

ECKEL

# Robograph 2

Operating manual

## Foreword

The Robograph 2 is a modern and highly sensitive measuring instrument.

To achieve the required accuracy the **installation instructions** and the section on **error sources** must be read carefully. This is especially true for operation in the vicinity of electromagnetic interference systems.

Despite the fact that the Robograph 2 is very simple to operate, we urgently recommend that you **read** through the entire operating manual carefully since otherwise you will be unable to use all the facilities.

It is possible that some software errors may occur in the operating interface. If this occurs, make a note of the situation and, if possible, the type of error and the error message shown. You will then be sent a correct program version by me as quickly as possible. Please also let me know about minor errors. If you do so, you will help prevent yourself and future users suffering inconvenience.

We have chosen a ring binder for the operating manual so that the manual can be amended with improvements and expansions. You will be sent the relevant pages together with the software update automatically.

Eckel GbR  
Magnetmesstechnik  
Am Teich 5  
D-19348 Berge GT Grenzheim  
Tel.: +49 38785 / 60910 Fax: 60911  
E-mail: [info@w-eckel.com](mailto:info@w-eckel.com)  
[www.w-eckel.com](http://www.w-eckel.com)

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## 1. General description of the unit

The Robograph 2 is a digital hysteresis measuring instrument for magnetic segments and material samples.

The measurement of hard magnetic segments is a flux measurement on the basis of BOSCH test instructions No. 3 139 918 950. The magnetic segment is placed in a segment-shaped measurement insert in a yoke and magnetised in both directions one after the other well beyond the saturation point. By means of the simultaneous measurement of the field strength and magnetic flux the complete hysteresis curve of the segment can be recorded. This is then released of the  $a \cdot \mu_0$  gradient to allow the pure material properties to be calculated.

The rectangular shape of this demagnetisation characteristic curve is decisive for the resistance of permanent magnets under the influence of strong opposing fields. The remanence flux and the flux in a freely selected opposing field are specially calculated.

The measurement of material samples is conducted using a different measurement insert. Regardless of the size of the sample, the simultaneous measurement of the field strength and induction is used to record the hysteresis curve of the material. This curve is then also released from the gradient  $\mu_0$  to calculate the pure material properties.

In addition to the remanence induction and the coercitive field strength of the material, a limit field strength is calculated up to which the material may be loaded without the magnetisation being lost.

Both measurements are absolutely physically calibrated without a calibration sample and can be temperature-compensated to 20°C. The material measurement must be recalibrated with a nickel sample to compensate for losses in the measurement insert. Nonlinear saturation compensation is available.

The results are shown in graphic form and can be printed out and saved and also a statistical evaluation is available.

The repetition measurement tolerance of the Robograph is well below the fluctuations caused by external influences.

## 2. Installation

### 2.1 Hardware requirements

The Robograph 2 is connected to a conventional personal computer. This PC is to be provided by the client together with the periphery and Windows software. In detail the following is required:

A standard **Pentium PC**. Also older computers are suitable. Hardware requirements are low and depend only on Windows version.

**Keyboard** of your choice. No special characters are required.

**Colour monitor** of your choice. We recommend a demagnetisable monitor ("Degauss" switch) since if it is installed too close to the measurement yoke the picture tube may be permanently magnetised and therefore discoloured. Best choice is a flat LCD monitor since it is not harmed by magnetic fields.

**Mouse** of your choice. Only one mouse button is required.

**Printer** including printer cable of your choice. However, it must be possible to configure the printer under Windows. We highly recommend a **laser printer** if you intend to print out measurement curves.

**One serial RS 232 interface for the Robograph and one parallel interface or USB port for printer.**

**CD-ROM drive.**

Software **Windows™** from **98 to Vista (32bit)**.

This is the hardware and software to be provided by the client.

Furthermore, the following hardware and software is required, which is generally supplied by us:

**Robograph 2** table top unit

**Measurement yoke.** If only flux measurements are required, it may be possible to use an existing measurement yoke.

**Hall probe.**

**Temperature probe.**

Mains cable, RS 232 connection cable, Hall probe cable, temperature probe cable, push button, 2 BNC cables.

Operating and evaluation **software.**

**Operating manual.**

In addition, a **flux measurement insert** for each segment form and a **material measurement insert** for material measurements are required. These inserts must be ordered separately.

## 2.2 Hardware installation

### Measurement yoke and Hall probe

When installing the measurement yoke remember to give consideration to its great **weight**. The table should have a sturdy **steel frame** and **no casters** on the feet.

As a result of the measurement inserts and the Hall probe, the **distance** to electromagnetic **interference units** should be as large as possible.

The Hall probe is the most sensitive measurement sensor. Ensure that the **connection cable** to the Hall probe is **as far as possible** away from and under no circumstances parallel to mains cables.

The measurement yoke with its **temperature sensor** should not be positioned in **draughts** because otherwise the temperature measurement could be incorrect. Further details are given in the section entitled "Error sources".

The yoke itself generates an **extreme**, slow-changing **magnetic leakage field**.

**IMPORTANT: This represents a danger to all magnetic data carried in the vicinity**, such as diskettes, hard drives or magnetic tapes. Even after the measurement, the remanence of the measurement yoke is dangerous for diskettes.

**Colour monitors** may suffer **permanent discolouration** by their picture tube being magnetised.

Loose iron parts or magnets in the area can suddenly be attracted by the measurement yoke during the measurement.

### **Robograph 2 table top unit**

The Robograph 2 is not influenced by the magnetic field generated by the measurement yoke and can therefore be positioned next to it. **In no circumstances should the measurement yoke be placed on the Robograph 2.**

The unit is not designed to withstand the weight. Ensure that the **air intake** on the rear and the **ventilation slots** are not blocked. Do not place the unit under a cover which will inhibit the air circulation.

In any event you must prevent **fluid** getting into the unit through the ventilation slots.

Extreme electromagnetic interference sources such as scintillating motor collectors or arcs will also influence the Robograph 2 so that a correct measurement will be impossible as a result of the effects on the sensors.

### **Personal computer**

The PC itself is not sensitive to slow-changing magnetic fields. Since, however, there is an **extreme risk** to the **hard drive** and **diskettes**, the PC, too, must be positioned **as far** away from the measurement yoke **as possible**.

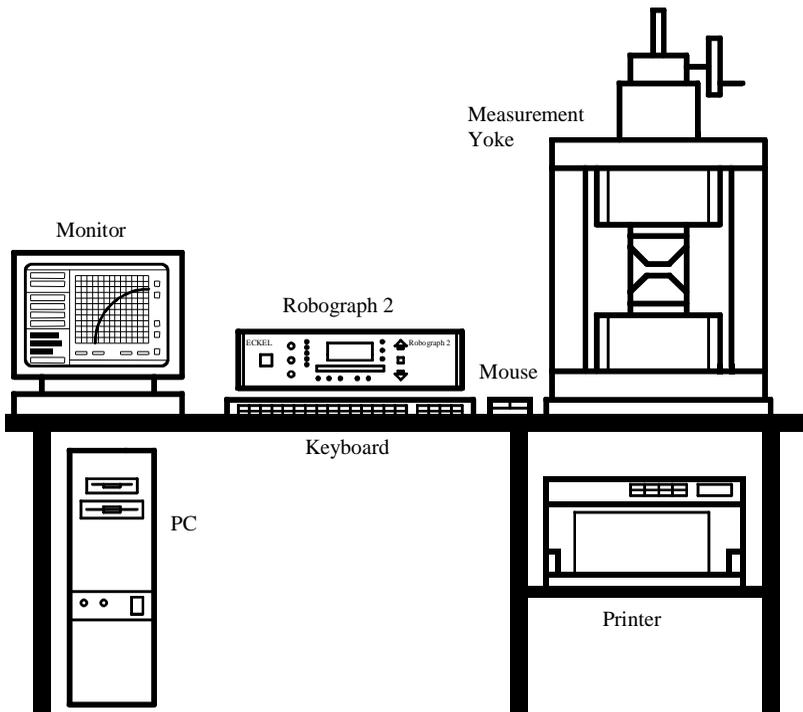
## **Monitor**

The CRT colour monitor shows signs that it has been influenced by the leakage field by considerable **colour changes** during the measurement. At a distance of **1 m** from the measurement yoke, however, no permanent magnetisation of the tube should occur. If it does happen, however, a demagnetisable monitor can be demagnetised by pressing the "Degauss" button. If this is not possible, the magnetisation will generally be reduced over the course of a period of a few days or weeks.

## **Printer**

The printer can be positioned wherever you would like. Although the toner in laser printers is slightly magnetic, even if it were to be positioned directly next to the measurement yoke, the printer would not suffer, particularly because no measurements are generally taken when the printer is operating.

Optimum installation positions for the components:



## **Cable connections**

The cables and all plug connectors are marked. All the plug connectors, apart from the two BNC cables, are **impossible to mix up**.

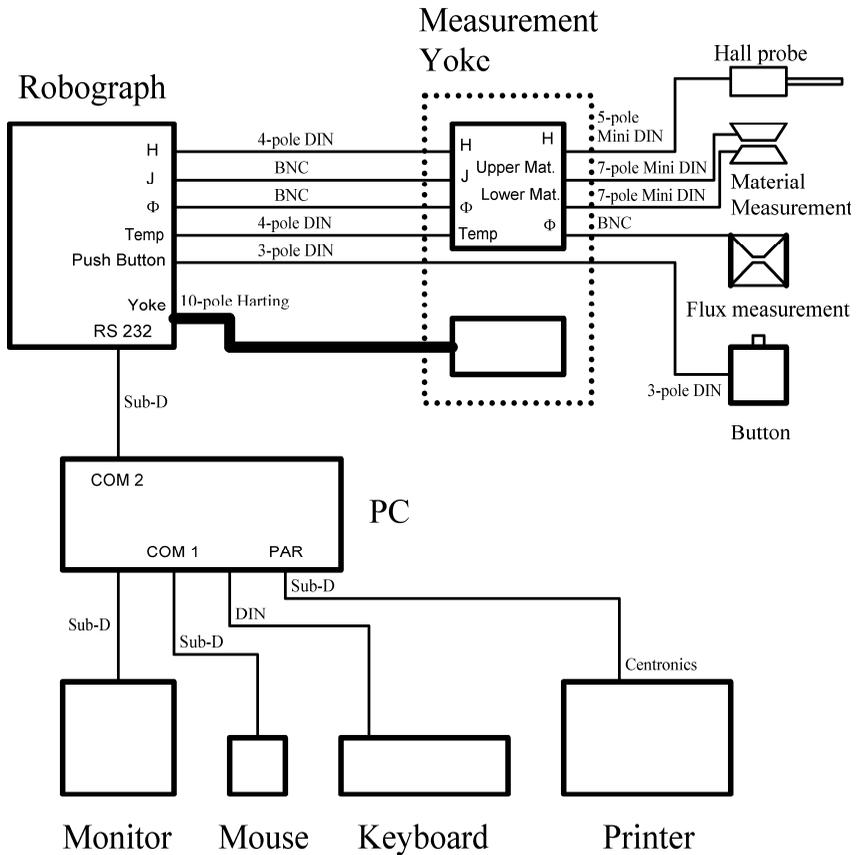
All the connections should be locked or screwed, depending on their type. To release the measurement yoke plug it is a good idea to lever up the lock carefully with a screwdriver.

Lay the cables in such a way that they are not tensioned and cannot be ripped out accidentally.

The Hall probe must be pushed into the mounting with the plastic side facing upwards.

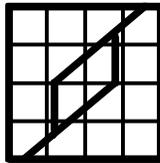
The **Hall probe** must **under no circumstances** be subjected to a mechanical load at the tip, twisted or even **bent** since it contains a very fragile Hall element.

The cables are to be connected as shown in the following diagram:



## 2.3 Software installation

The software is installed by an installation program. This presupposes that Windows is already installed. When installing the software on the PC for the **first time**, place the CD-ROM into the appropriate drive and start the program "ROBINST.EXE". This program opens a directory called "ROBO" on hard drive "C:". In this directory there will be a program "ROBO2.EXE" as well as calibration, tolerance, parameter and archive files. Furthermore a window called "Robograph 2" will be generated in the Windows™ program manager. The following icon will be installed in this window for the Robograph 2:



Robograph 2

The program "ROBO2.EXE" can now be started by double clicking this icon. It is also possible to start the program direct in the file manager.

However, the program can **only operate under Windows™**, since all the Windows functions of the operating interface are not included in the program but can only be called up from it. This explains the relatively small size of the program.

For the installation of a **software update**, the "ROBO2.EXE" program is overwritten directly with the new program. This prevents the possibility of changing the other files.

### 3. Robograph 2 table top unit

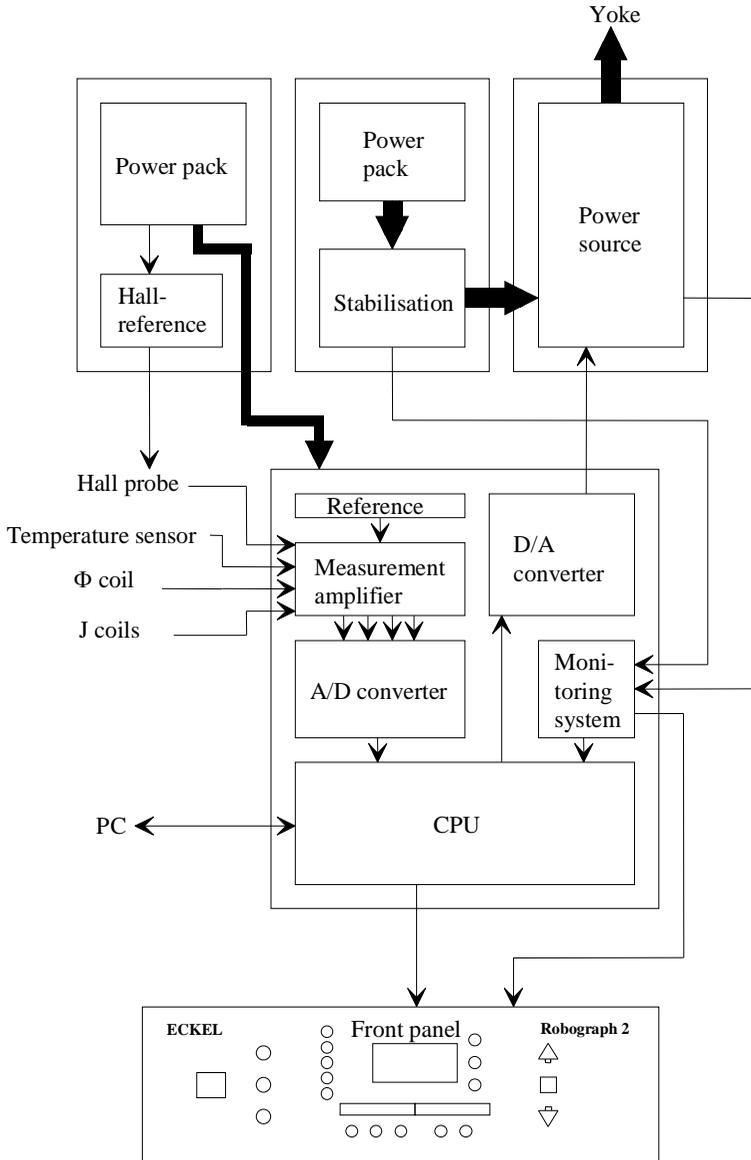
#### 3.1 Structure and function

The Robograph 2 essentially consists of the **measurement and control unit** and the **power output stage** with a power pack. There is a **microcontroller** on the measurement and control unit with its own **on-chip software**. The microcontroller is designed to complete several tasks:

- Safety monitoring of the output stage and power pack
- Error identification before the measurement
- Control of the power source output stage
- Registration of measurement values
- Coding of measurement values
- Connection to the personal computer
- Control of the displays on the front panel

The output stage is made up of **two** independent controllable **power sources** which control the two excitation coils on the measurement yoke. These power sources have been specially designed for permanent operation under a heavy inductive load and can produce an effective output of 250 W each. To prevent interference from system hum, the output stage has a **stabilised power pack**.

Unit diagram



## 3.2 Displays on the front panel

The displays are divided into four areas:

- Unit status
- Measurement result
- Evaluation
- Control displays

Unit status:

Green = Ready, self-test OK.

Yellow = Measurement in progress, do not interrupt.

Red = Error. **Red flashing light** means: **major hardware error**, can be read off control display, **switch off unit and repair** it. The sole exception is: if the yoke is not connected when a measurement is taken, a hardware error will be displayed due to overload after the measurement. Here it is simply necessary to connect the yoke. A permanent red light after the start of the measurement means: Error on the measurement sensors as shown by error message on screen. Rectify error and restart the measurement. See Chapter 5.1 for a more detailed description.

Measurement result:

On the left is the description of the measurement value shown, on the right is the relevant unit, green is for flux measurement and yellow for material measurement. See Chapter 4.3 for selection details. The measurement value appears in the middle of the display.

Evaluation:

Yellow = Above tolerance

Green = Within tolerance

Red = Below tolerance

See Chapter 4.10 for details of adjusting the tolerances.

There are **two settings**:

- Tolerance evaluation only for the displayed measurement value
- Tolerance evaluation for all measurement values

See Chapter 4.12 Parameters for a more detailed description.

Control displays:

**Current display** using light bars. The displayed value is the average value of the two excitation currents. The display may **only be lit during the measurement**.

OL = Overload of one or two output stages. It is quite safe for this to light up briefly at maximum amplitude and has no influence on the measurement, but means that the unit and the internal resistance of the excitation coils have not been adjusted properly.

PS = Power supply voltage incorrect or **power pack defective**.

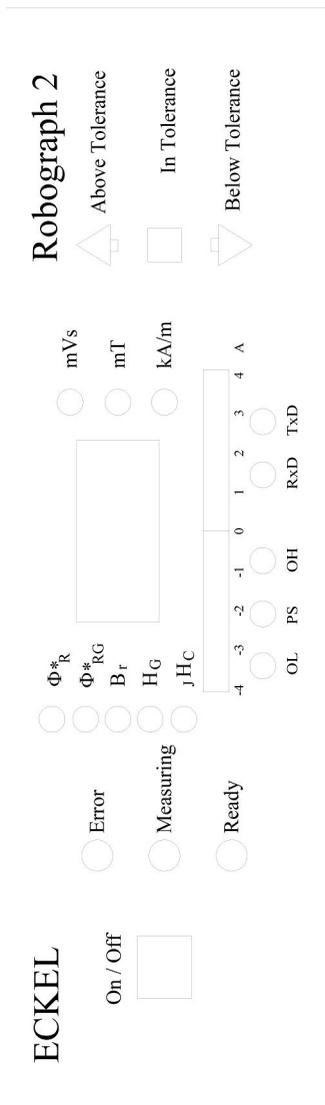
OH = Unit overheated.

