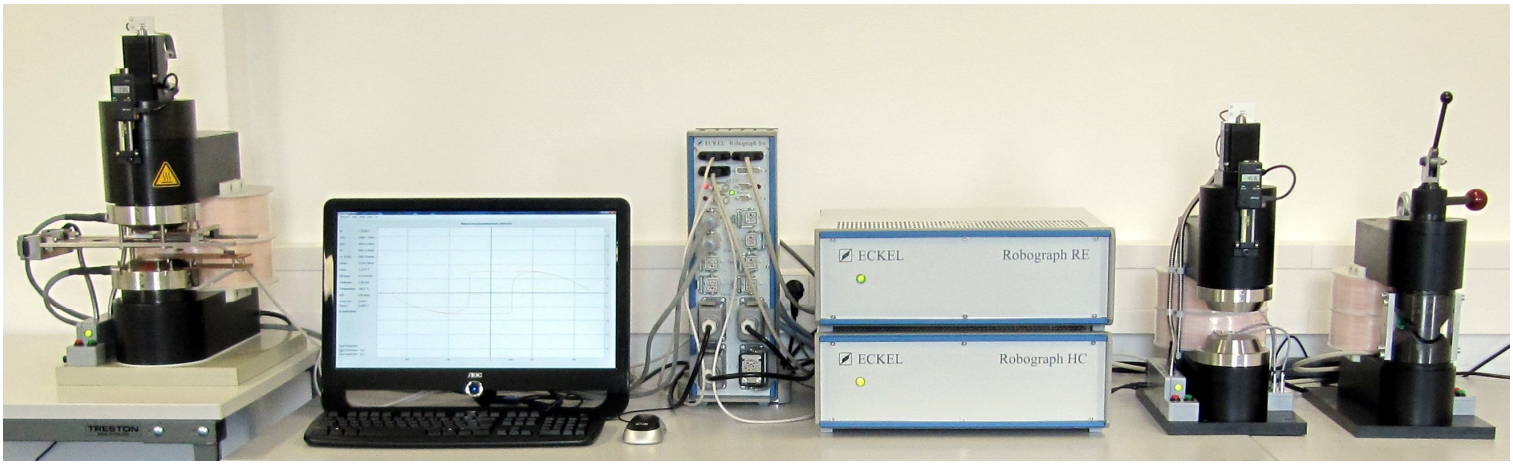
ECKEL
Robograph RE



Operating Manual

V 1.4

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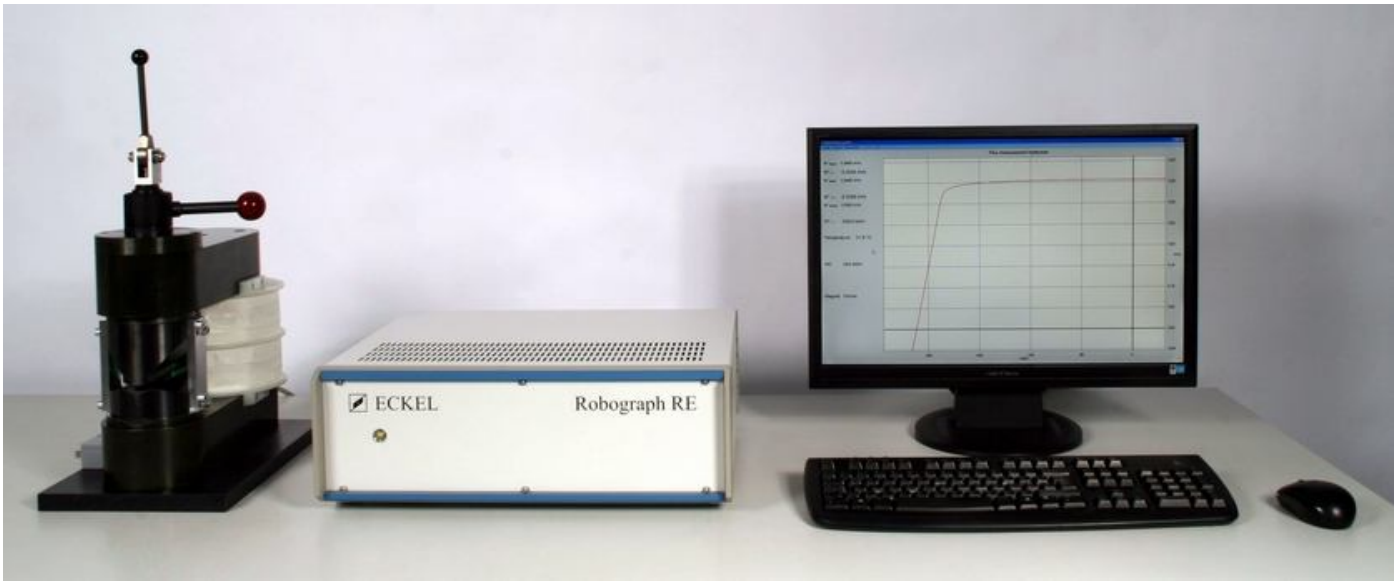
Content

General description of the ECKEL Robograph RE

Digital high performance measuring system for hysteresis and demagnetisation measurement of hard magnetic materials like material and flux measurement of flat samples and flux measurement of ferrite segments according to BOSCH standard.

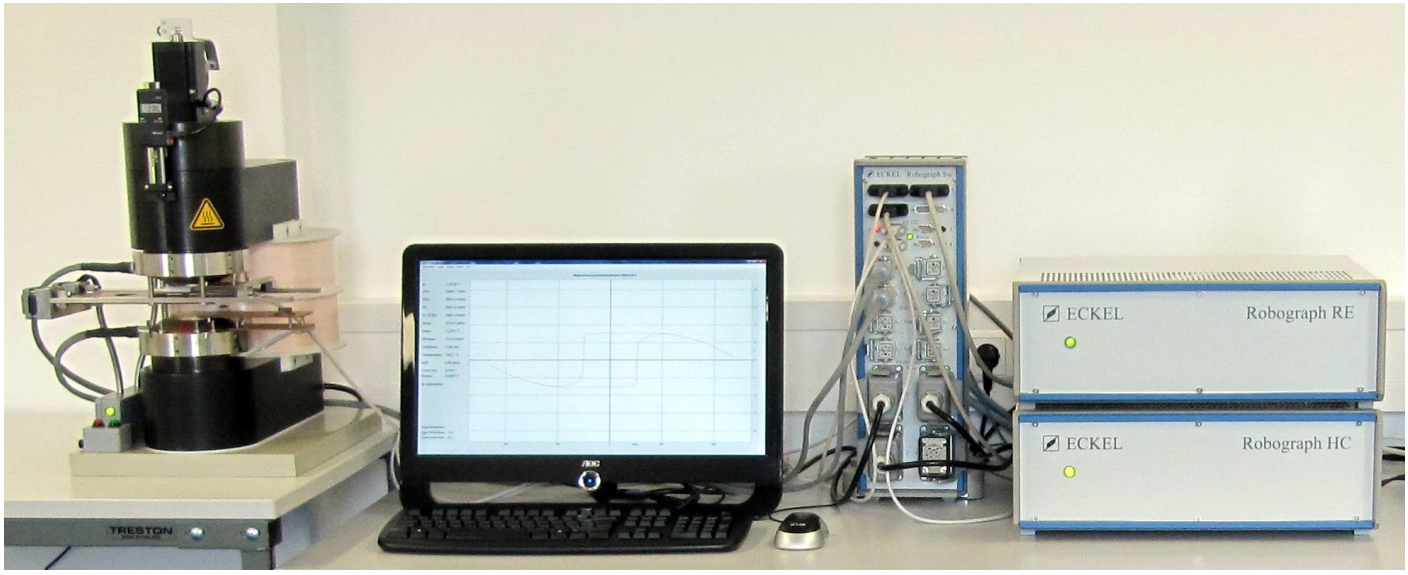


Robograph RE for flux hysteresis measurement of ferrite segments

After 15 years of worldwide success since the introduction of Robograph 2, ECKEL presented the new Robograph RE (Rare Earth).

With complete new digital technology the Robograph RE sets new standards in hysteresis and demagnetisation measurement of hard magnetic materials.

While functions of flux hysteresis measurement of ferrite segments according to Bosch specification with some improvements in handling and operation mainly stay the same as with the Robograph 2, new ways are opened for measurement of flat samples of Rare Earth, AlNiCo or ferrite material. Also flux measurement of flat samples with air gap is possible.



Robograph RE for material and flux measurement of flat Rare Earth and ferrites (with switch Robograph Sw)

With the Robograph RE ECKEL offers the only fully motor driven electromagnet yoke in the world for completely automatic measurement of flat samples.

A hysteresis measurement instrument determines the properties of a magnet by simultaneous recording of field strength and magnetic flux respectively induction over a preselected field range. Thereto the magnet must be exposed to an external magnetic field.

For hysteresis measurement normally the magnetic field is driven to positive and negative saturation. If field strength is not sufficient for this, only demagnetisation measurement is possible. Here the field is only driven in one direction opposing to the internal field of the magnetized magnet.
The display of all data results in the desired graph.

All competitors hysteresis measurement instruments offered for this purpose consist of two analogue integrating flux meters with digital display and with the results being read and displayed via PC. Only some values per second can be read by this method.
In contrast to that, all test inputs of the Robograph RE are digitally sampled and processed by a PC.

The software of the Robograph RE allows for a signal processing like offset correction, switching of amplifications and time outs during measurement, which would not be possible with analogue systems.

The extraordinary signal quality of the Robograph RE nevertheless allows an evaluation without any direct signal conditioning or filtering.

Resolution of analog/digital converters is 24 Bit (16.777.216 steps) at sample rates from 125 Hz to 2.000 Hz. Output noise of the power amplifier has been minimized. By different input amplifications (1, 2, 4, 8, 16, 32, 64 and 128) the measuring signal is levelled to optimum. Input noise is only 1 ppm of full-scale at input amplification of 1. Thereby repeatability is improved to better than 0.1% (if magnet stays in fixture). Thus the result is shown with one more digit as usual (0.1 µVs, 0.1 mT and 0.1 kA/m resolution).

ECKEL Robograph RE

Using a PC as an integrator provides higher performance at significantly lower costs if compared to two high-quality analogue flux meters. By evaluating data via software the Robograph RE benefits permanently from performance enhancements which are provided by software updates. Also firmware of the Robograph RE can be updated by the user. Adequate programs will be provided at our website.

The Robograph RE is connected to the PC via USB.

To generate the magnetic field the Robograph RE has 2 controlled power current sources. Output of the power amplifier is 1.400 VA and the fan is temperature regulated.

The Robograph RE has complete control over all voltages, currents and temperatures of the power amplifier. Stability of the power amplifier has been tested with 100.000 measurements at non-stop operation.

Since excitation of the power amplifier is digital, the time course of field strength can have any shape.

With different speeds and selectable maximum field strength hysteresis measurement as well as demagnetisation and 2-quadrant demagnetisation or even loops or recoils are possible. Also New Curves of unmagnetized magnets can be shown.

After measurement demagnetisation or hysteresis curve are shown as selected. The graph can be expanded by mouse as desired until single dot display. As usual all results can be temperature compensated.

Display of Hall probe and coil signals is possible. All graphs can be printed.

As power supply for the Hall probe the Robograph RE has a symmetrical current source switchable from 7 mA (flux hysteresis measurement) to 5 mA (Rare Earth material measurement).

The Robograph RE is self calibrating at all input amplifications and has a reference signal output to perform an external calibration and certification using any calibrated multimeter.

Resolution, repeatability, speed and easy handling of the Robograph RE have never been reached before.

The Robograph RE software needs a Windows operating system and is available in English.

Features of the Robograph RE:

Internal, automatic calibration of the device, no offset calibration of analogue integrating flux meters.
The internal ultrahigh accuracy symmetrical reference voltage source (combined with the calibration software integrated in the system) performs a calibration of all test inputs within some seconds. By using an external calibrated multimeter this internal calibration can be checked by means of integrated control software and a calibration certificate can be issued.

Measurement of the complete hysteresis curve within a minimum of 8 seconds with high resolution (approximately 10.000 dots).
Other slower units often only measure the demagnetization curve to save time. With that kind of process an offset error of the analogue integrators can corrupt the result, although the error cannot be identified visually. With the high resolution of the Robograph RE there are no knees of the curve, which may however be usual when using flux meters being read by PC.

