

<b>MANNESMANN REXROTH</b>	<b>Hydraulic motor (Radial Piston, Multi-stroke) Type MCR 05, Series 3X</b>			<b>RE 15 206/02.98</b>
	Sizes 380 to 820	up to 450 bar	up to 820 cm <sup>3</sup>	up to 4844 Nm Replaces: 09.97

**Characteristics:**

- Compact, sturdy construction
- Smooth running even at very low speeds
- Low noise
- Reversible
- Sealed taper roller bearings
- High radial forces permitted on the output shaft
- Shaft seal up to 10 bar
- Freewheeling
- Available with optional built-on holding (multi-disc) brake or dynamic (drum) brake



Type MCR 05 C...F180Z-3X/B4M/..

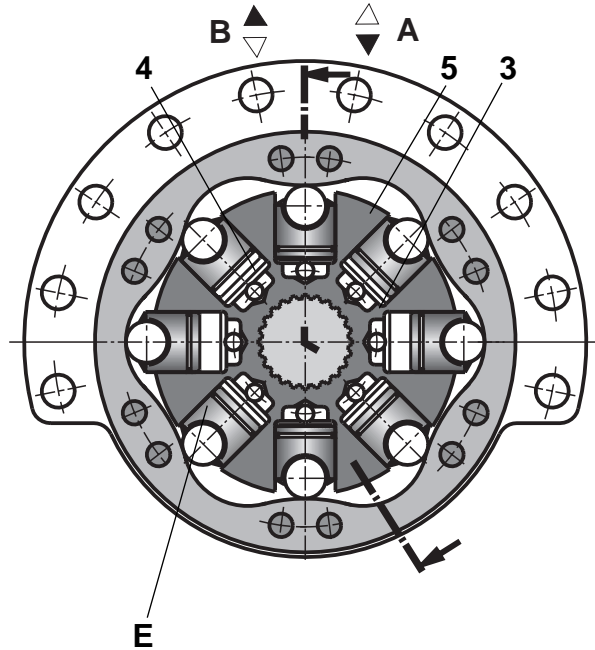
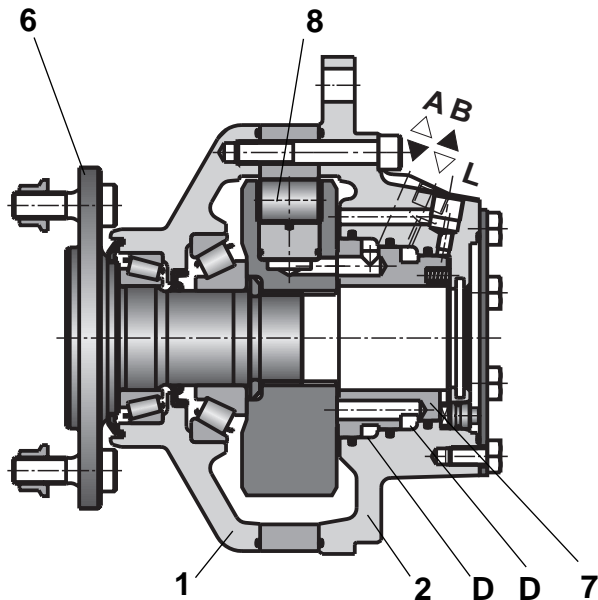


Type MCR 05 H... ZZ-3X/A0M/..

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**Functional description**



Hydraulic motors type MCR are radial piston motors with a rotating shaft.

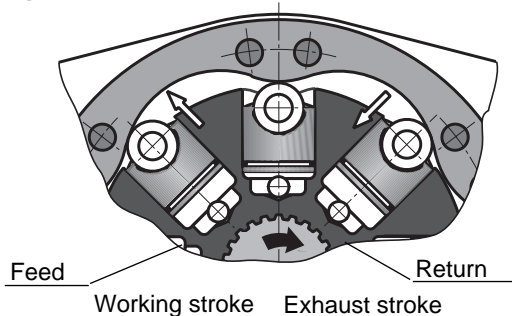
**Construction**

Two part housing (1: 2), rotor-piston assembly (3: 4), cam (5), output shaft (6) and control section (7).

**Transmission**

The rotor (4) is connected to the shaft (6) by means of splines. The pistons (3) are arranged radially in the rotor (4) and are supported on the cam plate (5) by way of rollers (8).

**Torque generation**



The number of working and idle strokes corresponds to the number of lobes on the cam.

**Open loop control**

The cylinder chambers (E) are connected to ports A and B via the axial bores and the annular passages (D).

**Bearings**

Tapered roller bearings are capable of absorbing high axial and radial forces.

**Freewheeling**

If the two ports A and B are connected with no pressure loading and a pressure of 2 bar simultaneously applied to the housing by way of port "L", the pistons will be forced into the rotary piston assembly. The rollers will no longer be lying against the cam curve and it will be possible for the end of the shaft to be rotated freely.

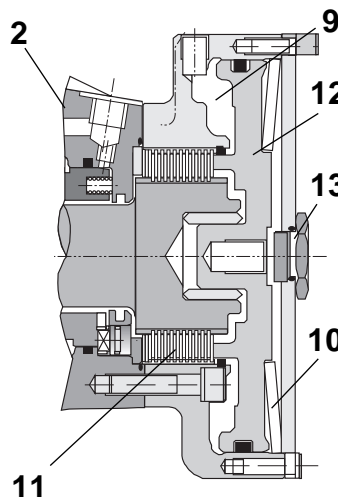
**Switching to half displacement**

On certain models of radial piston motors halving of displacement is possible. This means that during the working stroke only half the pistons are supplied with fluid by way of a valve in the control system. The remaining pistons are connected to the outlet side of the motor. When connected the motor will run at twice the speed but at half torque.

**In the switched position please take into account the preferred direction of rotation!**

**Brake mounting**

**Holding brake (multi-disc brake)**



**Mounting:**

by way of control housing (2) and through-drive facility.

**Brake application**

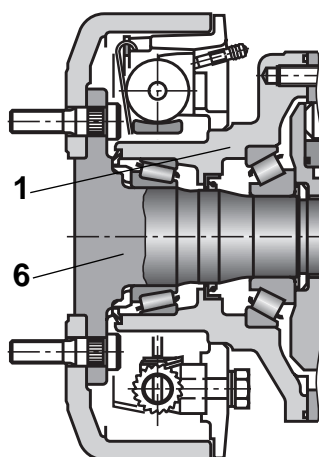
If the pressure in the annular area (9) fails to reach a certain pressure the Belleville washer (10) will compress the disc package (11).

**Release of holding brake**

If the pressure in the annular area (9) exceeds the required level, the brake piston (12) is pushed against the Belleville washer. The load is taken off the multi-disc package (11) and the holding brake is released.

The brake may also be released manually by removing plug (13) and inserting a screw and supporting washer into the hole in the piston (12).

**Travel brake (drum brake)**



**Mounting**

directly on drive shaft (6) and flange housing (7).

