

The Drive & Control Company

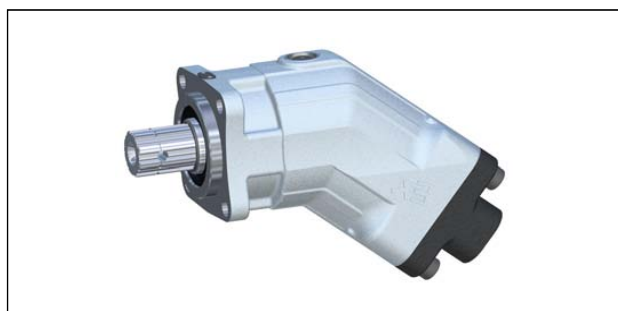
Rexroth
Bosch Group

Axial piston fixed pump A17FO Series 10

RE 91520

Issue: 11.2015

Replaces: 10.2014



- ▶ High-pressure pump for use in commercial vehicles
- ▶ Sizes 23 to 107
- ▶ Nominal pressure/maximum pressure 350/400 bar
- ▶ Bent-axis design
- ▶ Open circuit

Features

- ▶ Flange and shaft designed for direct mounting on the power take-off of commercial vehicles
- ▶ Weight-optimized thanks to diecast aluminum housing.
- ▶ No case drain line necessary
- ▶ Reduced noise
- ▶ Straightforward adjustment of direction of drive
- ▶ Excellent suction performance
- ▶ High total efficiency
- ▶ Long service life

Contents

Ordering code	2
Hydraulic fluid	3
Operating pressure range	4
Technical Data	5
Direction of rotation	7
Dimensions, sizes 23, 32	8
Dimensions, size 45	9
Dimensions, size 63	10
Dimensions, size 80	11
Dimensions, size 107	12
Accessories	13
Installation instructions	15
Other related documents	15
Project planning notes	16
Safety instructions	16

RE 91520/11.2015, Bosch Rexroth AG

Knowledge is POWER – Motion Force Control is our Business

HYQUIP Limited New Brunswick Street Horwich Bolton Lancashire BL6 7JB UK

2 A17FO Series 10 | Axial piston fixed pump Ordering code

Ordering code

01	02	03	04	05	06	07	08	09	10	11	
A17F	O		/	10	N	L	W	K0	E8	1	-

Axial piston unit

01	Bent-axis design, fixed, nominal pressure 350 bar, maximum pressure 400 bar, for commercial vehicles (truck)	A17F
----	--	------

Operating mode

02	Pump, open circuit	O
----	--------------------	---

Sizes (NG)

03	Geometric displacement, see table of values on page 5	023	032	045	063	080	107
----	---	-----	-----	-----	-----	-----	-----

Series

04	Series 1, index 0	10
----	-------------------	----

Configuration of port and fastening threads

05	Metric, port threads with profiled sealing ring according to DIN 3852	N
----	---	---

Direction of rotation¹⁾

06	Viewed on drive shaft	counter-clockwise	L
----	-----------------------	-------------------	---

Sealing material

07	FKM (fluor-caoutchouc) including the 2 shaft seal rings in FKM	W
----	--	---

Mounting flange

08	Special flange ISO 7653-1985 (for trucks)	K0
----	---	----

Drive shaft

09	Splined shaft similar to DIN ISO 14 (for trucks)	E8
----	--	----

Service line port

10	Threaded ports A and S at rear	1
----	--------------------------------	---

Standard / special version

11	Standard version	0
	Special version	S

Note

Note the project planning notes on page 16.

¹⁾ Changing the direction of rotation see instruction manual 91520-01-B, chapter 6.4.2

Hydraulic fluid

The fixed pump A17FO is designed for operation with HLP mineral oil according to DIN 51524.

Application instructions and requirements for hydraulic fluids should be taken from the following data sheets before the start of project planning:

- ▶ 90220: Hydraulic fluids based on mineral oils and related hydrocarbons
- ▶ 90221: Environmentally acceptable hydraulic fluids
- ▶ 90222: Fire-resistant, water-free hydraulic fluids (HFDR/HFDU)

The axial piston unit is not suitable for operation with water-containing HF hydraulic fluid.

Notes on selection of hydraulic fluid

The hydraulic fluid should be selected such that the operating viscosity in the operating temperature range is within the optimum range (v_{opt} see selection diagram).

Note

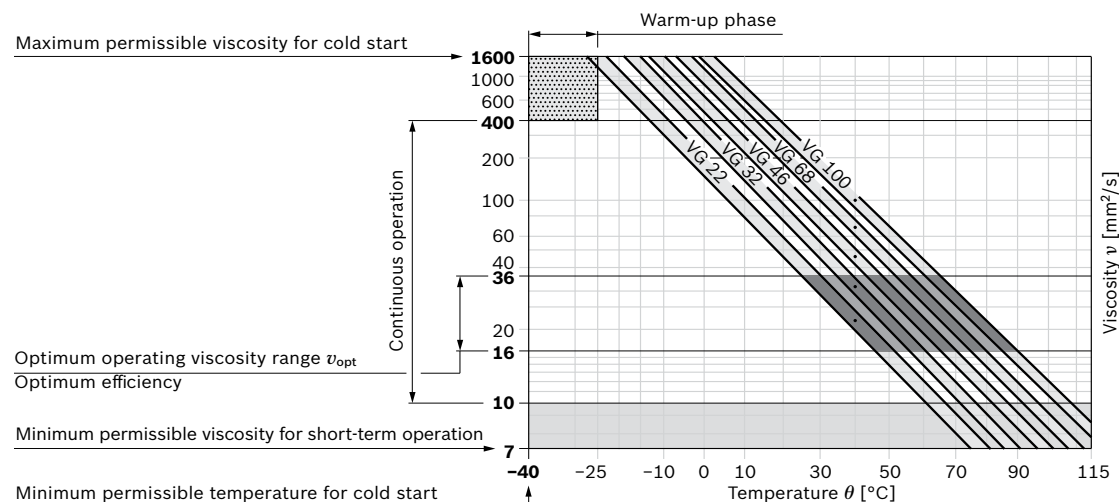
At no point of the component may the temperature be higher than 115 °C. The temperature difference specified in the table is to be taken into account when determining the viscosity in the bearing.

Please contact us if the above conditions cannot be met due to extreme operating parameters.