Self-explanatory Windows user interface with one-key control after pre-selection of operating mode.
Operating the Robograph RE unit does not involve working with complicated menu sections. All information and the results with regard to the measurement are presented on one single page. The desired process regarding the measurement, the evaluation, the presentation of a graphics, the printout and the archiving are pre-selected and can afterwards be performed automatically, or if desired by operating a push button at the measuring yoke.

Extensive parameter settings.
Using parameter settings allows for a set-up of the measurement according to individual requirements.

Software and operating manual in German and English.
The language of the user interface will be selected by a parameter setting and the operating manual is also available in German and English as pdf file. The operating manual is continuously updated with information about software upgrades.

Archiving of measurements and tolerance archive for all segment types and materials.
If you want to review measurements at a later point in time, you can save all measurements. This can be performed on the local hard disk, or the Robograph unit can transmit this data to your network server. Also the measurements can be exported as EXCEL file. All original samples are archived each time. For each magnet type at the flux measurement and for each material at the material test the individual limit values are set one time and are then stored. Before the measurement is started, the tolerance data to be applied will be loaded.

Temperature compensation for ferrite and Rare Earth materials.
As the limit values for the magnets are related to a temperature of 20 degrees Celsius, the Robograph RE unit has integrated temperature compensation in order to convert temperature-dependent results to 20 degrees Celsius. For material measurements the reference temperature is selectable.

Troubleshooting programs.
If you doubt a measurement result or if one of the various control routines reports an error, you can rely on a number of control programmes integrated in the unit that allow for error analysis with regard to simple operating errors up to defective individual PCB assemblies. A graphical debug surface allows control over all voltages, currents and temperatures of every single transistor.

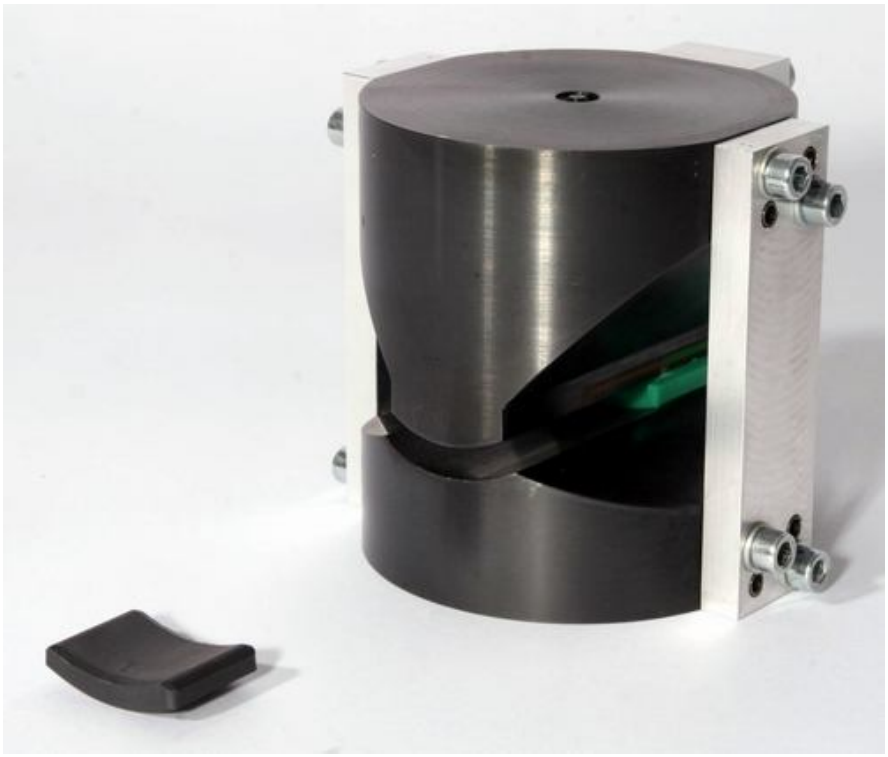
Firmware update.
The internal firmware of Robograph RE and Robograph HC will be automatically updated by the Robograph program whenever a new program version detects an old firmware.

A 1. Flux hysteresis measurement of ferrite segments according to Bosch specification

The Robograph was designed in co-operation with **Ro**bert **Bo**sch GmbH and the aim of the design was the automation of the Bosch test specification No. 3 139 918 950 for non-destructive flux measurement of magnetic segments.

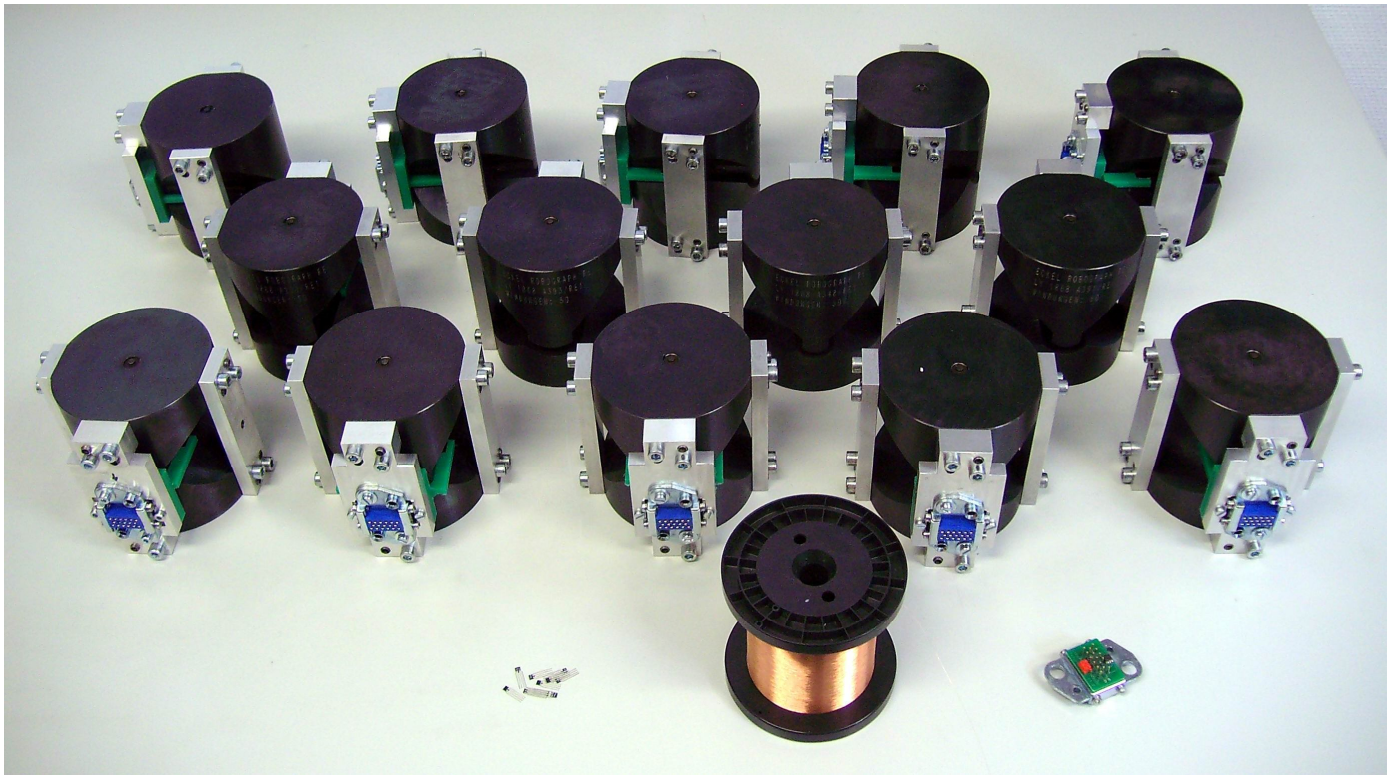
The traditional way of testing the quality of magnet segments by material test of single surface ground segments should not be performed anymore. The number of samples taken was too low to obtain a reliable statement for an entire delivery as too many efforts were involved with the grinding process. Apart from that, errors occurred when the radial preference direction was not considered or when the surfaces were not parallel. Furthermore, length and width which affect the magnetic flux, and especially the thickness of the segment, were not considered in the measurement.

With the flux measurement according to Bosch test specification No. 3 139 918 950 the segment is held inside a measuring fixture which resembles the individual pole housing and is magnetized in both directions beyond the saturation point. The magnetic flux is measured by means of a surrounding coil and the magnetic field is measured by means of a Hall probe. Full hysteresis is always measured.



New flux measurement fixture

These flux measurement fixtures can be obtained by us for Robograph RE as well as for Robograph 2.

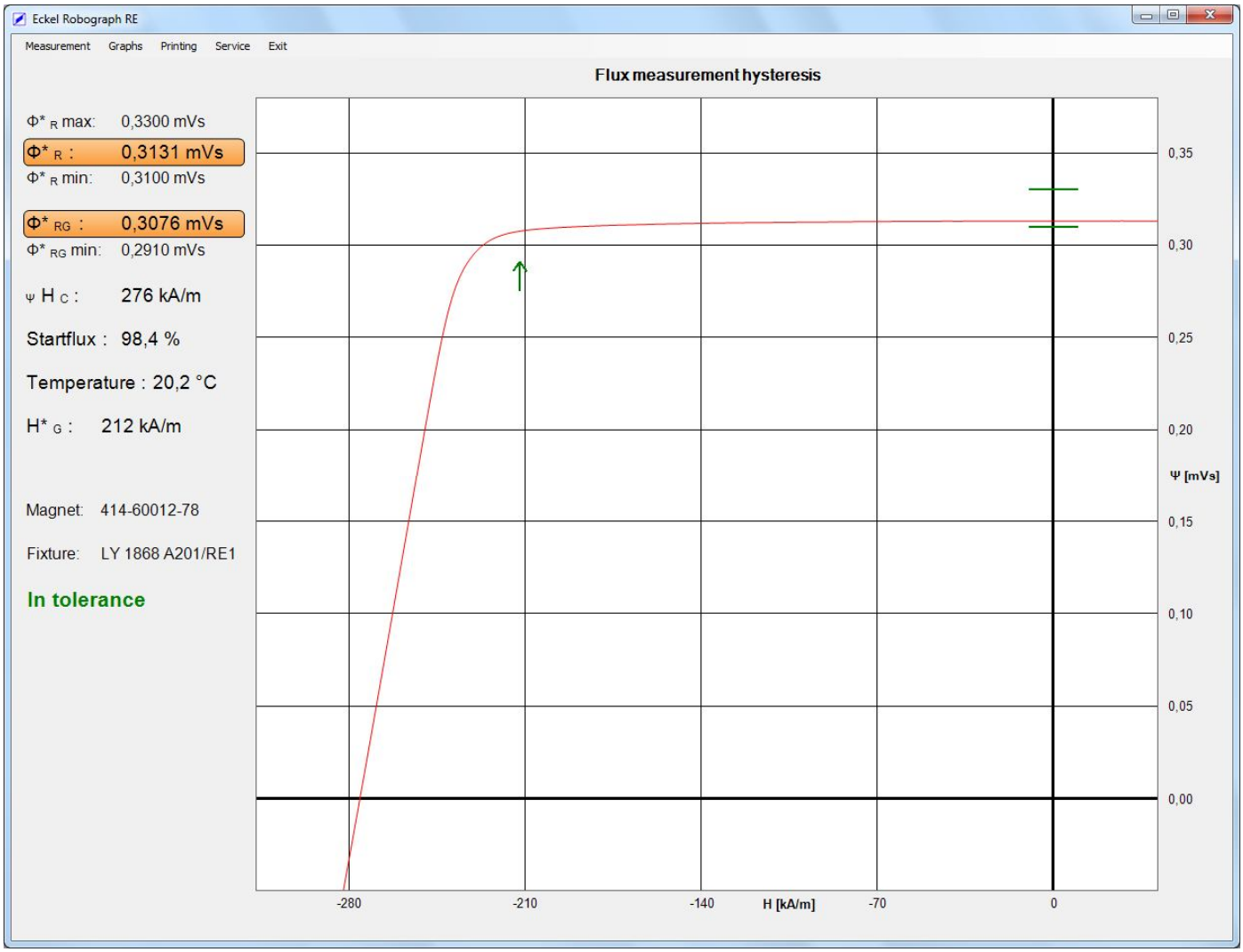


Flux measurement fixture production

As results of the flux measurement the remanence flux Φ^*_R and the remanence flux Φ^*_{RG} after an opposing field H^*_G are indicated. Also the value $H_{GF(80)}$ can be evaluated. These values are compared to the limit values which have been calculated for this magnet. By default a demagnetisation curve with display of tolerances is shown.

