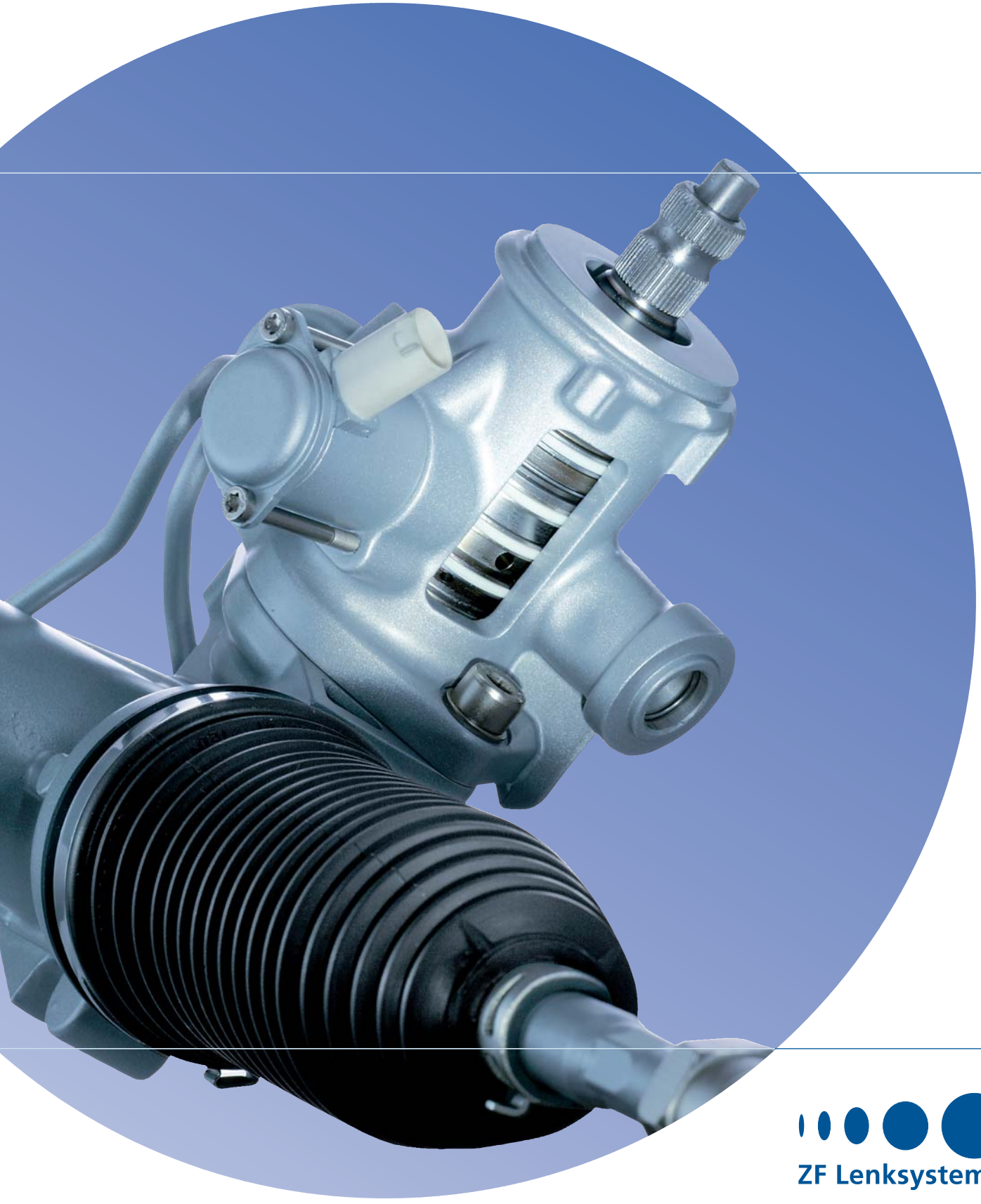
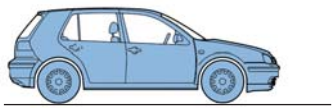
ZF Servotronic® 2

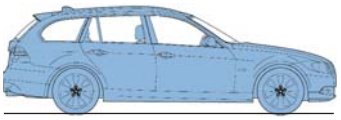
for Passenger Cars and Light Commercial Vehicles

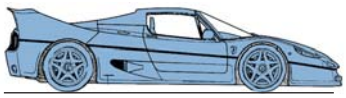


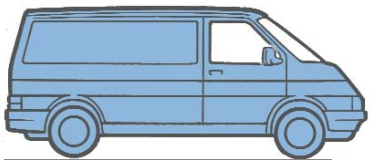
ZF Lenksysteme

Steering the right way.







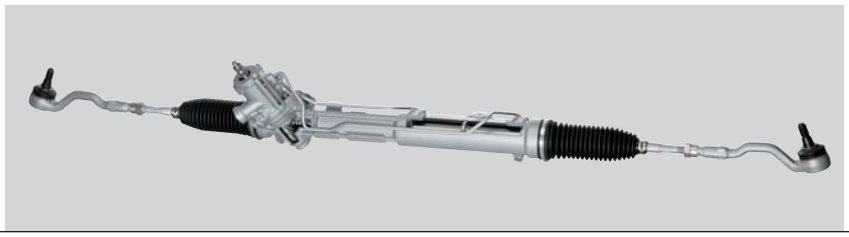


Millions of vehicles.
We can do the steering.

As vital for the vehicle as the engine and the wheels, as important for safety as the brake – the steering system is at the heart of every vehicle. Whether it be a question of operation, safety or ride comfort, one thing is clear – the overall quality of the vehicle also depends on the quality of the steering. The requirements are clearly defined – the steering must be precise and free from play, easy to operate and direct, compact and light in weight. Moreover, it should give the driver a good "feel" of the road and favor the return of the steered wheels into the straight-ahead position.

It has to work shock-free, should require as little maintenance as possible and, at the same time, offer a maximum of safety and comfort at both high and low speeds.

When it comes to safety potential, the power steering gear really comes into its own at high speeds. Abrupt steering corrections – when maneuvering to avoid an obstacle, for example – are easy to master thanks to the power assistance provided by the servo mechanism. Also, the hydraulic system will compensate for the most part for sudden, one-sided steering forces. The driver is able to react to the surprise, keep the vehicle on track and bring it to a halt. And all this only requires a little extra effort on the steering wheel.