Viscosity and temperature of hydraulic fluids

	Viscosity	Temperature	Comment
Cold start	$v_{max} \leq 1600 \text{ mm}^2/\text{s}$	$\theta_{St} \geq -25 \text{ °C}^{1)}$	$t \leq 3 \text{ min}$, without load ($p \leq 50 \text{ bar}$), $n \leq 1000 \text{ rpm}$
Permissible temperature difference		$\Delta T \leq 25 \text{ K}$	between axial piston unit and hydraulic fluid in the system
Warm-up phase	$v < 1600 \text{ to } 400 \text{ mm}^2/\text{s}$		at $p \leq 0.7 \times p_{nom}$, $n \leq 0.5 \times n_{nom}$ and $t \leq 15 \text{ min}$
Continuous operation	$v = 400 \text{ to } 10 \text{ mm}^2/\text{s}$		this corresponds, for VG 46 for example, to a temperature range of +5 °C to +85 °C (see selection diagram)
		$\theta = -25 \text{ °C to } +103 \text{ °C}$	measured at air bleed port R observe permissible temperature range of the shaft seal ring ¹⁾ ($\Delta T = \text{approx. } 12 \text{ K}$ between bearing/shaft seal and port R)
	$v_{opt} = 36 \text{ to } 16 \text{ mm}^2/\text{s}$		range of optimum operating viscosity and efficiency
Short-term operation	$v_{min} \geq 7 \text{ mm}^2/\text{s}$		$t < 3 \text{ min}$, $p < 0.3 \times p_{nom}$

▼ Selection diagram



¹⁾ The FKM shaft seal is permissible for temperatures of -25 °C to +115 °C, please contact us for temperatures below -25 °C.

4 A17FO Series 10 | Axial piston fixed pump Operating pressure range

Filtration of the hydraulic fluid

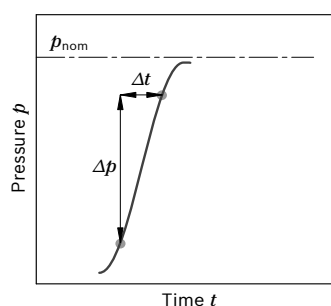
Finer filtration improves the cleanliness level of the hydraulic fluid, which increases the service life of the axial piston unit. A cleanliness level of at least 20/18/15 is to be maintained according to ISO 4406.

At very high hydraulic fluid temperatures (90 °C to maximum 103 °C, measured at air bleed port **R**), a cleanliness level of at least 19/17/14 according to ISO 4406 is necessary.

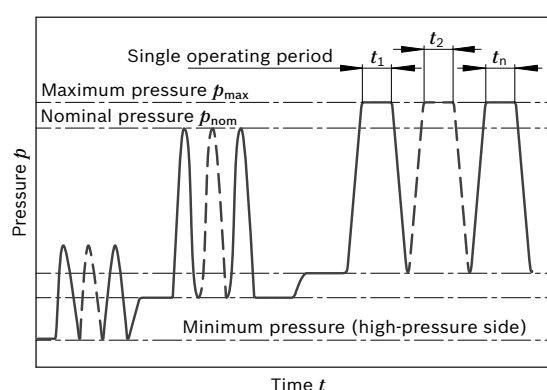
Operating pressure range

Pressure at service line port A (high-pressure side)		Definition
Nominal pressure p_{nom}	350 bar absolute	The nominal pressure corresponds to the maximum design pressure.
Maximum pressure p_{max}	400 bar absolute	The maximum pressure corresponds to the maximum operating pressure within the single operating period. The sum of the single operating periods must not exceed the total operating period.
Single operating period	5 s	
Total operating period	50 h	
Minimum pressure (high-pressure side)	10 bar absolute	Minimum pressure at the high-pressure side (A) which is required in order to prevent damage to the axial piston unit.
Rate of pressure change $R_{A max}$	9000 bar/s	Maximum permissible rate of pressure rise and reduction during a pressure change over the entire pressure range.
Pressure at suction port S (inlet)		
Minimum pressure $p_{S min}$	0.8 bar absolute	Minimum pressure at suction port S (inlet) which is required in order to prevent damage to the axial piston unit. The minimum pressure is dependent on the speed of the axial piston unit.
Maximum pressure $p_{S max}$	2 bar absolute	

▼ Rate of pressure change $R_{A max}$



▼ Pressure definition



$$\text{Total operating period} = t_1 + t_2 + \dots + t_n$$

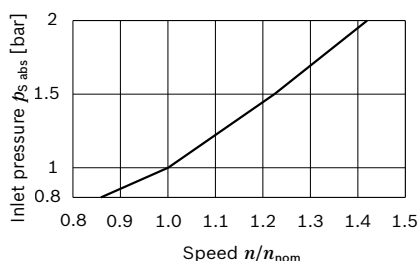
Note

Operating pressure range valid when using hydraulic fluids based on mineral oils. Values for other hydraulic fluids, please contact us.

Technical Data

Size	NG		23	32	45	63	80	107
Displacement, geometric, per revolution	V_g	cm ³	22.9	32	45.6	63	80.4	106.7
Speed maximum ¹⁾	$n_{nom}^{2)}$	rpm	3050	2750	2650	2200	2150	2000
	$n_{max}^{3)}$	rpm	4300	3900	3800	3200	3100	2800
Flow at n_{nom}	q_v	l/min	70	88	121	139	173	213
Power at n_{nom} and $\Delta p = 350$ bar	P	kW	41	51	71	81	101	124
Torque at $\Delta p = 350$ bar	T	Nm	127	178	254	351	448	594
Rotary stiffness	c	kNm/rad	2.56	3.12	4.18	6.25	8.73	11.2
Moment of inertia for rotary group	J_{TW}	kgm ²	0.0012	0.0012	0.003	0.0042	0.0072	0.0116
Maximum angular acceleration	α	rad/s ²	6500	6500	14600	7500	6000	4500
Case volume	V	l	0.25	0.29	0.4	0.5	0.6	0.75
Mass moment	T_G	Nm	4.7	4.7	8.6	9.9	15.3	20
Mass (approx.)	m	kg	5.9	5.9	8.4	9.3	12.3	15.0

▼ Maximum speed (limiting speed)



Determining the operating characteristics

Flow	$q_v = \frac{V_g \times n \times \eta_v}{1000}$	[l/min]
Torque	$T = \frac{V_g \times \Delta p}{20 \times \pi \times \eta_{hm}}$	[Nm]
Power	$P = \frac{2 \pi \times T \times n}{60000} = \frac{q_v \times \Delta p}{600 \times \eta_t}$	[kW]

Key

V_g	Displacement per revolution [cm ³]
Δp	Differential pressure [bar]
n	Speed [rpm]
η_v	Volumetric efficiency
η_{hm}	Hydraulic-mechanical efficiency
η_t	Total efficiency ($\eta_t = \eta_v \times \eta_{hm}$)


Note

- Theoretical values, without efficiency and tolerances; values rounded.
- Operation above the maximum values or below the minimum values may result in a loss of function, a reduced service life or in the destruction of the axial piston unit. Other permissible limit values, such as speed variation, reduced angular acceleration as a function of the frequency and the permissible angular acceleration at start (lower than the maximum angular acceleration) can be found in data sheet 90261.

