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POWER TAKE-OFFS

This booklet provides a general description of the various types of power take-off:
- How they can be used.
- How to calculate power and choose pump size.

Some propeller shaft theory is given at the end of the booklet.
The various Scania power take-offs are described in the same chapter but on a separate booklet.

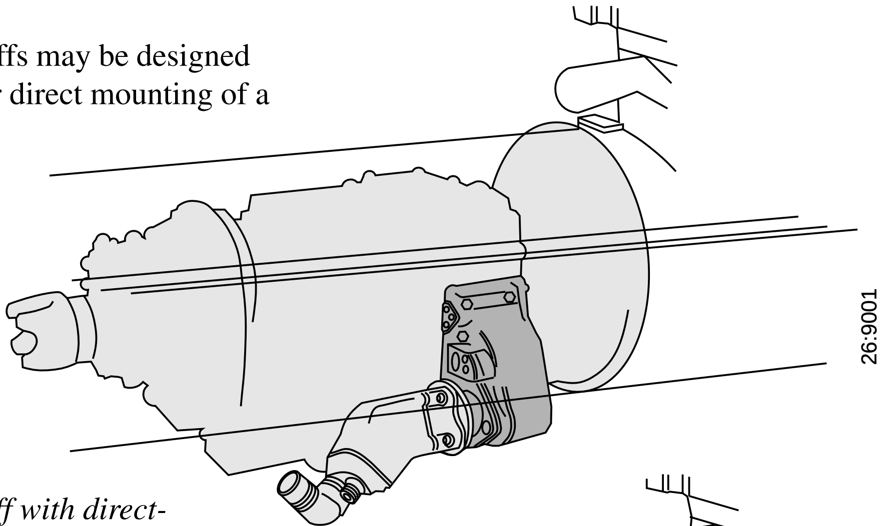
Power take-off alternatives

Some form of power take-off is required to drive a hydraulic pump, water pump, compressor or other equipment. Various power take-off alternatives can be chosen, depending on the bodywork, field of application and the unit being powered. Power take-offs can be divided into gearbox-driven and clutch-independent.

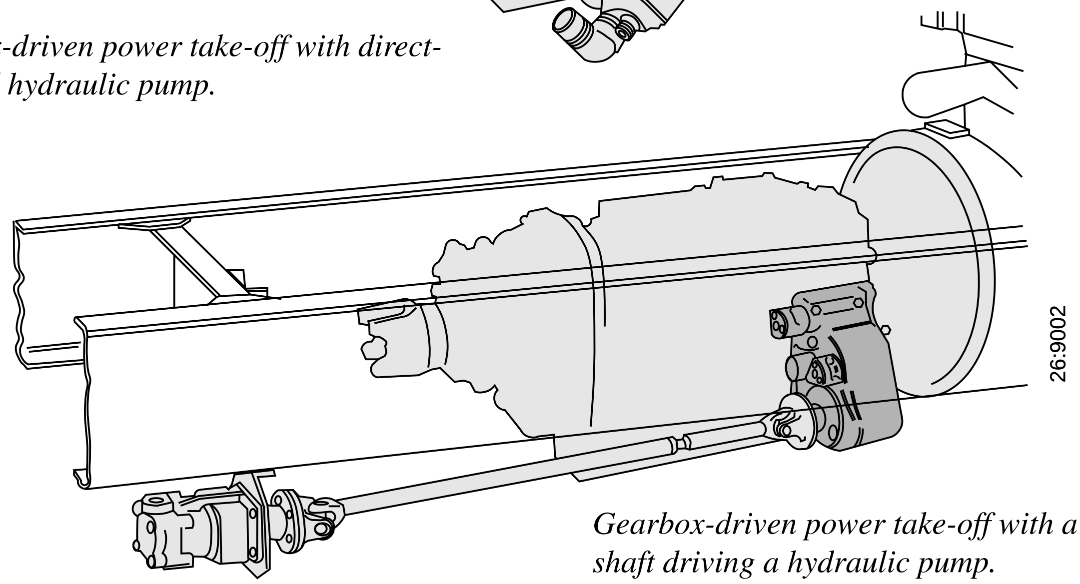
Gearbox-driven power take-offs

Gearbox-driven power take-offs are always clutch-dependent, meaning that drive in the power take-off ceases when the clutch is depressed. This type of power take-off can therefore only be used when the vehicle is stationary, such as for tipper or crane equipment.

Gearbox-driven power take-offs may be designed for propeller shaft drive or for direct mounting of a hydraulic pump.



Gearbox-driven power take-off with direct-mounted hydraulic pump.



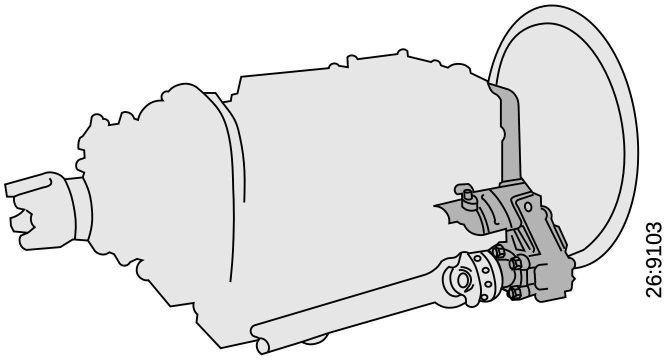
Gearbox-driven power take-off with a propeller shaft driving a hydraulic pump.

Clutch-independent power take-offs

An independent power take-off is not affected by engagement or disengagement of the clutch and can therefore be used when the truck under way.

Items of equipment which are used when the truck is being manoeuvred for loading and unloading, such as a hydraulic pump for a body exchange unit, must be driven by an independent power take-off.

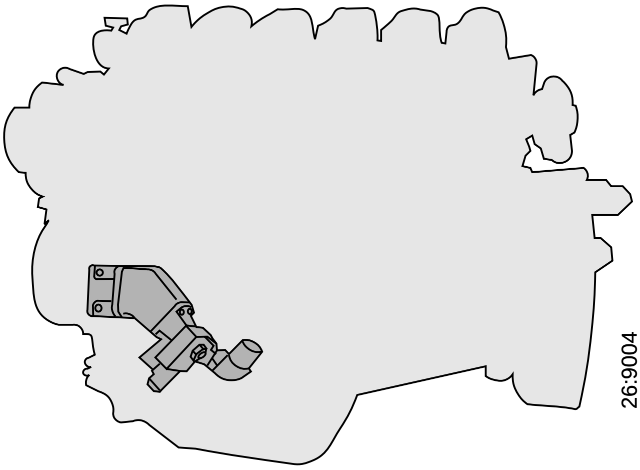
An independent power take-off usually has a flange for connection to a propeller shaft, but can also be designed for direct mounting of a hydraulic pump.