RxD and TxD are the monitors for the serial interface to the PC.

In contrast to the other displays on the front panel the control displays are purely **static** and are not controlled by the microcontroller.

See Chapter 5.1 for a precise description of error causes, messages and remedial action.

# Front panel



### 3.3 Connections on the rear of the unit

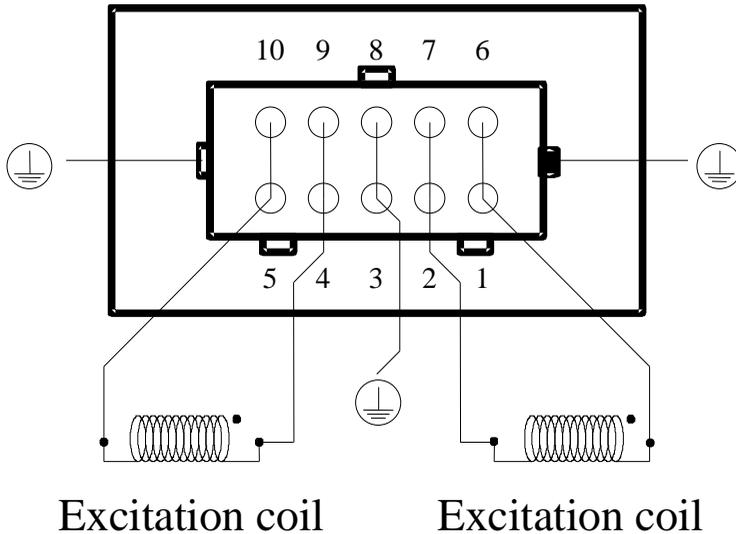
All the necessary plug connections for the Robograph 2 are on the rear of the unit. They are marked to indicate their function.

#### Mains connection:

The mains connection is an integral plug for a non-heating appliance in accordance with IEC 320 up to 65°C. The mains voltage may be 220 - 240 V or 110 - 115 V and is specified on the rating plate. The mains frequency is 50 - 60 Hz. The mains input contains a mains filter and the mains fuse. The Robograph 2 **must have a protective earth wire** in the mains cable. The correct fuse value is 4 A slow for 230 V and 10 A fast for 115 V . A spare fuse is supplied in the fuse holder. The mains connection is marked "AC".

Measurement yoke:

The connection for the measurement yoke is a 10-pole locking power plug connector. This is where the excitation coils for the measurement yoke are connected. The connection assignment is as follows:



The plug connector must be **locked** since if the connection is broken during the measurement, extremely high voltages may occur on the measurement yoke which place persons at risk and may damage the insulation on the measurement yoke. **None** of the excitation coil connections may be connected to ground or protective earth!

#### Serial interface:

The serial RS232 / V.24 interface is a 9-pole Sub D socket. The following are connected:

Pin 2 = Transmit data TxD

Pin 3 = Receive data RxD

Pin 5 = Ground

The transfer speed is 19200 baud. The serial interface is marked "**RS 232**".

#### Material measurement:

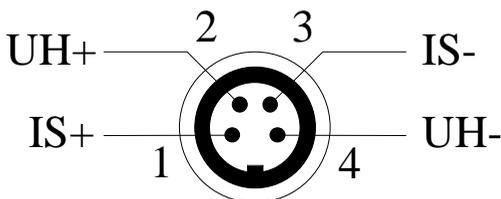
The connection for the J measurement coils for the material measurement is a BNC jack. It is marked "**J**". The maximum input voltage is 10 V. The differential input resistance is  $> 10$  MOhm.

#### Flux measurement:

The connection for the Flux measurement is a BNC jack. It is marked " **$\Phi$** ". The maximum input voltage is 5 V. The differential input resistance is  $> 10$  MOhm.

#### Hall probe:

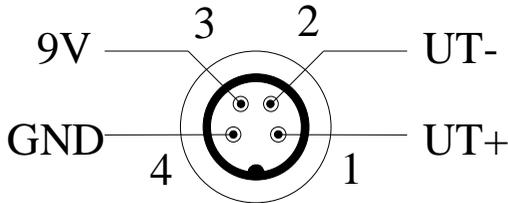
The connection for the Hall probe is a 4-pole socket of type KfV 40 to DIN 41524 with a screw lock. The connection assignment is as follows:



The control current for the Hall probe is 7 mA. The Hall probe connection is marked "**Hall**".

Temperature sensor:

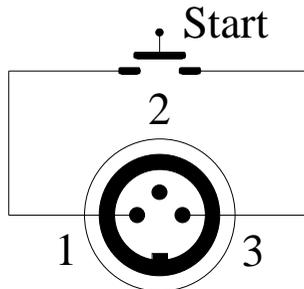
The connection for the temperature sensor is a 4-pole socket of type SFV 40 to DIN 41524 with a screw lock. The connection assignment is as follows:



The supply voltage for the temperature sensor is 9 V. The temperature sensor connection is marked "**Temp.**".

Button:

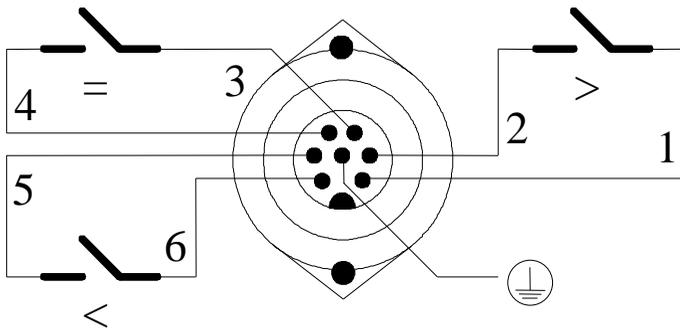
The connection for the button is a 3-pole socket of type KFV 30 to DIN 41524 with a screw lock. The connection assignment is as follows:



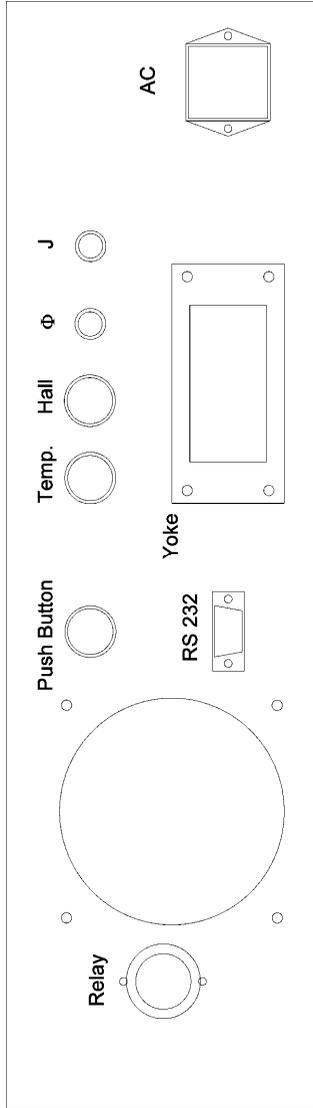
The button connection is marked "**Push Button**".

**Relay output:**

The output for the relay is a 7-pole mounted socket of type Hirschmann CA 6 with a screw lock. Dependent on the result, external processes can be controlled from here. The relay output is connected internally with non-potential relay contacts. The connection assignment is as follows:



The load capacity of the relay contacts is 250 V AC, 8 A. The relay connection is marked "**Relay**".



### 3.4 Safety instructions

The following instructions have been drafted to protect the hardware. They are designed to protect the unit from extreme loads. If they are ignored, however, it will not necessarily mean that the unit will suffer damage.

- Follow the instructions in Chapter 2.2 Hardware installation.
- The unit is **heavier** than it looks.
- If the unit, for example, has fallen, and you are not sure whether it still works, first switch it on **without connecting the yoke**.

If it is obvious that the unit has been damaged, it should be sent for repair without first switching it on.

- Lock the yoke plug into the connection.
- **In all circumstances avoid a short circuit between the output stages and between the output stages and the unit earth.** With some types of short circuits serious **damage may be suffered by the entire unit and the computer.**

In general, therefore, **after completing any work** on the connections of the excitation coils, **test them for short circuits.**

- Do not touch the connections on the excitation coils during the measurement. Direct voltages of up to **120 V** may be present.
- Only use the unit if the fan is in working order.
- Avoid **switching off** the unit **during a measurement.** Switching off the PC or disconnecting the PC during the measurement is absolutely safe, however.

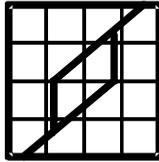
- Do not **switch** the unit **off and** then **on again immediately** ( less than one second ) to ensure that the microcontroller receives a proper reset signal.
- If the **current display moves** when there is **no measurement** being taken, **switch the unit off immediately**.
- Prevent metal dust or chippings and fluid getting into the unit.
- Do not replace the fine wire fuses inside the unit. If these fuses blow, check for a hardware error. Replacing the fuse without testing the hardware can cause further errors. In particular the fuses must **never** be replaced with one for a higher current.
- **Never work on the unit when it is switched on.** ☠

In addition to 230 or 115 V alternating voltage there is also 210 V direct voltage with a very high rating present in the unit. This voltage is also held for a lengthy period of time in the capacitors when the unit has been switched off. A short circuit of these voltages to any other line may destroy the entire unit. The best advice is not to open the unit at all since you will not be able to carry out any repairs inside it anyway.

## 4. Operating interface

### 4.1 Program start

The following icon is displayed on the Windows™ desktop:



Robograph 2

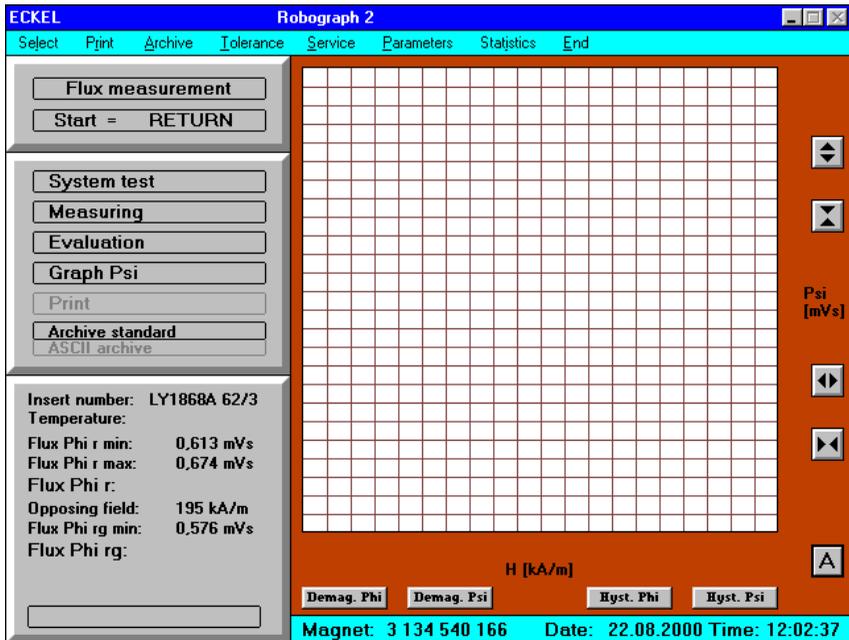
The program is started by a double click on this icon.

It is also possible to start the program direct by selecting "ROBO2.EXE" in the file manager.

When the program is started all the parameters and calibration values from the last time the unit was used are automatically loaded.

## 4.2 Main menu

After the program start the main menu is opened in which all the elements required for operation are shown on a single screen page.



The main menu for a flux measurement

At the top left is a field in which the set measurement type, **flux measurement** or **material measurement**, is displayed.

The field beneath this shows how the measurement can be started.

**Start = RETURN** means that the measurement can be started by pressing the RETURN key.

**Start = MOUSE** means that the measurement can be started by clicking the mouse on this field.

**Start = BUTTON** means that the measurement can be started by pressing the button on the base plate of the measurement yoke. This is beneficial if the parameters of the measurement are changed rarely and the user does not need to gain access to the program.

If the program is unable to open the selected serial interface or no serial interface has been selected, the message "**No interface**" will appear in the field and the field will have a red background. In this situation no measurement is possible and the appropriate menu points are disabled. Another serial interface can be opened under **Parameters**. It is possible that as a result of attempting to open a busy interface the program will no longer be able to open the correct interface. Then after setting-up the correct interface and saving the parameters ("OK") you should exit the program and start again.

In the block below this there are fields which indicate the status of the measurement. Their colour during the measurement provides information on the current process. "Blue" means that this process is currently being completed, "green" means that it has been successfully completed and "red" means that an error has occurred, whereby after an error message has been output the process is aborted if the error has occurred during the measurement or the evaluation process.

**System test, measurement and evaluation** are always active. **Graphic, print, archive and ASCII archive** can be deactivated and are then shown in "grey".

For **Graphic** the selected or current type of graph is shown - for flux measurement  $\Phi$  (Phi) or  $\Psi$  (Psi), for material measurements **B** or **J**.

For **Archive, standard, specification or individual specification** is displayed which determines the names or paths of the archive files. The path chosen in Select is always used for **ASCII archive**.

Below this is the result block. This contains the **material** entered, the **temperature** measured and the measurement results with the set tolerances - for flux measurements  $\Phi^*_R$  and  $\Phi^*_{RG}$ , for material measurements **B<sub>r</sub>**, **H<sub>G</sub>**, **jH<sub>C</sub>** and **b**. For the flux measurement the number of **turns** of the measurement insert and the **opposing field** for which  $\Phi^*_{RG}$  is calculated are also shown. The results are shown in different colours if they fall above or below the tolerance limits. They are shown in "yellow" if they are above the tolerance range and "red" if they are below it. At the bottom there is another field which contains the overall evaluation. **In Tolerance** in "green" or **Outside Tolerance** in "red".

On the right there is the graph field in which the measurement hysteresis curve is shown. On the right and bottom edge of the graph field the selected scaling is shown when the curve is drawn. The X axis represents the magnetic field strength **H** in **kA/m** whilst the Y axis can show the flux  $\Phi$  or the polarisation flux  $\Psi$  in **mVs** for a flux measurement and the induction **B** or the polarisation **J** in **mT** for a material measurement.

Using the buttons beneath the graph field the user can switch between the two graphs and the type of display. The entire **hysteresis** curve or the **demagnetisation** curve can be displayed. The **demagnetisation** curve is the second quadrant of the hysteresis curve in a larger resolution.

The tolerances are also shown with the  $\Psi$  and **J** demagnetisation curve.

Using the buttons on the right-hand side of the graph field the scaling of the X and Y axes can be changed upwards and downwards. Button **A** at the bottom right switches the automatic scaling system on and off and also automatically scales the curves when it is switched on.

The current magnet number and the current date and time are shown below the graph field.

In the top line of the menu there are functions which are explained in the next chapter.

The program can also be operated without a mouse if necessary. In this case the normal Windows™ functions must be used with "Alt" and the underline letters or the cursor keys.

The window has a permanent size of 640 \* 480 pixels.

When the window is minimized, the original colors are set again.

### 4.3 Selection

The selection menu can be opened by clicking the **Select** menu point.

**Select**

**Flux measurement**

Start with  Return  Mouse click  Button

Display result on unit  Switch relay

Phi r  Phi rg  Br  HG  JHC

Graph  Demag. Phi  Demag. Psi  Hyst. Phi  Hyst. Psi  None

Scale Psi  0.5  1  1.5  2  2.5  mVs  
 Auto H  200  300  400  500  kA/m

Print:  Result  Graph

Archive:  Standard  Specific.  Indiv. specific.  
 +Cpk indiv. Path specific. C:\

ASCII Archive: Path specific. C:\

Okay Cancel

The Selection menu for a flux measurement

To make the Robograph 2 as simple as possible to operate, the normal procedure for a measurement is preset in the Selection menu. When the measurement is started all the steps are

completed in order as per the preset procedure without having to be called up individually by the user, which makes the measurement considerably faster. Immediately afterwards the next measurement can be started.

The graph, print-out and archiving also can be called up manually after the measurement.

The top block shows what **type of measurement** is set. This setting cannot be changed here. It is determined by loading the appropriate tolerances.

The second block allows the method of **starting** the measurement to be set: By **Return** or a **mouse click** on the start field or using an external **button**. The selection is made by clicking the appropriate point with the mouse.

The third block allows the user to select whether, and if so, which **result** is to be displayed on the front panel of the unit. The results which may not be selected for the current measurement are shown in "grey".

If the result is not displayed all appear in "grey". Furthermore the user can select whether one of the **relays** is to be set after the measurement in accordance with the evaluation "Above / In / Below Tolerance" to start an appropriate external process.

The fourth block allows the user to select the **graph** which is to be displayed automatically after the evaluation process. Depending on the type of measurement the **demagnetisation** and the **hysteresis** curve of  $\Phi$  and  $\Psi$  or  $\mathbf{B}$  and  $\mathbf{J}$  respectively can be chosen. After the measurement the other graphs which were not selected can be called up from the main menu.

It is also possible to select **no** graph but this will only be beneficial for very slow PC's in terms of speeding up the process.

In the fifth block the **scale** of the selected graph can be selected. The number specifies the largest area which can be shown.

Depending on the type of graph the following scales can be used. For a flux measurement, demagnetisation  $\Phi$  or  $\Psi$ :

**0.5, 1, 1.5, 2 or 2.5 mVs and  
200, 300, 400 or 500 kA/m,**

for the hysteresis curve of the same measurement:

**1, 2.5, 5 or 7.5 mVs and  
400, 600, 800 or 1000 kA/m.**

For a material measurement, demagnetisation B or J:

**300, 400, 500, 600 or 1000 mT,**

and for the hysteresis curve:

**250, 500, 1000 or 1500 mT.**

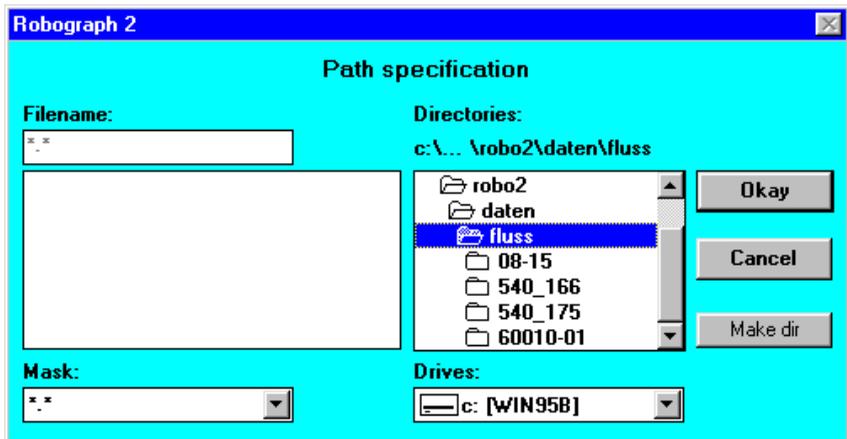
The scales for the field strength for the material measurement are the same as for the flux measurement.