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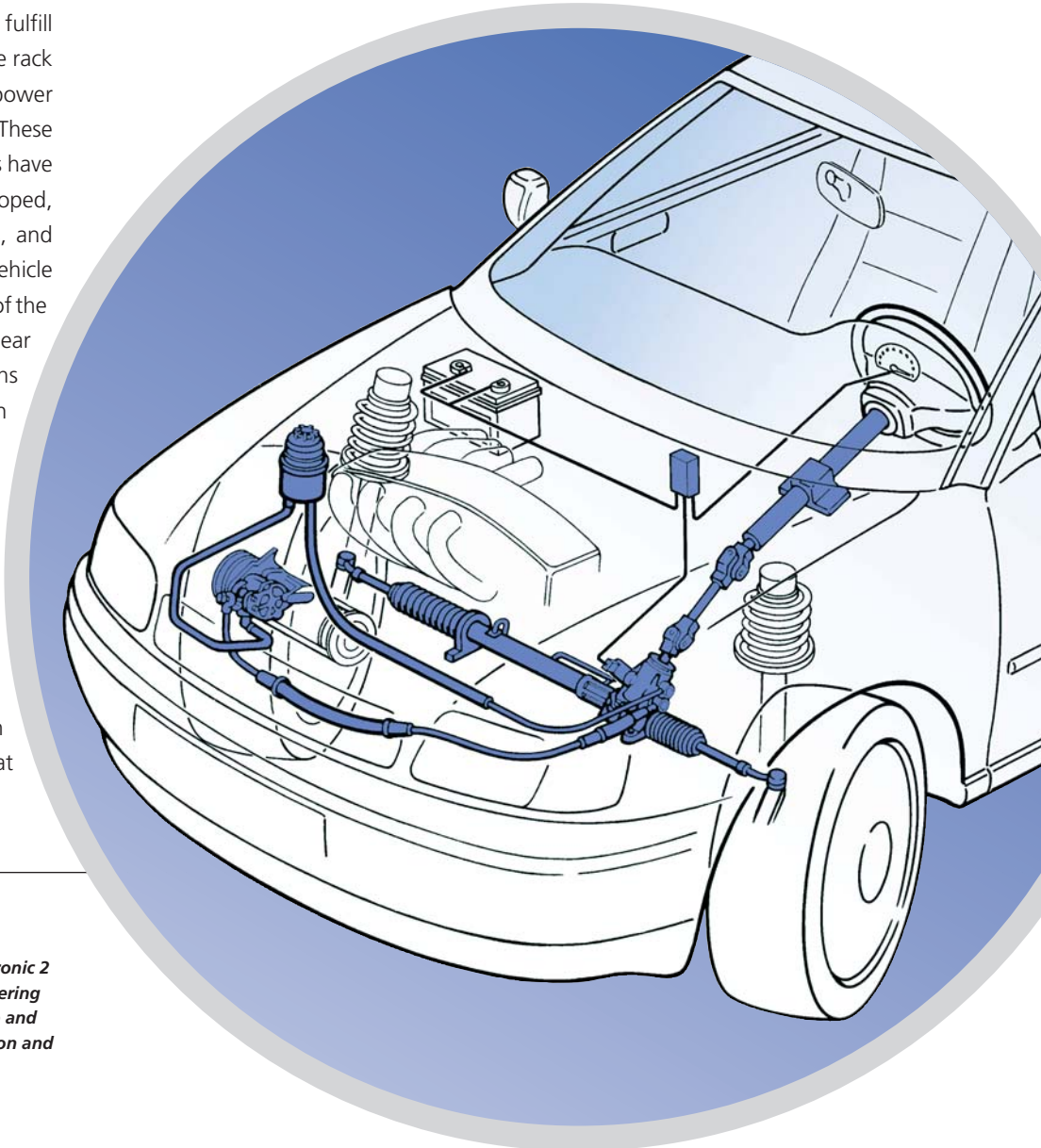
ZF Lenksysteme.
Steering toward the future.

As a joint venture of Robert Bosch GmbH and ZF Friedrichshafen AG, ZF Lenksysteme GmbH has produced power steering systems for passenger cars and commercial vehicles for several decades. The products fulfill every specified requirement. Take rack and pinion and recirculating ball power steering gears, for example. These tried-and-tested steering designs have been continually further developed, protected by numerous patents, and adapted to suit specific vehicle requirements. The development of the ZF compact power steering gear involved the forging of new paths both in valve design and in production processes.

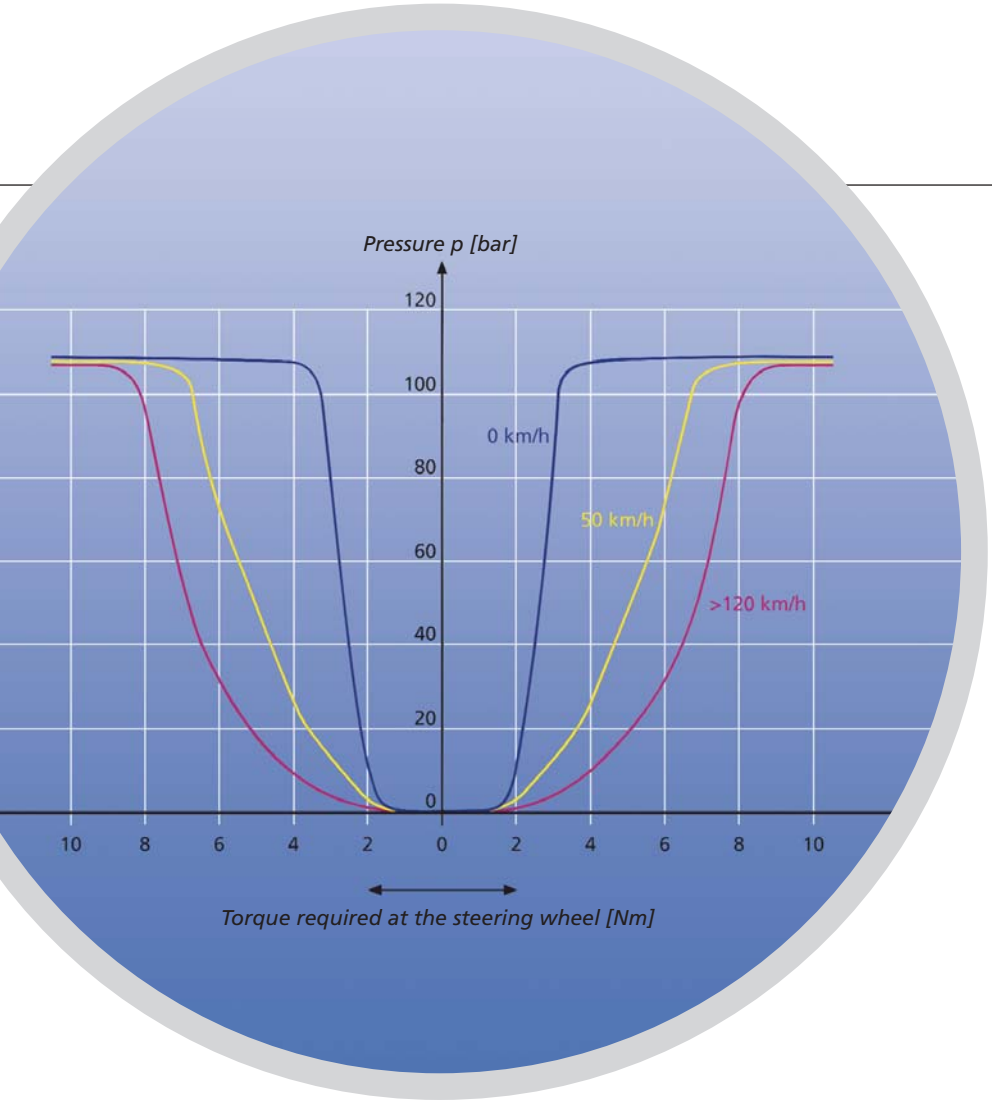
An outstanding result of innovative further development is the ZF Servotronic 2. This electronically controlled and speed-sensitive rack and pinion steering gear is characterized by easy, comfortable steering in parking and safe road feel at increasing speed. It is in particular the integrated positive-center-feel feature which optimizes steering wheel stiffness in high-speed driving. Further advantages over the first generation are derived from a more rugged design, simplified valve construction with considerably less parts and the possibility of a wider range of characteristics.



ZF Servotronic® is a registered trademark of ZF

Installation schematic for a ZF Servotronic 2 with electronic control unit (ECU), steering column, engine-driven steering pump and oil reservoir as well as pressure, suction and return lines.

ZF Servotronic® 2



Characteristic curves of the ZF Servotronic 2. The diagram shows how pressure and the torque required at the steering wheel vary with the driving speed. The shape of the characteristic curve may be adapted to match the character of the vehicle.

