



Basic principles of system design

■ Hydraulic motors BB & BBC

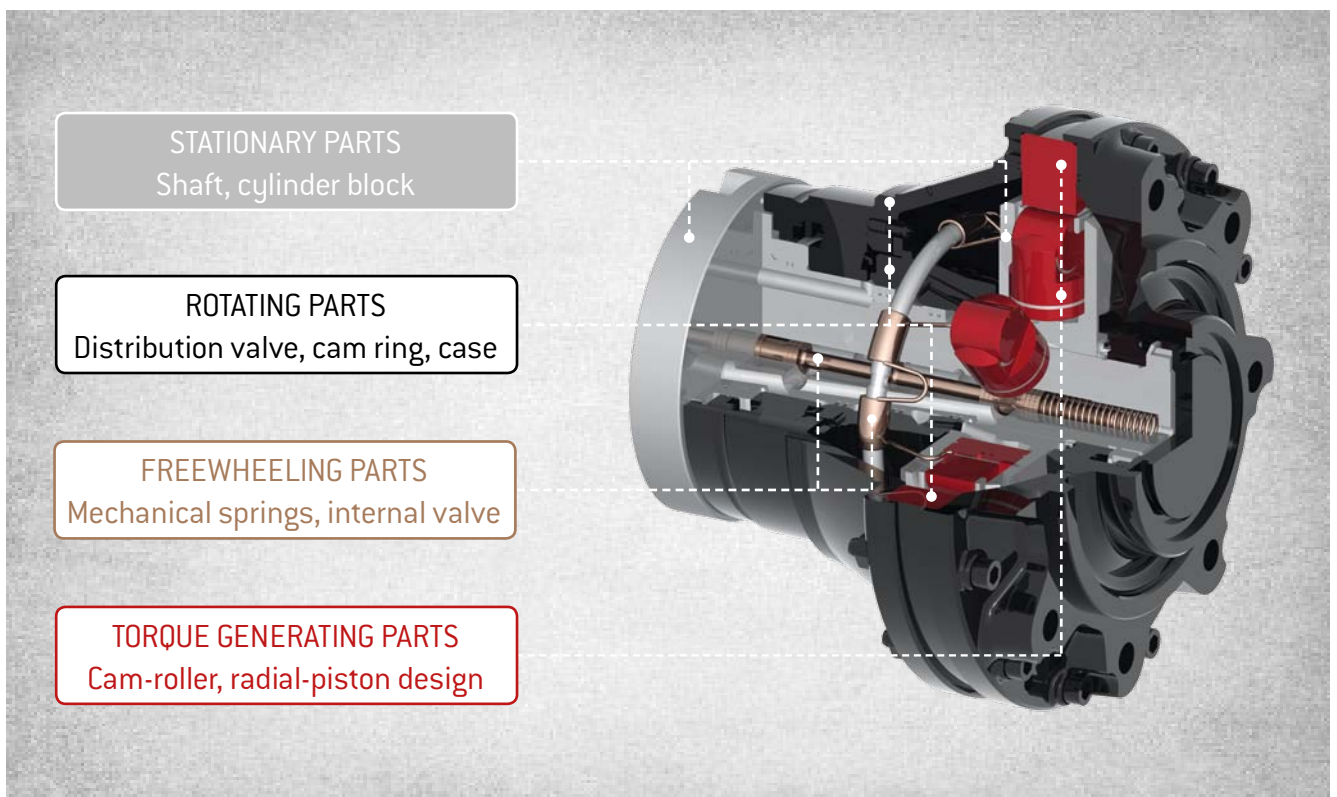
**Black
Bruin**
No power like it.

Forewords

No power like it.

Black Bruin motors can be found in multitude of mobile and industrial applications. The motors are based on Sampo Hydraulics's extensive research and development work and over 50 years of experience in the field of radial piston motors – a foundation the world's leading companies in the industry can rely on.

The Black Bruin LSHT (low-speed, high-torque) motor line consists of three series. The rotating case BB & BBC motors displacement range is 125 - 12 600 cm³, power 15 - 260 kW and torque 650 - 42 300 Nm. The rotating shaft S series represents the bigger, even powerful line, ranging from 4000 to 18 900 cm³ with performance up to 500 kW and 102 000 Nm.



■ Main parts of the rotating case Black Bruin motor (BB & BBC series).

DISCLAIMER:

Information contained in this publication is subject to change at any time without prior notice. For the latest technical information visit our website at www.blackbruin.com or contact Sampo Hydraulics Ltd. or its representative. The publication is for standard products only. Special versions may need additional specifications and instructions. Please contact motor manufacturer for more details. This publication has been executed in English language. In case of controversy due to improper translation to any other language, the English version shall prevail. The publication may not be reproduced in any form, either in its entirety, or in part, without the written permission of Sampo Hydraulics Ltd.

Overview of Black Bruin Hydraulic Motors

1 WORKING PRINCIPLE	4
1.1 Speed of rotation	4
1.2 Operating pressures	4
1.3 Freewheeling	4
1.4 Multi-speed motors	8
1.5 Permissable external loads	9
1.6 Wet multi-disc brake	9
1.7 Operating temperature	10
1.8 Oil requirements	10
1.9 Filtration	10
1.10 Conditions of installation and application	10
1.11 Hydraulic connections	10
1.12 Commissioning procedure	11
2 OPTIONS AND APPLICATIONS	13
2.1 Freewheeling	13
2.2 Grease ring and zerks	13
2.3 Speed sensors	13
2.4 Knuckle mounting	14
2.5 Flushing line	15
2.6 Variety of brakes	15

Overview of Black Bruin Hydraulic Motors

1 WORKING PRINCIPLE

1.1 Speed of rotation

Maximum rotational speeds given in this Design Guide refer to normal conditions. If the application requires speeds different from specifications, please consult the motor manufacturer or its representative.