**Operation of brake**

- hydraulic
- mechanical

### Ordering code

MCR	05				Z	-3X/	M	/		*
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Further information  
in clear text

**Frame size**

Size 05 = 05

**Flange housing**

- Short motor = A
- Compact version = C
- Flange motor = D
- Front mounted version = E
- Wheel motor = F
- Hydrobase = H

**Nominal size, displacement V**

- Size 380 = 380 cm<sup>3</sup> = 380
- Size 470 = 470 cm<sup>3</sup> = 470
- Size 520 = 520 cm<sup>3</sup> = 520
- Size 565 = 565 cm<sup>3</sup> = 565
- Size 680 = 680 cm<sup>3</sup> = 680
- Size 750 = 750 cm<sup>3</sup> = 750
- Size 820 = 820 cm<sup>3</sup> = 820

**Single shaft end**

- Splined to DIN 5480 = W50 <sup>1)</sup>
- Parallel with key Ø 50 mm = L50 <sup>2)</sup>
- With flange Ø 180 mm = F180 <sup>3)</sup>
- Without shaft = Z <sup>5)</sup>

**Without 2nd shaft end = Z**

- 1) only with flange housing A maximum torque 3000 Nm
- 2) only with flange housing D maximum torque 3000 Nm
- 3) only with flange housing C or F
- 4) only with flange housing F
- 5) only with Hydrobase

**Wheel bolt**  
No code = without wheel bolt  
/S = with wheel bolt

**Ports**  
01 = Pipe thread to ISO 228/1  
12 = UNF-SAE-thread

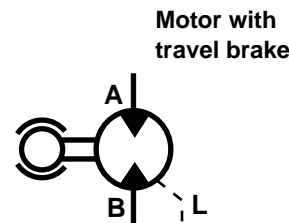
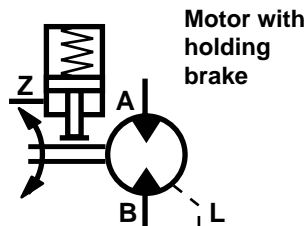
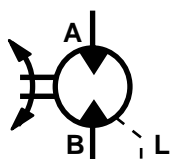
**Two speed operating**  
No code = not switchable  
2R = switchable clockwise rotation only  
2L = switchable anti-clockwise rotation only

**Seals**  
M = NBR seals suitable for mineral oil to  
DIN 51 524 (HL,HLP)  
(except drum brake see p.12)

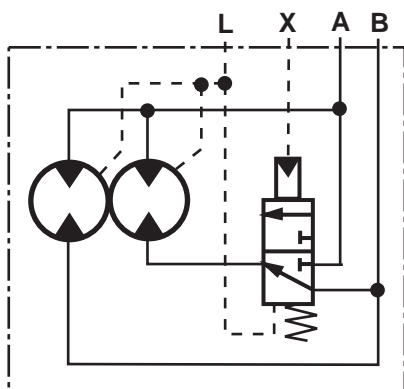
**Brake mounting**  
A0 = without brake  
B3.1 = hydraulic release holding brake  
(spring pressure disc brake)  
B4 = hydraulic release holding brake  
(spring pressure disc brake)  
<sup>4)</sup>C4R = dynamic brake (drum brake)  
for right hand side of vehicle (see Fig., p.12)  
<sup>4)</sup>C4L = travel brake (drum brake)  
for left hand side of vehicle (see Fig., p.12)

**Series**  
3X = Series 32 to 39  
(30 to 39: externally interchangeable)

### Symbols

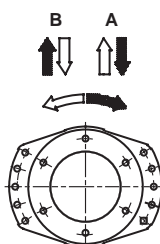


**2-speed motor**

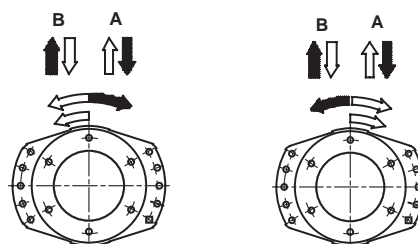


**Rotation (viewed on output shaft)**


Standard model



Switchable (preferred direction)



Ordering code ...2L..    Ordering code ...2R..

<b>Technical data</b> (For operation outside these parameters, please consult us!)									
<b>General</b>									
Description	Radial piston multi-disc motor with fixed displacement								
Frame size	MCR 05...								
Type of mounting	Flange mounting; face mounting								
Pipe connections	Threaded or flanged								
Mounting position	optional								
Shaft loading	see page 7								
Direction of rotation	Right/left - reversible								
Frame size	05								
Nominal size			380	470	520	565	680	750	820
Displacement	$V$	cm <sup>3</sup>	380	470	520	565	680	750	820
Flow at $n = 100$ rpm/100 bar	$q_V$	L/min	38	47	52	56.5	70	77	84
Output torque <sup>1; 7)</sup>									
– specific torque (at $\Delta p = 100$ bar)	$T$	Nm	604	748	827	899	1082	1194	1305
– peak torque	$T$	Nm	2528	3127	3459	3759	4017	4430	4844
Output speed <sup>1; 7)</sup>			5 to 10 when running smoothly, dependent on application						
– min. speed	$n$	rpm	5 to 10 when running smoothly, dependent on application						
– max. speed	$n$	rpm	220	220	220	220	200	170	150
– freewheeling speed	$n$	rpm	600						
Output power <sup>1; 7)</sup>									
– cont. power at full displacement	$P$	kW	29	29	29	29	35	35	35
– cont. power at half displacement	$P$	kW	19	19	19	19	23	23	23
Weight	$m$	kg	see unit dimensions pages 8 to 12						
Polar moment of inertia	$J_m$	kgmm <sup>2</sup>	see unit dimensions pages 8 to 12						
<b>Hydraulic</b>									
Nominal pressure	$p$	bar	250						
Pressure differential, cont. <sup>2; 3)</sup>	$\Delta p$		250						
– with mineral oil (HL, HLP)		bar	250						
Pressure differential, peak <sup>4; 3)</sup>	$\Delta p$		450						
– with mineral oil (HL, HLP)		bar	400						
Inlet pressure Port "A" or "B"	$p$	bar	470						
Summated pressure <sup>5; 3)</sup> ports "A" + "B"	$p$	bar	470						
Case drain pressure,max	$p$	bar	10						
Hydraulic fluid <sup>6)</sup>	Mineral oils (HL, HLP) to DIN 51 524								
Hydraulic fluid temperature range	$\vartheta$	°C	– 20 to 80						
Viscosity range	$\nu$	mm <sup>2</sup> /s	10 to 2000						
Fluid cleanliness	Maximum degree of contamination of the fluid to NAS 1638 class 9. We therefore recommend a filter with a minimum retention rate of $\beta_{10} \geq 75$ .								
<b>Brake</b>									
Holding brake (disc brake)			B2			B3.1		B4	
Holding torque	$T$	Nm	2200			2900		5000	
Release pressure, min – max	$p$	bar	15 – 30			15 – 30		15 – 30	
Volume to operate brake	$V$	cm <sup>3</sup>	23			38		46	
Travel brake (drum brake)	see table page 12								
<p><sup>1)</sup> the values given apply after 100 hours run-in time</p> <p><sup>2)</sup> continuous operation</p> <p><sup>3)</sup> when operating motors in series, please consult our technical office</p> <p><sup>4)</sup> peak values may occur for a maximum duration of one second only within an operating minute</p> <p><sup>5)</sup> we recommend <math>p_{min} = 15</math> bar in the return line</p> <p><sup>6)</sup> environmentally acceptable hydraulic fluids HETG, HEPG, HEES to RE 90 221</p> <p><sup>7)</sup>  <b>Warning!</b> During the running in period of the motor (min 20 hours) motors should not be run unloaded at greater than 50% maximum speed.</p>									

