

# Black Bruin



**Product Manual  
BPW60**

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# 1 General Instructions

## 1.1 About the manual

This manual contains the technical instructions for the Black Bruin BPW60 hydraulic motors. Take these instructions into consideration when planning the use of the product.

All information given in this manual is current and valid according to the information available at the time of publication.

Please contact the manufacturer for the most recent version of this manual. The product datasheets and the 3D-models are available from the manufacturer by request.

## 1.2 Intended use

The Black Bruin BPW60 hydraulic motors are designed to be used as hub motors in driven axles to produce traction on tractor-driven trailers and working equipment.

## 1.3 Warranty

Check the package and the product for transport damage when receiving goods. The package is not meant for long term storage; protect the product appropriately.

Do not dismantle the product. The warranty is void if the product has been disassembled.

The manufacturer is not responsible for damages resulting from misinterpreted, non-compliance, incorrect, or improper use of the product that goes against the instructions given in this document.

## 1.4 Product identification

The product identification data can be found on the identification plate attached to the motor.



### Note:

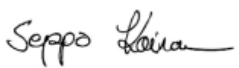
The serial number is also stamped on the motor. All manufacturing data can be found with the serial number.

## 1.5 Revision comments

24.08.2018 - This manual is published.

## 1.6

## Declaration of incorporation

|                                                                                                                                                                                                                                                                                                                                                                            |                                                                                     |                                   |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|-----------------------------------|
|                                                                                                                                                                                                                                                                                           |                                                                                     | DECLARATION OF INCORPORATION 1(1) |
| Black Bruin Inc.                                                                                                                                                                                                                                                                                                                                                           |                                                                                     | 2018-05-15                        |
| <b>DECLARATION OF INCORPORATION</b> (in accordance with EC Machinery Directive 2006/42/EC, Annex II B)                                                                                                                                                                                                                                                                     |                                                                                     |                                   |
| Manufacturer                                                                                                                                                                                                                                                                                                                                                               | Black Bruin Inc.                                                                    |                                   |
| Address                                                                                                                                                                                                                                                                                                                                                                    | Valmetintie 9<br>FI-40420 Jyskä, FINLAND                                            |                                   |
| Product description                                                                                                                                                                                                                                                                                                                                                        | Black Bruin hydraulic motor series:<br>▪ <b>BPW60</b>                               |                                   |
| We hereby declare that the product(s) specified above is intended to be incorporated into machinery or to be assembled with other machinery to constitute machinery covered by EC Machinery Directive 2006/42/EC, as amended.                                                                                                                                              |                                                                                     |                                   |
| And that the following harmonised standards have been applied: <ul style="list-style-type: none"> <li>▪ <b>EN ISO 4413:2010</b> (Hydraulic fluid power - General rules and safety requirements for systems and their components)</li> <li>▪ <b>EN ISO 12100:2010</b> (Safety of machinery – General principles for design – Risk assessment and risk reduction)</li> </ul> |                                                                                     |                                   |
| And furthermore declares that the product(s) covered by this declaration must not be put into service until the final machinery into which it is to be incorporated has been declared in conformity with the provisions of EC Machinery Directive 2006/42/EC.                                                                                                              |                                                                                     |                                   |
| The product(s) must be applied and installed in accordance with all the technical documents applicable to the product(s).                                                                                                                                                                                                                                                  |                                                                                     |                                   |
| This document supersedes all previous releases to this subject.                                                                                                                                                                                                                                                                                                            |                                                                                     |                                   |
| Place and date                                                                                                                                                                                                                                                                                                                                                             | Jyväskylä, 2018-05-15<br><br>On behalf of Black Bruin Inc.                          |                                   |
| Name                                                                                                                                                                                                                                                                                                                                                                       |  |                                   |
| Title                                                                                                                                                                                                                                                                                                                                                                      | Seppo Koiranen<br>Director, Operations                                              |                                   |
| <hr/> <p style="text-align: center;"> <small>             BLACK BRUIN INC.<br/>             P.O. Box 633, FI-40101 JYVÄSKYLÄ, FINLAND<br/>             +358 20 755 0755   info@blackbruin.com   www.blackbruin.com           </small> </p>                                                                                                                                 |                                                                                     |                                   |

## 2 Safety Instructions

The following instructions apply to all procedures associated with the motor. Read these instructions carefully and follow them closely.

- Use necessary personal protective equipment when working with the motor.
- Support the motor properly. Make sure the motor cannot fall over or turn around by accident.
- Use only appropriate equipment and attachments for lifting and transferring the motor.
- Do not use magnetic lifting devices.
- Always use the lifting equipment properly and check the load-bearing capacity.
- Prevent unintended use of the motor during installation and maintenance procedures by preventing pressurization of the hydraulic lines.
- The operating temperature of the motor may be over 60 °C (140 °F), which is hot enough to cause severe burns. Beware of hot hydraulic fluid when disconnecting the hydraulic connections.

### 2.1 Warning symbols

The following symbols are used in this manual:



**Note:**

Useful information.



**Danger:**

Danger of death or injury.



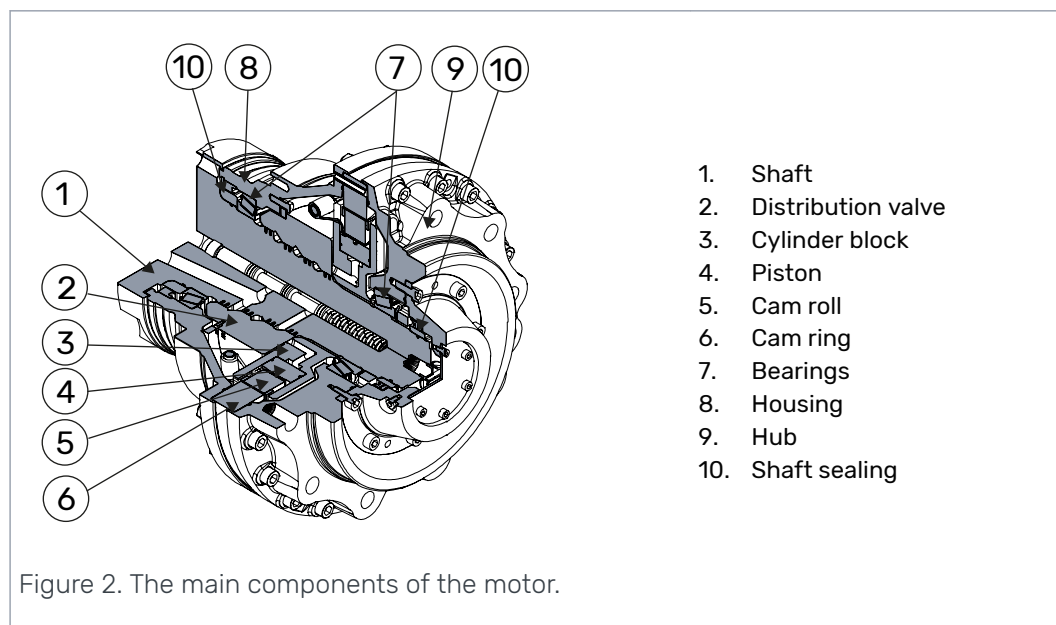
**Attention:**

May cause damage to the product.

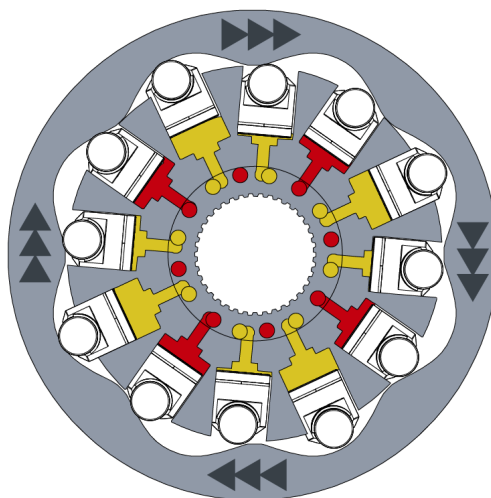
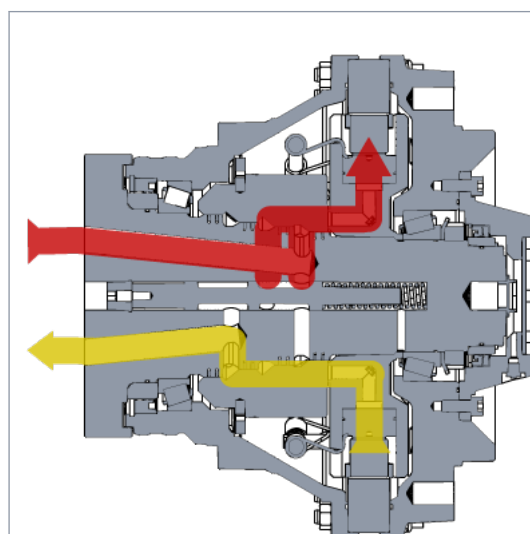
## 3 Motor Description

### 3.1 Working principle

BPW60 hydraulic motors are rotary-housing. This means the motor shaft and the cylinder block remain in place while the motor is running.



The rotation of the motor is achieved by feeding pressurized hydraulic fluid through the motor shaft to the distribution valve. The distribution valve directs the flow to the pistons which are on a power stroke. Pressure pushes the pistons and cam rolls outwards against the cam ring on the housing. The waveform of the cam ring transforms the force into torque. When the pistons reach the end of the power stroke, the distribution valve closes the flow to the pistons and switches the pistons to a return stroke. The cam ring pushes the pistons back into the cylinder block preparing them for the next outward power stroke.