- The values are applicable:
 - for the optimum viscosity range from $\nu_{opt} = 36$ bis 16 mm²/s
 - for hydraulic fluids based on mineral oils.
- The values apply at absolute pressure $p_{abs} = 1$ bar at suction port **S**
- Maximum speed (speed limit) with increased inlet pressure p_{abs} at suction port **S** (see diagram).

6 **A17FO Series 10** | Axial piston fixed pump
Operating pressure range

Permissible axial forces of the drive shaft

Size		NG	23	32	45	63	80	107
Maximum axial force, at standstill or pressure-free operation		+ F_ax max N	0	0	0	0	0	0
		- F_ax max N	24	33	43	53	60	71

- Note**
- ▶ The values given are maximum values and do not apply to continuous operation.
 - ▶ The permissible axial force in direction $-F_{ax}$ is to be avoided as the lifetime of the bearing is reduced.
 - ▶ Radial forces are not permissible.

Direction of rotation

The direction of rotation of the axial piston unit is defined by means of a pressure connection screwed into the service line port and can easily be changed.

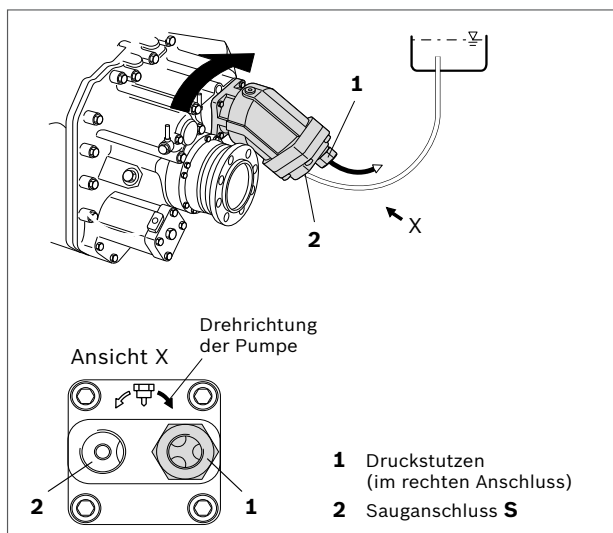
By changing the pressure connection, the service line port and the suction port are exchanged. As a result, the permissible drive direction is changed. This is necessary when mounting on a power take-off with counter-clockwise rotation, for example. The procedure for conversion of the pressure nipple can be found in the instruction manual (91520-01-B, chapter 6.4.2 "Direction of rotation and change of direction of rotation").

Direction of rotation on delivery

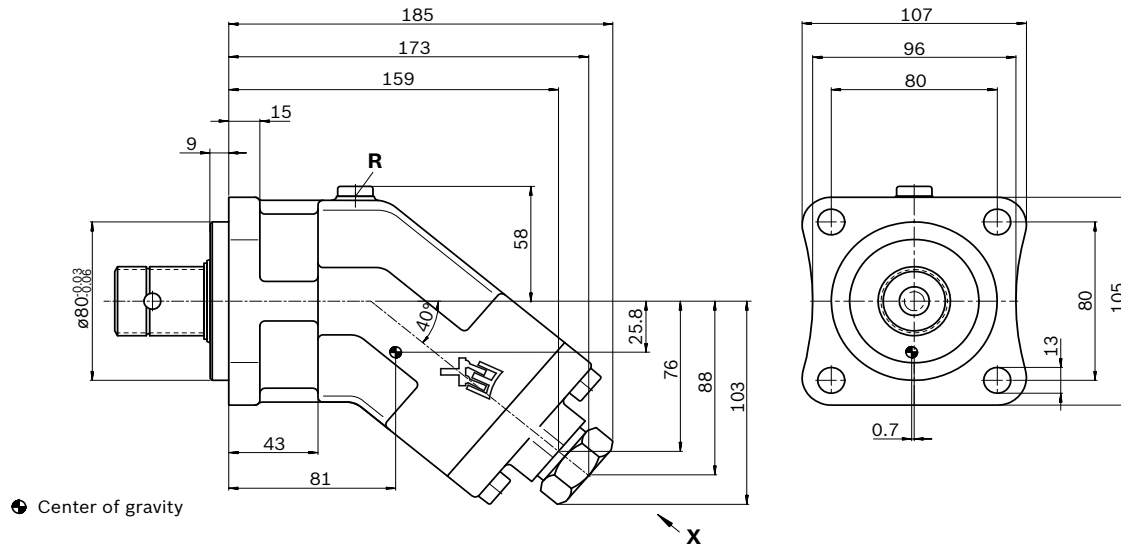
On delivery, the pressure connection (1) is pre-assembled in the right-hand service line port of the axial piston unit. The permissible drive direction of the pump looking at the drive shaft: counter-clockwise. The power take-off turns clockwise.

Note

The pressure connection is pre-installed upon delivery and must be tightened with the torque stipulated for the appropriate thread size prior to installation (see instruction manual).

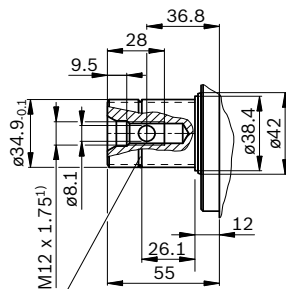


Dimensions, sizes 23, 32



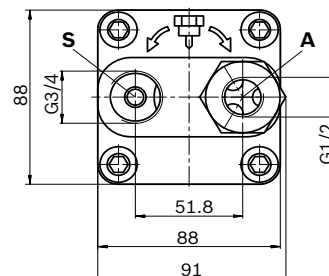
Drive shaft

Splined shaft similar to DIN ISO 14
E8 - 8x32x35



Groove for retaining ring 35 x 1.5 DIN 471

Detail **X**



Ports		Standard	Size	$p_{\max \text{ abs}}$ [bar] ²⁾	State ⁵⁾
A	Service line port	DIN ISO 228	G1/2; 14 deep	400	O
S	Suction port	DIN ISO 228	G3/4; 16 deep	2	O
R	Air bleed port	DIN 3852 ⁴⁾	M10 x 1, 8 deep	2	X ³⁾