The Bosch test specification No. 3 139 918 950 demands the measurement of a minimum number of magnets of each batch and a statistical evaluation with determination of the Cpk value. This value provides information about the usability of the entire batch. The Robograph RE unit provides an automatic calculation of the Cpk value.

The flux measurement can be applied for each magnet which allows for a measuring fixture with a diameter of no more than 100 mm. At a magnet thickness of more than 10 mm, a test on whether the magnetic material can still be saturated must be performed.



Demagnetisation of a ferrite segment

The Robograph RE provides the calculation of flux measurement fixtures and the approximation of limit values based on the magnetic geometry of magnet segments for fractional-horsepower motors. Bosch is using the more accurate FEMAG field calculation program for the determination of limit values.

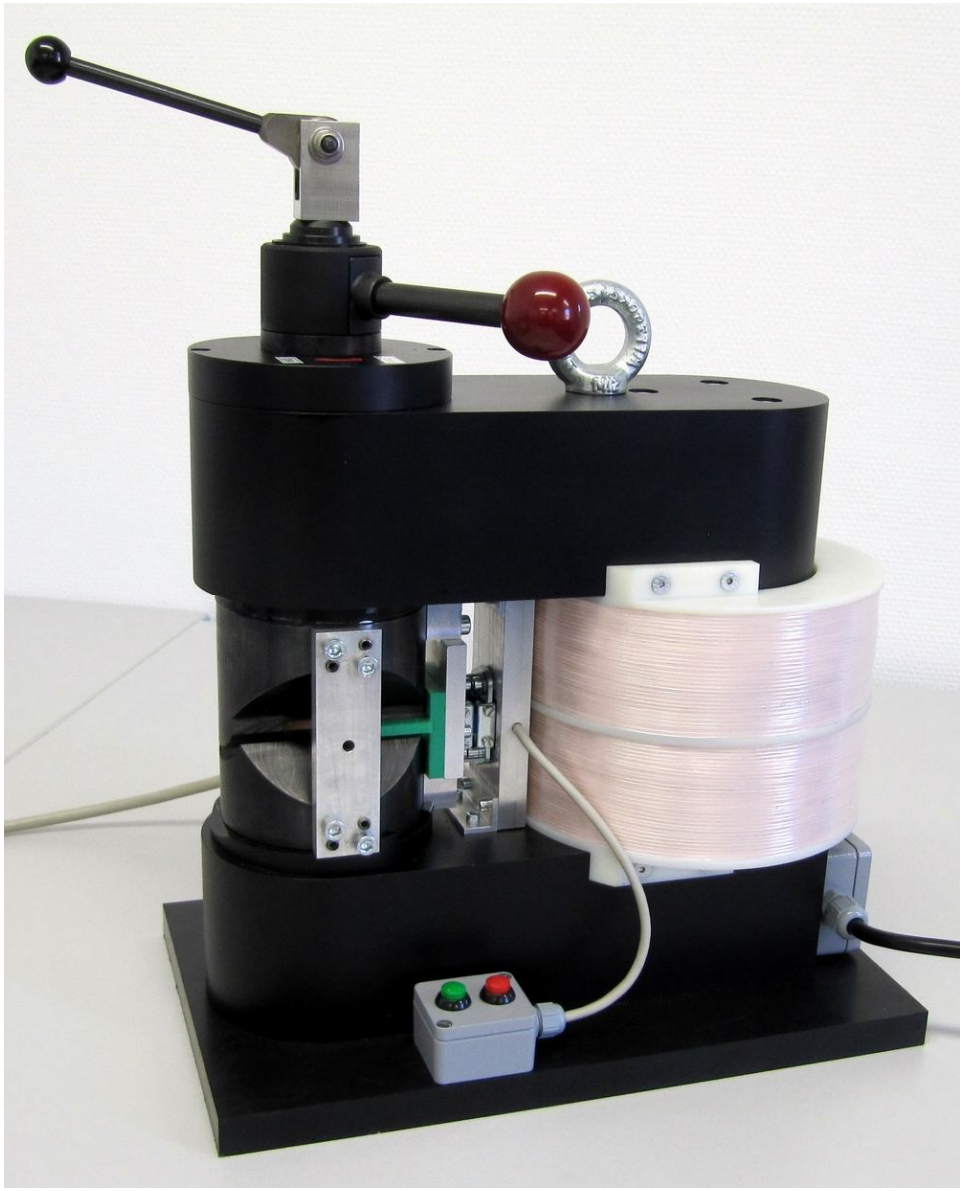
In a continuous calibration system the Robograph is also used for manufacturing calibration pole housings for flux measurement of finished pole housings. This flux measurement is preferably performed using the ECKEL DFM flux meter.

Both at Bosch and at its suppliers, the quality inspection of magnet segments is already based worldwide on the use of Robograph hysteresis measurement systems. On page "References" at www.eckelgbr.com you will find an extract from our customer base, where addresses of market leading companies regarding magnet technology are listed.

Meanwhile the Bosch test specification has become a worldwide standard that is also applied by other companies and thus demanded from their suppliers.

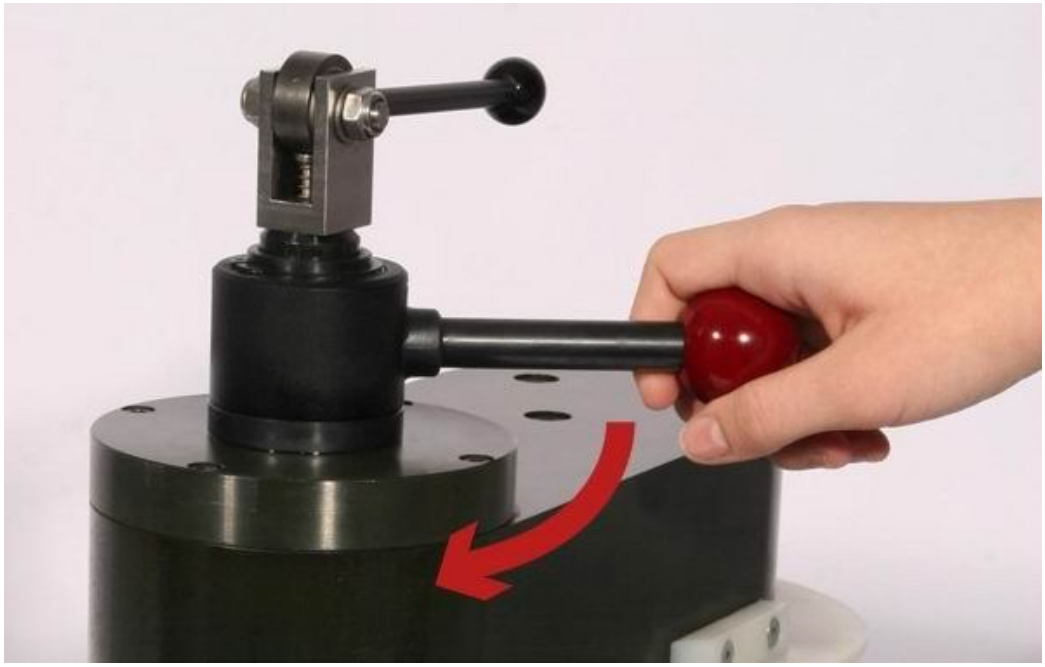
Measurement speed and fixture geometry (air gap) stay the same to get the same results as with the Robograph 2. Therefore all parameters except input amplification are fixed at this measurement. Sample rate was increased from 900 Hz to 2.000 Hz.

The Robograph RE and the new fixtures have been tested and approved at Bosch by comparing to the Robograph 2.



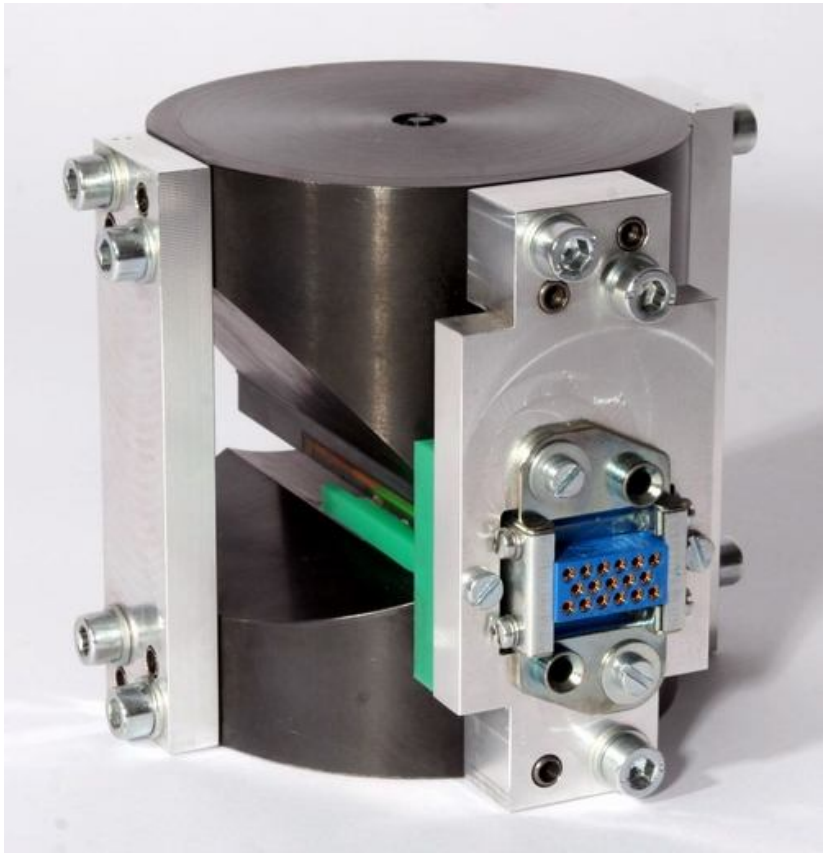
Yoke for flux measurement of ferrite segments

The electromagnet yoke for flux measurement of ferrite segments has been significantly reduced in size and weight compared to the Robograph 2 at same magnetic power (from 180 to 78 kg). The new horseshoe shape guarantees simultaneous saturation of all yoke parts at minimum magnetic path length. The measurement yoke can only accept flux measurement fixtures.



Open the yoke to change the fixture

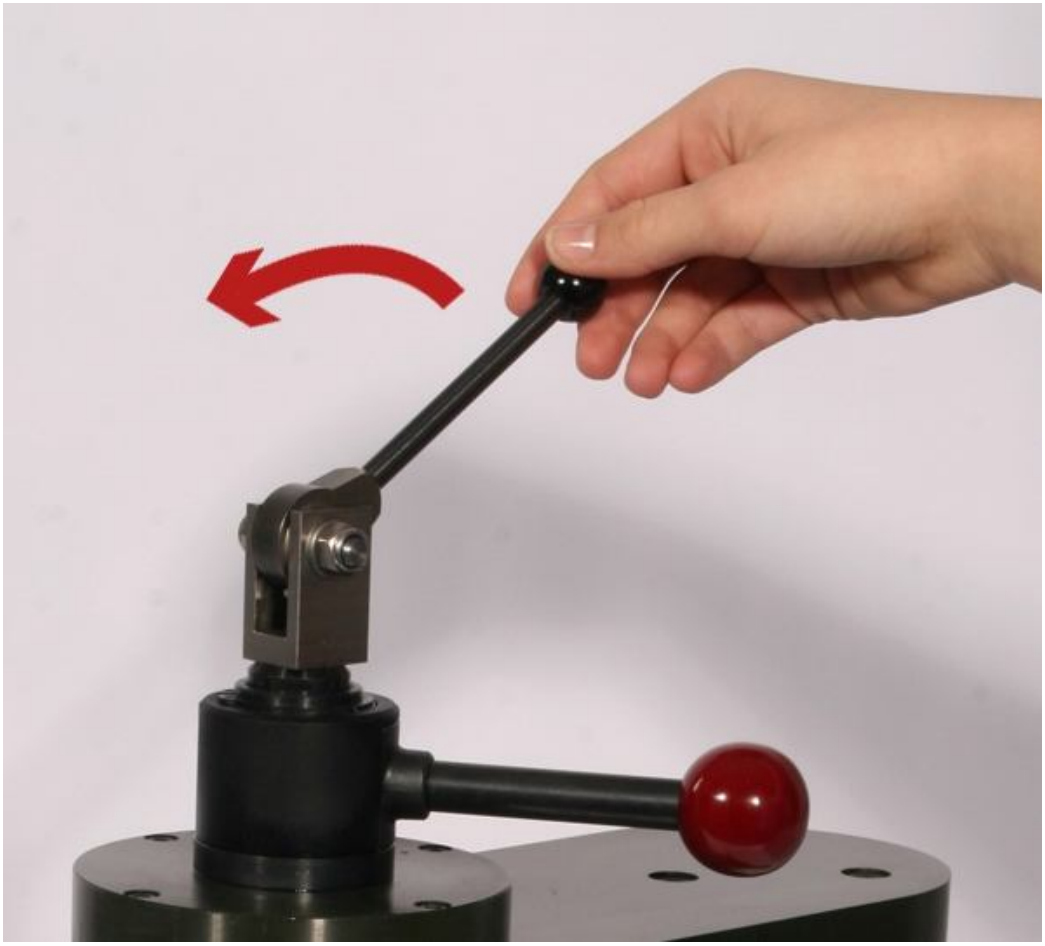
Changing the fixtures is now a matter of seconds. To open the yoke only one movement is necessary.