## 3.2 Product identification code

Black Bruin product identification code consists of motor model code and processing ID.

|                        |   |               |
|------------------------|---|---------------|
| <b>BPW60-0315-2NOL</b> | - | <b>010000</b> |
| Motor model code       | - | Processing ID |

### 3.2.1 Motor model code

|                                |                                                                                              |
|--------------------------------|----------------------------------------------------------------------------------------------|
| <b>BPW60 MODEL CODE</b>        | <b>AAAAA - BBBB - CCCC</b>                                                                   |
| <b>A: Frame</b>                | <b>AAAAA - BBBB - CCCC</b>                                                                   |
|                                | BPW60                                                                                        |
| <b>B: Displacement</b>         | <b>AAAAA - BBBB - CCCC</b>                                                                   |
|                                | <u>0200</u> : 2000 ccm/rev                                                                   |
| BPW60 displacements            | <u>0250</u> : 2500 ccm/rev                                                                   |
|                                | <u>0315</u> : 3150 ccm/rev                                                                   |
| <b>C: Displacement control</b> | <b>AAAAA - BBBB - CCCC</b>                                                                   |
| 1-speed                        | <u>1N00</u> : Fixed displacement                                                             |
|                                | <u>2N0R</u> : Right side - CW preferred                                                      |
| 2-speed valve                  | <u>2N0L</u> : Left side - CCW preferred                                                      |
| <b>Code example</b>            | <b>BPW60 - 0315 - 2NOL</b>                                                                   |
|                                | A - B - C                                                                                    |
| A =                            | The frame of the motor is "BPW60"                                                            |
| B =                            | The displacement of the motor is 3150 ccm/rev                                                |
| C =                            | Internal 2-speed valve for displacement control. The motor is CCW preferred in 2-speed mode. |

### 3.2.2 Processing ID

| BPW60 PROCESSING ID |                                       | R M S P D T                                               |
|---------------------|---------------------------------------|-----------------------------------------------------------|
| <u>R</u> M S P D T  | Lubrication                           | Definition of factory lubrication                         |
| 0                   | = Default / Not defined <sup>1)</sup> |                                                           |
| <u>R</u> M S P D T  | Painting                              | Definition of the painted surfaces                        |
| 0                   | = No painting                         | - Motors are washed and protected from corrosion.         |
| 1                   | = Painting type 1                     | - Unpainted interfaces: SHAFT, HUB <sup>2)</sup>          |
| 2                   | = Painting type 2                     | - Unpainted interfaces: SHAFT, HUB, HOUSING <sup>2)</sup> |
| <u>R</u> M S P D T  | Protection                            | Definition of the protection for storage/transportation   |
| 0                   | = Default / Not defined <sup>3)</sup> |                                                           |

| <b>R M S P D T</b> | <b>Packaging</b>                      | <b>Definition of the motor package</b> |
|--------------------|---------------------------------------|----------------------------------------|
| 0                  | = Default / Not defined <sup>4)</sup> |                                        |

| <b>R M S P D T</b> | <b>Documents</b>        | <b>Definition of the documentation to be attached to the delivery</b> |
|--------------------|-------------------------|-----------------------------------------------------------------------|
| 0                  | = Default / Not defined |                                                                       |

| <b>R M S P D T</b> | <b>Testing</b>                        | <b>Definition of the testing and reporting</b> |
|--------------------|---------------------------------------|------------------------------------------------|
| 0                  | = Default / Not defined <sup>5)</sup> |                                                |

| <b>Code example</b> | <b><u>0</u></b>                                                                                                     | <b><u>1</u></b> | <b><u>0</u></b> | <b><u>0</u></b> | <b><u>0</u></b> | <b><u>0</u></b> |
|---------------------|---------------------------------------------------------------------------------------------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|
|                     | R                                                                                                                   | M               | S               | P               | D               | T               |
| R =                 | The motor is lubricated according to general practices of the manufacturer.                                         |                 |                 |                 |                 |                 |
| M =                 | Prime coating. The shaft and hub interfaces of the motor are unpainted.                                             |                 |                 |                 |                 |                 |
| S =                 | Pressure openings and threaded holes of the motor are protected according to general practices of the manufacturer. |                 |                 |                 |                 |                 |
| P =                 | The motor is packaged according to general practices of the manufacturer.                                           |                 |                 |                 |                 |                 |
| D =                 | The documentation delivered with the motor is according to general practices of the manufacturer.                   |                 |                 |                 |                 |                 |
| T =                 | The motor is tested according to general practices of the manufacturer.                                             |                 |                 |                 |                 |                 |

<sup>1)</sup> The seals are lubricated lightly during assembly.

<sup>2)</sup> Prime coating: HEMPATANE HS 55610 or equivalent. Tint: glossy black.

<sup>3)</sup> Pressure openings and threaded holes are capped with plastic fittings. Hydraulic fluid is drained out.

<sup>4)</sup> Delivery on wooden pallet or in plywood box.

<sup>5)</sup> The manufacturer keeps test records of every manufactured motor.

### 3.3

### Technical data

| <b>TECHNICAL DATA</b>            | <b>BPW60</b> |       |       |
|----------------------------------|--------------|-------|-------|
| <b>Displacement [ccm]</b>        |              |       |       |
| at full displacement             | 2000         | 2500  | 3150  |
| at half displacement             | 1000         | 1250  | 1575  |
| <b>Maximum torque [Nm]</b>       |              |       |       |
| theoretical                      | 14300        | 17900 | 22600 |
| with 100 bar                     | 3180         | 3980  | 5010  |
| <b>Max. operating power [kW]</b> |              |       |       |
| at full displacement             | 90           |       |       |
| at half displacement             | 54           |       |       |
| <b>Max. rotating speed [rpm]</b> |              |       |       |
| at full displacement             | 175          | 140   | 110   |
| at half displacement             | 225          | 180   | 145   |
| at freewheeling                  | 400          |       |       |
| <b>Min. rotating speed [rpm]</b> | 2            |       |       |

| TECHNICAL DATA                                         | BPW60                      |    |    |
|--------------------------------------------------------|----------------------------|----|----|
| <b>Max. engaging speed (out of freewheeling) [rpm]</b> | 88                         | 70 | 55 |
| <b>Max. working pressure [bar]</b>                     | peak pressure              |    |    |
|                                                        | 450                        |    |    |
| <b>Max. case pressure [bar]</b>                        | intermittent <sup>1)</sup> |    |    |
|                                                        | 400                        |    |    |
| <b>Max. case pressure [bar]</b>                        | average                    |    |    |
|                                                        | 2                          |    |    |
| <b>Pilot pressure for internal valve [bar]</b>         | intermittent <sup>1)</sup> |    |    |
|                                                        | 10                         |    |    |
| <b>Pilot pressure for internal valve [bar]</b>         | valve released             |    |    |
|                                                        | 0-2                        |    |    |
| <b>Max. flow rate [l/min]</b>                          | valve engaged              |    |    |
|                                                        | 7-30 <sup>2)</sup>         |    |    |
| <b>Max. flow rate [l/min]</b>                          | at full displacement       |    |    |
|                                                        | 350                        |    |    |
| <b>Max. load capacity [t] <sup>3)</sup></b>            | at half displacement       |    |    |
|                                                        | 225                        |    |    |
| <b>Max. load capacity [t] <sup>3)</sup></b>            | 12,5                       |    |    |
| <b>Weight [kg]</b>                                     | 153                        |    |    |

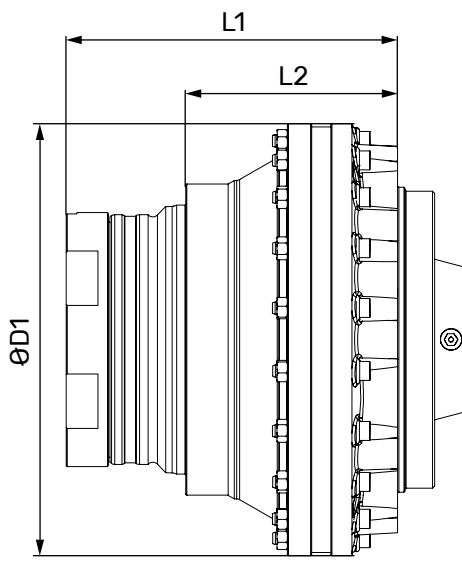
<sup>1)</sup> Intermittent operation: permissible values for maximum of 10% of every minute.

<sup>2)</sup> If pilot pressure over 30 bar is used, the pilot line should be throttled.

<sup>3)</sup> The load capacity must be estimated for every application.

## 3.4 Motor interfaces

### MAIN DIMENSIONS

|  | BPW60 |      |     |
|-------------------------------------------------------------------------------------|-------|------|-----|
|                                                                                     | L1    | [mm] | 313 |
|                                                                                     | L2    | [mm] | 200 |
|                                                                                     | D1    | [mm] | 408 |

### SHAFT INTERFACE

The motor is attached to the axle from the shaft flange. The hydraulic connections of the motor are located on the plane surface of the shaft flange.

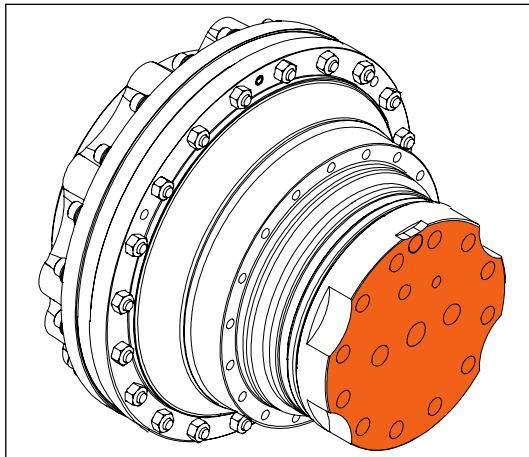


Figure 5. The shaft interface of the motor.

### HUB INTERFACE

The brake drum and wheel rim are attached to the motor hub.

