	19,02	18,16	17,87
			(0.8125)	(0.875/0.873)	(0.749)	(0.715)	(0.7036)
B-B	15	16/32	23,812	24,99/24,80	22,15	21,38	20,62
			(0.9375)	(0.984/0.978)	(0.872)	(0.840)	(0.8119)

82˚C (180˚F), SAE 10W oil, 9 cSt (55 SUS) 01 keyed shaft shown

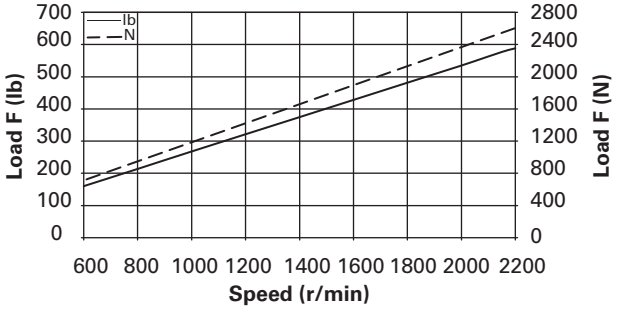


Note: Graphs based on B-10 life of 3000 hours

Frame size 25



Frame size 2525



Torque loading for direct drives

Single pumps (not thru-drive models)

All listed shafts are satisfactory up to maximum pressures in "Typical performance data" for each series.

Double and triple pumps

Where multiple cartridges are to be on-load together, check that the sum of their separate torques, taken from the graph on next page, does not exceed the torque limit in Table 1.

Thru-drive pumps (VSQ1**T models)

Where both the thru-drive pump and its rear-mounted pump are to be on-load together, check that the sum of the torques generated will never exceed the torque limit in Table 2.

Also check that the torque required on the rear-mounted pump never exceeds the thru-drive torque limit in Table 2.

Example:

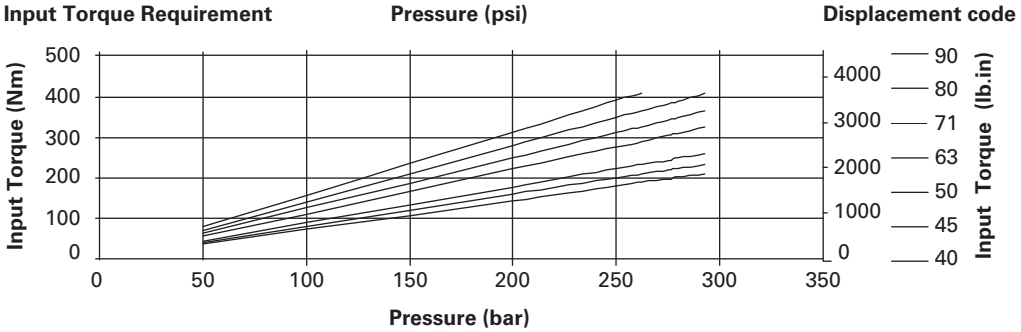
A VSQ2 2525 050 040 operating at 210 bar (3045 psi) front section and 210 bar (3045 psi) rear section will require over 300 Nm (2655 lb.in) input torque. Therefore, all listed shafts for the VSQ2 2525 050 040 will be acceptable.

Table 1. Single, double and triple pumps shaft torque ratings

Frame size	Shaft type	Type	SAE Code	Size mm	No. of teeth	Torque Nm	Rating (Lb. In.)
25, 2525	01	Keyed		25,40	N/A	407	(3600)
25, 2525	02	Splined	B-B	24,99	15	621	(5500)
25, 2525	05	Keyed		31,75	N/A	814	(7200)
25, 2525	09	Splined	B	21,82	13	328	(2900)

Table 2. Thru-drive pumps shaft torque ratings

		Max input torque		Max. Thru-drive torque	
Pump	Shaft	Nm	(Lb. In.)	Nm	(Lb. In.)
VSQ125T	01	407	(3600)	350	(3100)
	02	621	(5500)	350	(3100)
	05	814	(7200)	350	(3100)



Note: To realize the high input torque levels for keyed shafts (nos. 01 and 05), the corners of the key must be chamfered 0,76 to 1,02 mm (0.030 to 0.040 in) x 45° to clear the radii in the keyway.

