Chapter 5

Hydraulic motors

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1 Introduction

Hydraulic motors are used for converting hydraulic energy into mechanical energy.

As with hydraulic pumps, there are a variety of different types and designs of hydraulic motors. As there is no one type which can fulfil all the requirements to an optimum degree, the motor best suited for an application must be decided upon.

Speed

There are only a few motors which may be used at both very low speeds and at high speed of over 1000 rpm.

Hence hydraulic motors may be categorised into high speed motors (n = 500 to 10 000 rpm) and slow slow motors (n = 0 to 1 000 rpm).

Torque

The torque produced by the motor is dependent on the displacement and pressure drop at the motor. Slow motors are designed in such a way that large torques are already produced at small speeds. These LSHT (low speed - high torque) motors will be described in a separate section.

Power output

The power produced by a hydraulic motor is dependent on the flow and pressure drop at the motor. As the power is directly proportional to the speed, high speed motors are suitable for applications where a high power output is required.

2 Basic design

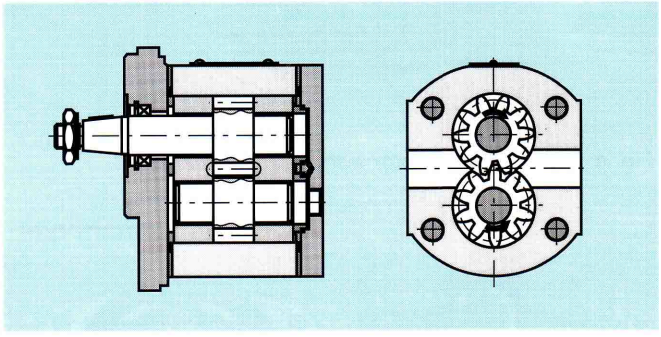

Fig. 1: *Gear motor*

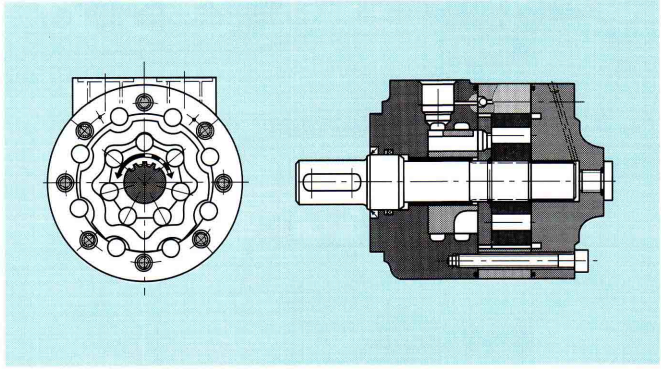

Fig. 2: *Gear ring or epicyclic gear motor*

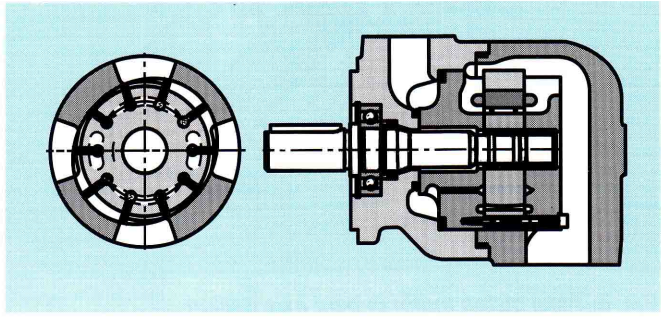

Fig. 3: *Vane motor*

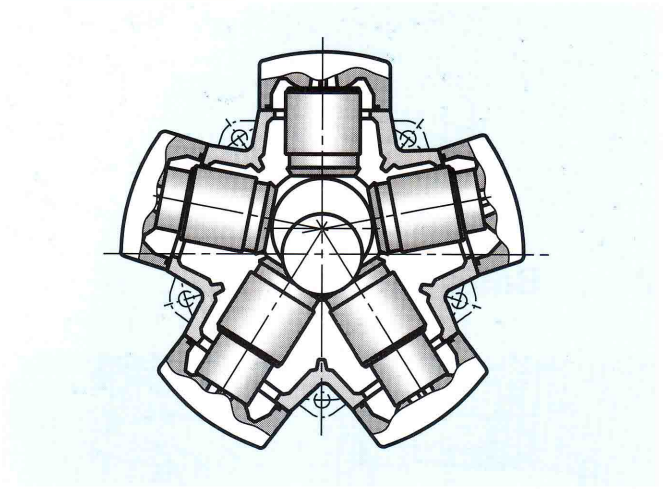

Fig. 4: *Radial piston motor with internal eccenter*

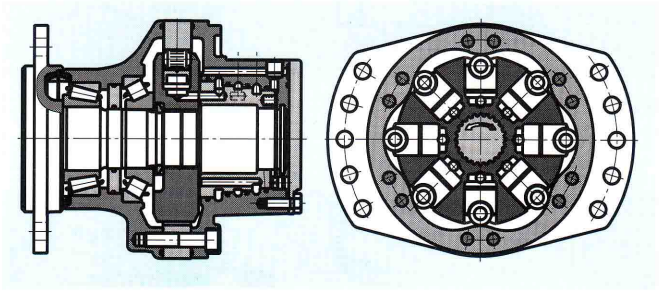

Fig. 5: *Multi-stroke radial piston motor with external cam*

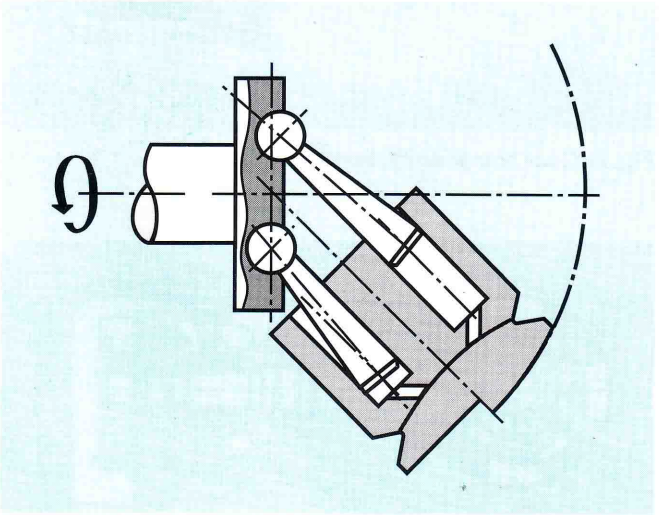

Fig. 6: *Axial piston motor in bent axis design*

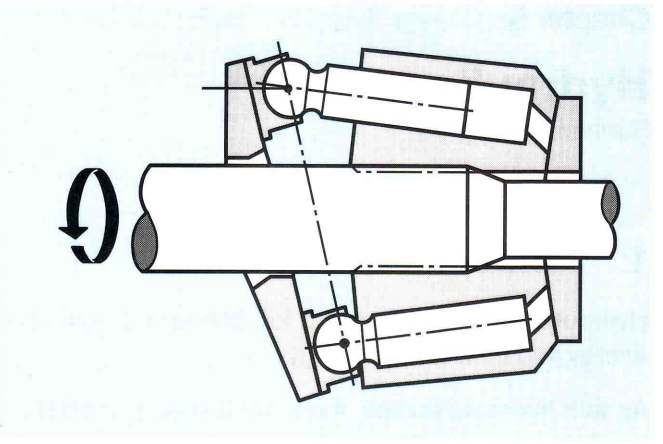

Fig. 7: *Axial piston motor in swashplate design*

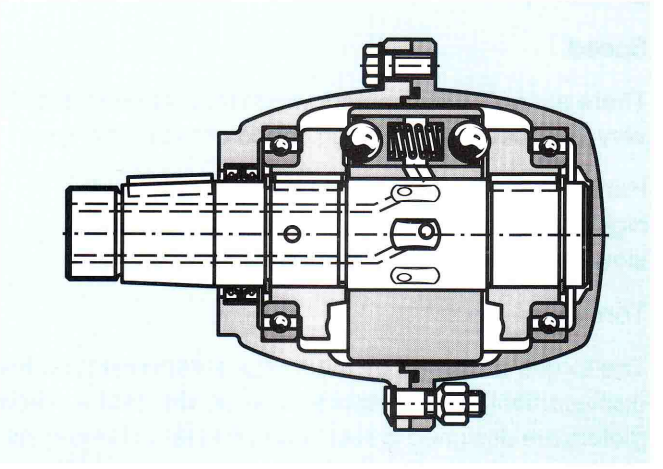

Fig. 8: *Multi-stroke axial piston motor with rotating case*

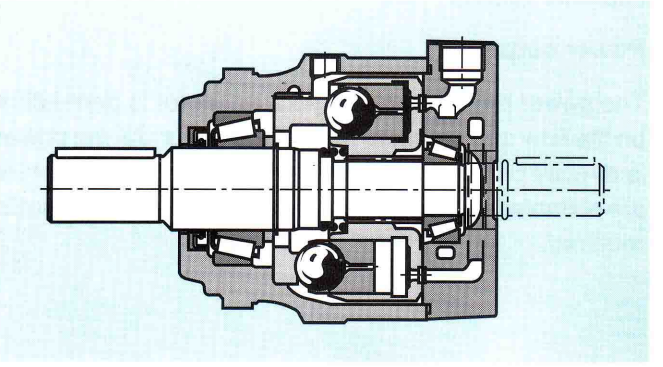

Fig. 9: *Multi-stroke piston motor with rotating shaft*

3 Functional descriptions

3.1 Gear motors

Gear motors are very similar in design to gear pumps (see chapter "Hydraulic pumps"). They are different in that the axial pressure field is different and gear motors have a drain case port, as they are designed for changing directions of rotation.

The fluid flowing to the hydraulic motor acts on the gears. A torque is produced which is output via the motor shaft.

Gear motors are often used in mobile hydraulics and in agricultural machinery to drive conveyor belts, dispersion plates, ventilators, screw conveyors or fans.