Clutch-independent power take-off

Engine power take-offs

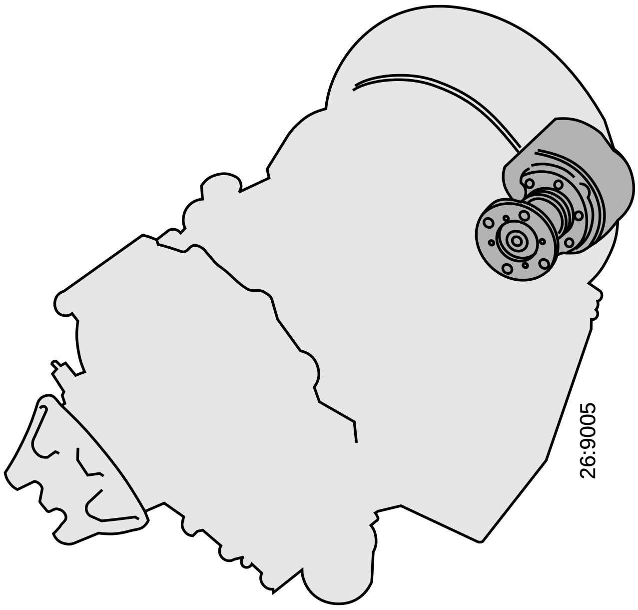
An engine power take-off belongs to the group of clutch-independent power take-offs It is employed principally for driving equipment which can be used while the truck is under way, such as a freezer or refrigeration unit, body exchange unit, plough or concrete mixer.



Engine power take-off with direct-mounted hydraulic pump

Automatic gearbox power take-offs

A power take-off on an automatic gearbox can normally only be used when the selector is in neutral, i.e. when the vehicle is stationary. With modified power take-off operation, the power take-off can also be used while the truck is being driven (selector set to drive).

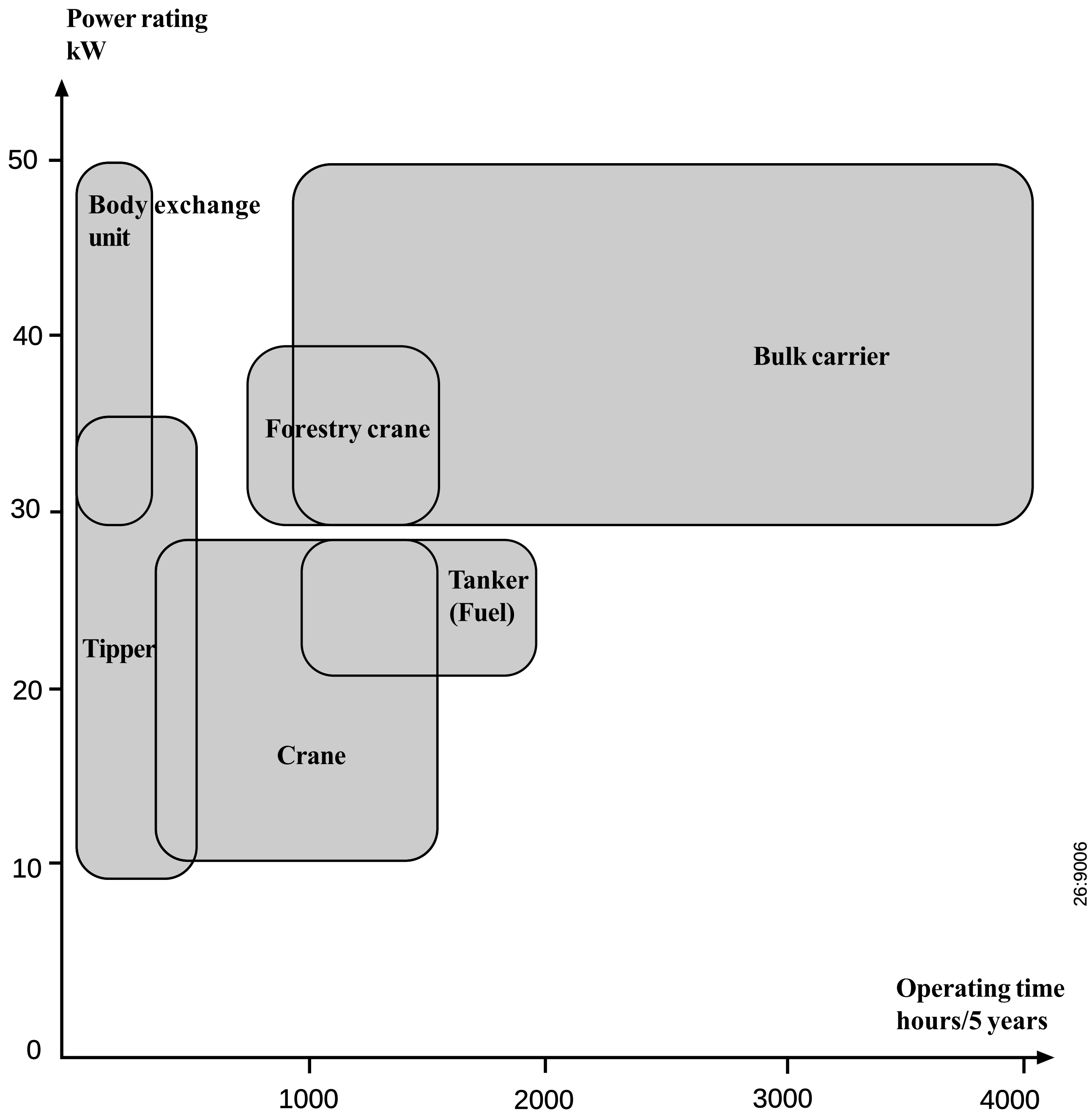


Power take-off on an automatic gearbox

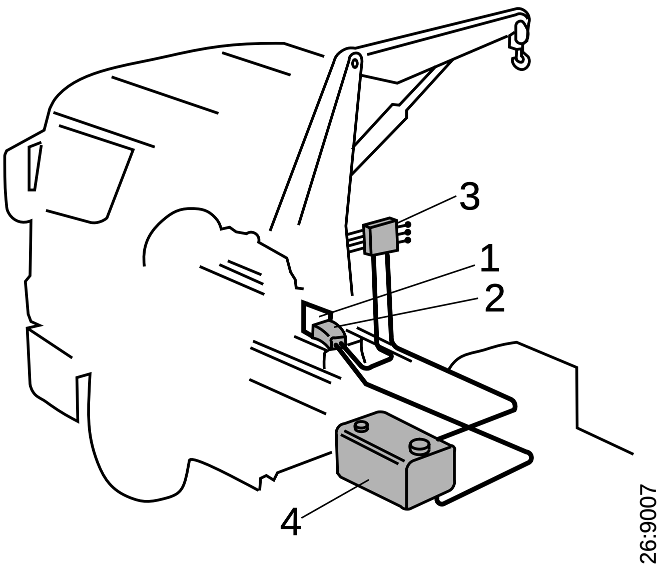
POWER TAKE-OFFS FOR BODY EQUIPMENT

Different power take-offs and power take-off arrangements can be employed to suit the body and auxiliary units specified for the truck. The following figures provide an outline of the power take-offs available and the system design for the most common auxiliaries and bodies. In several of these examples, the driven unit can be driven by other means, such as a separate diesel engine.

The graph below shows the power demand and the effective operating time of the power take-off in the various applications . This provides a rough idea of the demands made on the power take-off and the driven unit.