- 1) Center bore according to DIN 332 (thread according to DIN 13)
- 2) Momentary pressure spikes may occur depending on the application. Keep this in mind when selecting measuring devices and fittings.
- 3) Only open port **R** for filling and air bleeding.
- 4) The spot face can be deeper than as specified in the appropriate standard.
- 5) O = Must be connected (plugged on delivery)
X = Plugged (in normal operation)

Bosch Rexroth AG, RE 91520/11.2015

Knowledge is POWER – Motion Force Control is our Business

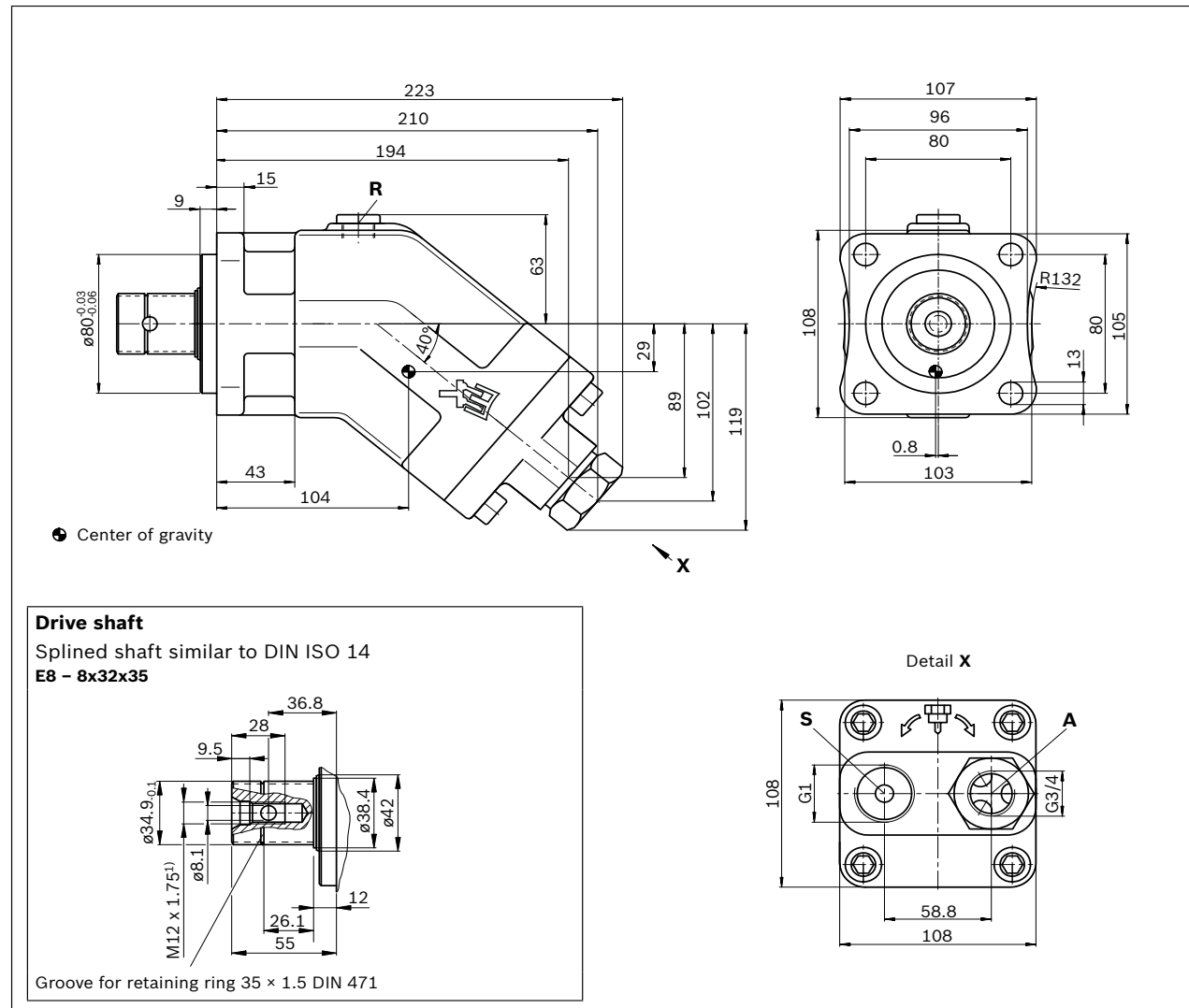
HYQUIP Limited New Brunswick Street Horwich Bolton Lancashire BL6 7JB UK

Dimensions [mm]

Axial piston fixed pump | **A17FO Series 10**
Dimensions, size 45

9

Dimensions, size 45



Ports		Standard	Size	$p_{\max \text{ abs}}$ [bar] ²⁾	State ⁵⁾
A	Service line port	DIN ISO 228	G3/4; 16 deep	400	O
S	Suction port	DIN ISO 228	G1; 18 deep	2	O
R	Air bleed port	DIN 3852 ⁴⁾	M10 x 1, 8 deep	2	X ³⁾

- 1) Center bore according to DIN 332 (thread according to DIN 13)
- 2) Momentary pressure spikes may occur depending on the application. Keep this in mind when selecting measuring devices and fittings.
- 3) Only open port **R** for filling and air bleeding.
- 4) The spot face can be deeper than as specified in the appropriate standard.
- 5) O = Must be connected (plugged on delivery)
X = Plugged (in normal operation)

