Operating and Assembly Instructions

for the electromagnetically released

Spring-applied Brakes FDR / BR300…800

— Protection Class IP55 —

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1. Preliminary Remarks

1.1 Introduction to the operating and assembly instructions

For validity, purpose and use, as well as terms and labels, see Chapter 1 "Information on the Operating and Assembly Instructions" in the current issue of the *General Introduction (...) PRECIMA Spring-Applied Brakes.* As noted there, please consult PRECIMA in case of doubt. Technical questions, notes and suggestions for improvement can also be sent to the following address:

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1.2 Conditions for assembly and operation

For personnel and product-related conditions, proper application, legal aspects and delivery scope and state, see Chapter 2 "Conditions for Assembly and Operation" in the current issue of the *General Introduction (...) PRECIMA Spring-Applied Brakes*

In addition, the following **general conditions of operation** apply to the FDR brakes:

Humidity: 0…80% ➔ with humidity >80%, a closed brake (FDW, FDS, FDX) should be used

Duty cycle
*(valid for installation on a **self-ventilated motor** with a **speed** of **at least 750 min^{-1}** **or** on a **force-ventilated motor**)*:

S1-100% at an ambient temperature of -20…+40°C
S1-100% at -20**…+60°C** and power reduction through a fast-acting rectifier
S3-60% at -20**...+60°C** generally
S3-60% at -20**…+80°C** and power reduction through a fast-acting rectifier

Heating at ambient temperatures < -20°C

Consultation with PRECIMA is required:

- *with the switching noise reduction option (NRB1, see 2.1.3) and an ambient temperature > 60°C*
- *with NRB1 and power reduction through a fast-acting rectifier (underexcitation)*
- *with a PWM (pulse width modulation) control*

1.3 Structure and functionality

For structure and functionality of a spring-applied brake in general, see the corresponding section (Chapter 3) in the current issue of the *General Introduction (…) PRECIMA Spring-Applied Brakes*

2. Product description

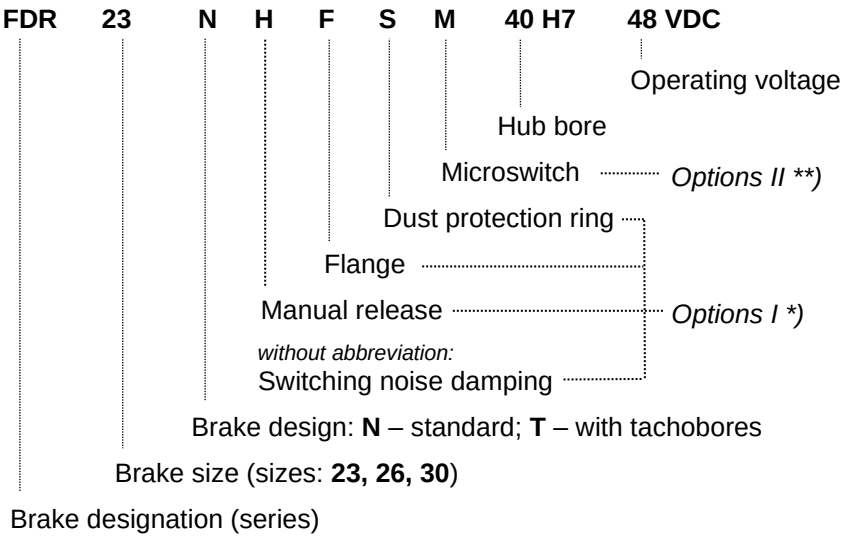
2.1 Marking

2.1.1 Type label

The type label of the spring-applied brake contains all its important data. These data and the contractual agreements for the brakes define the limits of their use.

2.1.2 Type code for FDR brakes (PRECIMA)

Example:

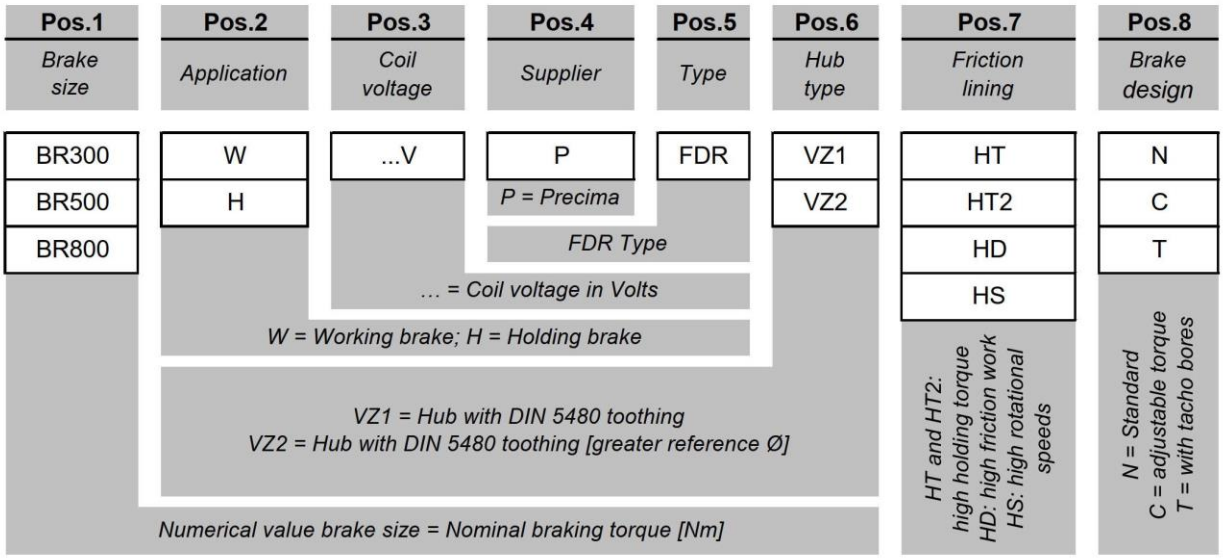


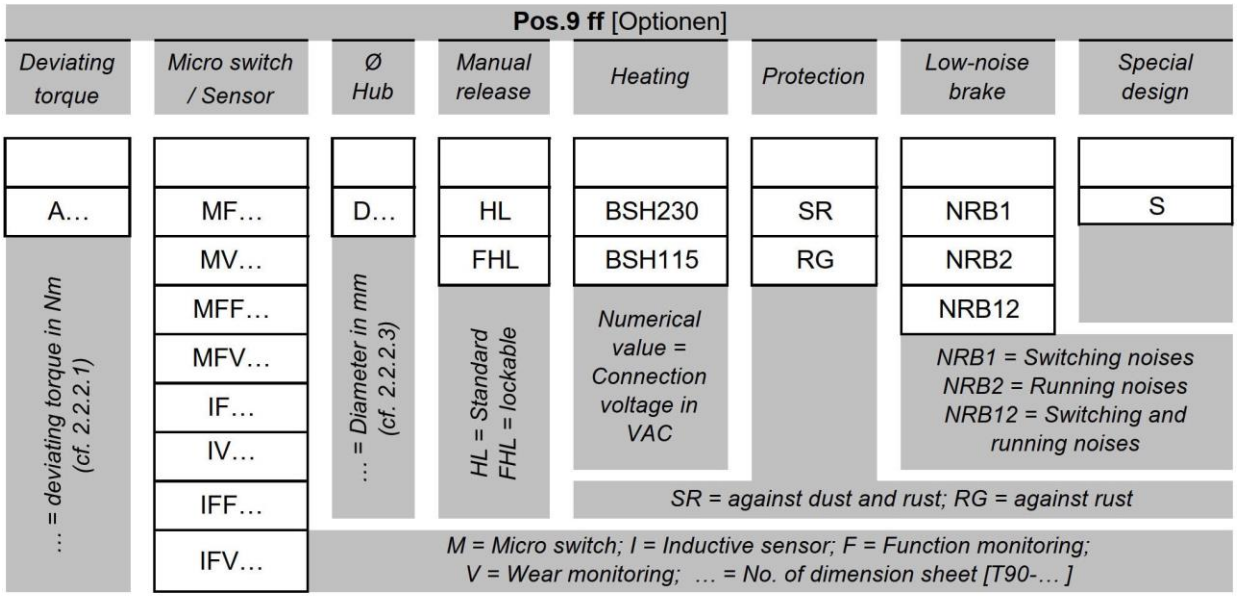
*) *Options I* are taken into account in these operating and assembly instructions, but, if desired, must be specified when placing the order. Except for the *switching noise damping* option, this can be done simply by entering the needed abbreviation.

**) *Options II* are *not* taken into account in these instructions. The M option (= microswitch), which is the only one included, must be specified when placing the order and cannot be retrofitted. For Options II, separate descriptions and adjustment instructions are available and must be observed in addition to this document.

2.1.3 **Brake nomenclature** (Getriebebau NORD)

The following two diagrams show how an FDR brake is designated by Getriebebau Nord. Pos.1 to Pos.8 must be listed in any case, Positions 9 ff only when the corresponding option is used, but then always in the sequence shown.





XXX
XXX
…

= *Selection fields of the corresponding position*

= *Selection field empty, i.e. a corresponding entry is omitted in the brake description*

Example: **BR800 W 180V P FDR VZ1 HS T MF322 D50 NRB2**

= Working brake FDR of size 800 in version T (tacho bores), with manual release, a 180 VDC coil, a rotor with HS friction lining and toothing according to DIN 5480 (VZ1), a hub Ø50, a microswitch according to T90-322 for function monitoring and a damping of the running noise, supplied by PRECIMA

2.2 Technical information

2.2.1 Special features of the brake

In addition to the general description of the function of the brake (see *General Introduction (...) PRECIMA Spring-Applied Brakes* / Chapter 3 “Structure and Functionality”; cf. 1.3), the FDR spring-applied brakes are **designed with two rotors** (=double rotor brake), i.e. with **four pairs of friction surfaces** in total: as a result, **a high braking torque** can be achieved **with a relatively small installation space** (in the radial direction). The standard version of the spring-applied brake is supplied with the braking torque M_{bN}. This torque can be adjusted through the spring configuration (number of springs; in part type of spring) according to **2.2.2.1**. The double rotor brake is limited to **sizes** 23, 26 and 30 resp. **BR300, BR500, BR800**. It should be noted that the **IP55 protection class** assigned to the brakes only applies when they are installed under a corresponding **fan cover**, but shall not apply to an attached FDR brake as such.

2.2.2 Technical data

2.2.2.1 Nominal braking torques and number of springs

➔ Nominal braking torque / **working brake** = **dynamic braking torque** at 1 m/s friction speed
➔ Nominal braking torque / **holding brake** = **static holding torque** (= tearing off torque)
➔ For explanation see: *General introduction (...) PRECIMA spring-applied brakes* / Chapter 5

Size	**BR300** *FDR 23*	**BR500** *FDR 26*	**BR800** *FDR 30*
Nominal braking torques ***M_{bN}*** [Nm]	**300**	**500**	**800**
	210	375	600
	170	250	400
	125		

Size	**BR300** *FDR 23*	**BR500** *FDR 26*	**BR800** *FDR 30*
Number of springs for the specified M_{bN}	**7**	**8**	**8**
	5	6	6
	4	4	4
	3		

— Permissible deviations of the actual braking torque:
Working brake up to BR40 (dynamic torque)**: -20/+30%** (new and run-in*)
Working brake from BR60 (dynamic torque)**: -20/+30%** (new) **or ±20%** (run-in*)
Holding brake (static holding torque)**: -10/+50%** (new) **or -10/+40%** (conditioned*) **—**

