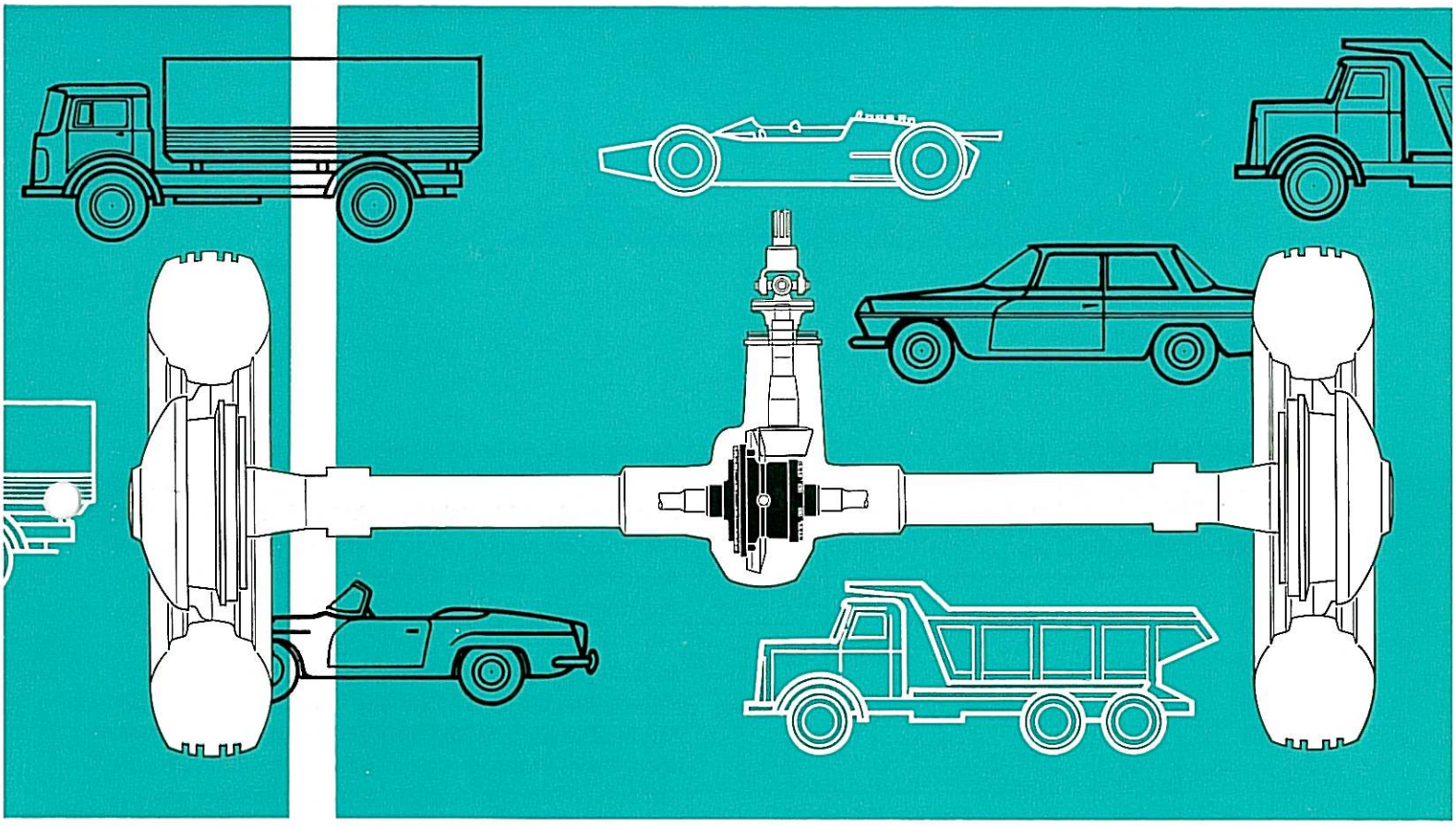
ZF MULTIPLE-DISC SELF-LOCKING DIFFERENTIAL LOK-O-MATIC