RE 91520/11.2015, **Bosch Rexroth AG**

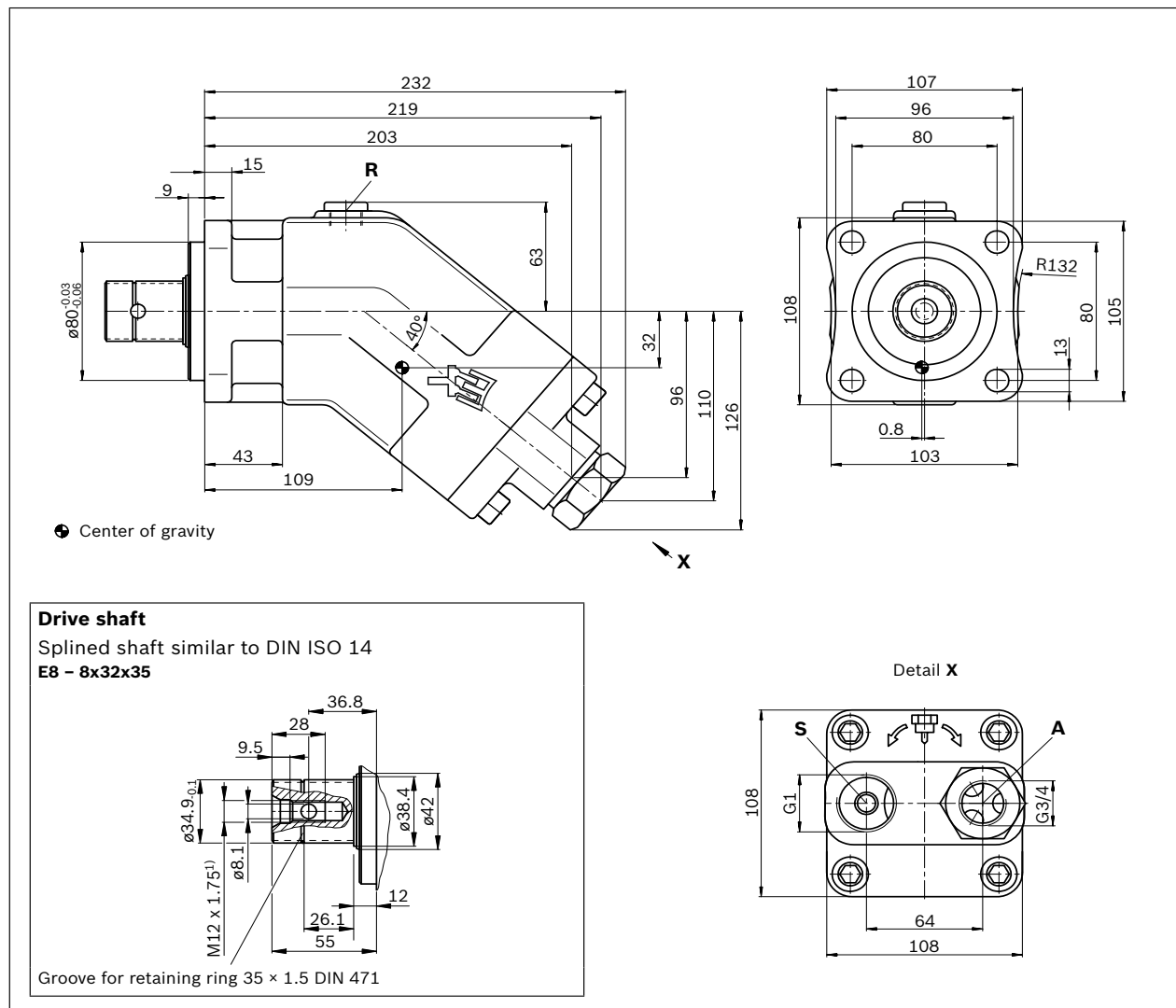
Knowledge is POWER – Motion Force Control is our Business

HYQUIP Limited New Brunswick Street Horwich Bolton Lancashire BL6 7JB UK

10 A17FO Series 10 | Axial piston fixed pump Dimensions, size 63

Dimensions [mm]

Dimensions, size 63



Ports	Standard	Size	$p_{\max \text{ abs}}$ [bar] ²⁾	State ⁵⁾
A	DIN ISO 228	G3/4; 16 deep	400	O
S	DIN ISO 228	G1; 18 deep	2	O
R	DIN 3852 ⁴⁾	M10 x 1, 8 deep	2	X ³⁾

- 1) Center bore according to DIN 332 (thread according to DIN 13)
- 2) Momentary pressure spikes may occur depending on the application.
Keep this in mind when selecting measuring devices and fittings.
- 3) Only open port R for filling and air bleeding.
- 4) The spot face can be deeper than as specified in the appropriate standard.
- 5) O = Must be connected (plugged on delivery)
X = Plugged (in normal operation)

Bosch Rexroth AG, RE 91520/11.2015

Knowledge is POWER – Motion Force Control is our Business

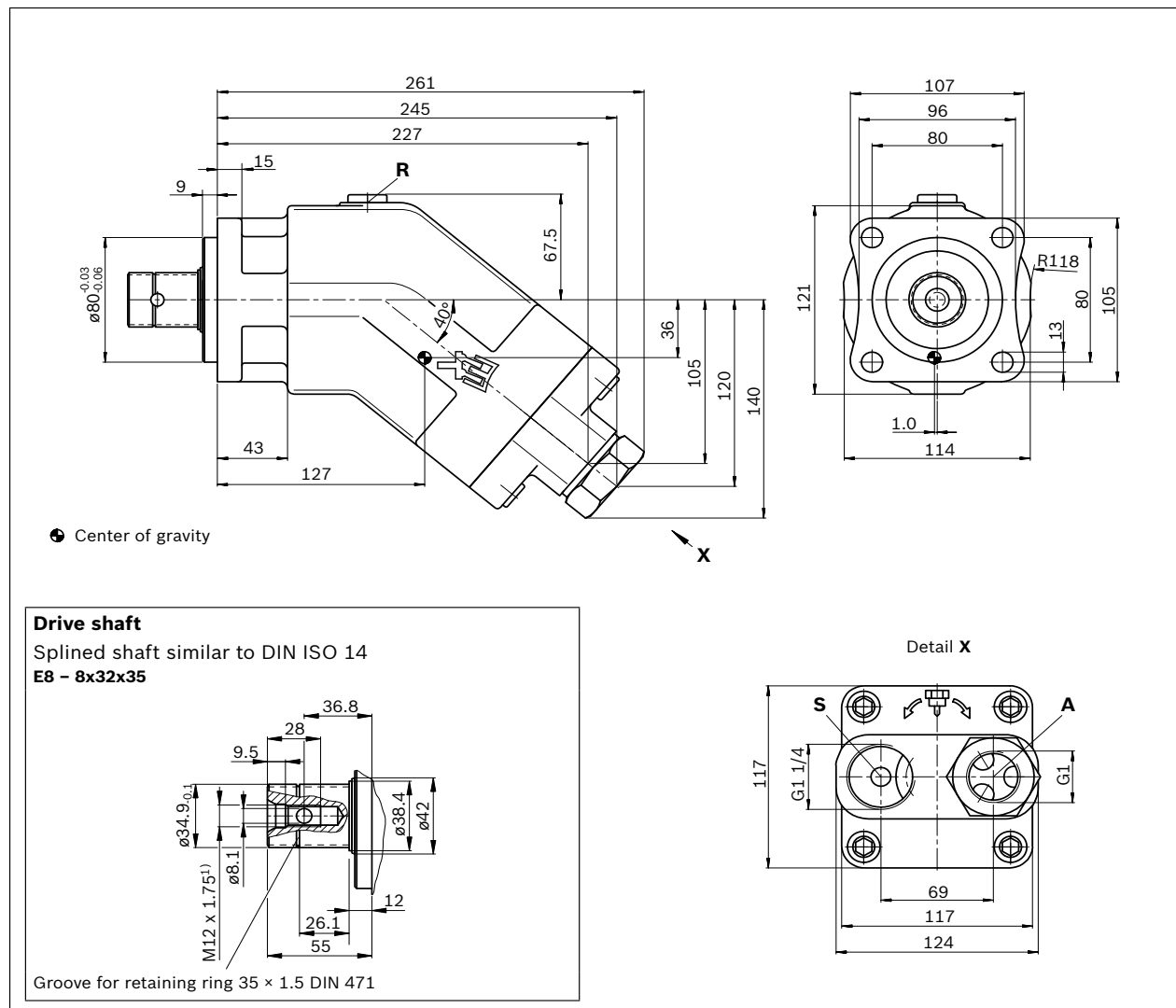
HYQUIP Limited New Brunswick Street Horwich Bolton Lancashire BL6 7JB UK