Design and function

The basic steering gear for the ZF Servotronic 2 is mainly the well-proven ZF rack and pinion power steering gear – millions of which have already been fitted – or, if required, the basic ZF compact power steering gear. On the modified rotary valve of the rack and pinion power steering gear, the principle of direct hydraulic reaction is applied. By using modern electronics and an electro-hydraulic transducer and by modifying the steering valve accordingly, it has become possible to have the ZF Servotronic 2 operate dependent on the driving speed existing at a given moment, a feature which distinguishes it from conventional power steering gears. A prerequisite of the installation of a ZF Servotronic 2 is either an electronic speedometer or a suitable ABS control unit. The speed signals coming from one of these units are transmitted to the electronic control unit, which can either be a separate component or integrated in the existing vehicle electronics. The signals are analyzed by the micro-processor of the Servotronic control unit and converted into a controlled electric current which actuates the electro-

Figures sheet 5:

Schematic representation of the ZF Servotronic 2 based on the rack and pinion power steering gear, type 7852.

1 Electronic speedometer in the vehicle
2 Electronic control unit (ECU)
3 Electro-hydraulic transducer
4 Rack and pinion power steering gear
5 Steering pump
6 Oil reservoir with fine filter
7 Anti-vibration expansible hose
8 Manually adjustable steering column

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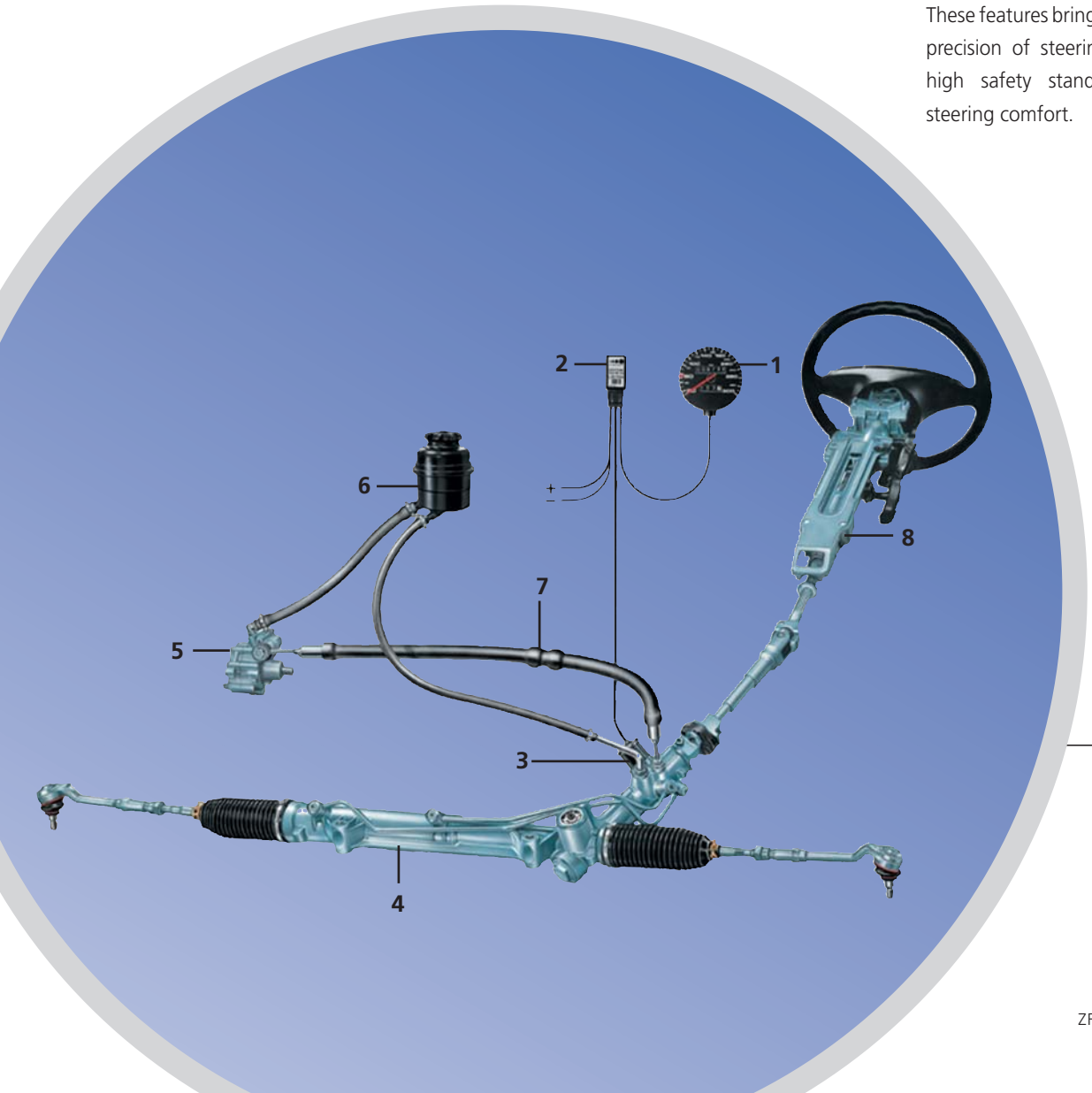
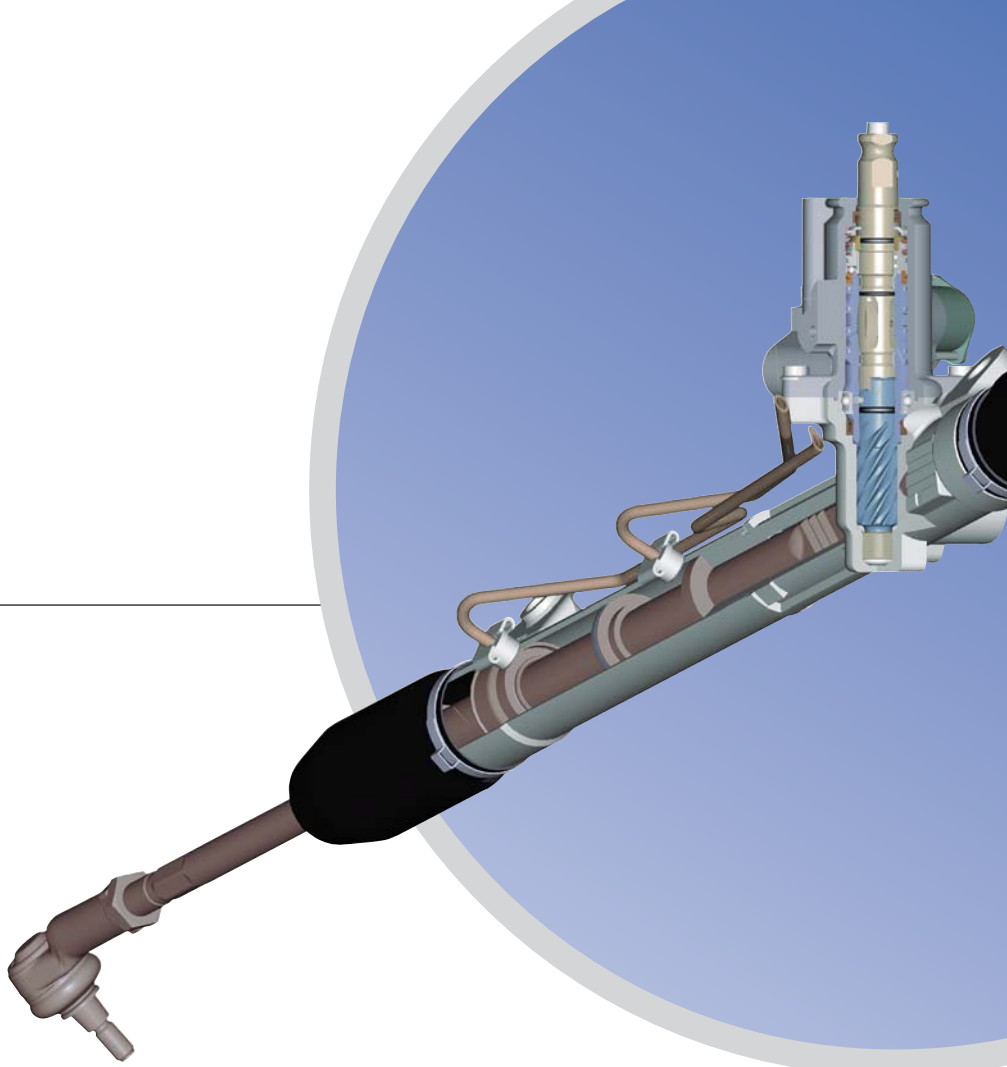
hydraulic transducer. On the basis of this influence, the transducer which is directly attached to the valve housing determines the hydraulic reaction at the rotary valve and, thus, the amount of input torque at the steering wheel.