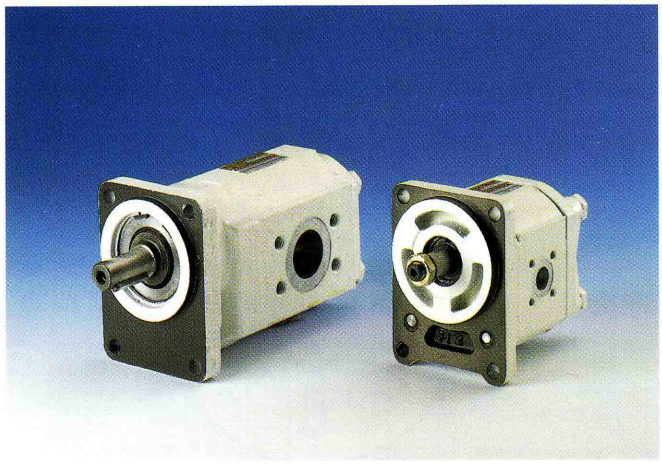

Fig. 11: *Gear motors*

Important parameters

Displacement	approx. 1 to 200 cm^3
Max. operating pressue	up to 300 bar
Range of speeds	500 to 10 000 rpm

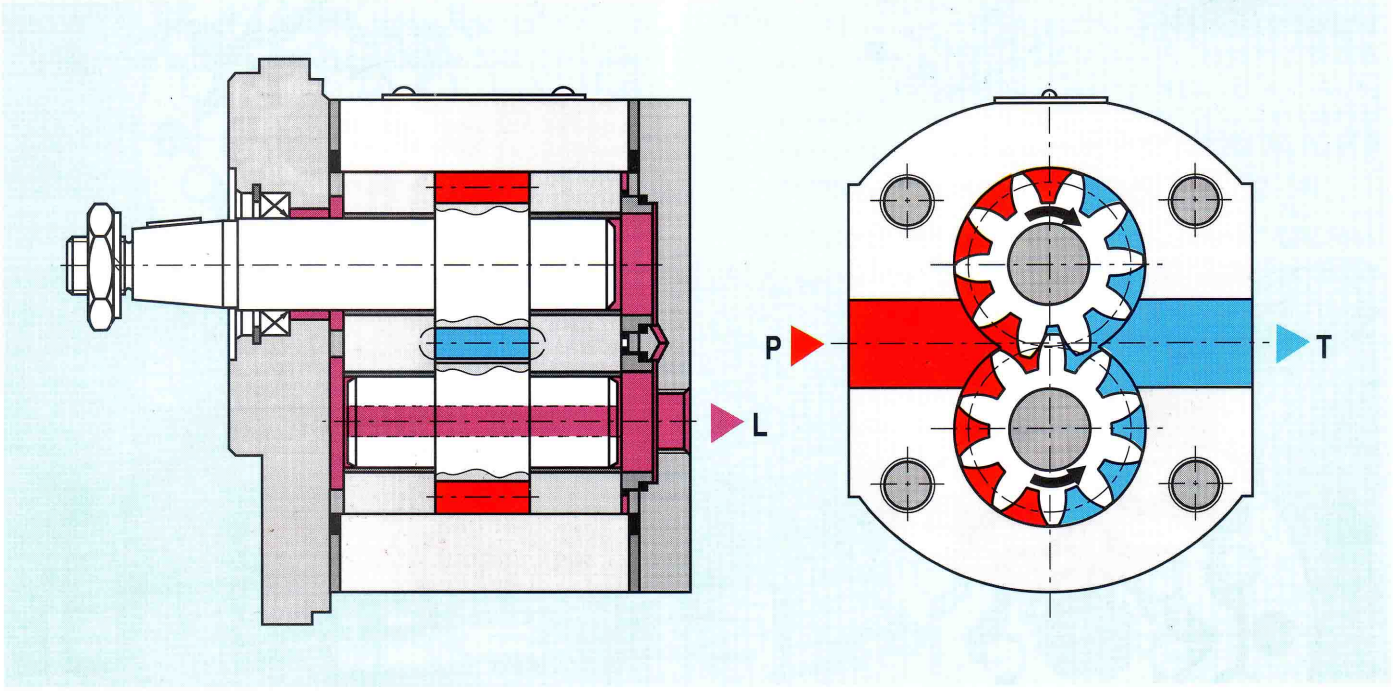

Fig. 10: *Gear motor, type G2*

Gear motors and axial piston motors (see chapter "axial piston machines") are high speed motors. Fast motors are used for speeds of over 500 rpm. For applications requiring low speeds, either high speed motors are used with gears or slow speed motors are used. Slow speed motors or LSHT (low speed - high torque) motors exhibit their best characteristics and efficiencies for speeds of less than 500 rpm.

3.2 LSHT motors (slow speed motors)

3.2.1 Epicyclic gear motors with central shafts

Hydraulic motors, type MZ belong to the group of epicyclic gear motors. Their main feature is to offer large dispacements within small dimensions.

This is achieved due to a large number of displacement processes occurring per revolution of the output shaft.

Fig. 12: *Epicyclic gear motors*

The operation is as follows:

In the commutator (2) which is pressed into the housing (1), fluid is fed to and from the control disc (10) via 2 ring channels (13) and 16 longitudinal bores. The control plate is connected to the shaft (4) via a spline. The rotor (6) and control disc (10) rotate at the same speed.

The connection between commutator (2) and displacement chambers is achieved via control apertures (11) arranged radially in the control disc. The displacement chambers are formed by the internal surface of the internal gear (7), external surface of the rotor (6) and internal rollers (8).

Within the commutator, half of the 16 longitudinal bores are connected to the high pressure and the other half are connected to the low pressure.

All displacement chambers which are currently increasing in volume are connected to the high pressure side via the control plate. All displacement chambers which are currently decreasing in volume are connected to the low pressure side.

The pressure in these chambers produces a force which acts on the rotor, which creates a torque. The internal gear (7) is thus supported by the external castors (9).