**Technical data** (Mean values, measured at  $v = 46 \text{ mm}^2/\text{s}$  and  $\vartheta = 45 \text{ }^\circ\text{C}$ )

- All torques apply to run-in motors  $T$  = Torque in Nm
- For half displacement operating mode multiply the torques, charge pressure and  $q_{vL}$  values by 0.5  $q_v$  = Input flow in L/min
- For maximum case leakage multiply  $q_{vL}$  by 2  $q_{vL}$  = Mean case drain flow in L/min
- $p$  = Minimum charge pressure in pump mode

Pressure diff. $\Delta p$ in bar		Speed $n$ in rpm							Speed $n$ in rpm						
		0	25	50	100	150	220		0	25	50	100	150	220	
		MCR 05 . 380							MCR 05 . 680						
100	$T$ Nm	393	513	538	544	525	507		5,95	989	995	908	821	698	
	$q_v$ L/min	0.3	9.8	19.3	38.6	57.7	84.4		0,88	17,64	34,93	70,01	102,76	139,54	
	$q_{vL}$ L/min	0.15	0.15	0.15	0.30	0.35	0.40		0,44	0,47	0,50	0,57	0,64	0,64	
200	$T$ Nm	846	1075	1123	1111	1087			1407	1938	2017	1973	1862		
	$q_v$ L/min	0.7	10.2	19.7	38.9	58.0			2,4	18,55	36,09	72,17	103,61		
	$q_{vL}$ L/min	0.35	0.35	0.35	0.45	0.50			1,20	1,22	1,24	1,30	1,41		
300	$T$ Nm	1268	1613	1685	1667				2338	2964	3026	3013			
	$q_v$ L/min	0.9	10.4	19.9	39.2				3,7	19,24	36,82	71,98			
	$q_{vL}$ L/min	0.45	0.45	0.45	0.60				1,85	1,91	1,97	2,14			
400	$T$ Nm	1691	2150	2247					3116	3939	4017				
	$q_v$ L/min	1.5	11.0	20.5					4,34	19,91	38,18				
	$q_{vL}$ L/min	0.75	0.75	0.75					2,17	2,35	2,33				
450	$T$ Nm	1903	2419	2528											
	$q_v$ L/min	2.2	11.7	21.2											
	$q_{vL}$ L/min	1.1	1.1	1.1											
Charge Pressure	$p$ bar	1	4	4	6	9	14		1	2	3	7	12	23	
Speed	$n$ rpm	0	25	50	100	150	220		0	25	50	100	150		
		MCR 05 . 470							MCR 05 . 750						
100	$T$ Nm	484	632	662	670	647	625		657	1091	1098	1002	906		
	$q_v$ L/min	0.40	12.2	23.9	47.8	71.5	105.0		0,88	19,39	38,43	77,01	113,26		
	$q_{vL}$ L/min	0.20	0.20	0.20	0.40	0.50	0.80		0,44	0,47	0,50	0,57	0,64		
200	$T$ Nm	1042	1324	1384	1369	1339			1551	2137	2224	2176			
	$q_v$ L/min	0.80	12.6	24.3	48.2	71.9			2,40	20,30	39,59	79,17			
	$q_{vL}$ L/min	0.40	0.40	0.40	0.60	0.70			1,20	1,22	1,24	1,30			
300	$T$ Nm	1562	1986	2076	2053				2578	3270	3338				
	$q_v$ L/min	1.2	13.0	24.7	48.6				3,7	20,99	40,32				
	$q_{vL}$ L/min	0.60	0.60	0.60	0.80				1,85	1,91	1,97				
400	$T$ Nm	2083	2649	2768					3438	4345	4430				
	$q_v$ L/min	2.0	13.8	25.5					4,34	21,66	41,73				
	$q_{vL}$ L/min	1.0	1.0	1.0					2,17	2,35	2,37				
450	$T$ Nm	2344	2980	3114											
	$q_v$ L/min	3.0	14.8	26.5											
	$q_{vL}$ L/min	1.5	1.5	1.5											
Charge Pressure	$p$ bar	1	5	5	7	10	16		1	3	4	9	15		
Speed	$n$ rpm	0	25	50	100	150	220		0	25	50	100	150		
		MCR 05 . 520							MCR 05 . 820						
100	$T$ Nm	538	702	737	744	683	620		718	1192	1200	1095	990		
	$q_v$ L/min	0.4	13.4	26.4	52.8	79.0	116.0		0,88	21,14	41,93	84,01	123,76		
	$q_{vL}$ L/min	0.20	0.20	0.20	0.40	0.50	0.80		0,44	0,47	0,50	0,57	0,64		
200	$T$ Nm	1158	1472	1537	1520	1487			1697	2337	2432	2380			
	$q_v$ L/min	0.80	13.8	26.8	53.2	79.4			2,40	22,05	43,09	86,17			
	$q_{vL}$ L/min	0.40	0.40	0.40	0.60	0.70			1,20	1,22	1,24	1,30			
300	$T$ Nm	1735	2207	2305	2281				2819	3573	3649				
	$q_v$ L/min	1.2	14.2	27.2	53.6				3,70	22,74	43,82				
	$q_{vL}$ L/min	0.60	0.60	0.60	0.80				1,85	1,91	1,97				
400	$T$ Nm	2314	2942	3074					3758	4750	4844				
	$q_v$ L/min	2.0	15.0	28.0					4,34	23,35	45,18				
	$q_{vL}$ L/min	1.00	1.00	1.00					2,17	2,35	2,37				
450	$T$ Nm	2604	3310	3459											
	$q_v$ L/min	3.0	16.0	29.0											
	$q_{vL}$ L/min	1.5	1.5	1.5											
Charge Pressure	$p$ bar	1	6	6	7	11	17		1	4	6	11	19		

**Technical data** (Mean values, measured at  $v = 46 \text{ mm}^2/\text{s}$  and  $\vartheta = 45 \text{ }^\circ\text{C}$ )

- All torques apply to run-in motors
- For half displacement operating mode multiply the torques, charge pressure and  $q_{VL}$  values by 0.5
- For maximum case leakage multiply  $q_{VL}$  by 2

$T$  = Torque in Nm  
 $q_V$  = Input flow in L/min  
 $q_{VL}$  = Mean case drain flow in L/min  
 $p$  = Minimum charge pressure in pump mode

