Type V30D

Variable displacement axial piston pump

Product documentation

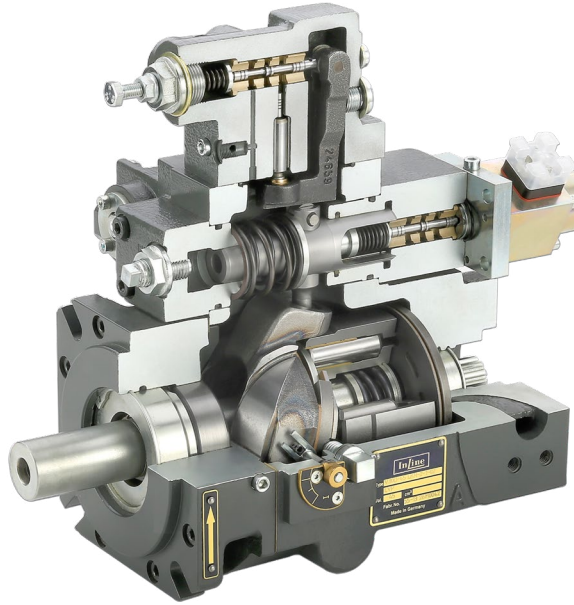
2024-04-01

Open circuit

Nominal pressure $p_{nom\ max}$: 250~350 bar

Peak pressure p_{max}: 350~420 bar

Geometric displacement V_{max}: 45~250 cm^3/rev



V30D-045

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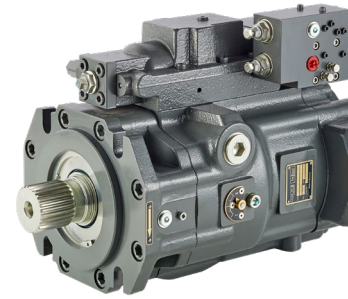
1 Overview: variable displacement axial piston pump types V30D

The axial piston variable displacement pumps of the type V30 of D offer extremely high function safety. Its remarkably low noise levels, the high pressure rating (peak = 420 bar / perm. = 350 bar), optimined power-to-weight-ratio as well as the wide controller range make it possible to employ it for most industrial and mobile applications. The variable displacement pumps work according to the swash plate principal: 9 pistons operate in a rotating cylinder cavities where they fulfill one suction and one pressure stroke per rotation.

Opening and closing of the cylinder cavities is via openings in the control disc. The axial movement of the pistons is provided by an adjustable swash plate. The setting angle (0 - max) can be steplessly varied in proportion to the desired displacement/flow. The setting range can be mechanically limited by setting screws (with V and VH controller only fixed limitation is possible). The position of the swash plate can be controlled via a visual mechanical indicator.
The latest knowledge and experience with regard to noise reduction has been used in the development of this pump design. V30D is therefore rather quiet, even when taken to the limit. All components used in the V30D are manufactured from high grade materials and machined with close tolerances.
The wide range of modular controllers along with a thru-shaft (option for mounting auxiliary pumps or a second V30D) open up a wide range of application possibilities.
Therefore type V30D features a pump design, which ideally suits the special requirements of modern industrial, mobile hydraulic drive systems, marine, offshore, and other industries.

Features and benefits:
- Low-noise emissions
- Wide controller options
- Full torque available at the second pump in tandem pump applications

Intended applications:
- Coal mining
- Concrete pump
- Extruder
- Industrial plants
- Marine cranes and winches
- Pile driving machine
- Power pack assembly
- Presses
- Tunnel boring machine
- Ship engine

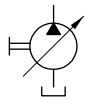


Type V30D-250
Variable displacement axial piston pump

2 Available versions, main data

2.1 Basic version

Circuit symbol:



Order coding example:

V30D	-095	R	D	G	N	-1	0	-XX	/LSN	-2	/190	-400	C411

Flange version
Table 12: Flange versions (output side)

Pressure specification (bar)

Torque Setting / Power setting
Table 10: Torque Setting / Power setting

Addition execution / Special versions
Table 8: Addition execution / Special versions

Controller
Table 11: Controllers

Release
Release

Additional function
Table 7: Additional functions

Housing version
Table 6: Housing version

Seal
Table 5: Seals

Flange version
Table 4: Flange versions (input side)

Shaft version
Table 3: Shaft version

Rotating direction
Table 2: Rotating direction

Nominal size
Table 1: Nominal size

Basic type

2.1 Basic version

Table 1: Nominal size

Coding	Geometric displacement (cm^3/rev.)	Nominal pressure P_{nom} (bar)	Peak pressure P_{max} (bar)
-045	45	350	420
-075	75	350	420
-095	96	350	420
-115	115	250*	300*
-140	142	350	420
-160	164	250*	300*
-250	250	350	420

*Higher pressure is only possible with reduce displacment.

Table 2: Rotating directions

Coding	Description	
L	Anti-clockwise	facing the drive shaft
R	Clockwise	
B*	both directions (begin size -075)	

* Customized application, please ask InLine Hydraulik for information and confirmation.

Table 3: Shaft versions

Coding	Description	Designation/Standard	Max. drive torque (Nm)
D	Spline shaft	W35×2×16×9g DIN5480 (V30D-045)	550 Nm
		W40×2×18×9g DIN5480 (V30D-075/-095/-115)	910 Nm (-075); 1200 Nm (-095/-115)
		W50×2×24×9g DIN5480 (V30D-140/-160)	1700 Nm
		W60×2×28×9g DIN5480 (V30D-250)	3100 Nm
K	Key shaft	AS 10×8×56 DIN6885 (V30D-045)	280 Nm
		AS 12×8×70 DIN6885 (V30D-075)	460 Nm
		AS 12×8×80 DIN6885 (V30D-095/115)	650 Nm
		AS 14×9×80 DIN6885 (V30D-140/160)	850 Nm
		AS 18×11×100 DIN6885 (V30D-250)	1550 Nm
S	Spline shaft	SAE-C 14T-12/24DP (V30D-045/-075)	500 Nm
		SAE-D 13T-8/16DP (V30D-095/-115/-140/-160)	1200 Nm
U	Spline shaft	SAE-D 13T-8/16DP (V30D-250)	1200 Nm

Table 4: Flange versions (input side)

Coding	Description	Designation
G	Flange	125 B4 HW ISO 3019-2 (V30D-045)
		140 B4 HW ISO 3019-2 (V30D-075)
		160 B4 HW ISO 3019-2 (V30D-095/-115)
		180 B4 HW ISO 3019-2 (V30D-140/-160/-250)
F	Flange	SAE-C 4-hole 14T-12/24DP (V30D-045/-075)
		SAE-D 4-hole 13T-8/16 DP (V30D-095/-115/-140/-160)
W	Flange	SAE-D 4-hole 13T-8/16 DP (V30D-250)

2.1 Basic version

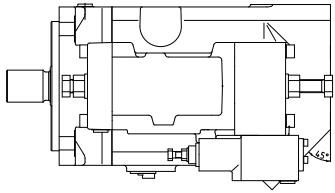
Table 5: Seals

Coding	Description
N	NBR
V	FKM
E	EPDM
C	FKM suitable for HFC

Table 6: Housing versions

Coding	Description
1	No thru-shaft (Suction port 45°)
2	Thru-shaft for tandem pump (Suction port 45°)
3	No thru-shaft (Suction port 90°)
4	Thru-shaft for tandem pump (Suction port 90°)

Suction port 45°(Normal)
Pressure Port radial



Suction and Pressure Port radial

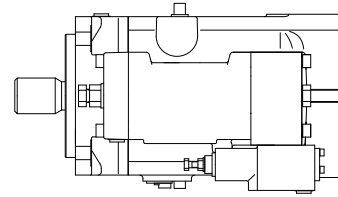


Table 7: Additional functions, pivoting angle indicator

Coding	Description
0	None
1	With indicator
2	With pivoting angle pick-up (Hall sensor)

Table 8: Addition execution / Special versions

Coding	Description
0	Without cover
-1	Prepared for L-controller

Table 9: Option for displacement limitation

Coding	Description
-2	With adjustable stroke limitation
-2/··· *	Stroke limitation fixed with specification of the set geometric displacement V_g (cm^3/rev.)

* If regulation with V or VH only a permanently declined stroke limitation is possible internally!

Table 10: Torque Setting / Power setting

Torque setting in Nm ; alternative power in kW and speed in rpm (min-1)

2.1 Basic version

Table 11: Controller

Coding	Description
-... V	The controller V is used to control flow or speed in electronic or computer controlled systems. The V controller consists of a proportional solenoid acting on a servo valve that determines the position of the pump setting piston. The displacement of the pump is proportional to the current through the 24V DC solenoid (about 250 - 750mA). In order to minimize valve hysteresis, a pulse width modulated control signal of approx. 80-100Hz frequency is recommended.
-... VH	The VH is a flow controller. It is similar to the V controller but the control signal is hydraulic. The required signal range is 7...32bar (215...725psi). The pump displacement is determined by the control signal (refer to the diagram). Pilot pressure can be supplied either from the system through a pressure reducing valve, or from an auxiliary pump. The pump should provide a pulsating flow of about 100Hz; gear pump with 7 teeth and 750 rpm is recommended. If the system pressure is below 40...60bar (580...870psi) (depending on size) a small auxiliary pump is required to secure proper functioning of the controller.
-... N	Pressure controller, adjustable directly at the pump. Pressure controller automatically mainains a constant system pressure independant of the required flow. Therefore it is suited for constant pressure systems, where differing flow is required or as efficient pressure limitation of the hydraulic system.
-... P	Remotely adjustable pressure setting; the pressure is set with a pilot relief valve. The pilot relief can be positioned up to 20m (60 ft) from the pump.
-... Pb	Like coding N, recommended only for systems with tendency to ozcillations (accumulator systems). Exterral lines are necessaery.
-... PD5	In comparison with the remote pressure control, several pumps with parallel pressure control can work parallel at the same pressure and the same displacement.
-... Q	The flow compensator maintains a constant flow, with small power losses, in spite of variations in shaft speed and ressure. The flow is determined by the size of the flow restrictor.
-... Qb	This is a special version of the Q compensator above. It has been developed to meet the accuracy and response requirement of hydrostatic transmission for generator drives and similar applications. The flow restrictor should be installed close to the pump in the main high pressure line. Pressure is sensed before and after the flow restrictor and connected to the compensator with two external lines. This provides increased control accuracy.
-... L	The V30D pump with power controller is used in applications with highly varying pressure demands and where it is important to protect the electric motor (engine) from overload. The controller limits the hydraulic power (at constant shaft speed) according to the ideal curve "pressure × flow = constant". The product of pressure and flow cannot exceed the pre-set power value. If, for example, the pressure doubles (at max power) the flow is automatically reduced by 50%.
-... Lf	Power shift control (positive power characters), the power will increase with the pilot pressure increase. And it could also servo as hydraulic proportional flow controller (the performance curve is not linear), the displacement of the pump will increase with the increase of pilot pressure.
-... Lf1	Power shift control (negative power characters), the power will decrease with the pilot pressure increase. And it could also servo as hydraulic proportional flow controller (the performance curve is not linear), the displacement of the pump will decrease with the increase of pilot pressure.
-... LS	Load-Sensing-Controller. This controller is designed for load sensing systems utilizing a suitable directional control valve.
-... LSN	Like coding LS, but with additional pressure limitation.
-... LSP	Like coding LS, but with additional pressure limitation remote control.
-... LSD	In comparison with standard LS control, several pumps with LSD control can work parallel at the same pressure and the same displacement.

2.1 Basic version

Order coding example:

V30D	-095	R	D	G	N	-1	0	-XX	/LSN	-2	/190	-400	**C311**

Table 12: Flange versions (output side)

Coding V30D							Flange	Shaft	
045	**075**	**095**	**115**	**140**	**160**	**250**			
C411	**C421**	**C431**	**C441**	**C451**	**C461**	**C471**	SAE-A 2-hole J 744 82-2 ISO 3019-1	SAE-A J 744 (16-4 ISO 3019-1) 9T 16/32 DP	
C412	**C422**	**C432**	**C442**	**C452**	**C462**	**C472**	SAE-A 2-hole J 744 82-2 ISO 3019-1	SAE-A J 744 (16-4 ISO 3019-1) 9T 16/32 DP [1)]	
C413	**C423**	**C433**	**C443**	**C453**	**C463**	**C473**	SAE-A 2-hole J 744 82-2 ISO 3019-1	J 744 (19-4 ISO 3019-1) 11T 16/32 DP	
C414	**C424**	**C434**	**C444**	**C454**	**C464**	**C474**	SAE-B 2-hole J 744 101-2 ISO 3019-1	SAE-B J 744 (22-4 ISO 3019-1) 13T 16/32 DP	
C415	**C425**	**C435**	**C445**	**C455**	**C465**	**C475**	SAE-B 4-hole J 744 101-4 ISO 3019-1	SAE-B J 744 (22-4 ISO 3019-1) 13T 16/32 DP	
C416	**C426**	**C436**	**C446**	**C456**	**C466**	**C476**	SAE-BB 2-hole J 744 101-2 ISO 3019-1	SAE-B J 744 (25-4 ISO 3019-1) 15T 16/32 DP	
C417	**C427**	**C437**	**C447**	**C457**	**C467**	**C477**	SAE-C 2-hole J 744 127-2 ISO 3019-1	SAE-C J 744 (32-4 ISO 3019-1) 14T 12/24 DP	
C418	**C428**	**C438**	**C448**	**C458**	**C468**	**C478**	SAE-C 4-hole J 744 127-4 ISO 3019-1	SAE-C J 744 (32-4 ISO 3019-1) 14T 12/24 DP	
C419	**C429**	**C439**	**C449**	**C459**	**C469**	**C479**	SAE-CC 2-hole J 744 127-2 ISO 3019-1	SAE-C J 744 (38-4 ISO 3019-1) 17T 12/24 DP	
-	-	**C440**	**C450**	**C460**	**C470**	**C480**	SAE-D 4-hole J 744 152-4 ISO 3019-1	SAE-D J 744 (44-4 ISO 3019-1 13T 8/16 DP	
C500	**C501**	**C503**	**C506**	**C510**	C515	**C521**	ISO 3019-2 125-4	D—DIN 5480 W35×2×16×9g	V30D-45
-	**C502**	**C504**	**C507**	**C511**	C516	**C522**	ISO 3019-2 140-4	D—DIN 5480 W40×2×18×9g	V30D-75
-	-	**C505**	**C508**	**C512**	C517	**C523**	ISO 3019-2 160-4	D—DIN 5480 W40×2×18×9g	V30D-95
-	-	-	**C509**	**C513**	C518	**C524**	ISO 3019-2 160-4	D—DIN 5480 W40×2×18×9g	V30D-115
				C514	C519	**C525**	ISO 3019-2 180-4	D—DIN 5480 W50×2×24×9g	V30D-140
				-	C520	**C526**	ISO 3019-2 180-4	D—DIN 5480 W50×2×24×9g	V30D-160
				-	-	**C527**	ISO 3019-2 180-4	D—DIN 5480 W60×2×28×9g	V30D-250

[1)] ANSI B 92.1, FLAT ROOT SIDE FIT, spline width deviating from the standard, s = 2.357-0.03

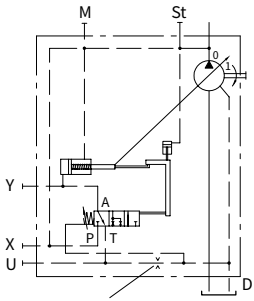
Note:
Pay attention to the maximum permissible drive torque, as the flange or shaft may be damaged otherwise.

Note:
An additional support is to be provided for pump combinations. Other versions on request.

2.2 Controller switching symbols

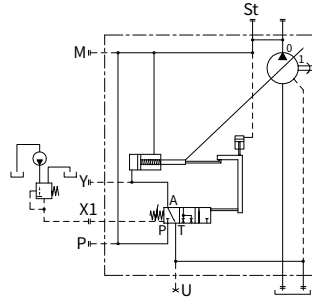
Variable displacement axial piston pump with controller

Coding L

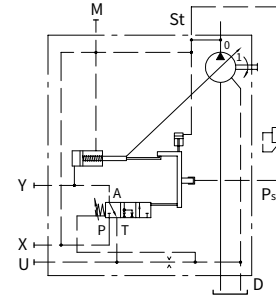


Orifice U
(see Chapter 4.3, “Controller”)

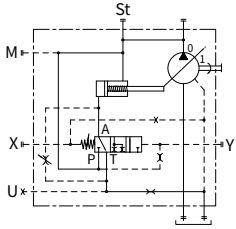
Coding Lf



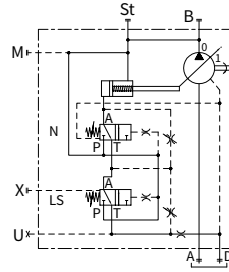
Coding Lf1



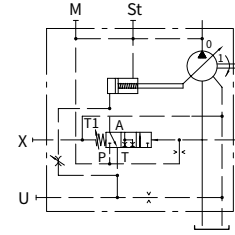
Coding LS [1)]



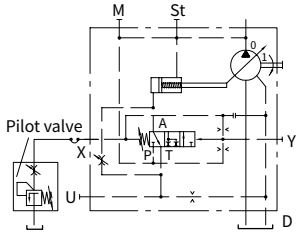
Coding LSN

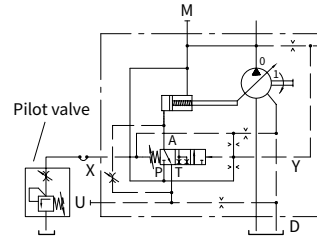


Coding N



Coding P



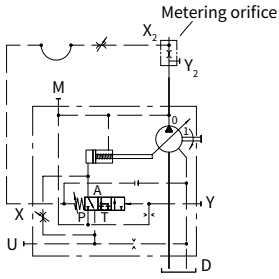


[1)] The pressure limiting valve "N" is not available with type LS (version without pressure cut-off)

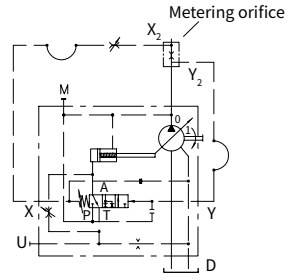
2.2 Controller switching symbols

Variable displacement axial piston pump with controller

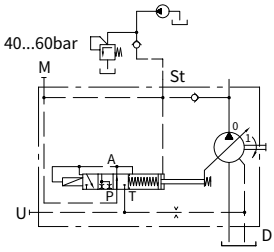
Coding Q



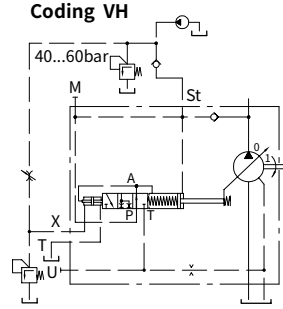
Coding Qb



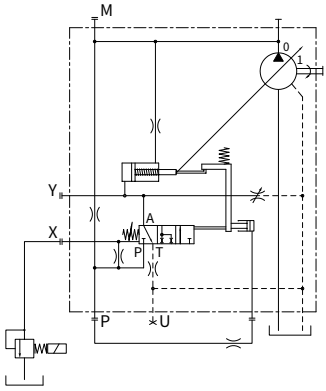
Coding V



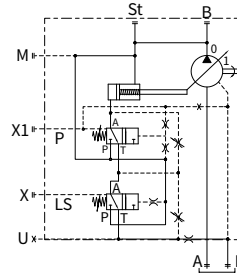
Coding VH



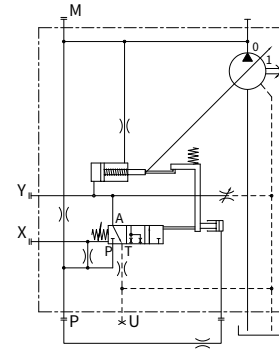
Coding PD5



Coding LSP



Coding LSD



3 Parameters

3.1 General

Description	Variable displacement axial piston pump
Design	Axial piston pump according to the swash plate principle
Mounting	Flange mounting or foot bracket
Surface	Primed
Drive/output torque	See Chapter 3, "Parameters", under "Additional parameters"
Rotating direction	Clockwise, anti-clockwiseor or bidirectional
Ports	· Suction port · Pressure port · Drain port · Pressure gauge connection
Hydraulic fluid	Hydraulic oil: according to DIN 51 524 Part 1 to 3; ISO VG 10 to 68 according to DIN 51 519 Viscosity range: min. approx. 10; max. approx. 1000 mm^2/s Optimal operating range: 16 to 35mm^2/s, when lower than 16mm^2, please contact InLine Hydraulik. Also suitable for biologically degradable pressure fluids type HEPG (polyalkalene glycol) and HEES (synthetic ester) at operating temperatures up to approx. +70°C . HFC pressure fluids (water glycol);
Purity class	19/17/14, ISO 4406
Temperatures	Ambient: approx. -40 to +60°C , oil: -25 to +80°C , pay attention to the viscosity range! Start temperature: down to -40°C is permissible (observe start-viscosity!), as long as the steady-state temperature is at least 20K higher for subsequent operation. Biologically degradable pressure fluids: note manufacturer specifications. With consideration for the seal compatibility, not above +70°C .
Housing pressure	1 bar / dynamic 2 bar The housing pressure is only allowed to be 1 bar higher than the suction pressure.