Dimensions [mm]

Axial piston fixed pump | **A17FO Series 10**
Dimensions, size 80

11

Dimensions, size 80



Ports		Standard	Size	$p_{\max \text{ abs}}$ [bar] ²⁾	State ⁵⁾
A	Service line port	DIN ISO 228	G1; 18 deep	400	O
S	Suction port	DIN ISO 228	G1 1/4; 20 deep	2	O
R	Air bleed port	DIN 3852 ⁴⁾	M10 x 1, 8 deep	2	X ³⁾

- Center bore according to DIN 332 (thread according to DIN 13)
- Momentary pressure spikes may occur depending on the application. Keep this in mind when selecting measuring devices and fittings.
- Only open port **R** for filling and air bleeding.
- The spot face can be deeper than as specified in the appropriate standard.
- O = Must be connected (plugged on delivery)
X = Plugged (in normal operation)

RE 91520/11.2015, Bosch Rexroth AG

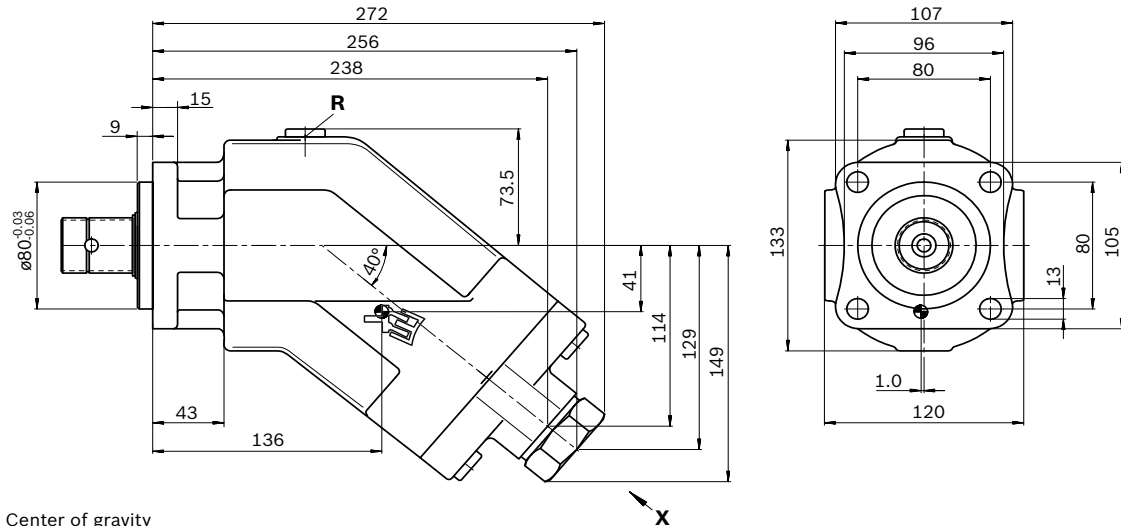
Knowledge is POWER – Motion Force Control is our Business

HYQUIP Limited New Brunswick Street Horwich Bolton Lancashire BL6 7JB UK

12 **A17FO Series 10** | Axial piston fixed pump
Dimensions, size 107

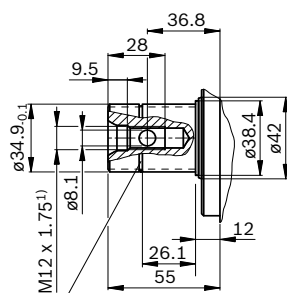
Dimensions [mm]

Dimensions, size 107

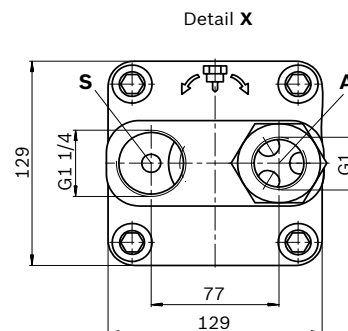


Drive shaft

Splined shaft similar to DIN ISO 14
E8 – 8x32x35



Groove for retaining ring 35 x 1.5 DIN 471



Ports		Standard	Size	$p_{\max \text{ abs}}$ [bar] ²⁾	State ⁵⁾
A	Service line port	DIN ISO 228	G1; 18 deep	400	O
S	Suction port	DIN ISO 228	G1 1/4; 20 deep	2	O
R	Air bleed port	DIN 3852 ⁴⁾	M10 x 1, 8 deep	2	X ³⁾

- 1) Center bore according to DIN 332 (thread according to DIN 13)
- 2) Momentary pressure spikes may occur depending on the application. Keep this in mind when selecting measuring devices and fittings.
- 3) Only open port **R** for filling and air bleeding.
- 4) The spot face can be deeper than as specified in the appropriate standard.
- 5) O = Must be connected (plugged on delivery)
X = Plugged (in normal operation)

Bosch Rexroth AG, RE 91520/11.2015

Knowledge is POWER – Motion Force Control is our Business

HYQUIP Limited New Brunswick Street Horwich Bolton Lancashire BL6 7JB UK

Dimensions [mm]