The steering effort which is by this means related to the vehicle speed is extremely low when the vehicle is steered under standstill conditions or when it is manoeuvred into or out of a parking space. As the hydraulic reaction changes in proportion to the vehicle speed, the steering effort increases as the vehicle goes faster (see fig. on page 4).

At higher speeds the driver thus has particularly good road contact and is able to steer the vehicle precisely and with directional stability. A further advantage of the ZF Servotronic 2 is the fact that oil pressure and oil flow are never reduced and can therefore be utilized immediately in emergencies where sudden and unexpected steering corrections may become necessary. These features bring about extraordinary precision of steering, together with a high safety standard and optimum steering comfort.



ZF Servotronic® 2



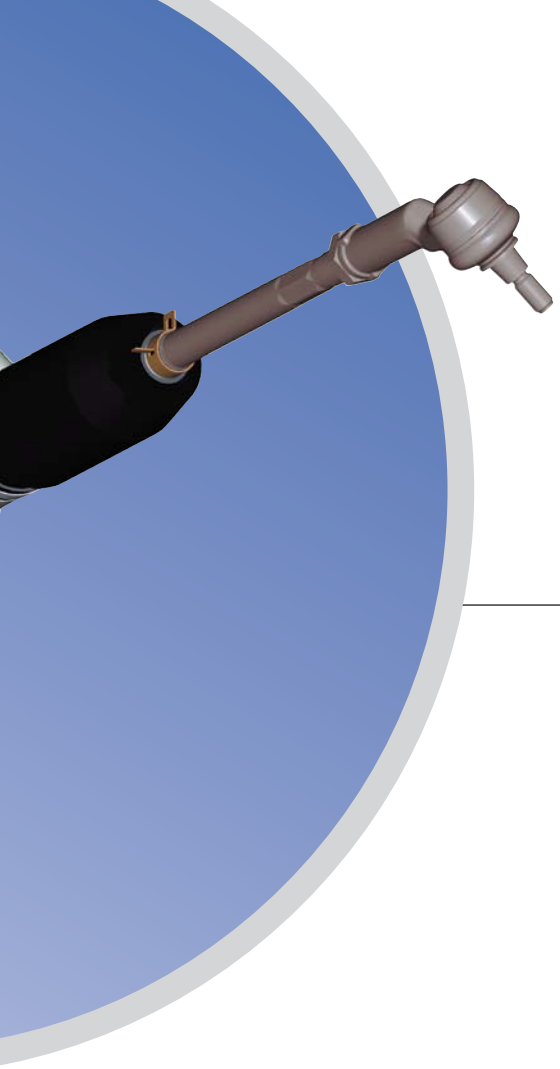
Mechanical construction

The ZF rack and pinion power steering gear basically comprises a mechanical steering gear, the steering valve and an integrated power cylinder.

The rack (21, see fig. on page 9) with the integrated piston (18) is guided in wear-free plain bearings within the power cylinder of the housing (19). The pinion (20), which runs in bearings in the valve area, meshes with the rack teeth. The rack is pressed against the pinion by means of a spring-loaded yoke so that the teeth always mesh without play. The pinion is connected with the valve rotor (16) through a torsion bar (15). The rotary motion of the steering wheel is transformed by the pinion into an axial motion of the rack and transferred to the steering arms by tie rods (22).

The ZF rotary valve (see figures on pages 7 to 13) adapted to Servotronic 2 requirements is used in order to control the pressurized oil needed for power assistance. This valve design mainly comprises the valve rotor (16), which has at least six control grooves on its surface area, and the valve sleeve (17) securely connected with the pinion (20). The valve bore of the valve sleeve has axial grooves that are matched to the control grooves of the valve rotor.

Centralizing the valve rotor (neutral position) is chiefly done by a torsion bar (15) which provides at the same time the connection between the valve rotor, pinion and valve sleeve. The centralizing effect (similar to the positive-center-feel torsion bar) is additionally increased by the prism-guided balls (13) between the centering piece (14) securely connected to the valve sleeve and the reaction piston (9) loaded with a compression spring (10), and these balls have a decisive influence on the functioning of the hydraulic reaction. Toward the inside, the coaxially guided reaction piston is connected to the valve rotor by means of two axially arranged ball guides such that rotation is prevented. The valve rotor and pinion run in anti-friction bearings to ensure the precision of operation and the functional safety of the steering valve even at high pressures.



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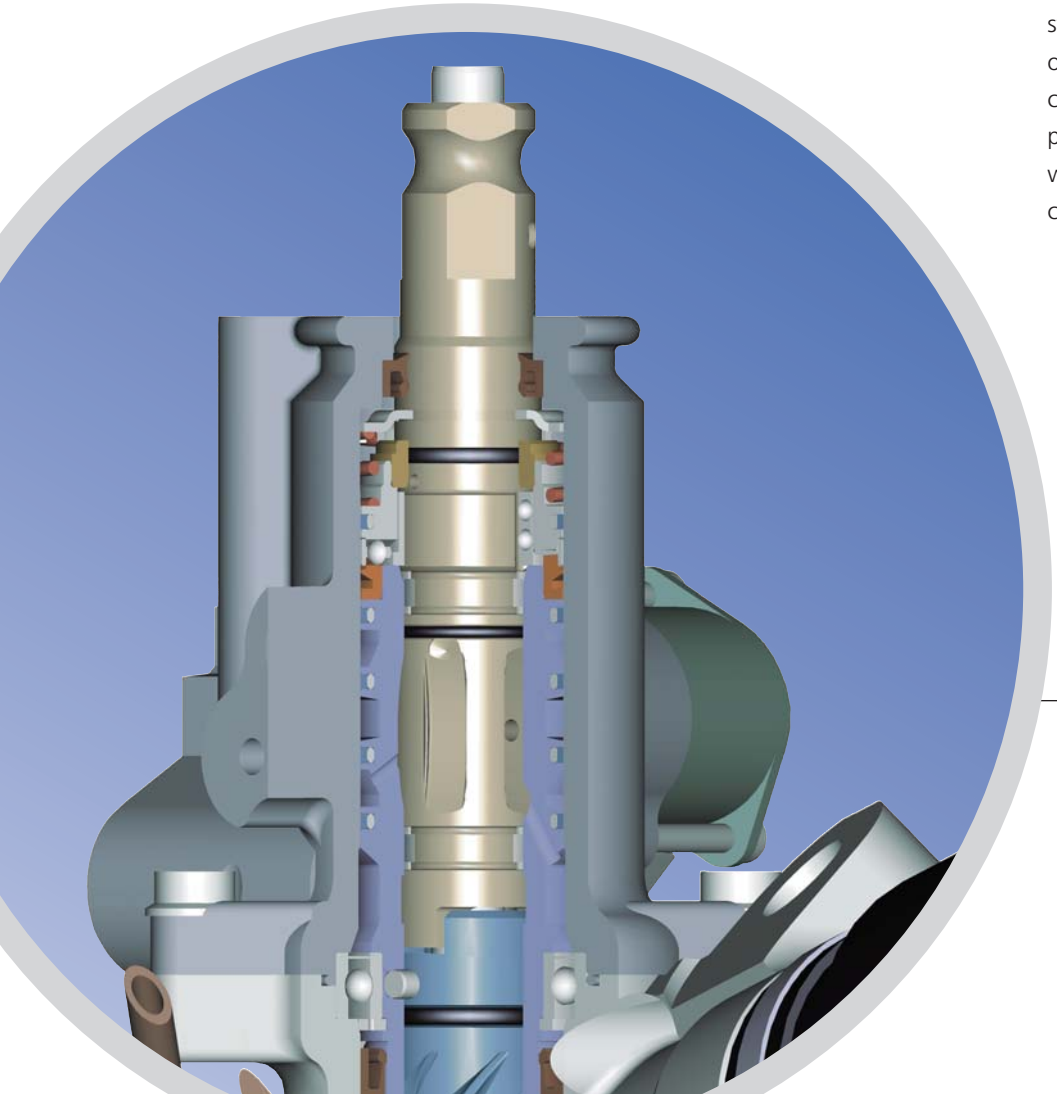
ZF Servotronic 2, type 7831, with ZF compact power steering gear as the basic unit, constant or variable ratio, rotary valve and end take-off