1.2 Operating pressures

A) MINIMUM WORK LINE PRESSURE:

A minimum pressure in work lines is needed to guarantee continuous contact between cam rollers and cam ring. Required minimum pressure depends on the rotational speed and case pressure.

The minimum pressure (often referenced as charge pressure) requirement for each displacement, at zero case pressure, can be found under displacement specific performance curves (BBC starting on page 24 and BB on page 60). Charge pressure over 30 bar (435 psi) is not recommended.

Note: Minimum work line pressure values are given at zero case pressure. To calculate system specific minimum pressure, add case pressure to the minimum pressure value from the chart.

Insufficient pressure in work lines will cause piston hammering and can damage the motor in a long run.

B) MAXIMUM PRESSURE:

Unless governed by the power limit, oil temperature or oil viscosity, the maximum continuous work pressure.

NOTE: Motor life depends on average speed and pressure. Higher the pressure, shorter the expected life. For Lh_{10} calculations, please consult the manufacturer.

C) CASE PRESSURE:

The recommended case pressure for standard motors is 0-2 bar (0-30 psi). The maximum intermittent case pressure is 10 bar (145 psi). Make sure that the motor case is always full of oil. * NOTE: If motor is placed above the reservoir, add check valve with 1 bar (15 psi) pressure to case drain line to ensure case oil fill. Max. continuous case pressure 2 bar (see fig. 01).

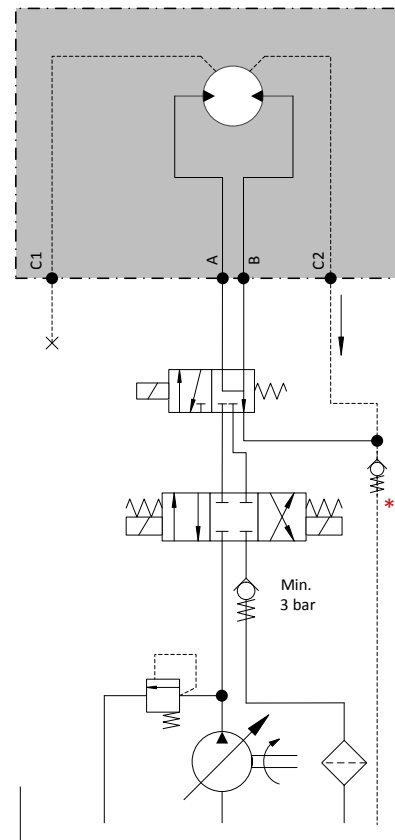


FIG. 01. Black Bruin motor with mechanical freewheeling, external freewheeling valve and check valve.

1.3 Freewheeling

To disengage the motor, both work lines (i.e. inlet line and return line) have to be depressurized to allow the pistons to retract from the work mode.

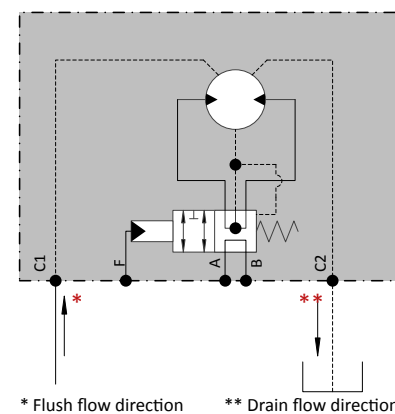


FIG. 02. Black Bruin motor with internal freewheeling valve (open loop).

Overview of Black Bruin Hydraulic Motors

1.3.1 Mechanical freewheeling

In systems using mechanical freewheeling, the drain line should be connected directly to the reservoir to ensure lowest possible case pressure.

To ensure there is no pressure differential between the work lines A and B (acting under the pistons) and case drain line C (over the pistons), the three (3) lines are to be connected together in freewheel mode.

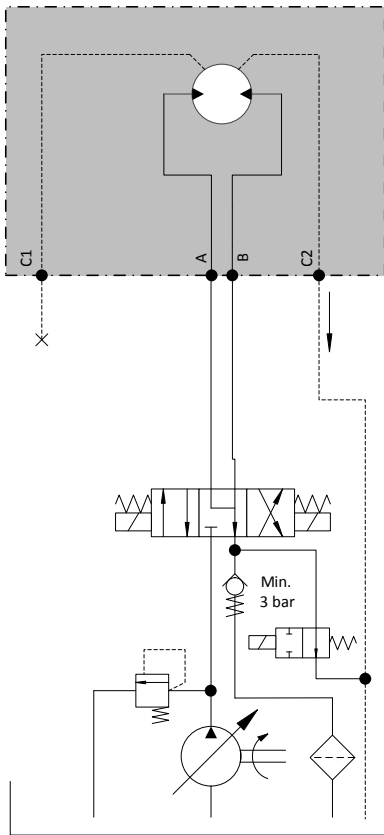


FIG. 03. Black Bruin motor with mechanical freewheeling and a 2/2-valve to depressurize work lines to case drain (open loop).