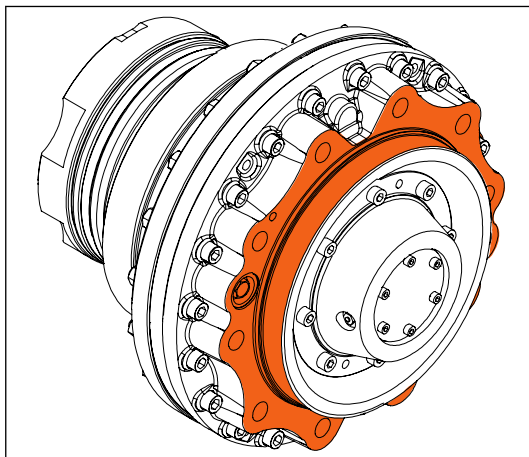


Figure 6. The hub interface of the motor.



**Note:**

The attachment screws are not included in the motor delivery. Ensure correct dimensioning and availability of the hub screws.

### HOUSING INTERFACE

The housing interface can be used, for example, to attach a brake disc of a disc brake.

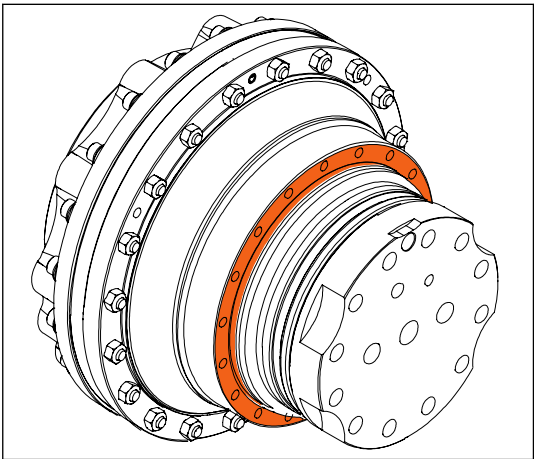


Figure 7. The housing interface of the motor.



**Note:**  
Surface roughness (Ra) of the counterparts must be 12,5µm or better.  
More detailed interface dimensions and tolerances are indicated on the product datasheet.

**3.5 Rotating direction**

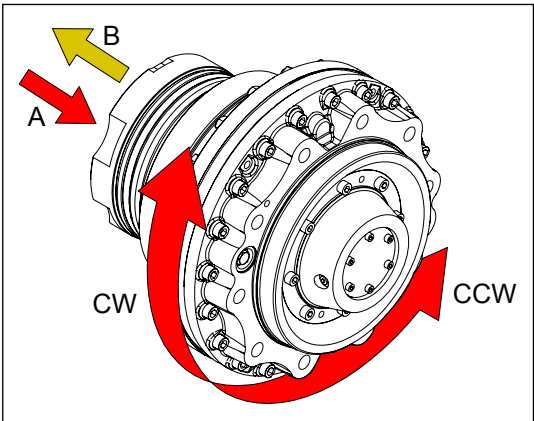


Figure 8. Rotating direction of the motor.

The rotating direction of the motor is defined as the rotating direction of the housing viewed from the hub to the shaft.

The rotating direction of the motor and the flow direction in the working lines is given in the table below.

Table 1: Rotating direction and flow direction.

| ROTATING DIRECTION | flow direction |       |
|--------------------|----------------|-------|
|                    | A → B          | B → A |
| 1N00               | CW             | CCW   |
| 2N0R               | CW             | CCW   |
| 2N0L               | CCW            | CW    |

**Preferred operating direction**

|       |   |      |   |                    |
|-------|---|------|---|--------------------|
| AAAAA | - | BBBB | - | <b><u>2NOR</u></b> |
| AAAAA | - | BBBB | - | <b><u>2NOL</u></b> |

The preferred operating direction applies to motors with 2-speed valve (see [2-speed valve : 2NOR / 2NOL](#) on page 15).

The preferred operating direction is the rotating direction of the motor when the flow direction is from port A to B.

- **2NOR** = CW motor (For the right side of a vehicle.)
- **2NOL** = CCW motor (For the left side of a vehicle.)

### 3.6 Mechanical freewheeling

The mechanical freewheeling is a standard feature in the Black Bruin BPW60 hydraulic motors.

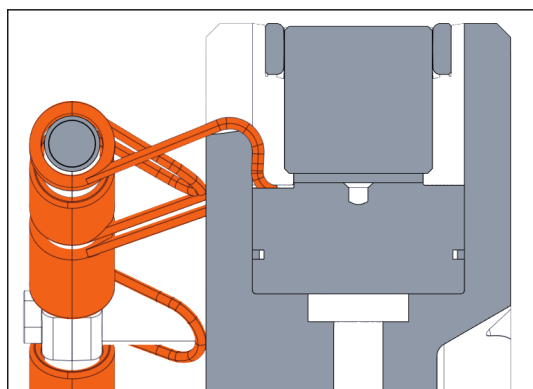


Figure 9. A piston with the freewheeling spring.

The motor is equipped with mechanical freewheeling springs, which enable the motor disengagement. When disengaged the motor may be used without active fluid supply from the hydraulic system.

**USING THE FREEWHEELING**

When the motor is depressurized and not rotating, the motor will disengage automatically. The motor disengagement during motion is done with a freewheeling valve.

The freewheeling valve connects the working lines (A and B) and the case drain line (C) together (see [External freewheeling valve](#) on page 21). The purpose of the valve is to remove pressure difference over the motor pistons. This allows the pistons to retract with aid of mechanical springs.

- **DISENGAGING THE MOTOR**

Open the freewheeling valve and depressurize the motor with the directional control valve to disengage the motor.

- **ENGAGING THE MOTOR**

Close the freewheeling valve and pressurize the motor with the directional control valve to engage the motor.

The directional control valve and the freewheeling valve are usually activated simultaneously.



**Note:**

Another use of the freewheeling is a more extensive speed range for vehicles having several hydraulic motors. Hydraulic system capacity may be divided between fewer motors, when some of the motors are disengaged.



**Attention:**

Any pressure in the working lines (A and B) during the freewheeling pushes the pistons out of the freewheeling position. This causes clattering noise when the pistons connect to the cam ring.

Constant clattering of the pistons may cause premature wear or failure of the motor.

### ROTATING SPEED

The rotating speed of the motor should be taken into account when implementing freewheeling.

- **FREEWHEELING SPEED**

The freewheeling speed is the highest permissible rotating speed of the motor during freewheeling.

- **ENGAGING SPEED**

The engaging speed is the highest permissible rotating speed when engaging the motor.

The permissible freewheeling and engaging speeds can be found on the technical data (see [Technical data](#) on page 9).

### DISENGAGING DELAY

While the pistons are retracting, there is a momentary flow of hydraulic fluid from the working lines to the casing of the motor. This causes always a small delay when disengaging the motor. Normal delay is about 1 - 2 seconds.

To minimize the disengaging delay the hydraulic fluid should have as open channel as possible:

- The external freewheeling valve should be positioned as close to the motor as possible.
- All components and lines, which connect the working lines to the case drain line, should be sized for highest feasible flow rate.



**Attention:**

Without freewheeling valve, the delay is considerably longer as the fluid must seep through the motor. Disengaging the motor during motion without a freewheeling valve may cause premature wear or failure of the motor.

## 3.7

### 1-speed : 1N00

|       |   |      |   |             |
|-------|---|------|---|-------------|
| AAAAA | - | BBBB | - | <b>1N00</b> |
|-------|---|------|---|-------------|

Displacement control selection 1-speed means the motor has a fixed displacement. These motors are known as 1-speed motors and are always in full displacement during operation.

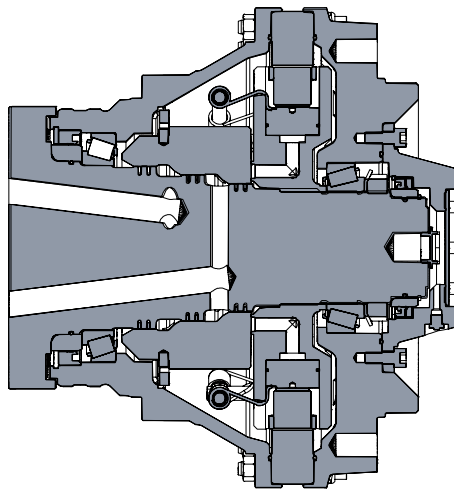


Figure 10. 1-speed motor.

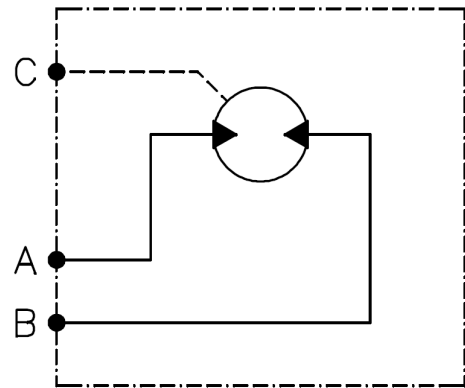


Figure 11. Hydraulic circuit, 1-speed motor.

### 3.8

#### 2-speed valve : 2NOR / 2NOL

|       |   |      |   |             |
|-------|---|------|---|-------------|
| AAAAA | - | BBBB | - | <b>2NOR</b> |
| AAAAA | - | BBBB | - | <b>2NOL</b> |

The 2-speed valve enables change of displacement during operation. The benefit of this function is a more extensive speed range with the same hydraulic system capacity. The motors are also known as 2-speed motors.

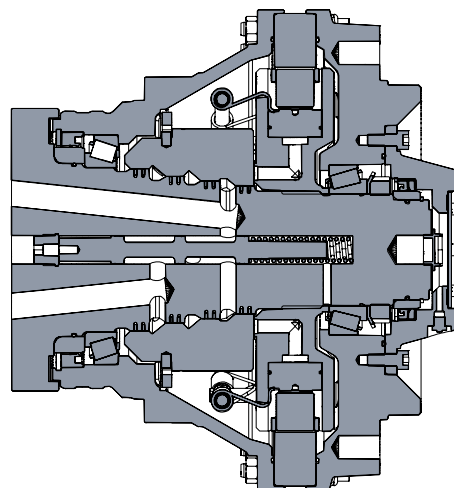


Figure 12. 2-speed motor.