If the automatic scaling facility has been selected, the scales which are available appear in "grey".

In the sixth block the user can select whether, and if so, how the result should be **printed** automatically after the measurement. Just the **result** or also the selected **graph** can be printed. If the graph is to be printed with the result, each magnet requires a separate piece of paper. If the print-out option is disabled, the selections appear in "grey".

If no graph has been selected, the demagnetisation curve  $\Psi$  or J is printed out automatically if **Print Graph** is selected.

In the last block the automatic **archiving** can be selected. The procedures **Standard**, **Specification** or **Individual Specification** are available. This determines where the measurement will be archived. If Standard has been selected the measurements will be archived on the hard drive under the type of measurement, magnet number, date and time. For Specification another path can be entered for all the subsequent measurements, for example a diskette drive or a network. This can be written direct into the text window. Alternatively a dialogue field can be opened by pressing the "Path Specification" button and an existing path can be selected or a new directory opened in the window.



File selector box for specifying the archiving path

If the "Make dir" button is pressed, the following entry field appears:



Entry field for the directory name

The entered directory will be generated in the previously selected directory.

For Individual Specification the system will ask for the desired path and the file name after every measurement. Measurements saved under Individual Specification **cannot** be evaluated in the **long term statistics**.

Please note that each archived measurement takes up approx. 2.5 kBytes of space so that automatic archiving should only be selected if it is really required. If Cpk flux measurements are conducted, they will be saved as a group without graphs if archiving has been selected which means a vast reduction in storage space. If the Cpk measurements are to be saved both as a group and individually with their graphs, the point "+**Cpk individual**" must also be activated. This can only be done for flux measurements. It is not possible to archive Cpk measurements only individually.

If archiving has been disabled, the selection possibilities appear in "grey".

Using the **ASCII archiving** point the measurements are archived as a text file without graphs and can be read in any editor. Using this function the results can also be evaluated on computers on which the Robograph software is not installed. It is not possible to evaluate the ASCII archive using the Robograph software. A path is specified in the selection menu using the same procedure described above for archiving for the ASCII archive. A structure broken down by magnet number and time is then created in the selected directory.

The selection menu can be closed by clicking the **OK** or **Cancel** button. If OK is pressed the displayed values will be saved and the main menu updated. If Cancel is pressed, all the values will be reset to their original status.

## 4.4 System test

When starting a measurement a **system test** is first performed in the Robograph 2. This test checks the hardware and the connected sensors. The possible errors which may occur are:

- **Non-permissible current flux before the measurement**
- **Output stage in overload**
- **Supply voltage incorrect**
- **Overheating**
- **Hall sensor error**
- **Error in the measurement coil**
- **No response from Robograph 2**

In all cases an **error message** is output and the measurement is aborted.

The first four errors will lead to the deactivation of the Robograph 2 and the **red "Error" light will flash**. In this case a **hardware error** must be assumed and an inspection is required. An overheating error can only occur if the fan is defective or the air circulation is blocked.

The errors on the sensors lead to the red "Error" light being set. The Robograph 2 does not necessarily have to be switched off, however, after remedying the error a new measurement may be started.

During the system test the field is "blue", after the test has been successfully completed it turns "green" and if an error has occurred it turns "red".

## 4.5 Flux measurement

The flux measurement is conducted in accordance with **BOSCH test instructions No. 3 139 918 950**. Using this measurement, finished magnet segments are subjected to quality tests at random after production.

**Hard magnetic magnet segments** made of ferrite, as used in electric motors, are placed in a measurement insert which is the same shape as the segment which in turn is placed in a yoke and the segments are then magnetised in sequence in both directions well above the saturation level.

The magnet segment is surrounded by a flux measurement coil with **n** turns and only fills part of the length of the air gap in the measurement insert. The voltage induced in this coil is calculated as follows:

$$u_F = -n \cdot \Delta\Phi / \Delta t$$

where

$\Phi$  ( Phi ) = magnetic flux

$\Delta t$  = sampling time interval

$\Delta\Phi / \Delta t$  = change in magnetic flux per unit of time

The induced voltage is integrated and divided by the number of turns. This produces the following flux:

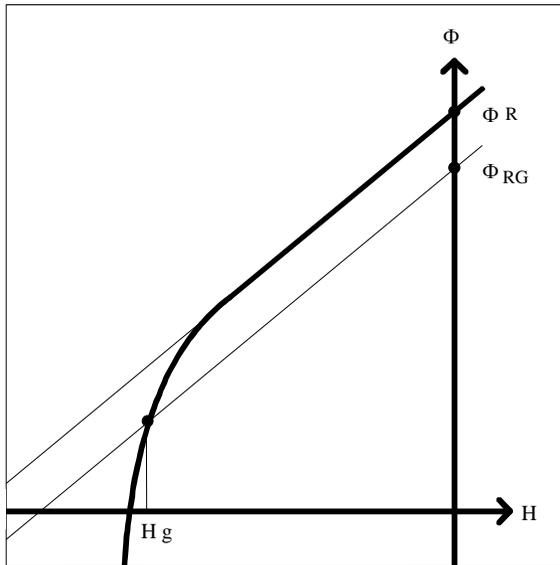
$$\Phi = -1/n \cdot \sum u_F \cdot \Delta t$$

Since the measurement insert is made of soft magnetic material, the field strength **H** can be regarded as homogeneous over the area. At the rear of the air gap there is a Hall sensor for measuring the magnetic field strength **H**.

By the simultaneous measurement of the field strength and the magnetic flux the complete **hysteresis curve  $\Phi$  against  $H$**  of the segment is recorded. It can be viewed under graph  $\Phi$  and supplies the value of the remanence flux  $\Phi^*_R$  when  $H = 0$ .

Furthermore the remanence flux  $\Phi^*_{RG}$  is to be calculated after the influence of a specified opposing field  $H_g$  to find how strong the segment has been demagnetised by this opposing field.

For this purpose a tangent to the hysteresis curve is placed through the point  $\Phi^*_R$ . Then a straight line is drawn through the point of the hysteresis curve at the opposing field  $H_g$  parallel to this tangent. The point at which these straight line intersects the Y axis when  $H = 0$  gives the desired value is  $\Phi^*_{RG}$ .



Definition of  $\Phi^*_R$  and  $\Phi^*_{RG}$

The idea behind this method is to obtain a statement on the pure material characteristics of the segment at  $\mathbf{H}_g$  which cannot be read direct from the  $\Phi$  curve.

In physical terms the flux can be calculated as follows:

$$\Phi = \mathbf{B} \cdot \mathbf{a}$$

and

$$\mathbf{B} = \mathbf{J} + \mu_0 \cdot \mathbf{H}$$

to obtain

$$\Phi = \mathbf{a} \cdot \mathbf{J} + \mathbf{a} \cdot \mu_0 \cdot \mathbf{H}$$

where

$\mathbf{B}$  = magnetic induction within the coil

$\mathbf{J}$  = magnetic polarisation of the segment

$\mathbf{a}$  = area of the coil

$\mu_0$  = magnetic field constant

The magnetic properties of the segment material are shown in the polarisation  $\mathbf{J}$ . In the flux  $\Phi$ , however, there is still the linear proportion  $\mathbf{a} \cdot \mu_0 \cdot \mathbf{H}$  which distorts the hysteresis curve.

The polarisation is not linear and has the desired hysteresis form. Multiplied by the area  $\mathbf{a}$  of the segment we obtain the polarisation flux  $\Psi$  ( **Psi** ).

$$\Psi = \mathbf{a} \cdot \mathbf{J}$$

To obtain  $\Psi$  the linear part  $\mathbf{a} \cdot \mu_0 \cdot \mathbf{H}$  is deducted from  $\Phi$ .

$$\Psi = \Phi - \mathbf{a} \cdot \mu_0 \cdot \mathbf{H}$$

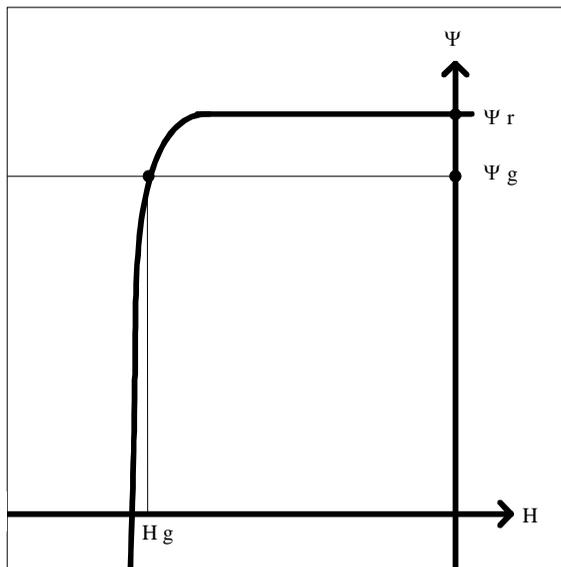
Since the area  $\mathbf{a}$  of the segment is not known, the following method is used.

Since this measurement is only permitted for **hard magnetic** materials, it is assumed that the polarisation  $\mathbf{J}$  of the segment material in the area around  $\mathbf{H} = 0$  is constant, and therefore that the hysteresis curve of  $\Psi$  runs horizontally.

Therefore the gradient of the tangent of the  $\Phi$  curve corresponds to the value  $a \cdot \mu_0$ .

By subtracting a straight line through the zero point with this gradient of the  $\Phi$  curve, we can obtain the  $\Psi$  curve.

Please note that the measurement material must be sufficiently hard magnetic to ensure that this method produces the physically correct result.



Definition of  $\Psi_r$  and  $\Psi_g$

The hysteresis curve of the polarisation flux  $\Psi$  represents the pure material properties of the segment and is much more informative in its form than the  $\Phi$  curve.

The parallel straight line through the flux  $\Phi$  at opposing field  $H_g$  has now become a horizontal line so that the value of  $\Psi_g$  at the opposing field  $H_g$  which can be read directly off the  $\Psi$  demagnetisation curve is identical to the required value  $\Phi^*_{RG}$ . This also applies if the segment is not sufficiently hard magnetic. The rectangular shape of this demagnetisation characteristic curve is decisive for the resistance of the permanent magnets under the influence of strong opposing fields.

If the segment is evaluated by K9 standard (see chapter 4.10) a third result  $H_{GF(80)}$  is calculated.  $H_{GF(80)}$  is the field strength that is necessary to demagnetize the segment to 80% of  $\Phi^*_R$ .

In order to carry out the flux measurement the measuring insert is placed in the yoke, which is then screwed shut without any force. The measuring coil of the measuring insert is now connected and the Hall sensor is pushed into the bracket with the plastic cover upwards and then tightened by means of the knurled screw. Ensure that the bracket is pushed in until it contacts the locating pin, as it acts as magnet end stop and so determines the position of the magnet.

The corresponding flux tolerance containing the limits and the number of windings is entered before the first measurement with this measurement insert.

Every magnet must be pushed centrally right up to the end stop and securely clamped with the plastic strips. Enormous forces act during the measuring process, so, if the magnet can move during the measuring process, it is possible that the result is false or even that a coding error is produced.

## 4.6 Material measurement

The material measurement allows the magnetic properties of material samples of any materials to be measured. These material samples must be ground flat on both sides so that they will fit into the material measurement insert without creating an air gap and their diameter must be more than 10 mm so that the measurement coil is covered in full. They should have a thickness of not less than 3 mm.

The measurement is performed in the form of a J-compensated measurement. Two identical measurement coils are used, each of them consisting of a bottom section and a top section and which are inserted into the measurement inserts.

A measurement with coils around the material samples which can supply a more accurate result if the exact sample size is known, is not completed for practical reasons. The shape of the sample is often irregular so that the area cannot be precisely determined and winding the coil around each sample would take too much time and cause too many errors. In addition the wound sample is very sensitive. A measurement with a J-compensated coil is also possible with the Robograph 2.

With the method adopted by the Robograph the induction is measured at the surface between the material sample and the measurement insert. The measurement coils are always the same. The influence of the measurement insert is minimised by using a highly permeable metal alloy and is not shown before values which are well outside the parameters to be measured are reached. This influence is shown in the form of a bend in the saturation area of the hysteresis curve.

The material sample is placed in the middle of the front **B** coil and clamped without any play. The **surface** must be **free of ferrite splinters** since these may damage the sample and the surface of the measurement insert or even the measurement coils. At the rear there is an identical **H** coil and on the left also the Hall sensor.

During the measurement the following voltage is induced in the B coil:

$$u_B = -n \cdot \Delta \Phi_M / \Delta t$$

At the same time the following voltage is induced in the H coil:

$$u_H = -n \cdot \Delta \Phi_A / \Delta t$$

where

$\Phi_M$  (Phi) = magnetic flux in the material sample

$\Phi_A$  (Phi) = magnetic flux in the air

$\Delta t$  = sampling time interval

$\Delta \Phi / \Delta t$  = change in the magnetic flux per unit of time

$\Delta t$  and the number of turns  $n$  are the same in both cases.

In physical terms the flux can be calculated as

$$\Phi = B \cdot a$$

and

$$B = J + \mu_0 \cdot H$$

to obtain

$$\Phi = a \cdot J + a \cdot \mu_0 \cdot H$$

where

$B$  = magnetic induction within the coil

$J$  = magnetic polarisation of the segment

$a$  = area of the coil

$\mu_0$  = magnetic field constant

This results in the following

$$\Phi_M = a \cdot J + a \cdot \mu_0 \cdot H$$

and

$$\Phi_A = a \cdot \mu_0 \cdot H$$

The B coil and the H coil are connected in series with opposing phases so that the difference in the induced voltages is formed:

$$u_J = u_B - u_H$$

$$u_J = -n \cdot \Delta(\Phi_M - \Phi_A) / \Delta t$$

$$u_J = -n \cdot a \cdot \Delta J / \Delta t$$

The induced voltage is integrated and divided by the constant  $k = (-n \cdot a)$  determined by the calibration. This means that the polarisation  $\mathbf{J}$  is

$$J = (1/k) \cdot \sum u_J \cdot \Delta t$$

At the same time the field strength  $\mathbf{H}$  is measured during the measurement using the Hall sensor, which means that the complete **hysteresis curve J against H** is recorded. This curve represents the pure material properties of the material sample. This method of the J-compensated measurement is used to minimise the influence of the measurement insert since this influence is shown in both measurement coils with almost identical results and is therefore compensated. By adding a straight line through the origin with a gradient of  $\mu_0$  the **hysteresis curve B against H** can also be viewed.

The values  $\mathbf{B}_r$ ,  $\mathbf{H}_G$ ,  $\mathbf{jH}_C$  and  $\mathbf{b}$  are determined from the demagnetisation curve J of the material sample.

The remanence induction  $\mathbf{B}_r$  is the induction at a field strength of 0. It is identical to the value  $\mathbf{J}_r$ , the intersection of the J curve with the Y axis.

The coercitive field strength  $\mathbf{jH}_C$  is the intersection of the J curve with the X axis and determines the field strength at which the material was completely demagnetised.

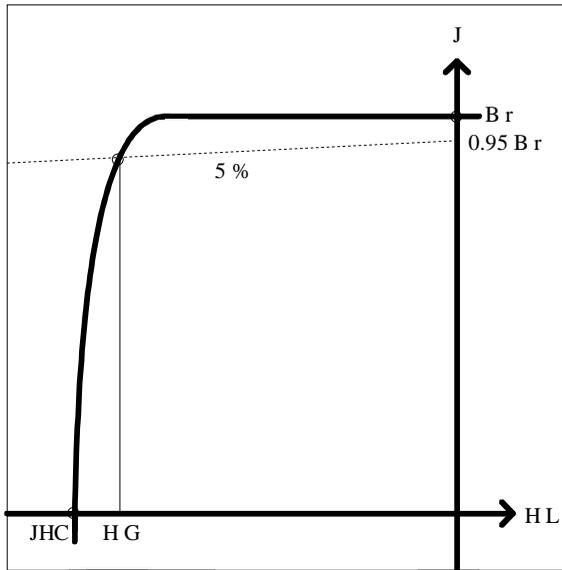
For calculating the limit field strength  $\mathbf{H}_G$  which states how far the material may be loaded without damaging the magnetisation, the following procedure is adopted.

A straight line is drawn through the point  $(0.95 \cdot \mathbf{B}_r)$  on the Y axis with the gradient  $(0.05 \text{ T} / 1000 \text{ kA/m})$ . The intersection of this straight line with the demagnetisation curve determines the limit field strength  $\mathbf{H}_G$ . With hard magnetic materials  $\mathbf{H}_G$  is at the start of the kink in the demagnetisation characteristic curve.

$\mathbf{b}$  is finally calculated from  $\mathbf{jH}_C$  and  $\mathbf{H}_G$ :

$$\mathbf{b} = \mathbf{H}_G / \mathbf{jH}_C$$

This value is given as a percentage.



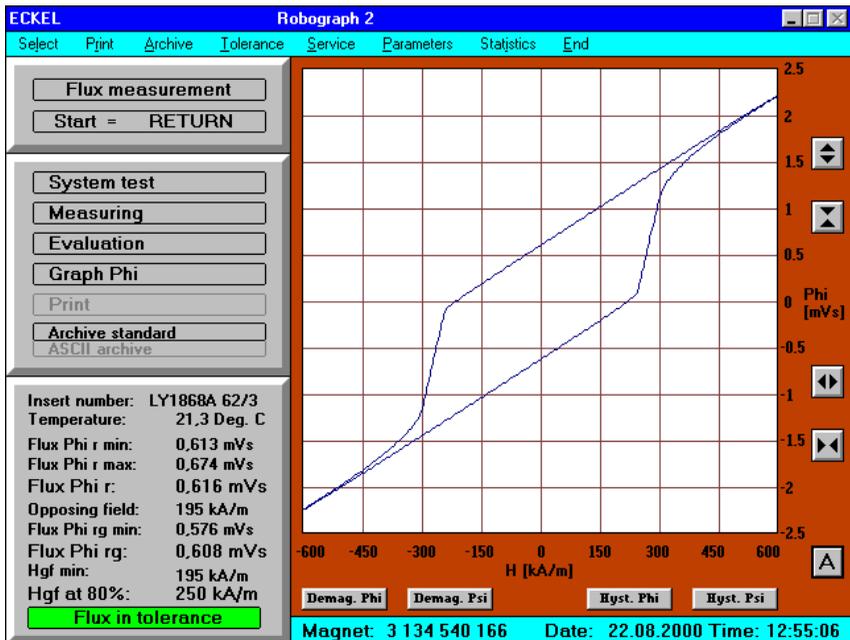
Definition of  $B_r$ ,  $JH_C$  and  $H_G$

During the measurement the field is "blue". After the successful completion of the measurement the field turns "green". If an error occurs, the field turns "red" and the measurement is aborted. The message "Measurement interrupted" then appears.