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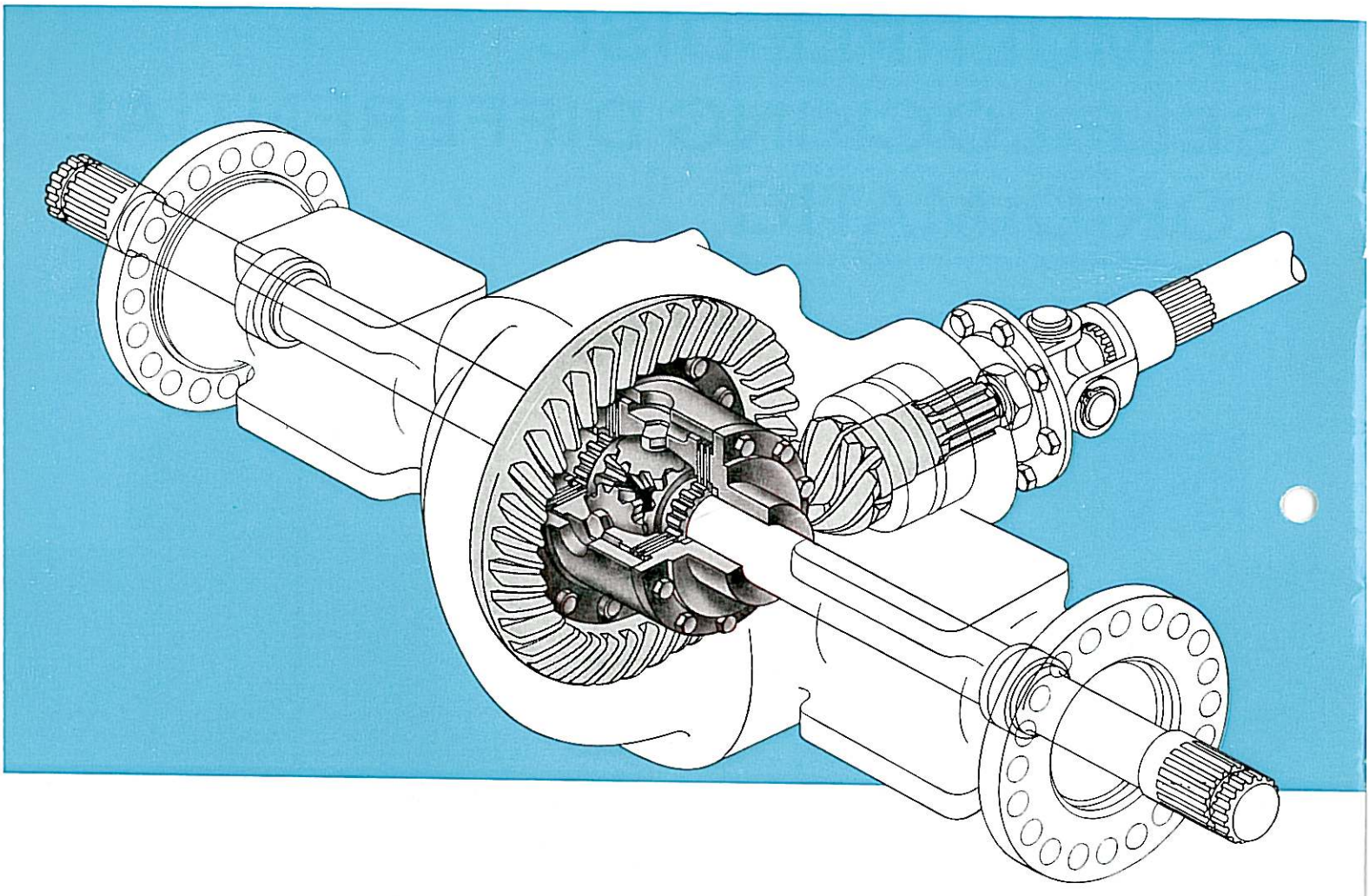