3.1 General

Pressure and delivery flow

Operating pressure	See Chapter 2, "Available versions, main data"
Geometric displacement	See Chapter 2, "Available versions, main data"

Weight

Type V30D	Without controller (kg)	With controller (kg)
045	40	46
075	60	66
095	70	76
115	70	76
140	85	91
160	85	91
250	130	136

Additional parameters

Description		Nominal size						
		045	**075**	**095**	**115**	**140**	**160**	**250**
Max. swash plate angle	°	17	17.5	17	20	17.5	20	17.5
Min. inlet pressure (absolute) open circuit	bar	0.85	0.85	0.85	0.85	0.85	0.85	0.85
	psi	12	12	12	12	12	12	12
Self-priming speed at max swash plate angle and 1bar (15psi) absolute inlet pressure	rpm	2600	2400	2200	2000	2200	1900	1800
Max. speed (requires increased inlet pressure)	rpm	3600	3200	2900	2800	2600	2500	2000
Min. continuous speed	rpm	500	500	500	500	500	500	500
Torque (theor.) at 100bar(1450psi)	Nm	71	119	153	185	226	261	414
	lbf ft	35	61	78	93	115	132	203
Input power at 250 bar and 1450 rpm	kW	30	50	64	77	95	109	174
at 3000 psi and 1800 rpm	hp	41	68	87	105	129	148	237
Inertia torque	kg m^2	0.0056	0.0124	0.0216	0.0216	0.03	0.03	0.0825
	ft. lbs. sec^2	0.0041	0.0092	0.016	0.016	0.022	0.022	0.061
Noise level at 250 bar and (1450 rpm)	dB(A)	72	74	75	75	76	76	77
or 3600 psi and max. (1800 rpm) displacement (measured in a semianechoic room according to ISO 4412 measuring distance 1m)	dB(A)	75	78	79	79	80	80	82

3.1 General

Max. permissible drive/output torque

Description		Nominal size						
		045	**075**	**095**	**115**	**140**	**160**	**250**
Spline shaft (D) input	Nm	550	910	1200	1200	1700	1700	3100
	lbf ft	405	670	885	885	1250	1250	2285
Spline shaft (D) output	Nm	275	455	600	600	850	850	1550
	lbf ft	205	333	445	445	625	625	1145
Key shaft (K) input	Nm	280	460	650	650	850	850	1550
	lbf ft	205	340	480	480	630	630	1145
Spline shaft (S) input	Nm	500	500	1200	1200	1200	1200	1200
	lbf ft	370	370	885	885	885	885	885
Spline shaft (S) output [1]	Nm	275	455	600	600	850	850	1000
	lbf ft	205	335	445	445	625	625	740

[1] (theoretical) Drive torque must not be exeeded

3.2 Planning information for parameters

Determination of nominal sizes

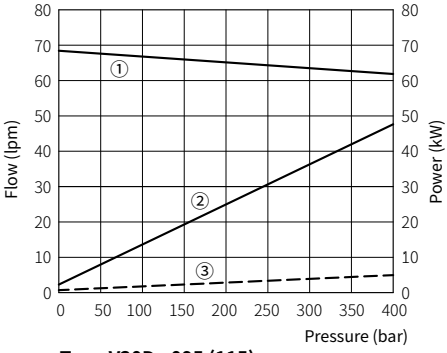
Delivery flow	$Q = \frac{V_g \cdot n \cdot \eta_V}{1000}$ (lpm)	V_g	= Geom. output volume (cm^3/rev.)
		Δp	= Differential pressure
Drive torque	$M = \frac{V_g \cdot \Delta p}{20 \cdot \pi \cdot \eta_{mh}}$ (Nm)	n	= Rotation speed (rpm)
		η_V	= Volumetric efficiency
Drive power	$P = \frac{2\pi \cdot M \cdot n}{60000} = \frac{Q \cdot \Delta p}{600 \cdot \eta_t}$ (kw)	η_{mh}	= Mechanical-hydraulic efficiency
		η_t	= Overall efficiency ($\eta_t = \eta_v \cdot \eta_{mh}$)

3.3 Characteristic curves

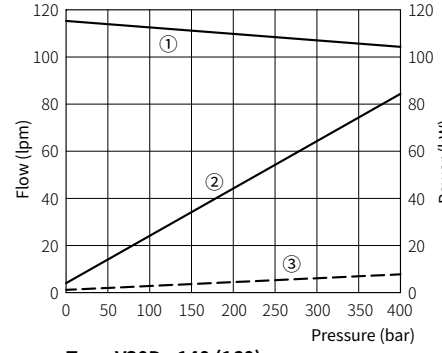
Delivery flow and power (basic pump)

The diagrams illustrate the delivery flow/pressure (without controller).
Required input power at max. swash angle and required input power when the pump is operating at "idling". Shaft speed: 1450 rpm

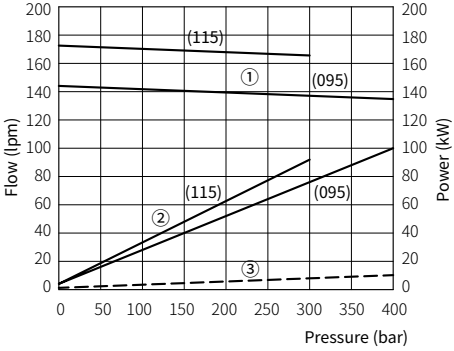
Type V30D - 045



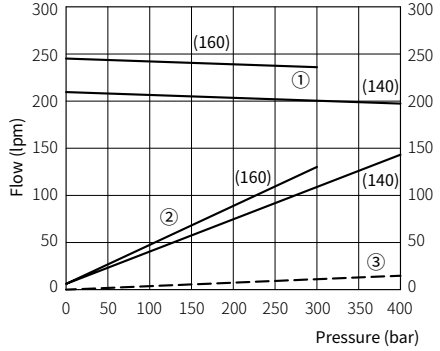
Type V30D - 075



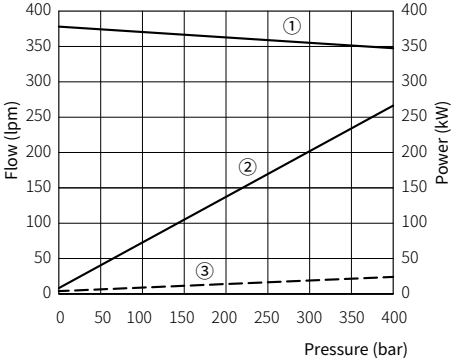
Type V30D - 095 (115)



Type V30D - 140 (160)



Type V30D - 250

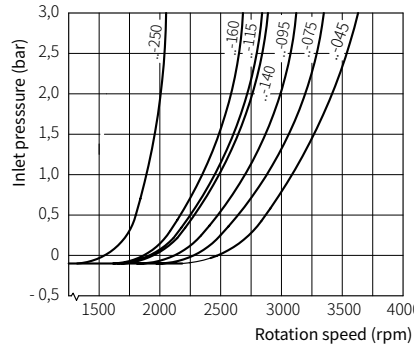


① Delivery flow/pressure
② Drive power/pressure
③ Drive power/pressure (zero stroke)

3.3 Characteristic curves

Inlet pressure and self-suction speed

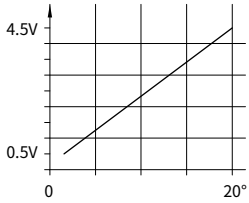
To avoid cavitation, it is essential to ensure that the pump inlet pressure always exceeds the min pressure shown in the diagram above.
The diagrams show the inlet pressure/speed at the max. swash plate angle and an oil viscosity of 75 mm^2/s.

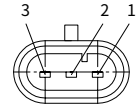


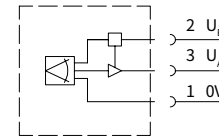
(0 bar relative = 1 bar absolute)

3.4 Swash angle pick-up

Swash angle pick-up (Hall sensor)





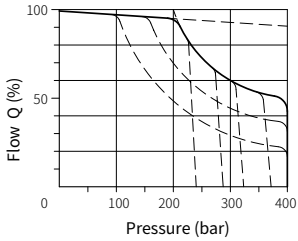


Operating voltage	U_B 10 to 30V DC
Output signal	U_A 0.5 to 4.5V
Tested for automotive field	DIN 40839
Test pulse	1, 2, 3 a/b
Field control	200 V/m
Electrical connection	3-PIN AMP
Superseal	1.5 plug

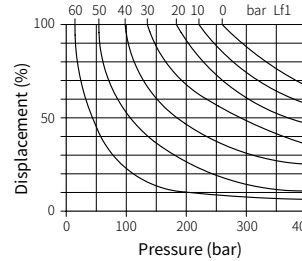
3.5 Controller characteristic curves

Coding L, Lf, Lf1

Pressure / flow



Pilot pressure

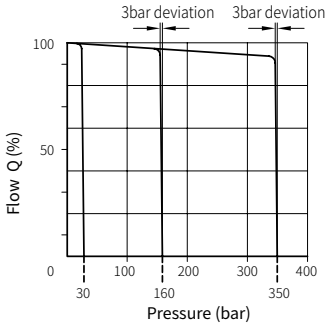


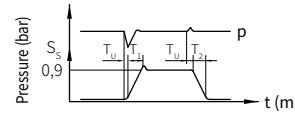
Lowest recommended torque setting: Valid only for version with power controller without additional combination

Coding	Nm (lbf ft)	Power kW/rpm (hp/rpm)
045	40 (29.5)	6 /1500 (10/1800)
075	70 (51.6)	11/1500 (18/1800)
095/115	99 (73.0)	15/1500 (25/1800)
140/160	146 (107.7)	22/1500 (37/1800)
250	271 (199.8)	41/1500 (69/1800)

Coding N, P, Pb

Pressure / flow

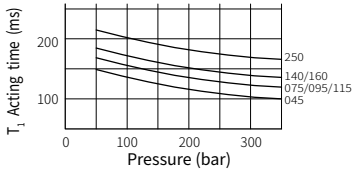




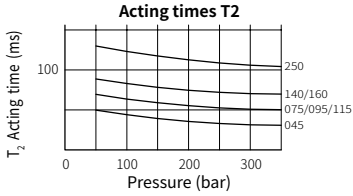
S_S	Positioning travel of actuator
T_U	Delay < 3 ms
T_1	On-stroke time
T_2	Destroke time
P	Pressure for hydraulic

Capacity 0.15 cm^3/bar (1.5 m pipe nom. dia. 20 mm)

Acting times T1

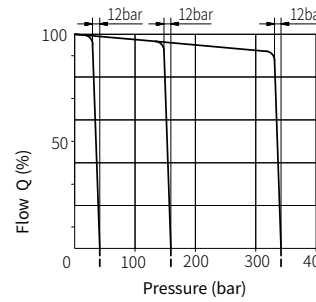


Acting times T2



Coding PD

Parallel pressure



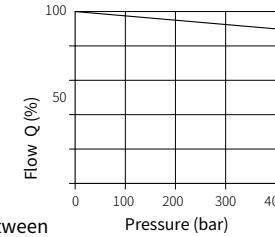
3.5 Controller characteristic curves

Codings Q, Qb, LS

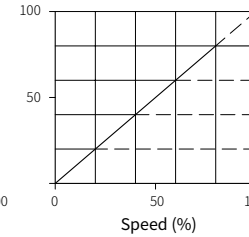
Calculation of flow Q:

Q	$= C \cdot A \sqrt{\Delta P}$ (lpm)
A	= Size of orifice (mm^2)
ΔP	= Pressure drop = 10 bar (LS = 30 bar)
	= 145 psi (LS = 435 psi)
C	= 0.6

Drive rotation speed constant



Speed varying



Caracteristics:

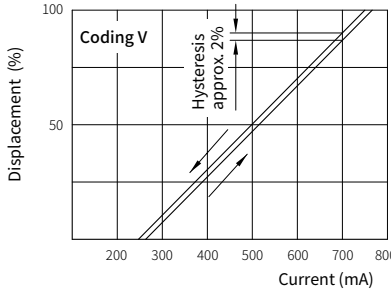
Accuracy with max. flow:

a) Speed "n" constant, pressure varying between 30 and 350 bar, (430 and 3600 psi): (< 3%)

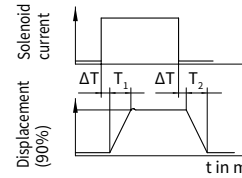
b) Pressure "p" constant, speed varying (< 1%)

Codings V, VH

Solenoid current /displacement

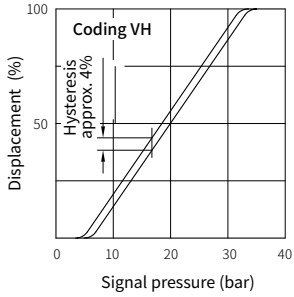


Acting times

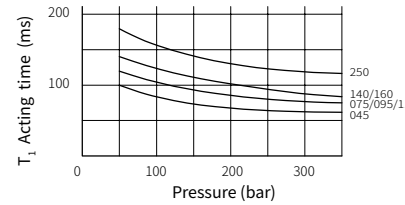


ΔT	Delay
T_1	On-stroke time
T_2	Destroke time

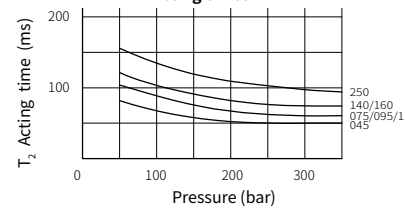
Signal pressure/displacement



Acting times T1



Acting times T2



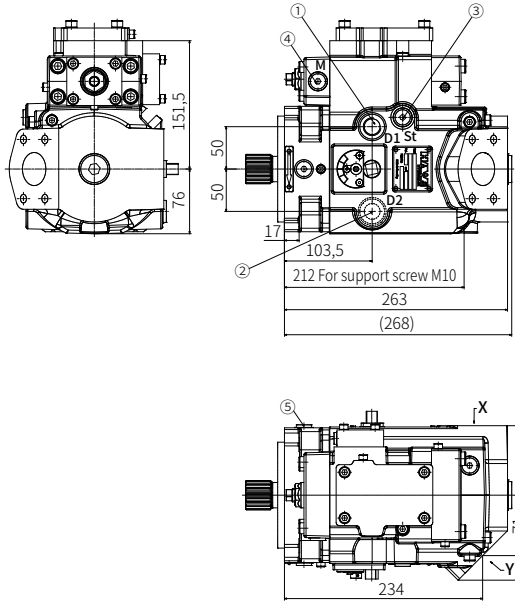
4 Dimensions

All dimensions in mm, subject to change!

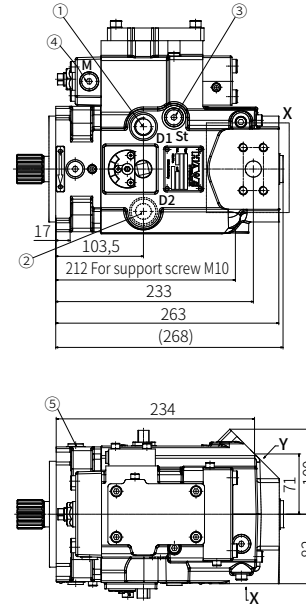
4.1 Basic pump

4.1.1 Type V30D-045

Rotating direction **clockwise**
(viewed from shaft journal)

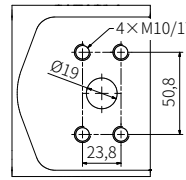


Rotating direction **anti-clockwise**
(viewed from shaft journal)

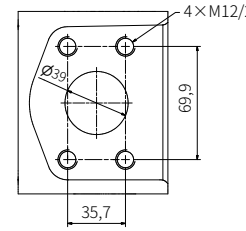


1, 2 Drain Port G1/2 (D1 / D2)
3 Auxilary pump conn. G 1/4 (St))
4 Measuring port G 1/4 (M)
5 Breather G 1/4

Pressure Port X
SAE 3/4" (6000 psi)



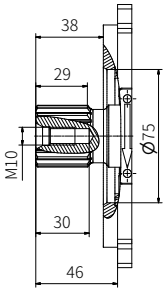
Suction Port Y
SAE 1 1/2" (3000 psi)



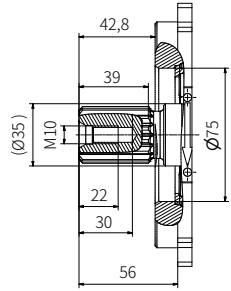
4.1.1 Type V30D-045

Shaft versions

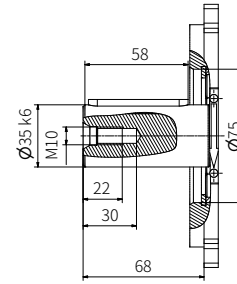
Spline shaft
Coding D
(DIN 5480 35×2×16×9g)



Spline shaft
Coding S
(SAE-C 14T - 12/24DP)

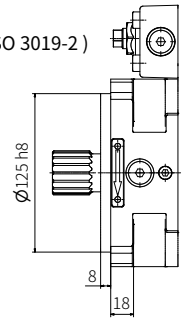


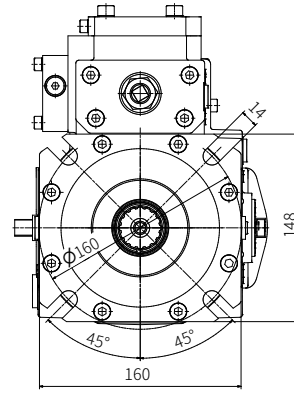
Key shaft
Coding K
(DIN 6885 Ø35 - 10×8×56)



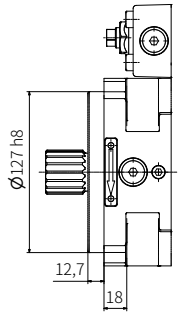
Flange versions

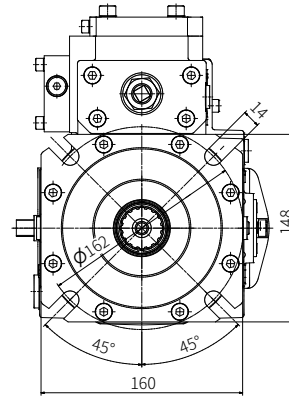
Coding G
(Flange ISO 3019-2)





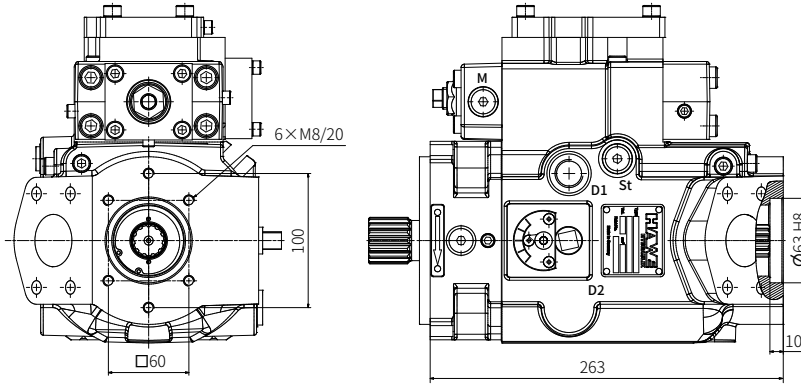
Coding F
(Flange SAE-C 4-hole 14T-12/24 DP)





4.1.1 Type V30D-045

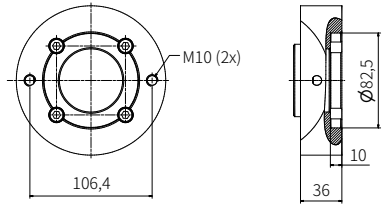
Housing version -2 (radial ports, with thru-shaft)



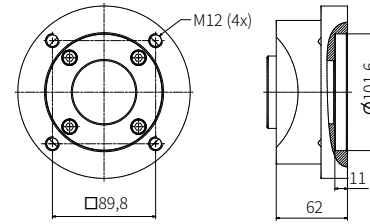
4.1.1 Type V30D-045

Flange version (output side)