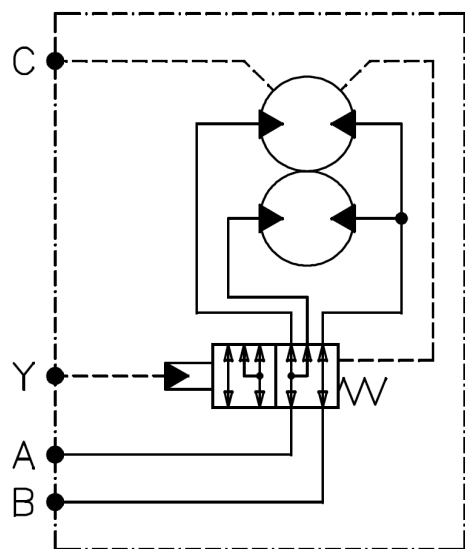


Figure 13. Hydraulic circuit, 2-speed motor.

The change of displacement works by switching the piston to idle on every second stroke. This is done with the in-built 2-speed valve, which changes the fluid circulation in the motor.

## USING THE 2-SPEED VALVE

Using the 2-speed valve works in the same manner as gear shifting.

- **SHIFTING TO HALF DISPLACEMENT**

The motor is switched to half displacement by applying the pilot pressure (see [Pilot pressure](#) on page 23) to the pilot line (Y).

When the motor operates at half displacement, it rotates twice as fast and generates half of the torque when compared to a motor on full displacement with the same flow rate and pressure.

The working pressure should be primarily applied into the working line A. The motor operates at lower efficiency and the operating temperature may rise if working pressure is applied into the working line B.

- **SHIFTING TO FULL DISPLACEMENT**

The motor is switched back to full displacement by releasing the pressure in the pilot line (Y).

When the motor operates at full displacement, it works like the 1-speed motor and it may be operated normally on both directions.



**Attention:**

Take the following things into consideration, when changing the speed range during motion.

- Hydraulic system supply must adjust to the rapid change of flowrate.
- The rapid change in flow rate may cause momentary jerk. This may be avoided by throttling the working lines lightly.
- Prevent operating conditions, in which the permissible performance values could be exceeded.

The permissible performance values are in the technical data (see [Technical data](#) on page 9).



**Attention:**

Continuous use of high working pressure in the working line B at half displacement may cause premature wear or failure of the motor.

## 4 System Design

### 4.1 Motor hydraulic circuit

#### 4.1.1 Simple connection

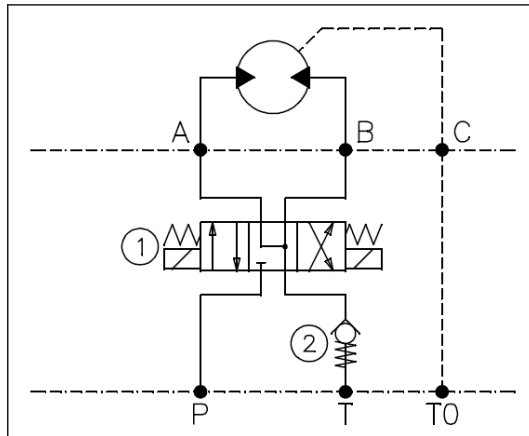


Figure 14. A simple motor hydraulic circuit in an open loop hydraulic system.

In an open loop hydraulic system the hydraulic circuit of the motor is usually implemented roughly as in the figure above.

- Select the operating direction with the directional control valve (1) by applying the working pressure (P) to the other working line (A or B).
- The minimum pressure (see [Working line pressure](#) on page 24) required in the return line (T) is created with the cracking pressure of the check valve (2).
- The case drain line port (C) is connected to the system reservoir (T0) as directly as possible.



#### Attention:

The case drain line of the motor must always be connected to a reservoir, even during freewheeling. The case pressure of the motor may rise significantly, if the motor is completely plugged during use.



#### Note:

Using the motor on a closed loop hydraulic system is different from the open loop system. The closed loop system is more complex, but enables more functions, such as hydrostatic braking, series connection and counter pressure operation.

#### 4.1.2 Motors in parallel or series circuit

The traction of a vehicle may be increased by connecting multiple motors in parallel or in series.

A single powered wheel may transmit only a certain amount of power to traction. By dividing the power to multiple wheels, the vehicle gets more traction. This is advantageous especially in slippery operating conditions.

### PARALLEL CIRCUIT

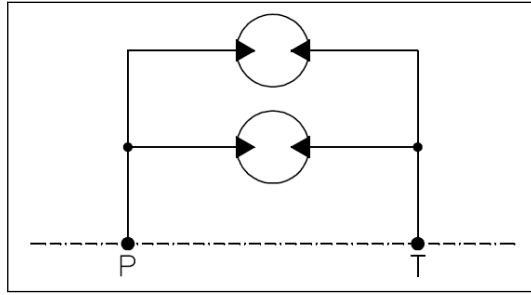


Figure 15. Two motors in parallel circuit.

Two motors in parallel circuit generate double torque and run half slower than one motor with the same flow rate and pressure.



#### Note:

The flow distribution of the motors must be ensured, if the operating conditions are very slippery or if some of the powered wheels carry much smaller load. The system prefers to rotate only the motor, which has the least resistance.

The flow distribution may be done by sizing the working lines to a certain flow rate or by throttling them slightly.

Ordinary flow divider valve can not be used in most cases, because its resistance of flow increases too much as the speed of the vehicle increases.

The flow distribution is usually required only when starting to move the vehicle. A reliable solution is a flow divider valve, which can be bypassed or switched on when necessary.

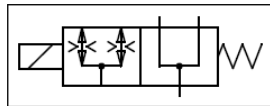


Figure 16. A pilot controlled flow divider valve.

### SERIES CIRCUIT

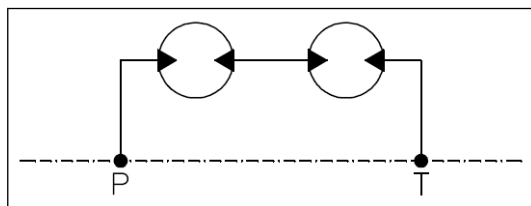


Figure 17. Two motors in series circuit.

Two motors in series circuit generate same torque and rotate as fast as one motor with the same flow rate and pressure.



#### Attention:

The minimum pressure and a sufficient feed flow must be ensured for all motors.

The use of series circuit is challenging and therefore is not recommended.

### 4.1.3 Counter pressure operation

Counter pressure operation is needed mainly in series connection (see [Motors in parallel or series circuit](#) on page 17). Counter pressure operation means using the motor with high back pressure in the return line.

The counter pressure operation affects the torque output of the motor due to decreased pressure difference over the working lines.

**Attention:**

Make sure the combined pressure in the working lines does not exceed the permissible values of the working pressure during counter pressure operation.

Counter pressure operation is not recommended, because high back pressure stresses the motor more than usual operation.

### 4.1.4 Hydrostatic braking

Hydrostatic braking means using the output torque of the motor to decelerate the speed. The output torque is generated by closing the return line of the motor, in which case a working pressure will form in the return line. The minimum pressure and feed flow must be maintained in the feed line of the motor during hydrostatic braking.

**Note:**

The hydrostatic braking requires an active hydraulic fluid supply.

**Danger:**

Do not use the hydrostatic braking without relief valves in the working lines. When an external load is rotating the motor, the hydraulic pressure may increase indefinitely. This leads to danger if a hydraulic hose or component brakes under high pressure.

### 4.1.5 Short circuit operation

Short circuit operation means connecting the return flow of the motor directly to the feed line of the motor.

Short circuit operation is needed, if the motor must be rotated faster than the hydraulic system can supply and freewheeling the motor is not possible (see [Mechanical freewheeling](#) on page 13).

Make sure the minimum pressure is maintained in both working lines of the motor during short circuit operation.

**Note:**

The short circuit operation requires an active hydraulic fluid supply.

**Attention:**

Make sure the motor does not overheat during short circuit operation.

## 4.2 Hydraulic connections

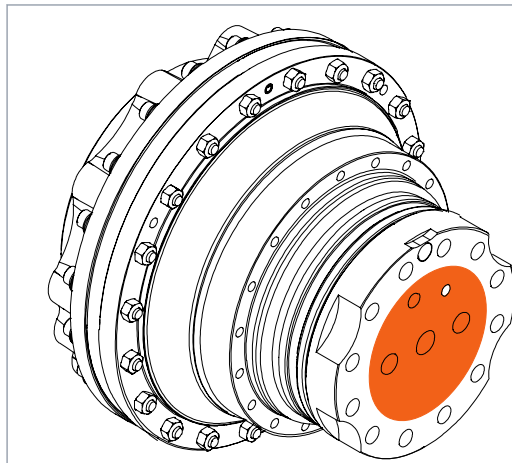


Figure 18. The interface of the motor hydraulics.

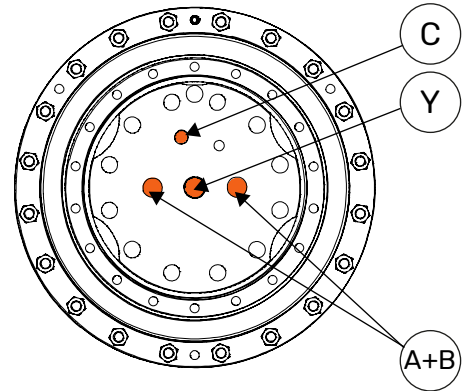


Figure 19. The hydraulic connections.

All hydraulic connections of the motor are on the shaft mating surface.