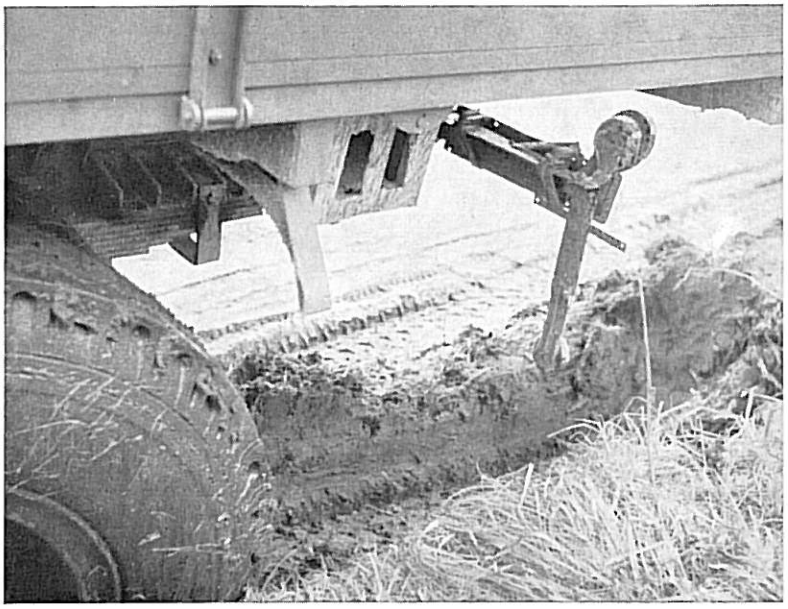
ZF-MULTIPLE-DISC SELF-LOCKING DIFFERENTIAL LOK-O-MATIC

During recent years the demand for self locking differentials has increased steadily. This fact is by no means an indicidental phase but rather confirms that the installation of a self locking differential is of great advantage for various types of vehicles, if not an absolute necessity. In the following two examples are given:

In a conventional differential gearing, just called the differential, the initial torque is transmitted via the differential cage to the differential bevel gears, and these then transmit the torque in equal proportions to the left and the right drive shaft. If road conditions are bad on one side and the torque transmitted to the driving wheels cannot be taken up by one of the wheels, this wheel will begin to turn faster; it "spins". Due to this the engine torque is used up mainly for speeding up the gears and shafts of the gearbox, the cardan shaft, the differential, one wheel axle and the spinning wheel.

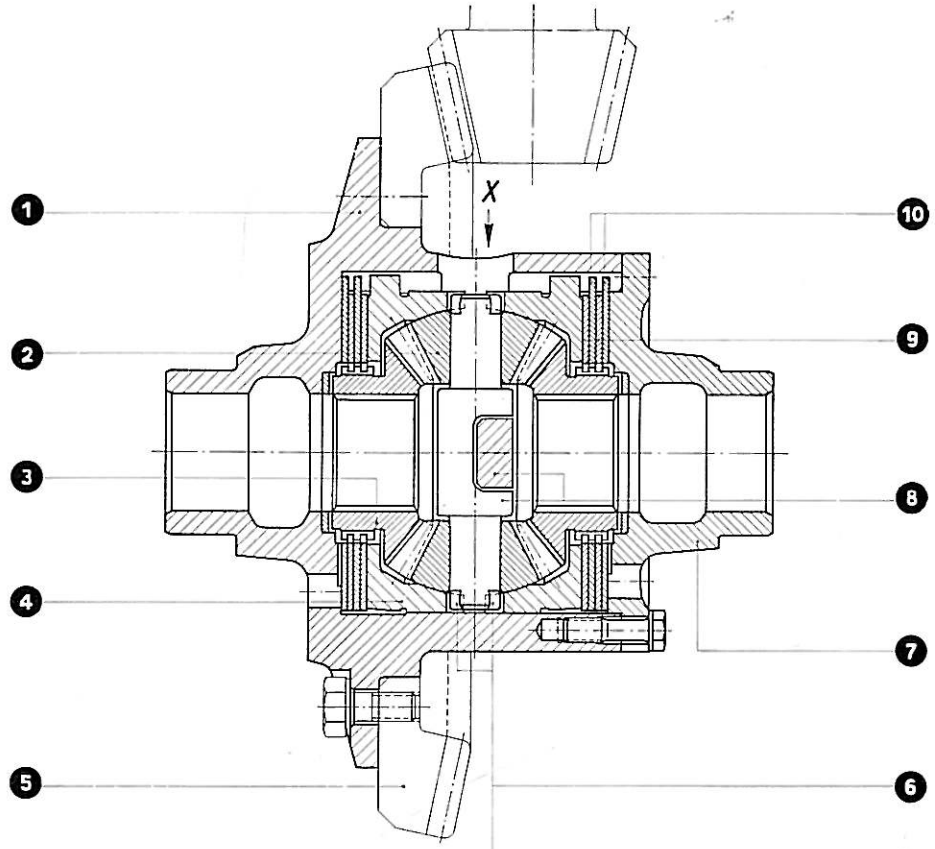
If the accelerated wheel now reaches again firm ground, it will be slowed down with a jerk and a shock torque will be transmitted via the differential gears to the other driving wheel. Such behaviour will be extremely dangerous at high speeds; the vehicle is likely to skid. A similar condition can occur when a powerful vehicle is travelling on an even road in heavy rain at high speed, because due to a wedge-like water build-up the drive is distributed unevenly to the two driving wheels. Starting on uneven ground can also be a gret disadvantage when the vehicle is equipped only with a conventional differential. The sinking of one of the driving wheels into sandy or muddy soil is a familiar occurrance, which everybody is most anxious to avoid.