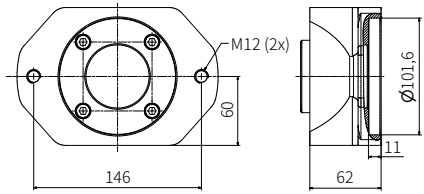
Coding C411; C412; C413
(SAE-A 2-hole)



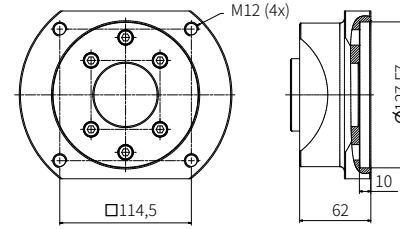
Coding C415
(SAE-B 4-hole)



Coding C414 and C416
(SAE-B 2-hole / SAE-BB 2-hole)

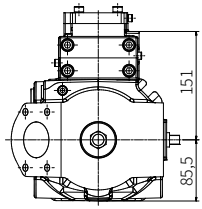


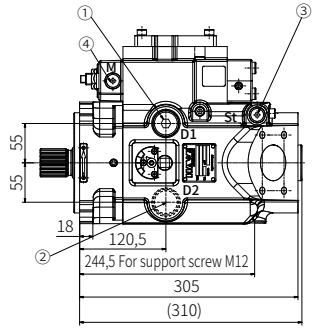
Coding C418
(SAE-C 4-hole)



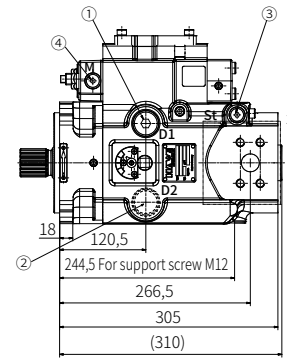
4.1.2 Type V30D-075

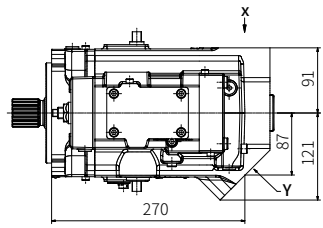
Rotating direction **clockwise**
(viewed from shaft journal)

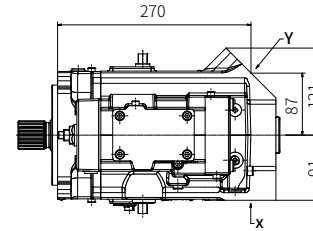




Rotating direction **anti-clockwise**
(viewed from shaft journal)

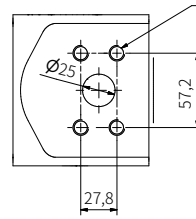




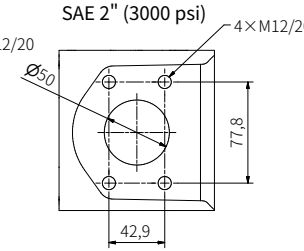


1, 2 Drain Port G1/2 (D1 / D2)
3 Auxilary pump conn. G 1/4 (St))
4 Measuring port G 1/4 (M)
5 Breather G 1/4

Pressure Port X
SAE 1" (6000 psi)



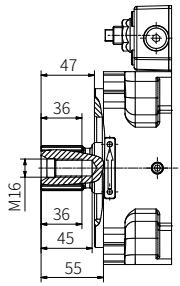
Suction Port Y
SAE 2" (3000 psi)



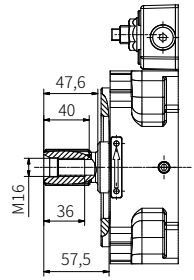
4.1.2 Type V30D-075

Shaft versions

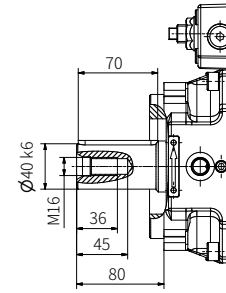
Spline shaft
Coding D
(DIN 5480 W40×2×18×9g)



Spline shaft
Coding S
(SAE-C 14T - 12/24 DP)

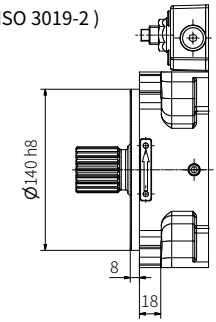


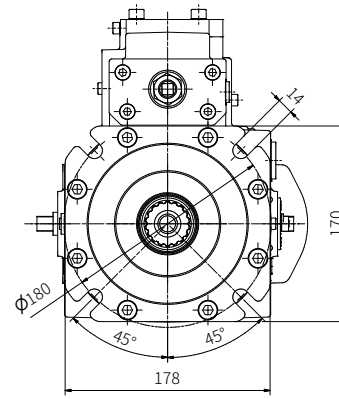
Key shaft
Coding K
(DIN 6885 Ø40 - 12×8×70)



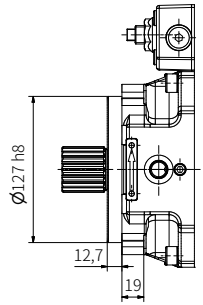
Flange versions

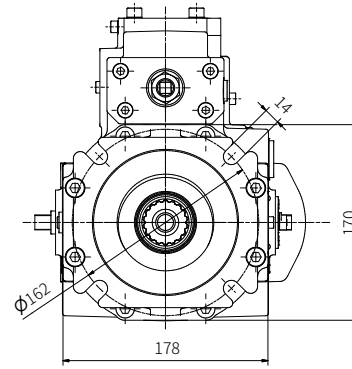
Coding G
(Flange ISO 3019-2)





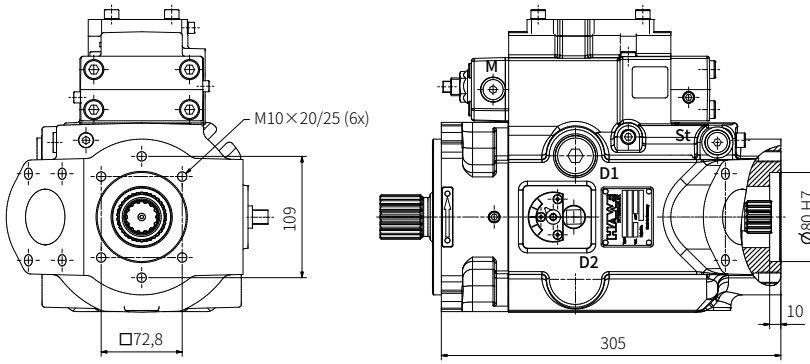
Coding F
(Flange SAE-C 4-hole 14T-12/24 DP)





4.1.2 Type V30D-075

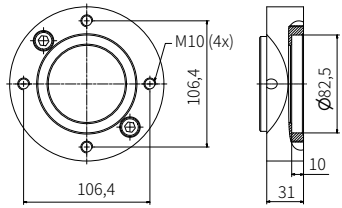
Housing version -2 (radial ports, with thru-shaft)



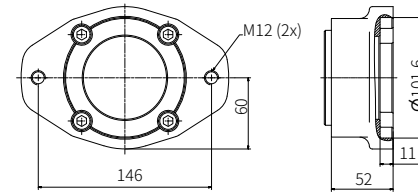
4.1.2 Type V30D-075

Flange version (output side)

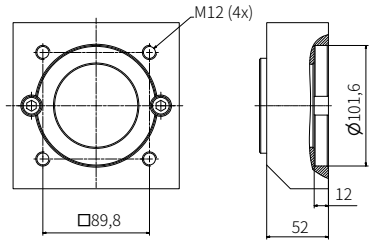
Coding C421; C4422; C423
(SAE-A 2 hole)



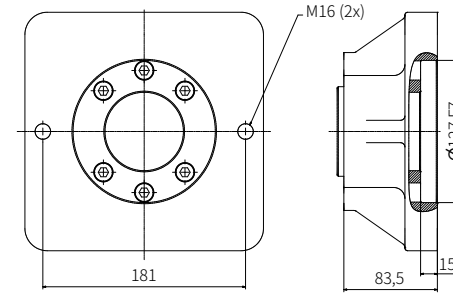
Coding C424 and C426
(SAE-B 2 hole / SAE-BB 2 hole)



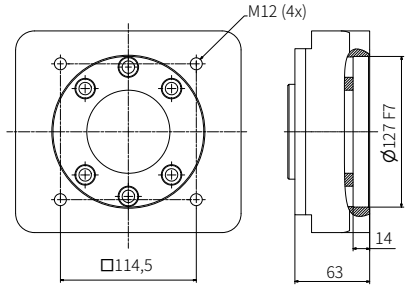
Coding C425
(SAE-B 4 hole)



Coding C427
(SAE-C 2 hole)

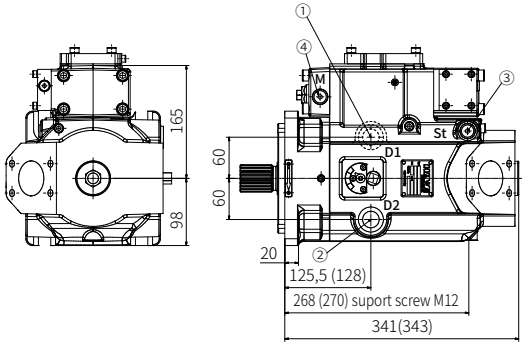


Coding C428
(SAE-C 4 hole)

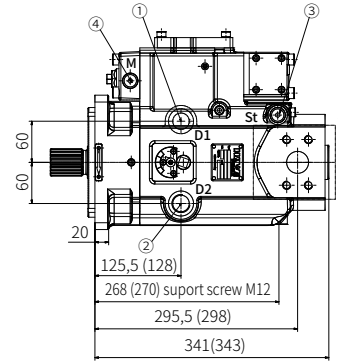


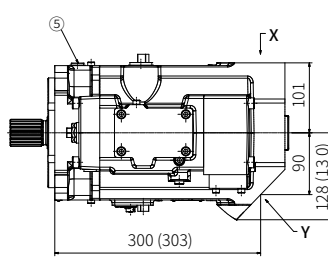
4.1.3 Type V30D-095 (115)

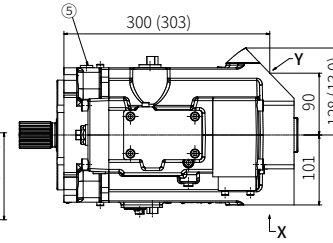
Rotating direction **clockwise**
(viewed from shaft journal)



Rotating direction **anti-clockwise**
(viewed from shaft journal)

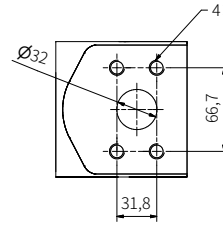




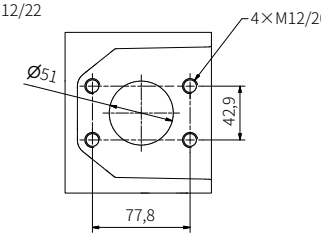


1，2 Drain Port G3/4" (D1 / D2)
3 Auxilary pump conn. G 1/4 (St))
4 Measuring port G 1/4" (M)
5 Breather G 1/4

Pressure Port X
SAE 1 1/4" (6000psi)



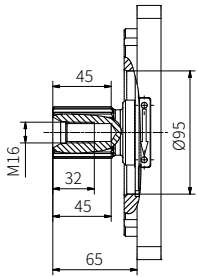
Suction Port Y
SAE 2" (3000psi)



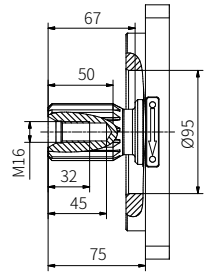
4.1.3 Type V30D-095 (115)

Shaft versions

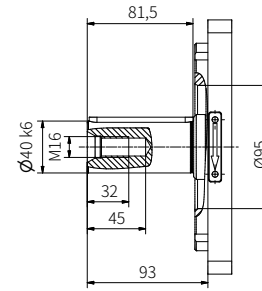
Spline shaft
Coding D
(DIN 5480 W40×2×18×9g)



Spline shaft
Coding S
(SAE-D 13T-8/16 DP)

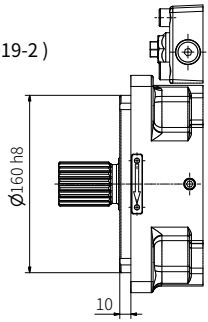


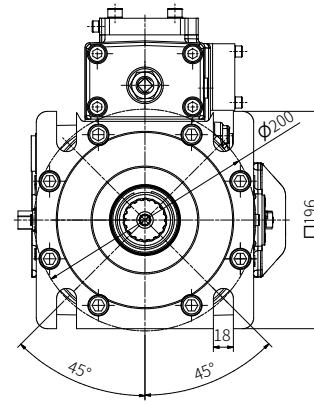
Key shaft
Coding K
(DIN 6885 12×8×80)



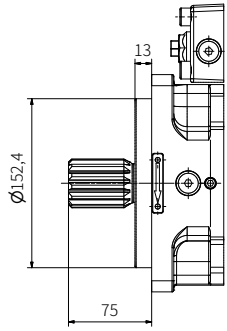
Flange versions

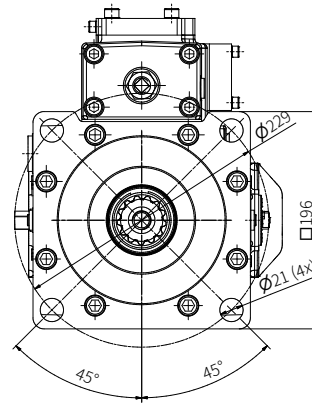
Coding G
(Flange ISO 3019-2)





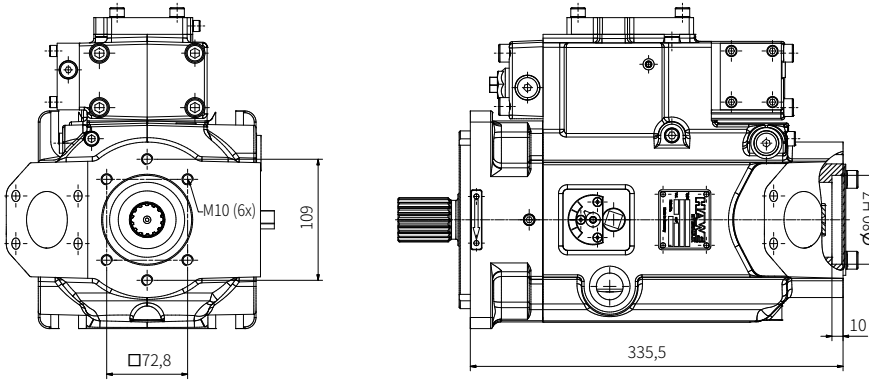
Coding F
(Flange SAE-D 4-hole 13T - 8/16 DP)





4.1.3 Type V30D-095 (115)

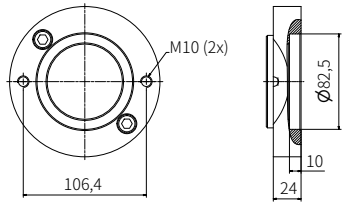
Housing version -2 (radial ports, with thru-shaft)



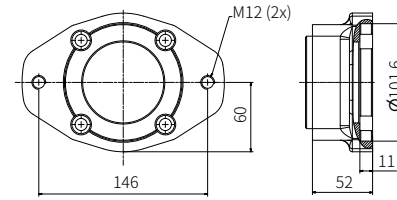
4.1.3 Type V30D-095 (115)

Flange version (output side)

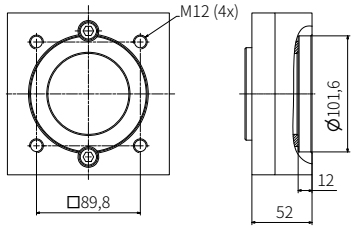
Coding C431 (C441) ; C432 (C442); C433 (C443)
(SAE-A 2-hole)



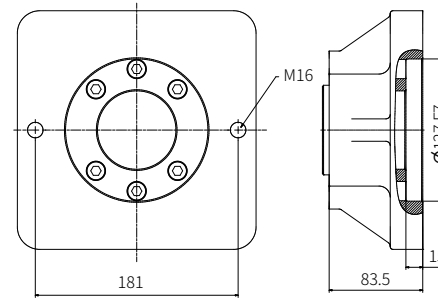
Coding C434 (C444) and C436 (C446)
(SAE-B 2 hole / SAE-BB-2 hole)



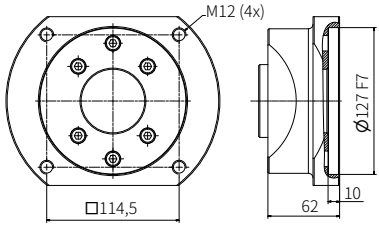
Coding C435 (C445)
(SAE-B 4-hole)



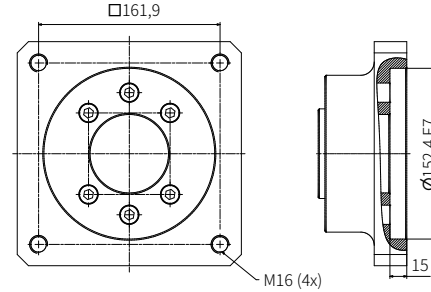
Coding C437 (C447)
(SAE-C 2-hole)



Coding C438 (C448)
(SAE-C 4-hole)

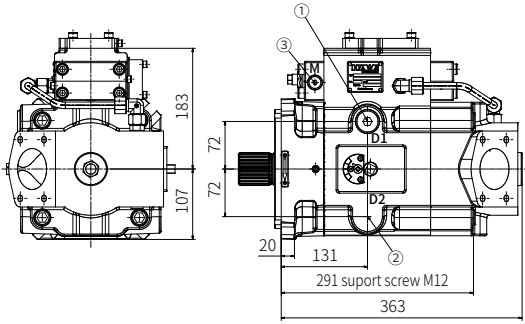


Coding C440 (C450)
(SAE-D)

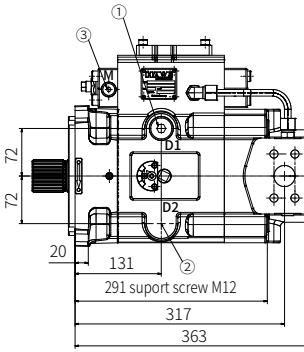


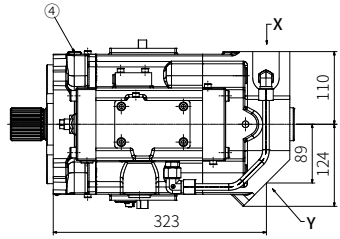
4.1.4 Type V30D-140 (160)

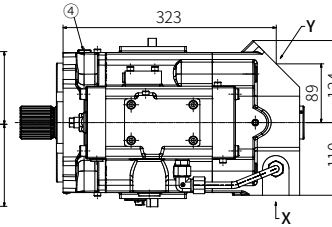
Rotating direction **clockwise**
(viewed from shaft journal)



Rotating direction **anti-clockwise**
(viewed from shaft journal)

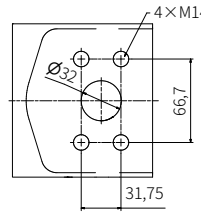




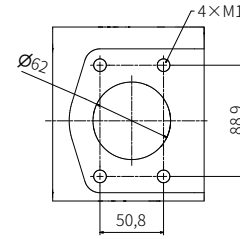


1，2 Drain Port G3/4" (D1 / D2)
3 Measuring port G 1/4" (M)
4 Breather G 1/4

Pressure Port X
SAE 1 1/4" (6000psi)



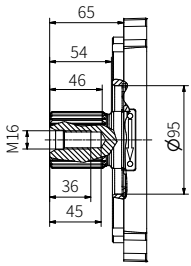
Suction Port Y
SAE 2 1/2" (3000psi)



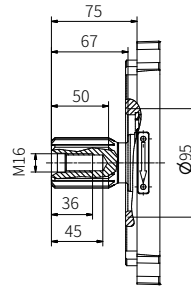
4.1.4 Type V30D-140 (160)

Shaft versions

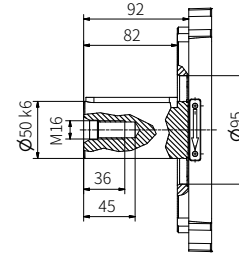
Spline shaft
Coding D
(DIN 5480 W50×2×24×9g)



Spline shaft
Coding S
(SAE-D 13T - 8/16 DP)

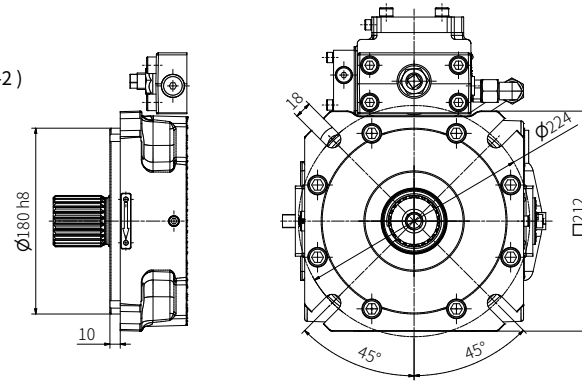


Key shaft
Coding K
(DIN 6885 14×9×80)