After the measurement the evaluation of the measured data takes place. The evaluation field is also "blue" and then "green" or "red". Errors may occur if, for example, the Hall sensor has been inserted the wrong way round or the magnet has moved a great deal during the measurement. The large number of possible error messages which do not occur during the normal procedure, however, is listed in Chapter 5.1.

## 4.7 Graph

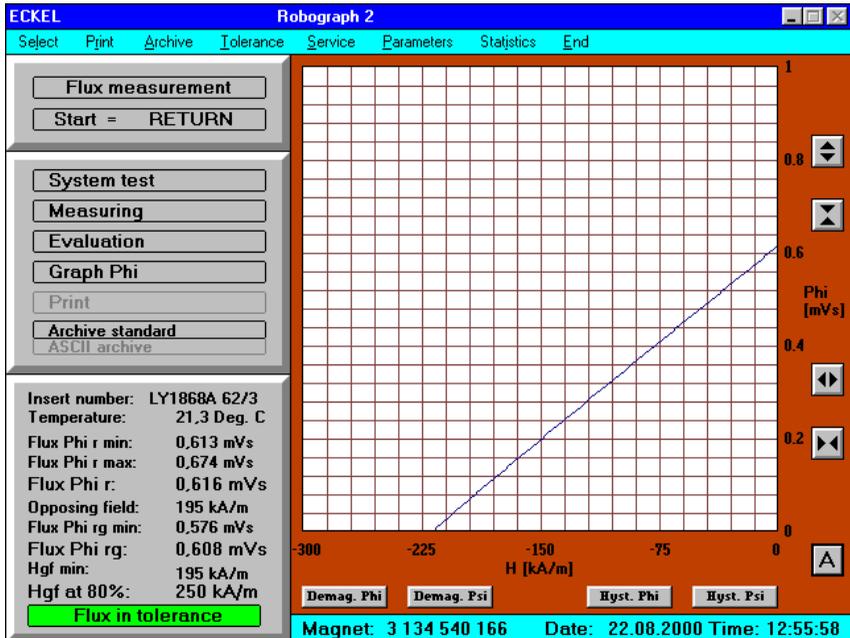
After the measurement and the calculation of the result, the **graph** selected in the Selection menu is displayed. For both measurements there is a total of four graphs to choose from. For the flux measurement these are the **hysteresis** and **demagnetisation Phi ( $\Phi$ )** graph as well as the **hysteresis** and **demagnetisation Psi ( $\Psi$ )**. For demagnetisation  $\Psi$  the set tolerances are also displayed. If a tolerance has been maintained, it is shown in "green" if it has been exceeded it is shown in "red".



Hysteresis  $\Phi$

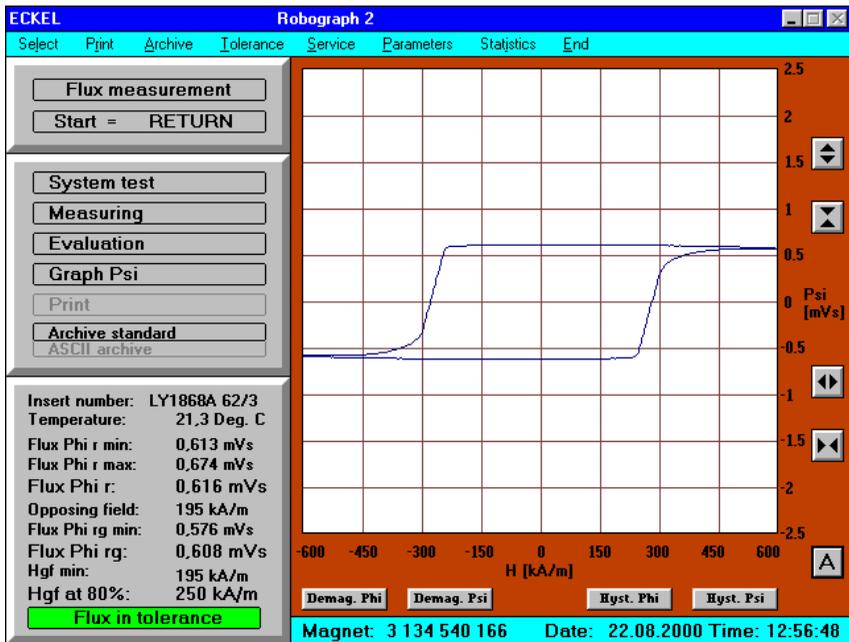
The **hysteresis  $\Phi$**  represents the actual curve measured.

The **demagnetisation**  $\Phi$  represents the top left-hand quadrant of the hysteresis curve in an enlarged resolution. For hard magnetic materials such as those normally used for a flux measurement, it plays a minor role since the interesting part of the curve is not shown by it.



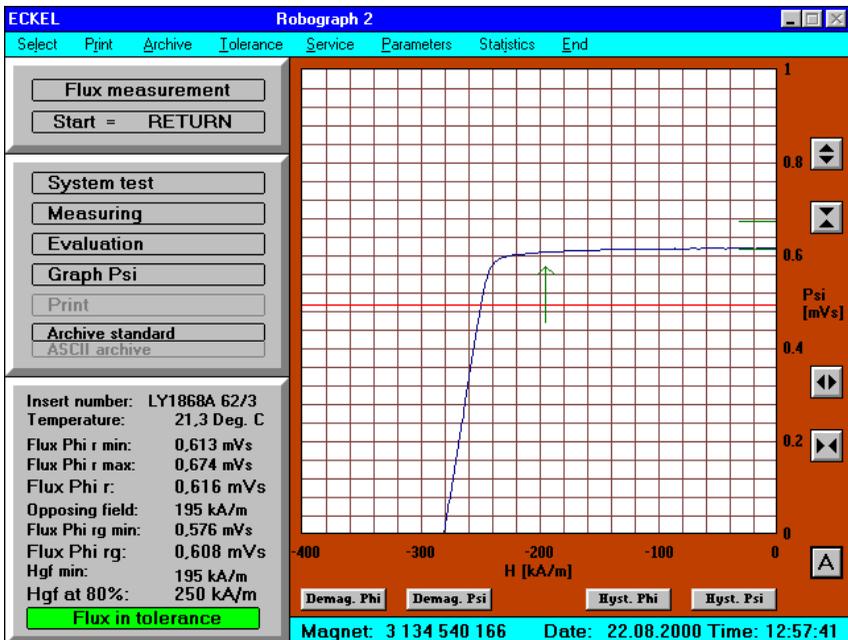
Demagnetisation  $\Phi$

The hysteresis  $\Psi$  is calculated from the hysteresis  $\Phi$ . Using BOSCH test instruction No. 3 139 918 950 the hysteresis curve is tilted by the gradient of the curve at the remanence point where  $H = 0$  so that it is horizontal there. If the magnet is sufficiently hard magnetic which can basically be assumed for segments, the pure material properties of the magnet can be provided.



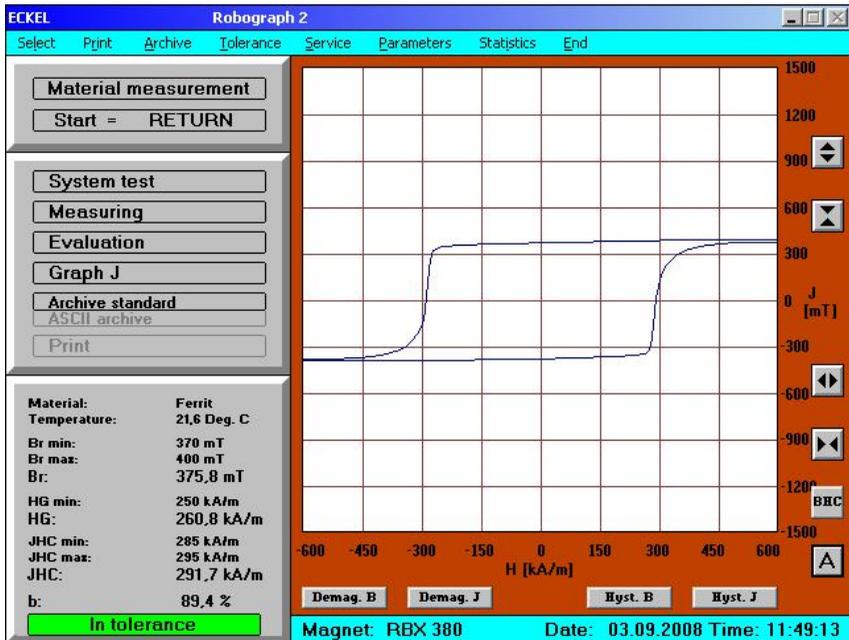
Hysteresis  $\Psi$

The **demagnetisation**  $\Psi$  again represents the top left-hand quadrant of the hysteresis  $\Psi$ . It shows the **most interesting** part of the curve. This shows how the magnet acts during its demagnetisation process. The tolerance bars at  $\Phi^*_R$  respectively  $\Psi_r$  have been drawn in and the minimum  $\Psi_g$  value which corresponds to the minimum  $\Phi^*_{RG}$  is shown in the form of an arrow. If the  $\Phi^*_R$  value is between the tolerance limits the tolerance bars will be shown in "green". If one of the tolerance limits is exceeded, the corresponding tolerance bar will be shown in "red". The  $\Phi^*_{RG}$  value is adequate if the demagnetisation curve runs above the tip of the arrow. If this is not the case, the arrow is also shown in "red" rather than "green".



Demagnetisation  $\Psi$

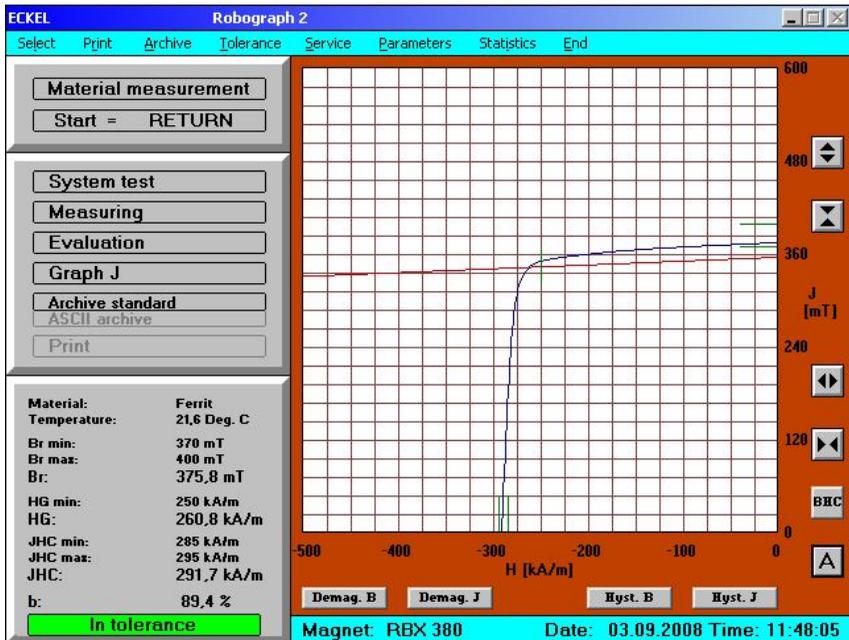
For the material measurement the **hysteresis** and **demagnetisation B** and the **hysteresis** and **demagnetisation J** can be shown. For the demagnetisation J the set tolerances and the determining straight line for  $H_G$  is also shown. In this case, too, the tolerances are shown in "green" or "red".



### Hysteresis J

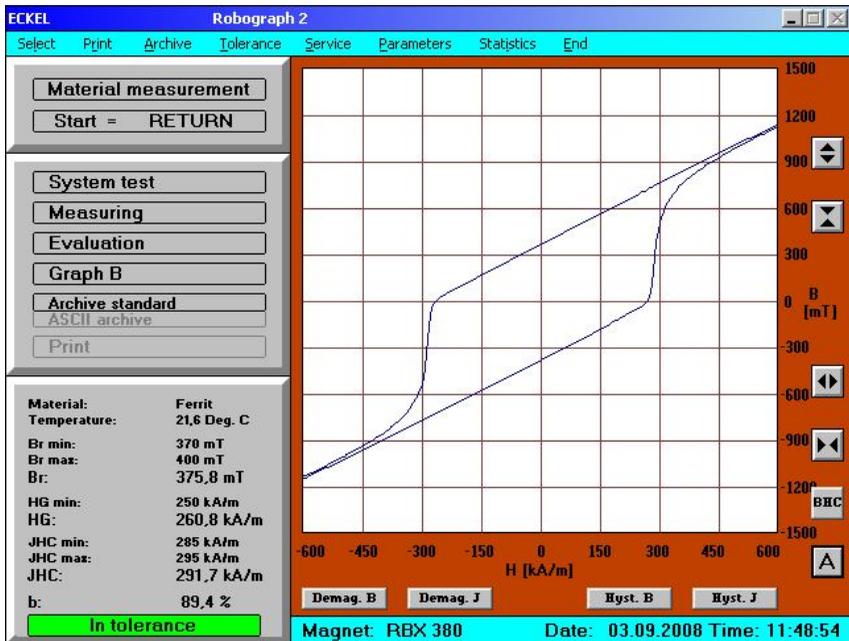
For the material measurement the **hysteresis J** represents the actual measurement curve since the J-compensated measurement supplies better results for this purpose.

The **demagnetisation J** once again represents the top left-hand quadrant of the hysteresis J. It comprises the **most interesting** part of the curve. This shows how the magnet acts during its demagnetisation process. The tolerance bars at  $B_r$  respectively  $J_r$ ,  $J_H C$  and the limit field strength for this material  $H_G$  have been drawn in. The straight line which falls towards the left-hand side has also been drawn in. The point at which it intersects the demagnetisation curve determines the value  $H_G$ . If the values are between the tolerance limits the tolerance bars will be shown in "green". If one of the tolerance limits is exceeded, the corresponding tolerance bar will be shown in "red".



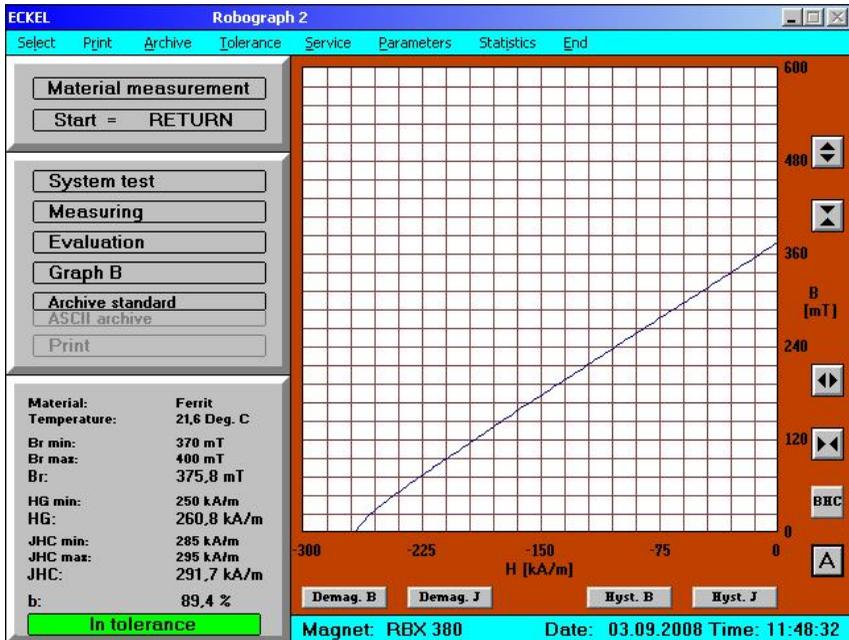
Demagnetisation J

Since the normal representation of the **hysteresis B** is often required, this can be calculated by tilting the hysteresis J curve through  $\mu_0$ . This corresponds to the hysteresis curve which would have been measured without J compensation.



Hysteresis B

The **demagnetisation B** once again represents the top left-hand quadrant of the hysteresis B. For soft magnetic materials this curve can also provide an impression of the demagnetisation properties.



Demagnetisation B

After displaying the selected graph the other graphs can also be called up using the keys below the graph field. All the graphs can be **scaled** in the X and Y directions using the keys on the right-hand side of the graph field. If the automatic scaling function (button "A") is active, the graphs are shown in such a way that all the axis intersections are visible. For the demagnetisation  $\Psi$  and J curves the graphs will automatically be scaled in such a way that the tolerance bars are also visible.

At material measurement an additional button is visible beside the graphik field. This button allows switching between the display with  $\mathbf{H}_G$  and the display with  $\mathbf{B}\mathbf{H}_C$  without entering the Parameter menu. The function is identical to the preselection in the Parameter menu.

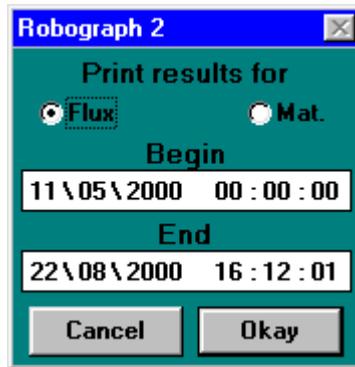
## 4.8 Print-out

For printing out it is possible to print with or without graphs.

If only the **result** is printed, a header is placed on the print-out containing all the main data for the measurement. After this a line is filed for each measurement showing the results and the evaluation.

With laser printers the page is automatically ejected when it is full and a new page is started. The page is also ended if the tolerance, magnet number or other data which are shown in the header are changed so that the print-out would no longer be correct for subsequent measurements. Printing a graph, on the other hand, does not lead to the page being ejected with the result print-out. This is continued after the graph has been printed. The started page can also be ejected at any time under the "**Print**" menu point. A **result** print-out can also be started or continued **after** each measurement under this menu point if the automatic print-out facility has not been selected.

Archived measurements can also be printed in the form of a result. Using the menu point "**Archive results**" a file selector box is opened to select the **magnet number**. If a **date file** is also selected, this date is also automatically taken as the **data start**. Otherwise the first date in this file would be taken as the data start. A time selection window would then be shown.