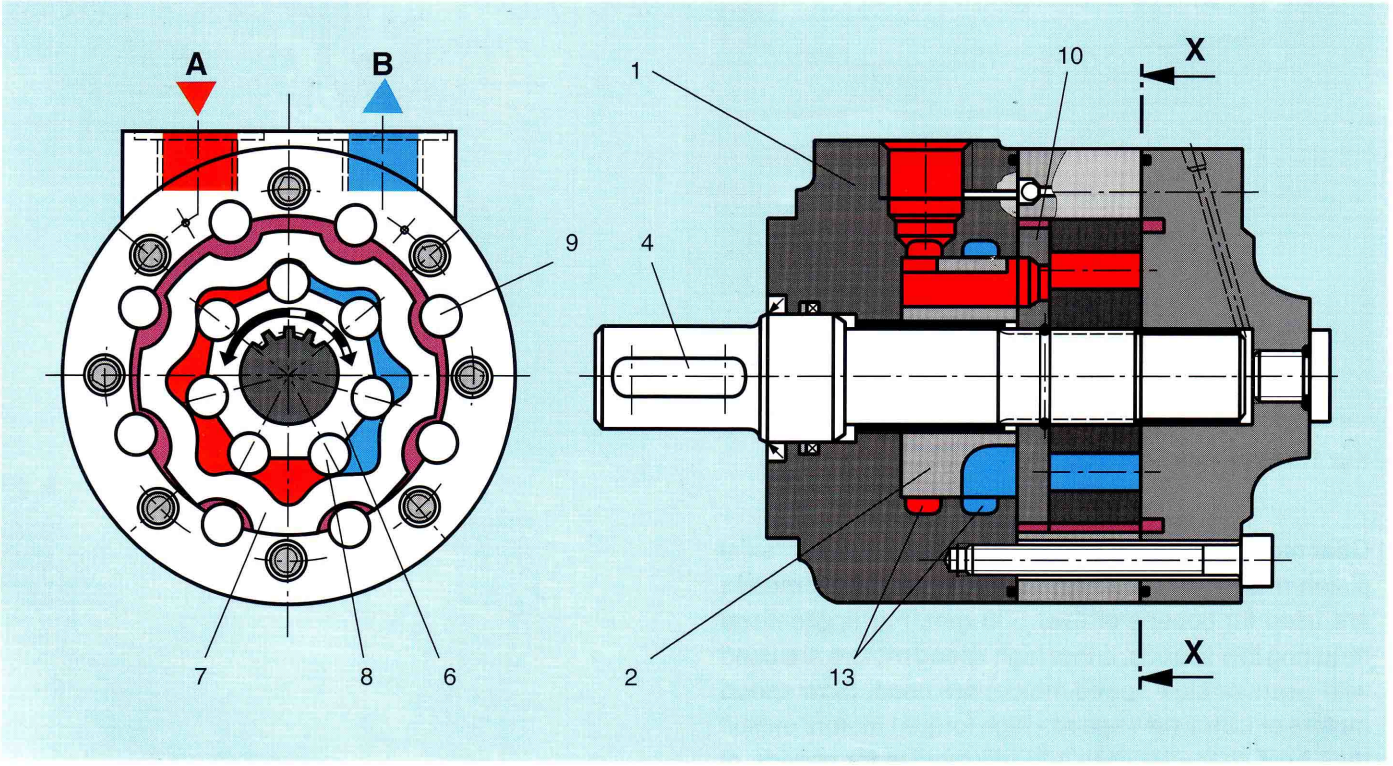

Fig. 13: *Epicyclic gear motor, type MZD*

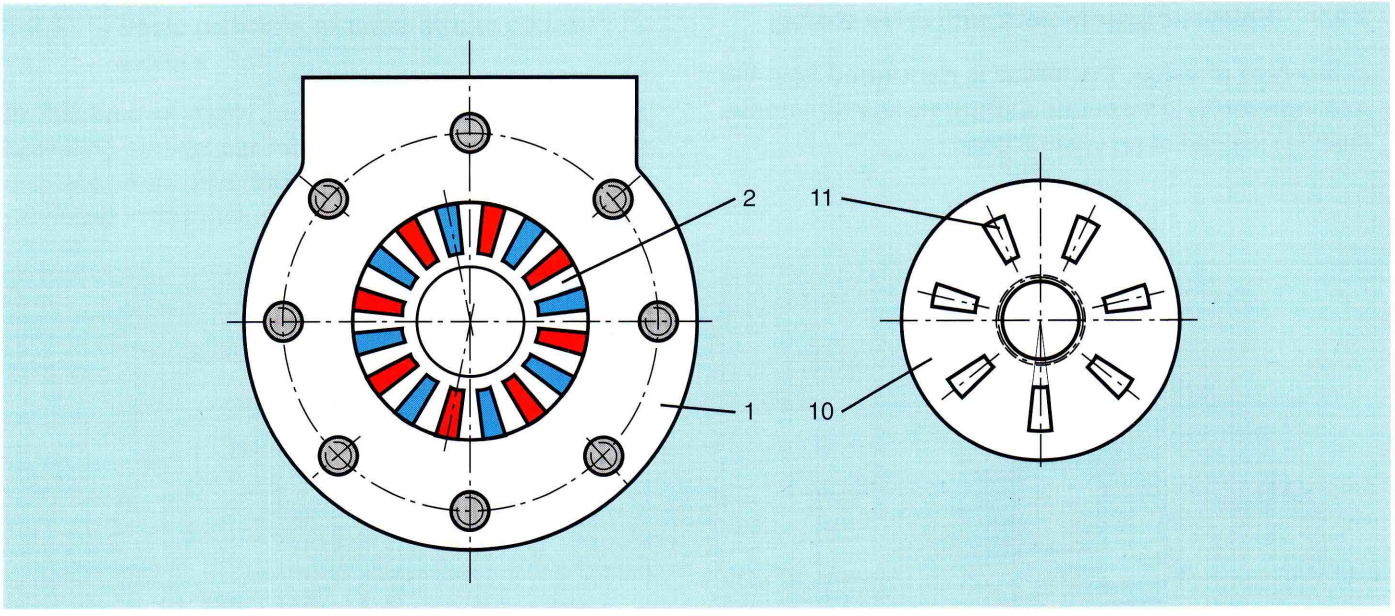

Fig. 14

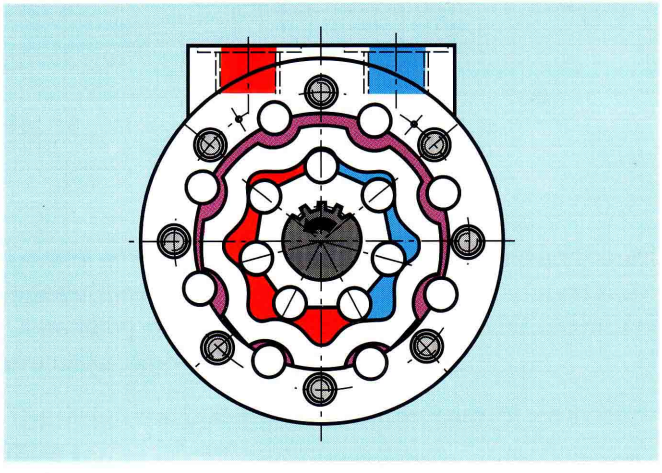

Fig. 15

Each time the largest or smallest chamber volume is produced, the control is reversed. 8 changes in volume occur per chamber per shaft rotation. Thus 7 chambers x 8 = 56 displacement processes take place per revolution. This is the reason for the relatively high displacement which occurs per rotation.

It is possible to mount a holding brake onto the central output shaft or to use the second shaft end for the output of rotational movement (for example) (see *Fig. 16*).

Internal check valves are used to feed internal leakages to the current low pressure side. As the pressure in this region may exceed the permissible value, it is essential that the drain case port is connected to tank.

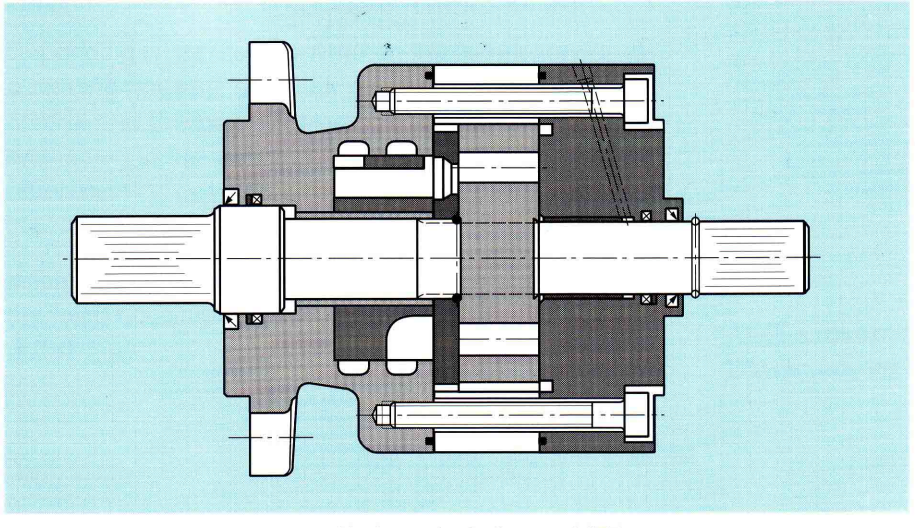

Fig. 16: *Epicyclic gear motor with through shaft, type MZD*

3.2.2 Epicyclic gear motors with drive shafts

In this type of motor, the torque is transferred from the rotating rotor (2) to the output shaft (3) via an internal drive shaft (1) instead of an internal gear.

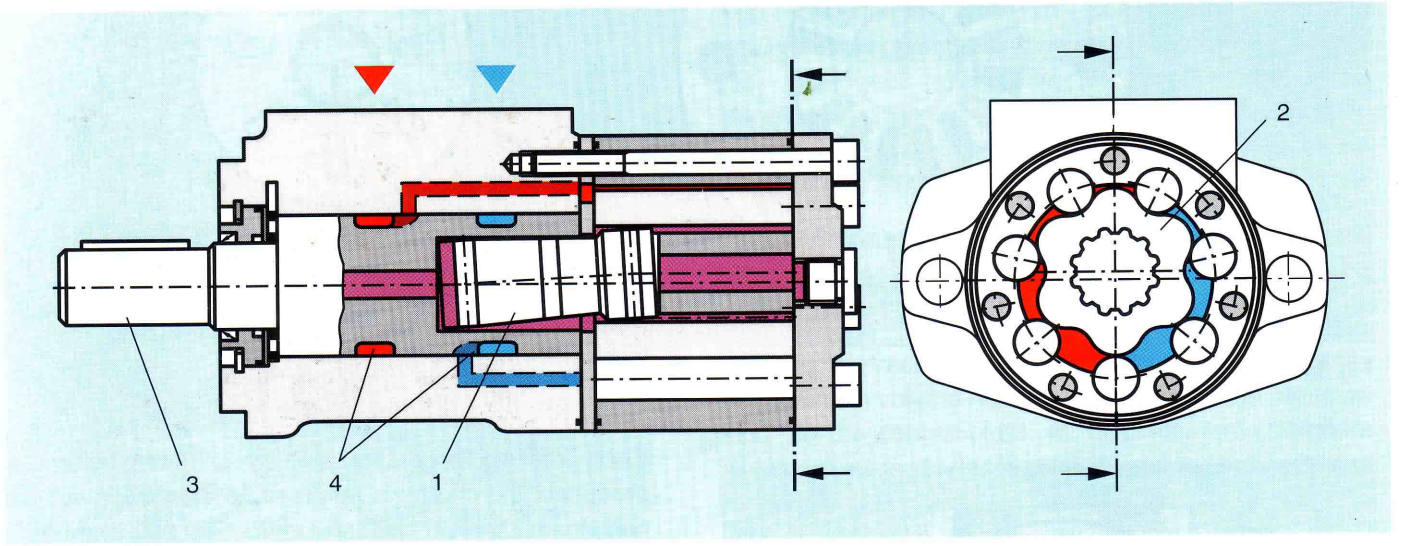

Fig. 17

The operating fluid flowing to the hydraulic motor is distributed in the output shaft via bores (4) and fed to the displacement chambers in the housing via bores. The fluid is returned by the same method.

A large variety of epicyclic hydraulic motors are available.

Important parameters

Displacement:	approx. 10 to 1000 cm^3
Max. operating pressure:	up to 250 bar
Range of speeds:	approx. 5 to 1000 rpm

3.2.3 Basic principle of multi-stroke piston motors

In this type of motor, each piston carries out several operating strokes per rotation of the shaft. Hence high displacements and thus high operating torques are produced in this motor.

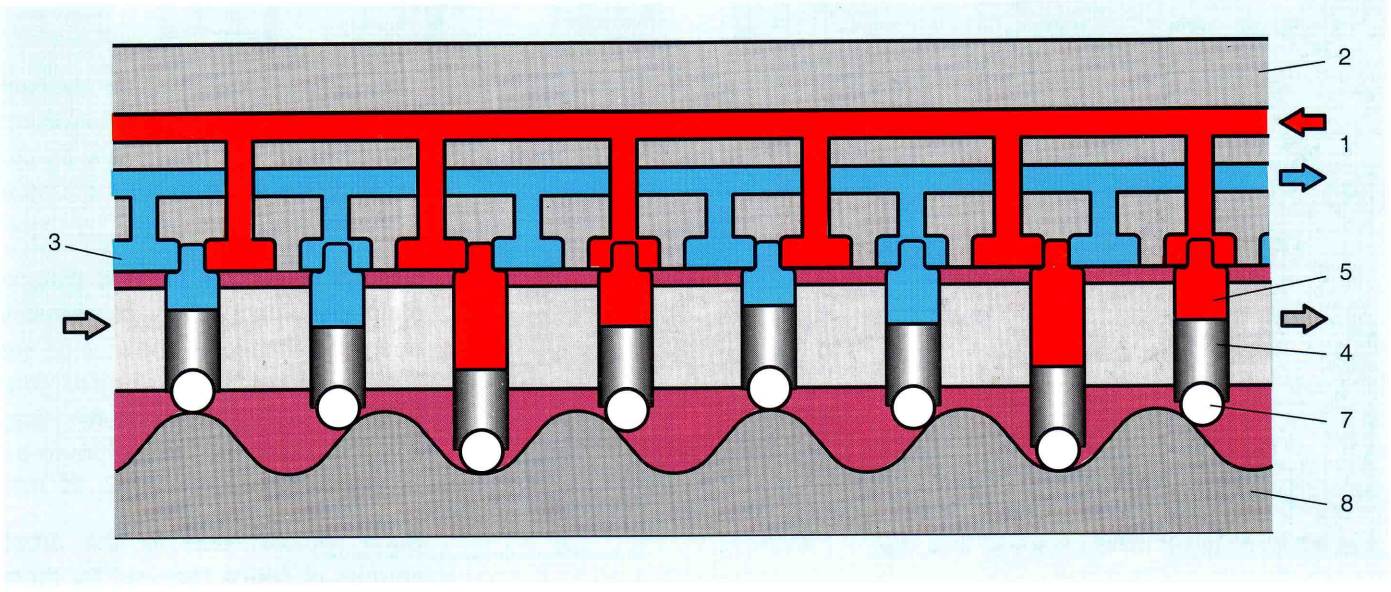

Fig. 18

Control windows (3) are connected to the feed and return sides of the motor via pipe connections (1) and control (2). Depending on the current position, cylinder chambers are either emptied or filled.