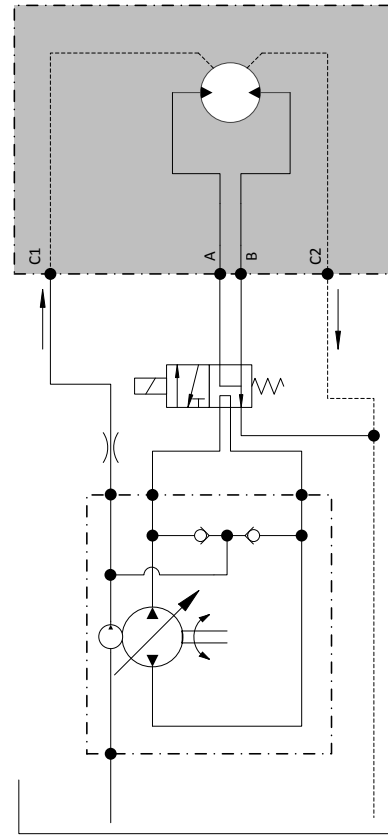


FIG. 04. Black Bruin motor with mechanical freewheeling and external freewheeling valve (closed loop).

The external freewheeling valve should be positioned as close to the motor as possible to ensure smooth and rapid mode change.

Overview of Black Bruin Hydraulic Motors

1.3.2 Hydrostatic freewheeling

Hydrostatic freewheeling requires a drain line check valve with 0,5 bar (8 psi) opening pressure and active feed between the check valve and the drain port of the motor.

A check valve in the drain line regulates the pressure in the case. To limit the pressure spikes in the case, the drain line and its check valve have to be sized to correspond with the maximum flow rate at the time of engagement.

In order to create the freewheeling pressure into the case, a fluid must be supplied to case drain line "C" (1-speed BBC and all BB motors without flush port "C1") between the motor and the check valve.

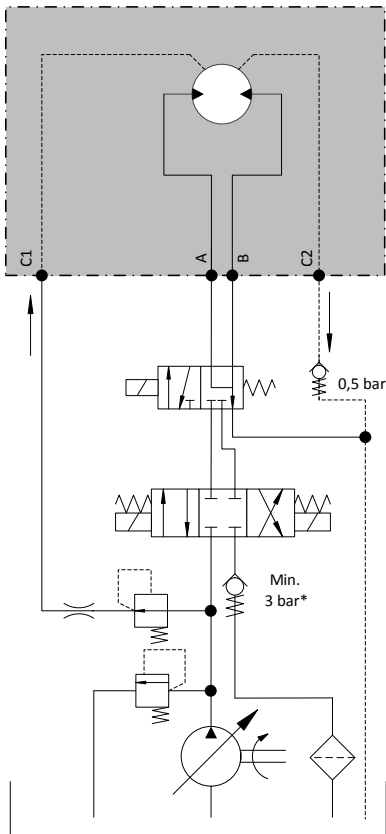


FIG. 05. Black Bruin motor with hydrostatic freewheeling and external freewheeling valve (open loop).

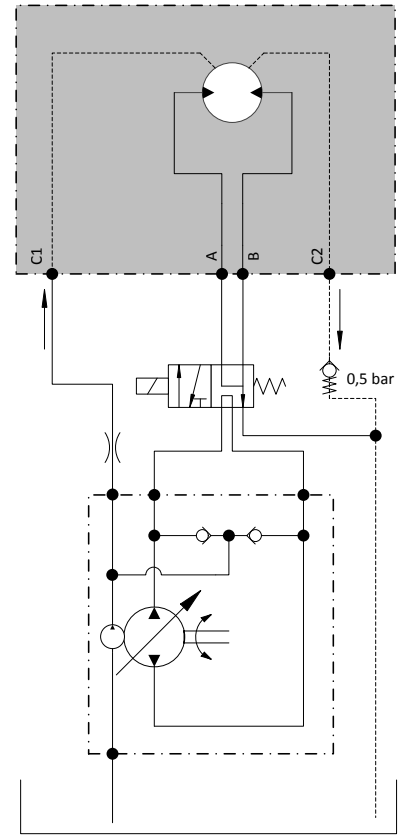


FIG. 06. Black Bruin motor with hydrostatic freewheeling and external freewheeling valve (closed loop).

1.3.3 Hydrostatic freewheeling of 2-speed BBC motor

In a 2-speed BBC motor without freewheeling springs, the freewheeling pressure is supplied to the motor case through additional case drain line "C1". 2-speed BBC motor without freewheeling springs has an in-built check and thus no external check valve in case drain line is required.

The freewheeling valve should be positioned as close to the motor as possible to ensure smooth and rapid mode change.

Overview of Black Bruin Hydraulic Motors

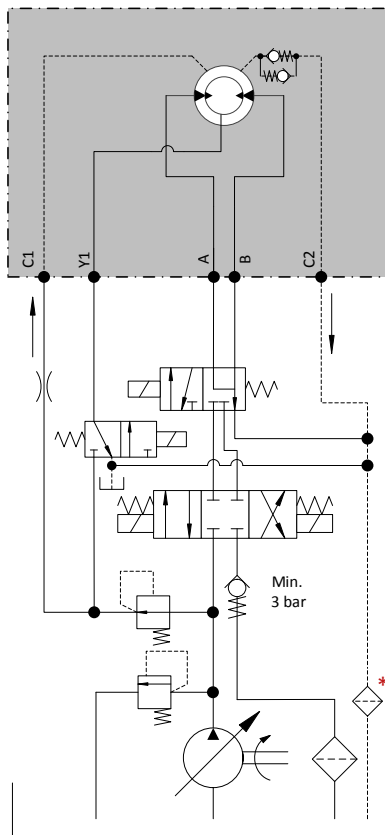


FIG. 07. 2-speed Black Bruin BBC motor with hydrostatic freewheeling and external freewheeling valve in open loop system. * NOTE: Max. case drain pressure 2 bar.