Time selection window

The period for which a print-out is required can be selected here.

The other method is to print the result of the measurement **with the graph**. For this print-out, each measurement requires one sheet of paper. The graph which is currently displayed on the **monitor**, in other words the selected graph, which was also selected for the graph output, is always the one which is printed. If no graph has been chosen in Selection, the demagnetisation Psi or J graph will be printed if the system is set for automatic printing. The **graph** print-out can also be started manually **after** each measurement. The graph can also be printed "**with remark**". In this case, before each graph is printed, the system asks for the additional information which is to be printed out with the graph. The print-out is formatted for A4 papersize. If shorter formats are used, the last rows may be missing.



Entry window for the remark

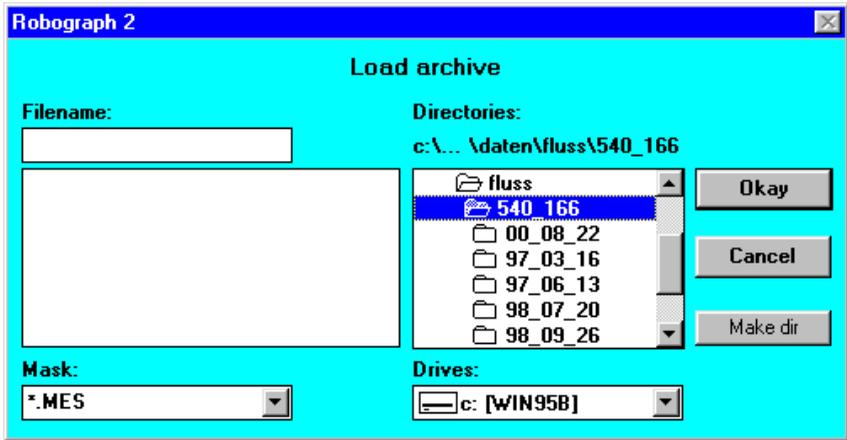
Under "Parameters" the user can select whether or not the **tolerance bars** should be printed with the demagnetisation curve  $\Psi$  or J. If an appropriate printer is connected, a **colour print-out** can also be activated here which will print the graph in the same colours as those on the monitor.

With the **Cpk** measurement, too, the user can select between printing the result without a graph and individual printing with a graph. In addition, **both** can be selected. Please note that **within** the Cpk measurement it is **not possible to start** printing individual measurements with graphs **by hand**, but this option must be selected. The entire **result** can also be printed out by hand **after** the measurement, however. An archived Cpk measurement can only be printed if it has first been loaded.

## 4.9 Archiving

The measurements may be archived if desired. For archiving **individual** measurements all the details of the measurement and the graph for the **demagnetisation curve**  $\Psi$  or J are saved. This archiving method can be set in the selection menu and then takes place automatically. A **path** must first be selected for the archiving process or **standard** archiving can be selected. For standard archiving the following path is used: **C:\ROBO\DATEN\FLUSS** (or **STOFF** (Material) or **CPK**)\ the last eight figures of the magnet number (**\_540\_089**)\ date (**95\_03\_12**)\ time (**17\_46\_55**).**MES** (or **CPK**). Please note that the last eight figures of the magnet number must be significant. It is also important to know that for this type of archiving the assignment to a magnet number and the date can only be produced by the path. If a file is removed from this position, this assignment can only be re-established by reading it with the Robograph 2.

To make things more clear the complete **magnet number** and **Fluss**, **Stoff** (material) or **Cpk** is displayed when reading the archive files in the **extended file selector box**. This additional function can be deactivated under "Parameters".



File selector box

The measurement can also be saved after measurement by hand using the menu point "**Archive**". In this case, too, the path setting in Selection is used. If **Individual Specification** is set, a file selector box is opened in which a path can be selected or created. The name of the file can also be changed. Measurements which have been saved using **Individual Specification** of the path **cannot** be evaluated with the long term **statistics**. Every archived measurement requires approx. 2.5 kByte of space. If the whole curve is saved, the required space increases up to approx. 10 kByte.

For Cpk measurements, too, the selected path is used. In this case the entire **group** of measurements are archived in **one** file **without graphs**. If "+CPK-Individual" is selected the individual measurements will also be archived with their graphs.

All types of measurement can also be filed as an **ASCII archive** without graphs. For this purpose a **text file** is created which can be read in any text editor. In this way the measurement results can, for example, be read by a network of computers on which the Robograph 2 software has not been installed. For this archiving method the path set in the Selection menu is always used in which again the path structure described above is created. It is not possible to specify the individual file name and path in this case. The file suffix is **.ASC**. The saved ASCII archives **cannot** be read and evaluated by the Robograph 2.

**Loading** archived measurements also takes place under the menu point "Archive". Another file selector box is opened in which the desired path can be set at which the files contained in this path are shown in the left-hand window. For standard or specification archiving these files are sorted by **hour / minute / second**.

**Individual measurements** are shown immediately after being loaded with all details and the demagnetisation curve  $\Psi$  or J. No other graphs can be selected. The measurement can then be printed with the graph. Even if the method used to measure the archived measurement is not the same as the current measurement method, the old setting will become active again when the archived measurement is displayed. The user can return to the current program interface by pressing "RETURN".

After being loaded, **Cpk measurements** are shown in a text window which is identical to the text window which appears immediately after a Cpk measurement. This text window can also be printed.

## 4.10 Tolerances

Under the menu point "**Tolerance**" the desired tolerances for flux and material measurements can be set. The **name** of the tolerance file is the **magnet number** so that only one tolerance can be entered for each magnet number. "**Current Tolerance**" contains the current setting. It also shows whether this is a flux or a material measurement since the tolerance values depend on the type of measurement.

The image shows a software dialog box titled "Current tolerance" with a green background. The title bar is blue and contains the text "Current tolerance" and a close button. The main content area is green and contains the following fields and controls:

- Flux measurement** (Section Header)
- Magnet number:** 3 134 540 224
- Evaluation:**  K4  K9
- Insert number:** LY 1868 A 167/1
- Nickname:** (empty text box)
- Buyers name:** (empty text box)
- Turns:** 461
- Flux Phi r min:** 0,304 mVs
- Flux Phi r max:** 0,322 mVs
- Opposing field:** 280 kA/m
- Flux Phi rg min:** 0,286 mVs
- Calibration Psi:** 1,000
- Material:** 5 997 946 000
- Hall value:** 2,0070  individual
- Temp-C. H:** 0,220 % / °C
- Temp-C. Psi:** — 0,200 % / °C
- Use Calibration  Calculate Phi rg min
- With Hardware 2.00:**  Field Strength Limit

At the bottom of the dialog box are three buttons: "Okay", "Save", and "Cancel".

Current tolerance for flux measurement

**The measurement method can be changed by loading another tolerance or setting a new tolerance.** The current tolerance is the last tolerance to be loaded or created. It is saved and loaded when the program is started automatically.

The current tolerance can be **changed** as necessary. It is not possible to enter incorrect figures.

The **magnet number** must be significant and also specifies the name of the tolerance file.

**Evaluation K4 or K9** must be selected.

Evaluation **K4** gives  $\Phi^*_R$  and  $\Phi^*_{RG}$  as results that are compared to the limits. With **K9** additionally the value  $H_{GF(80)}$  is calculated and compared to  $H_{GF\ min}$ .

At Cpk measurement with **K4** the Cpk value of  $\Phi^*_R$  must be at least 1.33. For  $\Phi^*_{RG}$  no Cpk value is calculated.

With **K9** for  $\Phi^*_R$ ,  $\Phi^*_{RG}$  and  $H_{GF(80)}$  Cpk values are calculated, that must be at least 1.00 in all cases.

Bosch has determined **K9** as a special evaluation of magnets for starter motors.

**Insert number** is written on the measurement insert and must be entered for identification reasons.

**Nickname** (of the magnet) and **buyers name** are only for information and are shown on the printout.

**Turns** is the number of turns of the coil of the measuring insert. It is marked on the insert and must be entered correctly since it scales the measurement result.

**Flux  $\Phi^*_{R \text{ min}}$ ,  $\Phi^*_{R \text{ max}}$ , opposing field  $H_g$ , flux  $\Phi^*_{RG \text{ min}}$**  and maybe  $H_{GF \text{ min}}$  are defined in the magnet drawing.

If "**Calculate  $\Phi^*_{RG \text{ min}}$** " has been selected under "Parameters" this value cannot be altered here, but is automatically set to **0.94\*  $\Phi^*_R \text{ min}$** .

If " **$\Phi^*_{RG \text{ min individual}}$** " has been selected under "Parameters", anyway automatic calculation can be activated for this tolerance. Else this value can be entered as desired below  $\Phi^*_R \text{ min}$ .

**Calibration  $\Psi$**  is used to compensate small deviations between measurement inserts of the same type. This is only done by Bosch and then marked on the insert. If not existing, enter the value 1.000.

**Material** is only for information and is shown on the printout.

The **Hall value** is shown on the Hall probe and must be entered correctly since it scales the measurement result. If the older version of the measurement inserts with changeable Hall probe is used, where always the same Hall probe is used, the Hall value is entered at "Parameters". If the new type with inbuilt Hall probe is used, activate "individual" and enter the individual Hall sensor value to the tolerance.

At **Temp-C. H** and **Temp-C. B** the temperature coefficients of the material for temperature compensation are entered. They depend on the material. Standard values are 0.4 %/°C for H and -0.2 %/°C for  $\Psi$ .

If you use material according to Bosch specification, you can use the **Selection** button to open a temperature coefficient table for different materials.

Temperature coefficients							
Br min mT	Hcj min kA/m	HG min kA/m	BOSCH Standard			Tk (Hcj) %/K	Tk (Br) %/K
400	260	240	5 976	350 000	DM1S06-29-26-a	0.4	-0.2
400	300	280	5 983	110 000	DM1S11-29-30-a	0.36	-0.2
390	355	330	5 997	602 000	DM1S16-28-35-a	0.32	-0.2
415	270	250	5 983	100 000	DM1S10-32-27-a	0.39	-0.2
410	330	310	5 997	944 000	DM1S21-27-39-a	0.34	-0.2
380	300	280	5 976	830 000	DM1S07-27-30-a	0.36	-0.2
390	340	300	5 983	120 000	DM1S07-27-24-a	0.33	-0.2
360	380	360	5 997	601 000	DM1S15-25-38-a	0.30	-0.2
420	290	270	5 997	942 000	DM1S19-27-29-a	0.37	-0.2
415	320	290	5 997	943 000	DM1S20-27-32-a	0.35	-0.2
400	340	320	5 997	945 000	DM1S22-27-34-a	0.33	-0.2
380	390	370	5 997	948 000	DM1S25-27-39-a	0.29	-0.2
430	240	220	5 997	940 000	DM1S17-27-24-a	0.41	-0.2
420	385	365	5 997	949 000	DM1S25-27-39-a	0.2	-0.2
430	346	326	5 997	946 000	DM1S23-27-25-a	0.22	-0.2
450	274	254	5 997	941 000	DM1S18-27-28-a	0.24	-0.2
460	310	290	to be defined			0.17	-0.2
450	340	320	to be defined		to be defined	0.16	-0.2
440	380	360	to be defined		to be defined	0.15	-0.2

OK

Temperature coefficient table

Here you can select a material and by clicking OK, the coefficients are entered to the tolerances.

**Use Calibration** does not mean the calibration  $\Psi$  above. It allows changing the results according to a reference segment. For this after activation at "Service" a flux measurement insert calibration must be executed. This was a customer's wish and is not part of the Bosch specification. **This option must not be used for Bosch magnets!**

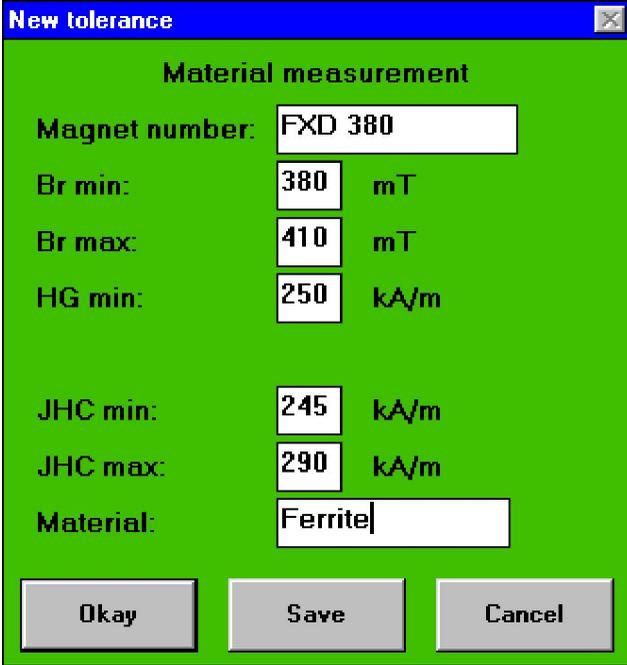
**Field Strength Limit** will limit the maximum magnetizing field during measurement to see how the magnet reacts on poor magnetization. The maximum field strength is entered before the measurement. For this option a test run for training is necessary for each different segment. See at "Service". This option works only with hardware versions from 2.00.

This is a special test program and must be deselected for normal operation.

The changes are valid as from the next measurement if it has been confirmed with "**OK**" or "**Save**". A new tolerance can also be created using "Save". However, it is not possible to change the measurement method here. If the current tolerance has been changed but not saved, a warning is given when the program is terminated or a new tolerance is loaded.

A tolerance which has been created earlier can be loaded using "**Load**". It will be stored on the path **C:\ ROBO\ TOLERANZ \ FLUSS** (or **STOFF (Material)**)\ the last eight figures of the magnet number (**\_540\_089**).**TOL** and can be selected in the file selector box. Here, too, the complete magnet number can be displayed. When a tolerance has been loaded, it automatically becomes the current tolerance.

New values for a new magnet number can be entered using "**New Tolerance Flux / Material**". These tolerances also become the current tolerance automatically when they are confirmed or saved. The path and name will be given to save them. However, they can be changed so that using this method, tolerances can also be created with names which are not identical to the magnet number.



The image shows a dialog box titled "New tolerance" with a blue header bar and a green background. The title bar includes a close button (X) on the right. The main content area is titled "Material measurement" in bold black text. Below this title, there are several input fields and labels:

- Magnet number:** A text box containing "FXD 380".
- Br min:** A text box containing "380" followed by "mT".
- Br max:** A text box containing "410" followed by "mT".
- HG min:** A text box containing "250" followed by "kA/m".
- JHC min:** A text box containing "245" followed by "kA/m".
- JHC max:** A text box containing "290" followed by "kA/m".
- Material:** A text box containing "Ferrite".

At the bottom of the dialog box, there are three buttons: "Okay", "Save", and "Cancel", each in a grey rectangular box.

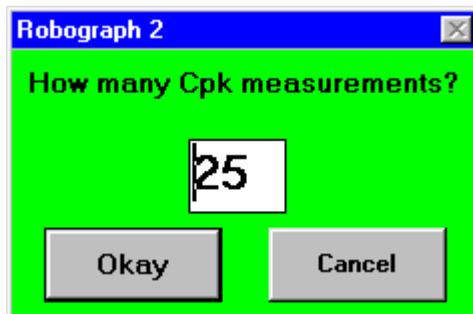
New tolerance for material measurement

## 4.11 Statistics

### 4.11.1 Cpk calculation

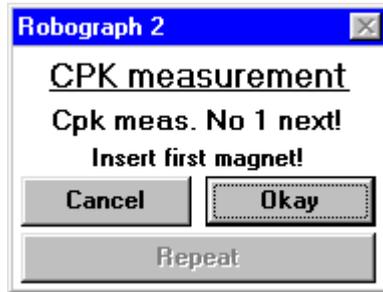
**BOSCH test instructions No. 3 139 918 950** states, that a **statistical evaluation** must be completed for the random sample measurement of magnet segments. This evaluation is designed to provide information on all segments produced. The method of Cpk measurement required for this purpose is integrated in the Robograph 2 software. For this type of measurement the group of measurement random samples are evaluated as a whole. This method forms the **mean value** and the **standard deviation** of the measured  $\Phi^*_{R}$  and  $\Phi^*_{RG}$  values. The Cpk value provides the difference of the mean value from the nearest limit value divided by three times the standard deviation. The Cpk measurement has been passed if the **Cpk value is greater than 1.33** and no limit value has been violated.

When the Cpk measurement is started using "Current Cpk", the first value to be entered is the number of measurements, which are to be included in the calculation. This number must be greater than one.



Number of Cpk measurements

A number between 2 and 99 can be entered. After this the following message appears:



Confirmation of Cpk measurement

After the magnet has been inserted this message can be confirmed by pressing "OK" and the first measurement is started. The appropriate message for a new magnet appears after each measurement. If "Cancel" is pressed the entire Cpk measurement is aborted. If "Repeat" is pressed the last measurement is discarded and can be repeated if, for example, the segment moved during the measurement.

After the last measurement a **text window** is opened in which the details of the measurement and all the measurement values are listed. In addition the **mean value, standard deviation** and the **Cpk** value of  $\Phi^*_R$  for evaluation K4 and also the mean values, standard deviations and the Cpk values of  $\Phi^*_{RG}$  and  $H_{GF(80)}$  for evaluation K9 are shown. The user can move through the text window using the scroll bar on the right-hand side.

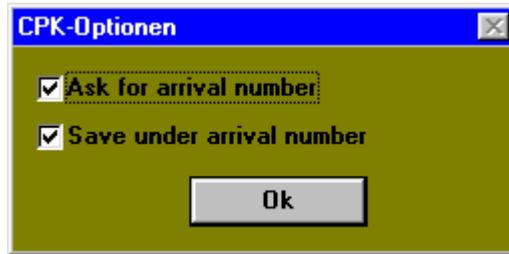
ECKEL -Robograph 2			
CPK measurement			
Magnet number:	3 134 540 166		
Material:	Ferrit		
Insert number:	LY1868A 62/3		
Calibration Psi:	1,000		
Measurement point:	ECKEL, Grenzheim		
Remanence flux Phi r:	Remanence flux Phi rg after 195 kA/m:		
Minimum 0,613 mVs	0,576 mVs		
Maximum 0,674 mVs			
Turns: 225			
Temperature compensation coefficients: H: 0,400 % / °C Psi: -0,200 % / °C			
Temperature: 22,1 °C / Measurement values corrected to 20 °C			
<u>MEASUREMENT VALUES</u>			
Date / Time	Phi r [mVs]	Phi rg [mVs]	Result
22.08.2000 / 16:20:39	0,618	0,609	in tolerance
22.08.2000 / 16:20:49	0,617	0,610	in tolerance
Mean value Phi r:	0,617500 mVs		
Standard deviation Phi r:	0,000500 mVs = 0,0810 %		
CPK display - back with ret.	Magnet: 3 134 540 166	Date: 20.01.2009	Time: 10:10:03

Text window after the Cpk measurement

If print or archive has not already been selected, this can now be done by hand. The print-out is identical to the complete content of the text window. **Individual archiving is not possible subsequently**, however. It must be selected using "+CPK-Individual". This is only done if automatic overall archiving is also active.