The piston is supported by the stroke cam (8) via a ball or roller (7).

The force (F_T) which is converted into torque is dependent on the force F_A (area of the piston x operating pressure) and on the angle of the stroke cam (α).

Depending on the design of motor, the output may be via a rotating housing; the shaft may contain an integrated control and the pipe connections may be permanently connected to the machine (see *section 3.2.3.1*). On the other hand the cylinders and pistons may be connected to the output shaft.

In this case, the control and stroke cam are situated within the fixed housing of the motor (see *section 3.2.3.2 and 3.2.4*).

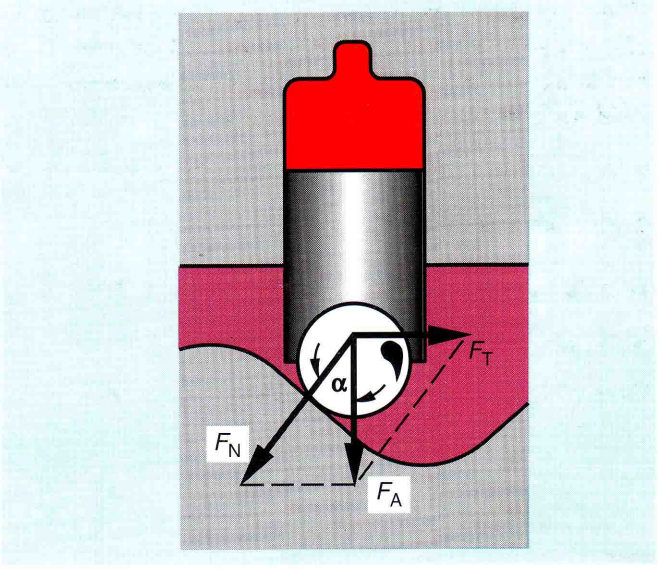

Fig. 19

Multi-stroke hydraulic motors have very good slow speed characteristics and are used in many applications.

3.2.3.1 Multi-stroke axial piston motors with rotating housing

This type of motor only requires a relatively small space for installation.

The control and pipe connections are integrated into the motor shaft.

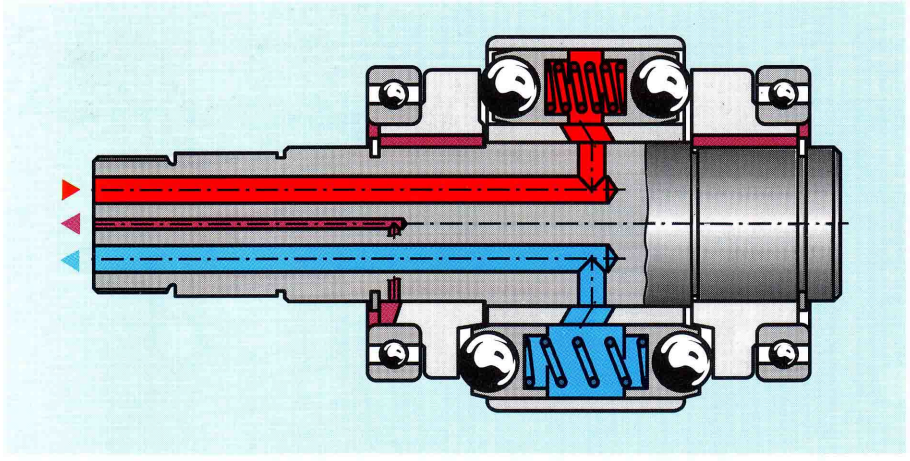

Fig. 20: *Insert motor without housing, type MCA*

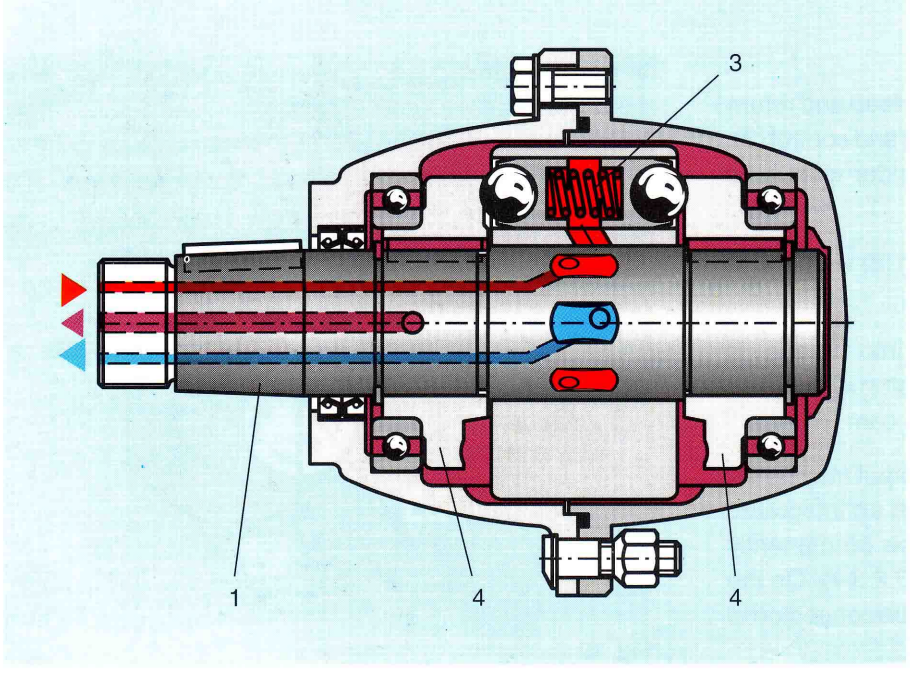

Fig. 21: *Axial piston motor with rotating housing, type MCH*

Two cams (4) are permanently fixed to the shaft (1). The rotor/piston groups are supported axially by the stroke cams and transfer the torque to the rotating housing.

Springs (3) ensure that the pistons maintain contact with the cams in any operating situation. If the springs are removed and if the housing chamber is placed under a low pressure (1 bar) it is possible for these motors to be free-wheeling.

Such motors, due to the small amount of space required for them are very suitable for use in gearbox or winch drive applications.