Plug of the new flux measurement fixture

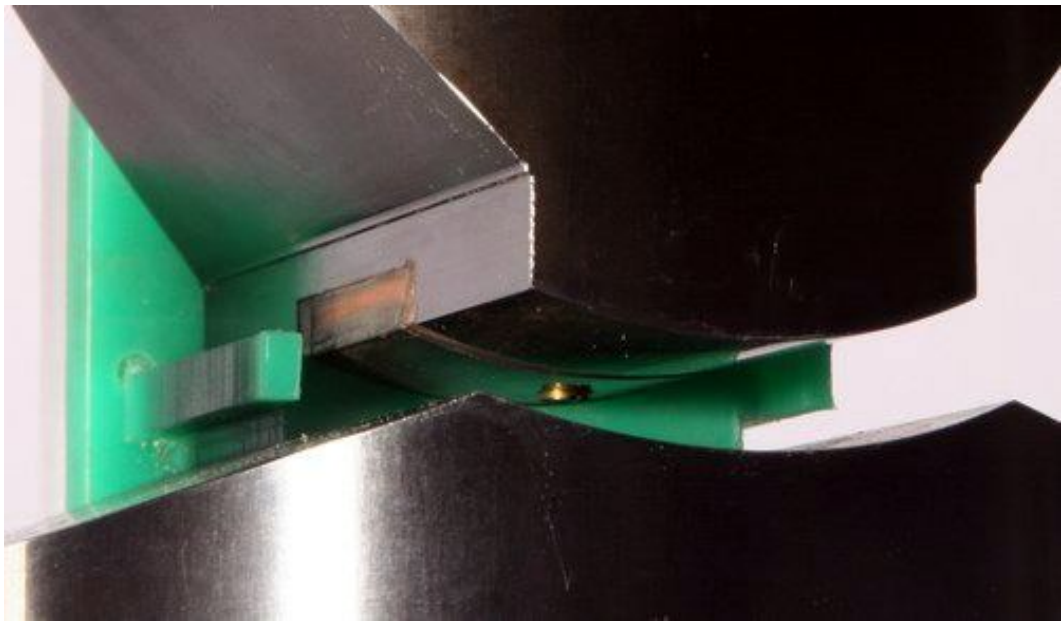
No cables are to be connected and no Hall probe to be entered. The new fixture has an inbuilt hall probe and a special plug, connecting coil, Hall probe and parameter EEPROM to the Robograph RE. The plug has a floating fit and guaranteed 100.000 mechanical cycles. The plug holder gives additional stability to the fixture.
The Hall probe holder offers additional position control for the magnet and is made from plastics to prevent errors by eddy currents around the Hall probe. No cable can be damaged when pulling out the fixture.

When entering the fixture, the Robograph RE recognizes the fixture and reads magnet number, number of turns (standard = 50), Hall probe parameters, temperature coefficients and flux limits from the EEPROM. These values are used for measurement evaluation. By different input amplifications the fixtures now can be produced with lower number of turns.

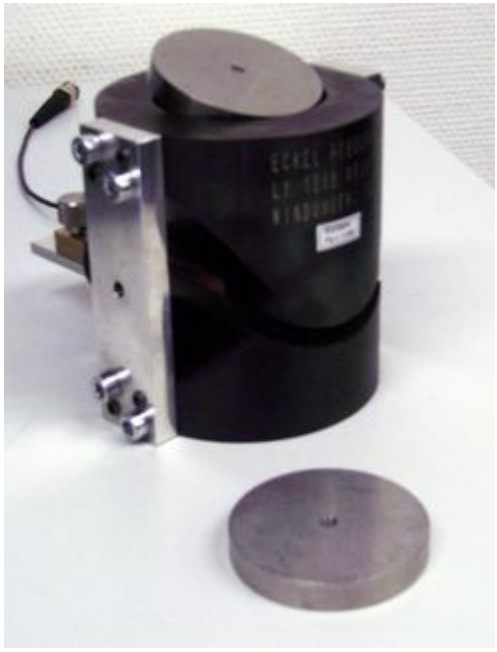


Hold the magnet

The magnet segment has no longer to be fixed by plastic stripes but is perfectly fixed with a bolt, pushed down by one sweep of the hand. The bolt has a below end of brass to ensure the air gap.
All this simplifies and speeds up handling significantly.

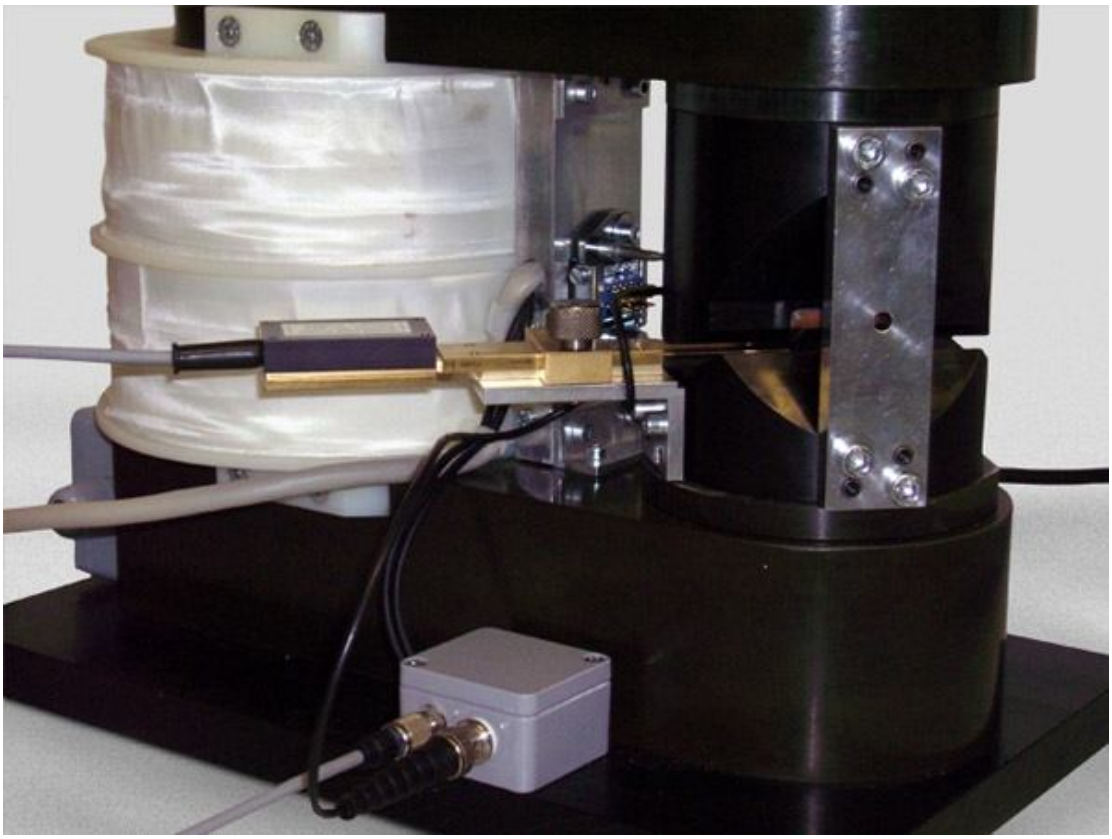


Bolt fixing the magnet



Metal discs for old fixtures

The new yoke can also be used with the old fixtures of Robograph 2. It is not necessary to change all fixtures. By inserting 2 metal discs of 60 x 10 mm the old fixture can be used. If it is only used with the new Robograph RE, these discs can be fixed with glue.



Connecting an old fixture

Of course connecting cables, entering the Hall probe and fixing the magnet by plastic stripes is still necessary with old fixtures.

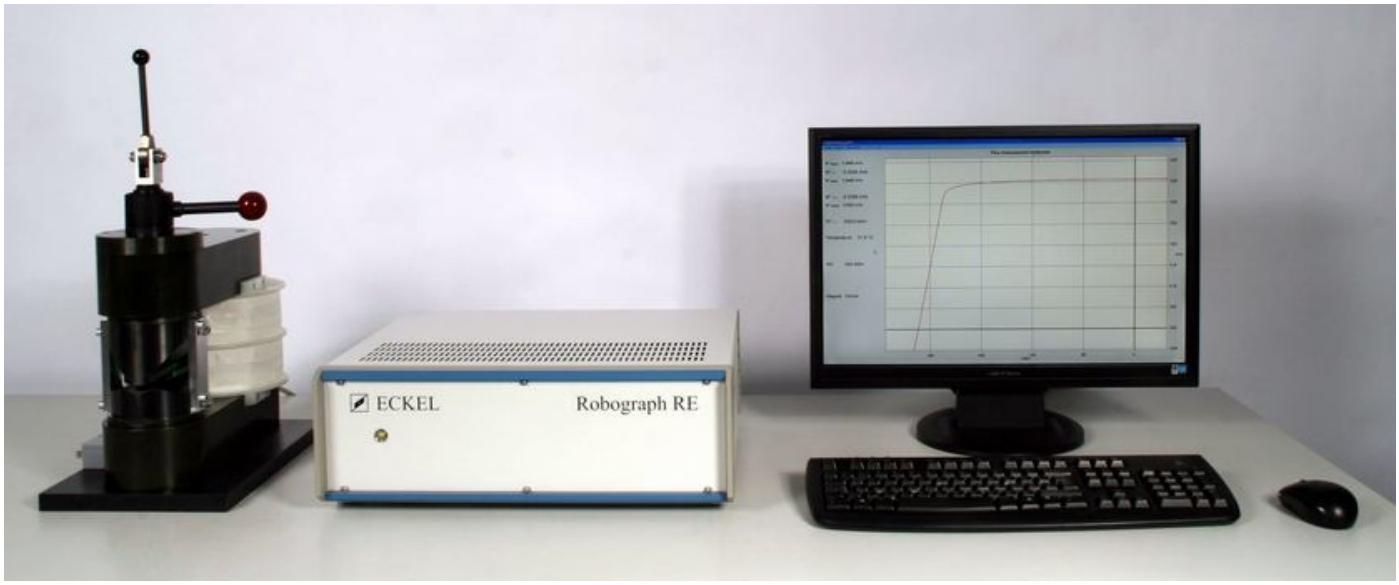
The Robograph RE in this combination with the small yoke replaces the Robograph 2.

A 2. Installation of the Robograph RE for ferrite segment measurement

Security information: Lift the yoke only at the iron ring!
Never lift the yoke at the levers!

Ring for lifting the yoke

When positioning the yoke, Robograph RE and monitor on the table remember the weight of about 100 kg. Take care that the table can bear this weight!



Positioning of Robograph RE for flux hysteresis measurement of ferrite segments

The yoke creates a strong DC magnetic field during measurement. This may harm your hard disk of the PC. Keep the PC away from the yoke.