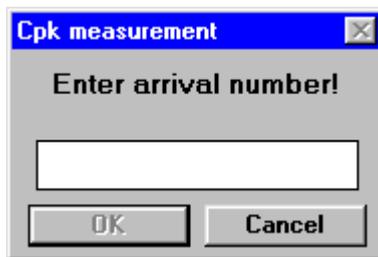
The user can return to the main menu by pressing "Return".

A variation in the archiving function can be switched on under **CPK Options**.



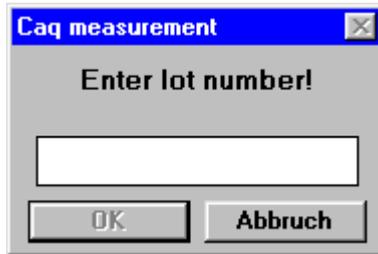
Enter Cpk options

With this function the archiving function can take place under the arrival number instead of the magnet number and date / time. Before every Cpk measurement therefore the arrival number must be entered, which can be up to 5 figures.



Enter arrival number before Cpk measurement

A further variation in the archiving process can be selected under **CAQ**.



Enter lot number before Cpq measurement

The Cpq measurement is similar to the Cpk measurement. A Cpk value is not calculated, but the results from a randomly large measuring group, with the additional input of the lot number, are stored in a file whose path is determined by the pre-selection of the archiving process. This index is normally a network server, which reads out this data and then processes it.

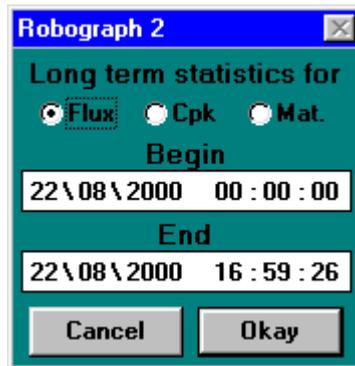
The data form is adapted to special customer requirements (BTMT).

The Cpq measurement can be started only for flux measurement and using the pre-selected archive path.

After the input of the lot number, a test is carried out to determine whether this lot number in the Cpq system has been reported to the server.

### 4.11.2 Long term statistics

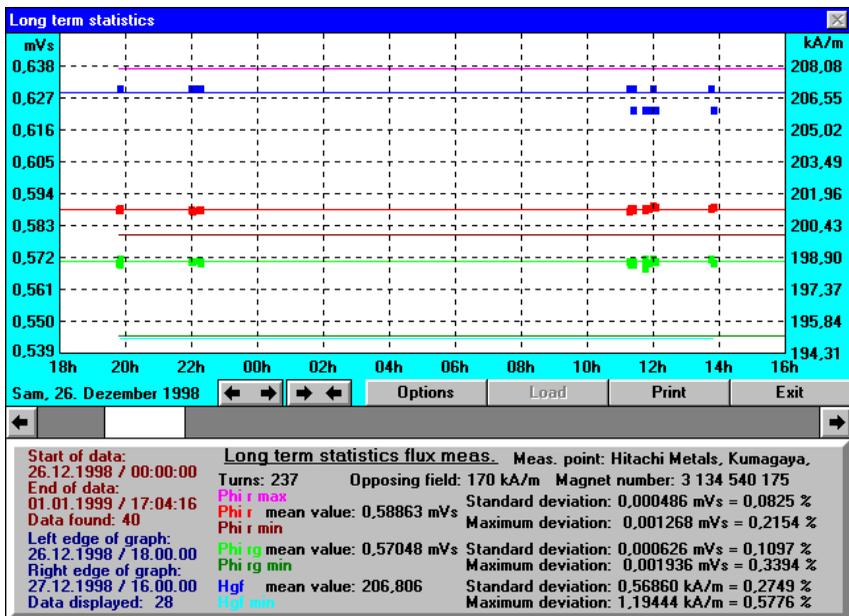
The long term statistics can be started using "**Long term**". It is possible to observe the development of flux, material and Cpk measurements of **one** magnet number over any period of time. To do this the path with the required **magnet number** is selected in the file selector box. If a **day file** is also selected this day is automatically taken as the **data start**. Otherwise the first day in this file is taken as the data start. After this the following window is opened:



Time selection window

If the data are saved under `..\FLUSS\..`, `..\STOFF\..` or `..\CPK\..` the type of statistics is automatically specified. If the file has another name the type of statistics must be specified here. The end time is the current time. The **period** to be shown can now be entered here.

After this, all the measurements taken during this period with this magnet number are loaded and the **long term statistics window** is opened. If there are data in the directory which do not conform to the main details, a warning is given. Data which obviously do not belong to this magnet number are discarded as invalid. If there are a very large number of measurements, the loading process may take a long time and it is possible that the memory will not be sufficient.



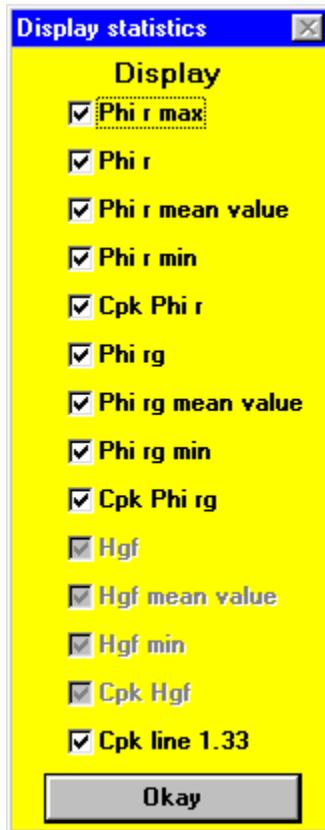
Long term statistics for flux measurement

In the graph window the measurement values in the specified range are shown as coloured **dots**. The tolerances are shown as **curves**. If the tolerances have been changed over the course of the period, this is also shown. In addition the mean values are shown as curves. Improvements in the production can be seen quite clearly using this display.

The **vertical scaling** is set **automatically** in such a way that all the values and tolerances can be shown.

The **horizontal scaling** can be varied using the "-><-" and "<- ->" keys from **1 Minute / Div** to **1 Year / Div**. The date and time are shown underneath the graph. Using the **scroll bar** the user can scroll through the entire period in the desired resolution. Please remember that the display of a very large number of measurements may take a considerable time, depending on the computing capacity of the PC.

If required, the display may be made clearer by not showing all the results and tolerances. To do this a selection window can be opened with "Options".



Selection window

The results and tolerances to be displayed can be selected in this window. Changes may result in the vertical resolution also being changed. The Cpk values can only be set if Cpk measurements have been loaded. The selected setting is saved automatically.

In the text block at the bottom next to the details of the measurement, the entire period being displayed and the **mean value**, the **standard deviation** and the **maximum deviation** of the measurement values over the **entire** period are shown.

The long term statistics currently displayed can be printed by pressing "**Print**". New values can be loaded by pressing "**Load**". Adding new values to the existing ones is not possible. The user can return to the main menu by pressing "**Exit**".

For the long term statistics for **Cpk measurements** the **mean values**, the average **standard deviation** and the average **Cpk values** are shown in the text block. The averages are taken by dividing by the number of Cpk measurements without any regard for the number of measurement values in the individual Cpk measurements. The scaling of the Cpk values is also shown on the right-hand side of the graph.

## 4.12 Parameters

Using the "**Parameters**" menu point settings can be made for the program which meet the requirements of the user and do not change constantly.

The screenshot shows the 'Parameters' dialog box with the following settings:

- Interface:** COM 1 (selected)
- Language:** English (selected)
- Hall sensor No.:** 063
- Value:** 2,0070
- Measurement point:** ECKEL, Grenzheim
- Flux measurement:**
  - Phi rg individual
  - Calculate Phi rg min
  - Max opp. field
  - Show start flux
  - Show PsiHC
  - Operator & Batchno.
  - Range check for:**
    - shown result
    - Phi r & Phi rg
- Material measurement:**
  - Phi-connection (higher resolution)
  - Surrounding coil meas.
  - Ext. Amplification:** 1
  - Turns:** 001,000
  - Saturation compensation
  - Average of material measurements
  - BHC instead of HG
  - Show BH max
  - Show Q
  - Without tolerance
  - +Gauss/Oversted
  - Range check for:**
    - shown result
    - Br
    - HG
    - JHC
- Font:** Size: 32, Text: A
- Logo L:** Size: 25, Text: CA
- Logo R:** Size: 25, Text: CA

Parameters window

The following settings can be made:

### Interface

The interface for the communication to the Robograph 2 is set here. If the selected interface cannot be opened, an error message to this effect is shown. **Important:** If the interface has been selected to which the mouse is connected, depending on the mouse driver it may still be possible to open the interface. In this case the **mouse is lost** and is not installed again even if the interface is then changed again. If this happens the program must

be terminated and Windows™ restarted.

### **Language**

The menu interface and all the messages can be displayed in **German, English** or **French**.

### **Hall sensor**

The numeric value **on the Hall sensor** is entered under "**Value**". It specifies the output voltage of the Hall sensor in **mV / kA/m** and is individual for every Hall sensor. The serial number can also be entered for security.

### **Measurement point**

In this text window the measurement point which appears on each **print-out** can be entered. Any sequence of characters can be entered up to a maximum length of **30 characters**.

### **Beep**

If the "Beep" is active, the PC generates a **warning sound** for each error message.

### **Colour print**

Colour print with a colour printer. This option should only be active if a colour printer is actually used, because other printers will **distort** the colours, depending on the printer driver, and the print-out may become **illegible**.

### **Extended file selector**

If the **magnet number** used is longer than the **eight characters** which can be displayed in DOS™ it may be a good idea to display the full magnet number when selecting files and tolerances. If a great deal is read from **diskettes** it may be a good idea, to save time, to **deactivate** this option since every file will have to be read.

**Display error on unit**

If active and an error occurs, the appropriate **error code** is shown on the **display** of the Robograph 2. The error codes are described in chapter 5.1.

**Save whole curve**

With this option the whole curve can be stored at archive. Thus the necessary place for each measurement increases to approx. **10 kByte**. The advantage is, that also for archived curves the **complete hysteresis** may be shown.

**Save Debug measurement:**

If activated, every measurement is saved in raw data at program folder with the name „testmess.dat”. This can be helpful if the Robograph software crashes during evaluation. This measurement can be read by us and then evaluated for error analysis.

**Print tolerance bar**

This can be used to select whether the tolerance bar should be **printed** with the **demagnetisation curves  $\Psi$  or J**, or not.

**Letter size** will set the paper size to US letter and change the position of the printout.

**Top space** allows entering additional space at the top of the printout to fit different printer drivers. If this value is set too high some text may be lost at the bottom of the document.

**Temperature in Fahrenheit**

If active, the measured temperature is shown in Fahrenheit, otherwise it is shown in **Celsius**.

### Temperature compensation

If the temperature compensation is active, the measurement values are converted to a temperature of **20°C**. The field strength **H** is scaled with  $[1-0.004 \cdot (\text{Temperature} - 20)]$  and the flux  $\Phi$  or the induction **B** with  $[1+0.002 \cdot (\text{Temperature} - 20)]$ . This is an assimilation of the temperature properties of **ferrite**. It is also possible to enter other temperature coefficients. The temperature compensation should usually be **active**.

If, for example, for a material measurement, materials are measured which have different temperature properties, the compensation can be deactivated here.

### Temperature test

If the temperature test is active, a **warning** is given in temperatures of **less than 5°C** and **over 35°C** because it may be assumed that this temperature is incorrect. Even if the temperature is correct, it must be noted that the temperature compensation cannot correct the properties of ferrite in this range perfectly.

### Change resolution

If this option is set the screen resolution will be set to 640 x 480 when the program is activated. If the window is reduced or the program is terminated the resolution of the screen is set back to original value.

### $\Phi^*_{RG}$ individual

When this option is activated the user can decide in each tolerance if  $\Phi^*_{RG}$  min is calculated or set by hand.

### Calculate $\Phi^*_{RG}$ min

**BOSCH test instructions No. 3 139 918 950** states that the value **0.94  $\cdot \Phi^*_R$  min** is used for  $\Phi^*_{RG}$  min. This can be activated here. If this function is not active, the value of  $\Phi^*_{RG}$  min can be

selected freely **below**  $\Phi^*_{\text{R min}}$ .

### Show maximum opposing field

If active, the **maximum possible opposing field**, where  $\Phi^*_{\text{RG}}$  is exactly  $\Phi^*_{\text{RG min}}$ , is shown after flux measurement. Thus the distance to the limit can be tested.

This value is **not archived** and will **not be printed**.

**Show start flux** will display the flux the segment had before magnetization by the Robograph. This option can help to find a magnetizer at an assembly line being responsible for poor motor performance when taking a sample from the line after magnetization. The start flux is set in relation to the 100% magnetization of the Robograph.

**Show  $\psi H_C$**  will display the intersection of the hysteresis with the field axis. This value is related to  $j H_C$  of the magnet material.

**Operator and Batchno** will ask for the operators name and the batch number before each measurement. They will be stored with the results.

### Range check

This is used to check **which** measurement results are to be used in the **Above / In / Below Tolerance evaluation**. For flux measurements the result in the **display selection on the unit** or **both** results are available. If more than one result is used in the evaluation, "**Below Tolerance**" will be dominant.

### $\Phi$ connection:

J compensated material measurements have the problem, that most time the input voltage is very low and then rises very high for a short time. If the measured material is **not very hard**, the  $\Phi$  **input** can be used for material measurement, which offers a

**higher resolution.** It is recommended **generally** to use the  $\Phi$  input and only to change to the J input after error messages. All **calibrations** must be performed using the  $\Phi$  input. Thus the J output of the yoke connection box must be connected with the  $\Phi$  input of the Robograph.

### **Surrounding coil material measurement**

With this option, the Robograph 2 can carry out a **material measurement with a J compensated surrounding coil.** This coil is connected to the **J input of the unit.** Before the measurement is carried out the **external amplification,** the **number of turns of the coil** and the **sample surface areas in mm<sup>2</sup>** are specified. External amplification is necessary if the coil has only a few turns and the output voltage is far less than the input voltage required, which can be seen from deformation of the hysteresis curve because of too little bit resolution. Care should be taken that the **precise** external amplification is known, as it will be used for scaling the result. If no amplification is needed, then **1** is entered here.

### **Saturation compensation:**

The saturation compensation carries out a **non-linear calculation of the saturation effects** during measurement of the material and **compensates** accordingly. As it is possible that finished materials have **slight differences in the quality of the metal alloy** at different times, which in turn can lead to different results, it is essential that this saturation compensation feature is switched on. The compensation is visible at the **ends of the hysteresis curve,** where a clear **decline in the curve** is possibly visible without compensation.

The linear loss compensation with the nickel sample is **always** carried out **with** the non-linear saturation compensation.

The saturation compensation can also lead to a slight increase in the variations of the measurement results from **one** Robograph. On the other hand the results between **different** measurement inserts are compensated

### **Average of material measurements**

Sometimes fairly **large samples** of materials that are not absolutely **homogeneous** across their entire surface are measured. Then it is possible to take an **average** of several measurements of one sample. If this option is selected then the **number** of measurements to be taken is requested before each material measurement. At the end of these measurements the **mean hysteresis curve** is calculated and is displayed along with the individual curves. The results are then calculated from the mean curve. When this measurement is saved only the mean result is saved as **one** measurement. This is accompanied by information to the effect that the measurement is a mean value. **Note:** It only makes sense to take an average if only **one** magnet is concerned. If an average is taken of various very different magnets then a **nonsensical result** will be produced with several kinks in the demagnetisation curve because a linear addition of the curves is carried out, the result of which is **not identical** to measurement of several magnets measured when **stacked**.

### **BHC instead of HG**

If this option is selected, then the **BHC coercitive field strength** is stated in the material measurement instead of the HG limit field strength. Value **b** is **not stated**. **Limiting values** can be specified for BHC in the tolerance. The **representation** of the demagnetisation curve  $J$  also changes. The  **$B=0$  line** is displayed for determination of BHC instead of the HG determining line. In addition the energy density lines  **$B \cdot H$**  are represented in  **$\text{kJ/m}^3$** .

**Show BHmax**

If this option is selected, the maximum value of **B\*H** is shown at **material measurement** and activated **BHC instead of HG**.

This value is **not archived** and will **not be printed**.

**Show Q**

If this option is selected, the value **Q = 10\*Br + 5\*JHC** is shown at **material measurement** and activated **BHC instead of HG**.

This value is **not archived** and will **not be printed**.

**Without tolerances** will delete the tolerances and disable the comparison with the tolerances. This is useful if not a special material is tested but some unknown sample.

**+Gauss/Oerstedt** will display the Gauss/Oerstedt results additionally to the mT / kA/m results. By reasons of space this option is only selectable if the tolerances are switched off.

**Range check**

This is used to check **which** measurement results are to be used in the **Above / In / Below Tolerance evaluation**. For material measurements only the displayed result or any **combination** of all results can be selected. If more than one result is used in the evaluation, "**Below Tolerance**" will be dominant.

**Logo Left** and **Logo Right** allows the user to enter two different logos on the top of the printout. The logos must be in Windows **true type .ttf** format. The size can be selected. The letters corresponding to the logos must be entered.

The parameters are confirmed by pressing "**OK**", whilst the previous status is reproduced if "**Cancel**" is selected.

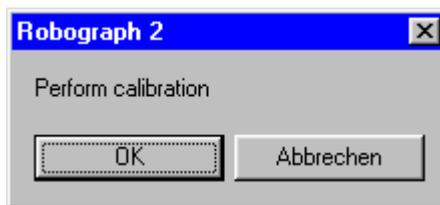
## 4.13 Service and calibration

Under the "**Service**" menu point there are several functions available to check the hardware.