***** For explanation see: *General introduction (...) PRECIMA spring-applied brakes* / Chapter 5

2.2.2.2 Dimensions, masses, fastening (see **Figure 2.1**)

Size	**Hub dimensions** [mm]			**General brake dimensions** [mm]					**Tachometer bore dimensions** [mm]		
	Toothed hub Ød H7	Mounting dimensions		Brake without / with dust-protection ring	Brake in new condition	Brakes with manual release			Bolt circle Øe1 ±0.1	(No. holes) x thread nominal Ø	Thread depth
	d	***m***	***n***	***d_7 / d_8***	***g / g_1***	***c***	***v / w***	***t / z***	***e_2***	***k_2***	***p_2***
BR300 *FDR 23*	40/45	62.5	4	225 / 231	119 / 130	82	25 / 12	250 / 224	95	(3x) M8	15
BR500 *FDR 26*	45/50/ 55*	70	4	258 / 264	130 ** / 141 **	89	35 / 19	330 / 258	110	(6x) M10	25
BR800 *FDR 30*	50/55/ 60/65*	82	4	306 / 312	137 / 150	92	35 / 19	357 / 304	138	(6x) M10	25

Standard keyway of the hub as per DIN 6885/1-JS9
* deviating keyway as per DIN 6885/**3**-JS9
** Screw heads protrude for 1 mm (overall dimension = 131 or 142)

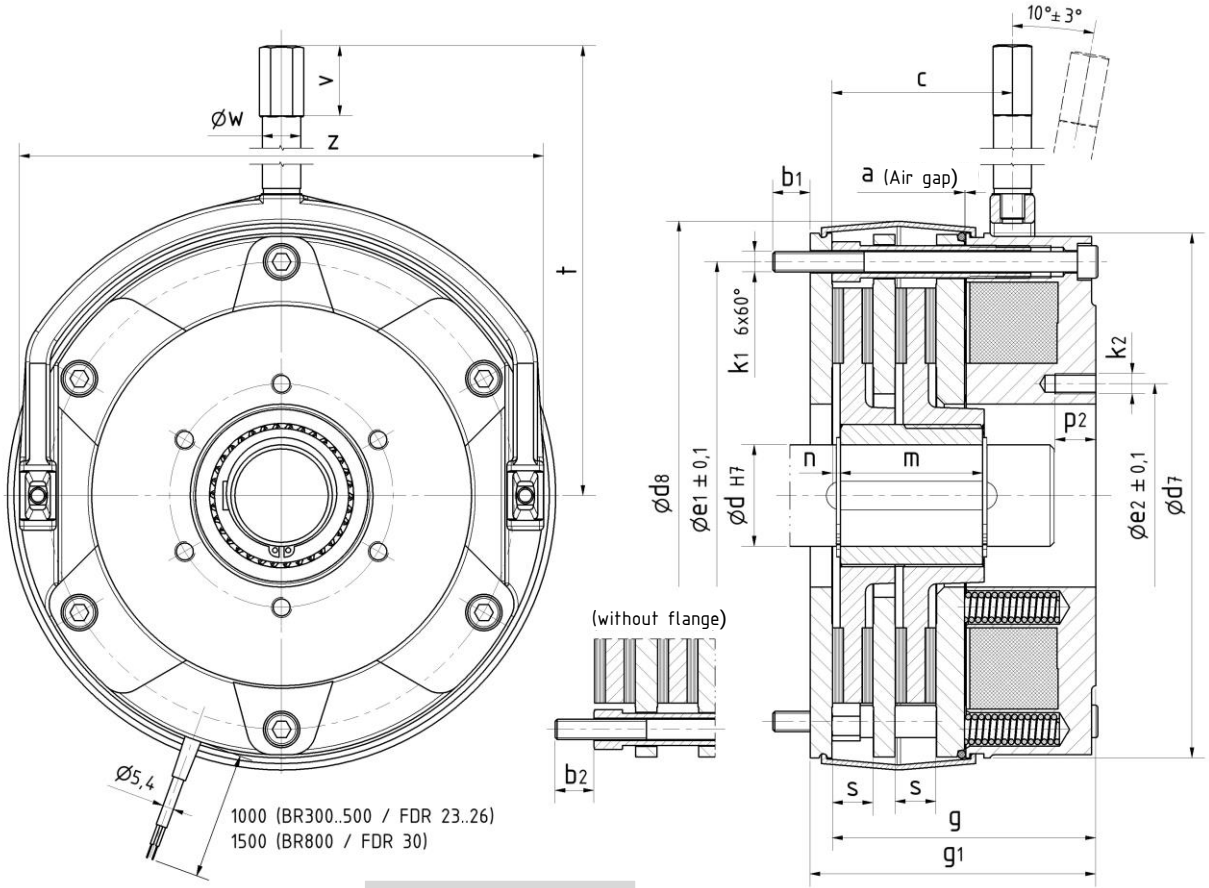


Figure 2.1:
Main dimensions of the brake

a (air gap) and **s** (rotor thickness): see 2.2.2.3

Size	Masses [kg]				Mounting dimensions [mm]				Tightening torque [Nm]	Adjustment dimension [mm]
	Brake without manual release and flange	Manual release	Intermediate flange	Flange	Bolt circle Øe1±0.1	(Number of holes) x thread nominal Ø	with Flange	without Flange	Fixing screws	Manual release
					e1	***k1***	***b1***	***b2***	***MA***	***y***
BR300 *FDR 23*	14.80	0.29	2.50	2.50	196	(5 x) M8	11	10	**25**	1.2
BR500 *FDR 26*	21.50	0.80	3.50	3.50	230	(6 x) M10	20	19	**50**	1.5
BR800 *FDR 30*	35.20	0.90	5.20	5.20	278	(6 x) M10	16	14	**50**	1.5