Important parameters

Displacement:
200 to 1000 cm^3

Max. operating pressure:
up to 250 bar

Range of speeds:
5 to 300 rpm

Max. torque:
up to 3800 Nm

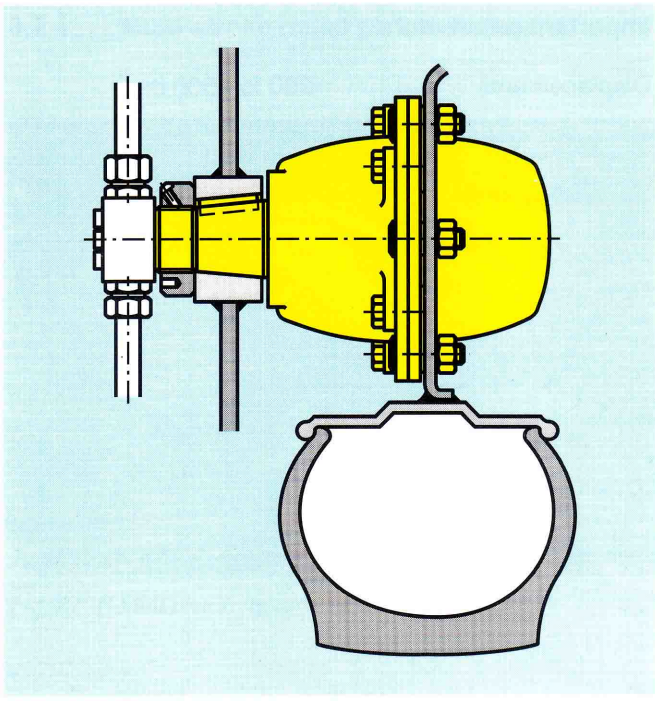

Fig. 22: *Schematic diagram of a wheel drive*

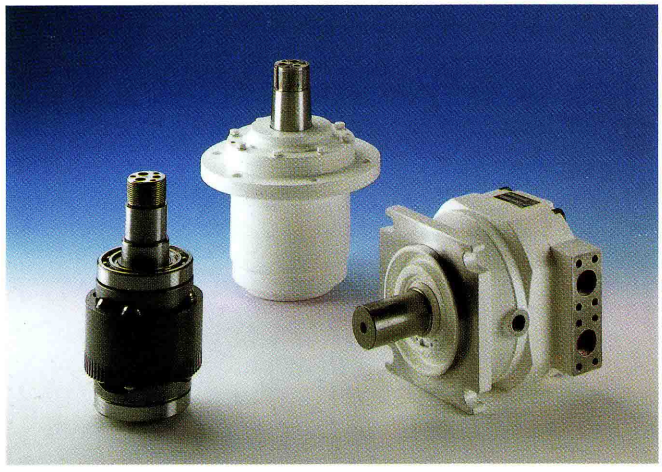

Fig. 24: *Axial piston motors, type MC*

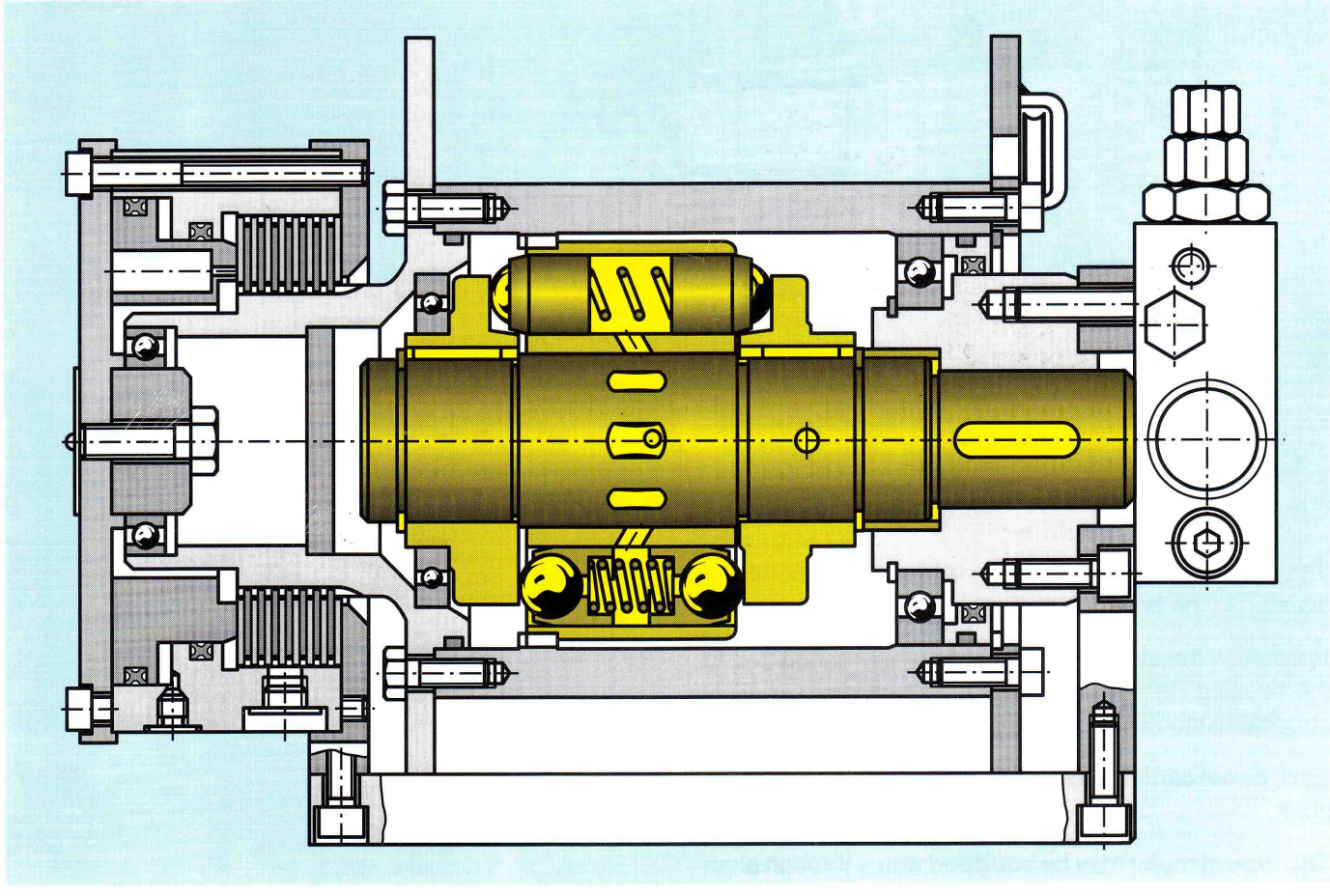

Fig. 23: *Complete winch*

3.2.3.2 Multi-stroke axial piston motors with rotating shaft

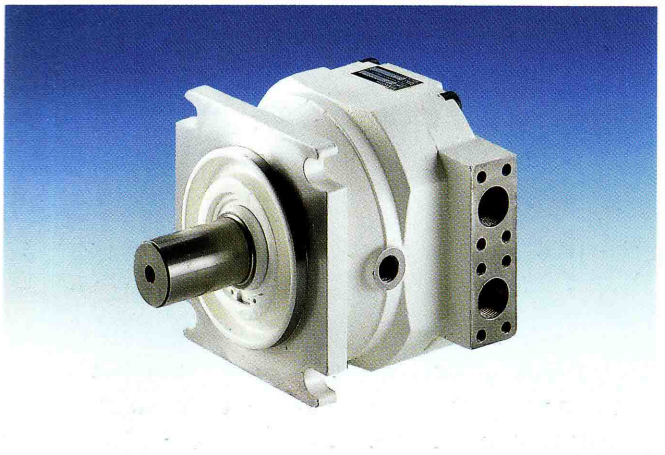

Fig. 25: *Axial piston motors, type MCS*

Important parameters

Displacements:	200 to 1500 cm^3
Max. pressure:	250 bar
Range of speeds:	5 to 500 rpm
Max. torque:	up to 5000 Nm

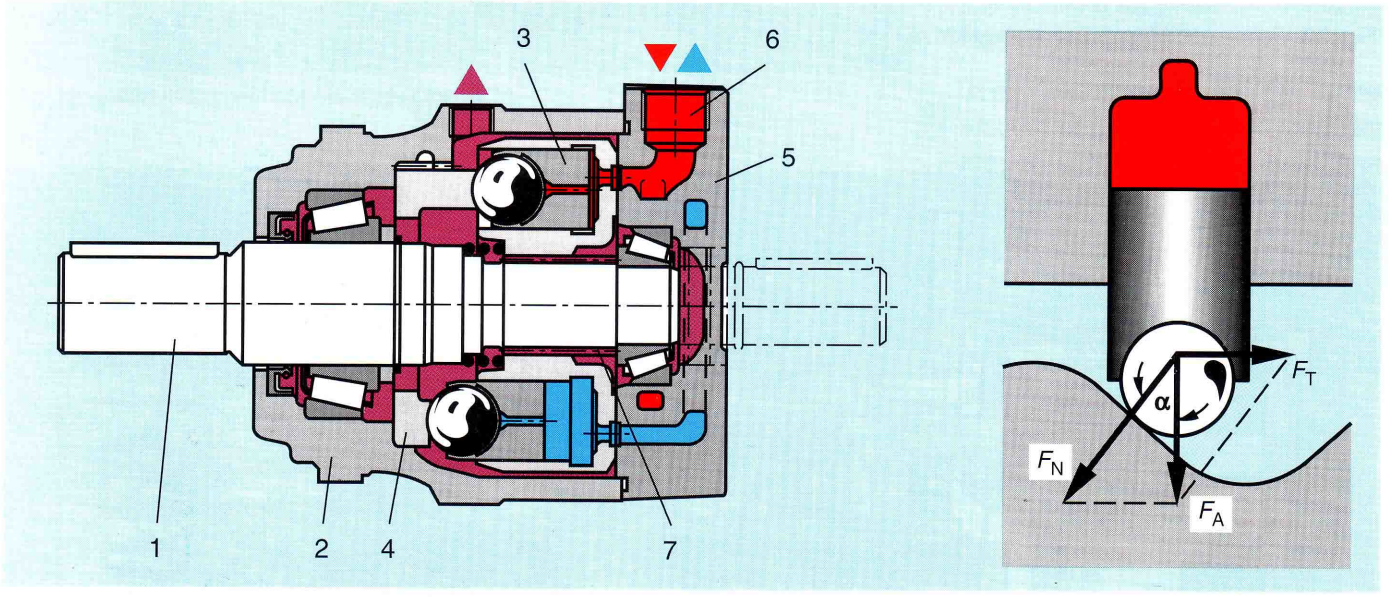

Fig. 26

The control and pipe connections (6) for this motor are situated in the housing (5).

In addition the stroke cam is permanently connected to the housing (2). However, the rotor/piston group (3) is coupled to the output shaft (1) via a spline (7).

Each piston carries out several strokes per rotation of the shaft.

This type of motor may be equipped with a through shaft for a holding brake or for a second output.

3.2.4 Multi-stroke radial piston motors

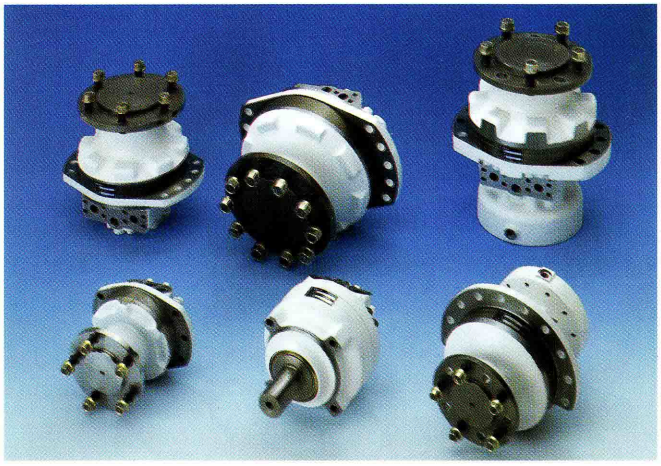

Fig. 27: *Radial piston motors, type MCR*

In this type of motor the pistons (3) arranged radially are supported via the rollers (8) on the cam (4). The cylinder chamber is supplied with fluid via the axial bores in the control (5). Each piston is loaded and unloaded with fluid as many times per rotation of the shaft as there are number of cams on the cam. The torque resulting from the curve of the cam is transferred from the rotor/piston group (3) to the output shaft (7) via a spline (6).

A tapered roller bearing is integrated into the housing (1), which is capable of receiving high axial and radial forces. A multiple-disc brake (9) may be mounted onto the control housing (2) via a through drive.

If the release pressure decreases below a certain value in the ring chamber (10) of this brake, the plate spring (11) presses the multiple discs together. The brake is hence operated.

If the release pressure exceeds the required value, the brake piston (13) is pushed against the plate spring. The multiple discs are separated and the brake is released.