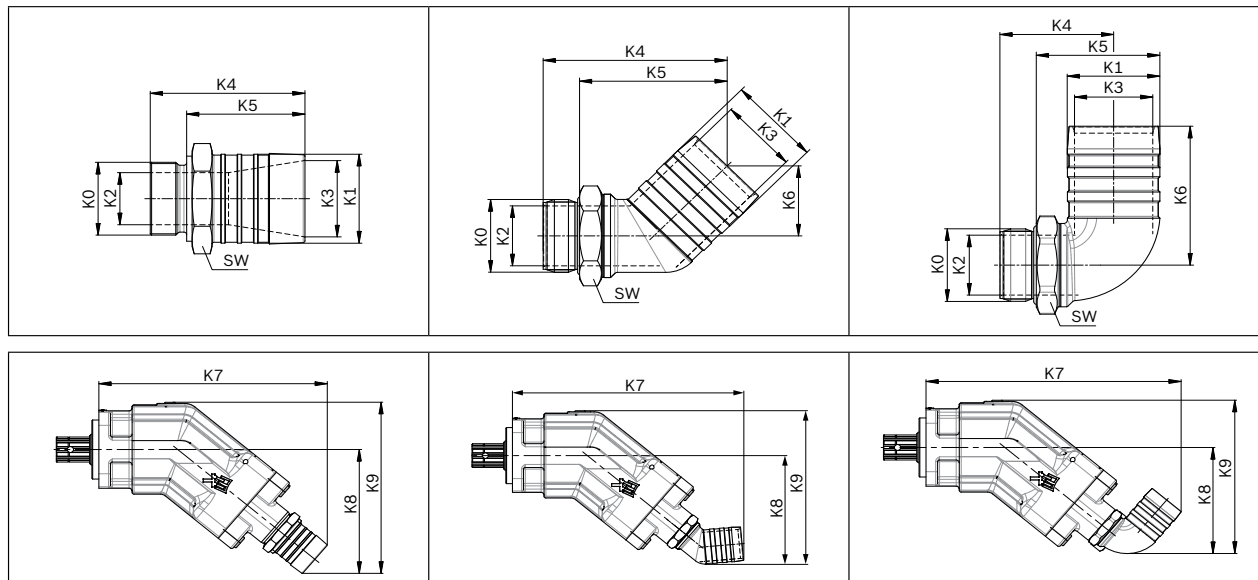
Axial piston fixed pump | **A17FO Series 10**
Accessories

13

Accessories

Suction stud

▼ Dimensions



Version	Pump size	Hose nominal width	Material number	Thread K0	K1	K2	K3	K4	K5	K6	K7	K8	K9	SW
Straight	23, 32	1 1/2"	R909831856	G3/4	39	18	33.5	70	54	–	221	132	186	41
	45	1 1/2"	R902600251	G1	39	23.5	33.5	72	54	–	248	139	197	41
	63	1 1/2"		G1	39	23.5	33.5	72	54	–	257	146	204	41
	63	2"	R902602028	G1	51	26	44	82	64	–	268	157	215	55
	80	2"	R902600252	G1 1/4	51	30	44	85	65	–	295	168	232	55
	107	2"		G1 1/4	51	30	44	85	65	–	306	177	245	55
	107	2 1/2"	R902601630	G1 1/4	63	31	54	82	64	–	308	180	248	65
45°	23, 32	1 1/2"	R909831601	G3/4	39	20	31	101	82	43	259	126	180	36
	45	1 1/2"	R909831600	G1	39	26	31	101	82	45	287	132	190	41
	63	1 1/2"		G1	39	26	31	101	82	45	296	139	197	41
	63	2"	R902602029	G1	51	26	43	100	81	44	295	145	203	41
	80	2"	R909831597	G1 1/4	51	34	43	101	81	40	317	156	220	50
	107	2"		G1 1/4	51	34	43	101	81	40	328	165	234	50
	107	2 1/2"	R902601631	G1 1/4	63	35	54	100	81	44	331	169	237	50
90°	23, 32	1 1/2"	R909831602	G3/4	39	20	31	62	43	81	265	117	171	36
	45	1 1/2"	R909831599	G1	39	26	31	64	44	85	296	127	185	41
	63	1 1/2"		G1	39	26	31	64	44	85	305	134	192	41
	63	2"	R902602030	G1	51	26	43	62	42	81	305	138	196	41
	80	2"	R909831598	G1 1/4	51	35	43	63	43	80	330	144	208	50
	107	2"		G1 1/4	51	35	43	63	43	80	341	153	221	50

The suction stud is not included in the scope of delivery and must be ordered separately.

RE 91520/11.2015, Bosch Rexroth AG

Knowledge is POWER – Motion Force Control is our Business

HYQUIP Limited New Brunswick Street Horwich Bolton Lancashire BL6 7JB UK

14 **A17FO Series 10** | Axial piston fixed pump
Dimensions, size 107

Dimensions [mm]

Notes on suction line

- ▶ Keep as short and straight as possible, without sharp bend
- ▶ Use a supporting ring for plastic hoses
- ▶ Use two hose clamps to protect the suction hose against air suction
- ▶ Note pressure resistance of suction hose compared to ambient pressure

Replacing seals

The O-rings used as seals to prevent air from entering the suction line are to be replaced after every removal and new installation in order to guarantee complete sealing.

Material number for O-rings:

- ▶ R909083796: O-ring for suction stud G3/4
- ▶ R909083802: O-ring for suction stud G1
- ▶ R909083808: O-ring for suction stud G1 1/4

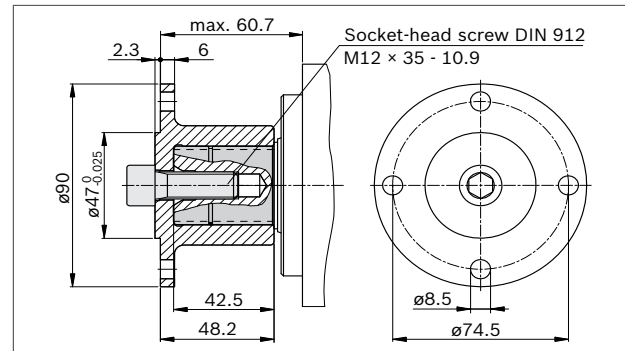
Coupling flange

There are special, modified coupling flanges in 4-hole and 6-hole design for the cardan shaft drive.

The coupling flange is not included in the scope of delivery and must be ordered separately.

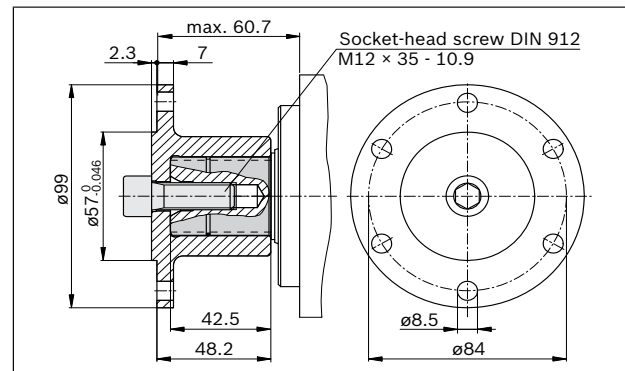
▼ 4-hole coupling flange, complete – ø 90

Material number: R902060152



▼ 6-hole coupling flange, complete – ø 100

Material number: R902060153



Note

- ▶ Assembly of the coupling flange is carried out by pulling onto the drive shaft with the aid of the threaded bore in the drive shaft end.
- ▶ The coupling flange must be clamped on the drive shaft using a socket-head screw. In addition, permanent lubrication should be applied between the drive shaft and the coupling flange.
- ▶ The socket-head screw should be secured in a suitable manner (e.g. gluing with Loctite 276) and tightened with a tightening torque of 130 Nm.
- ▶ Sudden axial impact upon the drive shaft will lead to rotary group damage and therefore must be avoided.