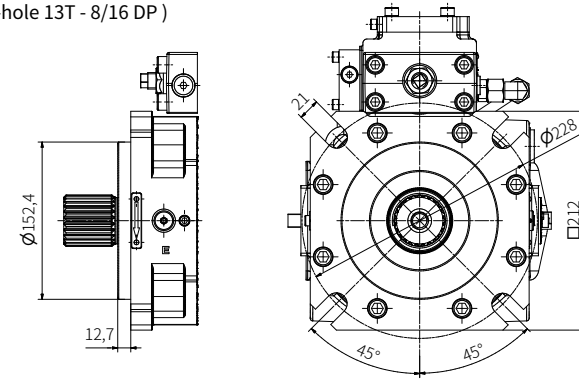


Flange versions

Coding G
(Flange ISO 3019-2)

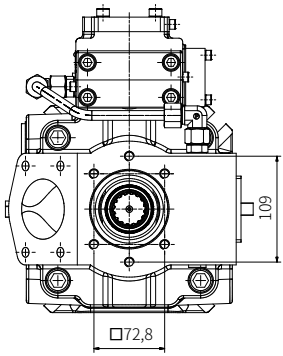


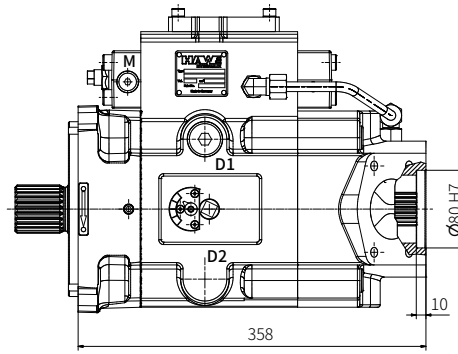
Coding F
(Flange SAE-D 4-hole 13T - 8/16 DP)



4.1.4 Type V30D-140 (160)

Housing version -2 (radial ports, with thru-shaft)

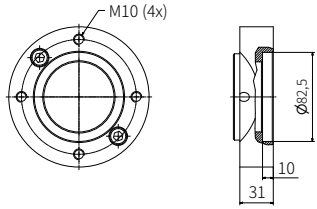




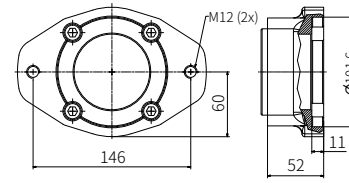
4.1.4 Type V30D-140 (160)

Flange version (output side)

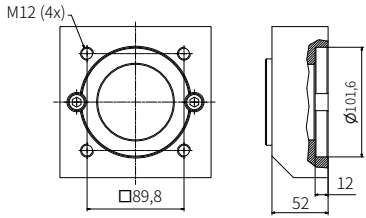
Coding C451 (C461) ; C452 (C462); C453 (C463)
(SAE-A 2-hole)



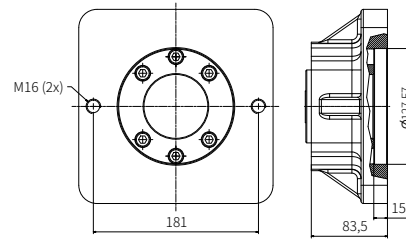
Coding C454 (C464) and C456 (C466)
(SAE-B - 2hole / SAE-BB - 2hole)



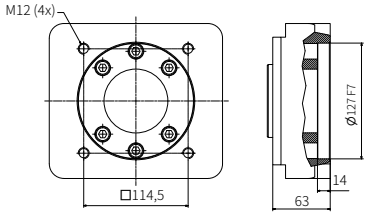
Coding C455 (C465)
(SAE-B 4-hole)



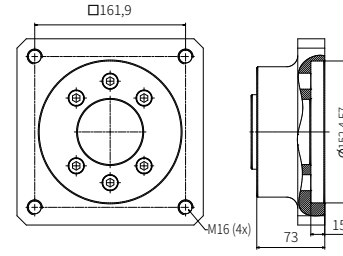
Coding C457 / C459 (C467 / C469)
(SAE-C 2-hole / SAE-CC 2-hole)



Coding C458 (C468)
(SAE-C 4-hole)

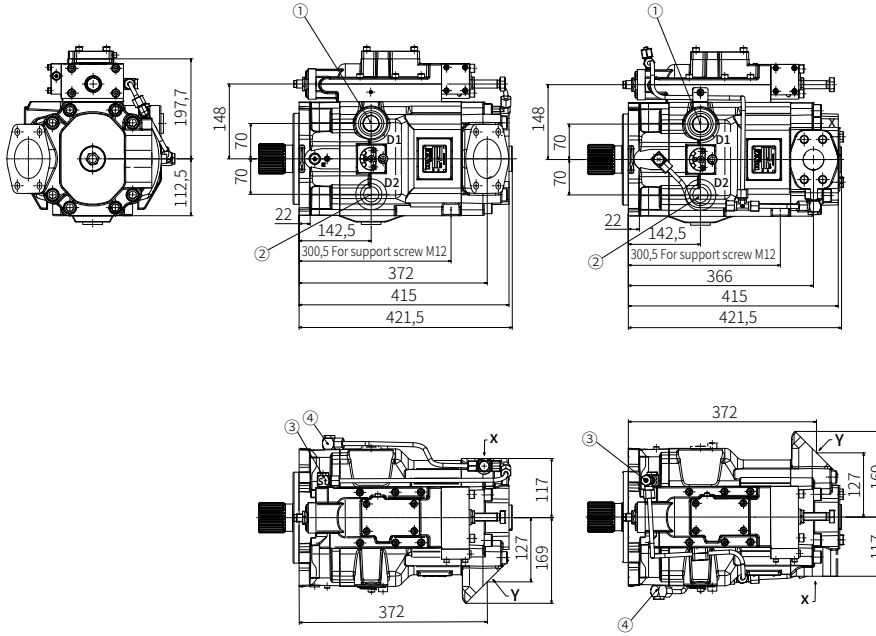


Coding C460 (C470)
(SAE-D)



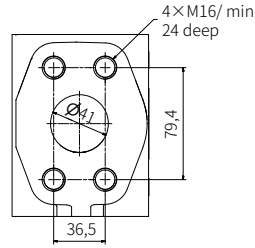
4.1.5 Type V30D-250

Rotating direction **clockwise** (viewed from shaft journal)

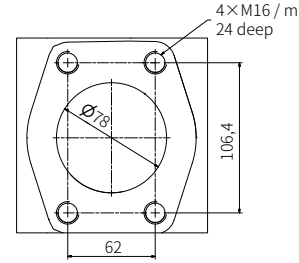


1，2 Drain Port M33×2 (D1 / D2)
3 Auxilary pump conn. Pipe 8 (St)
4 Breather G 1/4

Pressure Port X
SAE1 1/2" (6000 psi)



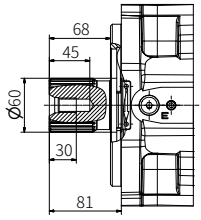
Suction Port Y
SAE 3" (3000 psi)



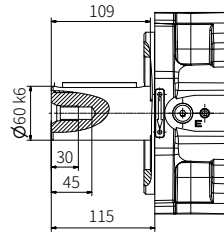
4.1.5 Type V30D-250

Shaft versions

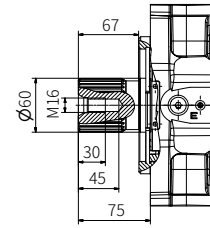
Spline shaft
Coding D
(DIN 5480 W60×2×28×9g)



Key shaft
Coding K
(DIN 6885 18×11×100)

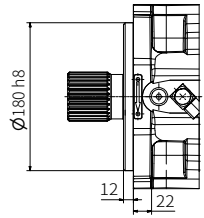


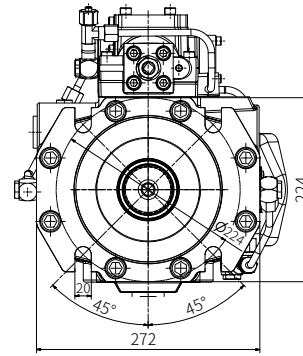
Spline shaft SAE
Coding U
(SAE-D 13T - 8/16 DP)



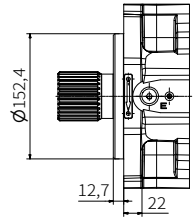
Flange versions

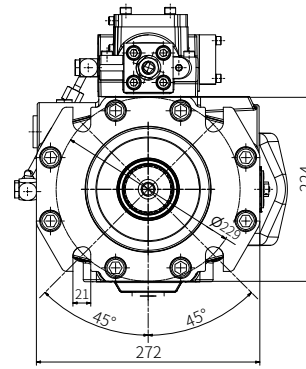
Coding G
(Flange ISO 3019-2)





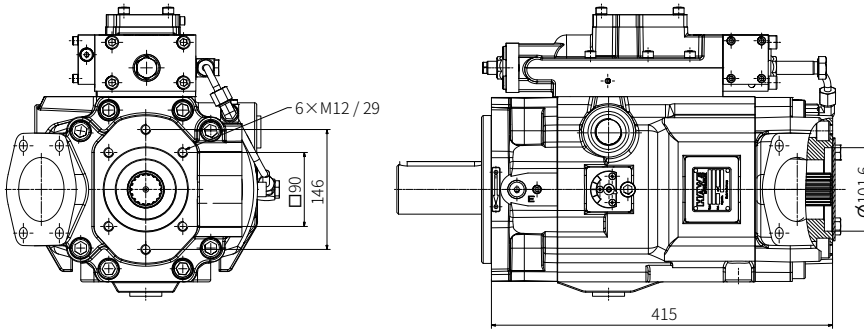
Coding W
(Flange SAE-D 13T - 8/16 DP)





4.1.5 Type V30D-250

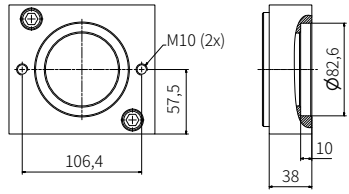
Housing version -2 (radial ports, with thru-shaft)



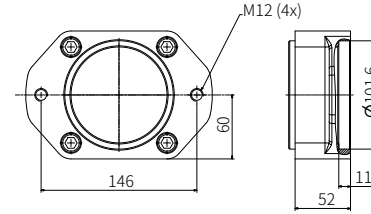
4.1.5 Type V30D-250

Flange version (output side)

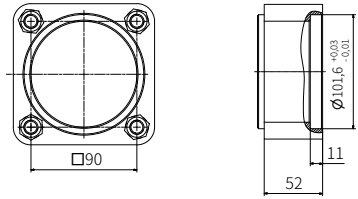
Coding C471; C472; C473
(SAE-A 2 hole)



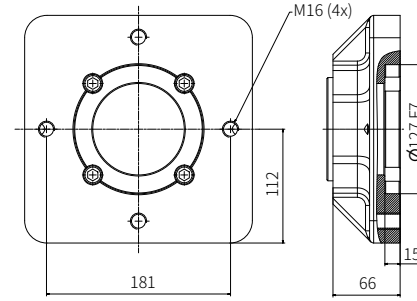
Coding C474; C476
(SAE-B 2 hole / SAE-BB 2 hole)



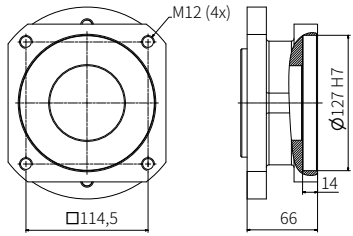
Coding C475
(SAE-B 4-hole)



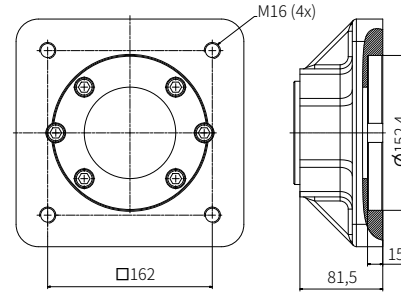
Coding C477,479
(SAE-C 2 hole / SAE-CC 2 hole)



Coding C478
(SAE-C 4-hole)

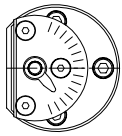


Coding C480
(SAE-D)

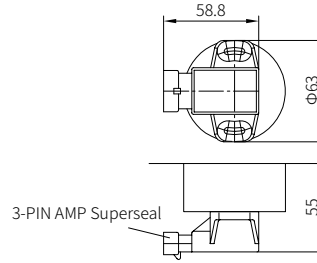


4.2 Pivoting angle indicator

Pivoting angle indicator

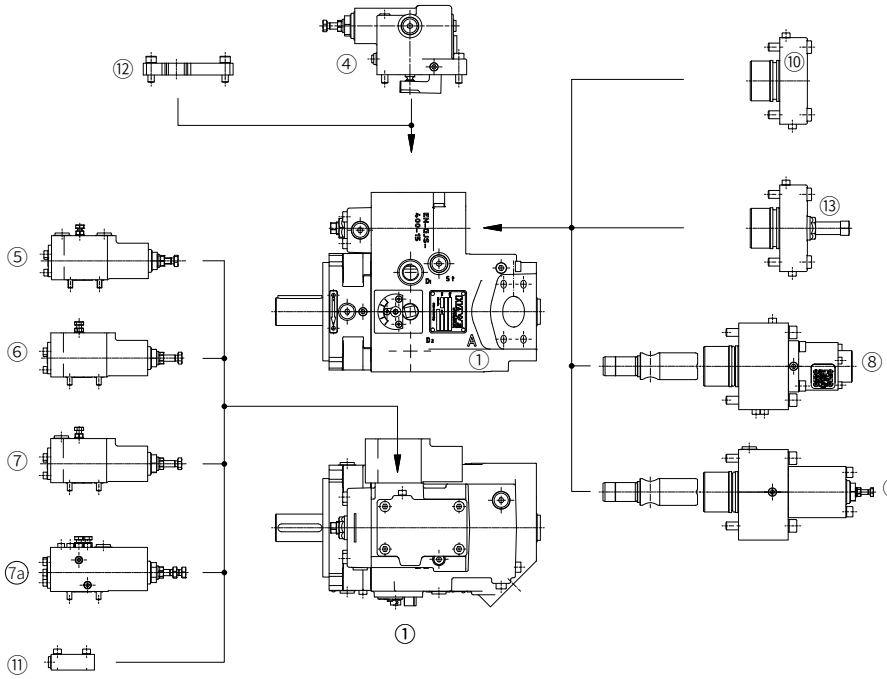


With pivoting angle pick-up (Hall sensor)



4.3 Controller

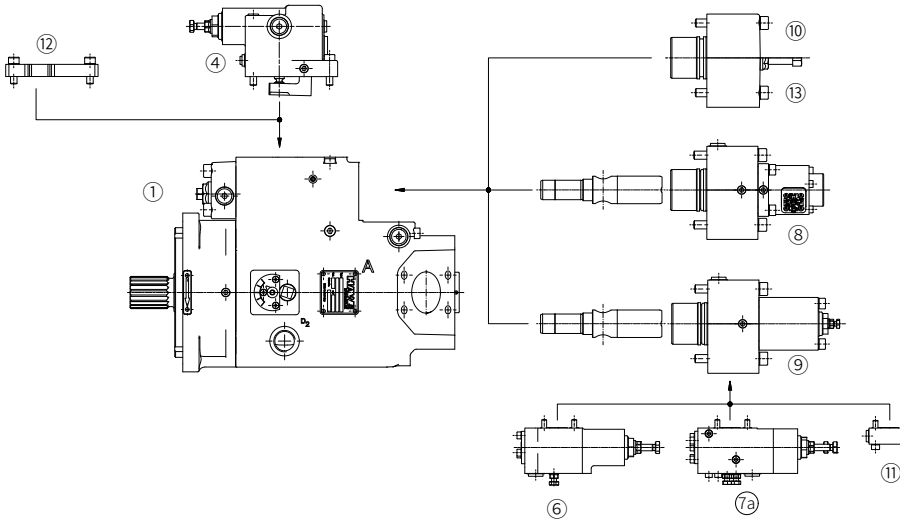
V30D-045/-075/-140/-160



1 Pump
2 Adaptor for controller L
3 Adaptor for all other controllers (standard)
4 Controller L, LF1
5 Controller N
6 Controller Qb
7 Controller Q, P, LS
7a Controller LSN
8 Controller V
9 Controller VH
10 Blanking, when without V or VH
11 Blanking, when without N, P, Q, Qb, LS, LSN
12 Blanking, when without L
13 Blanking, when without V or VH but with stroke limitation

4.3 Controller

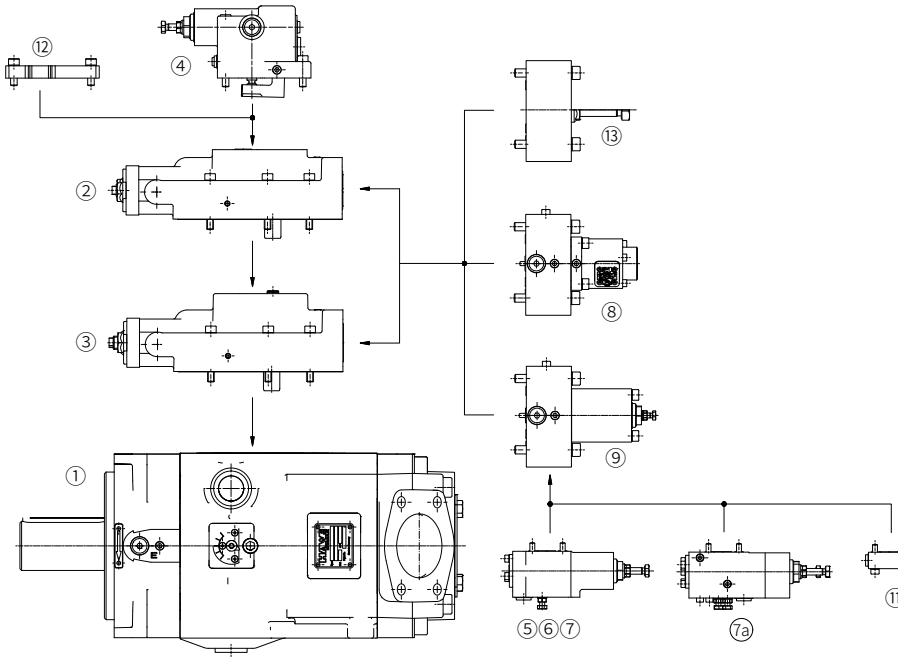
V30D-095



1 Pump
2 Adaptor for controller L
3 Adaptor for all other controllers (standard)
4 Controller L, LF1
5 Controller N
6 Controller Qb
7 Controller Q, P, LS
7a Controller LSN
8 Controller V
9 Controller VH
10 Blanking, when without V or VH
11 Blanking, when without N, P, Q, Qb, LS, LSN
12 Blanking, when without L
13 Blanking, when without V or VH but with stroke limitation

4.3 Controller

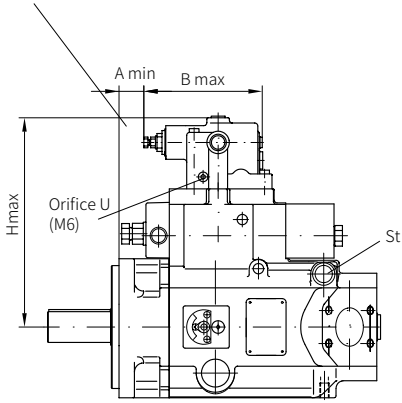
V30D-250



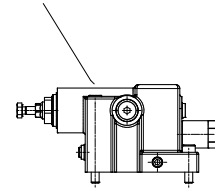
1 Pump
2 Adaptor for controller L
3 Adaptor for all other controllers (standard)
4 Controller L, LF1
5 Controller N
6 Controller Qb
7 Controller Q, P, LS
7a Controller LSN
8 Controller V
9 Controller VH
10 Blanking, when without V or VH
11 Blanking, when without N, P, Q, Qb, LS, LSN
12 Blanking, when without L
13 Blanking, when without V or VH but with stroke limitation

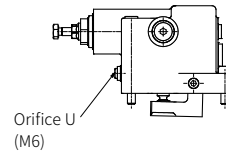
4.3 Controller

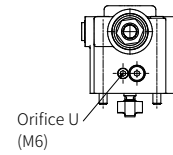
Coding L

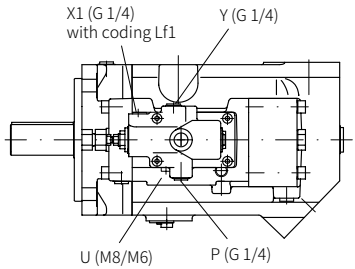


Coding Lf1









(G = BSPP)

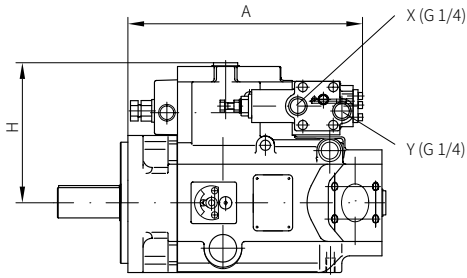
For missing dimensions, see basic pump Chapter 4.1!