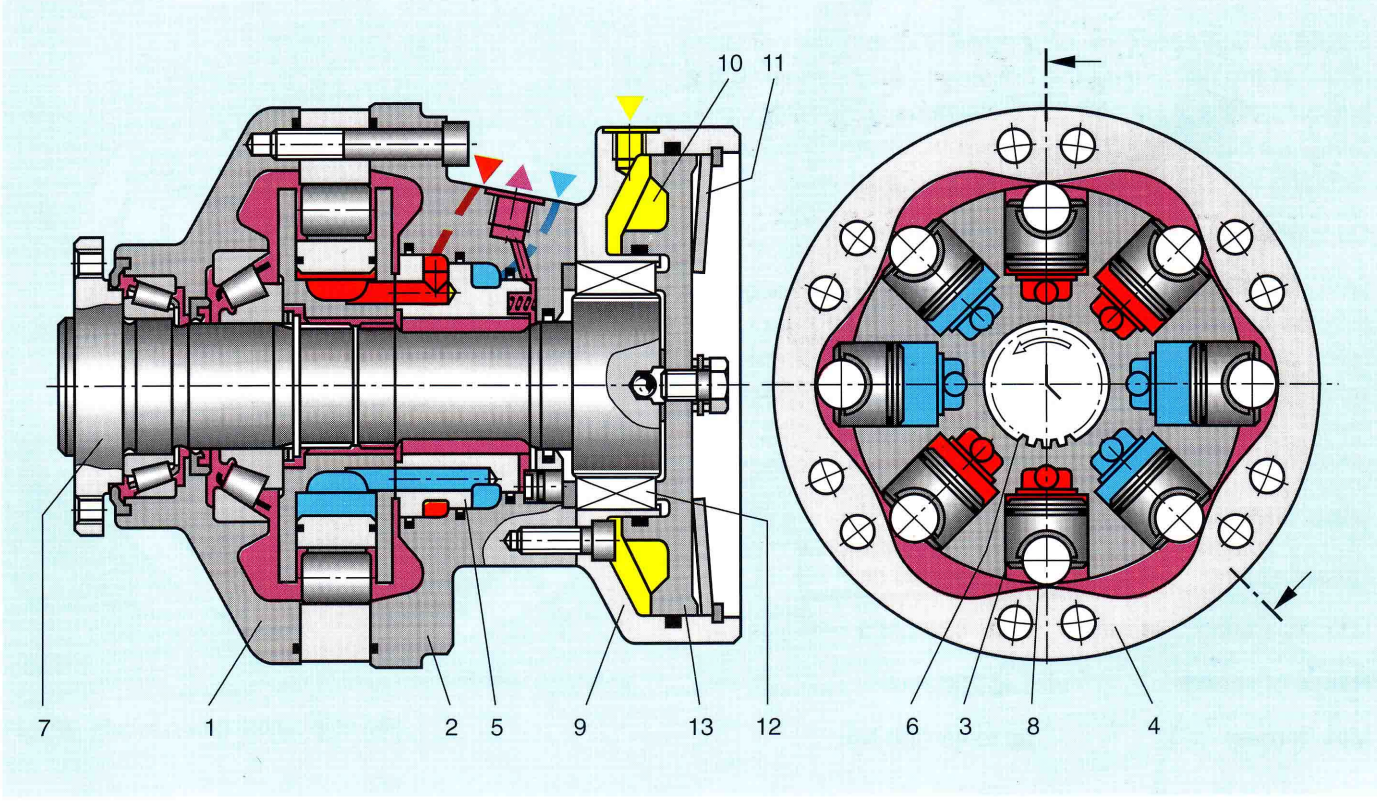

Fig. 28

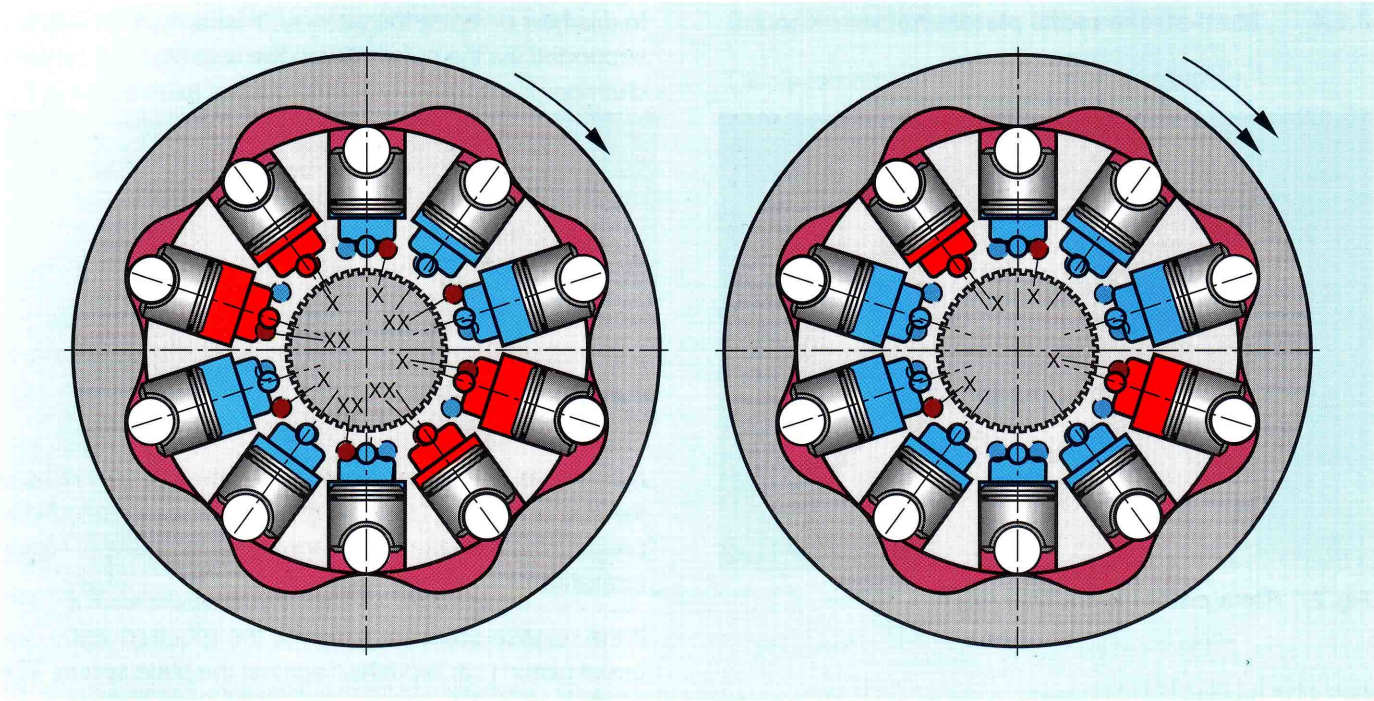

Fig. 29: *Left: set to 100% speed, 100% torque Right: set to 200% speed, 50% torque*

Freewheeling

If both ports A and B are connected to a very low pressure and if at the same time the housing is pressurised with a pressure of 2 bar via port "L", the pistons in the rotor/piston group are pushed in. The rollers do not remain on the stroke cam and the shaft end may then freely rotate.

Circuit with half the displacement

With certain models in radial piston motors the displacement may be halved. This is achieved by only half the pistons being supplied with fluid during a stroke. This is due to a valve in the control. The rest of the pistons are connected to the tank side of the motor. When connected in a circuit, this motor runs at twice the speed, but at half the torque.

Important parameters

Displacement:	200 to 8000 cm^3
Max. operating pressure:	up to 450 bar
Range of speeds:	1 to 300 rpm
Max. torque:	up to 45 000 Nm

3.2.4.1 Radial piston motors (single stroke) with internal eccenter

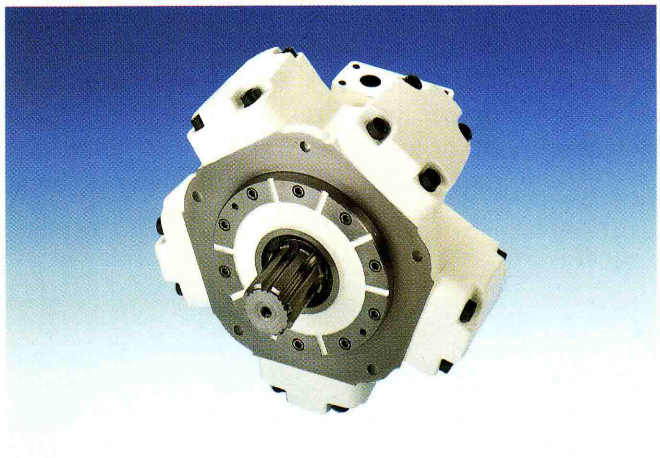

Fig. 30: *Radial piston motors, type MR*

The cylinder and pistons are arranged in the shape of a star around the central eccentric shaft.

Depending on the position of the eccentric shaft 2 or 3 (6) of the 5 (10) pistons are connected to the feed side (pressure side) and the rest of the pistons are connected to the return side (tank side).

The cylinder chambers are supplied with fluid via control (1).

The control basically comprises control plate (2) and distribution valve (3).

Whilst the control plate is connected via pins to the housing so that it rotates with the housing, the distribution valve rotates at the same speed as the eccentric shaft.

Connection to control plate and hence to the piston chambers is via bores in the distribution valve.