1.3.4 Disengaging and engaging on-the-fly – description of system function

A) DISENGAGING THE MOTOR (shifting to higher speed range / reducing system's total displacement):

1. A and B ports of the freewheeled motor(s) have to be connected together and disconnected from the hydraulic system.
2. A path from the above created A-B loop to the drain line is rapidly opened allowing freewheeling springs or positive case pressure to disengage the motor.
3. Charge pressure must be maintained at the pump(s) throughout the shifting procedure.
4. The system's total displacement changes in speed range shift. Pump flow may need to be softly adjusted to avoid jerking motion during the shift.

B) ENGAGING THE MOTOR (shifting to lower speed range / increasing system's total displacement):

1. A charge pressure is rapidly applied to the A-B loop of the freewheeled motor, bringing the pistons into contact with the cam ring.
2. Disengaged motors are brought into operation by separating A and B ports and connecting them into the hydraulic system.
3. The pump flow is adjusted to avoid jerking motion during the shift.

At the time of engagement, additional charge flow is momentarily required to bring out the pistons from the cylinder block and into contact with the cam ring. With limited capacity charge pump, an accumulator is required to maintain the charge pressure during the engagement shift. For charge pressure requirements, see chapter 1.2 A) on page 4.

Under certain circumstances (e.g. long hoses or pipes, high rotational speeds or high viscosity oil) it is recommended to connect an accumulator (with at least 1/4 of the displacement of the motor and pre-charge 2 bar) to the drain line "C" (1-speed motor) or "C1" (2-speed motor). The accumulator should be as close to the motor as possible.

When shifting on-the-fly, it is recommended to use motor manufacturer's valves, which perform all the required operations with the exception of pump flow modulation.

Maximum allowable disengaging and engaging speeds depend on the design of the hydraulic system. Please contact Black Bruin Application Engineering for more detailed information.

Black Bruin motors with mechanical freewheeling springs will automatically freewheel when motor's working line pressures equalize with case drain pressure.

Overview of Black Bruin Hydraulic Motors

1.4 Multi-speed motors

2-speed BB motors have preferred rotational direction at partial displacement. Operating the BB motor at partial displacement for an extended time in the non-preferred direction will lead into motor failure.

2-, 3- and 4-speed BBC motors do not have preferred rotational direction and can be operated at maximum rated power in both directions.

In 2-speed BB and standard 2-speed BBC motors, a 15-30 bar control pressure to "Y" port is required to activate 2-speed (partial displacement of a 2-speed motor).

Depressurizing the "Y" port will return the motor to full displacement. Do not use work/high pressure in "Y" port to control a standard 2-speed BB or BBC motor.

NOTE: Depressurize the 2-speed spool pilot Y to case drain line to prevent unwanted spool movement.

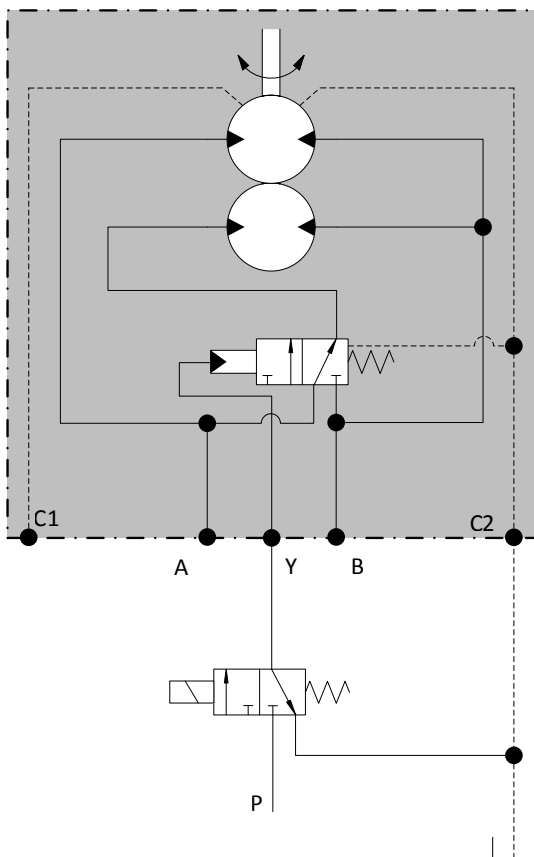


FIG. 08. 2-speed Black Bruin BB motor.

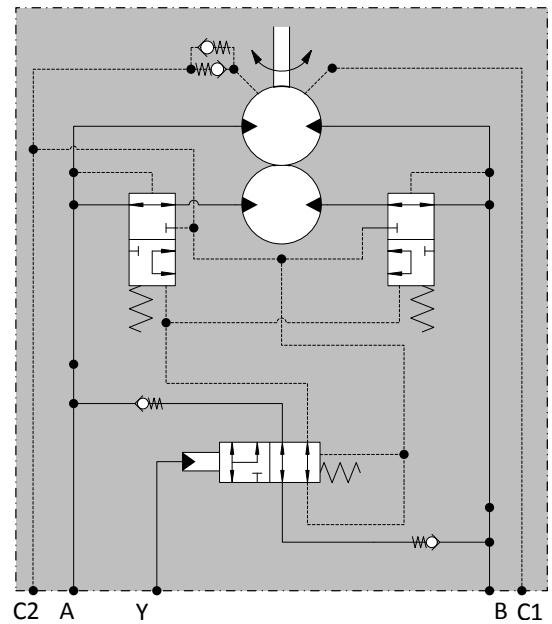


FIG. 09. 2-speed Black Bruin BBC motor.