The magnetic field may harm heart pacemakers. Don't stand near the yoke during measurement if you have a heart pacemaker!

Always use a LCD flat screen. A CRT monitor is disturbed by the magnetic field.

At the backside of the Robograph RE you find the connectors to line voltage, yoke and PC.

Backside of the Robograph RE

On the left side you see the line voltage input, power switch, and the electromagnet yoke connector.

Line voltage input, power switch and the electromagnet yoke connector

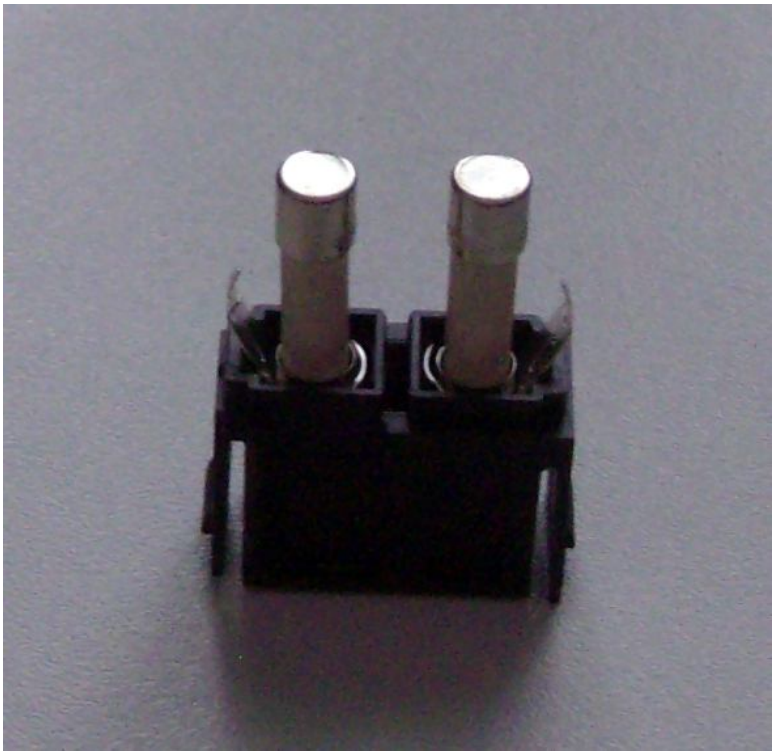
Always keep the fan, the slots at the backside and on the top uncovered!

Take care not to let any liquid soak inside the unit!

The line voltage input contents the fuses. Use a screwdriver to take them out if necessary.

Opening the fuse holder

The fuse holder contains 2 fuses 5x20 mm 8A T (slow)



Fuse holder with 2 fuses

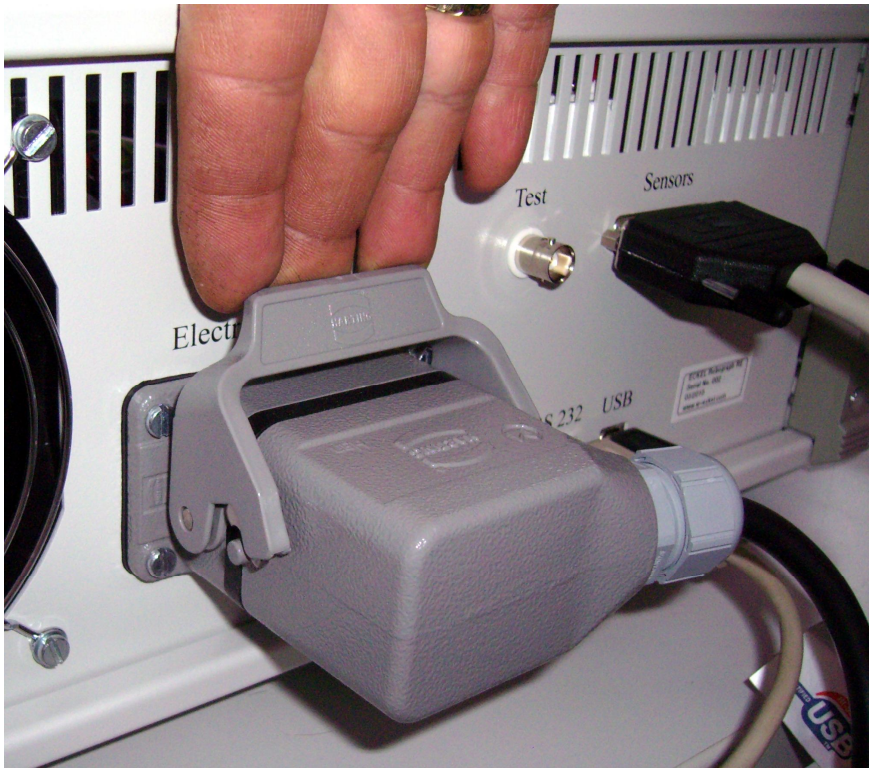
Connect the power cable to the line voltage input. Voltage is 220-240V, 50 or 60 Hz.
For correct and safe operation the line voltage must be combined with a protective earth.

Use the power switch to switch the unit on and off. The unit is on when “I” is pressed.

Line voltage connection

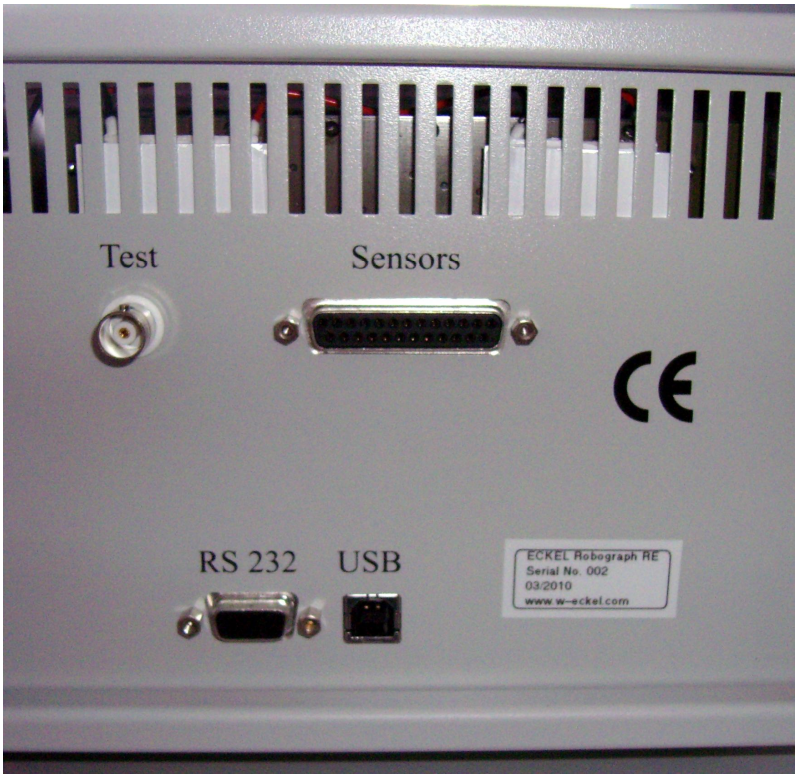
Connect the yoke power plug to the connector. It fits only in one position.
None of the yoke connector contacts may ever be connected to ground or protective earth!

Close the retaining bracket. If the connection is opened during measurement very high voltages may occur at the yoke power plug.



Closing the retaining bracket

On the right side you see the RS232, USB and Sensors input and the test output. Also serial No. and production date are marked.



Connectors on the right side

Connect the USB cable to the PC and the sensors plug of the yoke. Fix the sensors plug.

The RS232 cable is only needed in emergency cases of firmware update. Do not connect for normal use. If a switch Robograph Sw is used, connect it to this RS232 connection.

The test output is used for external calibration test for certification.

Connections to yoke and PC

At the front of the Robograph RE there is only a 10mm LED. This LED can be on in green, red or yellow. When switching on the unit the LED will be red for a short time. After successful system test the colour changes to green.

During measurement the LED is yellow. **Do not switch off the unit or disconnect the yoke!**

If the LED flashes red there is some error.

Front of the Robograph RE

After switching on the fan will start to turn slightly. Starting the fan makes some noise. This is normal.

The fan is temperature regulated and runs during measurement and 1 minute after. If transistor temperature is above 30 °C, the fan will always run with a speed depending on temperature until temperature falls below 30 °C. Then it is reset to power save mode.

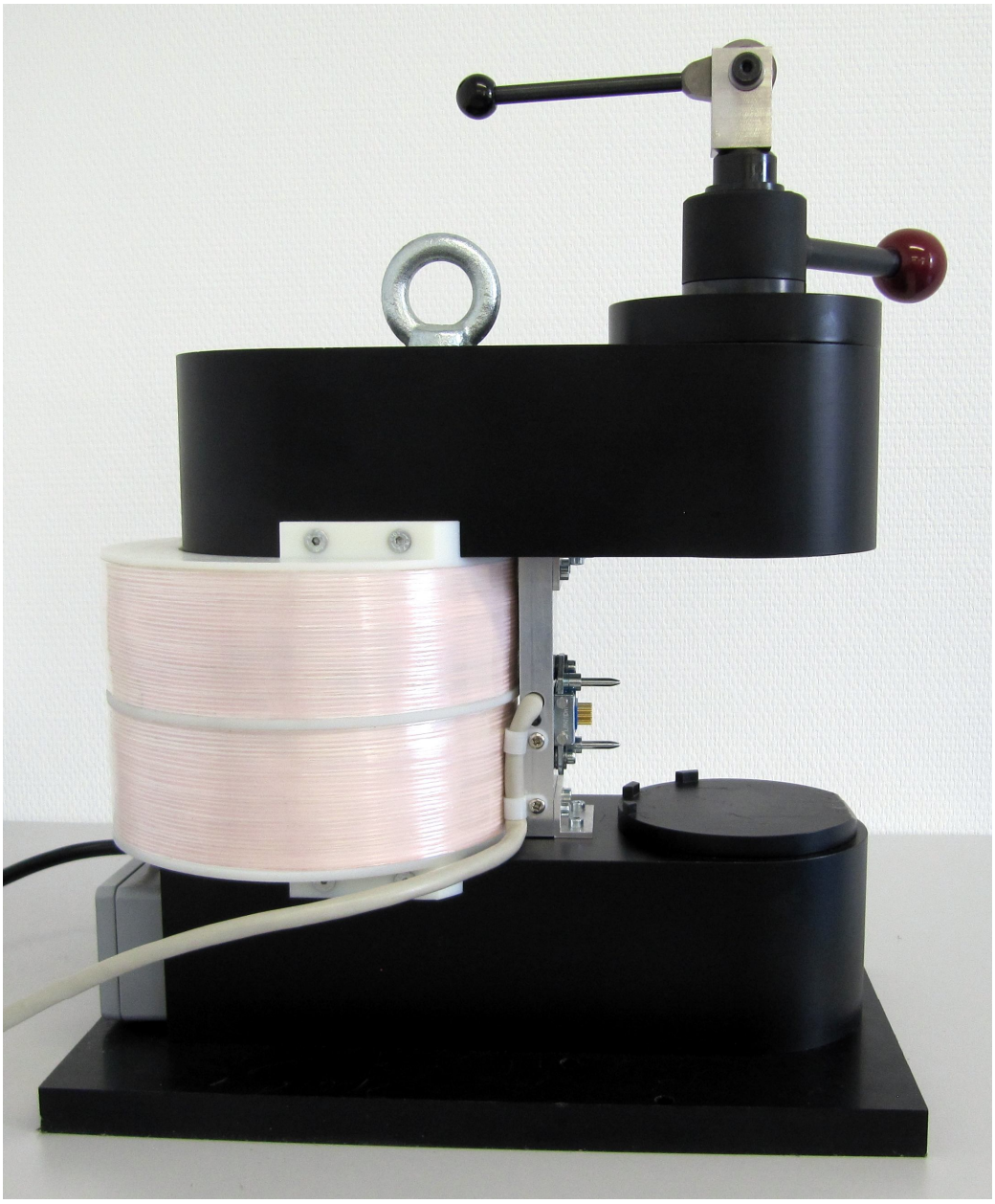
The power amplifier is not yet activated. It will be activated when first measurement is started.

The Robograph RE will recognize the yoke and the fixture (Robograph RE type) automatically.