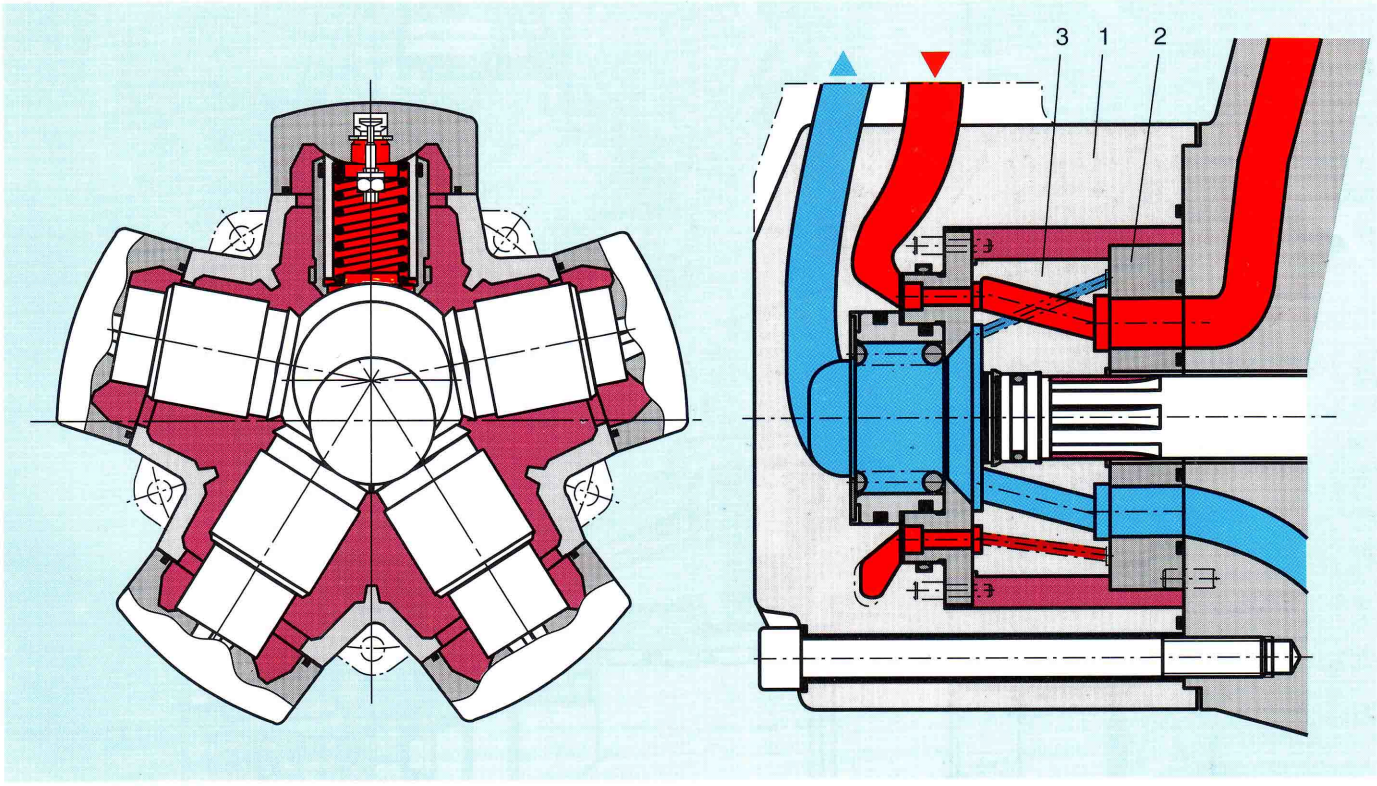

Fig. 31: *Radial piston motor, type MR*

Force may be transferred from the pistons to the eccentric shaft via various methods:

In the model shown in *Fig. 32*, the pistons are within the housing and are supported by special shaped rings on the eccentric shaft.

During rotation of the shaft a relative movement occurs between the piston and ring. In order to minimise friction the contact surface of the piston on the ring is hydrostatically unloaded.

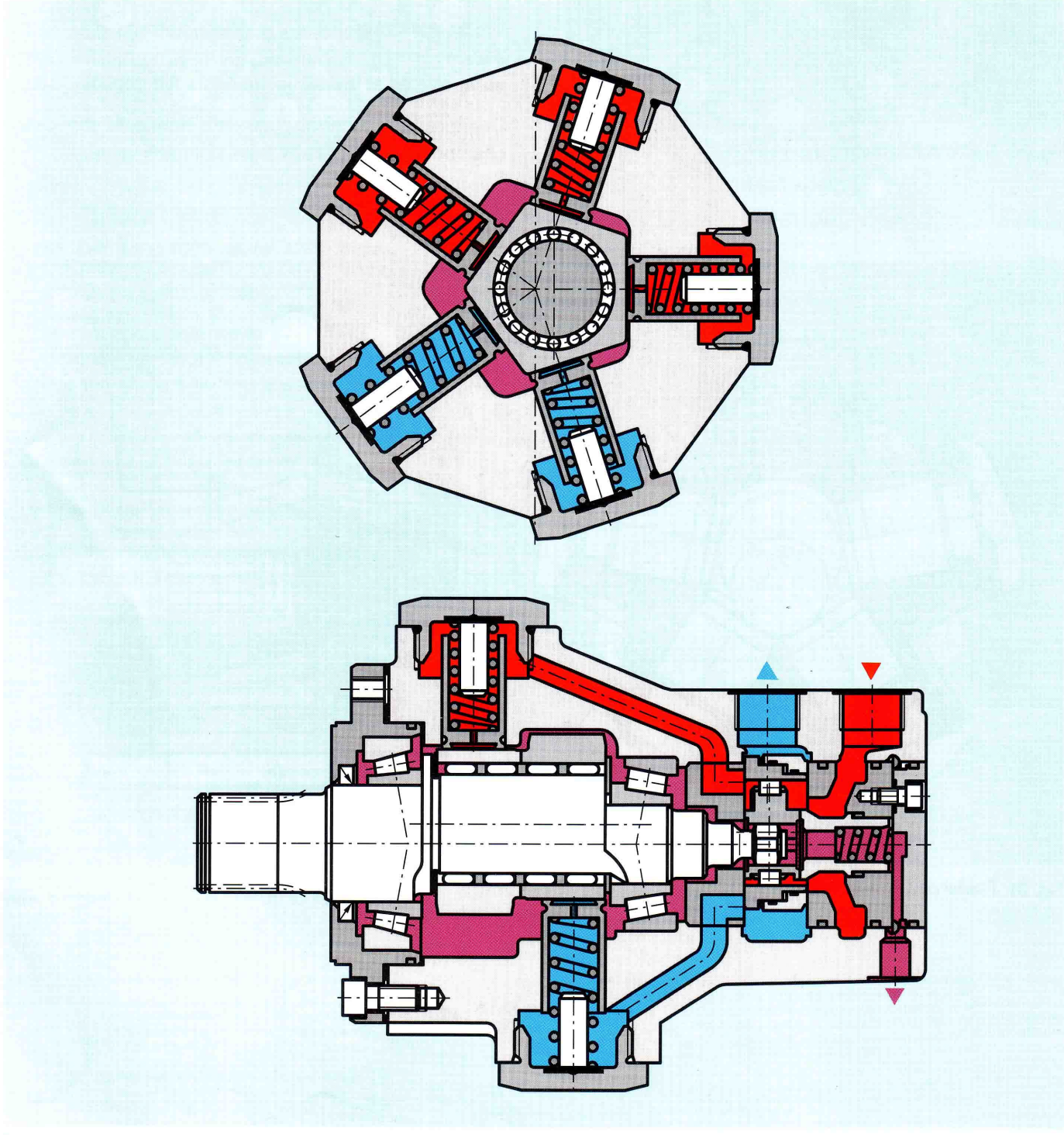

Fig. 32

In another type of model, the operating pressure acts on the eccentric shaft. Pistons and cylinder are supported by spherical surfaces and hence follow the eccentric shaft free of side loads.

The contact surfaces at the eccenter and housing are mostly hydrostatically unloaded, so that friction is minimal. This design is very efficient and has a good slow speed characteristic.

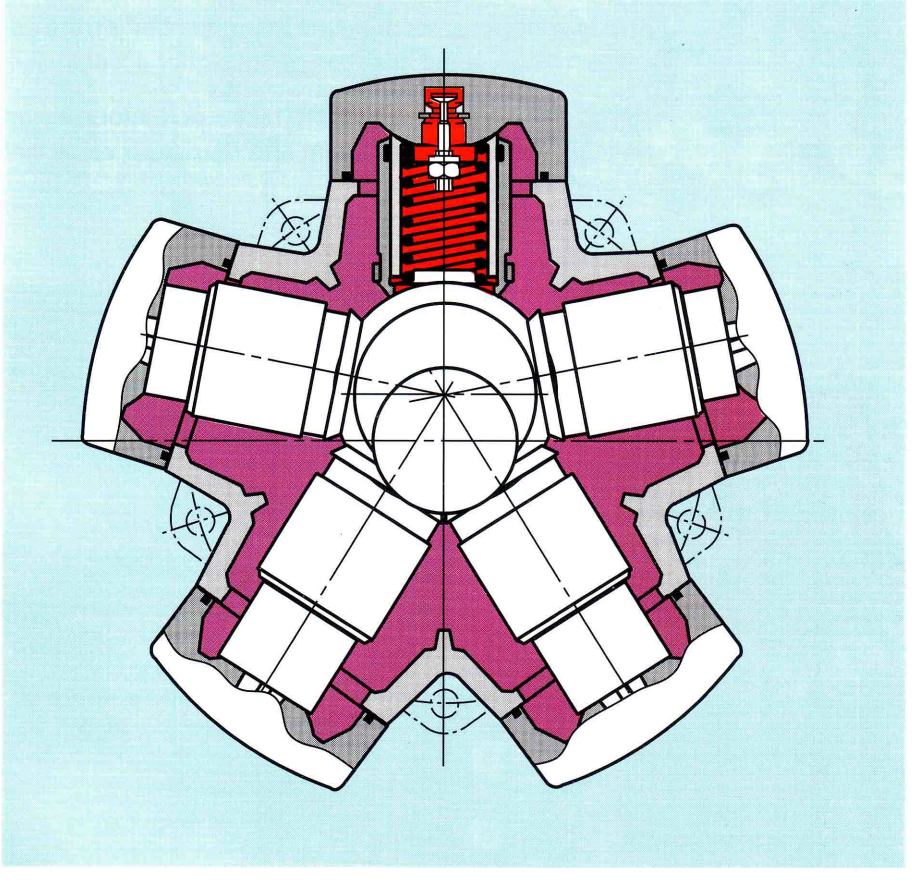

Fig. 33

Important parameters

Displacement:	10 to 8 500 cm^3
Max. pressure:	up to 300 bar
Range of speeds:	0.5 to 2 000 rpm (depending on size)
Max. torque:	up to 32 000 Nm

3.2.4.2 Variable displacement radial piston motors

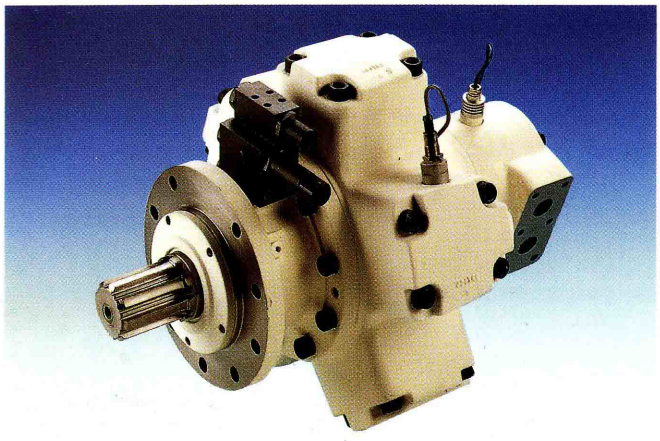

Fig. 34: *Radial piston motor, type MRV*

The basic design of these hydraulic motors is the same as the design described under *section 3.2.4.1.*

The difference to fixed displacement motors is found in the eccentric shaft.