CRANE BEHIND CAB



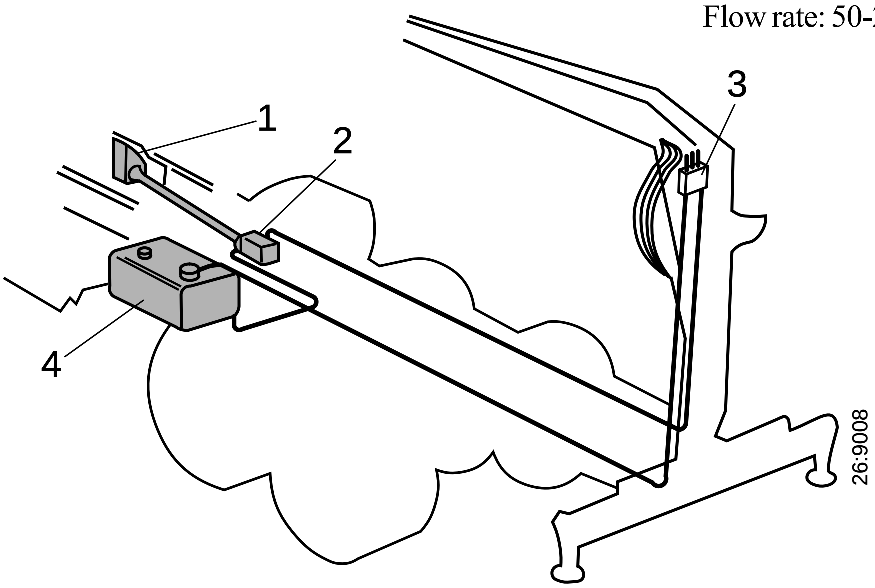
1. Gearbox-driven power take-off
2. Constant flow hydraulic pump
3. Valve assembly
4. Hydraulic fluid tank

System pressure: 150-350 bar
Flow rate: 40-80 l/min

Rear-mounted crane

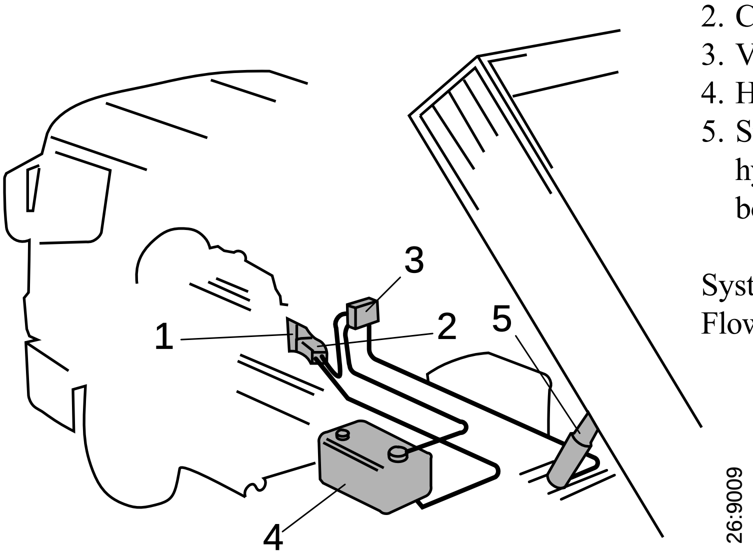
1. Gearbox-driven power take-off
2. Variable or constant flow hydraulic pump
3. Valve assembly
4. Hydraulic fluid tank

System pressure: 200-250 bar
Flow rate: 50-200 l/min



A gearbox-driven power take-off can be employed in both of the above cases, since the power take-off is only used when the truck is stationary.

TIPPER

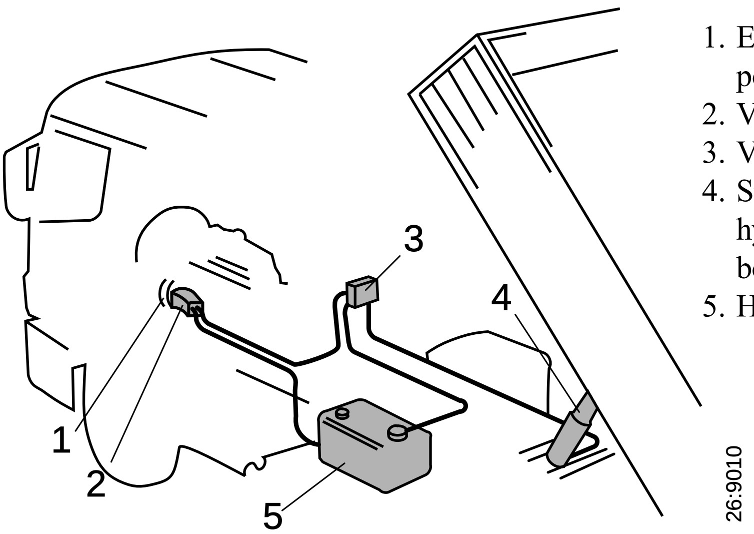


1. Gearbox-driven power take-off
2. Constant flow hydraulic pump
3. Valve assembly
4. Hydraulic fluid tank
5. Single-acting hydraulic cylinder (filled by the hydraulic pump and emptied by the weight of the body)

System pressure: 150-350 bar
Flow rate: 40-100 l/min

The hydraulic pump can be driven by a gearbox-driven power take-off, since the power take-off is generally used only when the truck is stationary.

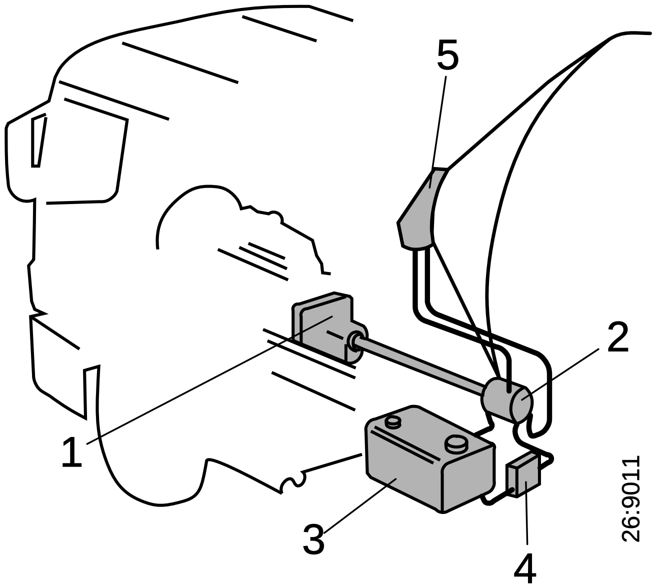
Tipper - Snow plough/sand spreader



1. Engine power take-off or other clutch-independent power take-off
2. Variable-flow hydraulic pump
3. Valve assembly
4. Single-acting hydraulic cylinder (filled by the hydraulic pump and emptied by the weight of the body)
5. Hydraulic fluid tank

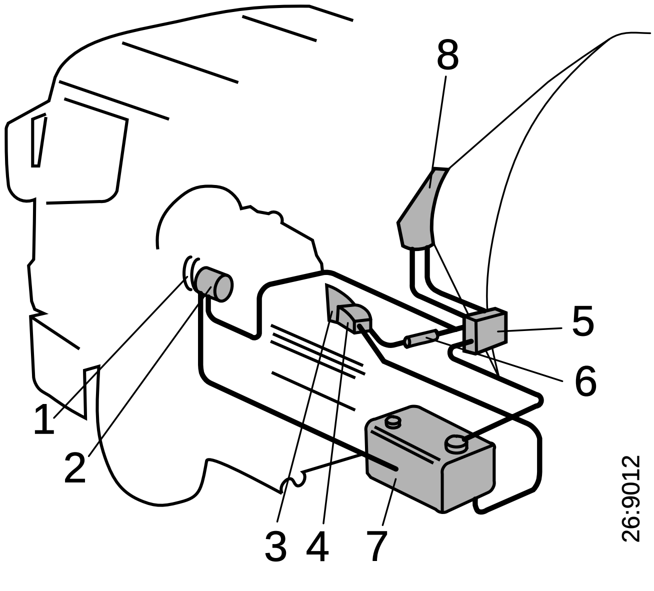
The difference between the above and a conventional tipper is that the tipper and snow plough/sand spreader are operated while the truck is travelling, and an independent power take-off must therefore be employed.