Basic type	A mm(in)	B mm(in)	H mm(in)
045	3.5 (0.14)	159 (6.26)	247 (9.7)
075	14.5 (0.57)	169 (6.65)	258 (10.2)
095/115	18.5 (0.73)	169 (6.65)	262 (10.3)
140/160	24.5 (0.96)	169 (6.65)	278 (10.9)
250	55.5 (2.19)	169 (6.65)	293 (11.5)

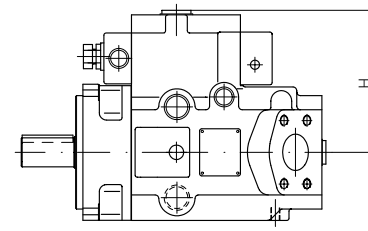
4.3 Controller

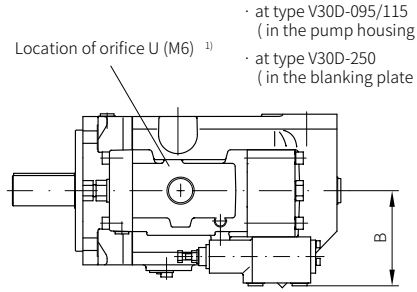
Coding N, P, Pb, Q, Qb, LS and LSN

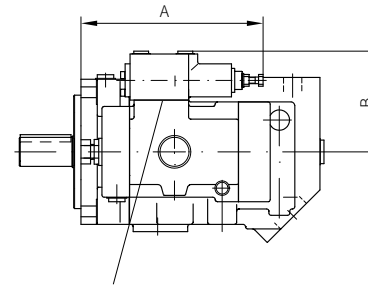
Type V30D-095/115
Type V30D-250



Type V30D - 045
Type V30D - 075
Type V30D - 140/160







(G = BSPP)

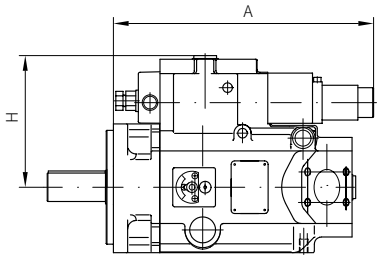
For missing dimensions, see basic pump Chapter 4.1!

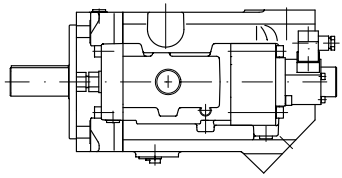
1) at version without power controller

Basic type	A mm(in)	H mm(in)	B mm(in)
045	208 (8.19)	157 (6.18)	117 (4.60)
075	224 (8.82)	171 (6.73)	117 (4.60)
095/115	307 (12.1)	185 (7.28)	120 (4.72)
140/160	240 (9.44)	191 (7.52)	118 (4.64)
250	365 (14.4)	209 (8.23)	122 (4.80)

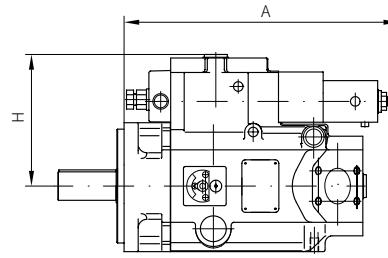
4.3 Controller

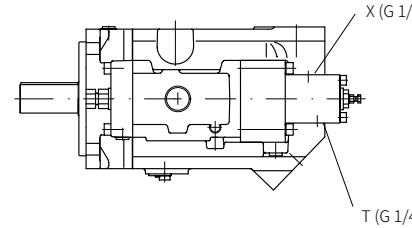
Coding V





Coding VH





(G = BSPP)

For missing dimensions, see basic pump Chapter 4.1!

Basic type	A mm(in)	H mm(in)
045	319 (12.56)	157 (6.18)
075	351 (13.82)	171 (6.73)
095/115	362 (14.25)	185 (7.28)
140/160	371 (14.61)	191 (7.52)
250	419 (16.49)	209 (8.22)

Basic type	A mm(in)	H mm(in)
045	338 (13.31)	157 (6.18)
075	371 (14.65)	171 (6.73)
095/115	381 (15.00)	185 (7.28)
140/160	390 (15.35)	191 (7.52)
250	438 (17.24)	209 (8.22)

4.4 Pump combinations

4.4.1 Tandem pumps

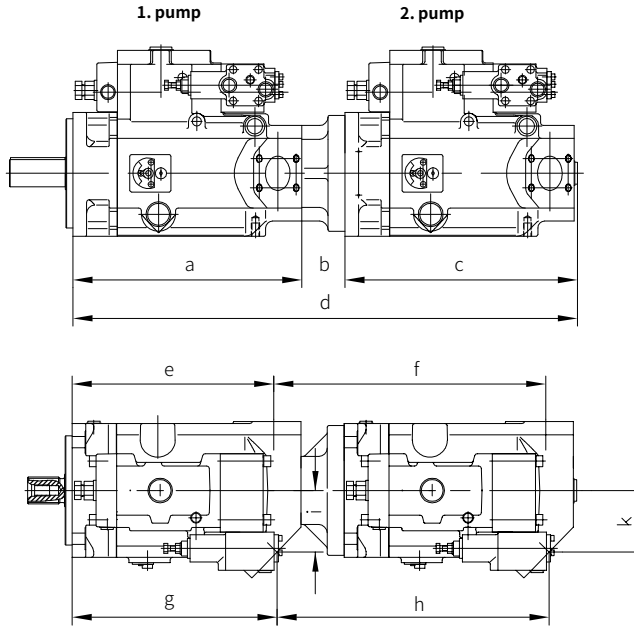
Two variable displacement axial piston pumps can be linked via an intermediate flange.
Available are shaft design "D" and "S".
Same controller range as for individual pumps.

Order coding example

V30D-140RDGN-2-1-XX/LLSN-2/120Nm-200bar-C514 ① : **1st pump**

V30D-140RDGN-2-1-XX/LLSN-2/120Nm-200bar ② : **2nd pump**

For type coding key, see Chapter 2



4.4 Tandem pumps

Table of dimensions

1st pump	**V30D-045**									
2nd pump	a	b	c	d	e	f	g	h	i	k
V30D-045	263	62	268	593	233	325	234	325	71	71

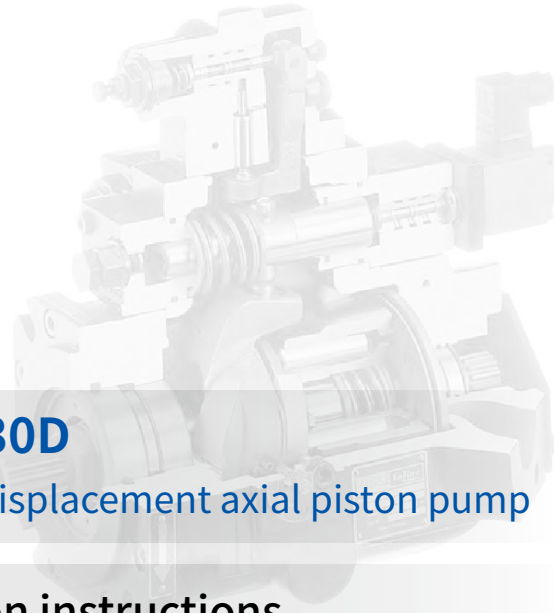
1st pump	**V30D-075**									
2nd pump	a	b	c	d	e	f	g	h	i	k
V30D-045	305	63	268	636	267	334	270	332	87	71
V30D-075	305	63	310	676	267	368	270	368	87	87

1st pump	**V30D-140 (160)**									
2nd pump	a	b	c	d	e	f	g	h	i	k
V30D-045	358	63	268	689	317	337	323	332	89	71
V30D-075	358	63	310	731	317	371	323	368	89	87
V30D-095 (115)	358	63	341	762	317	400	323	398	89	90
V30D-140 (160)	358	84	363	805	317	442	323	442	89	89

1st pump	V30D-095 (115)									
2nd pump	a	b	c	d	e	f	g	h	i	k
V30D-045	336	63	268	667	296	336	300	333	90	71
V30D-075	336	63	310	709	296	369	300	369	90	87
V30D-095 (115)	336	63	341	740	296	399	300	399	90	90

1st pump	**V30D-250**									
2nd pump	a	b	c	d	e	f	g	h	i	k
V30D-045	415	60	268	743	366	342	372	337	127	71
V30D-075	415	60	310	785	366	376	372	373	127	87
V30D-095 (115)	415	75	341	831	366	420	372	418	127	90
V30D-140 (160)	415	87	363	865	366	453	372	453	127	89
V30D-250	415	87	431	933	366	502	372	502	127	127

There are additionally several other combination possibilities via the SAE-flange. This enables direct connection of an auxiliary pump (e.g. gear pump).



Type V30D

Variable displacement axial piston pump

Operation instructions

2020-04-01

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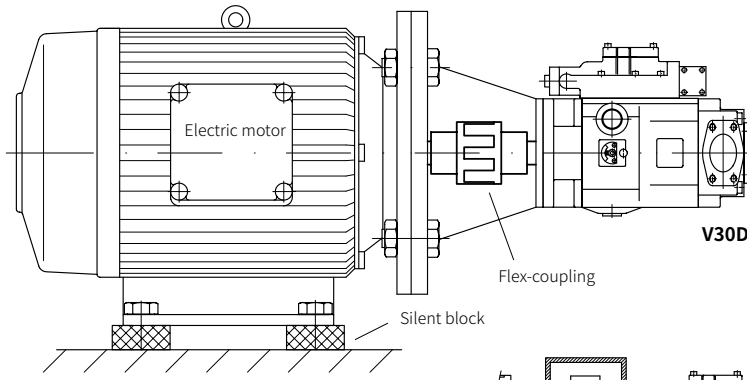
1 Pump installation

The following interfaces have to be connected for installation of a hydraulic pump in a hydraulic system:

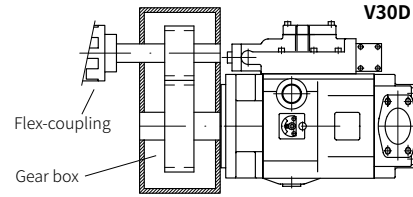
- Mechanical connection of the pump housing to the basic flange.
- Flexible coupling of the pump-shaft to a driving motor.
- Flexible hose connection of the pump-suction flange to the oil tank.
- Flexible hose connection of the uppermost positioned drain port to the oil tank.
- Flexible hose connection of the pressure port to directional valves or direct consumers.
- Flexible hose connection from remote control to pilot valve.
- Flexible hose connection to a auxiliary pump when a flow controller is specified.
- Electrical connection to the solenoid in case of electro-proportional control.
- Hydraulic connection to the tank for bleeding the pump housing when installed with erect pump drive shaft.

2 Execution of interfaces between pump and system

The mechanical connection of the pump housing to the drive motor flange, a gear box or a bell housing should be direct and solid, usually without any flexible parts in-between. This way the housings of drive motor and pump form one unit which itself should rest on silent blocks.



A flex-coupling should be installed between drive shaft and pump shaft. This prevents torsional oscillations from the drive (e.g. diesel engine) to be conducted to the pump shaft. Such a flex coupling should be used also before the pump when driven via a cardanic shaft or a gear box.

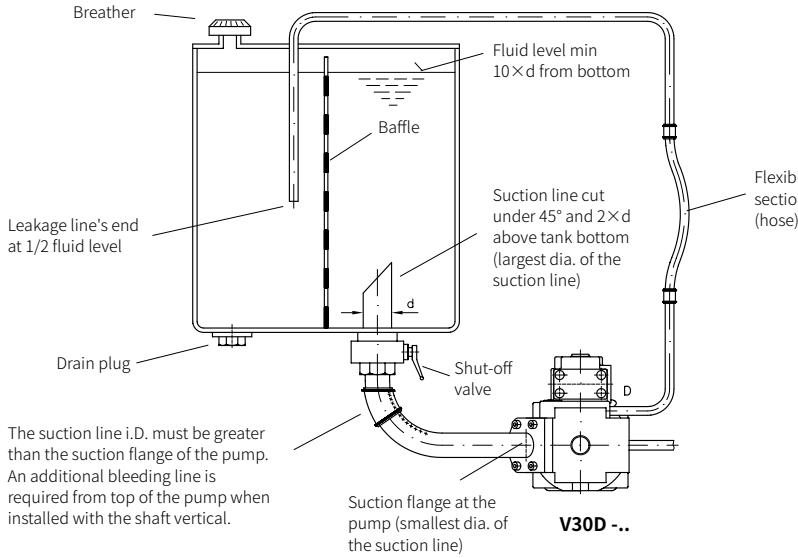


2.1 Suction line, self-priming pump

The suction line i.D. must be greater than the suction flange of the pump.
The internal diameter should be increased by 1cm/m of the suction line. The largest cross-section of the whole suction line should be the tube end in the tank. The end of the suction tube in the tank should be cut off at an angle of 45 ° or shaped like an open funnel. With several suction tubes in one tank the minimum distance has to be 5×d. The tube end should be a minimum of 8×d below the fluid level and 2 ×d above the tank bottom.
The passages from one diameter to a different one should be made with a slim cone. Tube bendings should be done with a maximum possible radius. Built-in shut-off valves must not reduce the inner diameter of the suction tube.
If several suction lines are connected to one main tube the cross-section of the main one must be at least the sum of the side-line's cross-sections. The passages from the main tube to the side-lines should be made with conical parts which do not interfere with the neighboring cross-sections.
The suction line close to the pump should be made with a hose or a rubber compensator.
It is important for the position of the compensator that the axis of the pump and compensator lies in the same plane. This ensures that the stress on the compensator which is caused by torsional oscillations of the pump is lateral and not longitudinal. This is because longitudinal stress on a compensator can cause cavitation and noise.

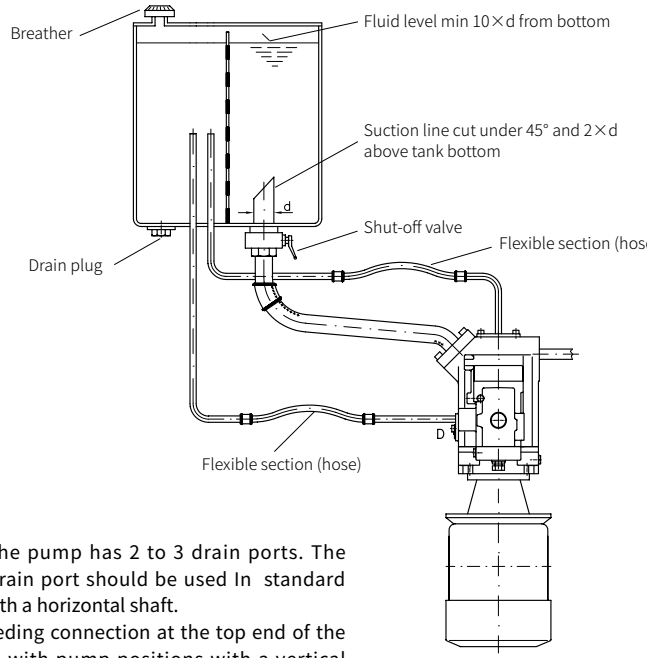
- Tank

The tank should have several, but minimum 2 chambers which are divided by baffles. This is to ensure that the return and leakage oil can be separated from the suction inlet. This is advantageous as contamination can settle down and the air bubbles can rise to the surface.
Filter and cooler should be positioned in the return line or in a auxiliary circuit. A sufficiently dimensioned breather should be used, i.e. the air flow at 0.1 bar diff. pressure should be the same as the maximum oil flow.
The fluid level in the tank should be always above the suction port of the pump with self-priming pumps. Basically the suction line should be routed straight from the tank to the pump, however, it is better to have it hanging like an arch so that the air can quickly rise to the tank and pump. It would be wrong to have one or more vaulted arches because then the air would collect in the vertices. This could cause noise and cavitation and it would take some time before the air is totally flushed out.

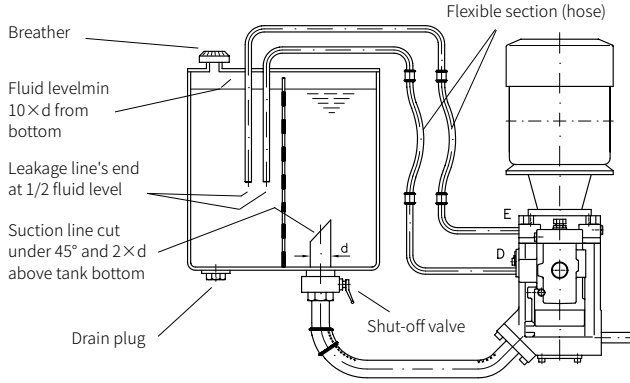


2.2 Drain line

There is no bleeding port with standard pumps, when the drive side is facing downwards. A special end cover can be ordered for such cases.
Drain and bleeder lines must never be reduced. In case any lines are added the main diameter has to be increased accordingly. The drain and bleeder lines should end roughly at 1/2 fluid level in the tank.



The housing of the pump has 2 to 3 drain ports. The highest located drain port should be used In standard pump positions with a horizontal shaft.
An additional bleeding connection at the top end of the pump is required with pump positions with a vertical shaft. Port 'E' (1/4") at the camplate bearing is used, when the drive side of the pump is situated on top.
Do not install this way if possible otherwise!



3 Control employing the pump as regulation

The controllers directly mounted at the pump measure the values in the hydraulic system and correct deviations by adjusting the displacement of the pump accordingly.
The following system values are controlled:

- System pressure
- Pressure drop via an orifice in the system (flow control)
- Product of displacement and pressure in the system (torque and power control)

The characteristic of these control values depends not only on the pump but also on the design of the whole circuit, including the kind of load. It is therefore necessary for the controller to be tuned for the corresponding circuit and the respective load characteristic.

Three different kinds of circuits are to be distinguished:

- Short lines, mainly pipes with small pressurized oil capacity
- Long lines, mainly hoses with large pressurized oil capacity
- Long lines with big gas accumulator and large pressurized oil capacity

3.1 Initial operation

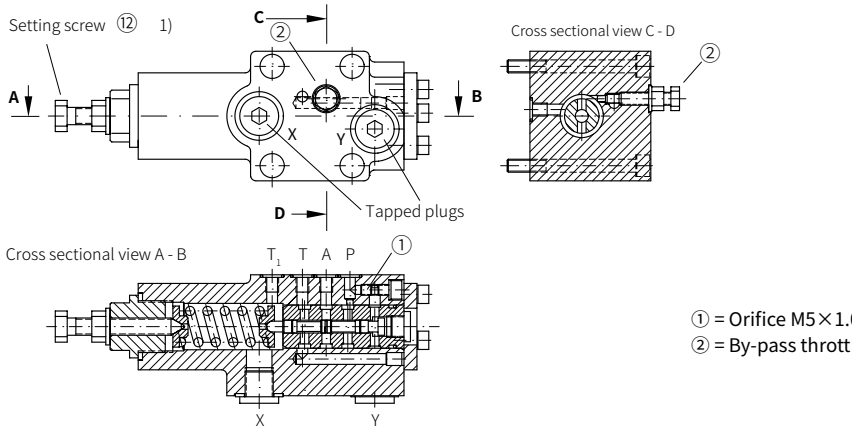
All suction lines, pumps, and hydraulic motors should be properly primed and bleeded prior to initial operation of the hydraulic circuit.
The pressure controller of the pump and the main pressure limiting valve should be set almost to zero for safety reasons.
This will cause the system pressure to be rather low easing bleeding of the complete circuit and lubricating all moving parts.
After 5-10 minutes most of the trapped air will be flushed out and the pressure can be gradually increased using the pressure control and the main limiting valve.
The final setting of the main limiting valve the pressure has to be 30 - 40 bar higher than the nominal pressure. The main pressure limiting valve should be fixed and the nominal pressure is set at the pressure control.