If a torque is transmitted to the valve rotor or the pinion/valve sleeve connection from the steering wheel or the steered wheels, a relative rotation is produced between the valve rotor and valve sleeve which is influenced by the torsion bar and the combined centering and reaction device. The valve rotor is thereby caused to change its position in relation to the valve sleeve bore surrounding it, so that the relative positions of the control grooves are changed, too. Pressurized oil can now flow through pipes to one of the two power cylinder chambers (ZL or ZR) and assists the axial movement of the rack if the turning motion is initiated from the steering wheel.

If, however, the axial movement of the rack is caused by the road wheels, the steering valve will, in spite of the steering wheel being held, direct the pressurized oil to that power cylinder chamber which counteracts rack axial movement. This braking effect dampens road shocks. When the steering wheel is released, the action of the twisted torsion bar makes the control grooves return to the neutral position, and the same system pressure will exist in both of the power cylinder chambers.



Section of ZF Servotronic 2 rotary valve

ZF Servotronic 2 rotary valve

Basic hydraulic function of the ZF rotary valve

The hydraulic fluid delivered by the steering pump (29) flows through a connnecting bore in the valve area, via the feed oil radial groove (4) and transverse bores in the valve sleeve (17), onward to the feed oil control grooves (23) of the valve rotor. In the valve neutral position (see fig. on page 9) the oil flows, over the open feed oil control edges (24), to all valve sleeve axial grooves (25) and from there, over the open return oil control edges (27), also to the return oil control grooves (26) of the valve rotor. From these grooves the oil flows back, via connecting bores, to the return oil chamber (7) and from there to the oil reservoir (30). At the same time, the radial grooves (5 and 6) of the valve body and their associated pipes provide for a connection between the right-hand (ZR) and left-hand (ZL) power cylinder chambers.

When turning the steering wheel clockwise (see fig. on page 13), the rack (21) with the integrated piston (18) will move to the right in the piston bore (to the left in the installed position on the vehicle) if the pinion (20) is situated on top. Due to the simultaneous rotation of the valve rotor to the right, the pressurized oil is directed, over the further opened feed oil control edges (24), to the associated axial grooves (25), via bores to the radial groove (5), and, via a pipe, to the left-hand power cylinder chamber (ZL), whereby the rack movement is hydraulically assisted. An individually adaptable pressure build-up is achieved by the fact that the partially or fully closed feed oil control edges (24) restrict or prevent a connection between the pressure oil inlet and the other axial grooves (25) connected to the radial groove (6). At the same time, the pressure oil outlet toward the pressurized axial grooves is restricted or prevented, too, by the closing return oil control edges (27). The oil displaced by the piston (18) from the right-hand power cylinder chamber (ZR) first flows through a pipe to the radial groove (6) and, through transverse bores, to the associated axial grooves and onward to the return oil control grooves (26) over the further opened return oil control edges (27). From here, the further return flow of the oil to the oil reservoir (30) takes place via the connnecting bores leading to the return oil chamber (7). When the steering wheel is turned counterclockwise (see fig. on page 10), the operating sequence will be analogous to the above.

1 Electronic speedometer
2 Electronic control unit (ECU)
3 Electro-hydraulic transducer
4 Feed oil radial groove
5 Radial groove
6 Radial groove
7 Return oil chamber
8 Reaction chamber
9 Reaction piston
10 Compression spring
11 Cut-off valve
12 Orifice
13 Ball
14 Centering piece
15 Torsion bar
16 Valve rotor
17 Valve sleeve
18 Piston
19 Housing
20 Pinion
21 Rack
22 Tie rod
23 Feed oil control groove
24 Feed oil control edge
25 Axial groove
26 Return oil control groove
27 Return oil control edge
28 Press. relief and flow limiting valve
29 Steering pump
30 Oil reservoir
ZL Power cylinder, left
ZR Power cylinder, right