Dimension y see 3.3.2 or Figure 3.3

2.2.2.3 Air gaps, rotor values

Size	Min. air gap [mm]	Max. air gap [mm]		Rotor thickness (new) [mm]	Rotor thickness (min.) [mm]	Rotor moment of inertia [kgm²]	Max. rotor speed [min⁻¹] *- permissible speeds higher than indicated may be applicable through special measures on request -*	
	a_{min}	a_{max}		s_{new}	s_{min}	$\sum J$	n_{max}	n_{max} turned rotor ++
BR300 *FDR 23*	0.5	1.10	0.80*	18.0 -0.1	14.5	5.6 x 10^{-3}	**3600**	4500 (6000+)
BR500 *FDR 26*	0.5	1.20	0.90*	20.0 -0.1	16.5	13.2 x 10^{-3}	**1800**	3000 (4500+)
BR800 *FDR 30*	0.6	1.20	0.90*	20.0 -0.1	16.5	38.5 x 10^{-3}	**1800**	3000 (4500+)

* holding brakes with emergency stop features + for max. 5 seconds ++ on request ➔ at high speeds a damping should be provided between rotor and hub (version NRB2, see 2.1.3)

2.2.2.4 Friction work, friction power

Size	Max. permissible friction power** [J/h]	Max. permissible friction work / braking [J]	Max. permissible friction power** [J/h]	Max. permissible friction work / braking [J]	Friction work / 0.1 mm total wear [J]
	Working brake lining		Holding brake lining		Working brake lining
	P_{Rmax}	W_{Rmax}	P_{Rmax}	W_{Rmax}	$Qr\ 0.1$
BR300 *FDR 23*	1620 x 10^3	112 x 10^3	810 x 10^3	56 x 10^3	170 x 10^6
BR500 *FDR 26*	1890 x 10^3	156 x 10^3	945 x 10^3	78 x 10^3	230 x 10^6
BR800 *FDR 30*	2160 x 10^3	224 x 10^3	1080 x 10^3	112 x 10^3	310 x 10^6

** with a uniform timely distribution of the braking

2.2.2.5 Electrical parameters

Size	Electrical power (*average value*) [W]	Voltage [VDC]	Rated current (*benchmark*) [A]	**Size**	Electrical power (*average value*) [W]	Voltage [VDC]	Rated current (*benchmark*) [A]
	$P_{20°C}$ =	U =	I_N =		$P_{20°C}$ =	U =	I_N =
BR300 *FDR 23*	76	24	3.20	**BR800** *FDR 30*	140	24	5.90
		103	0.86			103	1.36
		180	0.40			180	0.78
		205	0.34			205	0.68
BR500 *FDR 26*	105	24	4.17				
		103	1.12				
		180	0.60				
		205	0.54				

2.2.2.6 Switching times

Size	Nominal braking torque [Nm]	Disconnection time [ms]	Response delay [ms]	Connection time [ms]	Response delay [ms]	Connection time [ms]
			*switched on the **DC side***		*switched on the **AC side***	
	M_{bN} =	t_2 =	t_{11DC} =	t_{1DC} =	t_{11AC} =	t_{1AC} =
BR300 *FDR 23*	**300**	270	45	145	320	570
BR500 *FDR 26*	**500**	300	58	178	400	600
BR800 *FDR 30*	**800**	400	65	195	550	900

— The indicated switching times are to be understood as benchmarks with tolerances for the nominal air gap —

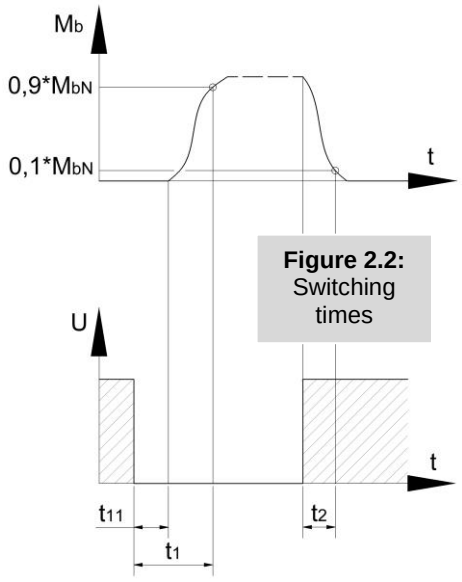


Figure 2.2: Switching times

t_2 = disconnection time = time between the switching on of the current and the ceasing of the braking torque ($M_b \leq 0.1*M_{bN}$)

– here overexcited by a fast-acting rectifier –

$t_{1\ DC}$ = connection time = response time during braking with interruption on the DC side by mechanical switches = time between the switching off of the current and the reaching of the full braking torque ($M_b \geq 0.9*M_{bN}$)

$t_{1\ AC}$ = connection time = response time during braking with disconnection on the AC side, i.e. by interruption of a *separately* powered rectifier

$t_{11\ DC}$ / **$t_{11\ AC}$** = response delay = time between the switching off of the current and the increase in the braking torque (included in the respective connection time)

– Depending on the operating temperature and the wear status of the brake discs, the actual response delays (t_2, $t_{1\ DC}$, $t_{1\ AC}$) can deviate from the benchmarks indicated here. During the DC-side switching, the voltage reduction is accounted for by means of a fast-acting rectifier –

3. Assembly

3.1 Mechanical installation

3.1.1 Requirements and preparation

- Check the unpacked spring-applied brake as to being undamaged and complete of all parts (according to the delivery note). Complaints regarding recognizable transport damage must be made immediately to the deliverer, while claims for recognizable defects and incompleteness must be made to PRECIMA (cf. also 2.5 in the *General Introduction (…) PRECIMA Spring-Applied Brakes*).
- Compare the nameplate of the brake with the agreed characteristics and the actual conditions

➔Attention!
Should any ambiguities or contradictions be revealed during the inspection, the brake must not be installed and put into operation without consulting PRECIMA.

3.1.2 Counter friction surface

3.1.2.1 Motor end shield etc. as a counter friction surface (= no flange)

- Check whether the provided counter friction surface meets the requirements (material: steel, cast steel, cast iron - *no aluminium / stainless steel with limitations* -; surface quality **Rz 6.3**) and whether it is free of grease and oil.