3.2 Pressure control (constant pressure systems)

a) Simple pressure controll via pressure controller type N

A simple controller type N is ideally suited for small circuits, mainly piped. It shows only minor amplification as it's strong measuring spring bears the whole pressure force of the control spool. Amplification here means the control valve opening per pressure deviation.
A weaker spring should be used for pressure below 250 bar as the pre-load of a strong 400 bar spring prevents full stroke to the control spool below 150 bar (type N400 / N250).
The controller type N features a by-pass throttle ② enabling fine tuning to the circuit and stabilization. The throttle is factory set at 1/4 -1/2 turn open. This is suitable for the frequent middle sized pressurized fluid capacities of approx. 2.5 l. The by-pass throttle should be opened further with smaller pressurized fluid capacities while it should be closed a bit further with larger pressurized fluid capacities to enhance the control accuracy.
A drain orifice can be mounted when oscillations do still occur despite bypass adjustment.
This orifice can be installed at controller piston housing right below stamping "U" with standard versions to enable controller combinations to be dampened (see illustration in Chapter 3.5). When the controller piston housing is prepared for fitting of a power controller, the drain orifice has to be installed at the power controller or at the replacement cover L right below "U". The orifice diameter ranges from M6×0.8 to M6×1.6 (for type V30D-250). This drain orifice slows down the response of the pump thereby dampening oscillations.

Pressure controller type N and ND



① = Orifice M5×1.0
② = By-pass throttle

Note:
1) The lock-nut has to be loosened before adjustment to prevent damage of the vulcanized thread seal!

3.2 Pressure control (constant pressure systems)

a) Simple pressure controll via pressure controller type N

- **Adjustment of controller type N (non piloted)**

The starting positions of the adjustment screws are as follows:

1. Adjustable bypass throttle ② 1/4 ... 1/2 turn open
   Tools: spanner 10 mm

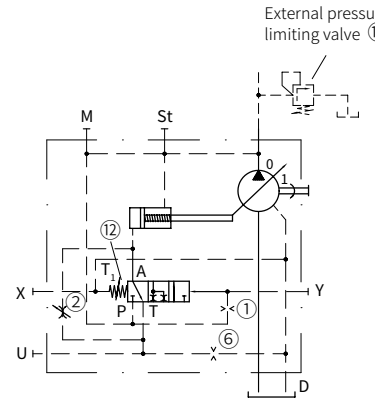
2. Drain orifice ⑥ (see Chapter 3.5)
   Remove tapped plug "U" (M6) and check the orifice for contamination when installed.
   Tools: Allan key 5 mmand 3 mm

3. Pressure adjustment screw ⑫
   Undo the locknut and rotate the adjustment screw anti-clockwise until the controller spring is totally unloaded.
   Tools: 2 spanners 13 mm

Note:
The lock-nut has to be loosened before adjustment to prevent damage of the vulcanized thread seal!

4. Check the external pressure limiting valve ⑬ in the pump line, whether a low pressure is set. Turn the screw anti-clockwise when necessary.

Guideline for adjustment ΔP (bar/turn)	
N 250	54
N 400	82

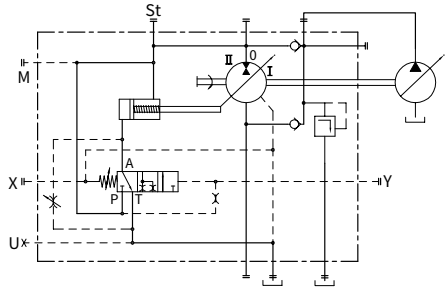


① = Orifice M5×1.0
② = By-pass throttle
⑥ = Open, optional orifice M6×1.2 (0.8 ... 1.6)

3.2 Pressure control (constant pressure systems)

b) Dampened pressure control with pressure controller type ND

The amplification or signal resolution must be higher than in the system a) when the pressure system is larger utilizing long pipe and hose lines.
The non-piloted pressure controller type ND shares the same spring with type N, but the differing piston features an increased signal resolution.
The pressure from the pump is conducted through the control piston to an annular gap at the spring sided piston guide.
The piston floats due to the pressure in this annular gap, thereby minimizing friction (induced by lateral components of the spring force) between sleeve and piston. This enables the piston to respond even on small pressure deviations causing an increased resolution.
It is also suited for higher pressure systems and systems utilizing gas type accumulators.
A weaker spring should be used for pressure below 250 bar as the pre-load of a strong 400 bar spring prevents full stroke to the control spool below 150 bar (type ND400 / ND250).
The controller type ND features a by-pass throttle enabling fine tuning to the circuit and stabilization. The throttle is factory set at 1/4 -1/2 turn open. This is suitable for the frequent middle sized pressurized fluid capacities of approx. 5 l. The by-pass throttle should be opened further with smaller pressurized fluid capacities while it should be closed a bit further with larger pressurized fluid capacities to enhance the control accuracy.
A drain orifice can be mounted when oscillations do still occur despite bypass adjustment.
This orifice can be installed at controller piston housing right below stamping "U" with standard versions to enable also controller combinations to be dampened (see illustration in Chapter 3.5). When the controller piston housing is prepared for fitting of a power controller the drain orifice has to be installed at the power controller or at the replacement cover L right below "U". The orifice diameter ranges from M6×0.8 to M6×1.6 (for type V30D-250). This drain orifice slows down the response of the pump thereby dampening oscillations.
Symbol, illustration are like with pressure controller type N (see Chapter 3.2.a)

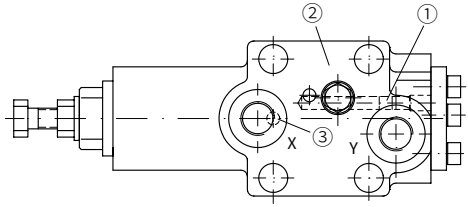


3.2 Pressure control (constant pressure systems)

c) Remote pressure control with pressure controller type P

The amplification or signal resolution must be higher than in the system a) when the pressure system utilizes long pipe and hose lines. A remote controlled pressure controller P has a substantially weaker measuring spring and therefore a substantially higher resolution which makes the P controller suitable for larger systems. The pressure range is not limited by the measuring spring because the pressure is determined by the piloting pressure limiting valve.
To attune the controller type P to the circuit and for stabilization purpose it has the bypass throttle ② and a pre-located dampening throttle ③ on the pilot valve. The signal line between controller type P and pilot valve must contain 50 ... 100 ml.
The pre-setting of the by-pass throttle is 1/4 -1/2 turn open. If the circuit is smaller than 5 l the bypass throttle can be opened further whereas it should be closed a bit further with larger pressurized oil capacities.
The control flow of the controller type P should be shut off till the pump pressure reaches 50 bar with the pre-located dampening throttle ⑨ on the pilot valve. At that point the throttle should be fixed.
When the controlled pressure range is intended to be lower than 50 bar, the oil capacity of the signal line must be at the upper limit of the appropriate capacity (100 ml). This way the pressure can be adjusted down to 25 - 30 bar without oscillations.
Should oscillations appear in spite of bypass adjustment, pre pilot throttle adjustment and appropriate capacity in the signal line a drain orifice ⑥ can be installed. The orifice diameter ranges from M6×0.8 to M6×1.6 (for type V30D-250).
This orifice can be installed at controller piston housing right below stamping "U" with standard versions to enable also controller combinations to be dampened (see illustration in Chapter 3.5). When the controller piston housing is prepared for fitting of a power controller the drain orifice has to be installed at the power controller or at the replacement cover L right below "U". This drain orifice slows down the response of the pump thereby dampening oscillations.

Adjustment of pressure controller type P (piloted)



① = Orifice M5×1.0
② = By-pass throttle
③ = Grub screw M6 at T1
(see illustration in Chapter 3.2.a)

3.2 Pressure control (constant pressure systems)

c) Remote pressure control with pressure controller type P

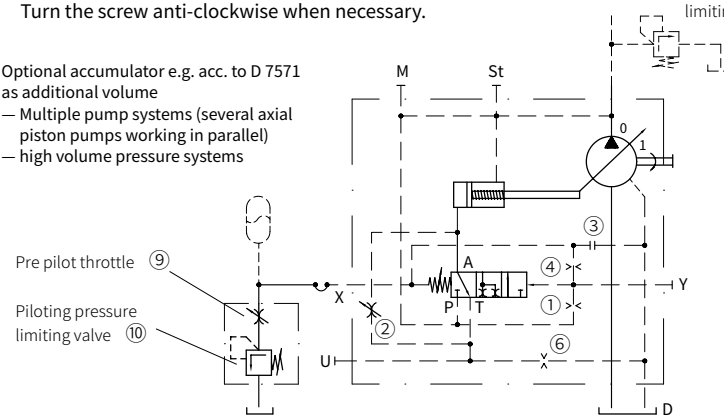
• Adjustment of pressure controller type P (piloted)

The starting positions of the adjustment screws are as follows:

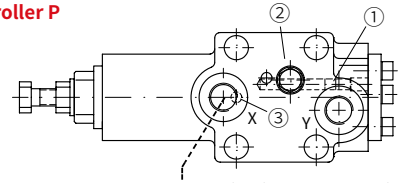
1. Adjustable bypass throttle ② :
   1/4 .. 1/2 turn open
   Tools: Spanner 10 mm
2. Drain orifice ⑥ (see Chapter 3.5) :
   Remove tapped plug "U" (M6) and check the orifice for contamination when installed.
   Tools: Allan key 5 mmand 3 mm
3. Pre pilot throttle ⑨
   Undo the locknut and turn the throttle needle anti-clockwise until it's 1 to 2 turns open
   Tools: Allan key 4 mmand spanner 13 mm
4. Pressure adjustment screw ⑩
   Undo the locknut and rotate the adjustment screw anti-clockwise until the controller spring is totally unloaded.
   Tools: 1 spanner 13 mm
5. Check the external pressure limiting valve ⑬ in the pump line, whether a low pressure is set.
   Turn the screw anti-clockwise when necessary.

External pressure limiting valve ⑬

Optional accumulator e.g. acc. to D 7571 as additional volume
— Multiple pump systems (several axial piston pumps working in parallel)
— high volume pressure systems

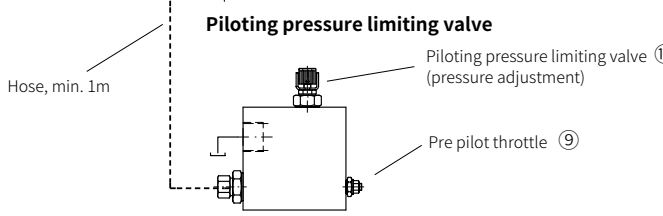


Pressure controller P



① = Orifice M5×1.0
② = By-pass throttle
③ = Grub screw M6 at T1
(see illustration in Chapter 3.2.a)
④ = Orifice 0.8 mm
⑥ = Orifice M6×1.2 (0.8 ... 1.6)

Piloting pressure limiting valve



3.2 Pressure control (constant pressure systems)

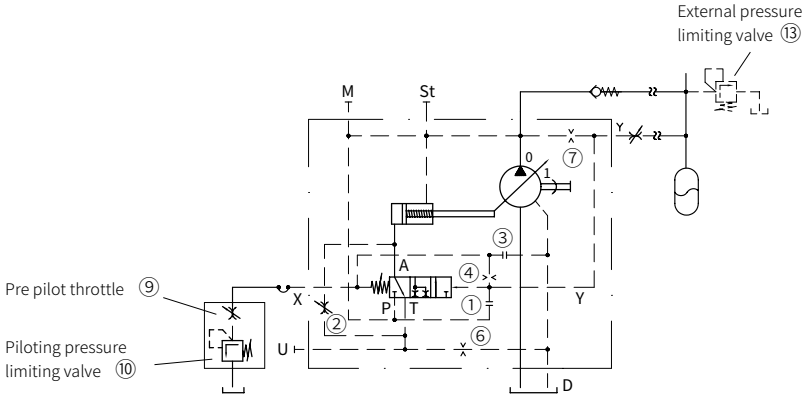
d) Remote pressure control for large circuits with pressure controller type Pb

(Pressure controller type ND with direct pressure reduction may be used as well, see Chapter 3.2.b)

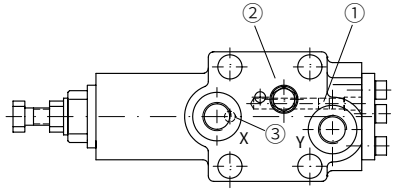
The measuring resolution must be even better for large circuits with big gas type accumulators than in system c), because the system pressure depends on the momentary filling grade of the accumulators and corresponds with that direct to the gas pressure. The compressibility is according to the relation of gas / oil amount with the factor 10 to 100 weaker than the compressibility of pure oil.
The measuring task of the pressure control becomes even more difficult when a check valve is installed (as in most of these cases) between pump and accumulator system. This check valve may close in bad cases and momentarily disconnect the pump from the system, which can lead to permanent oscillations.
Out of these reasons an additional signal port was added to the controller type P, enabling a more accurate measuring of the system pressure. This special controller is called Pb.
The special signal Port "Y" is connected via a T-connector directly to the pressure side of the control spool where two signal lines can be connected (between pos. ① and ④). The first line comes from the pressure port of the pump and can quickly inform the controller type Pb about the setting response of the pump.
The second signal line connects the controller type Pb to the circuit behind the check valve of the main line. This way the controller type Pb is permanently informed about the pressure in the whole system and can respond on even the slightest deviations.
Both signal lines are joint ahead of the controller type Pb and the pressure measuring side of the spool therefore gets a mixed pressure. That means an additional possibility to influence both lines with orifices differently. Thus it is possible to attune the controller type Pb optimally to the circuit. A stronger throttling of the signal line from the pressure port (orifice ⑦ has the effect that the pump is quicker on the up-stroke and slower on the down-stroke. Similarly the pump is slower stroking up and quicker stroking down if the signal line of the system is throttled stronger.
Also the controller type Pb features the standard bypass throttle and the pre-located dampening throttle on the pilot valve for stabilization and attuning to the system. While the bypass throttle is pre-adjusted to 1/4 -1/2 turn open, the pre-located throttle in the pilot signal line must be closed so far that the pump pressure reaches 50 bar with open pilot limiting valve.
The capacity of the signal line should be roughly 1% of the main line to ensure that the resonance characteristic of both match. The same applies to the accumulator. This way even pressure down to 25 ..30 bar can be set without oscillations.
Should there still be oscillations in spite of all these measures a drain orifice ⑥ should be installed. The orifice diameter ranges from M6×0.8 to M6×1.6 (for type V30D-250).
This orifice can be installed at controller piston housing right below stamping "U" with standard versions to enable also controller combinations to be dampened (see illustration in Chapter 3.5). When the controller piston housing is prepared for fitting of a power controller the drain orifice has to be installed at the power controller or at the replacement cover L right below "U". This drain orifice slows down the response of the pump thereby dampening oscillations.

3.2 Pressure control (constant pressure systems)

d) Remote pressure control for large circuits with pressure controller type Pb



Pressure controller Pb



① = Grub screw M5
② = By-pass throttle
③ = Grub screw M6 at T1
(see illustration in Chapter 3.2.a)
④ = Orifice 0.8 mm
⑥ = Orifice M6×1.2 (0.8 ... 1.6)
⑦ = Orifice M6×1.8

3.2 Pressure control (constant pressure systems)

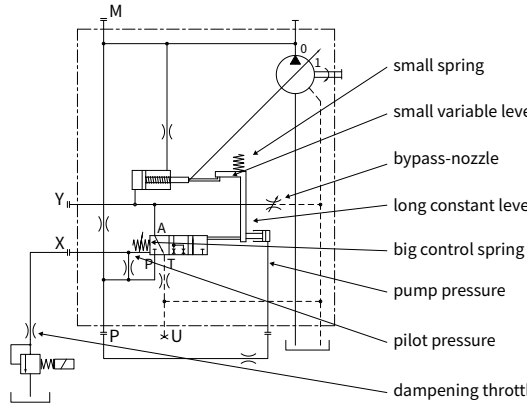
e) Remote parallel pressure control with pressure controller type PD5

A pressure control, that is capable to regulate pump pressure with swash angle in parallel to several neighbor pumps and their pressure controls, must get informed about the swash angle of his own pump. That information is given by the housing and the lever of the power control, in which a small spring force is subtracted from the bigger regulating spring, proportional to the stroke of the pump.

That will give an inclination to the characteristic control curve, which will be about 12 bar higher at zero than at full flow. That modulated characteristic allows the neighbor pump controls to regulate the same stroke at the same pressure level.
The regulating spring does not take full pressure force but a certain ΔP=40 bar only. The main amount of pressure created by the piloting PMVP valve resp. MVE valve.

To attune the control to the circuit and for stabilization purpose it has a bypass throttle and a pre-located dampening throttle on the pilot valve. The pre-setting of the bypass throttle is 1/2 turn out. The pre-setting of the dampening throttle is 0.8 mmas fixed one.

Should oscillations appear in spite of bypass and pre-pilot throttle adjustments a drain orifice (7) can be installed. The orifice diameter ranges from 1.2 mmto 0.8 mmand can be installed in the PD5 housing marked with the letter 'U'.



3.3 Flow control

a) Simple flow control with flow controller type Q

The flow of the pump can be maintained constant independent of the pump shaft speed and the pressure level in the system by means of a pressure-drop control via an orifice. Any consumer with fixed displacement e.g. a hydro-motor will be driven with constant speed independent of its load.
This controller type Q with only one signal line is suited for small systems, signal line has 10% of the main line capacity between pump and directional valve and a static accuracy of ± 2% is sufficient.
There is a metering orifice ⑮ in the main pressure line between pump and hydromotor, which has a pressure drop between 10-15 bar at the desired flow. The diameter for this orifice is calculated as follows:
$d(mm) = 0{,}7\sqrt{Q}$ Q = Flow (lpm).
The diameter determines the flow range which can be fine-tuned via the setting screw of the flow controller. Downstream this orifice is the Port "X_2" for the signal line to Port "X" at the controller type Q.
The signal line should be a hose with an internal diameter of 1/4" (6..9mm) and should have an adjustable needle throttle near to the measuring orifice.
For stabilization of the controller type Q there is a throttle ⑭ e.g. type ED11 acc. to D 7540 or type Q acc. to D 7730, beside by-pass throttle ② and drain orifice, in the signal line. The needle throttle should be set first with standard setting 1/2 to 1 turn open (a smaller adjustment gives a better dampening).
The standard opening of the bypass throttle ② is between 1/4 and 1/2 turn. A wider opening has beside the improved dampening effect also influence on the pressure drop of the control and increases it. Since, moreover, the amount of bypass oil increases with rising pressure (load) the opening of the by-pass throttle has more influence with higher pressure which causes an additional growing of the pressure drop. Therefore the output flow of the pump will increase over-proportionally with increasing load of the consumer (hydraulic motor). This influence is used to keep the output speed of consumers (hydro-motor) constant as this will compensate their higher leakage during load via a slightly increased pump delivery.
A drain orifice ⑥ can be mounted when oscillations should still occur in spite of proper adjustment of dampening and by-pass throttle ② . This orifice can be installed at controller piston housing right below stamping "U" with standard versions to enable also controller combinations to be dampened (see illustration in Chapter 3.5). When the controller piston housing is prepared for fitting of a power controller the drain orifice has to be installed at the power controller or at the replacement cover L right below "U". The orifice diameter ranges from M6×0.8 to M6×1.6 (for type V30D-250). This drain orifice slows down the response of the pump thereby dampening oscillations.

3.3 Flow control

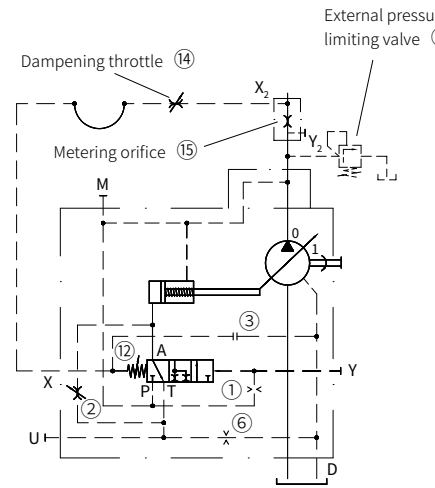
a) Simple flow control with flow controller type Q

• Adjustment of flow controller type Q

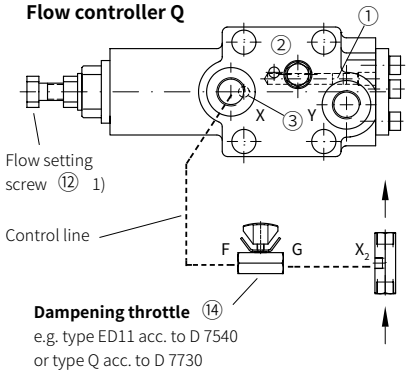
The starting positions of the adjustment screws are as follows:

1. Adjustable bypass throttle ② :
   1/4 .. 1/2 turn open
   Tools: Spanner 10 mm
2. Drain orifice ⑥ (see Chapter 3.5) :
   Remove tapped plug "U" (M6) and check the orifice for contamination when installed.
   Tools: Allan key 5 mmand 3 mm
3. Flow setting screw ⑫ [1)]
   Clockwise rotation increases, anti-clockwise rotation decreases the flow
   Tools: 2 spanners 13 mm
4. Dampening throttle ⑭
   Start with 1 ... 2 turns open
5. Signal line
   Hose, internal diameter 1/4" (6 ...9 mm)
6. Check the external pressure limiting valve ⑬
   in the pump line, whether a low pressure is set.
   Turn the screw anti-clockwise when necessary.