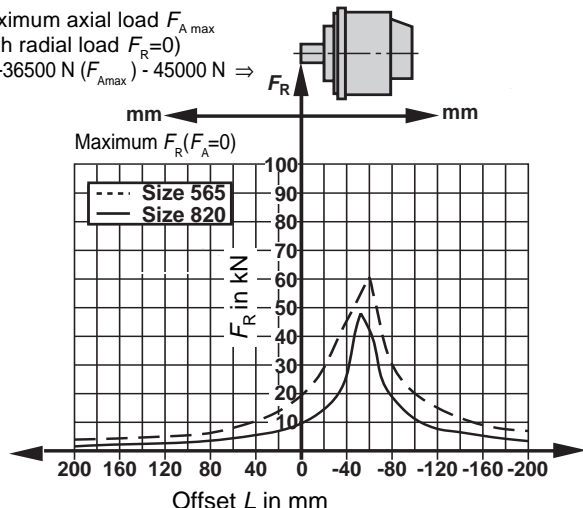
Pressure diff. $\Delta p$ in bar		Speed $n$ in rpm					
		0	25	50	100	150	220
		MCR 05. 565					
100	$T$ Nm	567	747	783	792	765	738
	$q_V$ L/min	0.4	14.5	28.7	57.3	85.8	125,9
	$q_{VL}$ L/min	0.20	0.20	0.20	0.40	0.50	0.80
200	$T$ Nm	1224	1566	1638	1620	1584	
	$q_V$ L/min	0.8	14.9	29.1	57.7	86.2	
	$q_{VL}$ L/min	0.40	0.40	0.40	0.60	0.70	
300	$T$ Nm	1836	2349	2457	2430		
	$q_V$ L/min	1.2	15.3	29.5	58.1		
	$q_{VL}$ L/min	0.60	0.60	0.60	0.80		
400	$T$ Nm	2448	3132	3276			
	$q_V$ L/min	2.0	16.1	30.3			
	$q_{VL}$ L/min	1.00	1.00	1.00			
450	$T$ Nm	2754	3524	3686			
	$q_V$ L/min	3.0	17.1	31.3			
	$q_{VL}$ L/min	1.5	1.5	1.5			
Charge Pressure	$p$ bar	1	6	6	8	12	18

**Permitted loading on output shaft (at speed  $n=50\text{rpm}$ , differential  $\Delta p=250\text{bar}$ , 2000 hrs L10 life at  $50^\circ\text{C}$ )**

Measured at a speed of  $n = 50 \text{ rpm}$ , pressure differential  $\Delta p = 250 \text{ bar}$ , 2000 hrs, L10 life at  $50^\circ \text{C}$

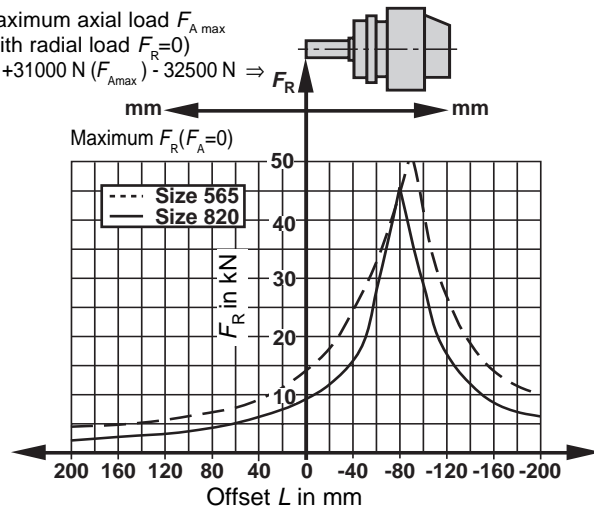
Shaft end ...**W50**... Flange housing...**A**...

Maximum axial load  $F_{A \text{ max}}$   
(with radial load  $F_R=0$ )  
 $\leftarrow +36500 \text{ N } (F_{A \text{ max}}) - 45000 \text{ N} \Rightarrow$



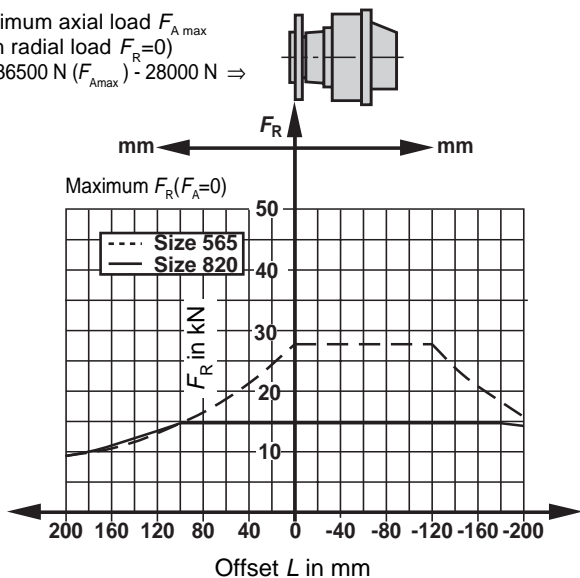
Shaft end ...**L50**... Flange housing ...**D**...

Maximum axial load  $F_{A \text{ max}}$   
(with radial load  $F_R=0$ )  
 $\leftarrow +31000 \text{ N } (F_{A \text{ max}}) - 32500 \text{ N} \Rightarrow$



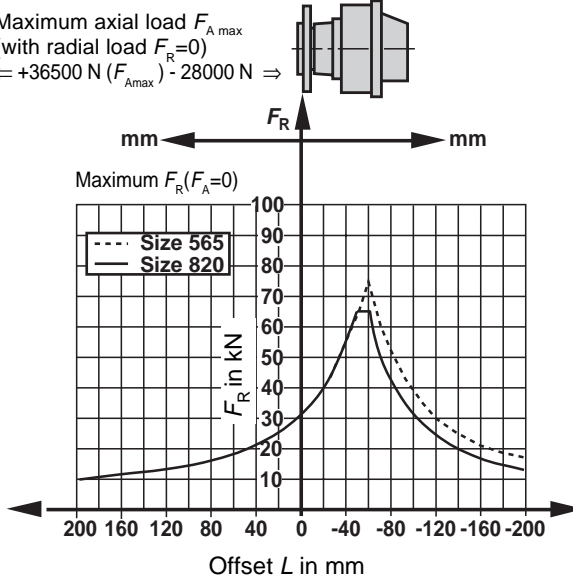
Shaft end ...**F180**...(5 studs M14) Flange housing ...**C**...

Maximum axial load  $F_{A \text{ max}}$   
(with radial load  $F_R=0$ )  
 $\leftarrow +36500 \text{ N } (F_{A \text{ max}}) - 28000 \text{ N} \Rightarrow$



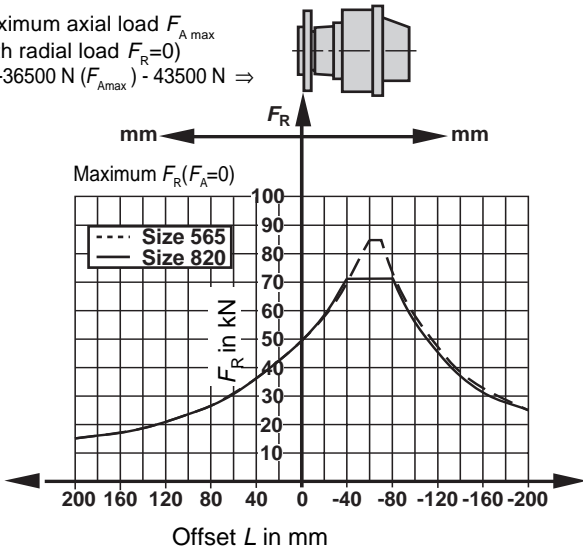
Shaft end ...**F180**...(10 studs M14) Flange housing ...**C**...