- WORKING LINE PORTS (A and B)

The working lines, aka the feed and return lines of the motor are the high pressure lines meant for running the motor.

- CASE DRAIN LINE PORT (C)

The case drain line is the return line from the housing cavity.

- PILOT LINE PORT (Y)

The pilot line is meant for controlling the 2-speed valve of the motor (see [2-speed valve : 2NOR / 2NOL](#) on page 15).

## 4.3 CTI connection

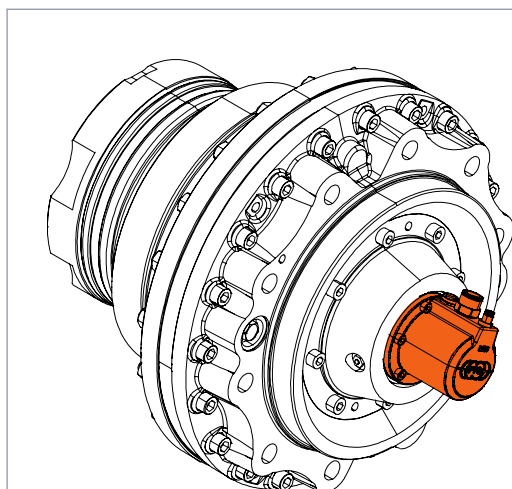


Figure 20. The CTI adapter.

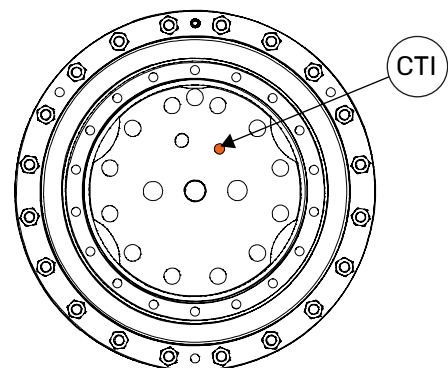


Figure 21. The CTI through hole.

The central tire inflation (CTI) connection allows connecting pneumatic lines through the motor to the CTI adapter. The CTI adapter is installed to the hub of the motor and pneumatic lines are connect to it via the CTI through hole. The CTI adapter is then connected to a valve controlling the tire pressure.



**Note:**

The CTI adapter and valve are not included in the motor delivery.

## 4.4 External freewheeling valve

The external freewheeling valve is used for disengaging the motor during motion (see [Mechanical freewheeling](#) on page 13).

The freewheeling valve should be normally open, so that the motor will disengage when the control system is off.

When the motor is disengaged the case drain port (C) should be connected as directly as possible to the working line ports A and B.

There are multiple possibilities for the external freewheeling valve. Some examples of these possibilities are described in this chapter.

### 2/2 VALVE

- When the motor is disengaged using the 2/2 valve (6a), the directional control valve (1) should have "Y" spool mid position.

Use of the 2/2 valve may be optimized by switching the freewheeling valve (6a) just before (max. 0,5 s) the directional control valve (1). This reduces the pressure in the return line and minimizes the disengaging delay.

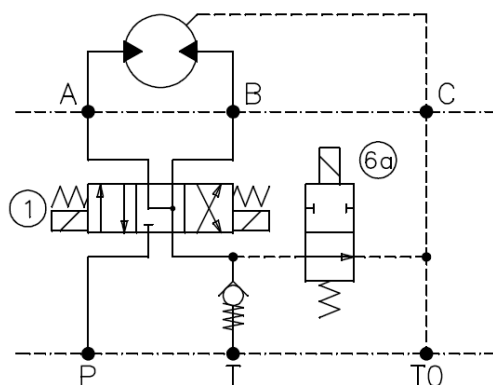


Figure 22. Freewheeling circuit with a 2/2 valve.

#### 4/2 VALVE

- Using the 4/2 valve (6b) may be necessary, if the size of the directional control valve (1) limits the disengaging delay.

Use of the 4/2 valve may be optimized by switching the directional control valve (1) just before (max. 0,5 s) the freewheeling valve (6b). This prevents case pressure peak caused by working pressure.

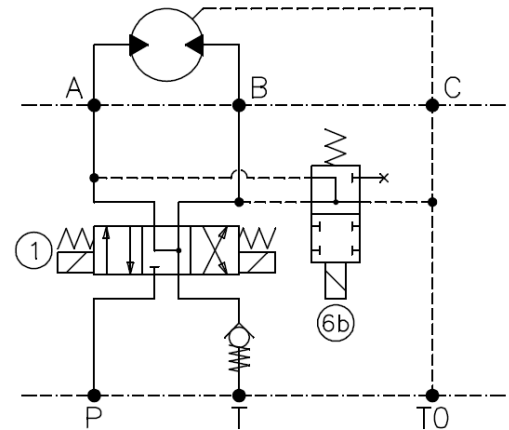


Figure 23. Freewheeling circuit with a 4/2 valve.

#### 6/2 VALVE

- With the 6/2 valve (6c), the motor may be disengaged using only the freewheeling valve.

The 6/2 valve is reliable as the external freewheeling valve, but it must be sized for full working line flow rate.

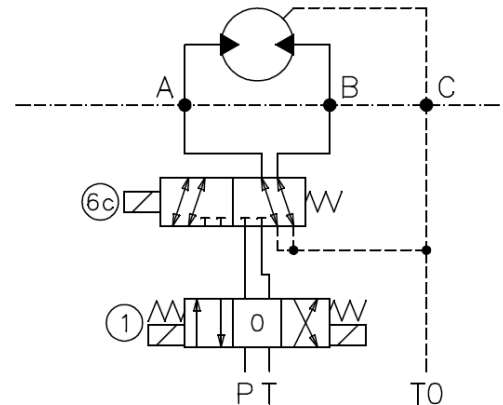


Figure 24. Freewheeling circuit with a 6/2 valve.

## 4.5

### Hydraulic fluid

#### 4.5.1

#### Hydraulic fluid type

Black Bruin hydraulic motors are designed to work with hydraulic fluids based on mineral oil. Consider the following requirements when choosing hydraulic fluid:

- Hydraulic oils in accordance with ISO 6743-4 are recommended to be used.
- Motor oils in accordance with API-grades SF, SG, SH and SL may also be used.
- Fire resistant hydraulic fluids HFB and HFC or similar may be used under certain circumstances.

#### 4.5.2

#### Hydraulic fluid properties

Requirements concerning the hydraulic fluid properties:

- The recommended fluid viscosity range for constant use is 25 - 50 cSt.

- The minimum permissible intermittent viscosity is 15 cSt.
- The maximum permissible viscosity during motor startup is 1000 cSt.
- The viscosity index must be at least 100.
- The water content of hydraulic oil should be less than 500 ppm (0,05 %).
- The hydraulic fluid must reach score 10 on a wear protection test FZG A/8,3/90 in accordance with ISO 14635-1 (DIN 51354)
- The effect of the additives improving the viscosity index can decrease during operation.

**Note:**

Temperature has a significant effect on the viscosity and the lubricating capability of the hydraulic fluid. Take into consideration the real operating temperature when defining the fluid viscosity.

The need for service and the overall service life may be improved by using hydraulic fluids with higher viscosity. In addition higher viscosity may improve the running smoothness.

### 4.5.3 Hydraulic fluid cleanliness

Hydraulic fluid must fulfill cleanliness level 18/16/13 in accordance with ISO 4406 (NAS 1638 grade 7).

**Note:**

The purity of the hydraulic fluid has a significant effect on the need for service and the overall service life of the motor.

## 4.6 Operating pressures

### 4.6.1 Case pressure

The case pressure of the motor affects the lifetime of the sealing. It is recommended to maintain as low case pressure as possible.

When the motor is running, the permissible average case pressure is 2 bar and the highest permissible intermittent case pressure is 10 bar.

When the motor is not running, the highest permissible constant case pressure is 10 bar.

**Attention:**

Running the motor with higher than allowed case pressure shortens the service life of the motor.

**Note:**

The lifetime of the sealing may be improved with an accumulator, which cuts the pressure peaks that are higher than the pre-charge pressure of the accumulator.

Recommended pre-charge pressure is 2 bar and the displacement should be about 25 % of the motor displacement. The accumulator should be connected to the case drain line port as close to the motor as possible.

### 4.6.2 Pilot pressure

|       |   |      |   |             |
|-------|---|------|---|-------------|
| AAAAA | - | BBBB | - | <b>2NOR</b> |
| AAAAA | - | BBBB | - | <b>2NOL</b> |

The pilot pressure is used to engage the 2-speed valve of the motor.

The recommended pilot pressure is 15 to 30 bar and the maximum allowed pilot pressure is 350 bar.



**Attention:**

Over 30 bar pilot pressure causes case pressure peaks. This effect should be minimized with an orifice in the pilot line. Recommended orifice size is 1 mm.

### 4.6.3 Working line pressure

#### WORKING PRESSURE

The working pressure is the high pressure that generates the output torque of the motor. The following values for the working pressure are in the technical data (see [Technical data](#) on page 9):

- PEAK PRESSURE

The value of the peak pressure is the maximum allowed value of the working pressure. Make sure the working pressure does not exceed this value under any circumstances.

- INTERMITTENT PRESSURE

The value of the intermittent pressure is a permissible value of the working pressure for a reference period of one minute (1 min). The working pressure may exceed this value for 10 % of the time during the reference period (for 6 seconds).

#### MINIMUM PRESSURE

The minimum pressure is a low pressure required in the working lines, which ensures the motor stays engaged when running. The motor is engaged when the pistons of the motor stay constantly connected to the cam ring.

The minimum pressure is maintained with back pressure or charge pressure. Type of the hydraulic system affects the implementation.