A 3. Insertion and connection of a flux measurement fixture

The yoke is equipped with a special zero insertion force plug with guaranteed 100.000 connecting cycles and a floating fit.

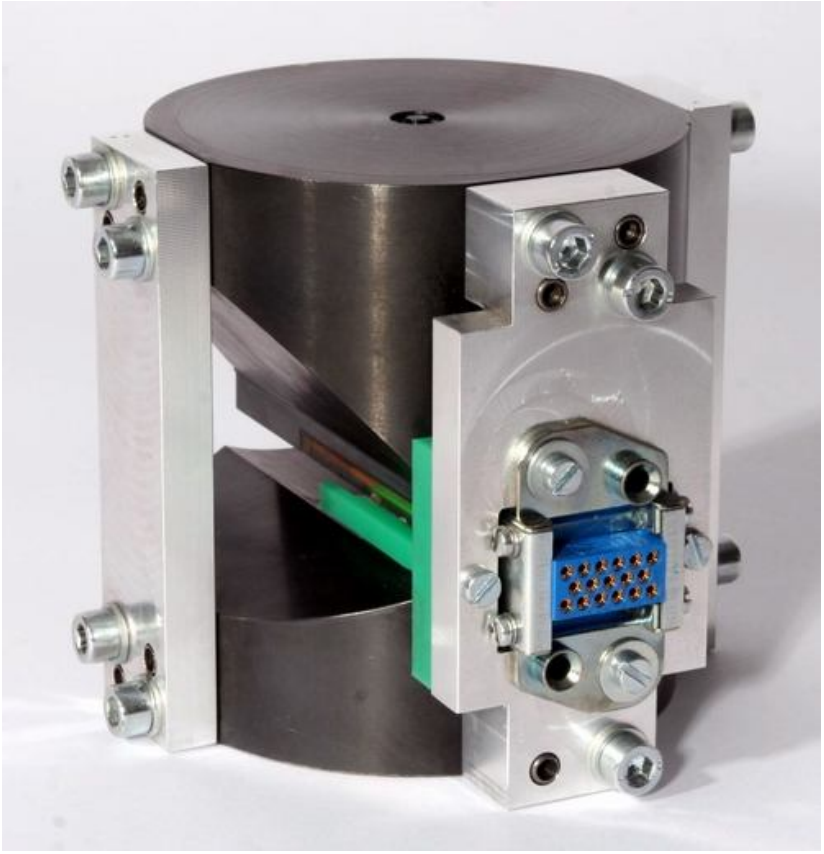
The fixture contains a flux coil, a Hall probe and a parameter EEPROM that are connected to the sensors input of the Robograph RE by this plug.



Yoke with fixture plug

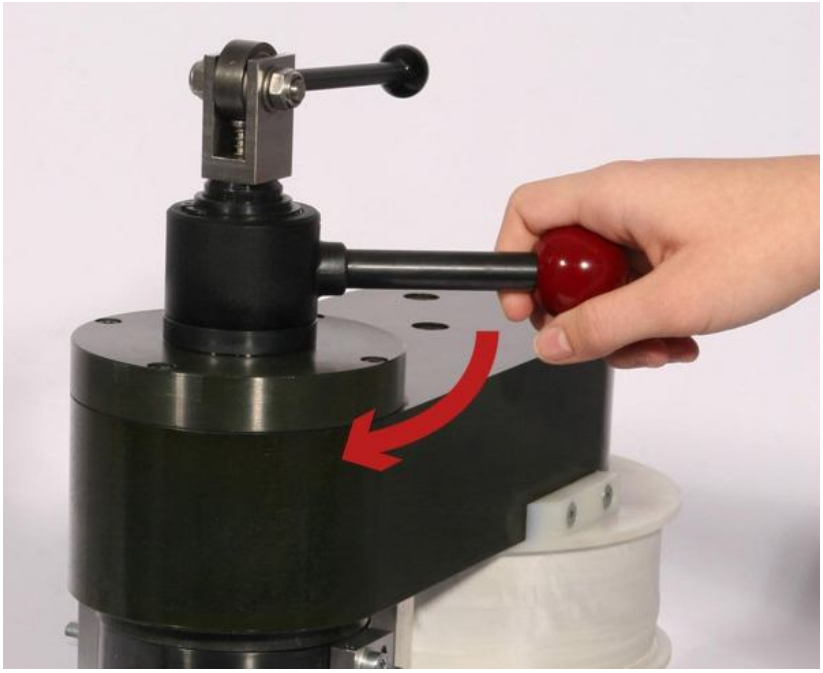
Take care not to damage the contacts of this plug. Also do not make some short circuit between the contacts.

The flux measurement fixture has the appropriate connector.



Connector at the back of the fixture

To enter the fixture, lift up the upper cylinder of the yoke pulling the big lever with the red knob to the front.



Opening the yoke

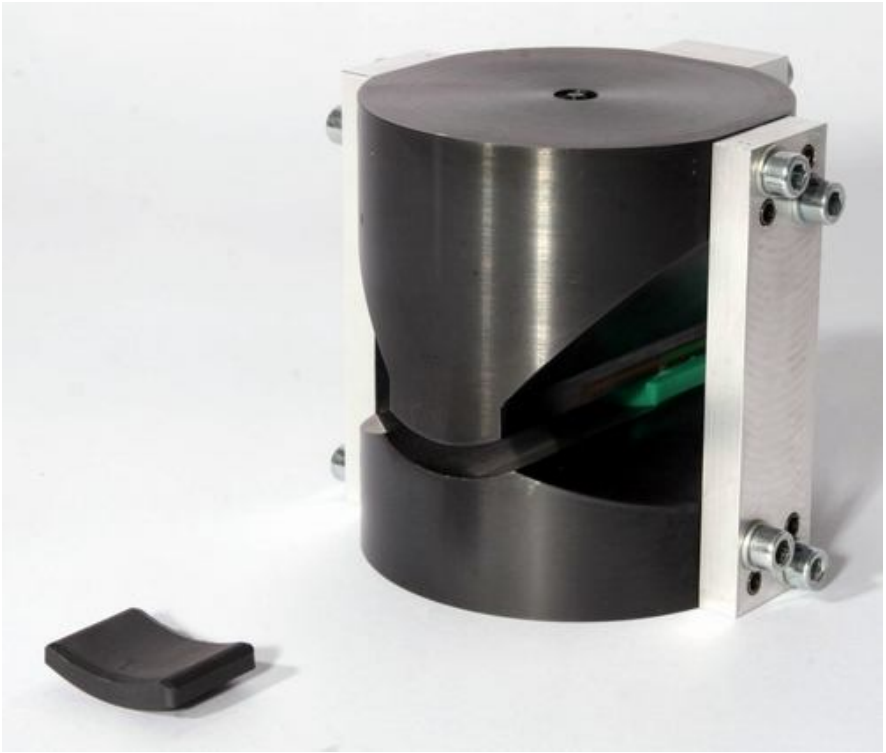
Take care that the small lever with the black knob is in back position when entering the fixture.

Insert the fixture with the connector to the plug. Stop collars at the bottom platform will care about right position and prevent damage of the plug. Push the fixture in until it has contact to the stop collars.

Close the yoke by pushing back the big lever with the red knob.

The Robograph RE will automatically read all necessary information about magnet, coil, Hall probe and limits from the EEPROM.

To enter a magnet the small lever with black knob must be in back position.

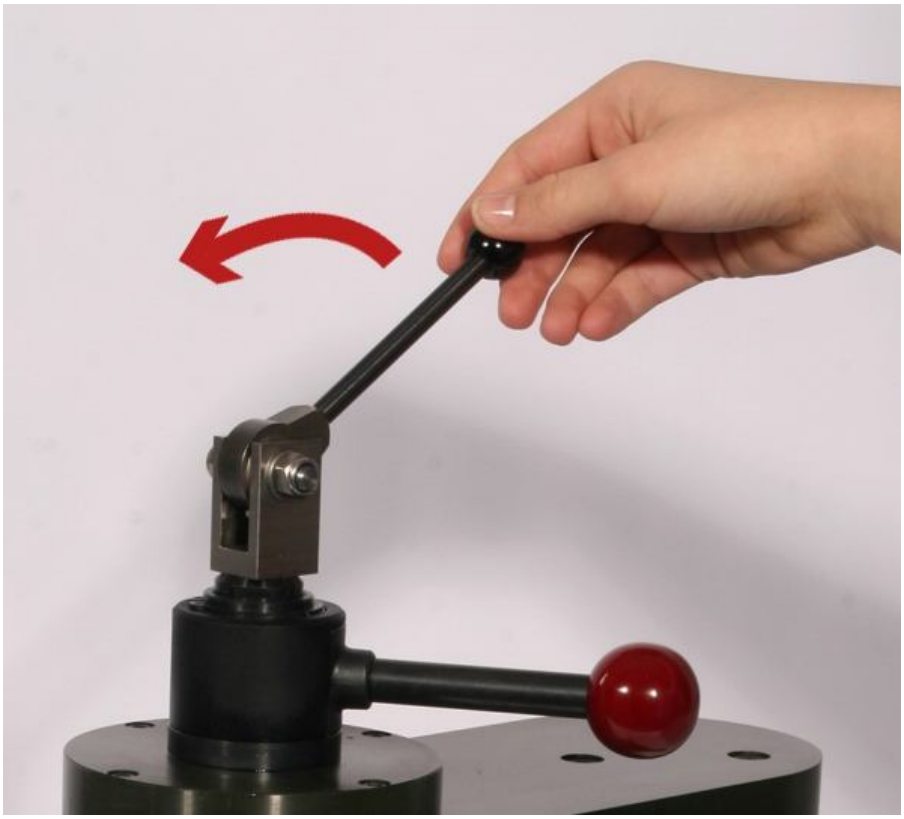


Fixture with magnet

Enter the magnet until it touches the Hall probe holder. The holder will give additional position control.

Be sure that the magnet has the same temperature as room temperature. Room temperature is used for temperature compensation. Put the magnets separately on the table for at least 30 minutes if temperature is not the same as room temperature. Do not hold it in the hand for a longer period.

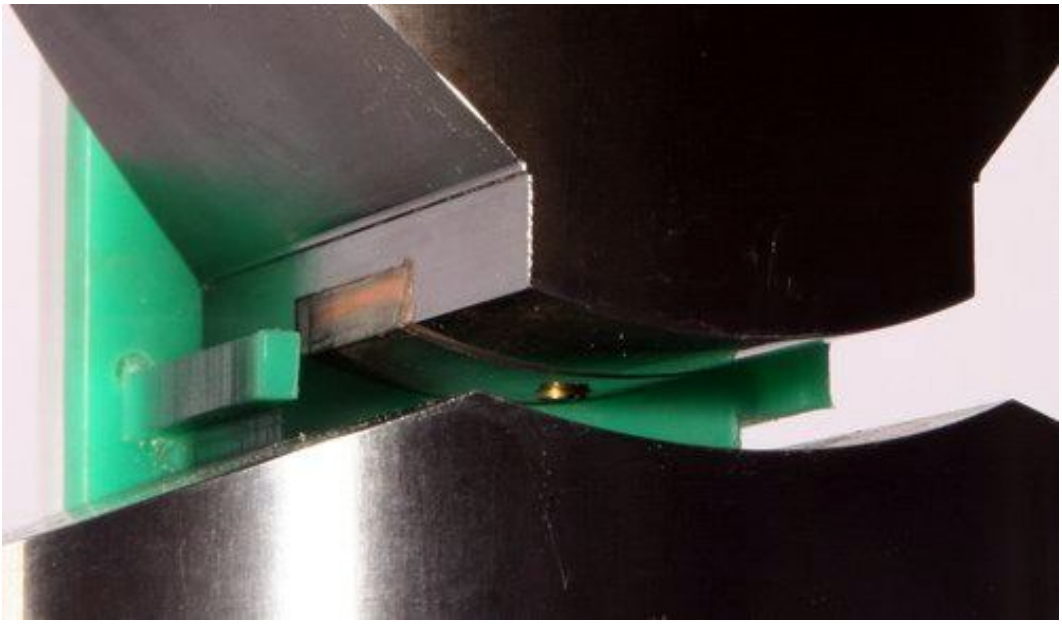
To fix the magnet to prevent it from moving during measurement move the small lever forward until you feel some resistance. Keep it in this position without any additional force.



Fix the magnet

This will press a bolt on the magnet to keep it down.