(Eaton ships keyed shafts with the corners of the key already chamfered.) Also, the key must be installed in the keyway 8,01/5,99 mm (0.316/0.236 in) back from the end of the shaft as shown on page 20.

Spline shaft ends (nos. 02 and 09) must be lubricated by gearbox lubricant or anti-seizure grease to prevent spline wear and fretting.

Water Glycol guidelines

Viscosity & speed requirements

Operating speed	Minimum intermittent viscosity	Minimum continuous viscosity	Optimum operating viscosity range	Maximum viscosity at full pressure	Viscosity range requiring <50% outlet pressure	Maximum viscosity at startup	Maximum/ Minimum
	cSt	cSt	cSt	cSt	cSt	cSt	RPM
Industrial	18	20	20-54	54	54-860	860	1800/900

Pressure & operating temperature requirements

Operating speed	Minimum inlet pressure absolute bar	Recommended operating inlet pressure - Gage	Maximum positive inlet pressure - Gage	Max. Continuous operating temperature C	Max. Transient operating temperature C	Max. Steady state outlet pressure - gage bar	Max. Transient outlet pressure (<0.5s) - gage bar
	(PSI)	bar (PSI)	bar (PSI)	(F)	(F)	(PSI)	(PSI)
Industrial	1.0 (14.5)	0 to 0.36 (0 to 5.2)	1.4 (20)	55 (131)	60 (140)	228 (3300)	250 (3625)

High temperatures

Viscosities must not be less than the minimum values shown in the table below. Temperatures should not exceed 99°C (210°F) because the life expectancy of cartridge kits and elastomers will decrease.

Pump drive

Direct coaxial drive is recommended. Refer to page 21 if imposing radial shaft loads are required.

Start-up procedure

Make sure the reservoir and circuit are clean and free of dirt/ debris prior to filling with hydraulic fluid.

Fill the reservoir with filtered oil and fill to a level sufficient enough to prevent vortexing at suction connection to pump inlet. It is good practice to clean up the system by flushing and filtering using an external slave pump.

Before starting the pump, fill with fluid through one of the ports. This is particularly important if the pump is above the fluid level of the reservoir.

When initially starting the pump, remove all trapped air from the system. This can be accomplished by loosening the pump outlet fittings or connections before starting the pump or by using an air bleed valve. All inlet connections must be tight to prevent air leaks. An air bleed valve is available for this purpose. (Refer to catalog 690.)

⚠ Caution:

No case drain. These pumps are drained internally into their inlet. System pressure at the pump inlet connection may not exceed 1,4 bar (20 psi). Also, the inlet hose should be sized large enough to provide a fluid velocity no greater than 2.44 m/s (8 ft/sec)

⚠ Caution:

Low outlet pressure. The minimum pressure differential between the outlet and inlet must be 3.5 bar (50 psig), otherwise, the pump may fail prematurely. Once the pump is started, it should prime within a few seconds. If the pump does not prime, check to make sure that there are no restrictions between the reservoir and the inlet to the pump, and that there are no air leaks in the inlet line and connections. Also check to make sure that trapped air can escape at the pump outlet.

After the pump is primed, tighten the loose outlet connections, then operate for five to ten minutes unloaded to remove all trapped air from the circuit.

If the reservoir has a sight gauge, make sure the fluid is clear - not milky.

Operating guidelines

Inlet pressure and operating temperature requirements

	Minimum inlet pressure absolute bar (PSI)	Recommended operating inlet pressure - gage bar (PSI)	Maximum positive inlet pressure - gage bar (PSI)	Maximum continuous operating temp. ˚C (˚F)	Maximum intermittent operating temp. ˚C (˚F)
Industrial	1.0 (14.5)	0 to 0.35 (0 to 5.0)	1.4 (20)	66 (150)	74 (165)

Proper fluid condition is essential for long and satisfactory life of hydraulic components and systems. Hydraulic fluid must have the correct balance of cleanliness, materials and additives for protection against wear of components, elevated viscosity and inclusion of air.