- BACK PRESSURE

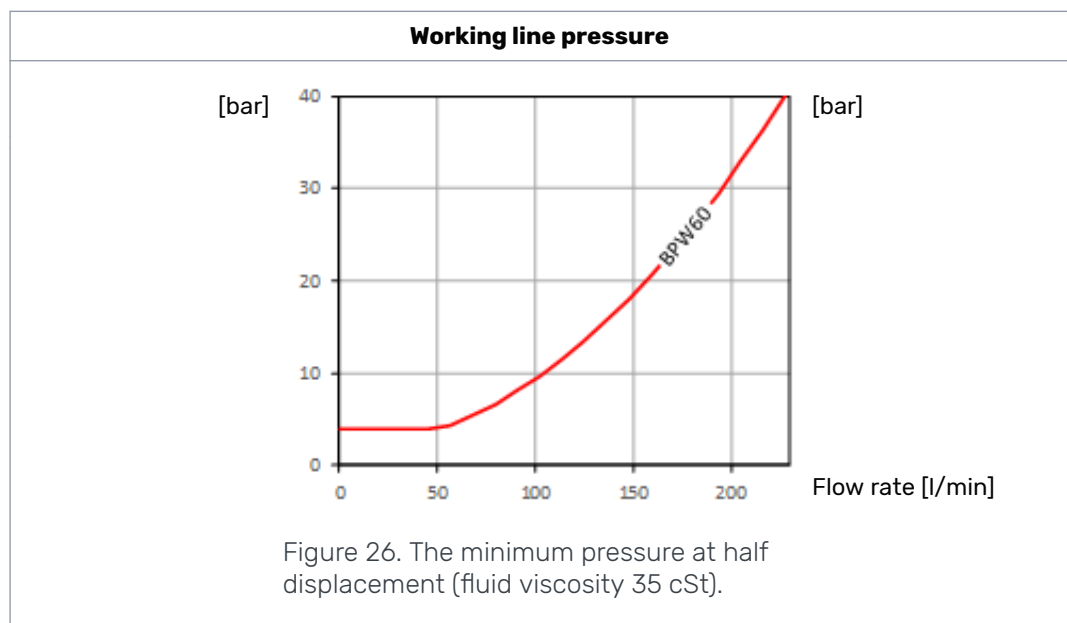
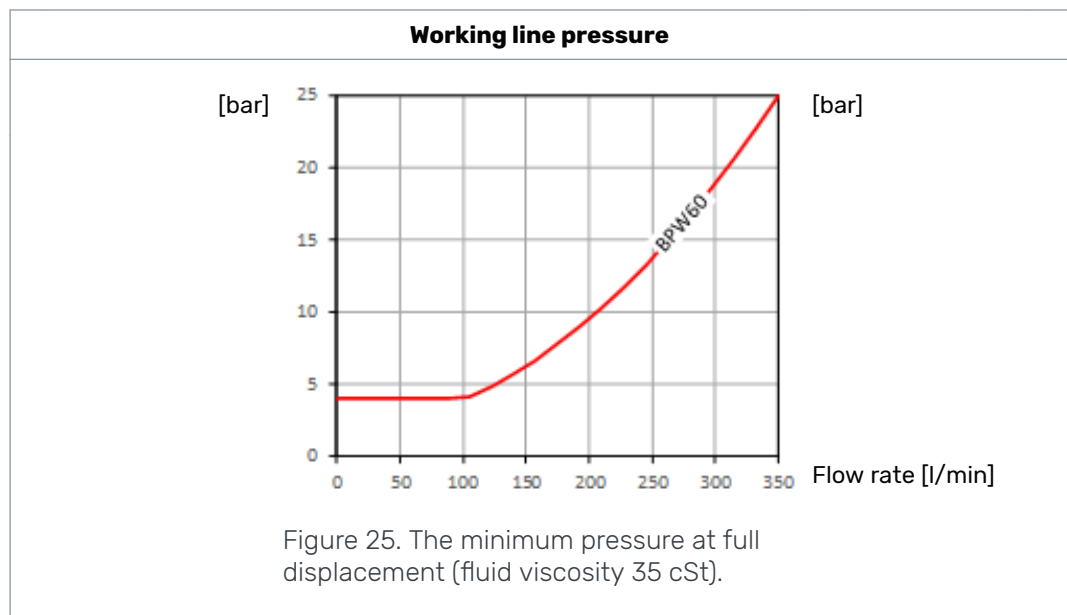
In open loop hydraulic system the minimum pressure may be done with back pressure. The back pressure is usually generated by a suitable check valve with cracking pressure.

- CHARGE PRESSURE

In closed loop hydraulic system the charge pressure is usually used as the minimum pressure.

In open loop hydraulic system the charge pressure may be done by a suitable pressure reducing valve.

The required minimum pressure depends mainly on the flow rate in the working lines. Recommended values for the minimum pressure are on the following figures:

**Attention:**

Too low pressure in the working lines causes the pistons to disconnect from the cam ring when the motor is running. The effect of this is clattering noise when the pistons reconnect.

Constant use with too low working line pressure may cause premature wear or failure of the motor.

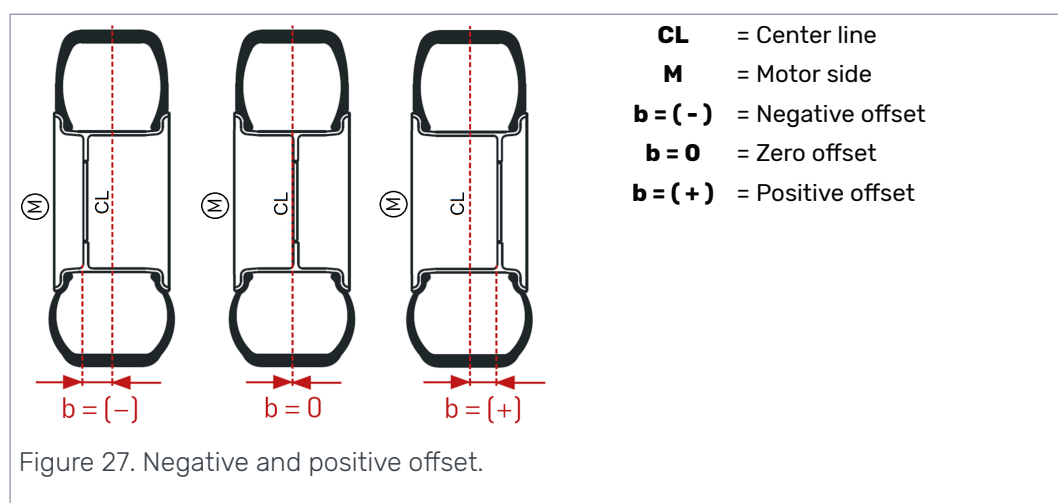
## 5 Motor Sizing

### 5.1 Load carrying capacity

#### 5.1.1 Wheel offset

The load carrying capacity of the motor is defined by the offset value of the wheel rim and the application specific safety factor.

The offset value is the distance from the wheel center line to the wheel interface. The load charts of the motors are given as a function of offset value. The given load curves refer to the average wheel load on a single motor.



**Note:**

Positive wheel offset allows significantly higher wheel loads.



**Attention:**

The motor load carrying capacity is applicable when the speed sensor connection (SSC) is orientated to the load direction.

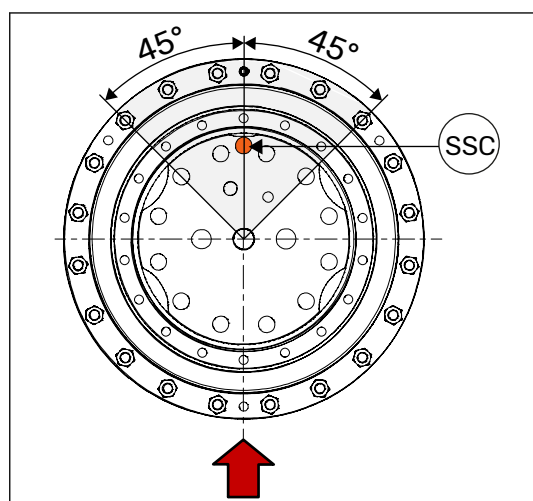
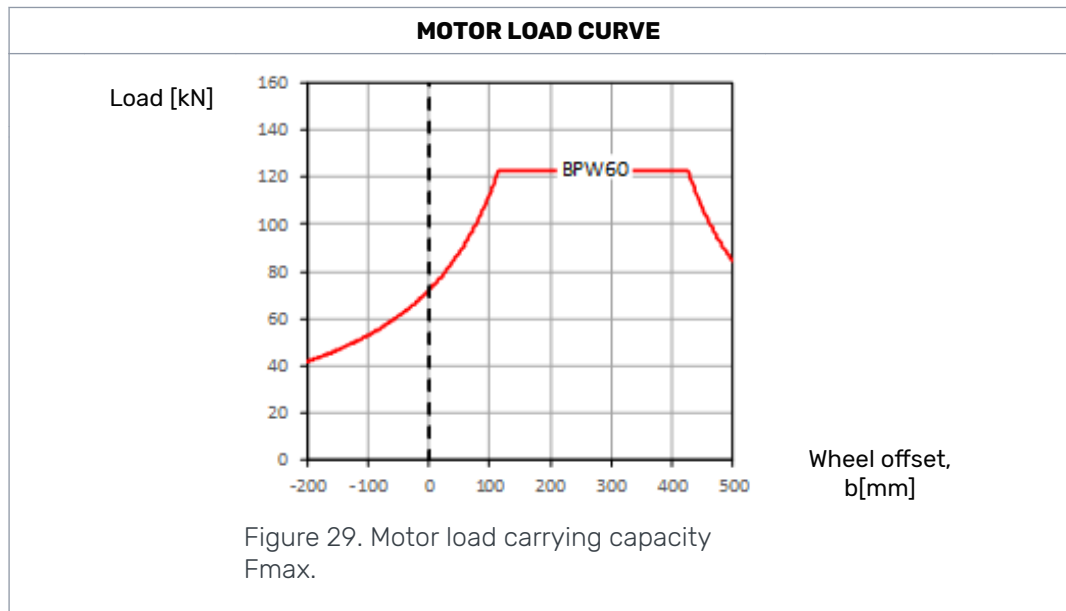


Figure 28. Motor orientation to the load direction.