CONCRETE MIXER



Alternative 1
1. Clutch-independent power take-off
2. Variable-flow hydraulic pump
3. Hydraulic fluid tank
4. Fluid cooler
5. Hydraulic motor

A variable-flow hydraulic pump and clutch-independent power take-off are used, partly for loading and unloading concrete, and partly to control the speed of rotation of the concrete mixer during transport, independent of engine speed.



Alternative 2
1. Engine power take-off
2. Small constant-flow hydraulic pump
3. Gearbox-driven power take-off
4. Constant-flow hydraulic pump
5. Valve assembly
6. Non-return valve
7. Hydraulic fluid tank
8. Hydraulic motor

During transport
System pressure: 250-350 bar
Flow rating: 30 l/min

When unloading
System pressure: 200-350 bar
Flow rate: 150 l/min

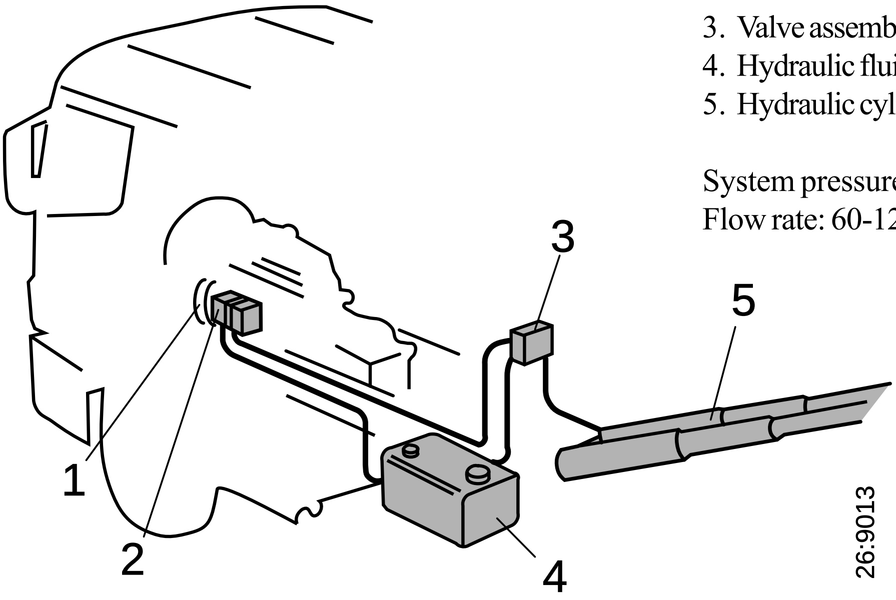
The engine power take-off and the small hydraulic pump are used for rotating the concrete mixer while the truck is under way.

The gearbox-driven power take-off and the second hydraulic pump are used when loading and unloading concrete.

BODY EXCHANGE UNIT

1. Engine power take-off or other clutch-independent power take-off
2. Constant-flow hydraulic pump
3. Valve assembly
4. Hydraulic fluid tank
5. Hydraulic cylinders

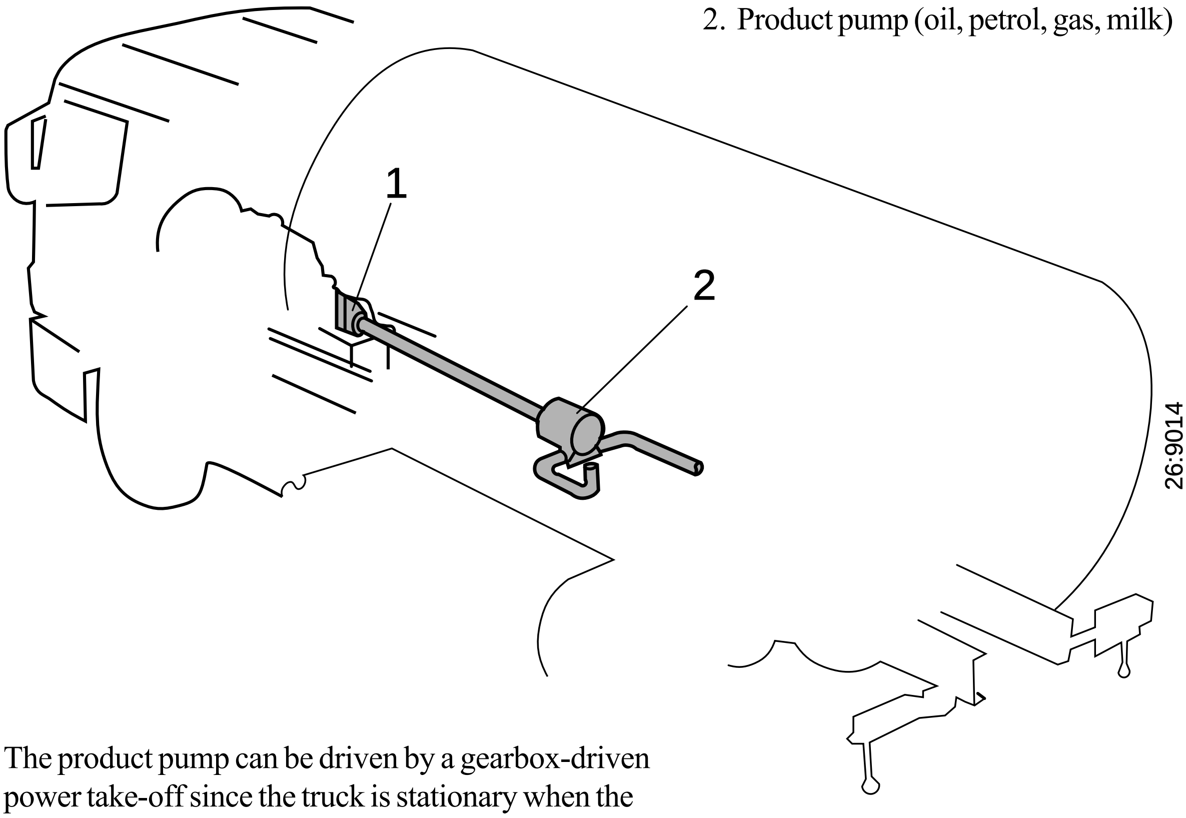
System pressure: 200-350 bar
Flow rate: 60-120 l/min



An independent power take-off is usually necessary since the hook of the body exchange unit must be operated while the truck is being manoeuvred (reversing).