In order to overcome such situations, differentials were developed, which have a braking effect on the drive axles when one driving wheel is turning faster. They are the so-called self locking differentials. The Schwäbisch Gmünd Works of the Zahnradfabrik Friedrichshafen AG., produce such differentials under the name ZF multiple disc self locking differential Lok-O-matic for passenger cars, sports cars, racing cars, trucks, construction machinery and other commercial vehicles.



Construction

The crown wheel is bolted to the cage of the self locking differential. The inside diameter of the differential cage has four axial grooves for receiving the two pressure rings and the outer discs. The components have lugs on their outer diameters, which engage in the grooves of the differential cage and thus only permit axial movement. The inner rings, which are arranged alternately between the outer discs, are coupled to the axle bevel gears by the engagement teeth. The inner faces of the pressure rings are wedgeshaped for receiving the differential axles, which have similarly shaped surfaces at the ends. The two differential bevel gears, carried on each differential axle, are in mesh with the axle bevel gears.



1 differential cage
2 differential bevel gear
3 axle bevel gear
4 pressure ring
5 crown wheel
6 wedge-shaped surfaces on differential axle and pressure rings
7 cover
8 differential axles
9 inner discs
10 outer discs

View of the differential axle seen in direction X

Function

The locking effect is due to the internal friction of the differential. It is produced by two multiple disc brakes arranged symmetrically in the differential cage. In the case of a conventional differential one wheel can be braked or held in position with hardly any resistance, when the vehicle is jacked up, the engine is running and the gear is engaged. The other wheel will then turn correspondingly faster. However, with a self locking differential the above procedure will be rendered considerably more difficult, due to the multiple disc brakes, in fact it will become more difficult with increasing input torque.
This behaviour is caused because the torque acting on the differential cage is transmitted to the differential axles via two pressure rings, which are unable to turn radially but can move axially, whereas with a conventional differential the torque is transmitted directly to the differential axles. The contact surfaces between the differential axles and the pressure rings are wedge-shaped. Outward axial forces are caused by the reaction at those surfaces when torque is transmitted. Therefore, an increased pressure will be produced on the pre-loaded discs. Since the outer discs engage with the differential cage and the inner discs with the axle bevel gears, relative motion between axle shafts and differential cage is rendered more difficult. The ZF multiple disc self locking differentials have the following two great advantages:

Firstly, a constant locking torque is obtained due to the axial pre-load of the discs, so that a locking effect is available immediately, even under most unfavourable travelling conditions. This is of special advantage for instance, when road conditions on one side are extremely bad.

Secondly, due to the outward forces occurring on the wedge-shaped surfaces, a load dependent locking