BBC motors with 3- and 4 speed hydraulic shift option, and motors with internal freewheeling valve (port F), have high pressure shift ports (Y or Y1 and Y2). To shift such motor, the highest available system pressure has to be applied to the shift port. Typically this highest system pressure is taken from motor work lines "A" and "B" by a shuttle valve.

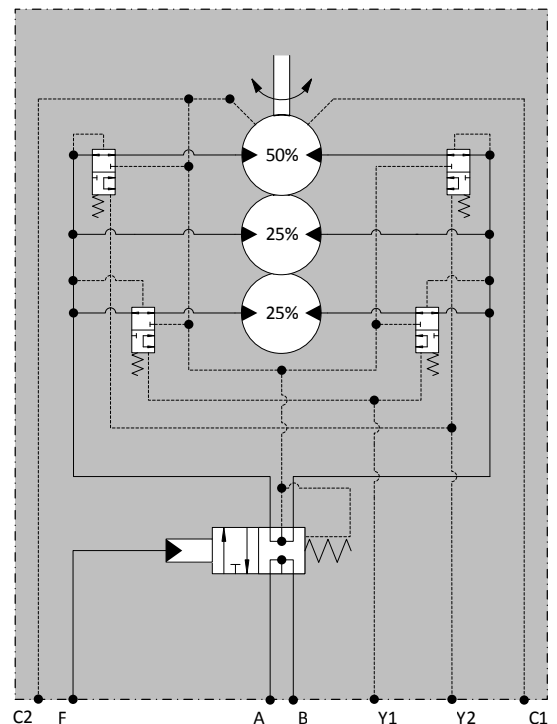


FIG. 10. 4-speed Black Bruin BBC motor with internal freewheeling valve.

Overview of Black Bruin Hydraulic Motors

3- and 4-speed BBC motors with electric shift do not require external pressure to shift the displacement. Partial displacement is activated by energizing the solenoid(s) in the shift block.

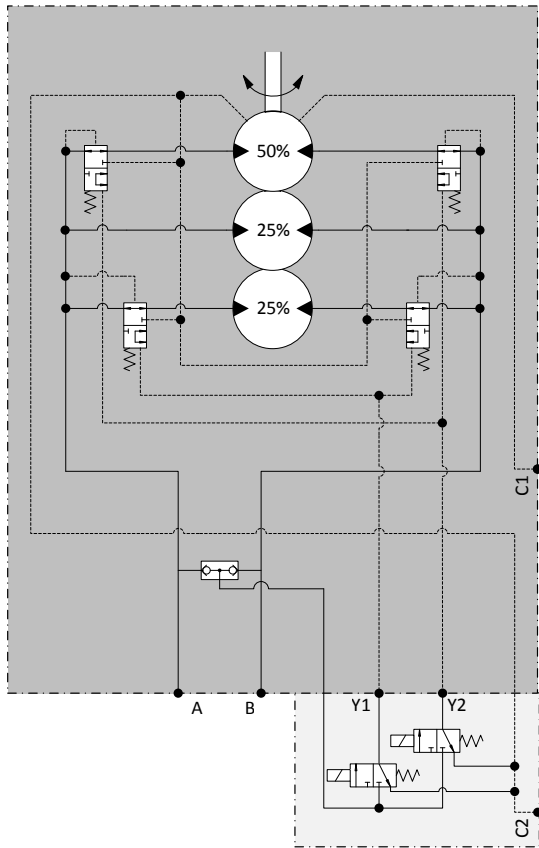


FIG. 11. 4-speed Black Bruin BBC motor with electric shift.

Always use “C2” port to connect the drain line of a multi-speed speed BBC motor. “C1” can only be used for flush oil or to install an accumulator into the motor. It is recommended that 3- and 4-speed motors, and 2-speed motors with internal freewheeling valve, are equipped with an accumulator in “C1” line. The volume of an accumulator should be 25 % of the motor’s displacement with pre-charge of 2 bars.

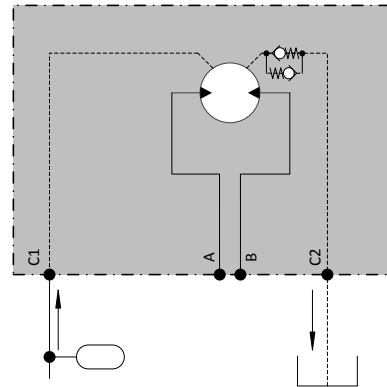


FIG. 12. Basic circuit of multi-speed Black Bruin BBC motor with case accumulator.

1.5 Permissible external loads

The maximum permissible shaft load depends on the load point. For exact data, see shaft load curves (BBC on page 21 and BB on page 57). With applications combining high radial and axial loads, please consult the motor manufacturer or its representative to determine maximum permissible loading.

1.6 Wet multi-disc brake

The spring applied, pressure to release, wet multi-disc brake is a parking brake, but it can be used dynamically as an emergency brake.