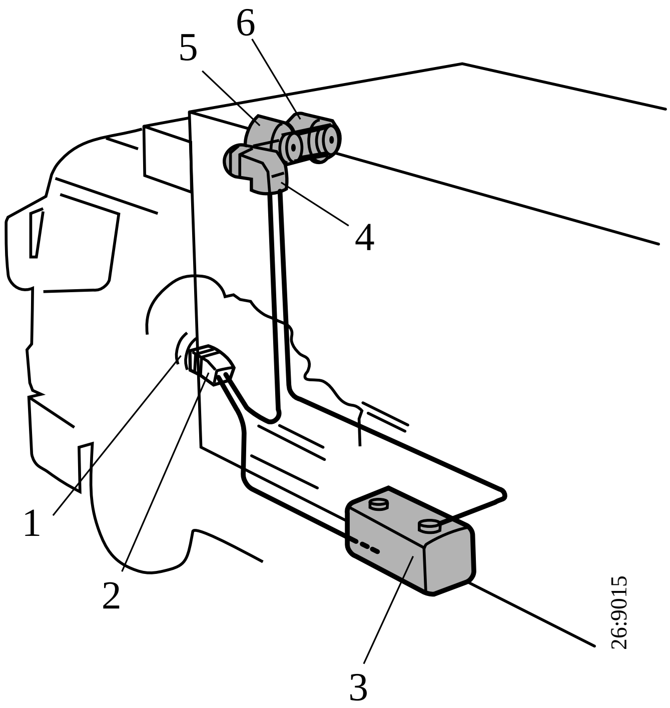
TANKER

1. Gearbox-driven power take-off
2. Product pump (oil, petrol, gas, milk)



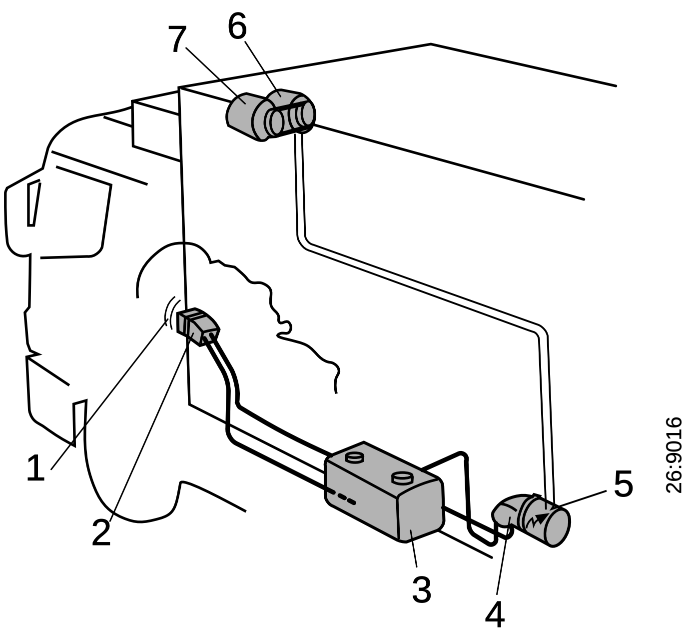
The product pump can be driven by a gearbox-driven power take-off since the truck is stationary when the pump is being used.

REFRIGERATION UNIT



Alternative 1

1. Engine power take-off
2. Variable or constant-flow hydraulic pump
3. Hydraulic fluid tank
4. Hydraulic motor
5. Refrigerant compressor
6. Electric motor (for driving the refrigerant compressor when the engine is switched off)

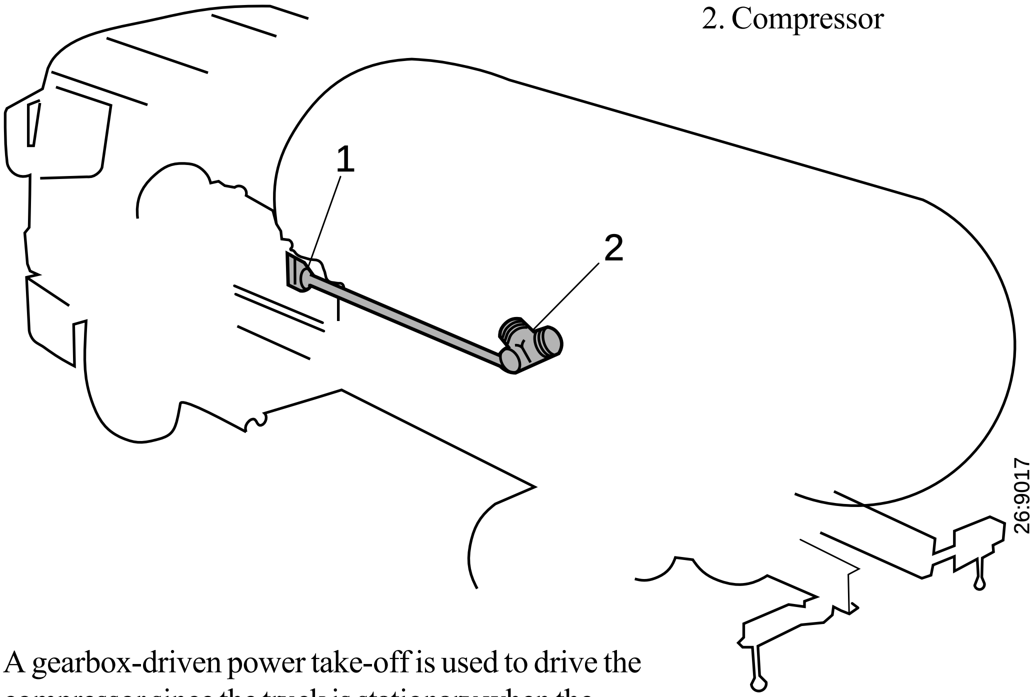


Alternative 2

1. Engine power take-off
2. Variable or constant-flow hydraulic pump
3. Hydraulic fluid tank
4. Hydraulic motor
5. Generator
6. Electric motor
7. Refrigerant compressor

In both of the above alternatives, the refrigerant compressor must be driven while the truck is under way, requiring an engine power take-off or a clutch-independent power take-off.