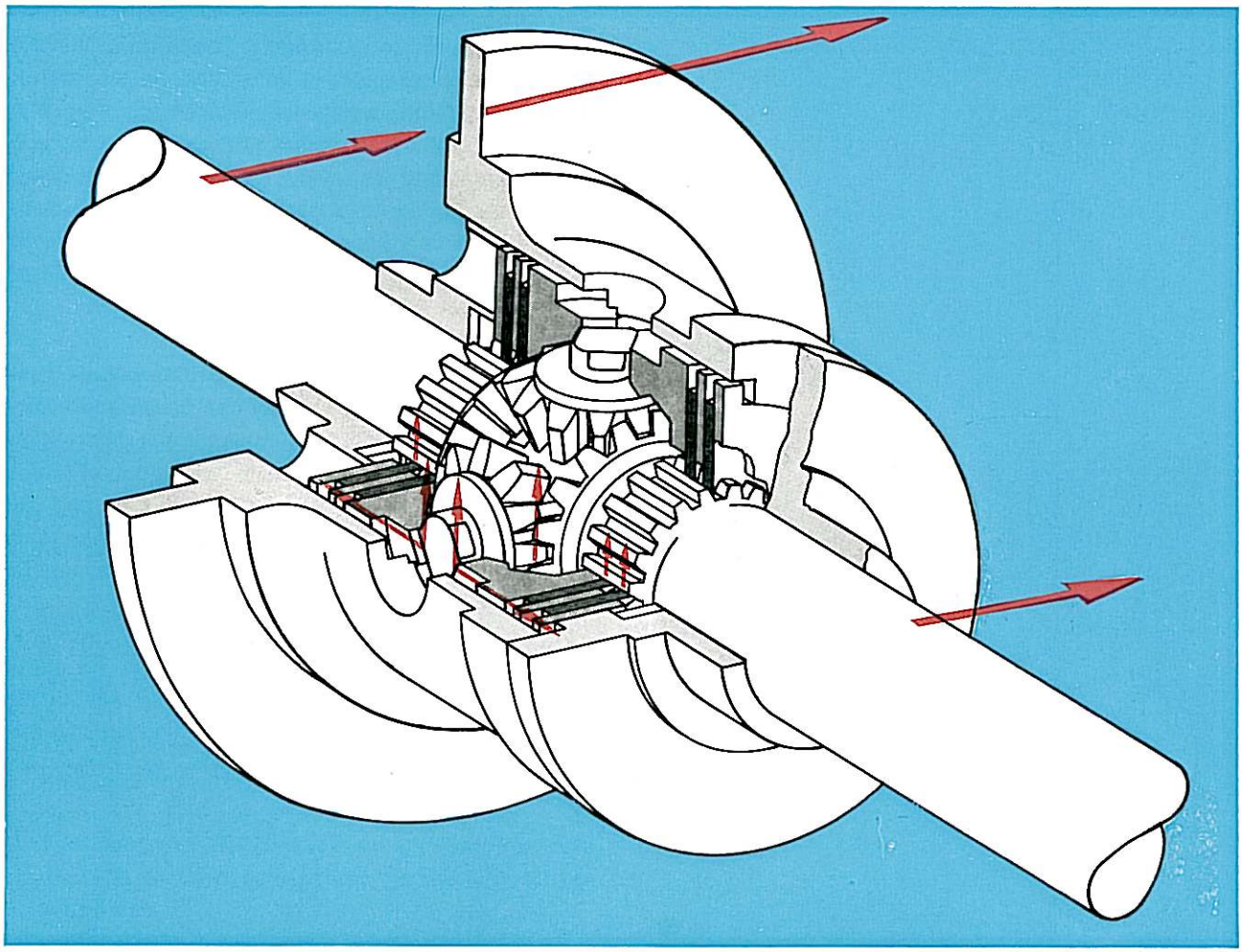


Illustration above:
Schematic dawing of power transmission in the differential. Assuming that each axle is taking equal torque. For better observation the power flow is shown as being transmitted to the axles from one differential axle only and one differential bevel gear.

torque is produced in the multiple disc clutches, which is always directly proportional to the input torque. The locking effect, therefore, adapts itself to the variable engine torque and also the torque increase in the different gear speeds. This is especially useful for heavy off-road operations when large torques must be transmitted. This characteristic considerably improves the safety of powerful passenger and sports cars travelling at high speeds.

Under locking effect we understand:

$$S = \frac{M_1 - M_2}{M_1 + M_2} \cdot 100 \text{ in } \%$$

assuming that:

M_1 = torque on wheel 1
M_2 = torque on wheel 2

When travelling round a bend, the inner wheel (1) normally takes the greater torque and the other wheel (2) the smaller torque (see illustration on page 6). The locking effect is generally 50%; but in special cases it can be altered in order to provide the best possible conditions for each type of vehicle. On request our self locking differentials can also be supplied with or without disc pre-load.