The shaft comprises shaft pivots (1 and 2) and moveable eccenter (3).

The piston chambers within the eccenter (5 and 6) are pressurised via control ports (4). If a higher pressure exists in these piston chambers (6), the eccenter moves in the direction of lower eccentricity. If chamber (5) is places under a higher pressure than chamber (6), the eccenter moves in the direction of the higher eccentricity.

Hence the displacement of the hydraulic motor may be switched between a minimum and maximum value, set by mechanical strokes.

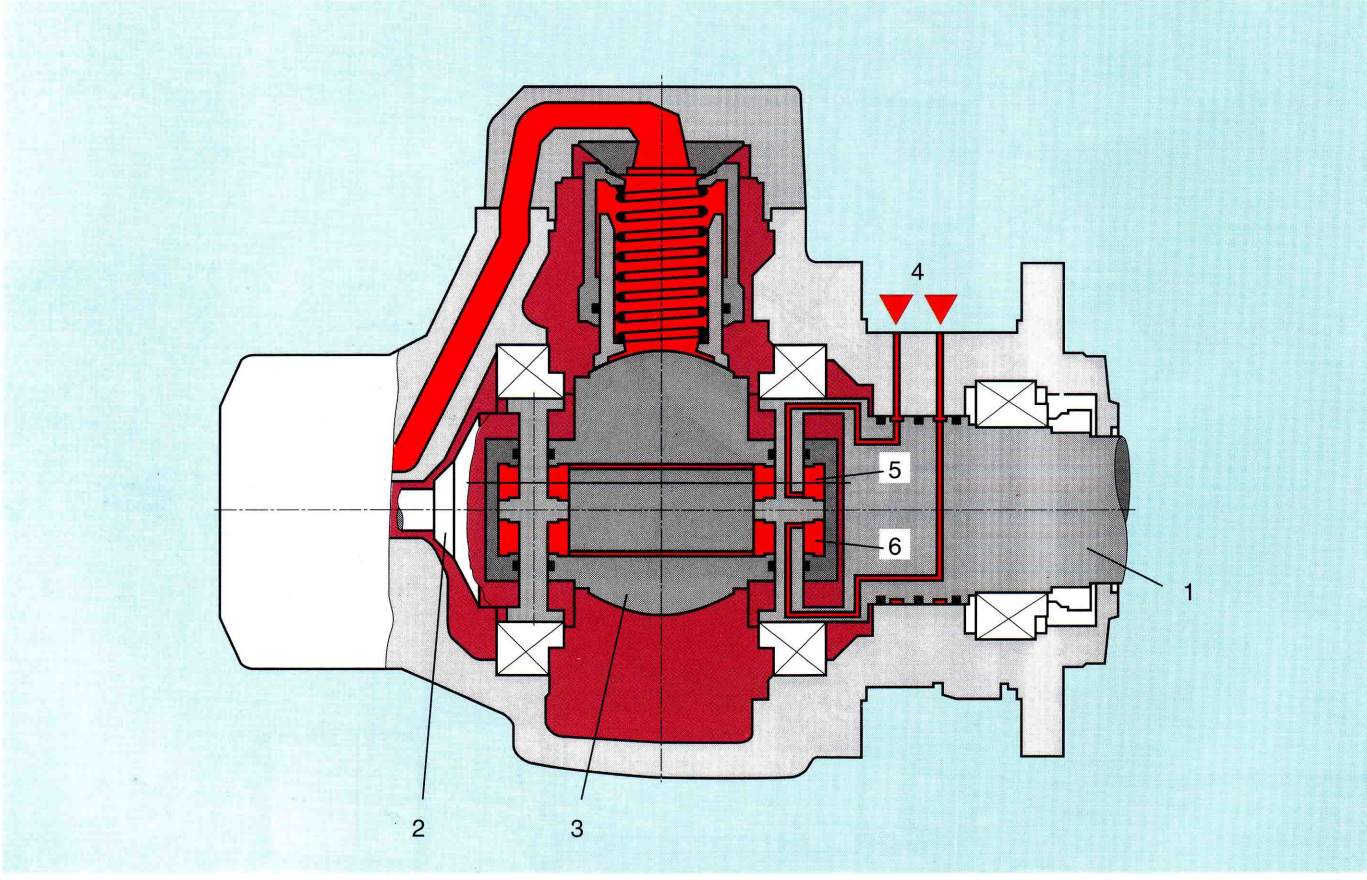

Fig. 35

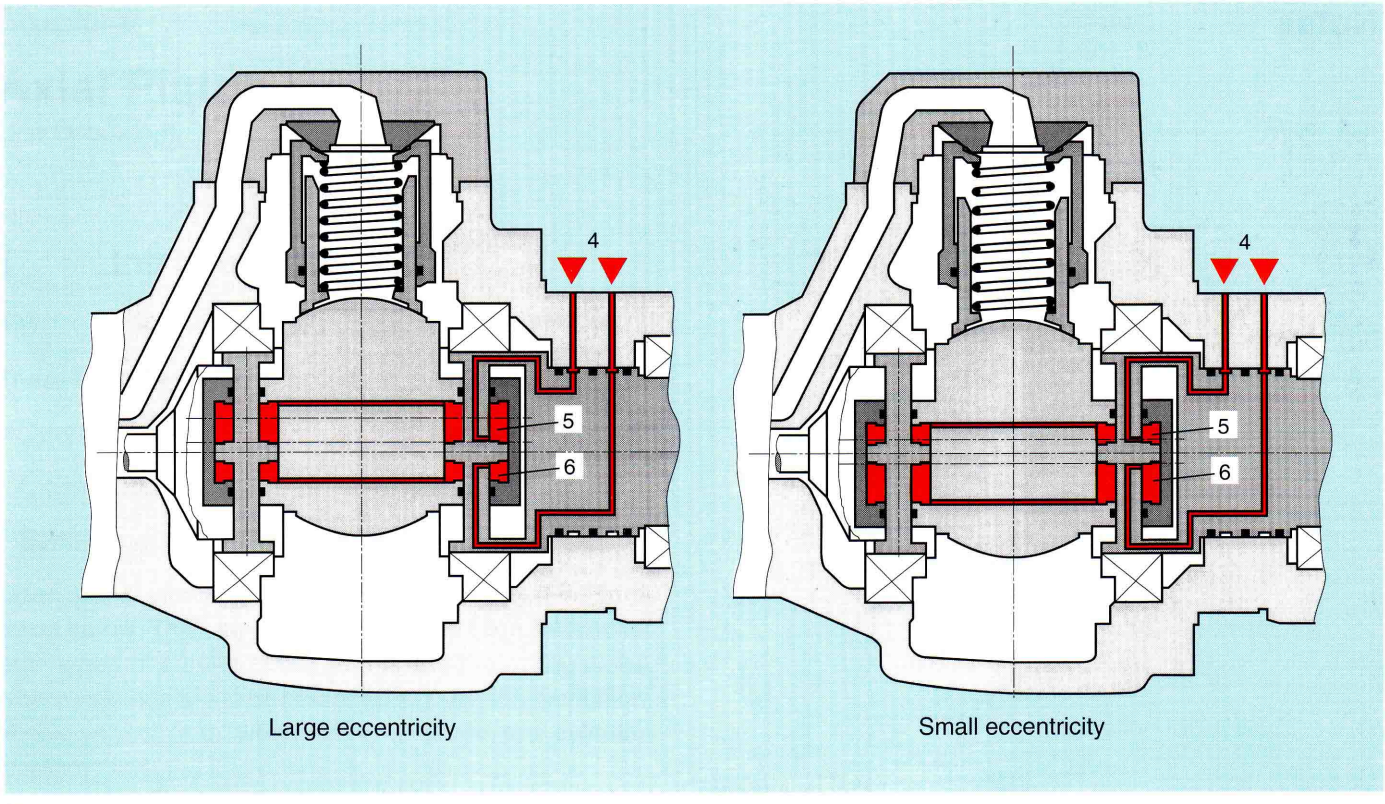

Fig. 36

In order to the displacement to be set smoothly it is necessary for the position of the eccenter to be controlled.

The amount of pendulum movement of the piston is taken as a comparison for the eccentricity.

The positional transducer (3) produces a signal (actual signal) which is compared with the command signal.

If the actual and command signals are not the same, either piston chamber (5) or (6) (depending on whether the deviation is positive or negative) is placed under pressure via a control valve and ports (4). The eccentricity is hence changed in the desired direction.

Radial piston motors with variable displacement together with speed transducers may be used for drives in closed loop control circuits.

Important parameters

Displacement:	200 to 5 500 cm^3
Max. pressure:	up to 300 bar
Range of speeds:	1 to 1 000 rpm
Max. torque:	up to 22 000 Nm

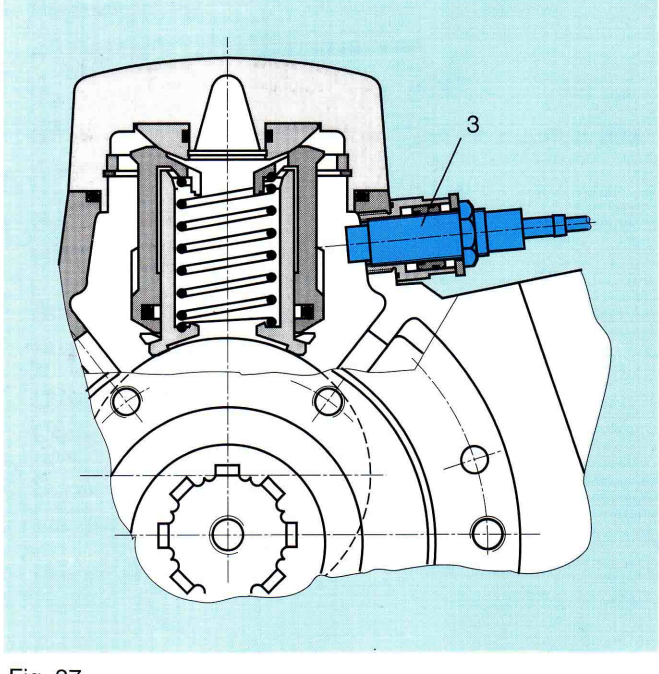

Fig. 37