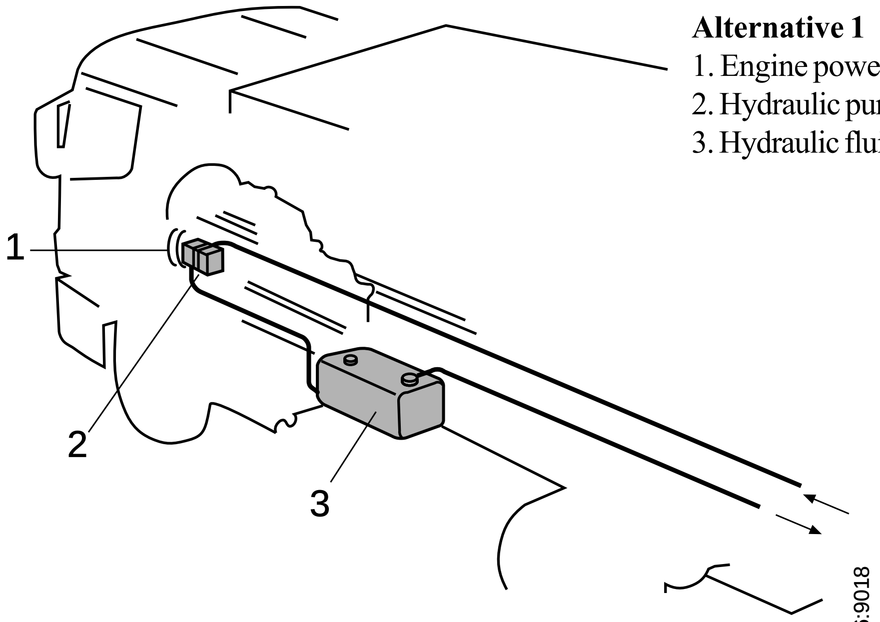
BULK CARRIER



1. Gearbox-driven power take-off
2. Compressor

A gearbox-driven power take-off is used to drive the compressor since the truck is stationary when the compressor is in use.

REFUSE COLLECTION UNIT

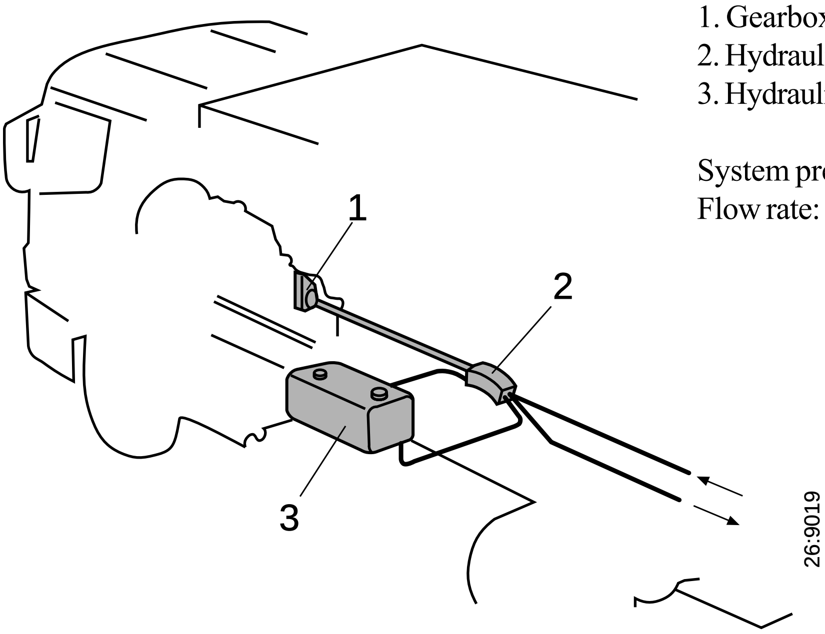


Alternative 1

1. Engine power take-off
2. Hydraulic pump
3. Hydraulic fluid tank

An engine power take-off must be used if the equipment on the refuse collection unit is to be used while the truck is under way.

As an alternative, the truck may be equipped with some other independent power take-off or an automatic gearbox power take-off.



Alternative 2
1. Gearbox-driven power take-off
2. Hydraulic pump
3. Hydraulic fluid tank

System pressure: 100-200 bar
Flow rate: 60-120 l/min

The gearbox-driven power take-off can be used if the refuse collection unit's hydraulic equipment is only used when the vehicle is stationary.

POWER TAKE-OFF RATIO

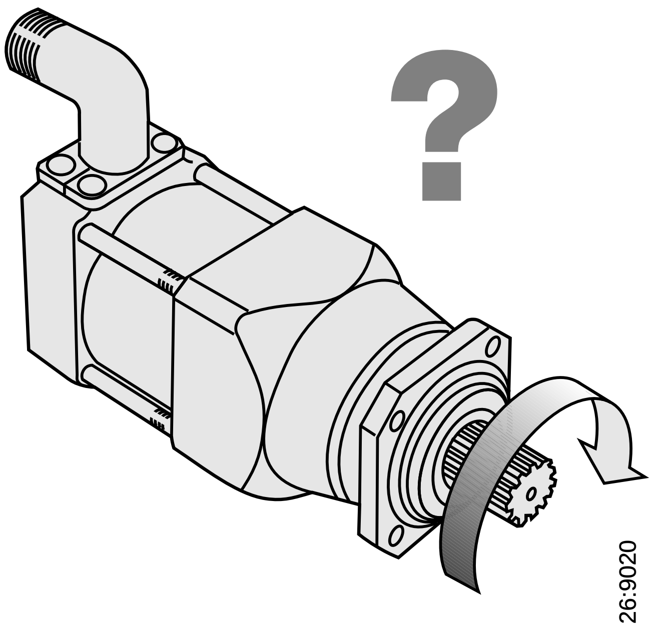
Factors affecting the gear ratio of the selected for the power take-off are engine speed, pump size or the speed requirement of other equipment to be driven.

Low speed power take-offs

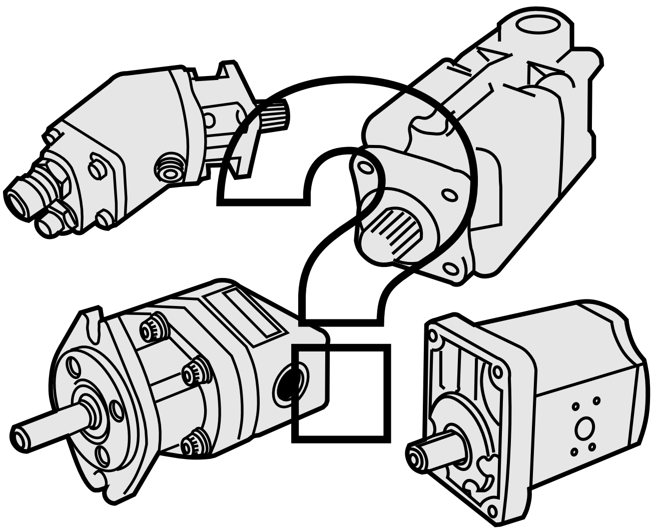
A low speed power take-off should generally be specified for pumps/equipment which is used while the truck is under way. This avoids the risk of overspeeding the pump/equipment.

High speed power take-offs

A high speed power take-off can always be specified for equipment which is used when the vehicle is stationary. A high speed power take-off delivers a higher flow with fewer hydraulic pumps.



POWER CALCULATION/SELECTION OF HYDRAULIC PUMP SIZE



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It is important to use the correct pump size in order to prevent overloading of the power take-off and to ensure the correct flow rate at the selected engine speed.

The size of the pump (displacement), D in cm^3 is calculated using the following formula:

$$D = \frac{Q \times 1000}{N \times Z}$$

D = Pump displacement (cm^3)
Q = Required flow rate (l/min)
N = Selected engine speed (rpm)
Z = Gear ratio of power take-off

Worked example 1
What size of pump should be used when required flow rate is 80 l/min, power take-off ratio is 0.82 and the selected engine speed is 1,300 rpm?

$$D = \frac{80 \times 1000}{1300 \times 0.82}$$

Answer: With the above requirements, pump size (displacement) should be 75 cm^3.