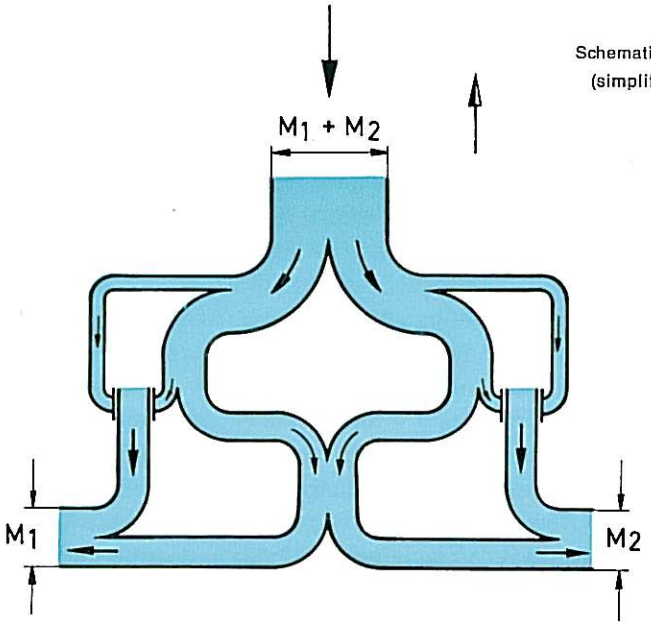
The locking effect is influenced by

1. The number of discs.
2. The angle of the wedge-shaped surface.
3. The disc pre-load, which increases the locking effect in cases of very bad road conditions or small input torque.

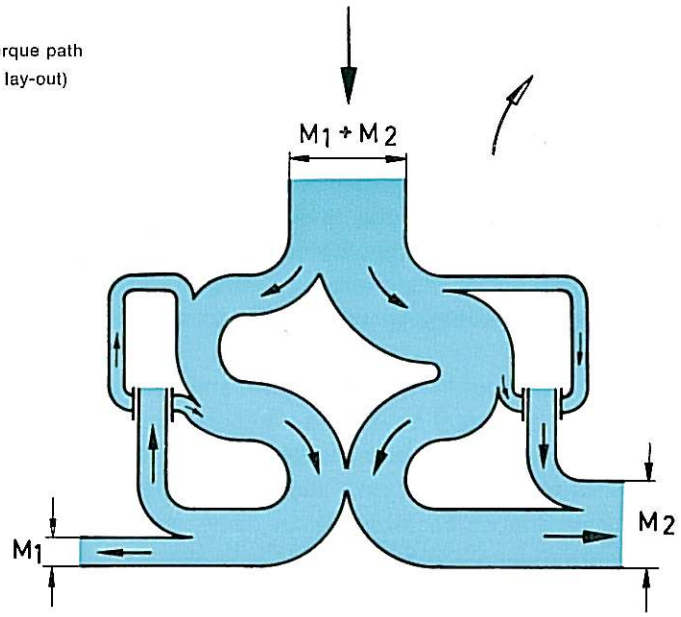
Installation

The ZF multiple disc self locking differentials have been dimensioned so that they can be installed without any difficulty in place of conventional differentials (the dimensions are given in the specification table). The crown wheel, the differential housing and the axles remain unaltered; only the differential has to be changed, so that a subsequent installation can be carried out without any difficulty.
Self locking differentials alter the load conditions of the axle shafts. Although there is actually no shock loading and it has also no influence on the driving performance, the designer, however, should take this into consideration when determining the cross sectional area of the axles.

Schematic torque path
(simplified lay-out)



straight ahead travel $M_1 = M_2$



travelling round a bend or with bad road conditions on one side
$M_1 < M_2$

Due to the automatic locking effect in the differential (50% locking effect) a maximum of 75% of the input torque will be distributed to one axle shaft and only 25% is transmitted to the other shaft. During the design of the axle shafts the shock loadings occurring when starting have been taken into consideration, the cross sectional areas, therefore, will be sufficiently dimensioned to take the increased loading of the self locking differential.

Driving characteristics

ZF multiple disc self locking differentials contribute considerably to the driving performance of a vehicle.

1. Spinning of one wheel when driving round a bend or with bad road conditions on one side, is prevented.

2. The tendency of a bouncing wheel to spin when travelling on uneven ground is greatly reduced.

3. The danger of skidding at high speeds on uneven roads is eliminated; especially in the case of powerful cars.

Compared with the differentials with engageable locking devices the self locking differentials have the advantage that the stress in the axle shafts can be limited according to the locking effect selected. Apart from this the self locking differential has the further advantage that it becomes immediately effective, automatically and without any action on the part of the driver.

Maintenance

ZF multiple disc self locking differentials require no special maintenance. Like in the case of conventional differentials, the housing is filled with hypoid oil. No other requirements are needed.

Construction subject to modifications.

The picture below shows a sports car accelerating in a right hand bend; the smoke coming from the right rear wheel shows that this wheel is spinning. Due to te centrifugal force, there is only very little load on it so that the engine torque can no longer be transmitted. When this picture was taken, the sports car was only equipped with a conventional differential. With a ZF multiple disc self locking differential the spinning of the right rear wheel would have been avoided.

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