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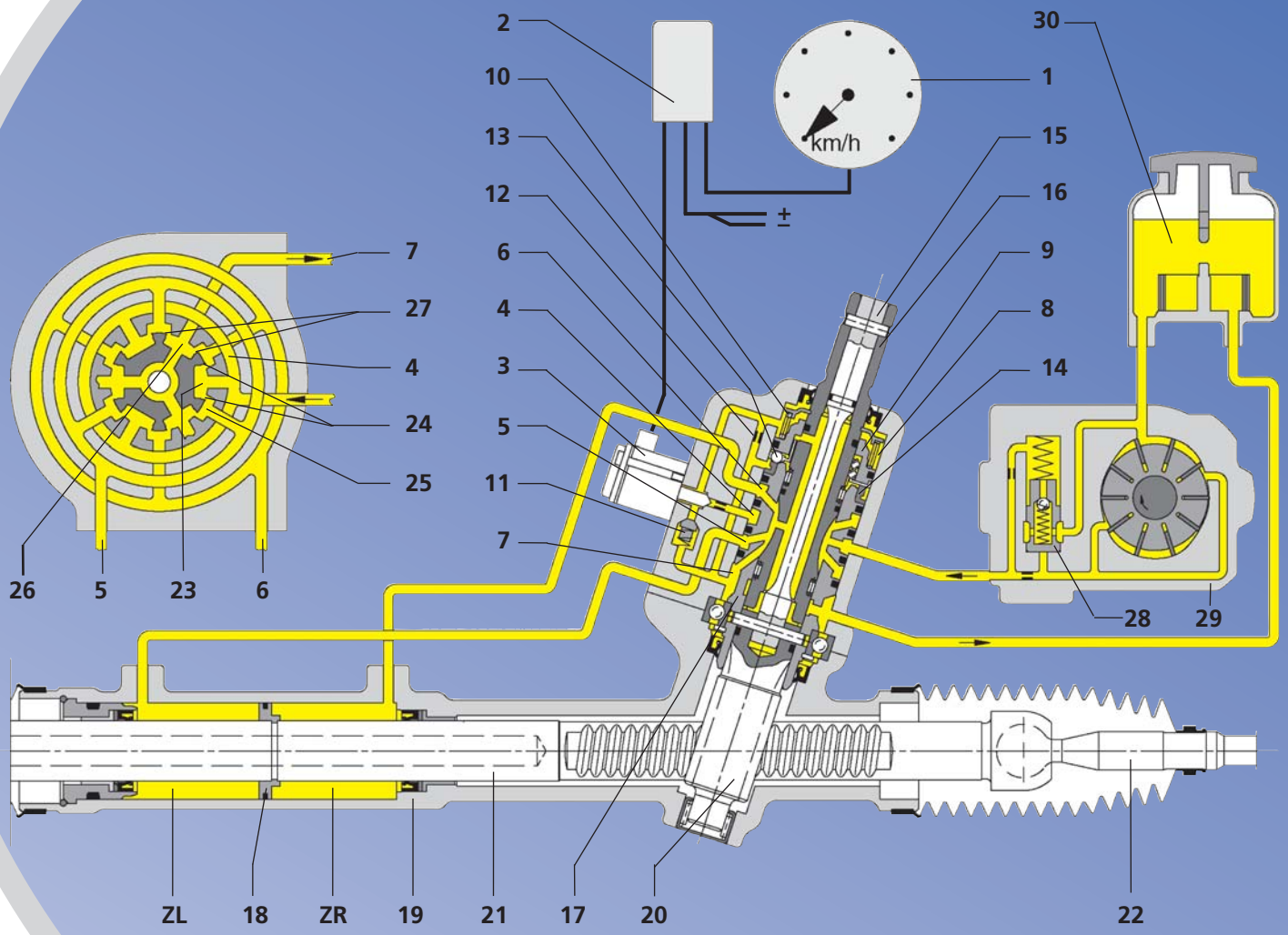
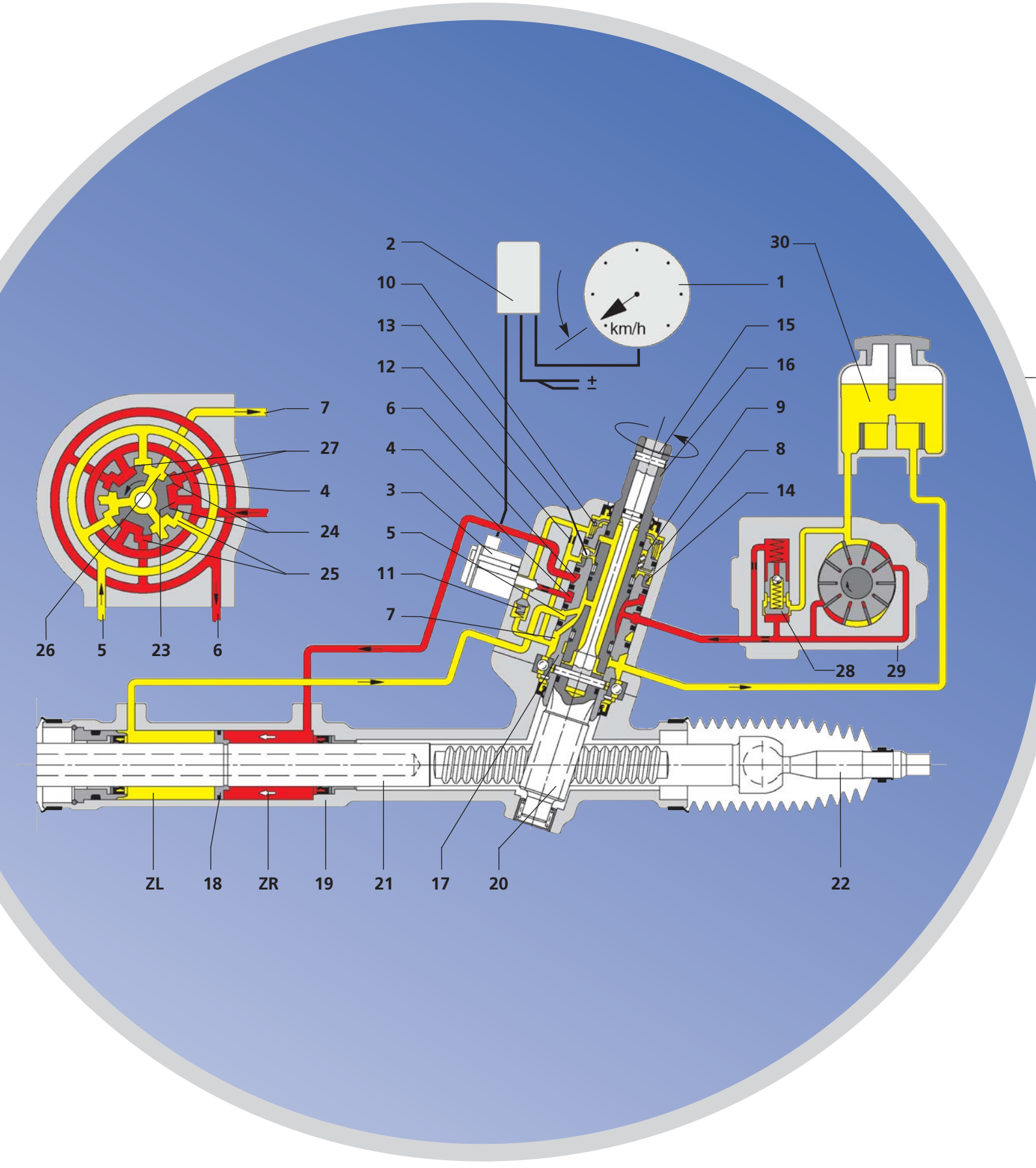


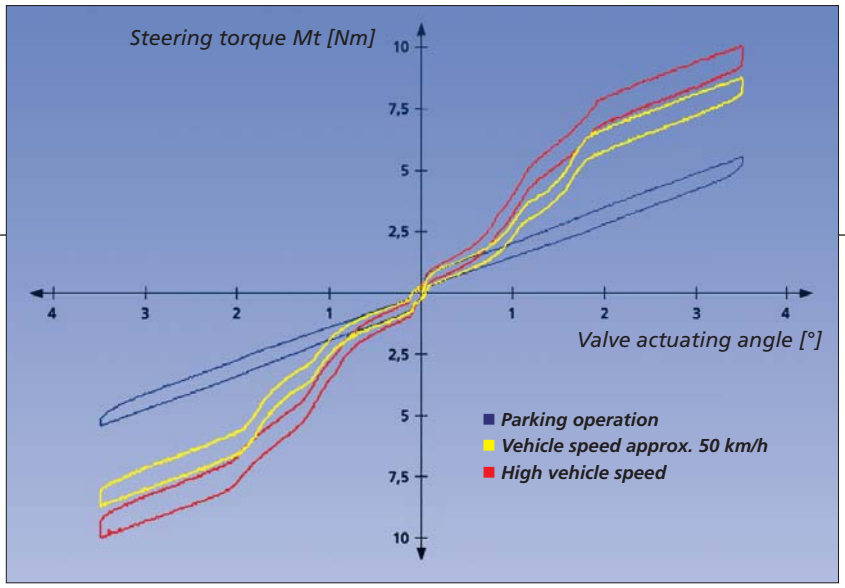
ZF Servotronic 2 based on rack and pinion power steering gear, type 7852.

Rotary valve in neutral position. Vehicle stationary.



ZF Servotronic 2 based on rack and pinion power steering gear, type 7852.

Rotary valve in working position. Steering wheel turned counter-clockwise. Driving at low speed (parking); transducer valve and cut-off valve shut, no hydraulic reaction.



Steering torque graph of a Servotronic 2 steering valve with combined centering and reaction device.

This shows the change in steering gear centralizing and steering stiffness as a function of vehicle speed.

Function of the ZF Servotronic 2

At low speeds (fig. on page 10), e.g. when the vehicle is manoeuvred into or out of a parking space, the electronic speedometer (1) or the ABS control unit transmit very few signals to the microprocessor integrated into the electronic control unit (2). The microprocessor analyzes the signals and passes them to the electro-hydraulic transducer (3) in the form of a correspondingly adapted control current. Due to the maximum current existing in that driving mode the transducer valve closes and prevents oil flowing from the feed oil radial groove (4) to the reaction chamber (8). An orifice (12) ensures that there is also return pressure level in the reaction chamber. Thus, the ZF Servotronic 2 steering valve acts in that mode in the same way as the normal rotary valve. Owing to the elimination of reaction, the steering is light in operation and can be handled with very little effort.