To avoid overloading the power take-off, it is important to calculate the torque required to drive the selected pump and the power demand on the power take-off.

Torque and power can be calculated as follows:

$$M = \frac{D \times Pbar}{63}$$

$$P = \frac{D \times N \times Z \times Pbar}{600 \times 0.95 \times 1000}$$

M = Torque (Nm)
D = Pump displacement (cm^3)
Pbar = System pressure (bar)
63 = Constant
P = Power (kW)
Z = Gear ratio of power take-off
0.95 = Pump efficiency (may vary between pump types)

Worked example 2
What will be the torque and the power demand on the power take-off if the pump from worked example 1 is selected and system pressure (Pbar) is 200 bar?

$$M = \frac{75 \times 200}{63} = 238 \text{ Nm}$$

$$P = \frac{75 \times 1300 \times 0.82 \times 200}{600 \times 0.95 \times 1000} = 28 \text{ kW}$$

Answer: The torque on the power take-off will be 238 Nm.
Power demand from the power take-off will be 28 kW.
The calculated load should then be compared with the maximum permissible load on the power take-off.

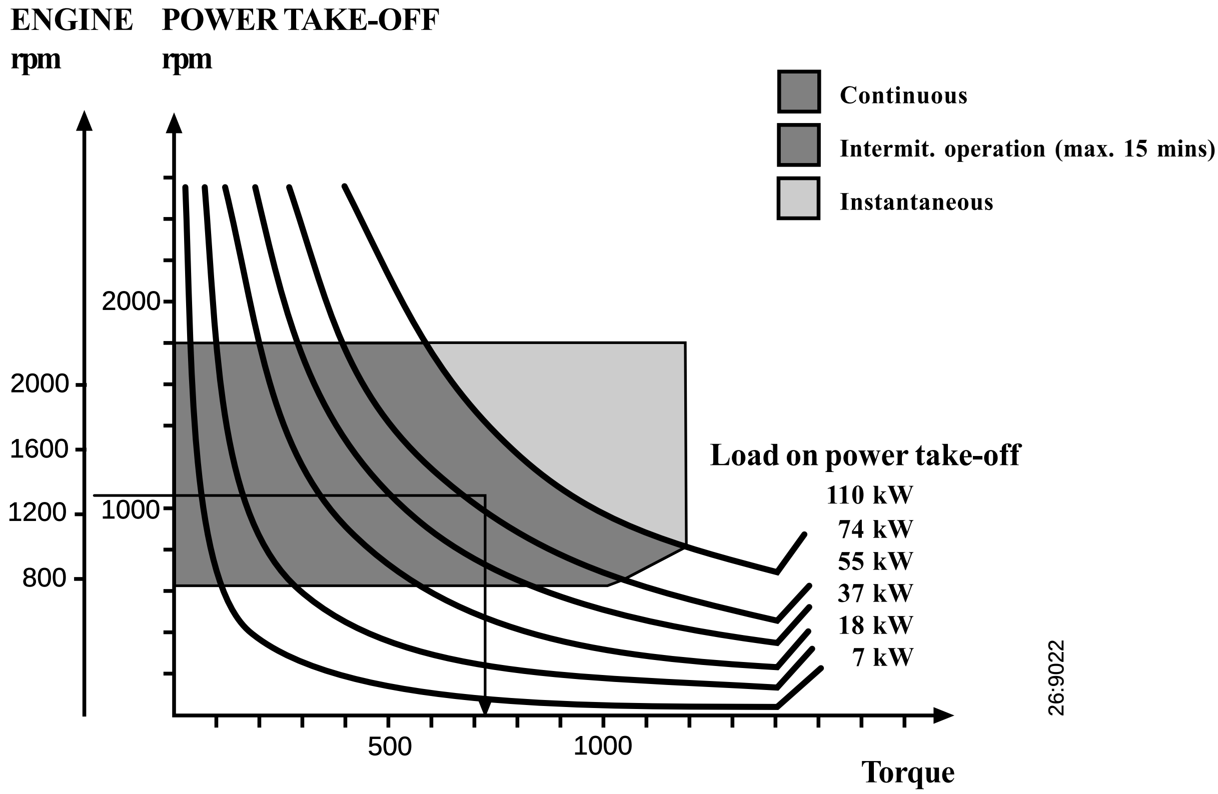
If the calculated load is greater than the maximum permissible value for the power take-off, a different pump size must be selected.

POWER TAKE-OFF SPECIFICATIONS

Power take-off graph

The power take-off graphs on the following pages indicate the limits within which the power take-offs can be used.

Three different loading conditions are marked for gearbox-driven power take-offs. Continuous operation, intermittent operation (max. 15 mins) and instantaneous load.



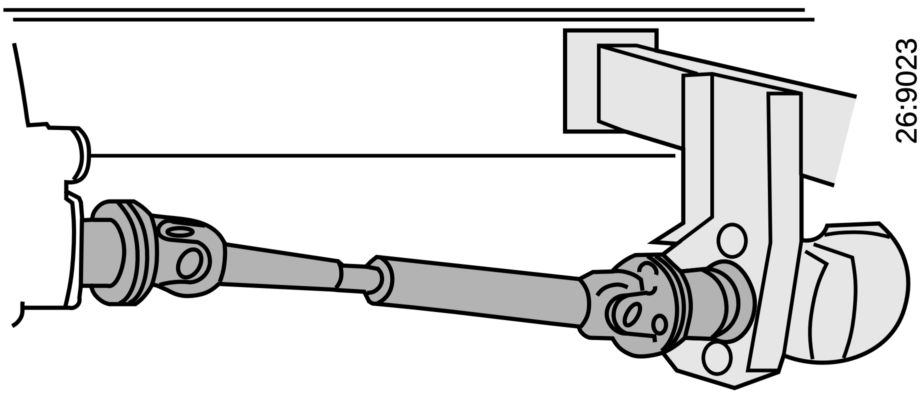
Power take-off graph

The limit for continuous operation is based on the high oil temperatures which arise in the gearbox when it is placed under load for long periods. If the power required for continuous operation is greater than permitted on the graph, the problem can be solved by equipping the gearbox with an oil cooler.

The limit for intermittent operation allows the power take-off to be run at a higher load for a short period of time (up to 15 mins).

The instantaneous load is that to which the power take-off may be subjected for a very short period of time, such as the peak load occurring before the relief valve in a hydraulic system opens.