3.1.2.2 Flange

- If the counter friction surface is supplied in the form of a flange (item **7**, **Fig. 3.1**), this component - which lies directly on the motor end shield - is fixed there together with the brake (see also 3.1.3, 3.1.4 and Figure 3.1).

➔Attention!
If the counter friction surface does not meet the requirements, the brake must not be installed and put into operation without consulting PRECIMA. Grease and oil on the counter friction surface must be removed completely before continuing!

3.1.3 Hub and first rotor (Figure 3.1)

➔Stop!
Before the assembly, check the thickness of the rotor according to the information in 2.2.2.3**. S_{new} is the value for a new rotor** (tolerance = 0/-0.1 mm)**, s_{min} is the lowest permissible rotor thickness. When installing a new brake, the values must be s = s_{new}; in case of a reassembly (e.g. after a maintenance-related dismantling) the values must be s > s_{min}, otherwise both rotors must be replaced.**
➔For rotor replacement, see also **4.1.3.2**.

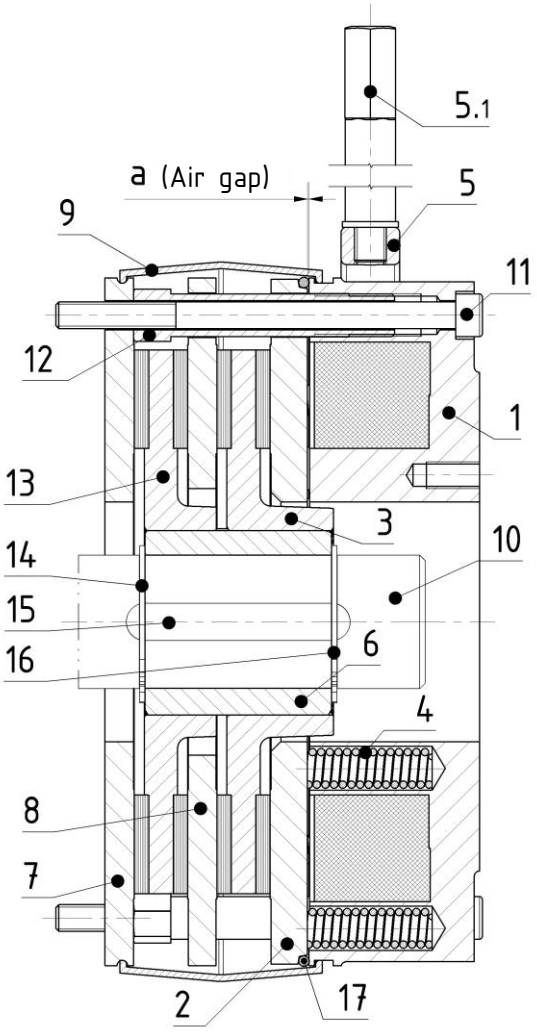
The rotor, as a rotating component of the motor to be braked, is fixed onto the shaft via the hub.

- Insert the first circlip (item **14**) into the rear radial groove of the shaft (item **10**)
- Insert the feather key (item **15**) into the axial groove of the shaft
- Push the toothed hub (item **6**) onto the shaft and over the feather key

- Fix the hub axially by inserting the second circlip (item **16**) into the front radial groove of the shaft
- If necessary, mount the counter friction surface (flange; item **7**)
- Push the first rotor (individually enclosed, with a short neck; item **13**) onto the hub, the rotor should still be axially displaceable

➔**Attention!** **Make sure that the rotor/hub pair runs smoothly!**

Figure 3.1: Assembly of the brake (sectional view)



3**.1.4 Brake with intermediate flange and second rotor** (Figure 3.1)

The brake with an intermediate flange and a second rotor (item **1** [including items 4+2] with items **8** and **3**) is attached to the motor flange (with the interposition of a flange if necessary). The functionally important settings are adjusted and the brake may be supplemented by additional components:

- Push the brake (with intermediate flange and second rotor) onto the hub, insert and screw in at first **three** fixing screws at 120° (item **11**) until the air gap **a** corresponds to the **nominal air gap** (values of nominal air gap and tolerance: see **2.2.2.3**).
- Tighten the corresponding hollow screws (item **12**) on the outer counter friction surface (flange, motor flange), then fasten the three fixing screws with the tightening torque according to **2.2.2.2**

- Check the size of the air gap **a** for compliance with the **nominal value** (+ tolerance) by means of a feeler gauge in the area of the three fixing screws and, if necessary, correct it by adjusting the hollow screws
  ➔ For the procedure to correct the air gap cf. **4.1.3.1**.
- Tighten the remaining hollow screws and fasten the associated fixing screws with the tightening torque as well according to **2.2.2.2**
- Mount the O-ring (item **17**; *only for brakes with "switching noise damping" option*)
- Mount the dust protection ring (item **9**; *only for brakes with S option*)
- Screw the manual release lever (item **5.1**) into the manual release bracket (item 5) with the attached washer and tighten it on the hexagonal surfaces (*only for brakes with manual release = H option*) ➔ **screw-in torque:**

Size	Thread lever	Screw-in torque [benchmark in Nm]
BR300 // FDR 23	M8	**18**
BR500/800 // FDR26/30	M10	**25**

- Remove the mounting aid (*only for brakes without manual release, see below*)