### System calibration

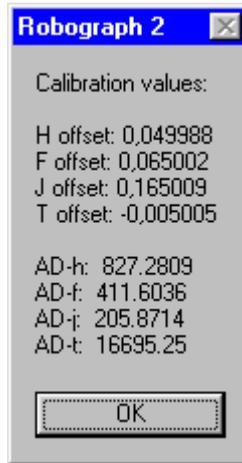
The internal **unit parameters** of the Robograph 2 are measured and transferred to the PC using System calibration. All the **amplification factors** and **offset values** can be measured with the help of an integral high constant **reference voltage** source. These values are used in the calculation of the measurement values and **must** therefore be measured once when the unit is **installed**. If there is any suspicion that there is a **hardware error** in the **measurement amplifier** sector, the unit can be checked using this function. The results are displayed and, if the specified limit values have been exceeded, declared as defective. In this case they cannot be saved.

If the "**System calibration**" menu point is selected, the following window appears:



Start system calibration

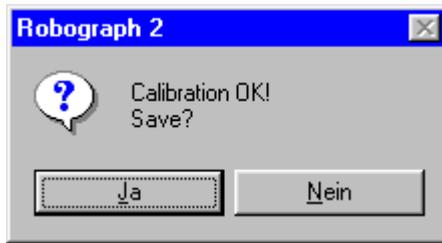
If the measurement result is outside the tolerances the results are shown compared to the desired values.



Calibration values within the tolerances

The **offset** is specified in bits. The **AD values** identify the digital output value of the A/D converter at **1 V** input voltage at the relevant measurement input.

The calibration values are **accepted** in any event. If they are **within** the tolerances they can be **saved**.



Save system calibration

### Coil equalisation:

**Coil equalisation** must be carried out **before** material calibration, so that **slight differences** between the B and H coils can be compensated.

For this purpose two **spindle trimmers** marked B and H are fitted in the **connection box** with the plug connectors on the yoke. This box must be opened. **Ensure that no cables are torn off!**

In the first instance both trimmers must be turned **completely to the right**. The trimmers can be turned 30 turns and they do not have an end stop. So turn 30 turns to the right.

Now clamp a **10 mm plastic distance piece**, applying the same **pressure** you would **normally** use for the measurement.

Now carry out the measurement ( **$\Phi$  input**) and turn one of the trimmers to the left **according to the instructions in the program** and then **repeat** the measurement. After some time you will arrive at a horizontal line with an **incline of almost 0** between - and + 500 kA/m. When shown the message "**end equalisation**", acknowledge it and close the connection box.

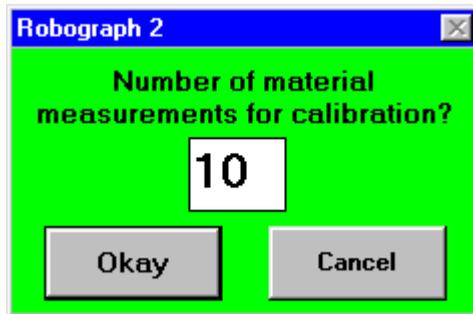
If using a new or repaired material measuring insert this coil compensation process must be repeated.

### **Material calibration**

The **material measurement insert** of the measurement yoke is measured using the material calibration option. If a **new** material insert is being used or the insert has been **repaired**, a **new material calibration** must be performed. In contrast to the flux measurement in which the segment size and therefore the coil size were included in the result, for the material measurement a **calibration factor** must be defined which contains the **number of turns** and the **turn area**. The calibration for the material measurement is completed by comparing the voltages induced in the measurement coils with the output voltage of the Hall sensor. Since these are in the air in the equation  $\mathbf{B} = \mu_0\mathbf{H}$ , **no calibration sample** is required. The Hall sensor must of course be linearised and calibrated. To measure **B** the **J compensation** must be **deactivated** by **moving the switch** on the connection box for the measurement coils. To obtain a defined condition the 10 mm thick **spacer** is clamped in the measurement yoke and the yoke fixed.

Attention: Use  $\Phi$  input!

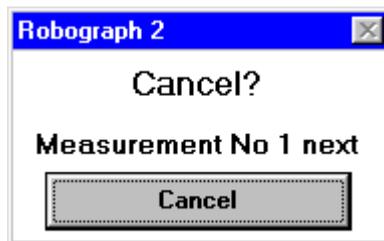
The following window appears when the "**Material calibration**" menu point is selected.



Number of material measurements for the material calibration

To increase the accuracy of the calibration process, an **average** may be taken from up to 99 measurements. 10 measurement are always recommended.

The following window appears before each measurement

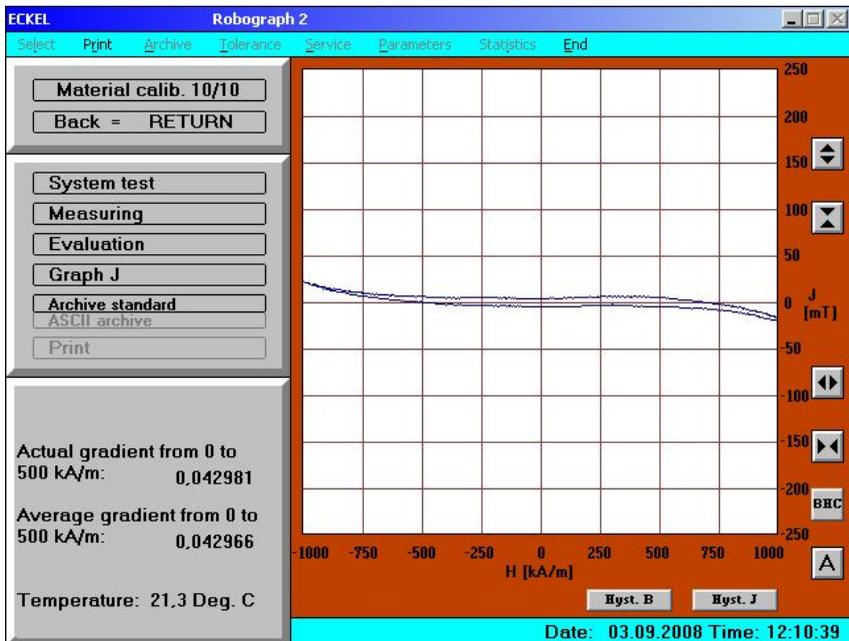


Cancel window for material calibration

Whilst the window is **visible** the entire material calibration process can be cancelled.

During the measurement the **hysteresis B** is measured. This shows signs of saturation at the ends but is **linear** in the middle and may have slight signs of hysteresis caused by the remanence of the material insert.

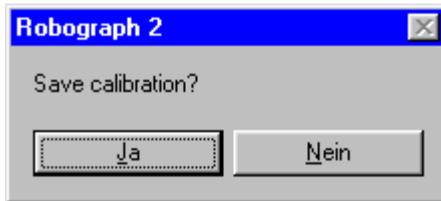
This remanence is **cancelled** in the J-compensated measurement. The gradient is calculated from the measured curve in the area around  $\pm 500$  kA/m. This gradient is  $k \cdot \mu_0$  where **k** is the required **calibration factor**. Using the hysteresis B, the **hysteresis J** can then be calculated and **displayed**. The fact that the hysteresis J is **horizontal** in the middle shows that the calibration factor k has been **correctly recognised**.



Hysteresis J for the material calibration

The current and the average **gradient value** are displayed. **Important:** compare whether the **graph** is similar to the one shown above. If not, the error must be found and the calibration must **not** be saved.

At the end of the measurements the calibration may be saved.



Save calibration values

A fixed storage space is provided for this since it is assumed that only **one** material measurement insert will be used.

**Do not forget to set the switch on the connection box back to J-compensated material measurement.**

**Difference compensation:**

In addition to the differences in the coils, it is also possible for a **slanted position of the measuring inserts** to each other to falsify the result. As these errors are dependent on thickness, further measurements are carried out without a coil but with a **4 mm distance piece**.

**Loss compensation:**

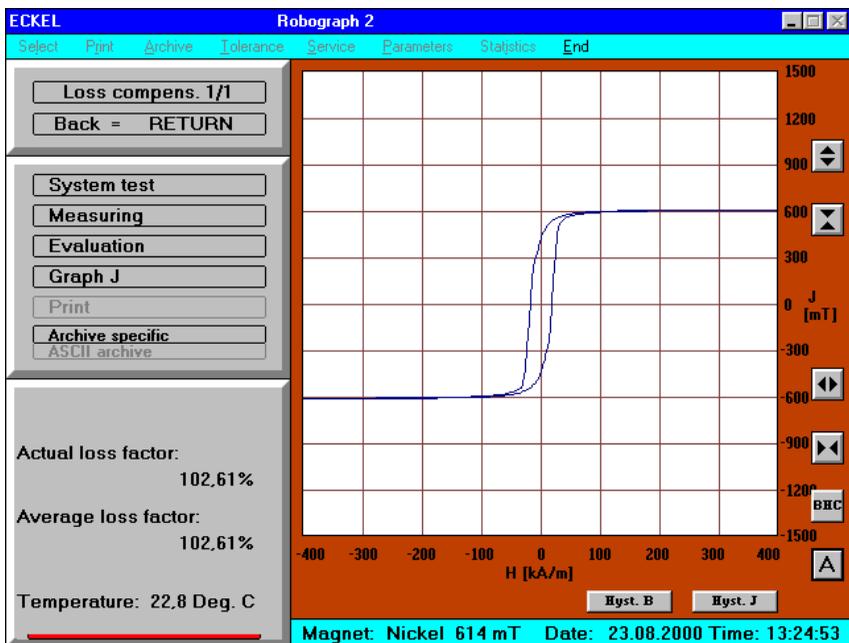
To compensate for the material measurement inserts **not being ideal** for high induction, a **reference measurement** with a **nickel sample** calibrated by the Physical-Technical Federal Institute must be performed.

During this measurement the **saturation induction** is observed which is **614 mT** for this nickel sample. A comparison with the measurement values produces a correction factor of around 1.02 to 1.05, in other words 2 to 5% more.

The loss compensation process is conducted in the same way as the material calibration. However, the **switch** on the connection box must be set to "**Measurement**".

The hysteresis J of the nickel sample including the loss compensation is displayed.

The loss compensation must also be saved when it has been successfully completed.



Loss compensation

# Physikalisch-Technische Bundesanstalt



## Kalibrierschein

Bestimmung der magnetischen Sättigungspolarisation einer Nickelprobe

Gegenstand: Nickelzylinder, 15 mm Durchmesser, 7 mm Höhe  
Material: Nickel 99,98%  
Hersteller des Materials: Fa. Balver Zinn KG  
Antragsteller: Fa. Robert Bosch GmbH, 7580 Büh1  
Geschäfts-Nr.: 2.42-7406/90  
Amtliches Zeichen: 3708 PTB 90

### Kalibrierverfahren:

Der oben näher bezeichnete Nickelzylinder wurde zur Kalibrierung zwischen die Polschuhe eines Elektromagneten mit 150 mm Polschuhdurchmesser gesetzt. Die Kräfte zwischen den Polschuhen wurden durch zusätzliche Zylinder aus unmagnetischem Material aufgefangen, so daß zwischen den Stirnflächen des Zylinders kein Druck auftrat.

Die magnetische Feldstärke wurde auf der Mantelfläche des Zylinders mit einer mit Kernspinresonanz kalibrierten Hallsonde gemessen, der Fluß durch die Probe mit einer Umspule, deren Ausgangsspannung mit Hilfe eines kalibrierten Spannungs-Frequenz-Wandlers und eines Zählers digital integriert wurde. Die wirksame Querschnittsfläche der Umspule wurde durch Vergleich mit einer Referenzspule im homogenen Magnetfeld bestimmt. Die Probenquerschnittsfläche wurde aus dem Mittelwert von Messungen des Durchmessers mit einer Mikrometerschraube an 20 verschiedenen Stellen des Zylinderumfangs zu  $1,778 \text{ cm}^2 \pm 0,002 \text{ cm}^2$  berechnet.

Aus den J- und H-Meßwerten der in die Sättigung einmündenden Hystereseschleife wurden durch Ausgleichsrechnung die Parameter der Funktion

$$J = J_s + a/H^2 + b H$$

bestimmt, wobei  $J_s$  die Sättigungspolarisation ist.

### Ergebnis:

Die Sättigungspolarisation der Nickelprobe beträgt bei einer Temperatur von  $23^\circ \text{ C} \pm 0,3^\circ \text{ C}$

$$0,614 \text{ T} \pm 0,001 \text{ T}.$$

Im Auftrag

*H. Ahlers*

H. Ahlers



Kalibrierscheine ohne Unterschrift und ohne Dienststempel haben keine Gültigkeit.

Die Kalibrierscheine dürfen nur unverändert weiterverbreitet werden.

Auszüge und Änderungen bedürfen der Genehmigung der Physikalisch-Technischen Bundesanstalt, Bundesallee 100, Postfach 33 45, D-3300 Braunschweig.

# Physical-Technical Federal Institute

## Calibration certificate

Determination of the magnetic saturation polarisation of a nickel sample.

Object	Nickel cylinder, 15 mm in diameter, 7 mm high
Material	Nickel 99.98%
Manufacturer	Balver Zinn KG
Applicant	Robert Bosch GmbH, 7580 Bühl
File No.	2.42-7406/90
Official ref.	3708 PTB 90

### Calibration process

The nickel cylinder described above was placed between the pole shoes of an electric magnetic with a pole shoe diameter of 150 mm for the calibration process. The forces between the pole shoes were absorbed by additional cylinders made of non-magnetic material so that there was no pressure between the ends of the cylinder.

The magnetic field strength was measured on the surface of the cylinder with a Hall sensor calibrated using nuclear spin resonance, the flux through the sample was measured with a surrounding coil whose output voltage was digitally integrated by means of a calibrated voltage - frequency converter and a meter. The effective cross section area of the surrounding coil was determined by means of comparison with a reference coil in the homogeneous magnetic field. The sample cross section area was calculated from the mean value of measurements of the diameter with a micrometer screw at 20 different positions along the circumference of the cylinder at  $1.778 \text{ cm}^2 \pm 0.002 \text{ cm}^2$ .

Using the J and H measurement values of the hysteresis loop in the saturation field, the parameters of the function

$$J = J_s + a/H^2 + bH$$

were found by calculations whereby  $J_s$  is the saturation polarisation.

### Result:

The saturation polarisation of the nickel sample at a temperature of  $23^\circ\text{C} \pm 0.3^\circ\text{C}$  is

$$0.614 \text{ T} \pm 0.001 \text{ T}$$

By order

H. Ahlers

Round stamp: PHYSICAL-TECHNICAL FEDERAL INSTITUTE

**External system calibration:**

With this program the internal calibration of the Robograph can be tested and certified using an **external voltage source** and a **certified voltmeter** of high resolution.

This procedure needs **special requirements** for connection cables and voltage source. A calibration unit generating the necessary voltages including all cables can be ordered at Eckel GbR. See at 4.14 5

**Flux insert calibration:**

This feature is selectable if **Use Calibration** is selected in the flux tolerance. After entering the reference values for  $\Phi^*_R$  and  $\Phi^*_{RG}$  for the actual used insert and magnet, the measurement will start and a calibration factor will be evaluated and stored with the tolerance. **This option is not allowed for Bosch magnets!**

**Field strength calibration:**

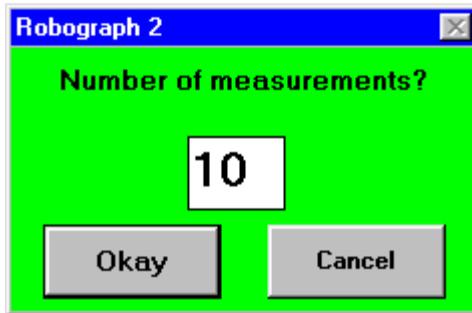
This feature is selectable if **Field strength limit** is selected in the Flux tolerance. The Robograph will perform 20 different measurements to calculate the relation between current and field strength for the actual used flux insert. This data will be stored and allows entering a field strength limit before measurement. This is used to examine different hysteresis for different magnetisations. **This option is not allowed for Bosch magnets!**

**Test flux insert:**

This program will test the empty flux insert. The first time the result will be only stored. If you repeat it later, the program will show if the properties of the insert have changed. This can help to find changes of the air gap or the Hall sensor position by damage or wearing out. A stored flux insert test can be loaded with **Load flux insert test**.

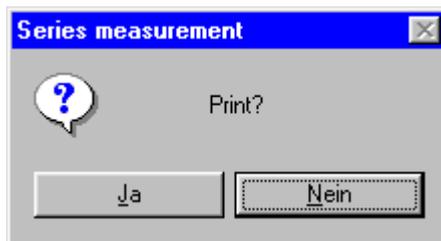
**Series measurement:**

Using series measurement a large number of measurements can be made using the same magnet to test the repetition accuracy of the Robograph 2. If "Series measurement" is selected the following window is opened



Number of measurements for the series measurement

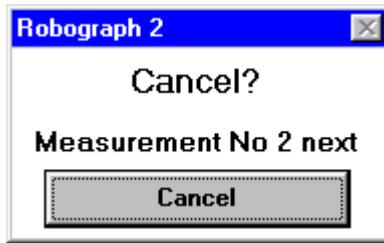
Numbers between 1 and 99 can be entered. The system then asks whether you want a print-out:



Print confirmation

Like the Cpk measurement, the print-out does not have a graph.

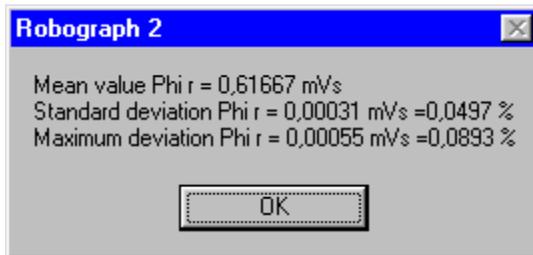
The following window appears before each measurement:



Cancellation window for series measurement

Whilst this window is visible the series measurement can be cancelled.

At the end of the series of measurements the mean value, the standard deviation and the maximum deviation is given for each result.



Statistics for  $\Phi^*_R$

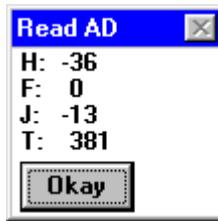
These statistics are also given on the print-out.

### Front panel test:

Using this function a test of the displays on the front panel of the unit can be started. This also tests the transfer of the control commands.

### Read A/D:

Using the "Read A/D" function the **four measurement inputs** are read. The following window is opened:

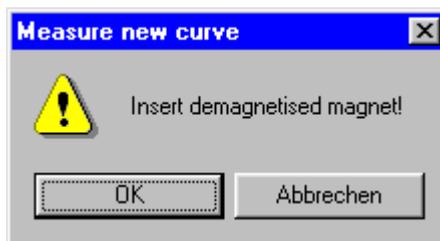


A/D output window

The **current measurement values** are shown here. If the Hall sensor is in the yoke, the remanence of the yoke is displayed. The measurement coil inputs should be at 0. The temperature determines the relevant A/D value. An **open input** can assume **any** value.