As the driving speed increases, the speed signals become more frequent and, after having been converted by the microprocessor, cause a reduction in the amount of control current transmitted to the electro-hydraulic transducer. As a result, the transducer valve takes up an opening position adapted to the instantaneous vehicle speed and allows a limited oil supply from the feed oil radial groove (4) to the reaction chamber (8). An orifice (12) prevents the outflow of larger amounts of oil to the return oil chamber (7) with the result that a higher pressure is built up in the reaction chamber. As a consequence, the higher oil pressure acting on the reaction piston (9) causes a greater compression on the prism-guided balls (13) which are between the reaction piston and the centering piece (14) that is securely connected to the valve sleeve (17). When driving straight ahead, this has especially positive effects on the exact centralizing of the steering valve. And when the steering valve is actuated, the balls with the higher load on them provide additional torsional resistance to the rotation of the valve rotor. Thus, this mode of operation of the hydraulic reaction requires an individually established higher steering wheel torque until a determined hydraulic assistance is raised in the right-hand (ZR) or left-hand (ZL) cylinder chamber.

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2 Electronic control unit (ECU)
3 Electro-hydraulic transducer
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20 Pinion
21 Rack
22 Tie rod
23 Feed oil control groove
24 Feed oil control edge
25 Axial groove
26 Return oil control groove
27 Return oil control edge
28 Press. relief and flow limiting valve
29 Steering pump
30 Oil reservoir
ZL Power cylinder, left
ZR Power cylinder, right

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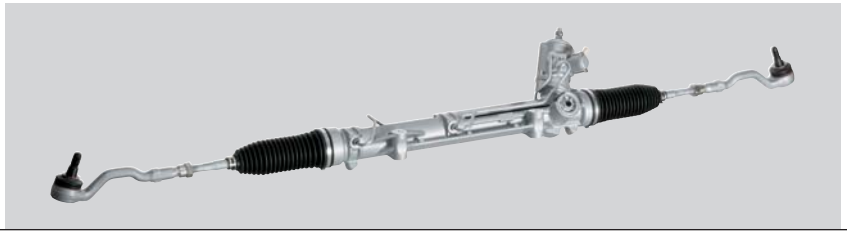
Electro-hydraulic transducer (full size)

At high driving speeds (fig. on page 13), for instance on the motorway, the transducer valve is fully open owing to a very low or non-existing control current for the actuation of the transducer. This enables maximum pressure supply from the feed oil radial groove (4) to the reaction device. When the steering wheel is turned clockwise, the reaction pressure increases in accordance with the existing operating pressure and pressurizes the reaction piston of the reaction chamber (8). As soon as the reaction pressure determined for a specific vehicle reaches its upper limit, the oil is discharged to the return oil chamber (7) through the opening cut-off valve (11) to avoid a further increase in reaction pressure. The input torque at the steering wheel thus achieved will not now rise any more and gives a safe driving feel owing to optimum road contact.

Safety of the ZF Servotronic 2

Even in the event of a failure of the main power supply or any other electrical fault, the steering gear remains fully operational. In such exceptional cases the ZF Servotronic 2 will work at maximum hydraulic reaction (high-speed characteristic) owing to the mechanically forced opening of the transducer valve. When speed signals all of a sudden are not transmitted any more during driving, for instance due to lack of cable contact or a defective speedometer, the highly advanced microprocessor in the electronic control unit is in a position to derive a constant control current from the last speed signals evaluated. This ensures a constant steering performance until the vehicle engine is turned off. When the engine is started again, maximum hydraulic reaction conforming to the high-speed characteristic will develop again.



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ZL Power cylinder, left
ZR Power cylinder, right

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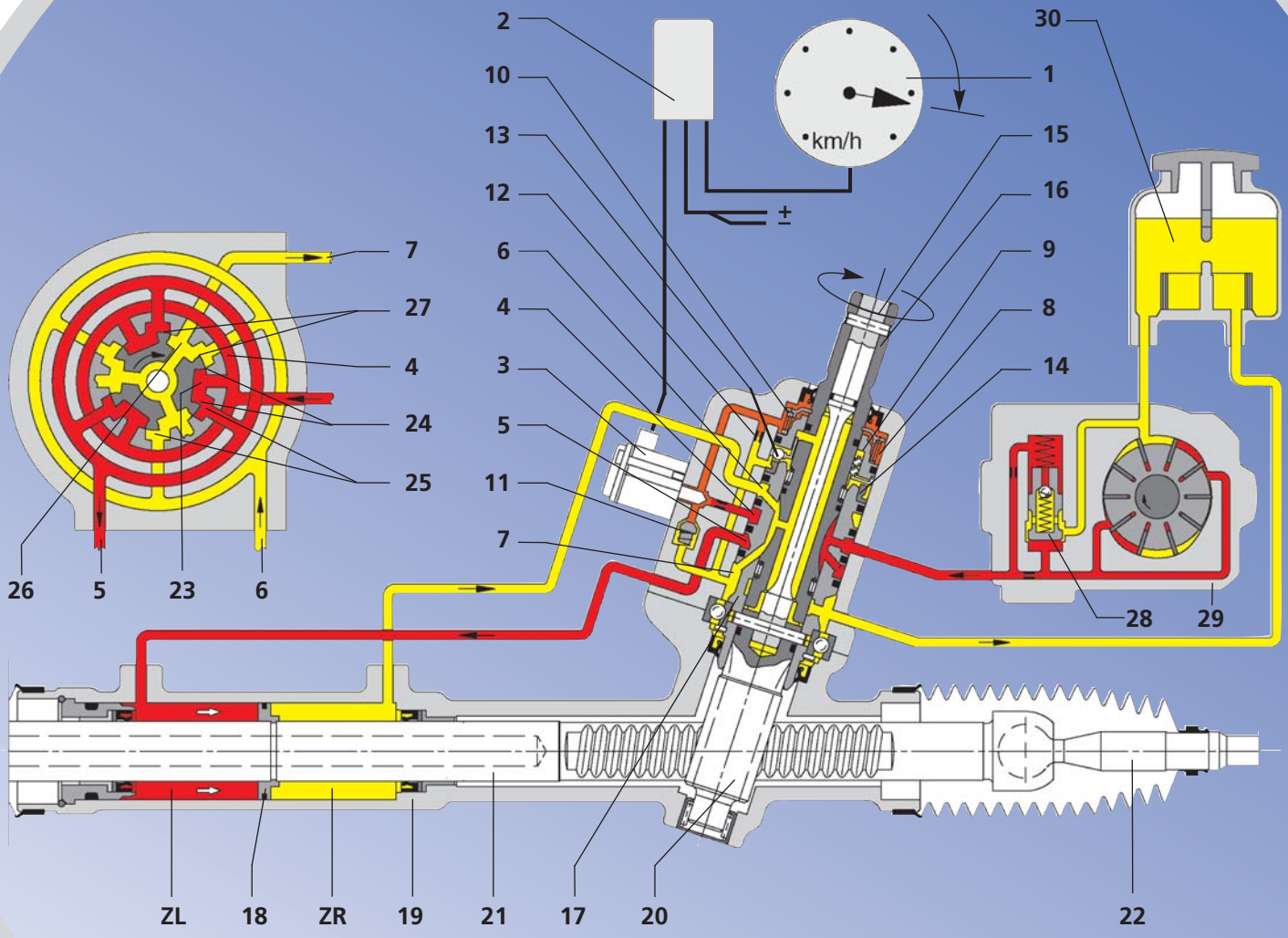
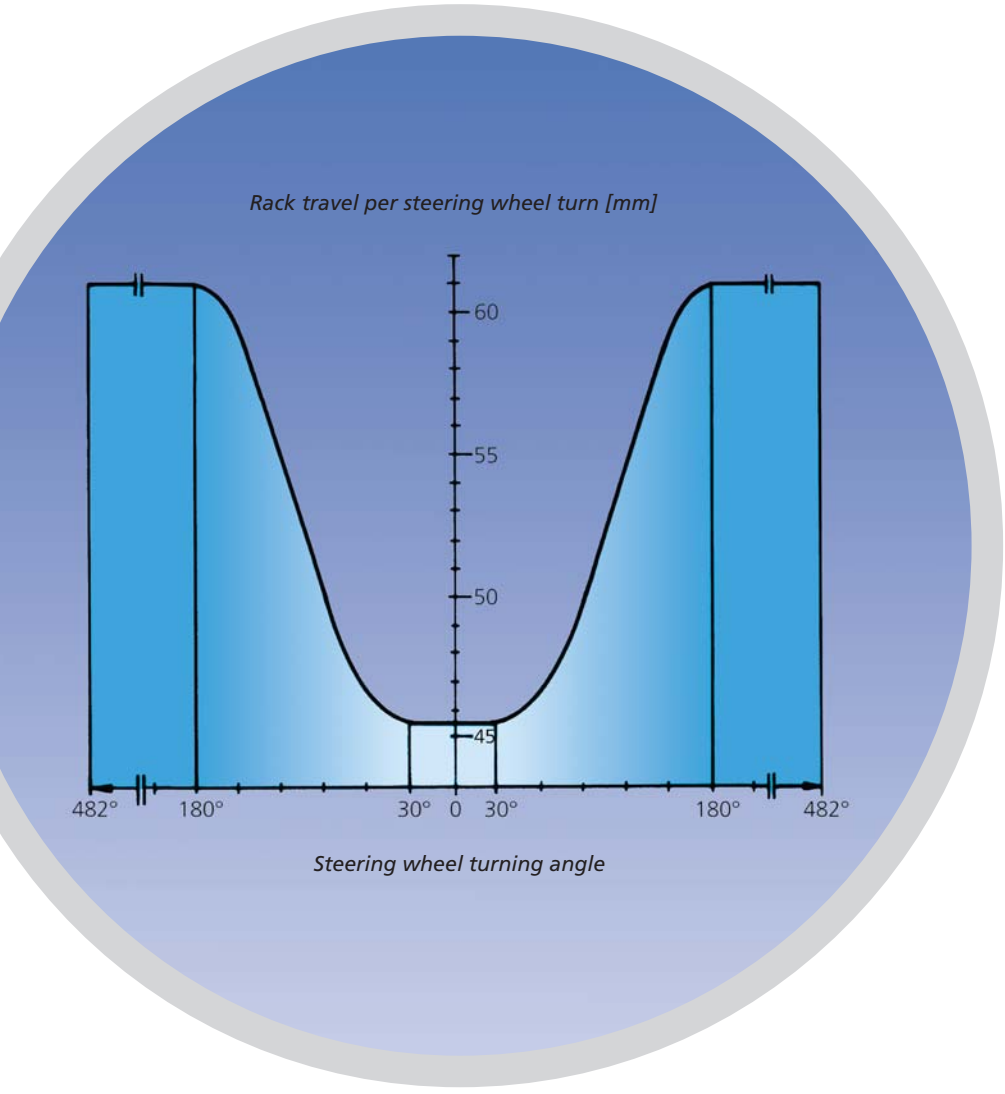