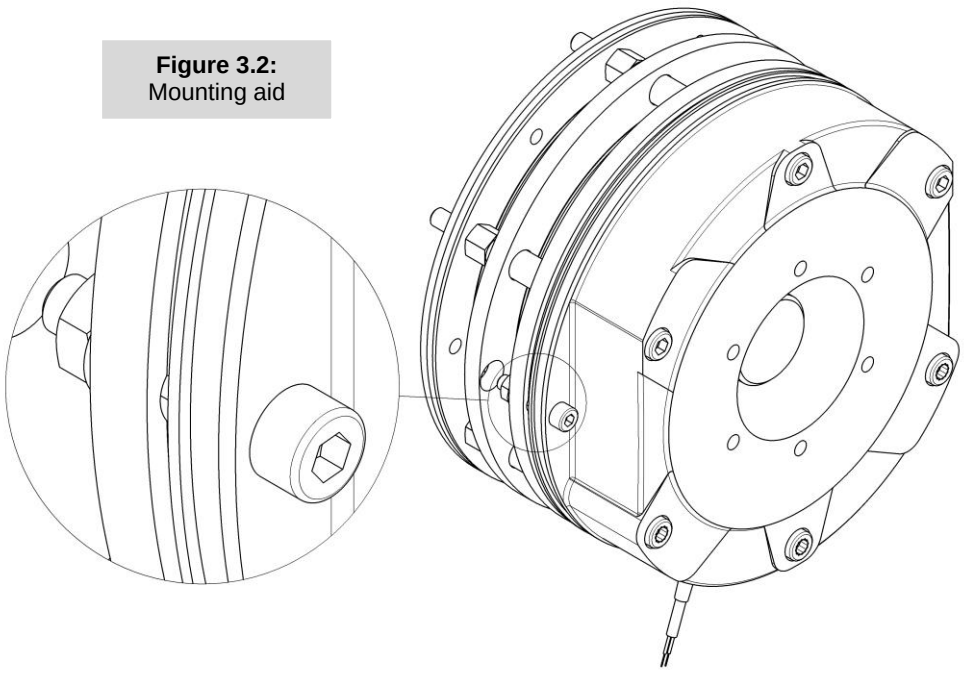
3.1.5 Mounting aid for brakes without manual release (Figure 3.2)

To simplify assembly, brakes of the FDR series **without** manual release are equipped with an appropriate aid consisting of two screw connections in the holes for the manual release. These screw connections pull the armature plate against the force of the compression springs on the magnet housing. The mounting aid must be removed before commissioning the brake and should be reattached before disassembly.

➔Attention!

A brake of the FDR series with mounting aid is <u>not</u> in an admissible state of application according to 2.2.3. in the *General Introduction (…) PRECIMA Spring-Applied Brakes* **and must <u>not</u> be put into operation in this form!**

Figure 3.2:
Mounting aid



3.2 Electrical installation

The electrical connection is only to be carried out in a de-energized state.
The operating voltage (DC) of the brake is indicated on the magnet housing (cf. 2.1.1 and Figure 2.2).

To achieve the lowest possible wear values, PRECIMA recommends using the PMG fast-acting rectifier with double overexcitation for the brakes of the FDR series.

3.3 Modifications and additions

3.3.1 Change of the braking torque

The braking torque can be adjusted by modifying the spring configuration in accordance with **2.2.2.1**. Make sure that at least the springs arranged on the outside are evenly distributed.

3.3.2 Retrofitting of the manual release (Figure 3.3)

For brakes that have been ordered as such with manual release (H option), the latter is already installed and its setting must not be changed (see below).

However, it is also possible to retrofit a manual release:

- Place the manual release bracket (item **5**) on the magnetic body (item **1**) and insert the two bolts with a cross-threaded hole (item **23**) into the corresponding holes of the manual release bracket
- Insert the screw (item **20**) with the attached washer (item **21**) and the compression spring (item **22**) into the holes of the armature plate. The screws go through the underlying holes of the magnet housing; the washer is placed below the screw head on the armature plate, while the compression spring is inserted between the washer and the magnetic body
- Screw the screws into the bolts (item **23**) and adjust dimension **y** evenly according to **2.2.2.2**. The two screws **must be locked by means of screw sealing wax** in the correct setting position.

➔Attention!

For safety reasons, the setting of the manual release must not be changed! The adjustment of the brake air gap a (cf. 4.1.3.1) **does not require any adaptation of dimension y!**

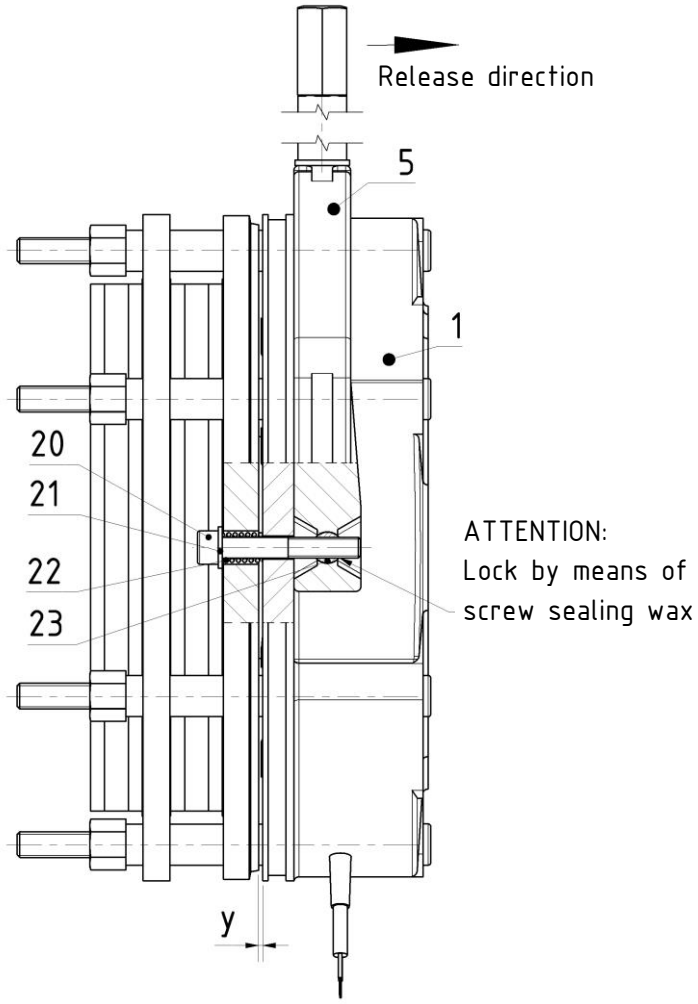


Figure 3.3:
Assembly of the manual release (partial sectional view)

4. Operation

4.1 Brake in operation

4.1.1 Commissioning

Before commissioning the brake, a **functional test** must be carried out first. This can normally and readily be done together with the motor to which the brake is attached. For possible malfunctions, see: 4.2.