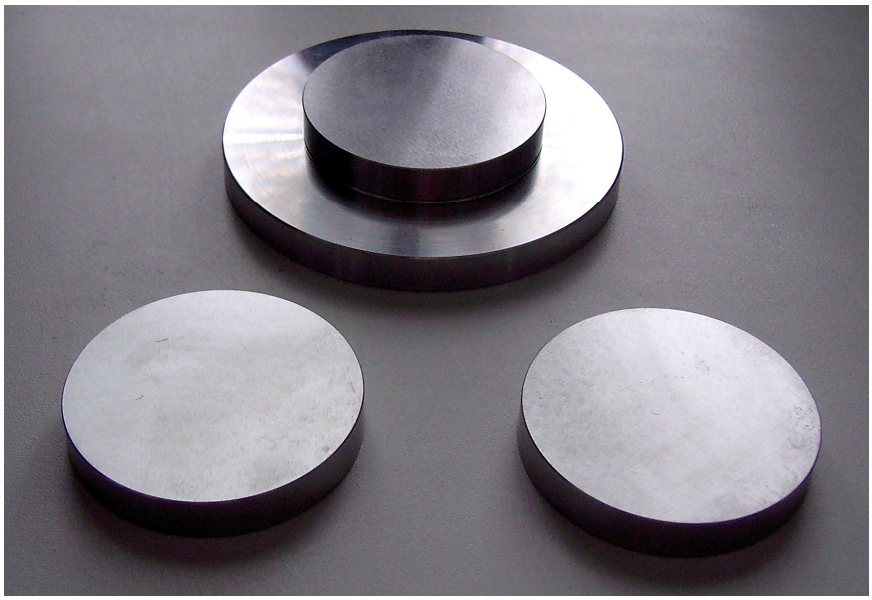
If you move the small lever too far, you will lift up the upper cylinder of the yoke. The magnet will not break by this action, but if you start the measurement in this position, the magnetic force will pull down the cylinder and break the magnet.



Bolt keeping the magnet down

For the use of the Robograph RE with old fixtures of Robograph 2 type adapter disks are needed.

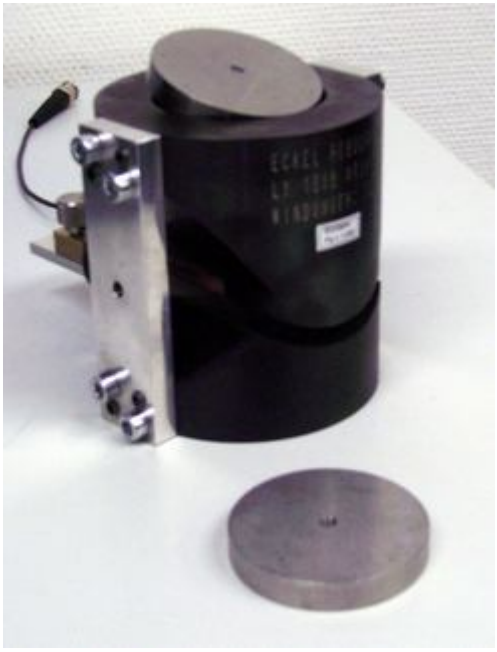
There are 2 types of adapter discs: Single discs of 59.9 mm diameter and 9.95 mm thickness and double discs with an additional 100 x 10 mm disc. They are made of soft magnetic iron (S 235 J).

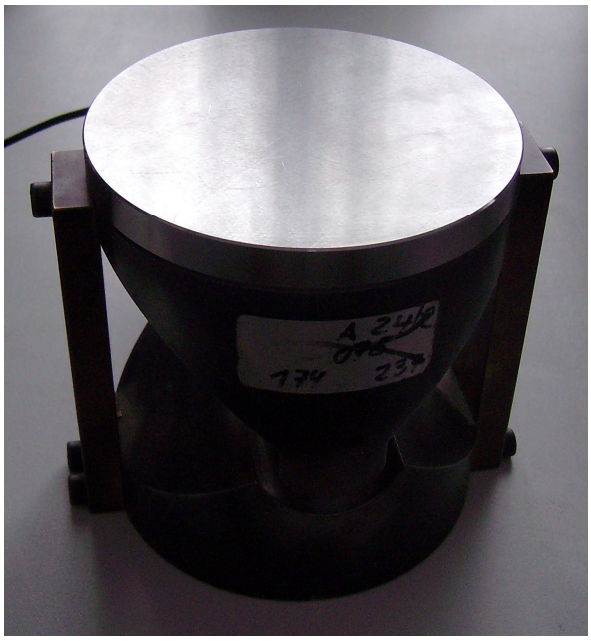


2 types of adapter discs

For the newer 110 mm high Robograph 2 type fixture 2 single discs are used to fill the recess on top and on the bottom of the fixture.

For an old 100 mm Robograph 2 type fixture 1 single disc for the bottom and 1 double disc for the top are used.





Robograph 2 fixtures with adapter discs

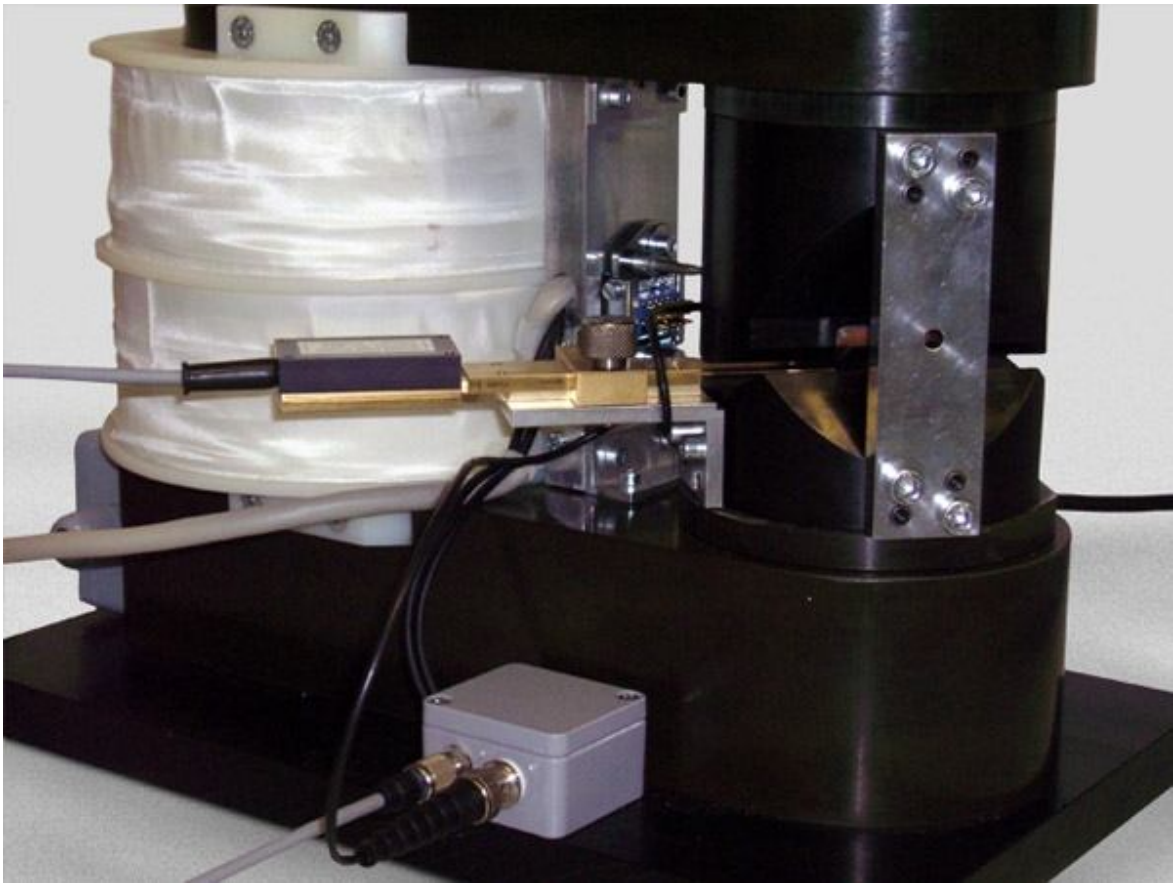
Check if you can enter the discs without force. If they need to be pressed into the fixture, they will not fall out again.

For permanent use with the Robograph RE the discs can be fixed with superglue.

For connection of the cable of old fixtures there is a connector box on the left side of the yoke. There are connectors for the Hall probe and the coil.

Connector box for old fixtures

The old fixture is inserted diagonally to have enough room for the Hall probe holder and the cables. The bottom platform of the yoke also has stop collars for this position.

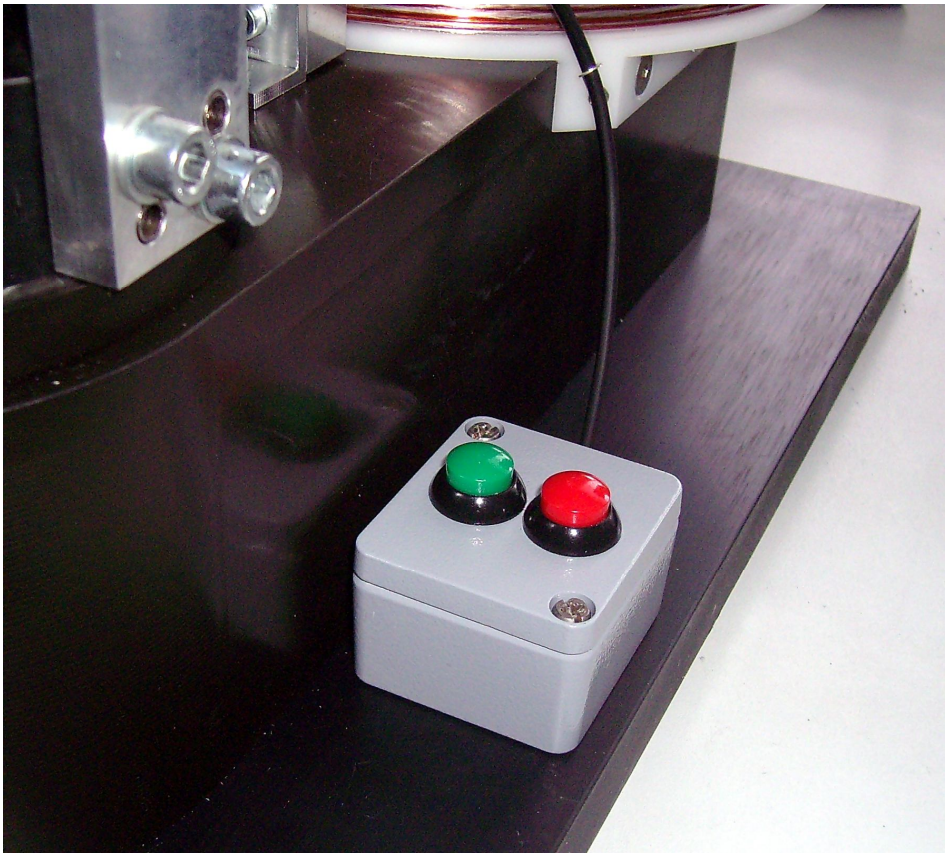


Old fixture inserted and connected

If old fixtures are used, it is still necessary to insert the Hall probe holder, position the magnet carefully and fix it with plastic stripes as before with the Robograph 2.