Maximum axial load  $F_{A \text{ max}}$   
(with radial load  $F_R=0$ )  
 $\leftarrow +36500 \text{ N } (F_{A \text{ max}}) - 28000 \text{ N} \Rightarrow$



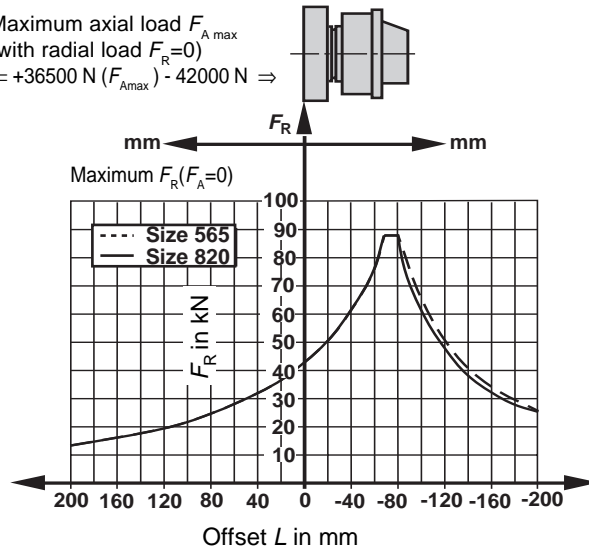
Shaft end ...**F180**...(10 studs M14) Flange housing ...**F**...

Maximum axial load  $F_{A \text{ max}}$   
(with radial load  $F_R=0$ )  
 $\leftarrow +36500 \text{ N } (F_{A \text{ max}}) - 43500 \text{ N} \Rightarrow$



Shaft end ...**F180**...(10 studs M18) Travel brake...**C4**...

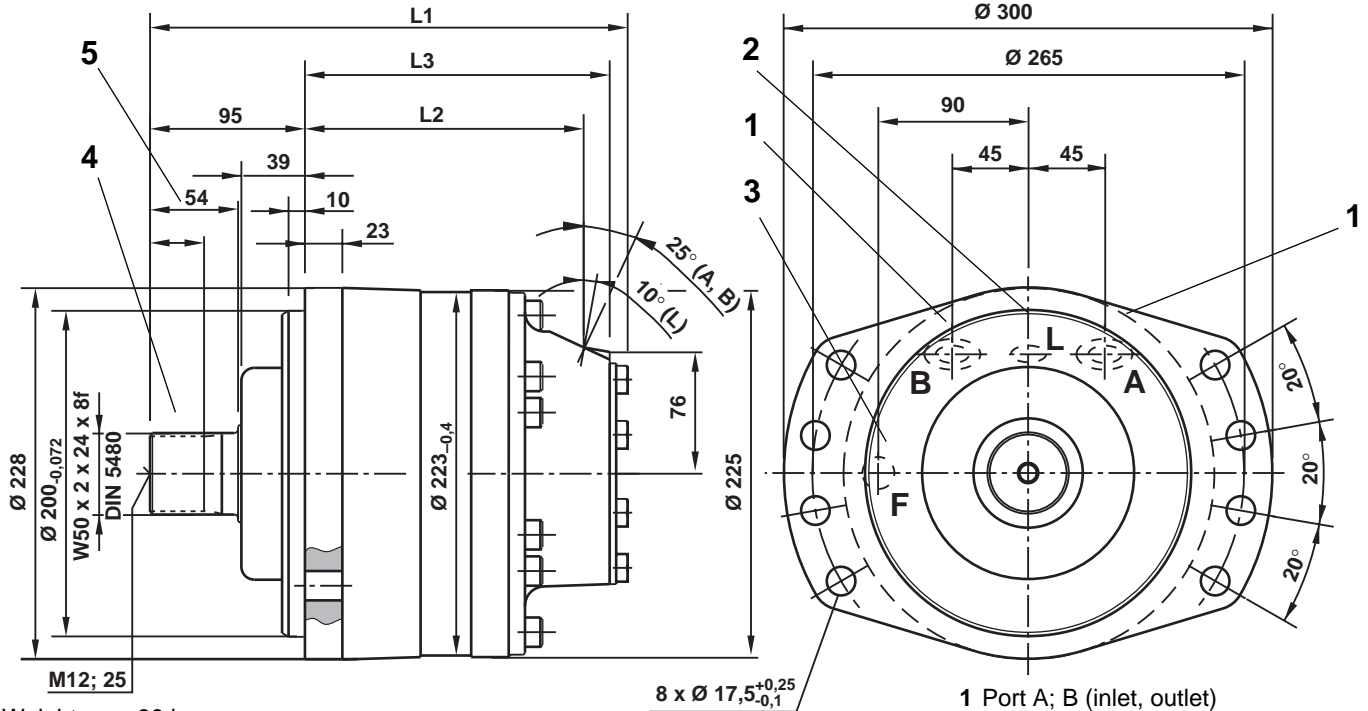
Maximum axial load  $F_{A \text{ max}}$   
(with radial load  $F_R=0$ )  
 $\leftarrow +36500 \text{ N } (F_{A \text{ max}}) - 42000 \text{ N} \Rightarrow$



**Unit dimensions**

(in mm)