➔Stop!
The full braking torque is only effective after the brake pads on the rotor have run in! ➔ Deviation values to M_{bN}: see 2.2.2.1

4.1.2 Ongoing operation

Ongoing operation requires no special measures without malfunctions. Only the **size of the air gap** (increasing because of the wear of the friction lining on the rotor) must be checked according to the following arrangement (see also: 4.1.3), unless a special sensor for wear monitoring has been installed on the brake. In case of malfunctions, proceed according to 4.2.

Control intervals:

Working brake: + according to tool life calculation
+ as per specification to be given by the customer

Holding brake: + at least once every two years
+ as per specification to be given by the customer
+ provide shorter intervals in case of frequent emergency stops

Furthermore, after a number of adjustments of the air gap a (see 4.1.3), the **rotor thickness s** must be checked. A reasonable control interval results from the ratio between the value of **2*(s_{new} - s_{min})** and the difference **a_{max} - $a_{nominal}$**, taking into account the respective tolerances.

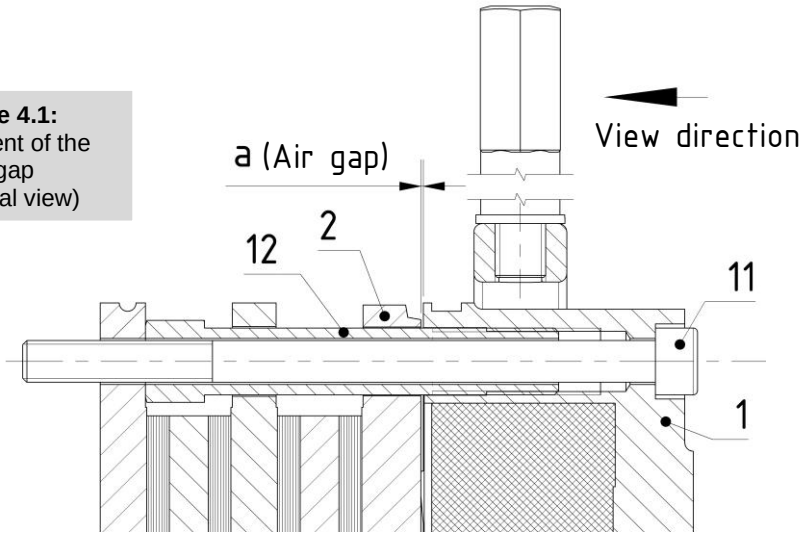
4.1.3 Maintenance

4.1.3.1 Adjusting the air gap (Figure 4.1)

The spring-applied brake is substantially maintenance-free. When the **maximum air gap a_{max}** specified in **2.2.2.3** is reached, an **adjustment (readjustment) of the air gap a** is necessary for the brake to work safely. If the functionality of the brake exceeds the maximum air gap just in individual cases, this does not change the above statement; **proper use is then no longer available**. In any case, as the wear progresses, the functionality and safety function of the brake are impaired.

How to readjust the air gap:
- Facing the brake (see **Figure 4.1**), loosen all fixing screws (item **11**) by half a turn *counterclock*wise.
- Screw the hollow screws (item **12**) into the magnetic body (item **1**) also by a *counterclock*wise rotation
- Screw the fixing screws (*clock*wise) into the (motor) flange until the *nominal* air gap (measured by means of feeler gauges between the magnetic body and the armature plate (item **2**)) of three points on the circumference is available.
- Reposition the hollow screws, i.e. unscrew them from the magnetic body (*clock*wise) until they make firm contact with the counter friction surface
- Tighten the fixing screws with the **tightening torque according to 2.2.2.2**
- Check the air gap; if necessary, readjust the settings

Figure 4.1:
Adjustment of the air gap
(sectional view)



4.1.3.2 Replacement of the rotors

When the minimum rotor thickness s_{min} according to **4.2.2.3** is reached, it is no longer possible to adjust the air gap a and the rotors must be replaced. Functionality of the brake that falls below the minimum rotor thickness just in individual cases does not change the above statement; **proper use is then no longer available**.

➔Stop!

Even after the rotors have been replaced, the full braking torque is only effective again after the brake linings have run in!
➔ Deviation values to M_{bN}: see 2.2.2.1

➔Attention!

When replacing the rotor, the mechanical components involved in the build-up and transmission of the braking torque must be checked for excessive wear (armature plate, hollow screws) or integrity (springs) and replaced if necessary!

4.2 Brake out of operation (malfunctions)

The table below shows typical malfunctions during ongoing operation (in some cases also during commissioning), their possible causes and instructions for their correction.

Malfunction	Possible cause	Remedy
Brake does not release	Air gap too large	Check air gap and readjust
	Brake is not supplied with voltage	Check electrical connection
	Voltage at the magnetic coil too low	Check magnetic coil supplied voltage
	Armature plate mechanically blocked	Remove mechanical blockage
Brake releases with delay	Air gap too large	Check and readjust air gap
	Voltage at the magnetic coil too low	Check magnetic coil supplied voltage
Brake is not applied	Voltage at the magnetic coil too high	Check supply voltage of the magnetic coil
	Armature plate mechanically blocked	Remove mechanical blockages
Brake is applied with delay	Voltage at the magnetic coil too high	Check supply voltage of the magnetic coil

5. Disassembly / Replacement

5.1 Dismantling of the brake

Dismantling of the brake shall be carried out analogous to the assembly, but in reverse order, and only when the brake and the motor are **switched off, de-energized and torque-free**.