Recommendations on contamination control methods and the selection of products to control fluid condition are included in publication 9132 or 561, "Guide to Systemic Contamination Control". The book also includes information on the concept of "ProActive Maintenance". The following recommendations are based on ISO cleanliness levels at 2 µm, 5 µm and 15 µm.

Eaton products, as any components, will operate with apparent satisfaction in fluids with higher cleanliness codes than those described. Other manufacturers will often recommend levels above those specified.

Experience has shown, however, that life of any hydraulic components is shortened in fluids with higher cleanliness codes than those listed above. These codes have been proven to provide a long trouble-free service life for the products shown, regardless of the manufacturer.

Product	System pressure level bar (psi)		
	<140 (<2000)	140-210 (2000-3000)	210+ (3000+)
Vane pumps, fixed	20/18/15	19/17/14	18/16/13
Vane pumps, variable	18/16/14	17/15/13	
Piston pumps, fixed	19/17/15	18/16/14	17/15/13
Piston pumps, variable	18/16/14	17/15/13	16/14/12
Directional valves	20/18/15	20/18/15	19/17/14
Proportional valves	17/15/12	17/15/12	15/13/11
Servo valves	16/14/11	16/14/11	15/13/10
Pressure/Flow controls	19/17/14	19/17/14	19/17/14
Cylinders	20/18/15	20/18/15	20/18/15
Vane motors	20/18/15	19/17/14	18/16/13
Axial piston motors	19/17/14	18/16/13	17/15/12
Radial piston motors	20/18/14	19/17/13	18/16/13

Hydraulic fluid recommendations

Viscosity requirements

	Minimum intermittent viscosity cSt	Minimum continuous viscosity cSt	Optimum operating viscosity range cSt	Maximum viscosity at full pressure cSt	Viscosity range requiring <50% outlet pressure cSt	Maximum viscosity at startup cSt
Industrial	10	13	16-40	54	54-860	860

Fluid selection

Fluid in a hydraulic system performs the multiple functions of transmission of power, lubrication of components, and cooling. It is a vital factor in a hydraulic system and proper selection is a necessity for satisfactory operation and life of components.

Basic requirements of a good petroleum oil for hydraulic systems are:

1. Sufficient anti-wear additives,

2. Proper viscosity at the operating temperature, and

3. Adequate rust and oxidation inhibitors.

A good quality fluid from reputable sources will provide these characteristics.

Two specific types of oil meet the requirements of modern hydraulic systems:

- Anti-wear type hydraulic oils that comply with the pump wear tests of ASTM-D-2882
- Automotive crankcase oils having the letter designations "SC", "SD", "SE", "SF" or "SG" per SAE J183 JUN89.

For additional information on the correct viscosity and proper selection of fluids for hydraulic systems, refer to Eaton publication 694.