**Flange housing: Ordering code "A"**



Weight:  $m = 39$  kg

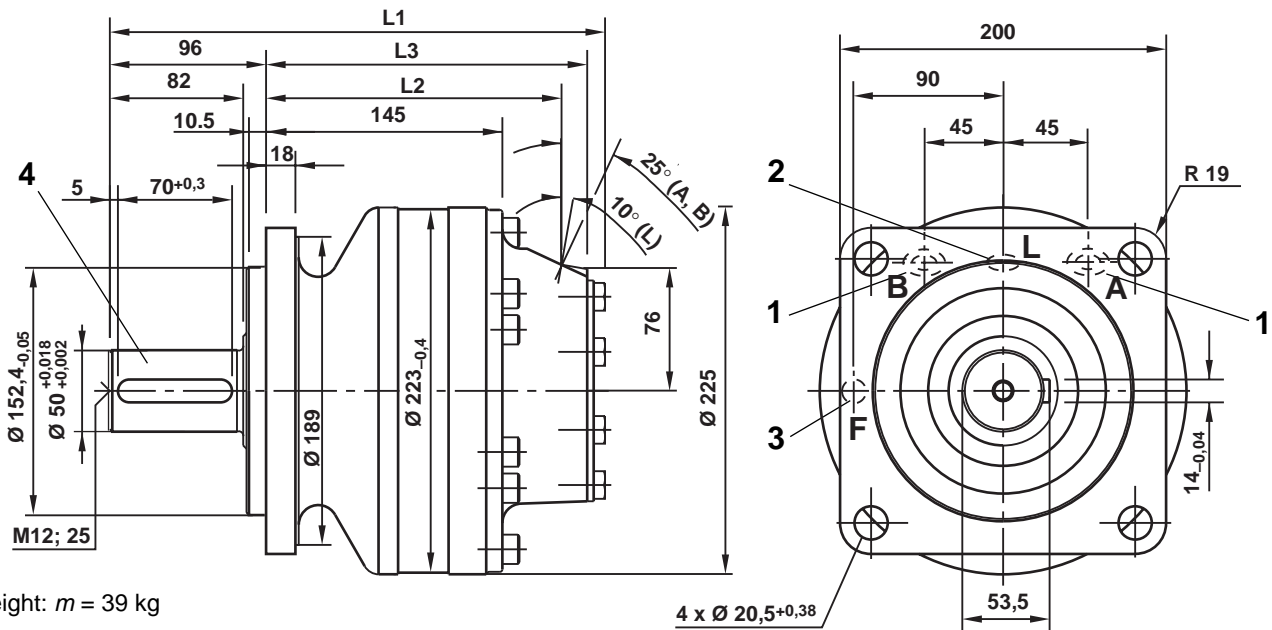
Port	Dimensions / Order code	
	01	12
A, B	G 3/4	1 1/16-12 SAE
L	G 3/8	3/4-16 SAE
F	G 1/2	3/4-16 SAE

Size	single speed	two speed
L1	296	307
L2 (A, B)	171	165
L2 (L)	171	179
L3	187	197

- 1 Port A; B (inlet, outlet)  
for 2-speed see page 10
- 2 Case drain port L
- 3 Filling port F, may also be used as drain port
- 4 Single shaft end splined to DIN 5480; order code "W50"
- 5 Usable spline length

Polar moment of inertia  $J_m = 25771$  kgmm<sup>2</sup>

**Flange housing: ordering code "D"**



Weight:  $m = 39$  kg

Port	Dimensions / Order code	
	01	12
A, B	G 3/4	1 1/16-12 SAE
L	G 3/8	3/4-16 SAE
F	G 1/2	3/4-16 SAE

Size	single speed	two speed
L1	307	318
L2 (A, B)	181	175
L2 (L)	181	189
L3	197	207

- 1 Port A; B (Input, output)  
for 2-speed see page 10
- 2 Case drain port L
- 3 Filling port F, may also be used as drain port
- 4 Single shaft end cylindrical Ø 50 mm, Order code "L50"

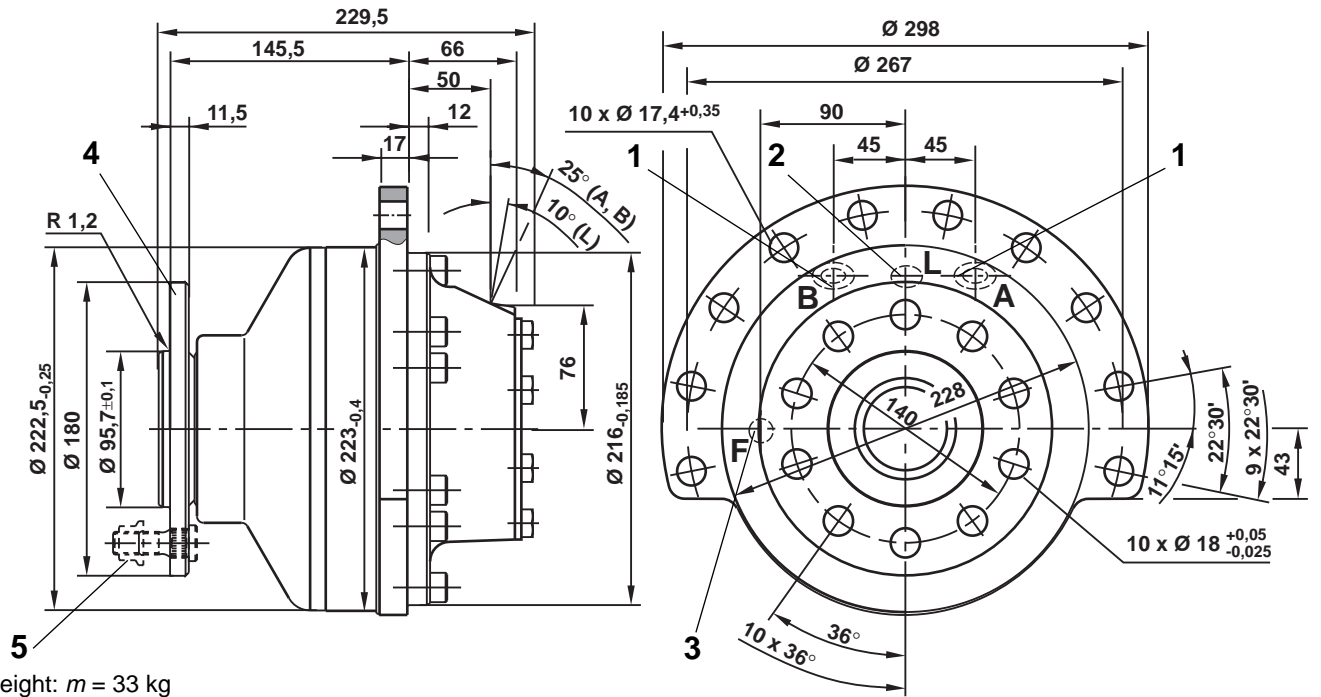
Polar moment of inertia  $J_m = 25771$  kgmm<sup>2</sup>



**Unit dimensions**

(in mm)