### 5.1.2 Allowed wheel load

The allowed wheel load is based on the fatigue strength of the shaft (curved part) and the load carrying capacity of the screw joints (flat part).

The load curve is based on peak loads that are about 2x the average load.



The safety factor of a known wheel load may be defined by the following equation.

$$s = \frac{G}{F_{max}}$$

$s$  = safety factor

$G$  = average wheel load [kN]

$F_{max}$  = motor load carrying capacity [kN]

If safety factor is predefined, the allowed wheel load may be estimated with the following equation:

$$G_{max} = \frac{F_{max}}{s}$$

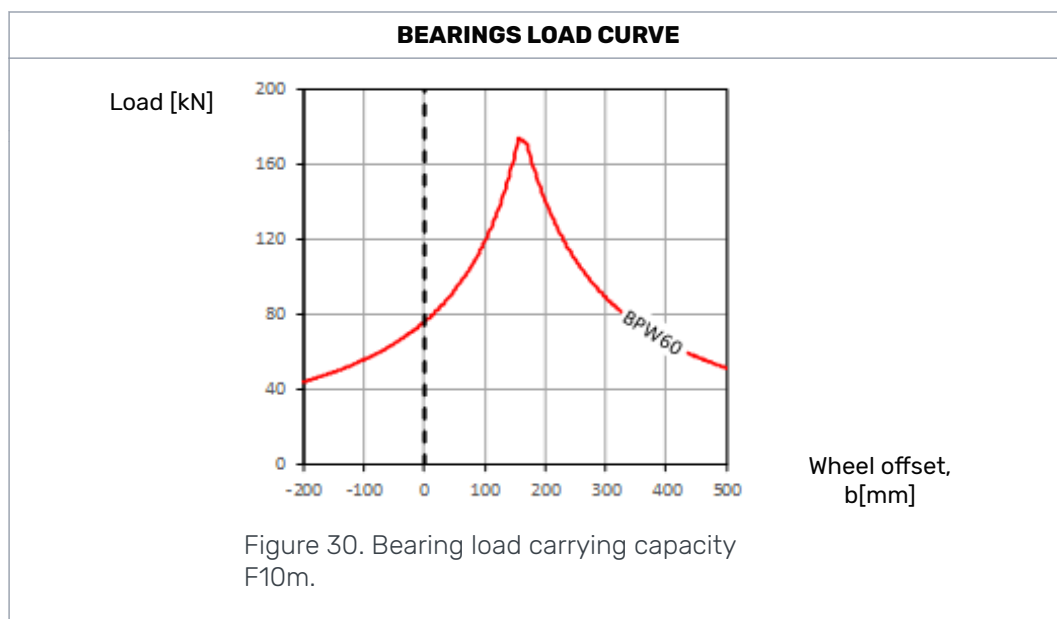
$s$  = safety factor

$G_{max}$  = allowed wheel load [kN]

$F_{max}$  = motor load carrying capacity [kN]

### 5.1.3 Service life

The service life of the motor is based on the rated life of its bearings. The bearings load curve gives the wheel load value, which the motors endures for 10 million rotations with 90 % reliability.



The service life may be estimated with the following equation:

$$L_{10h} = \frac{166\,667}{\text{RPM}} \cdot \left( \frac{G}{F_{10m}} \right)^{\frac{10}{3}}$$

$L_{10h}$  = nominal service life [h]  
 RPM = rotating speed [rpm]  
 $G$  = average wheel load [kN]  
 $F_{10m}$  = bearing load carrying capacity [kN]

## 5.2

### Performance

#### 5.2.1

#### Rotating speed and flow rate

Rotating speed of the motor and required flow rate may be calculated with the following equations:

##### ROTATING SPEED

$$\text{RPM} = 1000 \cdot \frac{Q}{V}$$

or

$$\text{RPM} = 2653 \cdot \frac{\text{KMH}}{R}$$

or

$$\text{RPM} = 9549 \cdot \frac{\text{MPS}}{R}$$

RPM = rotating speed [rpm]  
 KMH = vehicle speed [km/h]  
 MPS = vehicle speed [m/s]  
 $R$  = wheel radius [mm]  
 $V$  = displacement [ccm]  
 $Q$  = flow rate in working lines [l/min]

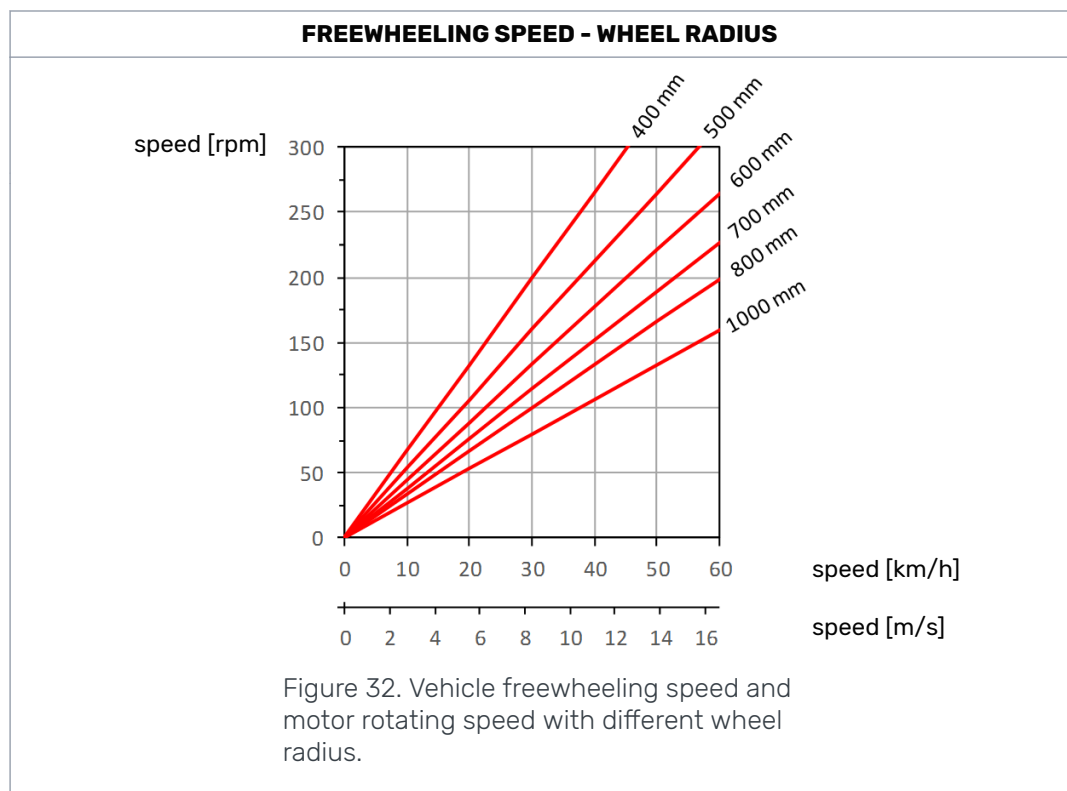
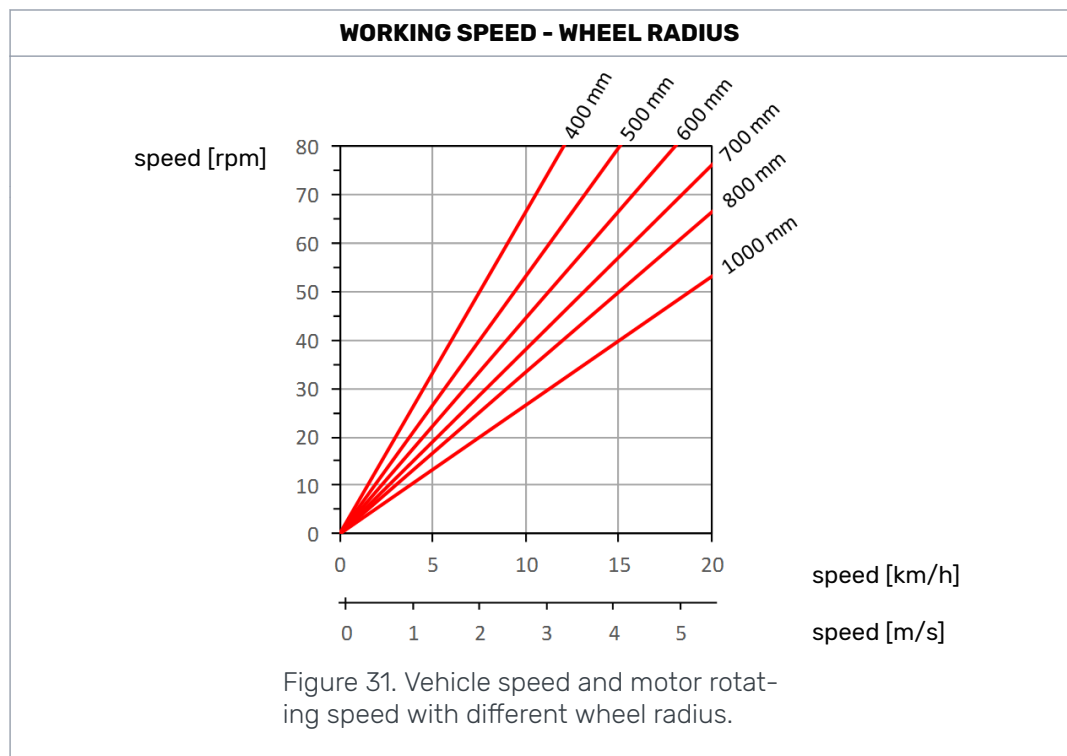
##### FLOW RATE

$$Q = \frac{\text{RPM} \cdot V}{1000}$$



#### **Note:**

Due to motor dynamics, a constant smooth operating speed of under 2 rpm may be difficult to achieve.