The minimum brake release pressure is shown in the chapter 2.7.5 on page 17. NOTE: The brake operating pressure in BBC and some special BB motors with low pressure brake can not be higher than 30 bar (435 psi). Depending on the Black Bruin frame size, the brake may have internal leakage (max. 0,6 l/min with oil viscosity of 35 cSt), which has to be considered in the brake circuit design.

Standard, high pressure, BB brakes are equipped with static seals and do not have internal leakage. Note that EP, HD and some anti-wear additives in oil can cause remarkable reduction in brake torque.

If service brake is required, see all brake options on pages 15-17 and consult the motor manufacturer or its representatives for more information.

Overview of Black Bruin Hydraulic Motors

1.7 Operating temperature

The maximum allowable case drain oil temperature is 75°C (167°F) for motors with DX (standard in BB) and 85°C (185°F) for motors with HiEx (standard in BBC) inserts. For continuous operation at maximum temperatures, case flush is required.

The minimum allowable oil viscosity is 15 cSt.

The lowest permissible operating temperature is -35°C (-31°F) and maximum allowable viscosity at start is 1000 cSt. At start-up, the difference between the motor and oil temperatures must not exceed 60°C (140°F).

With temperatures below 0°C (32°F), warm up the system before shifting the motors on-the-fly. To avoid thermal shocks at low temperatures, start warming up the motor at a low speed, unloaded, gradually increasing the speed and load.

1.8 Oil requirements

The mineral oil used should meet the following requirements:

- The viscosity index must be at least 100. If the oil contains additives improving the viscosity index, the effect of these ought to be as permanent as possible. The oil is to maintain the required viscosity throughout its service life.
- The minimum permissible viscosity is 15 cSt.
- The maximum viscosity is determined by the specifications of the system pump.
- The recommended viscosity range at operating temperature is 25-50 cSt.
- Wear protection test FZG A/8.3/90 minimum 10 according to ISO 14635-1.
- Water content 500 ppm maximum.

Hydraulic oils according ISO 6743-4 are recommended. Motor oils SF, SG, SH, SJ and SL conforming to the API – classification can also be used. Fire resistant fluids HFB and HFC or similar may be used under certain circumstances. Please always consult motor manufacturer or its representative before using these fluids.

1.9 Filtration

Required cleanliness level: ISO 4406 (1999) Code 18/16/13 (NAS 1638 Code 7) or better.

1.10 Conditions of installation and application

An Application Data Sheet (ADS) is used to select the correct Black Bruin hydraulic motor for each application. A filled and signed ADS is required for each motor model and application to validate the motor manufacturer's warranty. Always advise the motor manufacturer or its representative, when selecting motors for exceptional circumstances, like underwater applications, use with special fluids, etc.

1.11 Hydraulic connections

Hydraulic connections are located in the shaft flange and identified with capital letters. Please note, the figure below represents motor connections of specific BBC 02 and is therefore only suggestive. See the dimensional drawings (BBC starting on page 32 and BB on page 64) for detailed information.

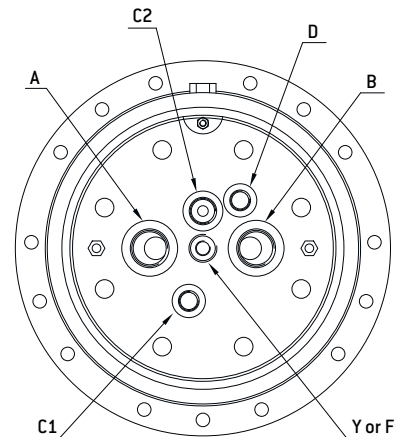


FIG. 13. Black Bruin BBC 02 motor hydraulic connections.

Work lines, motor's inlet and outlet, are marked with "A" and "B". Pressurizing port "A" will turn the housing of a single speed BB or any BBC motor in a clockwise direction, when facing the hub cover, opposite to the shaft flange end with hydraulic connections.

Please note, that pressurizing the port "A" of a two speed BB motor will turn the housing of the motor in the preferred rotational direction, clockwise or counterclockwise, depending on the motor (e.g. 406 315 1210 CW, 406 315 1310 CCW).

The case drain line is marked with "C". NOTE! Motors with case flush line "C1" have case drain line marked with "C2". To ensure motor functionality, "C1" line has to be either plugged or used for flush flow in and "C2" is always used for case drain flow out.

Overview of Black Bruin Hydraulic Motors

A dedicated drain line to oil reservoir is required and drain should not be connected to motor return or common tank line.

Brake pressure port is marked with "D". Multi-speed pilot port is marked with "Y" or "Y1" and "Y2". Internal freewheeling pilot port is marked with "F".