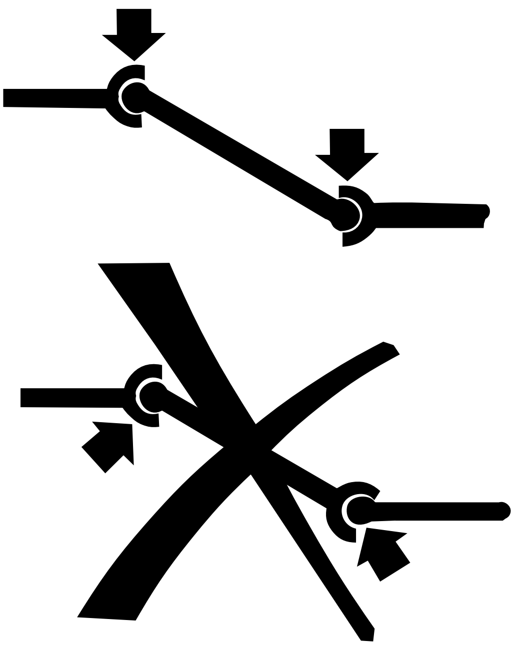
PROPELLER SHAFTS



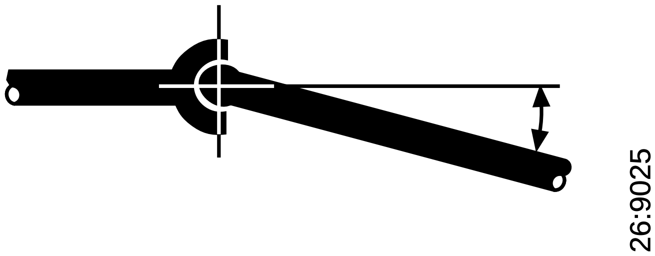
Propeller shaft performance

Universal joint positions
It is essential to the operation of a propeller shaft transmission that the universal joint angles are correctly selected and that the universal joints are correctly angled in relation to one another.

Note: The most common cause of vibration in propeller shafts is incorrect location of universal joints in relation to one another.



Variation in angular velocity
Universal joints are used for connecting two shafts which are at an angle to one another and for connecting parallel shafts which are not aligned.

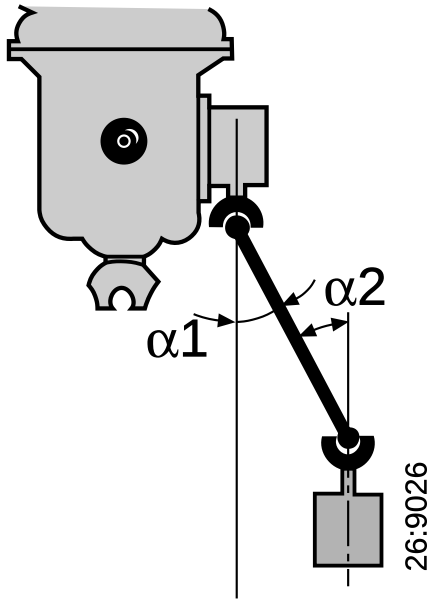


When this type of shaft system rotates, the universal joint will cause variations in angular velocity.

This variation in angular velocity is due to the angle in the universal joint, and is an unavoidable characteristic of these joints. The greater the angle of the universal joint, the greater the variation in angular velocity.

Importance of the angles
If the angles are the same size, this variation is not transmitted to the rest of the system.

A propeller shaft only has a constant speed of rotation if the angle of the input universal joint is 0°. If universal joint angles are less than 3°, pressure damage may be caused to the trunnion block, reducing its service life.



Compensation by means of universal joints

If several universal joints are used in a propeller shaft system, each universal joint gives a variation in angular velocity depending on the size of the angle.

By measuring the universal joint angles and calculating the variation in angular velocity, the installation can be adjusted to avoid disturbing vibration.

If the yokes of the propeller shaft are in the same plane, variations in angular velocity from one universal joint can be reduced or phased out using the other.

A propeller shaft with two yokes in the same plane will have no variation in angular velocity after the second joint, provided that the joint angles are the same.

Since the yokes are in the same plane, the angular velocity of the first joint increases as the other decreases and vice versa.

The angular velocity of the propeller shaft itself varies, increasing and decreasing every 90°.

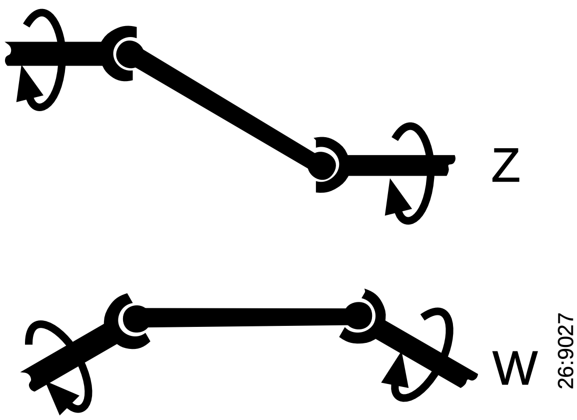
The correct position of the joints in relation to one another is important, irrespective of whether the propeller shaft system has two or more universal joints.

Two basic cases

Two basic alternatives are available for installing a propeller shaft system. These are known as the Z pattern and the W pattern. Combinations of these may also be employed.

Z pattern
In a Z pattern, the shafts of the driving and driven units are parallel or close to parallel.

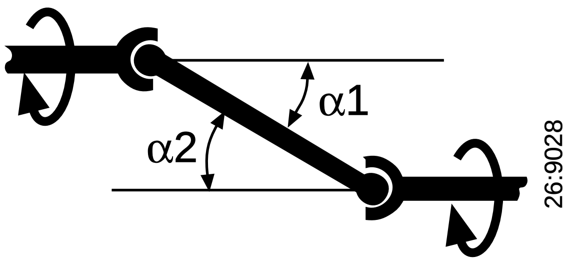
W pattern
In a W pattern, the shafts of the driving and driven units are not parallel.



Simplified calculation of the variation in angular velocity

Comprehensive calculations of the variation in angular velocity of the propeller shaft are very complicated. We therefore offer a simplified method for calculating variation in angular velocity.

If all angles are less than 3°, there is seldom a problem with variations in angular velocity. It is therefore unlikely that this type of system would require adjustment.



$$\alpha 1^2 - \alpha 2^2$$

Propeller shaft with two universal joints
Yokes 1 and 2 of the propeller shaft are in the same plane.

The universal joint angles are different and the shaft will therefore transmit variations in angular velocity to the remainder of the system.

Angle of universal joint 1 $\alpha_1 = 7°$
Angle of universal joint 2 $\alpha_2 = 8°$

The following formula can be applied when the universal joint yokes are in the same plane:

$\alpha_1 2 - \alpha_2 2 =$ variation in angular velocity if the universal joints are in the same plane.

(7x7) - (8x8) = -15

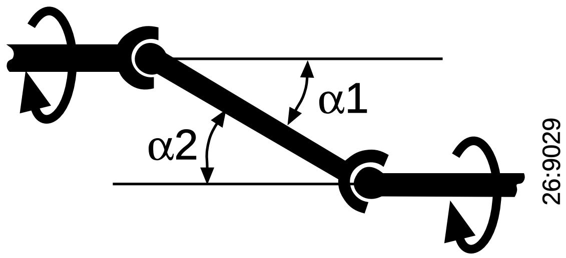
The variation in angular velocity is thus (-) 15 units (the minus sign has no significance).

If the universal joints are incorrectly fitted to the shaft and are not in the same plane, variation in angular velocity is cumulative.

$\alpha_1 2 + \alpha_2 2 =$ variation in angular velocity if the universal joints are incorrectly fitted i.e. at 90° to one another.

(7x7) + (8x8) = +113

This variation is too high for continuous operation. It is only acceptable in extreme cases and for short periods at low load.



$$\alpha 1^2 + \alpha 2^2$$

Consequences of variation in angular velocity
The strength of the drive is not normally significantly affected, provided that the variation in angular velocity is confined between the universal joints. But variation may give rise to vibration and noise that may sometimes be detrimental to comfort.