**Flange housing: Ordering code "C"**



Weight:  $m = 33 \text{ kg}$

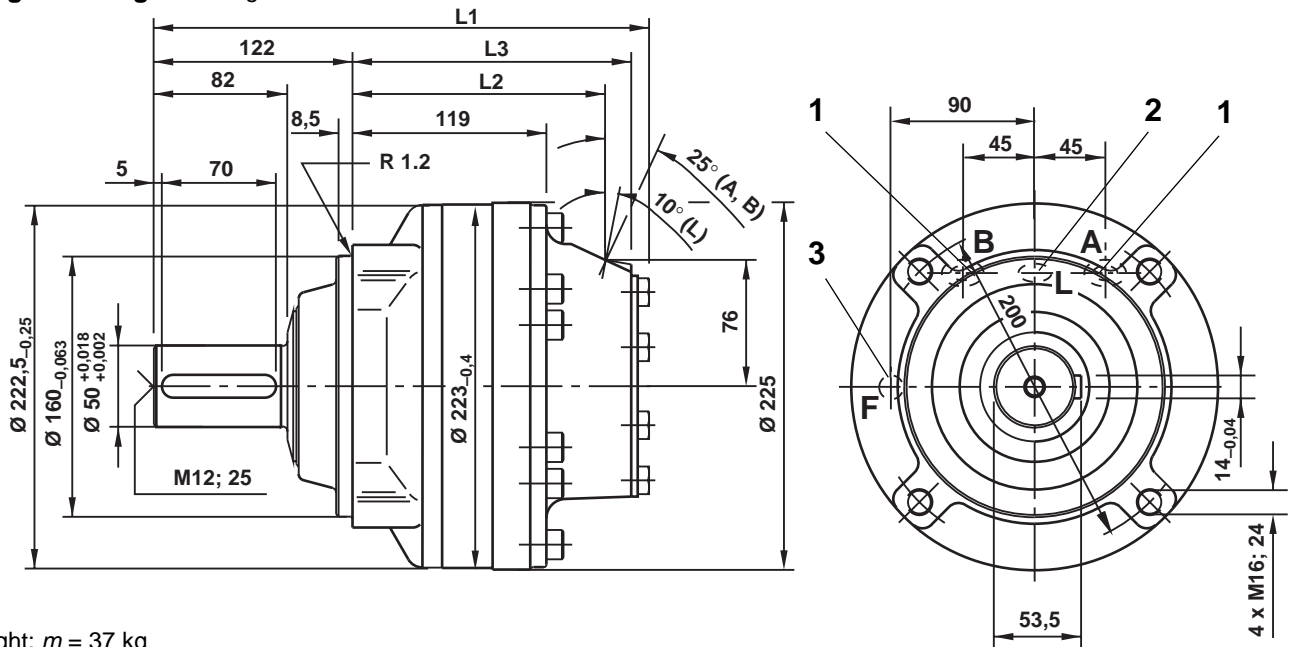
Port	Dimensions / Order code	
	01	12
A, B	G 3/4	1 1/16-12 SAE
L	G 3/8	3/4-16 SAE
F	G 1/2	3/4-16 SAE

Size	single speed	two speed
L1	233	243.5
L2(A, B)	50	44
L2(L)	50	58
L3	66	76

- 1 Port A; B (inlet, outlet, for 2-speed see page 10)
- 2 Case drain port L
- 3 Filling port F, may also be used as drain port
- 4 Single shaft with flange; order code "F180"
- 5 Studs M14 x 1,5, with shouldered hex. nut for wheel fixing, clamping length 5 to 20 mm; ordering code "S"

Polar moment of inertia  $J_m = 34153 \text{ kgmm}^2$

**Flange housing: Ordering code "E"**



Weight:  $m = 37 \text{ kg}$

Port	Dimensions / Order code	
	01	12
A, B	G 3/4	1 1/16-12 SAE
L	G 3/8	3/4-16 SAE
F	G 1/2	3/4-16 SAE

Size	single speed	two speed
L1	307	318
L2 (A,B)	155	149
L2 (L)	155	163
L3	171	181

- 1 Port A; B (Input, output) for 2-speed see page 10
- 2 Case drain port L
- 3 Filling port F, may also be used as drain port
- 4 Single shaft end cylindrical  $\varnothing 50 \text{ mm}$ , Order code "L50"

Polar moment of inertia  $J_m = 25771 \text{ kgmm}^2$



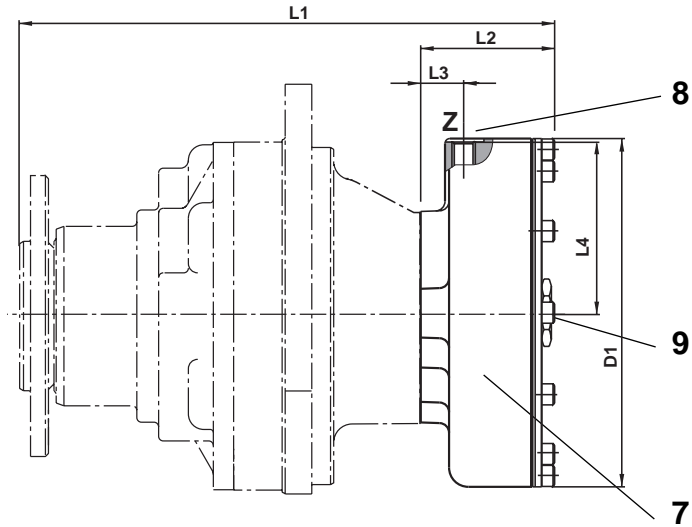
**Unit dimensions**

(in mm)

**Holding brake (multi-disc brake):**

Ordering code **B3.1; B4**

Port	Dimensions / Ordering code	
	01	12
Z	G 1/4	9/16-18 SAE



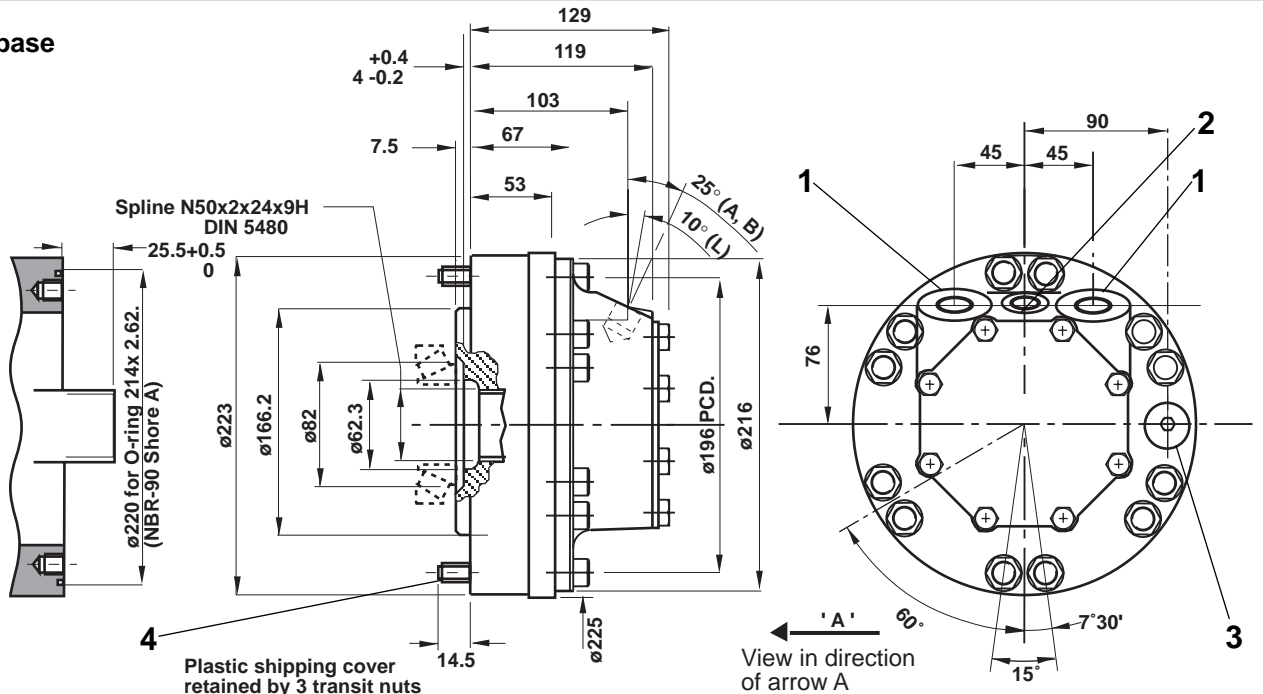
7 Holding brake (multi-disc brake) Ordering code "B4"