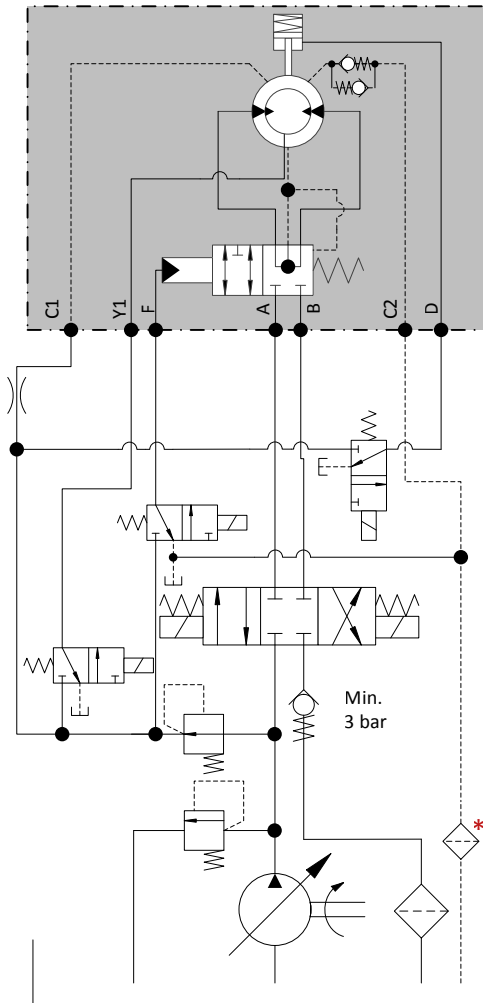


FIG. 14. 2-speed Black Bruin BBC motor with internal freewheeling valve and brake. * NOTE: Max. case drain pressure 2 bar.

1.12 Commissioning procedure

A) FLUSHING OF THE HYDRAULIC CIRCUIT:

Flushing should be performed at initial start-up and after every system modification or repair. Prior to connecting the motor or the pump as part of the system, THE CIRCUIT MUST ALWAYS BE FLUSHED by circulating oil through a filter installed in place of the motor.

In flushing, the oil is to be circulated through the complete system with minimal pressure, for at least an hour. After flushing, renew all filters. During installation or service work, always plug open ports and hoses. When filling the reservoir, add oil through a filter.

B) AIR BLEEDING / FILLING THE MOTOR CASE WITH OIL:

DO NOT START MOTOR UNLESS THE CASE IS FILLED WITH OIL!

1. Turn the motor in a position in which the bleed screw is in its topmost position and unscrew it half a turn.
2. Wait for the air to bleed out (case is filled by system charge pressure or flow through case drain line). When oil is seen at the bleed screw, close the screw.
3. If charge pressure is not available (open loop) or return flow through drain line prevented, fill the case manually by pouring oil in through the bleed screw hole.



FIG. 15. Hub cover bleed screw (topmost position)

Overview of Black Bruin Hydraulic Motors



FIG. 16. Rear cover bleed screw (topmost position).

C) INITIAL START UP

After flushing and filling has been completed, start the motor without load. Increase the motor speed and load gradually while monitoring leaks and abnormal noises. For the first 50 hours of operation, operate the motors at average of 50% of rated speed and pressure and do not exceed 75% of maximum pressure for more than two seconds every minute.

D) BLACK BRUIN MOTORS TIGHTENING TORQUES (Nm)

ITEM	HUB COVER	SHAFT FLANGE
SCREW / HARDNESS	f10,9	f12,9
M12	110	135
M14	180	215
M16	275	330
M18	383	460
M20	540	650
M22	728	874

The tightening torques are valid for standard and fine thread. Please note, maximum torque might be limited at lower value by the motor attachment.

2 CUSTOMIZATION AND OPTIONS

Black Bruin motors can be equipped with various options. Because of this, it is possible to optimize the motors performance to meet the special requirements/conditions of the application.

2.1 Freewheeling

Black Bruin motors can be freewheeled without energy loss or overheating problems (stationary cylinder block - no centrifugal forces), even with high speeds. The motors can be re-engaged or disengaged during movement. See chapter 1.3.1 on page 4 for more detailed information.

2.1.1 Mechanical freewheeling

Motors can be equipped with mechanical freewheel springs. When there is no pressure in the working lines of the motor, the springs push the pistons down into the cylinders and hold them there. Thus, no pump output is needed to keep the motors freewheeled.

2.1.2 Internal freewheeling valve

The internal freewheeling valve in a Black Bruin motor means simplified circuit, minimal system losses and improved durability. Equipped with mechanical freewheel springs, the internal freewheeling valve enables smooth shifting on the fly and secure freewheeling without external power source. The control pressure is 15 - 30 bar.

FEATURES AND BENEFITS:

- mechanical springs – freewheeling without pressure
- internal valve – reduced number of hose connections
- fast and secure shifting
- optional automatic shift to freewheel if work pressure is lost
- ideal for any assist drive application
- available for selected motor frames

2.2 Grease ring and zerks

Standard BBC Series motor is equipped with a grease ring to protect the shaft seal area from external contamination. For BB motors this is an option and not included into a standard motor. Grease zerks are placed radially onto a grease ring or/and axially into the shaft flange.

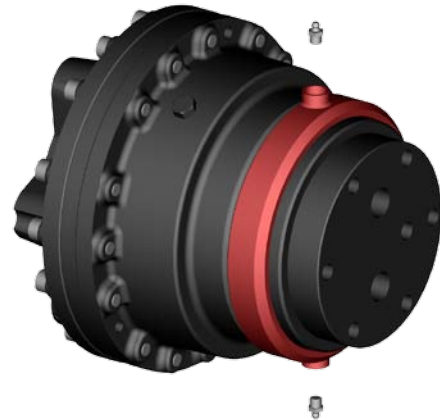


FIG. 17. Black Bruin motor with a grease ring.



FIG. 18. Black Bruin motor with axial grease zerks.

2.3 Speed sensors

An inductive sensor is placed either axially into the shaft flange, where it is well protected, or radially onto a grease ring, where it is easy to install and access. You can have one (1) or two (2) sensors on a motor. Motors with a speed sensor option (machining) are also available.