① = Orifice M5×1.0
② = By-pass throttle
③ = Grub screw M6 at T1
(see illustration in Chapter 3.2.a)
⑥ = Orifice M6×1.2 (0.8 ... 1.6)



Flow controller Q



Guideline for adjustment:
≙ ΔQ (lpm) ≈ 1.23 d^2/turn
(Δp = 4.5 bar/turn)
d-Orifice diameter (mm)

Note:
The lock-nut has to be loosened before adjustment to prevent damage of the vulcanized thread seal!

3.3 Flow control

b) Flow control with increased accuracy with flow controller type Qb

It is advisable to choose the more accurate controller type Qb for large systems, signal line has 10 % of the main line capacity between pump and directional valve and a static accuracy of ± 1 % is required.
The pressure-drop control over a constant orifice maintains a constant pump delivery flow, independent of the pump speed and the pressure level in the system. Any consumer with fixed displacement e.g. hydraulic motor will be driven with constant speed independent of its load.
There is a metering orifice ⑮ in the main pressure line between pump and hydromotor, which has a pressure drop between 10-15 bar at the desired flow. The diameter for this orifice is calculated as follows: $d(mm)=0{,}7\sqrt{Q}$ Q = Flow (lpm).
The diameter determines the flow range which can be fine-tuned via the setting screw of the flow controller type Qb. Upstream this orifice is Port "Y_2" for signal connection to Port "Y" of the flow controller type Qb. Downstream of it is the Port "X_2" for the signal line to Port "X" at the controller type Qb.
Both signal lines should be hoses with an internal diameter of 1/4" (6 ... 9 mm). Line X2-X should have an adjustable throttle ⑭ e.g. type ED11 acc. to D 7540 or type Q acc. to D 7730 near to the measuring orifice for stabilization of the controller. The additional Y signal line ensures more accuracy compared to the controller type Q because disturbances of the execution of the main pressure line and of the pump setting do not influence the measuring of the pressure drop directly at the measuring orifice ⑮ .
For stabilization of the controller type Qb there is beside the by-pass ② and the drain throttle yet the needle throttle (pos. 4) in the signal line. The needle throttle should be set first with standard setting 1/2 to 1 turn open (a smaller adjustment gives a better dampening). The standard opening of the bypass throttle ② is between 1/4 and 1/2 turn. A wider opening has beside the improved dampening effect also influence on the pressure drop of the control and increases it. Since, moreover, the amount of bypass oil increases with rising pressure (load) the opening of the by-pass throttle has more influence with higher pressure which causes an additional growing of the pressure drop. Therefore the output flow of the pump will increase over-proportionally with increasing load of the consumer (hydraulic motor). This influence is used to keep the output speed of consumers (hydraulic motor) constant as this will compensate their higher leakage during load via a slightly increased pump delivery.
A drain orifice ⑥ can be mounted when oscillations should still occur in spite of proper adjustment of dampening and by-pass throttle ② . This orifice can be installed at controller piston housing right below stamping "U" with standard versions to enable also controller combinations to be dampened (see illustration in Chapter 3.5). When the controller piston housing is prepared for fitting of a power controller the drain orifice has to be installed at the power controller or at the replacement cover L right below "U". The orifice diameter ranges from M6×0.8 to M6×1.6 (for type V30D-250). This drain orifice slows down the response of the pump thereby dampening oscillations.

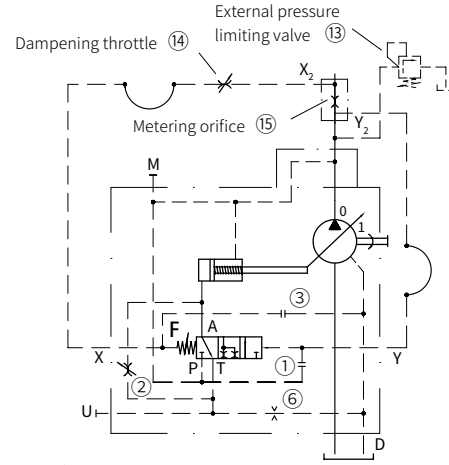
3.3 Flow control

b) Flow control with increased accuracy with flow controller type Qb

• Adjustment of flow controller type Qb

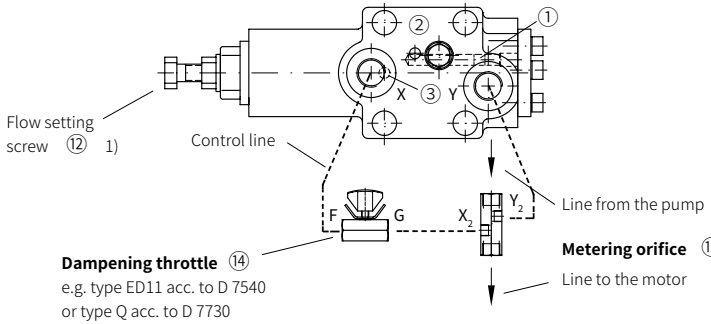
The starting positions of the adjustment screws are as follows:

1. Adjustable bypass throttle ② :
   1/4 .. 1/2 turn open
   Tools: Spanner 10 mm
   Ancestor version: Fixed by-pass orifice M6×1.0
   Tools: Allan key 5 mmand 3 mm
2. Drain orifice ⑥ (see Chapter 3.5) :
   Remove tapped plug "U" (M6) and check the orifice for contamination when installed.
   Tools: Allan key 5 mmand 3 mm
3. Flow setting screw ⑫ [1)]
   Clockwise rotation increases, anti-clockwise rotation decreases the flow
   Tools: 2 spanners 13 mm
4. Dampening throttle ⑭
   Start with 1 ... 2 turns open
5. Signal line
   Hose, internal diameter 1/4" (6 ...9 mm)
6. Check the external pressure limiting valve ⑬
   in the pump line, whether a low pressure is set.
   Turn the screw anti-clockwise when necessary.



Flow controller Qb

① = Grub screw M5
② = By-pass throttle
③ = Grub screw M6
⑥ = Orifice M6×1.2 (0.8 ... 1.6)



Note:
The lock-nut has to be loosened before adjustment to prevent damage of the vulcanized thread seal!

3.4 Load-Sensing controls

a) Simple Load-Sensing control with Load-Sensing controller type LS

The function of the controller type LS is quite similar to that of the flow controller type Q. Main difference is that type Q features a fixed main orifice whereas the one with type LS is variable, as usually several different consumers are to be supplied. Since the orifice can be even totally closed, it is not necessary that the pump pressure drops below the load pressure. In order to save energy the LS-signal line is automatically discharged to the tank when the main orifice is closed. This has the effect that the pump idles (zero stroke) with a standby pressure of only 20~30 bar which is created by the preload of the control spring.
The circuits with LS application spread from small up to large systems (see Chapter 3.3.a.+b.). These different sized systems require that the size of the signal line must be adapted to the respective system size.
The signal velocity respective the signal dampening is optimal when the capacity of the LS signal line has 10 % of the main line capacity between pump and directional valve. In case both lines have the same length the inner diameter of the LS signal line should be 1/3 of the inner diameter of the main pressure line. The signal line should preferably be a hose.
For fine tuning a needle throttle ⑭ should be installed in the signal line close to the directional valve. If some oscillations still occur this throttle can be closed down to 1/2 turn open.
In difficult cases a further stabilization can be achieved with the bypass throttle ② . It's preadjustment is between 1/4 and 1/2 turn open. The last step of stabilization is a drain orifice ⑥ that can be mounted when oscillations still occur in spite of proper adjustment of dampening and bypass throttle ② . This orifice can be installed at controller piston housing right below stamping "U" with standard versions to enable also controller combinations to be dampened (see illustration in Chapter 3.5). When the controller piston housing is prepared for fitting of a power controller the drain orifice has to be installed at the power controller or at the replacement cover L right below "U". The orifice diameter ranges from M6×0.8 to M6×1.6 (for type V30D 250). This drain orifice slows down the response of the pump thereby dampening oscillations.
A pressure control function can be obtained by connecting a pilot pressure limiting valve via a T-connector in the signal line between controller type LS and needle throttle (same function as with pressure controller type P acc. to 3.2.c.). Thus the controller type LS receives a pressure control function in addition as the pilot valve limits the pressure in the signal line resp. the pump pressure.

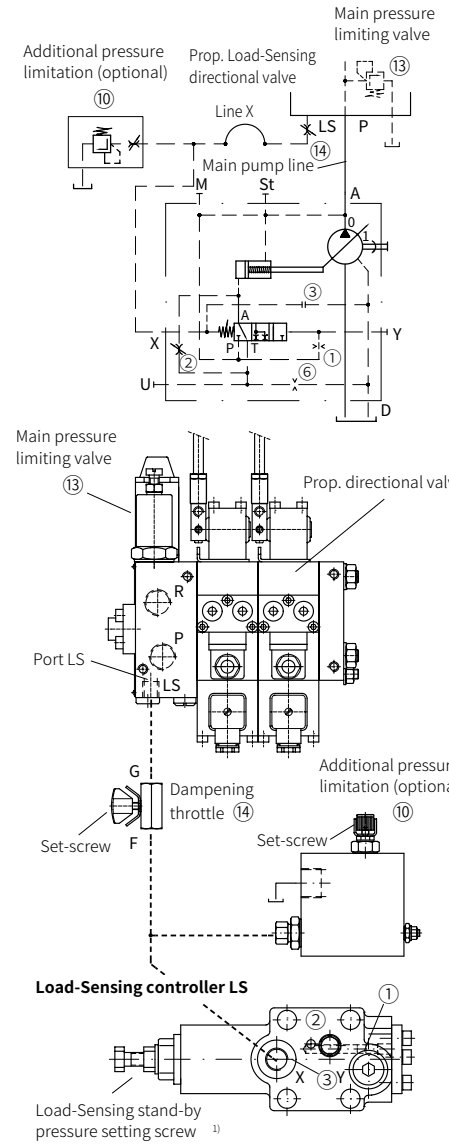
3.4 Load-Sensing controls

a) Simple Load-Sensing control with Load-Sensing controller type LS

• Adjustment of controller type LS

The starting positions of the adjustment screws are as follows:

1. Adjustable bypass throttle ② :
   1/4 .. 1/2 turn open
   Tools: Spanner 10 mm
2. Drain orifice ⑥ (see Chapter 3.5) :
   Remove tapped plug "U" (M6) and check the orifice for contamination when installed.
   Tools: Allan key 5mm and 3mm
3. Signal line
   The capacity of the LS signal line should be 10% of the main line capacity between pump and directional valve. In case both lines have the same length the inner diameter of the LS signal line should be 1/3 of the inner diameter of the main pressure line.
4. Dampening throttle ⑭
   Start with 2 ... 3 turns open
5. Pressure limitation for LS duct ⑩
   Turn set screw anti clockwise until stop.
6. Check the external pressure limiting valve ⑬ in the pump line, whether a low pressure is set.
   Turn the screw anti-clockwise when necessary.
7. Adjustment of standby pressure of the controller type LS.



① = Orifice M5×1.0
② = By-pass throttle
③ = Grub screw M6
⑥ = Orifice M6×1.2 (0.8 ... 1.6)

Adjustment guideline:
Δp = 14 bar/turn)

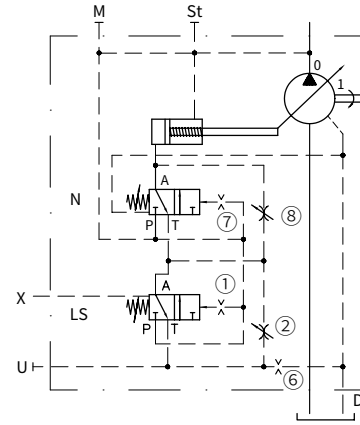
Note:
The lock-nut has to be loosened before adjustment to prevent damage of the vulcanized thread seal!

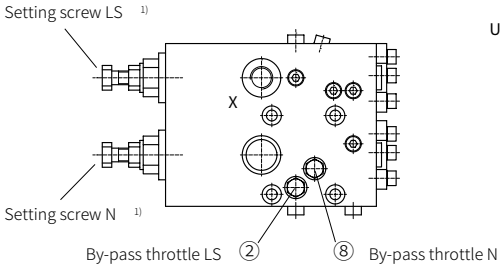
3.4 Load-Sensing controls

b) Load-Sensing control with additional pressure limitation with Load-Sensing controller type LSN

The function and stabilization of the controller type N is as detailed in Chapter 3.2.a).
Adjustment of the controller type LS is as detailed in Chapter 3.4.a)

When coordinating both controllers it is important that the by-pass throttle of the controller type N is always 1/2 turn more closed than the one of controller type LS. The drain orifice ⑥ (right below "U") covers both controllers and is installed and used as detailed in the previous sections.





① Orifice Ø1.0 mm(LS)
② By-pass throttle (LS)
⑥ Orifice M6×1.2 (0.8 ... 1.6)
⑦ Orifice Ø1.0 mm(N)
⑧ By-pass throttle (N)

Guideline for adjustment ΔP (bar/turn)	
LS	14
N 250	54
N 400	82

Note:
The lock-nut has to be loosened before adjustment to prevent damage of the vulcanized thread seal!

3.4 Load-Sensing controls

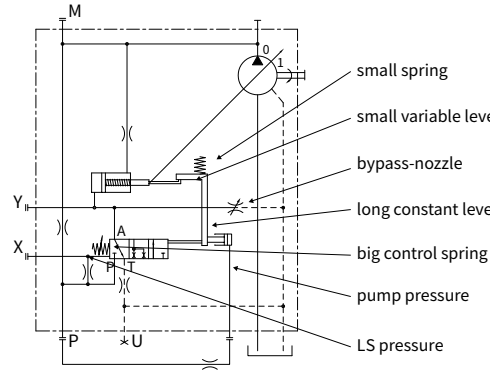
c) Parallel load-sensing control with load-sensing controller type LSD

A load-sensing control that is capable to regulate pump pressure with swash angle in parallel to several neighbor pumps and their load-sensing controls must get informed about the swash angle of his own pump.
That information is given by the housing and the lever of the power control in which a small spring force is subtracted from the bigger regulating spring proportional to the stroke of the pump.

That will give an inclination to the characteristic control curve, which will be about 12 bar higher at zero than at full flow. That modulated characteristic allows the neighbor pump controls to regulate the same stroke at the same pressure level.
The regulating spring does not take full pressure force but a certain ΔP=40 only. The main amount of pressure is created by load-pressure which is given from an LS valve via LS-line.

To attune the LSD-control to the circuit and for stabilization purpose it has a bypass throttle and a pre-located dampening throttle on the LS-line. The pre-setting of the bypass throttle is 1/2 turn open. The pre-setting of the dampening throttle is 0.8 mmas fixed one.

Should oscillations appear in spite of bypass and pre-pilot throttle adjustments a drain orifice (7) can be installed. The orifice diameter ranges from 1.2 mmto 0.8 mmand can be installed in the LSD housing marked with the letter 'U'.

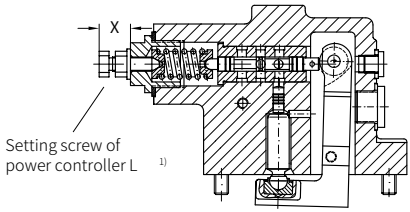


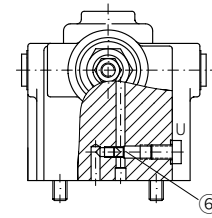
3.5 Power control

a) Power control with power controller type L

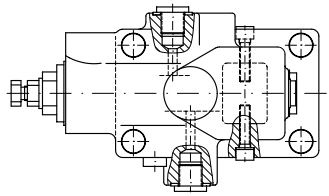
The power control can be used in all kinds of circuits in spite of the fact that it lacks a stabilizing by-pass throttle. The reason for this self-stabilization is that not one but two status values are fed back to the power control.
Apart from the actual system pressure also the actual displacement of the pump is fed to the force-comparing control spool by a stroke-depending length of a measuring lever.
This double feed back acts so prompt and well-timed that no further stabilization measures are necessary apart from a optional drain orifice.
This orifice is located below the letter "U" as detailed in the previous sections. This place was chosen in order to have only one drain orifice for all controller combinations. The drain orifice slows down the up-stroking of the pump and has a dampening effect on oscillation stimulations.
The thread is M6 and the hole is between Ø1.8 mmin the big V30D-250 and down to Ø0.8 mmin the smaller pumps.
Since the power controller type L is the last member in the chain of controller combinations, the drain orifice ⑥ must be installed also in the power controller for pre-connected controllers of the combination. This drain orifice slows down the response of the pump thereby dampening oscillations.
Guidelines for adjustment of the power controller L are illustrated in the curve in Chapter 3.5b).

Power controller L

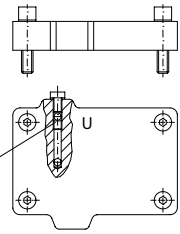




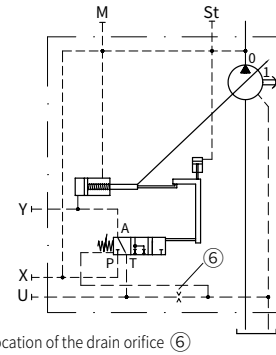
Drain orifice M6×1.2 (0.8 ... 1.6) for versions with power controller (not apparent with type N/ND)



Cover at the controller head
(without power controller L)

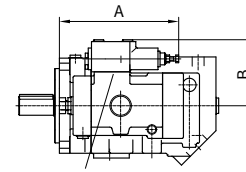


Optional drain orifice
M6×1.2 (0.8 ... 1.8)
in the pump housing with
type V30D- 095(115)



Location of the drain orifice ⑥
M6×1.2 (0.8...1.6) with type V30D-045 (075, 140, 160)
without power controller

Note:
The lock-nut has to be loosened before adjustment to prevent damage of the vulcanized thread seal!

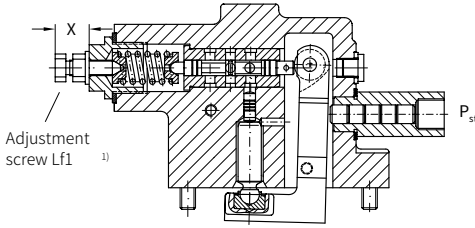


Orifice ⑥ below the controller

3.5 Power control

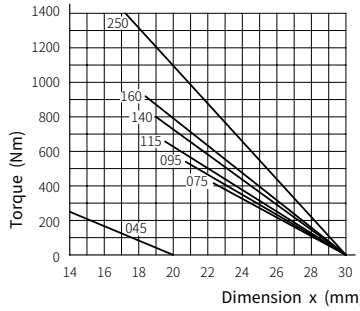
b) Variable power control with power controller type Lf1

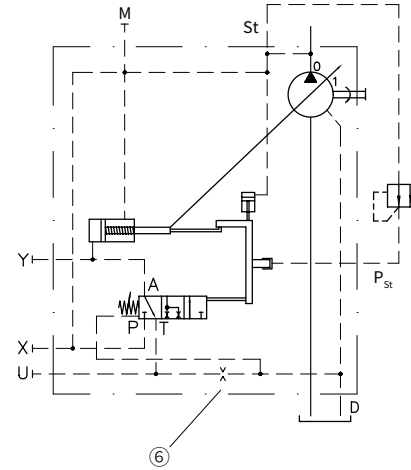
The hydraulically adjustable power controller type Lf1 works without control pressure at Port "P_{st}" just like a standard power controller type L.
The pressure at control Port "P_{st}" proportionally compensates the force of the controller spring and therewith reduces both the spring force set via the adjustment screw and the set power.
The working direction of the control pressure from nominal power to minimal power has the advantage that the own pump pressure can be used as source for the control pressure.
A pressure reducing valve installed between pump pressure and control pressure suffices to regulate the pump between nominal power (no control pressure) and zero power (open valve). At power less than 50% of the corner performance this controllable power controller can be regarded also as rough pump delivery flow control valve.
An additional advantage is that the set nominal power cannot be overridden by the control.
Stabilization is like with standard power controller L via a drain orifice. It has to be installed by the customer with pumps equipped power controller. Installation position is marked "U" below the (see illustration below).
Since the power controller type L is the last member in the chain of controller combinations, the drain orifice ⑥ must be installed also in the power controller for pre-connected controllers of the combination. Recommended diameter is Ø1.8 mmin the big V30D-250 and down to Ø0.8 mmin the smaller pumps. This drain orifice slows down the response of the pump thereby dampening oscillations.