8 Brake release port

9 Thread for mechanical emergency release of the holding brake

Brake Type	B3.1							B4							
	Flange housing	single speed L1	two speed L1	L2	L3	L4	D1	Item 9	single speed L1	two speed L1	L2	L3	L4	D1	Item 9
A Type		349.3	359.3	67.3	22	90	174	M12	362.7	372.7	82.6	26.5	106	215	M20
C Type		285.8	295.8	67.3	22	90	174	M12	299.2	309.2	82.6	26.5	106	215	M20
D Type		360.4	370.4	67.3	22	90	174	M12	373.8	383.8	82.6	26.5	106	215	M20
E Type		360.4	370.4	67.3	22	90	174	M12	373.8	383.8	82.6	26.5	106	215	M20
F Type		320.3	330.3	67.3	22	90	174	M12	333.7	343.7	82.6	26.5	106	215	M20
		Polar moment of inertia $J_m = 1420 \text{ kgmm}^2$ Weight: $m = 7 \text{ kg}$							Polar moment of inertia $J_m = 2229 \text{ kgmm}^2$ Weight: $m = 16 \text{ kg}$						

**Hydrobase**



4 Plastic shipping cover retained by 3 transit nuts

Pressure to port A = clockwise rotation  
Pressure to port B = anti-clockwise rotation

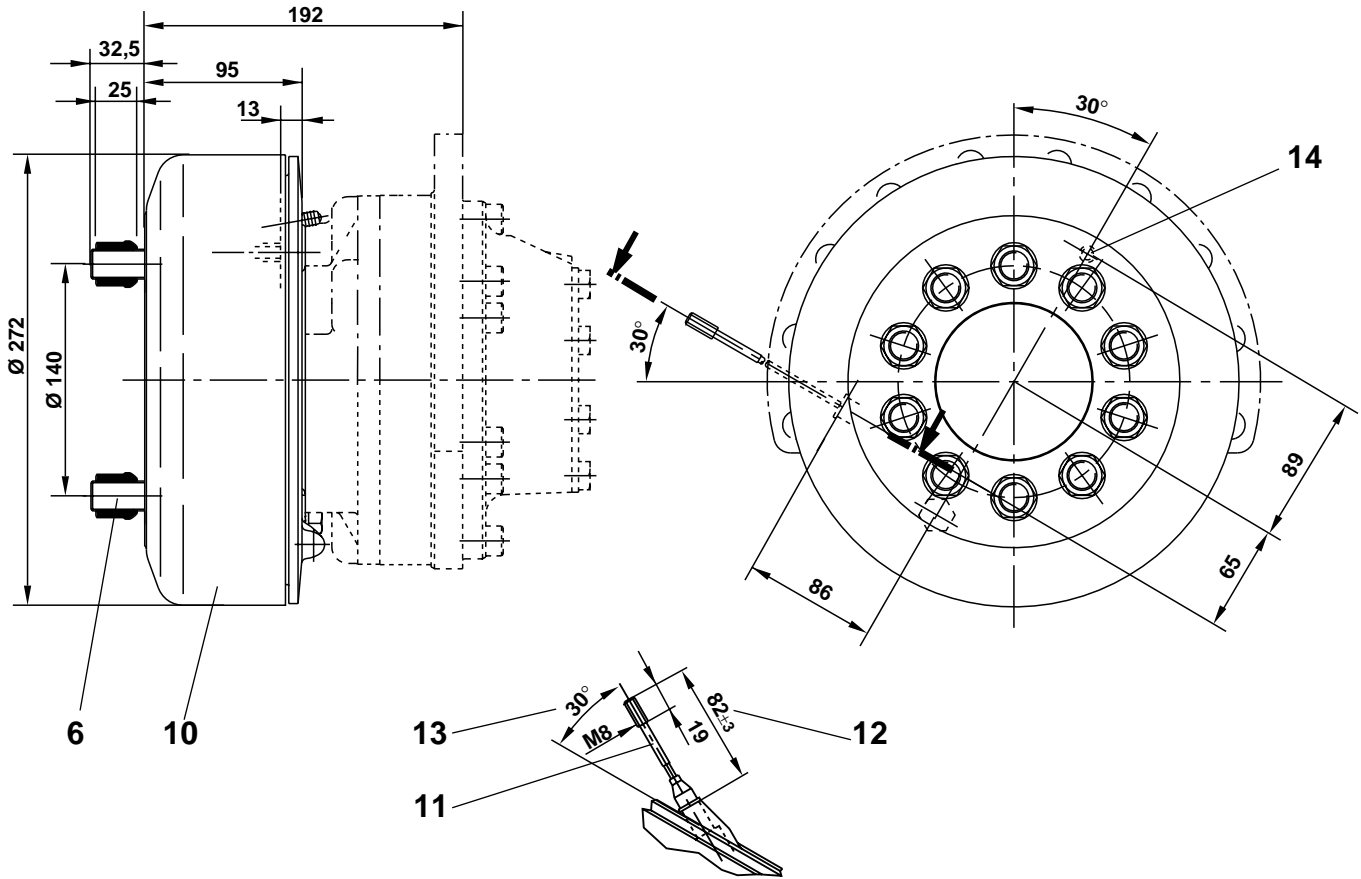
Port	Dimensions / Order code	
	01	12
A, B	G 3/4	1 1/16-12 SAE
L	G 3/8	3/4-16 SAE
F	G 1/2	3/4-16 SAE

- 1 Port A; B (inlet, outlet),
- 2 Case drain port L
- 3 Filling port F, may also be used as drain port
- 4 Studs M12 x 1,75 x 12-off

**Unit dimensions**

(in mm)

**Travel brake (drum brake) ordering code "C4<sup>R</sup><sub>L</sub>"**

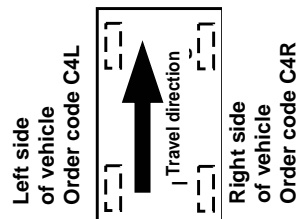


Weight:  $m = 19$  kg

Brake torque after run-in (100 braking operations)			
Braking torque	Cable Tension	Braking torque	Port pressure
3000 Nm	1270 Nm	3000 Nm	73 bar
4000 Nm	1661 Nm	4000 Nm	93 bar

Polar moment of inertia  $J_m = 53546$  kgmm<sup>2</sup>

- 6 Studs M18 x 1,5
- 10 Travel brake (drum brake) ordering code "C4.." for brake fluid DOT 3+4 or SAE JI 703
- 11 Braking cable (Bowden cable), the brake illustrated is for right side of the vehicle. The left side brake is a mirror image of this ( see fig. below).
- 12 Brake cable length
- 13 Angular position of brake cable
- 14 Brake port:  $p_{max} = 97$  bar
- 15 Brake cylinder operating volume  $V = 9$  cm<sup>3</sup>



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