#### Measure new curve:

Using this menu point the **new curve** for a **demagnetised** magnet sample can be measured. This is only possible for material measurements. If this menu point is selected, the following window appears.

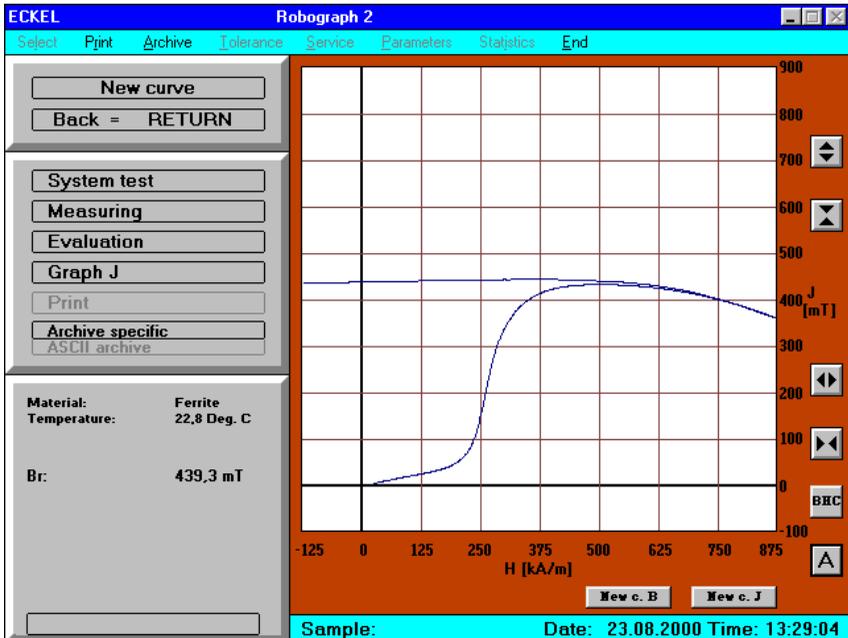


Measure new curve

The measurement can be started by pressing "OK". After this the **top right-hand quadrant** of the hysteresis curve is shown.

The properties of the magnet sample during **magnetisation** to **saturation point** and the **return** over  $B_r$  are shown. The user can

select between J and B display. The measurement curve may not start at  $H = 0$  but at the remanence field strength of the yoke.



New curve J

The  $B_r$  value is given.

The new curve may be saved as an **ASCII archive**. This has a special meaning here - approximately every 2000 **sampled pairs** of values on the B and J curve **up to  $B_r$**  are saved in a file in the **NEUKURVE** section numbered and sorted by date and time. From there the data can be taken and processed. It is **not possible to read the data back** into the Robograph 2.

If "Print graph" is selected the curve can be printed.

The **demagnetisation** of the material sample is **not possible** using the Robograph 2.

**Insert calculation:**

Using the "Insert calculation" option the **dimensions of the flux measurement inserts** for new segments shapes can be calculated. In addition the **limits for the flux measurements** are calculated, for which an approximation formula is used. The results are **not necessarily identical** to the results of the FEMAG calculation. The calculation recommended here is ideal for those who do not have access to a FEMAG program.

The image shows a software dialog box titled "Magnet datas" with a pink background. It is divided into two main sections: "Data for insert calculation" and "Additional data for limit calculation".

**Data for insert calculation**

- Magnet number:
- Maximum magnet thickness:  mm
- Maximum magnet width:  mm
- Minimum magnet length:  mm
- Motor housing diameter:  mm

**Additional data for limit calculation**

- Minimum magnet thickness:  mm
- Minimum thickness at the edge:  mm
- Minimum Br:  mT
- Minimum HG:  kA/m

At the bottom of the dialog box are two buttons: "OK" and "Cancel".

Input window for magnet dimensions

When entering the minimum and maximum values it is important that the quoted **tolerances are always included!**

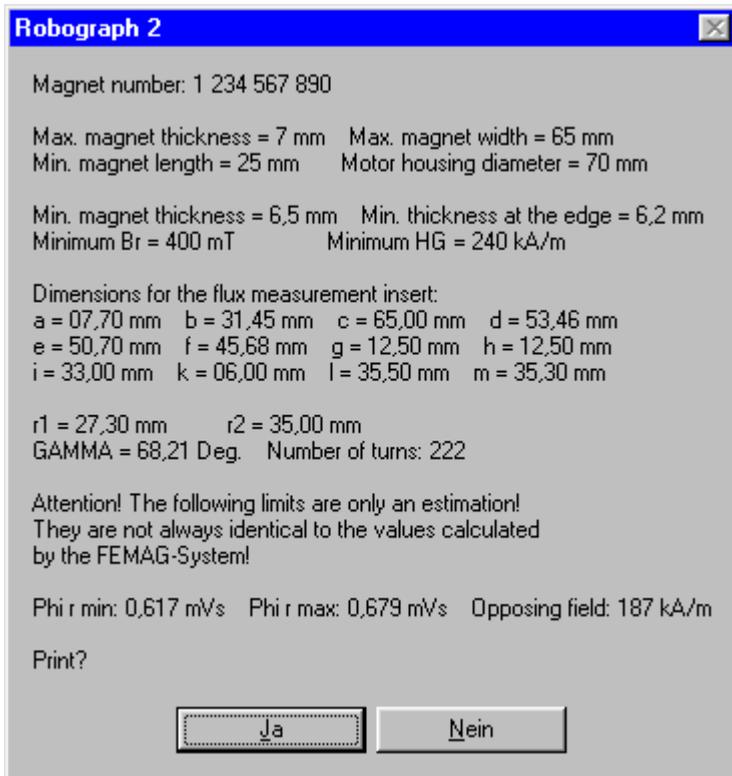
Max. and min. magnet thickness are taken in the **centre**.

In the case of the pole housing diameter enter the **nominal diameter**. If this is not specified in the magnet drawing, it is also possible to enter **double the external radius** of the segments.

The minimum HG is a Bosch specification for ferrite material. The standard value is JHC - 20 kA/m.

If the measuring insert is to be produced for the **first time**, the **print-out** of the calculation must be included when the order is paced with Kohler.

**Important:** If the measuring insert has already been manufactured **before**, it must be reproduced **identically**, even if the dimensions of the magnet have changed in the meantime. This is the only way that identical results can be achieved.



Results of the calculation

**Delete file:**

Using this function files can be deleted. To prevent damage only files with the **suffixes .MES, .CPK, .ASC or .TOL** can be deleted, in other words archive and tolerance files. If this function is selected a file selector box is opened in which the file to be deleted can be selected.

**Information:**

If this function is selected an information box is opened in which the **software version**, the hardware version (if the hardware is switched on), the serial number and the licence number are shown.

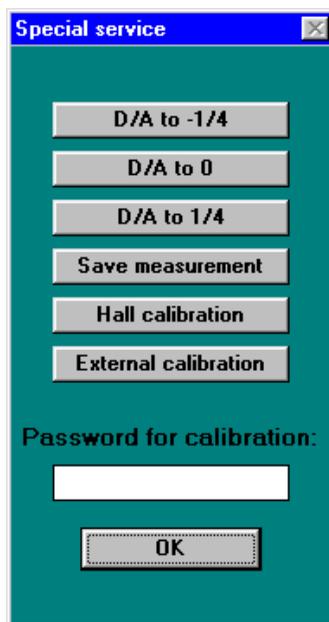


Information box

#### 4.14 Extra service:

If the **code word** ..... is entered, the extra service menu is opened automatically. This menu is used by the **service engineer** to set the hardware and to protocol the measurements. It is not designed for the user.

The following window is opened in the Extra service menu:



Extra service window

#### **D/A to -1/4, 0, 1/4**

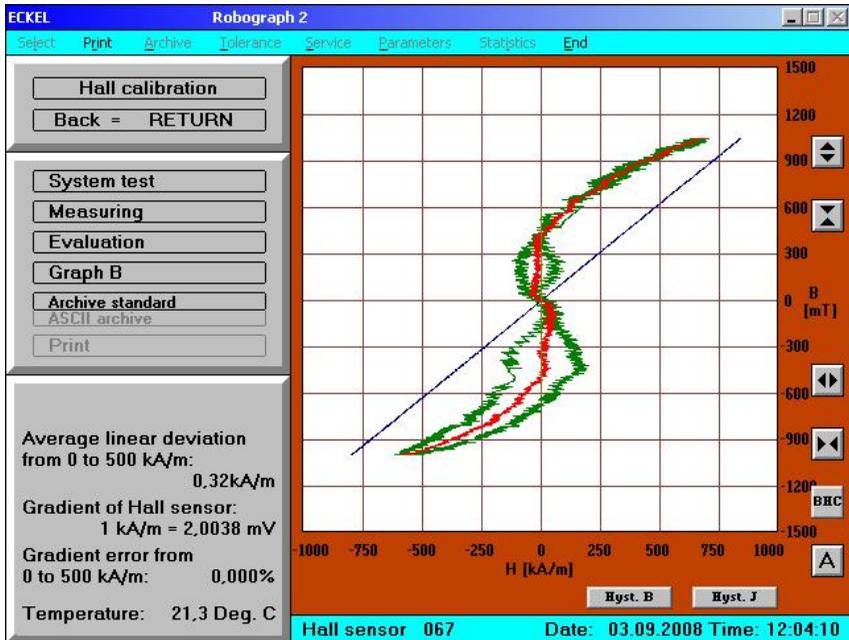
Using these buttons a fixed output current of + 1 A and - 1 A can be activated. This is used to **assimilate** the controlled power course. When the window is closed the current is automatically reset to 0.

### **Save measurement**

Using this function all the transferred measurement values and the **curve points** calculated from them are saved as an ASCII text. This allows, for example, code errors resulting from an overflow to be viewed. The storage space required is approx. 650 kByte per measurement.

### **Hall sensor calibration**

A **new** Hall sensor element must be **linearised** with a terminating resistor. In addition the **output amplitude** must be measured which is then specified on the Hall sensor and entered in "Parameters". To do this a **special insert** for the Hall sensor, which contains a precisely defined **measurement coil**, is placed in the material measurement insert. This measurement coil is connected to the  $\Phi$  input. By pressing the "Hall sensor calibration" button the measurement can be **started immediately**. The output amplitude of the Hall sensor in a range between **0 and 500 kA/m** and the average **linear deviation** from a straight line with this gradient are calculated using the reference coil. This can take some time. To prevent an error in the algorithm the error in the gradient calculation, which must be almost 0, is also specified.



Hall sensor calibration graph

The graph shows the measured **hysteresis** which shows hardly any deviation from the line. In addition one hundred times the **deviation from the linearity** is shown in "green". Since this is an hysteresis, the mean value is calculated from this deviation. This is shown in "red". The resolution is so great that individual bit stages can be seen. If the gradient has been correctly recognised, the line will have precisely the gradient  $\mu_0$ .

The red deviation curve must be **perpendicular** on average in the range from -628 to +628 mT (which corresponds to -500 to + 500 kA/m). To check this, a **green line** is drawn which represents this mean value. Since the linearization process is performed in the range up to 500 kA/m, the point from which the deviation starts to increase considerably is also within that range. However, this is the optimum calibration since values above 500 kA/m have no influence on the measurement results.

The graph can then be **printed**. The Hall sensor **serial number** which was entered under "Parameters" is used.

After a Hall calibration process the Extra service option closes automatically and must be called up again for the next calibration measurement.

**External calibration:**

For **testing the system calibration**, this calibration can be performed with an external voltage source. Therefore the external voltage source is connected to the tested input with positive polarity. The voltage must relate to a load of **about 80%** and is measured by a **very exact volt meter**. Then 100 samples are taken. This procedure is repeated with negative polarity. As result the offset and the average sample values of the inputs are shown. By calculating the sample values to an input voltage of **1 volt**, the results can be compared to the system calibration. **The system calibration of the Robograph 2 can not be changed but is only tested by this procedure.**

The necessary test voltages are:

Temp.	100 mV
H	2 V
$\Phi$	4 V
J	8 V

**Password for calibration**

If a password is entered here, this password will be asked for before any calibration process is saved. If no password is entered, the password option is automatically disabled.

## 5. Errors

### 5.1 Error messages and error codes

Apart from hardware and software errors, error messages can also be displayed if the user attempts an incorrect action. Most error messages have error codes which, in addition to the message on the screen, are also shown on the unit display if the appropriate parameter is set.

List of error messages with error codes:

**E 00** = Unknown error

**Hardware errors** which are set by the Robograph 2 itself:

**E 01** = Non-permissible current flux

Load of the power source. May be visible on the front panel. The processor, D/A converter or output stage is defective.

**E 02** = Supply voltage.

The voltage stabilisation system is defective or internal fuse blown. "**PS**" LED is lit.

**E 03** = Output stage overloaded.

Overload on the desired load 0. Processor, D/A converter or output stage defective or yoke not connected. "**OL**" LED is lit.

**E 04** = Overheated

Fan defective or unit covered. "**OH**" LED is lit.

These error messages may also be generated if the **RS 232** connection is inserted whilst the unit **is running** because this may mean that an incorrect command is received. **Watch the red LED's.**

Errors during **system test**:

**E 05** = Hall sensor error

Hall sensor not connected or defective.

**E 06** = Flux coil error

Flux coil not connected or defective.

**E 07** = J coils error

J coils not connected or defective.

Errors during **evaluation**:

**E 08** = Unusual temperature.

Below 5 °C or above 35 °C. Temperature sensor not connected or defective? Only if parameter set.

**E 09** = Polarity H / J /  $\Phi$  / calibration coil incorrect.

Excitation coils or measurement coils connected with incorrect polarity, Hall sensor inserted upside down.

Errors during the **curve calculation**

**E 10** = Curve cannot be closed

**E 11** = Positive remanence intersection not found

**E 12** = Negative remanence intersection not found

**E 13** = Remanence value for  $H_g$  not found

**E 14** =  $\Phi^*_{RG}$  greater than  $\Phi^*_R$

**E 15** = Negative coercitive intersection not found

**E 16** = Intersection for  $H_G$  not found

**E 17** =  $H_G$  greater than  $jH_C$

**E 18** = Impossible result

Possible causes:

- Measurement yoke not connected.
- Flux measurement taken with material measurement insert or vice versa.
- Material measurement taken without J compensation (incorrect switch position).

- Hall sensor not inserted.
- Possibly measurement without a magnet.
- Magnet not correctly positioned.
- Magnet has moved during measurement.
- With an extremely thick sample: magnetisation not sufficient for complete hysteresis.
- Overload at material measurement with  $\Phi$  input.

Other errors

**E 20** = No material calibration

Perform material calibration!

**E 21** = System calibration incorrect

Test hardware!

**E 22** = Printer not ready

Printer not connected, not switched on or no paper.

## 5.2 Error sources

In addition to the errors for which comments can be output, incorrect actions by the operator and external influences can affect the measurements.

The Robograph 2 has **sensitive sensors** and is designed for taking precise measurements even of small **magnetic fields**. Naturally **electromagnetic interference sources** may affect the measurements since this interference is also measured and may even be visible on the hysteresis curve. Units which generate **arcs** or, for example, **demagnetisation units** should not be operated in the vicinity during the measurement. Since for the **Hall sensor**, which is a four-pole element, the differential compensation cannot work perfectly, its cable must not, for example, be laid **parallel to mains cables**. The useful voltage of the Hall sensor is in the mV range. Excessive mains hum on the Hall voltage can be seen on the measurement curves in the form of **wavy lines**. The measurement yoke must be **earthed**.

During **flux measurements** deviations may occur as a result of the fact that the **temperature** of the magnet is not the same as the measurement room temperature. The difference in the flux is  $0.2\% / ^\circ\text{C}$ . Therefore the segments must always have lain in the room where the measurement is to be taken for a **sufficiently long period**. If the segment is picked up **in the hand**, even for a short time, the result will inevitably be too low.

Other errors may be produced if the **Hall sensor** is not inserted as far as it will go or if the segment has not been **positioned** properly. The error caused by different positions of the magnet is larger than the measurement error of the Robograph 2 even if it normally remains below 1%. Furthermore the segment must not be allowed to **move** at all during the measurement. This can easily cause errors of around 2%.

A slight error may be caused by the temperature coefficient of the Hall sensor. This is approx.  $0.03\% / ^\circ\text{C}$ . This can slightly be shown by the fact that the Hall sensor gets hot if several measurements are taken in a short period of time. Overall, however, the error level is very low.

For **material measurements** the temperature is also a decisive factor, of course. On the other hand the temperature compensation may be **incorrect** if materials other than ferrite are used. This is why it can be disabled.

For material measurements the Hall sensor must also be correctly positioned. In any event the correct **gradient** value of the Hall sensor must be set correctly in "Parameters".

Furthermore, it must be ensured that the top and bottom material inserts are positioned in such a way, that the measurement coils are directly **on top of each other**. The top stamp of the yoke must be **held in position** since otherwise it will move and influence the measurement.

The sample must **cover** the measurement coils sufficiently. Therefore it must not be too small.

For material thicknesses of **less than 4 mm** the fact that the permeability of the material measurement insert is not infinite will slowly become apparent so that at that point it is no longer possible to assume that it is independent of thickness.

## 6. Technical data

Flux measurement to BOSCH test instruction No. 3 139 918 950:

Repeat accuracy  $\Phi^*_{\text{R}}$  above 0.2 mVs:

**+/- 0.25% +/- 1  $\mu$ Vs**

Repeat accuracy  $\Phi^*_{\text{RG}}$  above 0.2 mVs:

**+/- 0.5% +/- 1  $\mu$ Vs**

Material measurement:

Repeat accuracy  $\mathbf{B}_r$  above 200 mT: **+/- 0.25% +/- 1 mT**

Repeat accuracy  $\mathbf{H}_g$  above 200 kA/m:

**+/- 0.5% +/- 1 kA/m**

Repeat accuracy  $\mathbf{jH}_C$  above 200 kA/m:

**+/- 0.25% +/- 1 kA/m**

Calibration:

**Internal, automatic**

Maximum field strength:

**1000 kA/m**

Controllable power source:

**500 VA**

Control current:

**4 A**

Hall sensor control current:

**7 mA**

Measurement time:

**approx. 8 seconds**

Data connection:

**RS232, 19200 baud**

Power consumption:

**700 W**

Supply voltage:

**220 - 240 V**

**or 115 V**

Size:

**47 x 44 x 15 cm**

**(19", 3 HU)**

Weight:

**15.5 kg**

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