Installation instructions

General

During commissioning and operation, the axial piston unit must be filled with hydraulic fluid and air bled. This must also be observed following a long standstill as the axial piston unit can empty via the hydraulic lines.

The pump housing is internally connected to the suction chamber. A separate drain line from the housing to the reservoir is not needed.

To achieve favorable noise values, decouple all connecting lines using elastic elements and avoid above-reservoir installation.

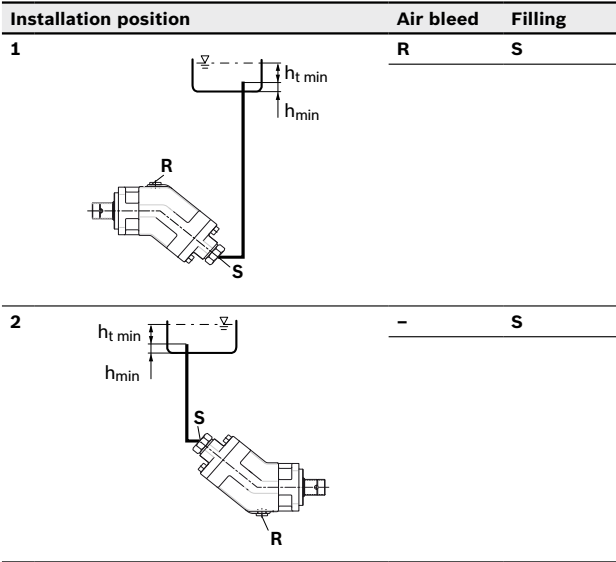
In all operating conditions, the suction line must flow into the reservoir below the minimum fluid level. The permissible suction height h_s results from the overall loss of pressure. However, it must not be higher than $h_{s\ max} = 800\text{ mm}$. The minimum suction pressure at port **S** must also not fall below 0.8 bar absolute during operation and during cold start.

Installation position

See the following examples **1** to **4**.
Further installation positions are available upon request.
Recommended installation position: **1** and **2**.

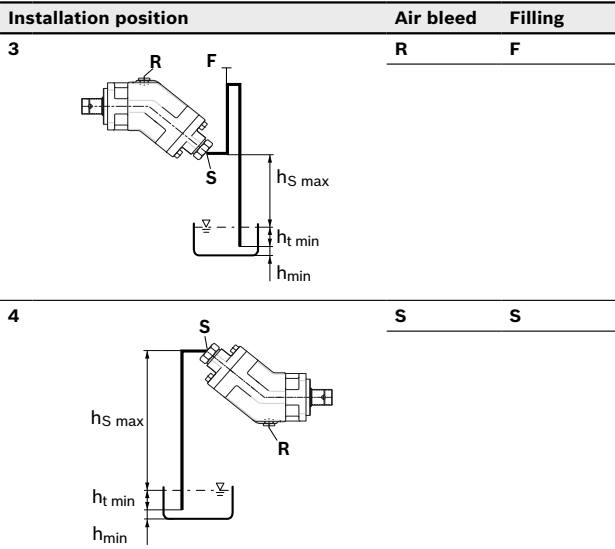
Below-reservoir installation (standard)

Below-reservoir installation means that the axial piston unit is installed outside of the reservoir below the minimum fluid level.



Above-reservoir installation

Above-reservoir installation means that the axial piston unit is installed above the minimum fluid level of the reservoir. Observe the maximum permissible suction height $h_{s\ max} = 800\text{ mm}$.



Key	
F	Filling/air bleed
R	Air bleed port
S	Suction port
$h_{t\ min}$	Minimum required immersion depth (200 mm)
h_{min}	Minimum required distance to reservoir bottom (100 mm)
$h_{s\ max}$	Maximum permissible suction height (800 mm)

Note
Port **F** is part of the external piping and must be provided on the customer side to make filling and air bleeding easier.

Other related documents

Other pumps with special characteristics and dimensions for use in commercial vehicles can be found in the following data sheets:

- ▶ 91510: Fixed pump A17FNO, 250/300 bar
- ▶ 92270: Variable pump, A18VO 350/400 bar
- ▶ 92280: Variable pump, A18VLO 350/400 bar

16 **A17FO Series 10** | Axial piston fixed pump
Project planning notes

Project planning notes

- ▶ The A17FO pump is designed to be used in open circuits.
- ▶ The project planning, installation and commissioning of the axial piston unit requires the involvement of qualified personnel.
- ▶ Before using the axial piston unit, please read the corresponding instruction manual completely and thoroughly. If necessary, these can be requested from Bosch Rexroth.
- ▶ Before finalizing your design, please request a binding installation drawing.
- ▶ The specified data and notes must be observed.
- ▶ Depending on the operating conditions of the axial piston unit (operating pressure, fluid temperature), the characteristic may shift.
- ▶ Preservation: Our axial piston units are supplied as standard with protection to preserve for a maximum of 12 months. If longer preservative protection is required (maximum 24 months), please specify this in plain text when placing your order. The preservation periods apply under optimal storage conditions, details of which can be found in the data sheet 90312 or the instruction manual.
- ▶ Not all variants of the product are approved for use in safety functions according to ISO 13849. Please consult the responsible contact person at Bosch Rexroth if you require reliability parameters (e.g. MTTF_d) for functional safety.
- ▶ Be sure to add a pressure relief valve to the hydraulic system.
- ▶ Please note the details regarding the tightening torques of port threads and other threaded joints.

▶ Working ports:

- The ports and fastening threads are designed for the specified maximum pressure. The machine or system manufacturer must ensure that the connecting elements and lines correspond to the specified application conditions (pressure, flow, hydraulic fluid, temperature) with the necessary safety factors.
- The service line ports and function ports can only be used to accommodate hydraulic lines.

Safety instructions

- ▶ During and shortly after operation, there is a risk of burns on the axial piston unit and especially on the solenoids. Take appropriate safety measures (e.g. by wearing protective clothing).