Note:
The lock-nut has to be loosened before adjustment to prevent damage of the vulcanized thread seal!

Rough guideline for the setting of the power controller





Power calculation:
P (kW) = M (Nm) × n (rpm) / 9550
Example: V30D.250.../L; x = 21mm, i.e. torque M, 1000 Nm
Drive motor speed n, 1450 rpm; P = 1000 • 1450/9550, 152 kW

3.6 Proportional flow control

a) Hydraulic proportional controller type VH

The displacement of a variable pump with hydraulic proportional control can be set according to the pilot pressure in the range 7 ... 32 bar.

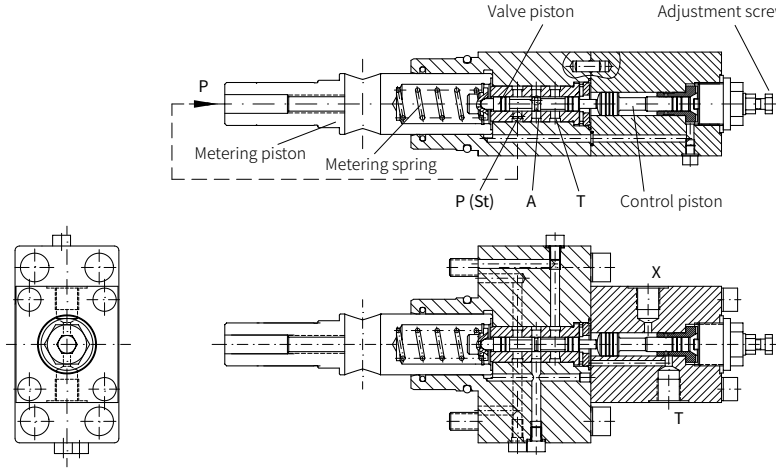
- **Design**

A variable piston pump features a swash plate that can be tilted and which is linked to the setting piston. The stroke of the setting piston determines the displacement of the pump. For a hydraulic proportional control there is a measuring spring acting on the larger side of the setting piston and on the spool of the proportional valve.
Because the setting pressure is also acting on the proportional spool, the opposite end is counterbalanced by receiving the same pressure. In the control part it is the same case. Both far ends of the spools (small areas) get the same setting pressure. The annular areas of the differential spool have at the side to the proportional valve a pressureless tank connection and at the plug side the control pressure P_{St}. That offers the possibility to act with a control pressure against the measuring spring.

- **Supply and control circuit diagram**

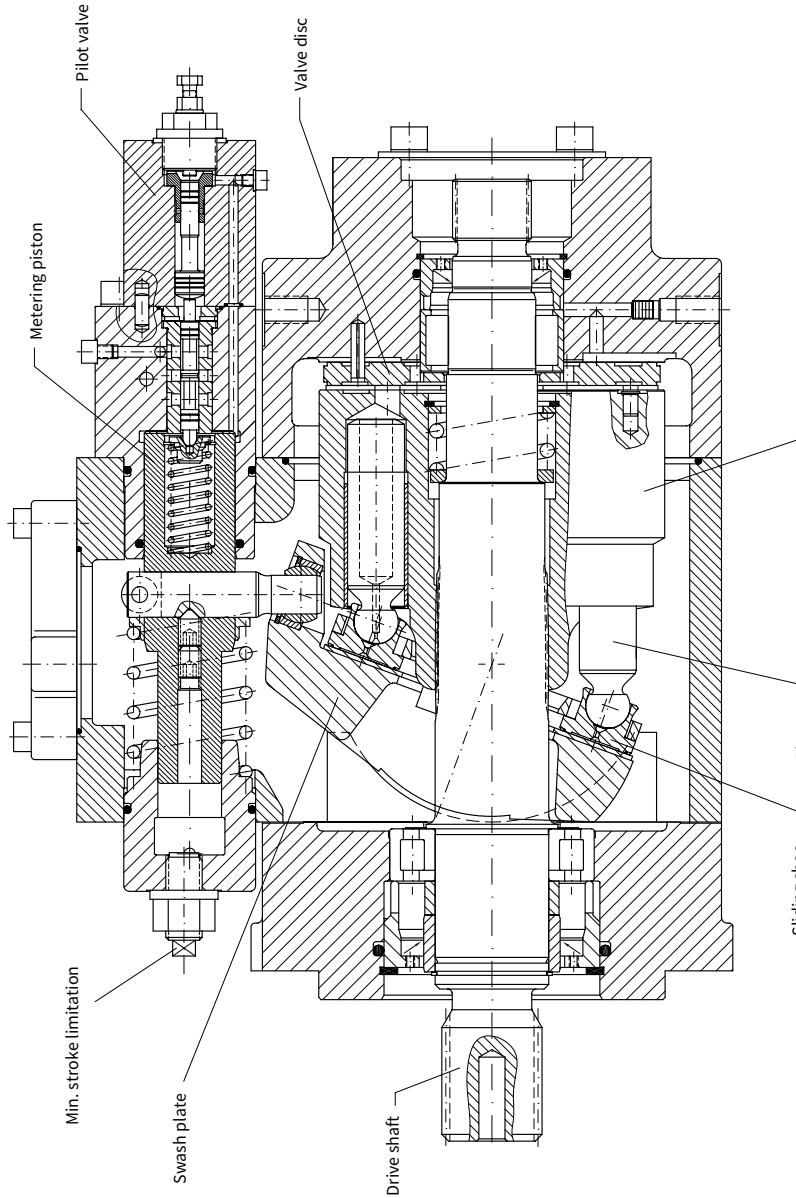
The minimum displacement of the main pump is no stroke i.e. zero flow therefore no sufficient pressure to supply the controller piston is available in such conditions. Therefore a servo pump is needed, which has to be connected to Port "St" via a check valve.
The other check valve in the main pump makes sure that always the higher pressure is fed to the controller piston. The servo pump should deliver 14 lpm (for V30D 250) and 7...10 lpm for the smaller pumps at a pressure of 50 - 60 bar.
A second pressure line from the servo pump can be used as supply for the control port respectively for the pilot pressure limiting valve. This line must have an orifice to limit the flow down to 1 ... 2 lpm.
The control pressure must show a range of approx. 7 bar (zero flow) up to approx. 32 bar (full pump delivery flow).

Hydraulic proportional controls type VH



3.6 Proportional flow control

a) Hydraulic proportional controller type VH



Hydraulic proportional controls type VH

3.6 Proportional flow control

a) Hydraulic proportional controller type VH

- **Function**

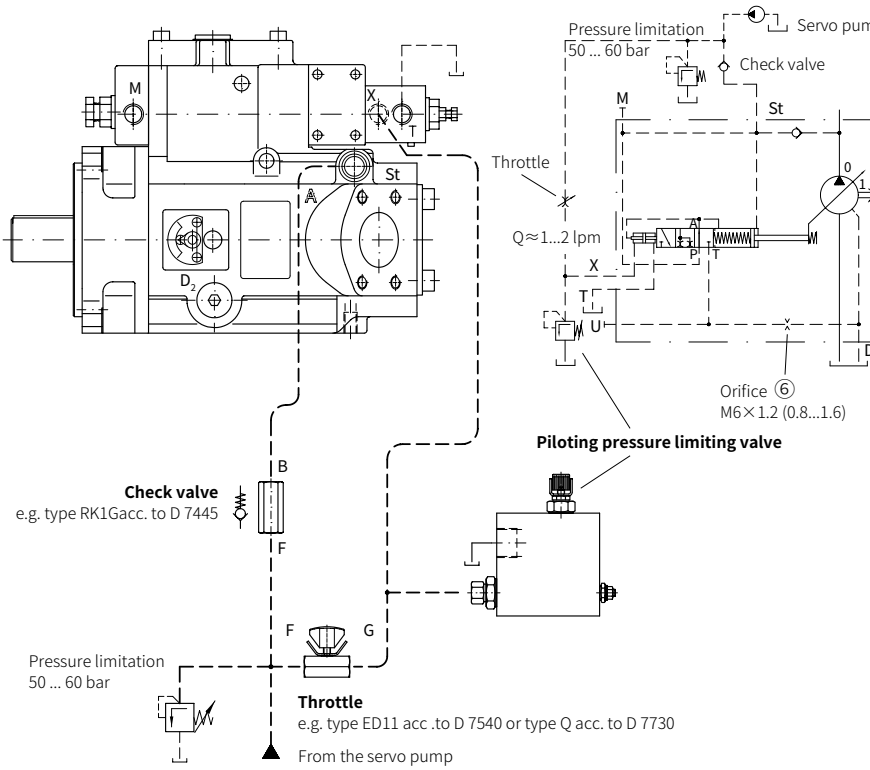
The cross-sectional view of the controller shows the parts in idle position. The main pump is supplied with servo pressure via Port "St" as soon as the servo pump is started. The piloting pressure limiting valve is usually open during start of operation, i.e. only a minimum pressure is apparent at Port "X". Thus enabling the metering spring to push the piston to its mechanical stop. This opens a passage to the larger area of the piston which returns the swash plate to its idle position. There is always pressure apparent at the smaller side of the control piston.
When the piloting pressure limiting valve is set higher than 7 bar both control and valve piston will move with the metering spring connecting the larger area of the control piston with the tank. The control piston will move the swash plate against the metering spring in direction of increased delivery flow and loading the metering spring. This movement will stop as soon as the forces of the metering spring and the pressure at the piloting pressure limiting valve are balanced thereby closing the prop. valve.
The swash plate is completely elevated (full stroke of the pump pistons) when 32 bar of piloting pressure are achieved. A gear pump is recommended as servo pump.

- **Adjustment**

The stroke of the valve is adjustable via a set screw (M6 with seal lock nut) at the facial side of the valve, allowing a fine tuning of the amplification and resolution. The servo pump must be running and the piloting pressure limiting valve be open for any kind of adjustment (main pump may stand still).
The first thing to do is to detect the response point of the swash plate. Turn the set screw clockwise after the lock nut is loosened. The swash plate will respond immediately after a few turns (visible at the swash plate angel indicator). Now the set screw is turned counter-clockwise by 1 to 1.5 turns after the first response is detected. The lesser the set screw is turned back the more sensitive the pump will be.
A drain orifice ⑥ can be installed when oscillations (uneven pump delivery) occur. This orifice can be installed at controller piston housing right below stamping "U" with standard versions to enable also controller combinations to be dampened (see illustration in Chapter 3.5).
When the controller piston housing is prepared for fitting of a power controller the drain orifice has to be installed at the power controller or at the replacement cover L right below "U". The orifice diameter ranges from M6×0.8 to M6×1.6 (for type V30D-250). This drain orifice slows down the response of the pump thereby dampening oscillations.

3.6 Proportional flow control

a) Hydraulic proportional controller type VH



Hydraulic proportional controls type VH

3.6 Proportional flow control

b) Electro-hydraulic proportional controls type V

The displacement of a variable displacement pump can be adjusted via an electro-hydraulic proportional adjustment. Control current range is ca. 300 mA to ca. 800 mA.

- **Design**

An adjustable axial piston pump features a hinged swash plate linked with a control piston. The lift of the control piston determines the displacement of the pump. The electro-hydraulic proportional control is based on a balance of forces between the solenoid and the metering spring both connected via the valve piston. Both the control piston and the proportional solenoid are pressure compensated to prevent any influence of the control pressure. This allows influencing the position of the control piston via the current applied to the proportional solenoid.

- **Supply with servo pressure**

The main pump cannot supply sufficient pressure for the control piston when idling (zero delivery position). It is therefore necessary that a servo pump is connected to Port "St" of the main pump via a check valve. This check valve and the one installed in the main pump act like a shuttle valve making sure that always the higher pressure is fed to the control piston. The servo pump must deliver 14lpm for the V30D-250 and 7 to 10lpm for the smaller versions at 50 to 60 bar.

- **Current supply**

A special power supply for the prop. solenoid is required to ensure a low hysteresis. A amplifier card should be used for the solenoid which delivers the required current in rectangular pulses. Recommended are the InLine Hydraulik prop. amplifiers type EV1M2 acc. to D 7831/1, EV22K2 acc. to D 7817/1 or EV1G1 acc. to D 7837 or the programmable logical valve controls type PLVC acc. to D 7845.
The solenoid force is determined via the pulse width, dither frequency should be 80 Hz. Both min. and max. current values can be adjusted to suit the prop. solenoid. The min. current value should be a set just below the point where the pump starts delivering to prevent any start-up hesitation. The max. current value should be set below the max. rating for the proportional solenoid.
The reference voltage can be set via a potentiometer (0 ... 10V DC) which is self-supplied by the card.
The response time can be set via ramp functions.

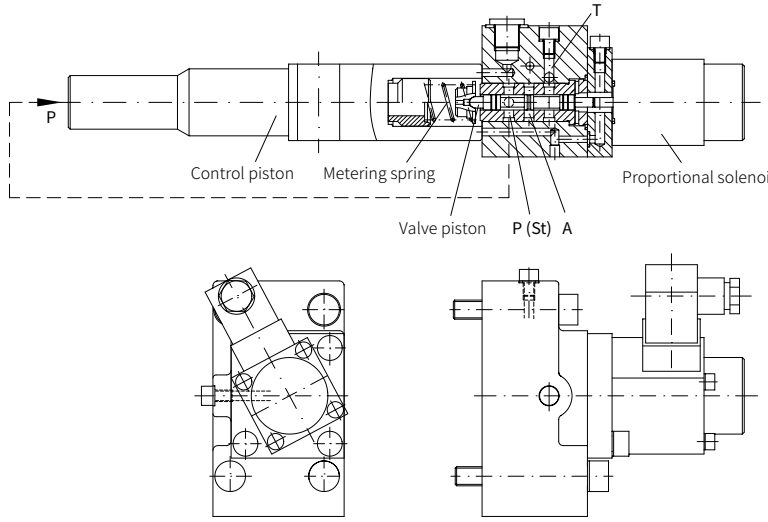
3.6 Proportional flow control

b) Electro-hydraulic proportional controls type V

- **Function**

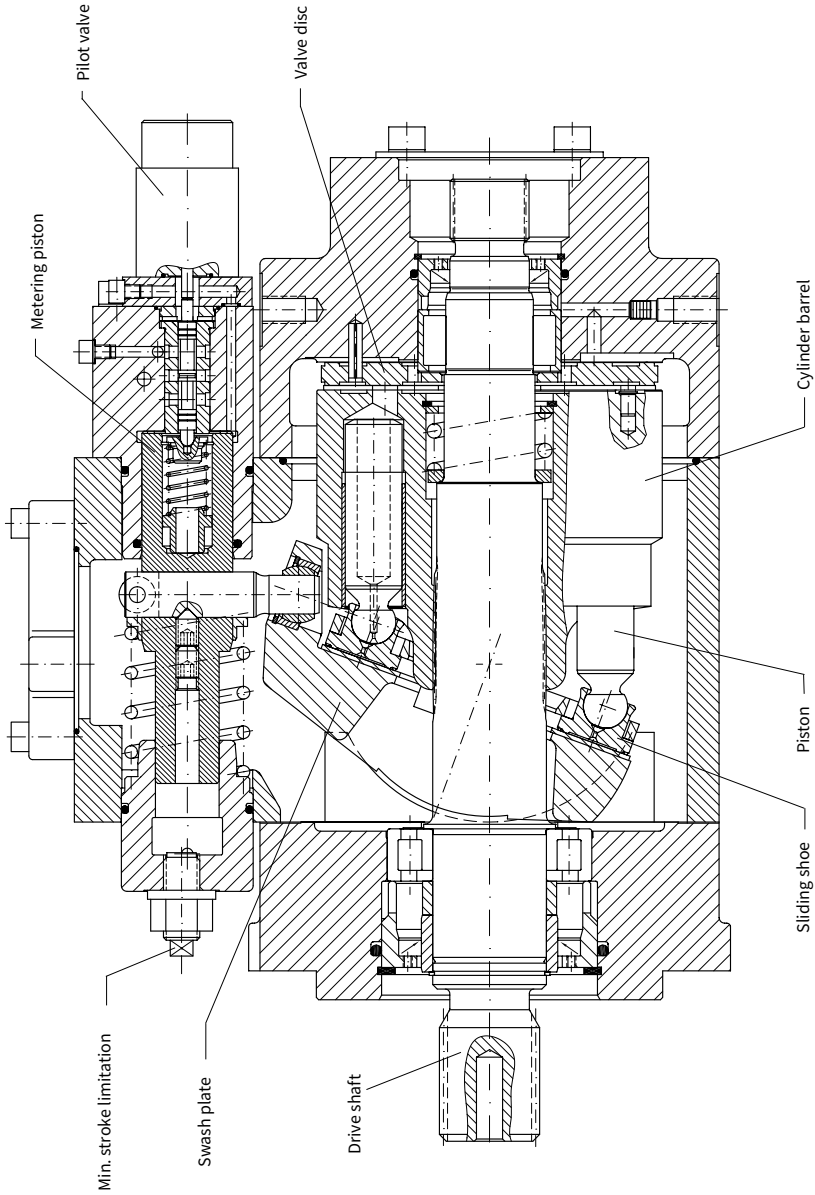
The cross-sectional view of the controller shows the parts in idle position. The main pump is supplied with servo pressure via Port "St" as soon as the servo pump is started. The solenoid is usually deenergized during start of operation, i.e. the valve piston is pushed against its stop by the metering spring. This opens a passage to the larger area of the piston which returns the swash plate to its idle position. There is always pressure apparent at the smaller side of the control piston.
When the solenoid is energized with 300 mA (24V DC-solenoid) or 600 mA (12V DC-solenoid) it will push the valve piston against the spring force thereby connecting the larger area of the control piston with the tank. The control piston will move the swash plate against the metering spring in direction of increased delivery flow and loading the metering spring. This movement will stop as soon as the forces of the metering spring and the proportional solenoid are balanced thereby closing the prop. valve.
Both total delivery flow and total stoke of the solenoid are achieved when the solenoid is energized with 800 mA (24V DC-solenoid) or 1600 mA (12V DC-solenoid).

Hydraulic proportional controls type V



3.6 Proportional flow control

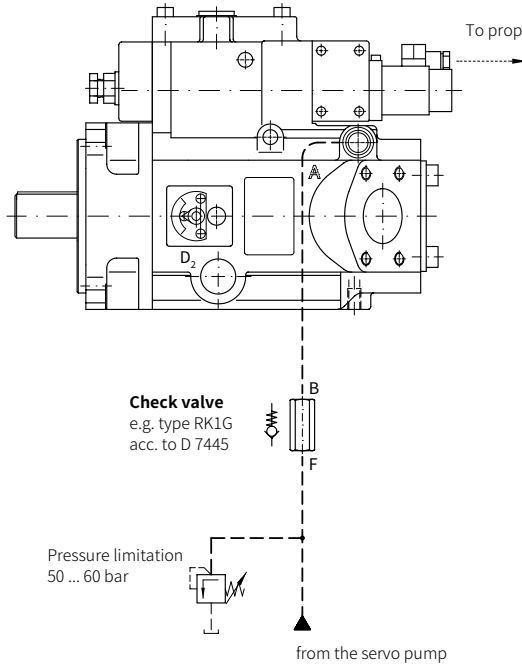
b) Electro-hydraulic proportional controls type V

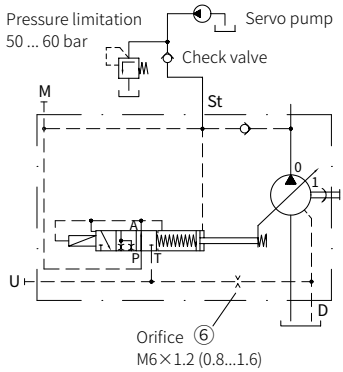


Electro-hydraulic proportional controls type V

3.6 Proportional flow control

b) Electro-hydraulic proportional controls type V





A drain orifice ⑥ can be installed when oscillations (uneven pump delivery) occur. This orifice can be installed at controller piston housing right below stamping "U" with standard versions to enable also controller combinations to be dampened (see illustration in Chapter 3.5).

When the controller piston housing is prepared for fitting of a power controller the drain orifice has to be installed at the power controller or at the replacement cover L right below "U". The orifice diameter ranges from M6×0.8 to M6×1.6 (for type V30D-250). This drain orifice slows down the response of the pump thereby dampening oscillations.

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