Additional data

Conversion factors

To convert ←		Into →		Multiply by
Into ←		To convert →		Divide by
Unit	**Symbol**	**Unit**	**Symbol**	**Factor**
Atmospheres	Atm	bar	bar	1,013250
BTU/hour	Btu/h	kilowatts	kW	0,293071 x 10-3
Cubic centimeters	cm^3	litres	l	0,001
Cubic centimetres	cm^3	millilitres	ml	1,0
Cubic feet	ft^3	cubic metres	m^3	0,0283168
Cubic feet	ft^3	litres	l	28,3161
Cubic inches	in^3	cubic centimetres	cm^3	16,3871
Cubic inches	in^3	litres	l	0,0163866
Degrees (angle)	°	radians	rad	0,0174533
Fahrenheit	°F	Celsius (centigrade)	°C	■
Feet	ft	metres	m	0,3048
Feet of water	ft H_2O	bar	bar	0,0298907
Fluid ounces, UK	UKfl oz	cubic centimetres	cm^3	28,413
Fluid ounces, US	US fl oz	cubic centimetres	cm^3	29,5735
Foot pounds f	ft lbf	joules	J	1,35582
Foot pounds/minute	ft lbf/min	watts	W	81,3492
Gallons, UK	UK gal	litres	l	4,54596
Gallons, US	US gal	litres	l	3,78531
Gallons, US	US gal	cubic inches	in^3	231
Horsepower	hp	BTU/min	BTU/min	42,2
Horsepower	hp	foot pounds/minute	ft lb/min	33,000
Horsepower	hp	kilowatts	kW	0,7457
Inches of mercury	in Hg	millibar	mbar	33,8639
Inches of water	in H_2O	millibar	mbar	2,49089
Inches	in	centimetres	cm	2,54
Inches	in	millimetres	mm	25,4
Kilogramme force	kgf	newtons	N	9,80665
Kilogramme f. metre	kgf m	newton metres	Nm	9,80665
Kilogramme f./sq. centimetre	kp/cm^2	bar	bar	0,980665
Metric horsepower*	*	kilowatts	kW	0,735499
Microinches	µin	microns	µm	0,0254
Millimetres of mercury	mm Hg	millibar	mbar	1,33322
Millimetres of water	mm H_2O	millibar	mbar	0,09806
Newtons/square centimetre	N/cm^2	bar	bar	0,1
Newtons/square metre	N/m^2	bar	bar	0.00001
Pascals (newtons/sq metre)	Pa	bar	bar	0.00001
Pints, UK	UKpt	litres	l	0,568245
Pints, US	US liq pt	litres	l	0,473163
Pounds (mass)	lb	kilogrammes	kg	0,4536
Pounds/cubic foot	lb/ft^3	kilogrammes/cubic metre	kg/m^3	16,0185
Pounds/cubic inch	lb/in^3	kilogrammes/cubic centimetre	kg/cm^3	0,0276799
Pounds force	lbf	newtons	N	4,44822
Pounds f. feet	lbf ft	newton metres	Nm	1,35582
Pounds f. inches	lbf in	newton metres	Nm	0,112985
Pounds f./square inch	lbf/in^2	bar	bar	0,06894
Revolutions/minute	r/min	radians/second	rad/s	0,104720
Square feet	ft^2	square metres	m^2	0,092903
Square inches	in^2	square metres	m^2	6,4516 x 10-4
Square inches	in^2	square centimetres	cm^2	6,4516

■ °C = 5 (°F - 32)/9

* In German, Pferdestarke (PS)

In French, cheval vapeur (ch) or (CV)

Fluid power equivalents

1 bar	= 105 N/m²
1 bar	= 10 N/cm² = 1 dN/mm²
1 pascal	= 1 N/m²
1 litre	= 1000 cm³
1 centistoke (cSt)	= 1 mm2/s
1 joule	= 1 wattsecond (Ws)
1 US gallon	= 231 in³
Hertz (Hz)	= cycles/second

Atmospheric pressure at sea level = 1,01 bar (14.7 psi).
Atmospheric pressure decreases approximately 0,028 bar (0.41 psi) for each 305m (1000 feet) of elevation to 7015m (23000 feet)

Pressure (bar)	= head (m) x 0.1 x specific gravity
Pressure (psi)	= head (ft) x 0.433 x specific gravity

Specific gravity of petroleum-based oil is approximately 0.85

Practical hydraulic formula

Geometric flow rate (pumps and motors)

l/min $= \frac{cm^3/r \times r/min}{1000}$

USgpm $= \frac{in^3/r x r/min}{231}$

Theoretical shaft torque (pumps and motors)

Nm $= \frac{cm^3/r \times bar}{20\pi}$

lbf in $= \frac{in^3/r \times psi}{2\pi}$

Hydraulic power

kW $= \frac{l/min \times bar}{600}$

hp $= \frac{USgpm \times psi}{1714}$

Velocity of fluid in pipe

m/s $= \frac{l/min \times 21,22}{D^2}$

where D= inside diameter of pipe in mm

ft/s $= \frac{0.4084 \times USgpm}{D^2}$

where D= inside diameter of pipe in inches

Volumetric efficiency

(pump) $= \frac{Outputl/min(USgpm)}{Theoretical\ l/min\ (USgpm)} \times 100$

(motor) $= \frac{Theoreticall/min(USgpm)}{Input\ l/min\ (USgpm)} \times 100$

Overall efficiency

$\frac{Output\ kW\ (hp)}{Input\ kW\ (hp)}$

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