➔Danger!

The disassembly of the brake will result in a suspension of its passive braking function. There are no risks associated with this suspension!

5.2 Component replacement

The only component that can be regularly replaced on site is the **rotor** when it reaches the wear limit (see 4.1.3.1); when the **hub** shows signs of noticeable wear, it can be replaced if necessary. Furthermore, all other components listed in ***5.4 Spare parts*** can also be generally replaced.

➔Attention!

Before reassembling a brake, the fastening elements must be checked for proper functionality and replaced if necessary!

5.3 Brake replacement / disposal

The components of our spring-applied brakes have to be recycled separately due to the presence of different materials. The official regulations must also be observed.
Important code numbers of the Waste Catalogue Ordinance (German designation: AAV) are given below. Depending on the material composition and the type of disassembling process, other key numbers may also apply to the components made from these materials.

- Ferrous metals (key no.160117)
- Non-ferrous metals (key no.160118)
- Brake pads (key no.160112)
- Plastics (key no. 160119)

5.4 Spare parts

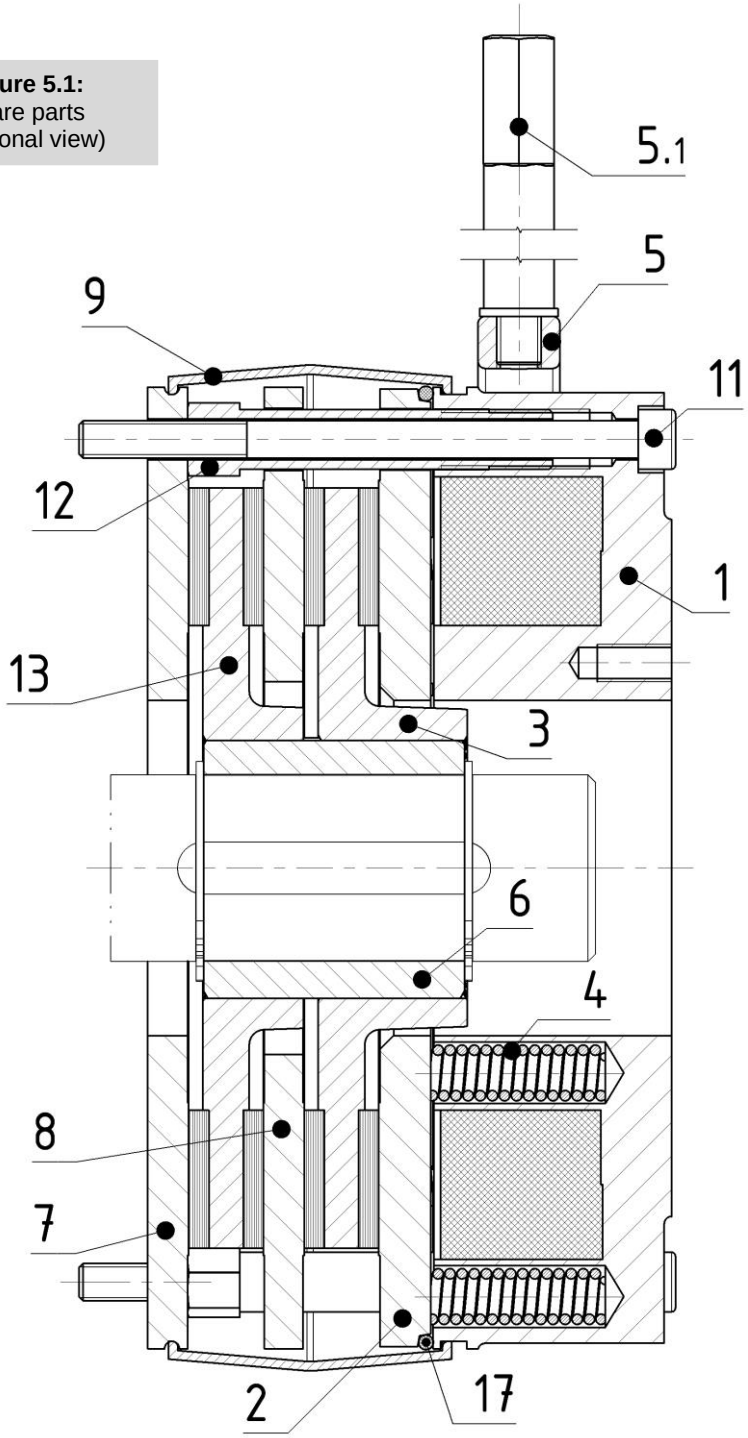
Figure 5.1 shows all the spare parts that can be ordered for the FDR spring-applied brakes which are listed below.

When ordering spare parts, please provide the brake lettering data (see 2.1.1)!

➔Attention!

PRECIMA Magnettechnik GmbH excludes any liability and warranty for damage resulting from the use of non-original spare parts and accessories (cf. 2.2.3 in the *General Introduction (…) PRECIMA Spring-applied Brakes*).

Figure 5.1:
Spare parts
(sectional view)



Position	Designation	Position	Designation
1	Magnetic body	7	Flange
2	Armature plate	8	Intermediate flange
3	Rotor 2 (long neck)	9	Dust protection ring
4	Springs	11	Fixing screw
5	Manual release complete	12	Hollow screw
5.1	Manual release lever	13	Rotor 1 (short neck)
6	Hub	17	O-ring

Document history

Issue	Version	Description
05.2020	0.0	Created
11.2021	*1.0*	General: FDR as general brake **type** designation, BR500..BR800 as NORD-specific brake **size** designation (instead of BRE...) 2.1.3: Adaptation of Getriebebau NORD nomenclature 2.2.2: Table values for holding brakes/high braking torques omitted 2.2.2.1: Definition of nominal braking torques added; tolerance values revised.