Overview of Black Bruin Hydraulic Motors



FIG. 19. Black Bruin motor with two speed sensors in the shaft flange.



FIG. 20. Black Bruin motor with a radial speed sensor.

2.3.1 Number of pulses and coupling of a speed sensor

* 10 - 30V DC / 200 mA. Max. wire length between the sensor and the resistor is 1,9 m. Longer wire requires smaller resistor.

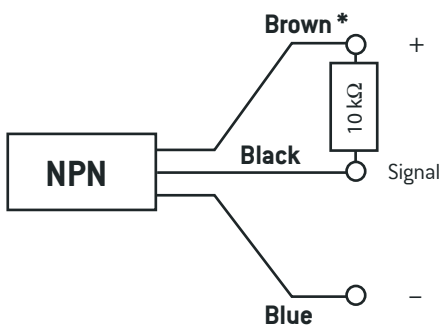


FIG. 21. NPN Sensor.

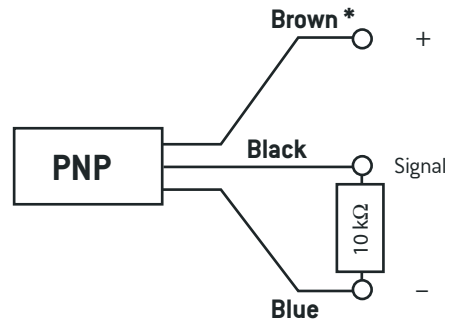


FIG. 22. PNP sensor.

MOTOR	PULSES
BBC 01	128
BBC 02	80 / 94 / 152
BBC 03	135
BBC 04	135
BBC 05	92 / 119 / 120
BBC 06	150
BB 4	80
BB 5	90 / 152
BB 6	94 / 168
BB 7	100

2.4 Knuckle mounting

With certain frame sizes, an integrated steering yoke is available.

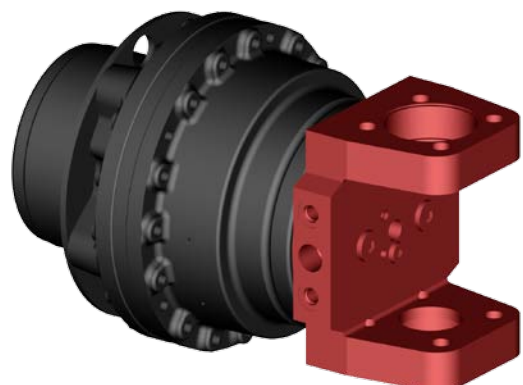


FIG. 23. Black Bruin motor with an integrated steering yoke.

Overview of Black Bruin Hydraulic Motors

2.5 Flushing line

Most of the Black Bruin motors are equipped with the case flushing line. The flushing line is an extra case line. From a charge pump, or an alternative source, cool oil from reservoir is fed into motor housing through the flushing line (C1). Case drain line, C or C2, is used for case drain and returning flush oil. Please note you can not use C1 as case drain line.

2.6 Variety of brakes

There is a variety of brakes available for Black Bruin motors. Brakes, like motors, are designed in compact, powerful packages and tailored to meet the customer specific requirements in various applications.

2.6.1 Static multi-disc brake

- spring applied, pressure to release, parking / emergency stopping brake
- low [16-30 bar] pressure to open, manual release for emergency towing
- optional high pressure and pressure to apply models

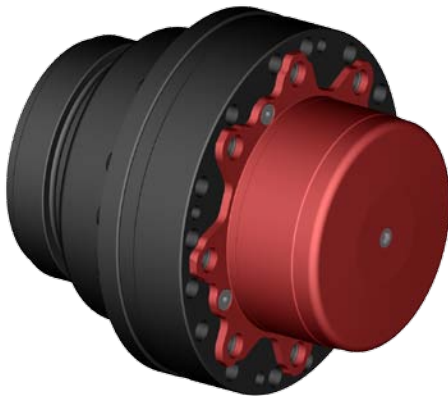


FIG. 24. Black Bruin BBC 04 motor with static multi-disc brake.

2.6.2 Caliper disc brake

- optimal fit for the rotating case motor
- shortest brake motor in the LSHT marketplace
- dynamic and static brake calipers
- can be used with a static multi-disc brake
- pressure operated brake calipers



FIG. 26. Black Bruin BB 5 motor with caliper disc brake.

2.6.3 Drum brake

- dynamic and parking brake functions
- natural fit around the motor case for minimal length addition
- certified models for selected motor frames
- mechanically operated
- can be used with a static multi-disc brake



FIG. 27. Black Bruin BB 5 motor with drum brake.

Innovative hydrostatic transmission and rotation solutions

Sampo Hydraulics Ltd. is one of the world's leading suppliers of radial piston hydraulic motors and rotators. Our trade mark Black Bruin offers a high quality solution for agriculture, construction and mining, road building and forestry equipment applications. As an international operator located in Jyväskylä, Central Finland, we employ more than 100 fully trained professionals and have a distribution network which covers over 25 countries.

Sampo Hydraulics Ltd. is part of the Sampo Rosenlew Group.

Sampo Hydraulics Ltd.
P.O. Box 633
FI-40101 Jyväskylä, Finland
Tel. +358 20 755 0755
Fax +358 20 755 0710
info@blackbruin.com
www.blackbruin.com

**Black
Bruin**
No power like it.