## 5.2.2

### Torque

The output torque of the motor is generated by the pressure difference of the working lines (pressure difference between ports A and B)

The output torque of the motor may be estimated with the following equations:

|                                             |                                        |
|---------------------------------------------|----------------------------------------|
| <u>MAXIMUM TORQUE</u>                       |                                        |
| $T_{\max} = 0,01592 \cdot V \cdot \Delta p$ | T = torque [Nm]                        |
| <u>STARTUP TORQUE</u>                       | V = displacement [ccm]                 |
| $T_o = 0,75 \cdot T_{\max}$                 | $\Delta p$ = pressure difference [bar] |

### 5.2.3

#### Power

The operating power of the motor should be determined for all operating conditions. The operating power may be calculated with the following equation:

|                                                     |                                        |
|-----------------------------------------------------|----------------------------------------|
| $P = \frac{Q \cdot p_w}{600}$                       | P = power [kW]                         |
| or                                                  | Q = flow rate in working lines [l/min] |
| $P = \frac{V \cdot \text{RPM} \cdot p_w}{600\,000}$ | RPM = rotating speed [rpm]             |
|                                                     | V = displacement [ccm]                 |
|                                                     | $p_w$ = working pressure [bar]         |



#### Note:

Rough estimate of the operating power may be checked by dividing the available hydraulic power between the motors.

## 6 Installation Instructions

### 6.1 Mounting the motor

The installation dimensions and tightening torques are given in the product datasheet.

Check the following things for mounting the motor:

- The counter surfaces must be clean and even.
- Make sure that the strength class (grade) of the fastening screws is sufficient.
- Make sure that the fastening screws are of suitable size and length.
- The fastening screws should be cleaned and oiled lightly before installing them.
- Use threadlocker only if necessary, removing the old threadlocker may be difficult.
- Remove any old threadlocker before mounting the motor.



**Note:**

When replacing fastening screws with new ones, renew all of the screws.



**Attention:**

When using stud bolts, do not tighten the bolt. Tightening of the stud bolt is done with the nut.

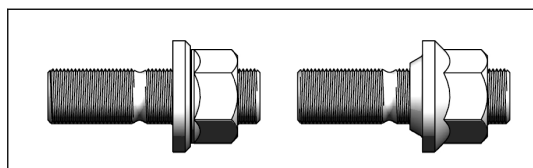


Figure 33. Stud bolt variants.

### 6.2 Flushing the hydraulic system

Prior to connecting the motor as part of the hydraulic system, the hydraulic circuit of the motor must always be flushed by circulating hydraulic fluid through a filter installed in place of the motor.

The flushing is carried out by circulating hydraulic fluid through the entire system with a minimum pressure for at least an hour.

- After flushing, renew all filters.



**Note:**

Flushing the hydraulic system should also be performed after every system modification or repair.

### 6.3 Air bleeding procedure

Air bleeding procedure is carried out to fill the housing of the motor completely with hydraulic fluid. Air is removed from the housing with air bleeding screws as follows:

- Locate the air bleeding screws of the housing and turn the motor to a position in which the screw is at its topmost position.
- Make sure the drain line of the motor is connected.

- Feed hydraulic fluid into the motor with low pressure throughout the procedure.
- Unscrew the air bleeding screw by half a turn and let air escape from the housing.
- Close the screw when only hydraulic fluid is pouring through it.
- Tighten the screw to a torque of  $39 \pm 3$  Nm.

The location of the air bleed screws is given in the product datasheet.



**Note:**

If feed pressure is not available, fill the housing manually by pouring hydraulic fluid in the motor through the topmost opening of the housing.

## 6.4

### Commissioning procedure

Ensure that the following things are in order before starting a new or replaced motor:

- The hydraulic circuit of the motor is flushed.
- Motor is installed appropriately.
- Air bleeding procedure is carried out.
- The reservoir of the hydraulic system is full.

During the initial stages of use, also take the following things into consideration:

- Do not run the motor immediately with full power. Increase the load and speed of rotation gradually.
- Observe the motor and the hydraulic system for external leaks or abnormal noises during the commissioning procedure.
- Start the motor break-in.



**Note:**

During all installation and service procedures, plug any open ports and hoses.

When filling the reservoir, add hydraulic fluid through a filter.



**Attention:**

Do not start the motor, if the air bleeding procedure has not been carried out.

Stressing an unused motor with full power may cause premature wear or failure of the motor.

## 7 Operating Instructions

### 7.1 Break-in period

The motor achieves its final properties during the first hours of use. Therefore all new and reconditioned motors should go through an initial break-in period.

Things to be considered during break-in period:

- The break-in period should last for at least first eight hours (8 h) of use.
- The power output should remain under 50 % of the maximum power capacity of the motor.
- The power output is limited by limiting the working pressure, the speed of rotation or both.
- The working pressure should be limited so, that pressure peaks which last over two seconds (2 s) remain under 75 % of the permissible values.



**Note:**

During the break-in period, the moving parts of the motor wear against each other so, that the wear of the parts sets to a stable state for the entire service life of the motor.

### 7.2 Use

Things to be considered during use of motors:

- Check the screw connections tightening torque and hydraulic connections regularly.
- Do not use pressure cleaning directly between the shaft flange and housing of the motor (the shaft seal area).
- Avoid situations in which the motors are completely submerged in water or mud.

### 7.3 Operating temperature

The operating temperature means the internal temperature of the motor. Take into considerations the following requirements for the operating temperature:

- For improved service life, avoid over 70 °C (158 °F) operating temperature.
- The highest permissible intermittent operating temperature is 85 °C (185 °F).
- The lowest permissible operating temperature is -35 °C (-31 °F).
- The temperature difference between the motor and the hydraulic fluid should be under 60 °C (140 °F).

The operating temperature may be measured from the hydraulic fluid returning from the motor. Take into account the temperature of hydraulic fluid returning from the drain line and from the return line (A or B).

### 7.4 Demounting the motor

Take into consideration the following things when demounting the motor for service or replacement:

- Release the pressure in the hydraulic lines and let the motor cool down.
- Disconnect all the hydraulic lines from the motor and plug all openings and hoses.
- Demount the motor and lift it away from its position.

## Operating Instructions

- Clean the outside of the motor thoroughly, but do not use any solvents.
- Protect the cleaned motor from corrosion.
- If possible, drain all the hydraulic fluid from the motor.



**Note:**

Dispose of hydraulic fluid should be done appropriately.

## 8 Special Instructions

### 8.1 Storing the motor

During short term storage of the motor, the following should be taken into consideration:

- Cover any pressure openings and open threaded holes with suitable caps.
- Protect the unpainted surfaces from dirt and moisture.
- Store the motor in a dry place with relatively stable temperature.
- The motor should not be stored in a same place as substances with aggressive corrosive nature (solvents, acids, alkalis and salts).
- The motor should not be exposed to strong magnetic fields.
- The motor should not be exposed to strong vibration.



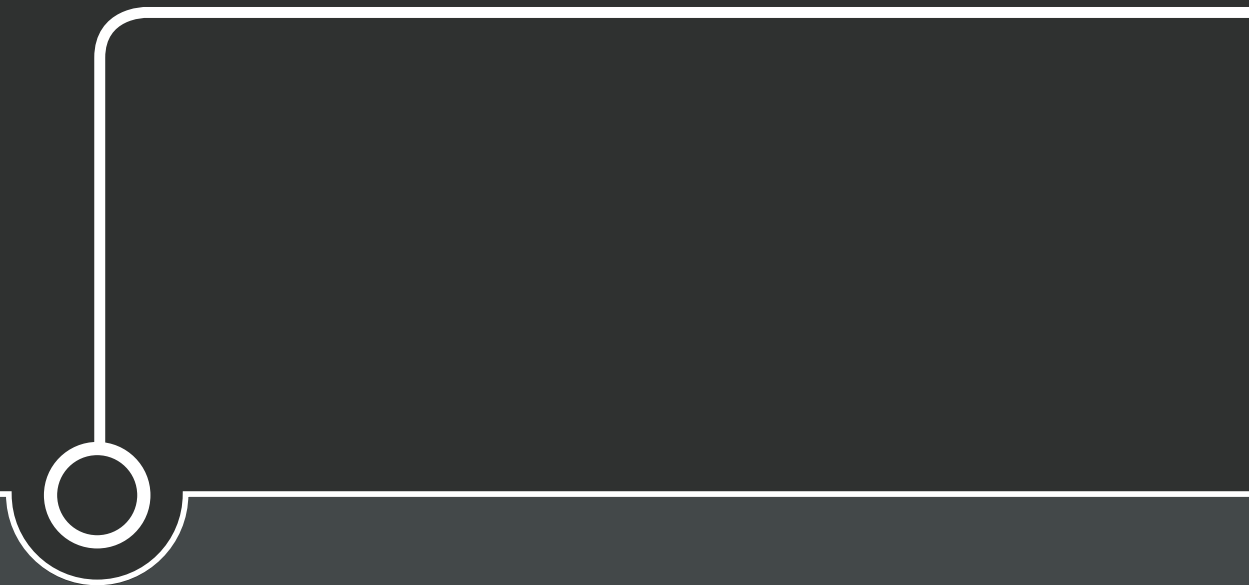
**Note:**

For long-term storage (over 9 months) the following additional actions are recommended:

- Damages to surface paint must be repaired.
- Protect the unpainted surfaces with suitable anti-corrosion treatment.
- Fill the motor completely with hydraulic fluid.

If these instructions are followed, the motor may be stored for approximately two years. However, as storage conditions do have a significant effect, these times should only be considered as guide values.

# No POWER like it.



## **Black Bruin Inc.**

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