ZF Servotronic 2 based on rack and pinion power steering gear, type 7852.

Rotary valve in working position. Steering wheel turned clockwise, high speed with rapid steering corrections, transducer valve completely open, maximum hydraulic reaction limited by cut-off valve.

Special Equipment



Schematic ratio diagram for ZF Servotronic 2 with variable ratio. One full turn of the steering wheel is shown as 360° on this graph.

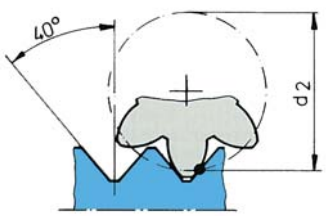
Special equipment

The ZF Servotronic 2 can be fitted with a number of equipment options in order to adapt it in an optimum way to the kinematic and motorization conditions existing on the vehicle.

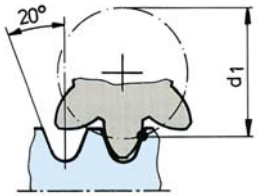
Variable ratio

Besides the constant ratio version, the Servotronic 2 can also be made available with a variable ratio. The rack teeth have varying modules and pressure angles so that, on the one hand, one can ensure that, around center (i.e. in straight-ahead driving), the steering offers the response the driver is accustomed to. On the other hand, as the steering wheel turning angles (to the right and to the left) become greater, the ratio becomes lower and the steering in consequence becomes more direct. The difference between the lowest and the highest ratio can be as much as 35%. As a result, values as unusually low as approx. 2 steering wheel turns from lock to lock can be achieved. The extraordinary ease of handling of a ZF

Rack teeth in the end regions



Rack teeth around center



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Servotronic 2 with variable ratio is equally suitable for mid-size sedans and light commercial vehicles as it is for sporty cars.It enables precise and rapid steering reactions at higher speeds without running the risk of abruptly pulling the steering wheel to the right or left, and optimizes the handling of the vehicle when maneuvering it into or out of a parking space, when turning it round in tight areas and during extreme cornering.

Full-lock damping

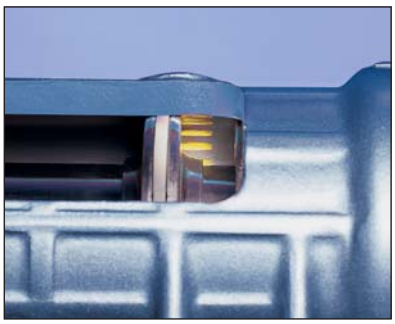
If required, the ZF Servotronic 2 can be fitted with flexible plastic components on the stroke limiters. The damping effect in front of the metallic stop (full lock) combats unwanted noise at maximum wheel lock.

Steering damping

The main reason for increased levels of steering comfort is the fact that shocks caused by the road and the chassis cannot be felt on the steering wheel. In particular cases, additional technical solutions can be adopted, such as fixing the steering gear by rubber mounts or tie rods with flexible elements. But it is also possible to use valve and orifice systems (variable orifices) which are integrated into the hydraulic system and act as dampers.

Hydraulic steering limiter

There are functional, economical and environmental advantages in integrating a hydraulic steering limiter into the ZF Servotronic 2. A chassis with sufficient self-aligning properties is, however, a prerequisite for this.



Specially developed connecting cross sections in the cylinder bore enable an overflowing of the oil from the cylinder chamber under high pressure to the return oil chamber separated from it by the piston, just before the end of the stroke. The pressure drop at the lock stop resulting from this protects the steering pump and the mechanical parts of the steering gear from excessive loads. A power assistance heavily reduced by the pressure drop causes an increase of the steering wheel input torque and, thus, informs the vehicle driver that maximum wheel lock is imminent.

As the hydraulic steering limiter reduces the power requirement of the steering pump, the engine idling speed can be set at a lower value, thus saving a considerable amount of fuel which, in turn, protects the environment.

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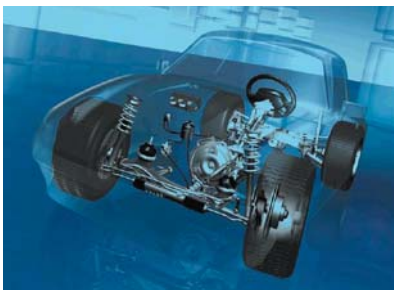
ZF Lenksysteme GmbH: the systems partner

ZF Lenksysteme GmbH is one of the largest independent manufacturers of power steering systems for passenger cars and commercial vehicles. Renowned automotive manufacturers from all over the world value us as a creative and efficient systems partner for the development of new and innovative solutions.

As a joint venture of Robert Bosch GmbH and ZF Friedrichshafen AG, ZF Lenksysteme GmbH offers its customers a unique source of expertise when it comes to integrating a wide range of top technologies in modules, system modules or entire chassis systems.

The benefits for the manufacturer are clear to see: even shorter development times and optimized production processes – with quality standards which just get better and better.



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Robert Bosch GmbH and
ZF Friedrichshafen AG

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