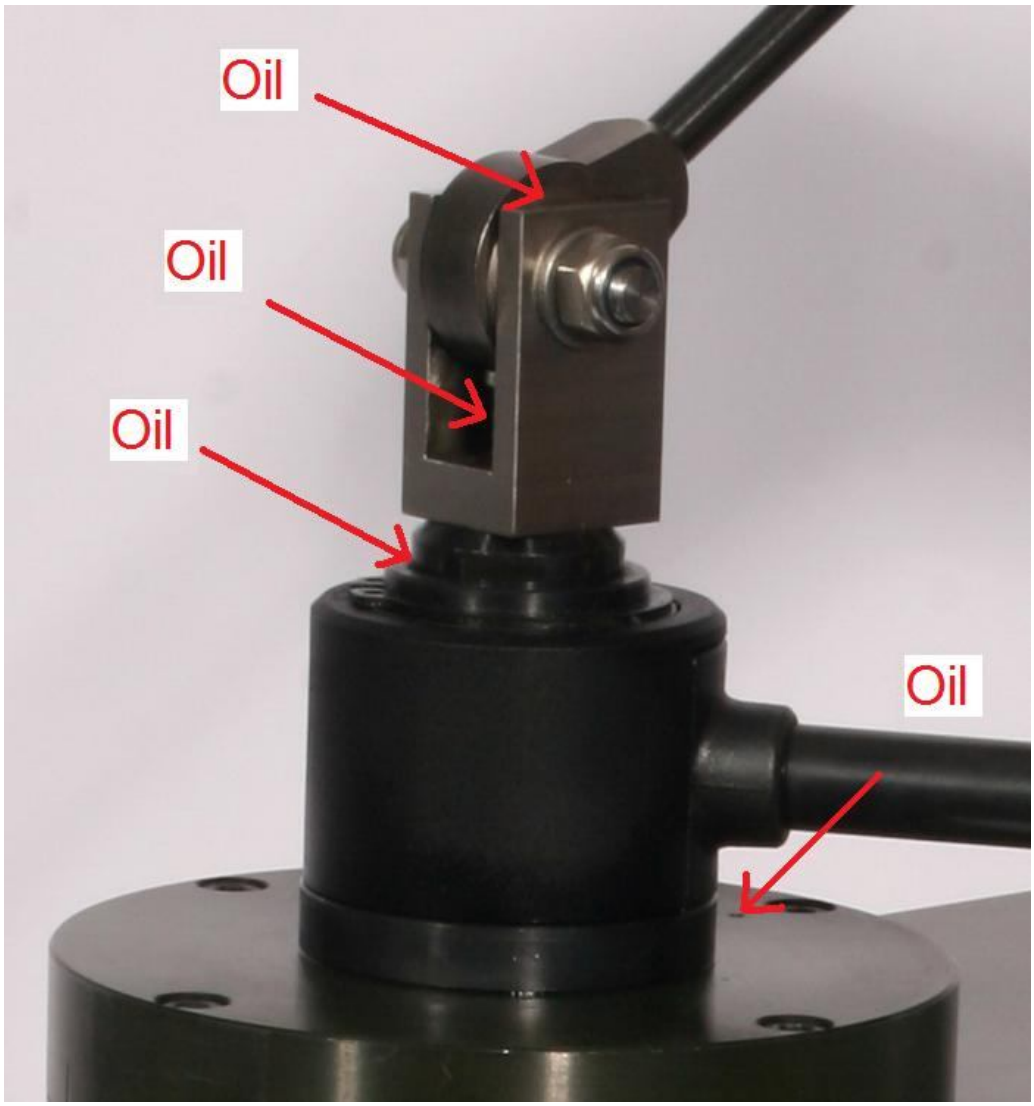
The temperature sensor for temperature compensation is also placed in the connector box to keep it away from the yoke. The coil of the yoke may get warm with permanent use.

On the right side of the yoke there is another box with 2 buttons. The green button starts a measurement. The red button is repeating the same measurement at Cpk measurement.



Buttons at the yoke

Always keep some oil at the upper cylinder of the yoke. Use the small hole in the upper cover to enter the oil. Also keep oil at the bolt for pressing down the magnet and at the center of the big lever and the axis of the small lever.



Oiling positions

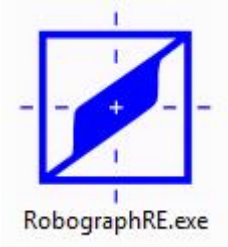
Also keep some oil on the adapter discs if used.

A 4. Flux measurement software

Minimum requirement for software installation is a PC with Windows XP, Vista or 7 operating system.

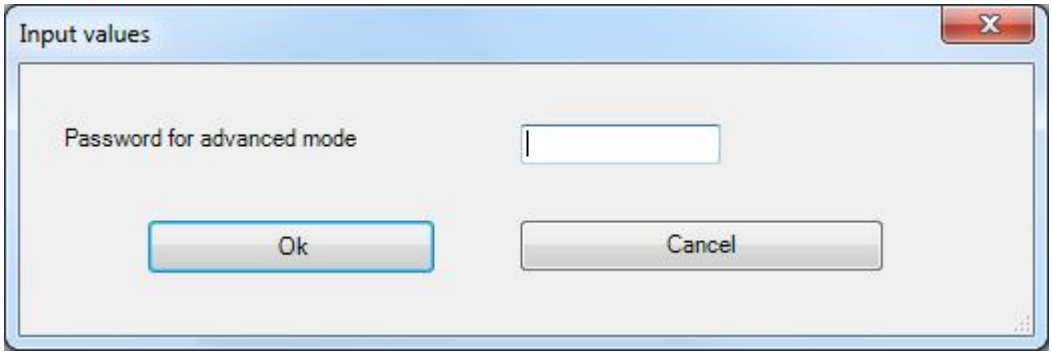
The Robograph RE software is installed by starting the program **setup.exe** on the installation CD.
Before power on of the Robograph RE unit execute the file Program Files/Eckel GbR/Robograph RE/USB Driver/**CDM20600.exe**. This will install the USB driver.

The Robograph RE program is started by double-clicking on the Robograph RE icon on the desktop.



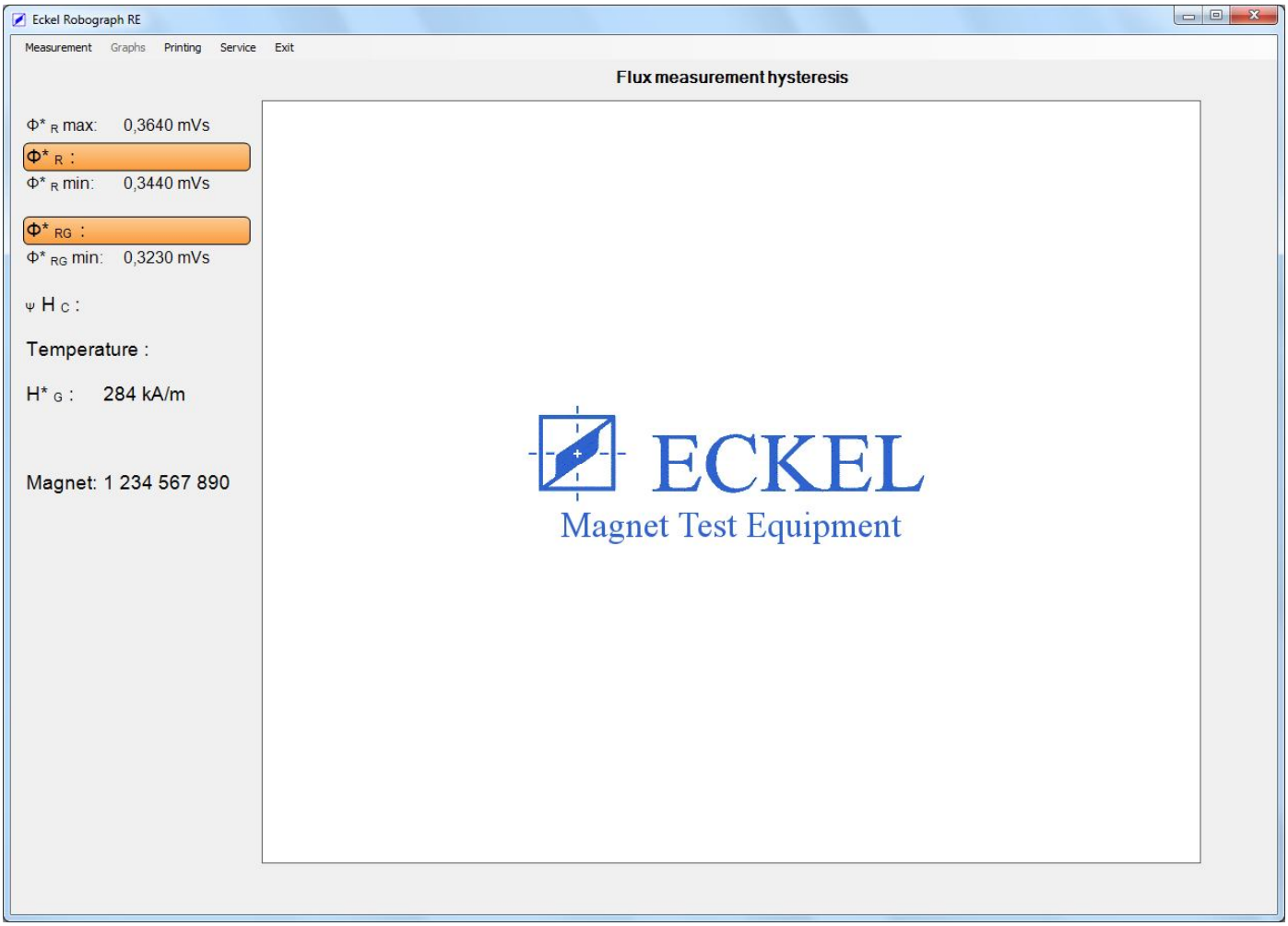
Robograph RE icon

If a password for advanced mode has been entered to parameters before, a window will open to enter this password. If the correct password is not entered here, only restricted mode will be available. For more information see chapter 4.4 Program options.



Input window for password for advanced mode

The main window shows the empty graph field, the result area at the left and the task bar on the top.

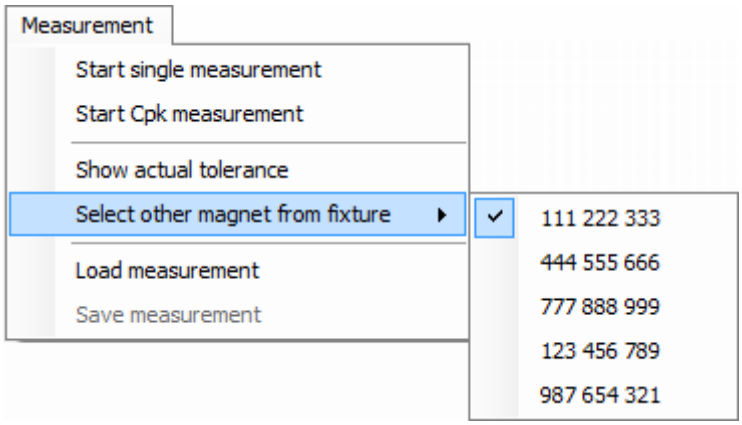


Main window

A 4.1. Flux measurement

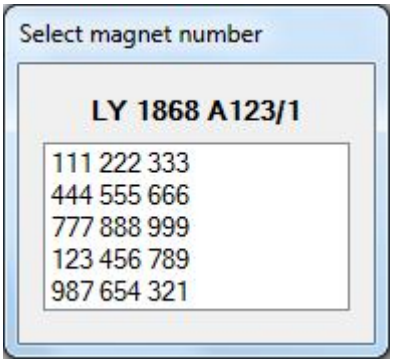
If the Robograph RE is connected to a small yoke, the menu will be set to flux measurement.

By moving the mouse to “Measurement” at the task bar the drop-down menu is opened.



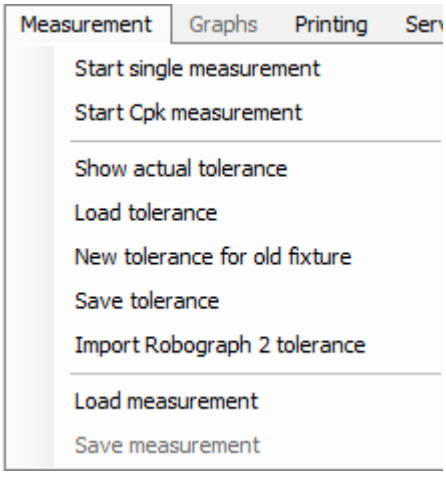
Drop-down menu for Measurement with new Robograph RE fixture

In the moment a new Robograph RE fixture is entered to the yoke, the new fixture will be recognized. If there is only one magnet type stored in the fixture EEPROM, this tolerance will be loaded. If there is more than one magnet type stored, this window will open to select the desired type:



Select magnet number

The measurement menu looks a little bit different for measurement with old Robograph 2 fixtures:



Drop-down menu for Measurement with old Robograph 2 fixture

This menu is shown if no Robograph RE fixture is inserted to the yoke. Then the tolerance cannot be read from the fixture.

It is also shown if the Robograph RE is not switched on or no yoke is connected.

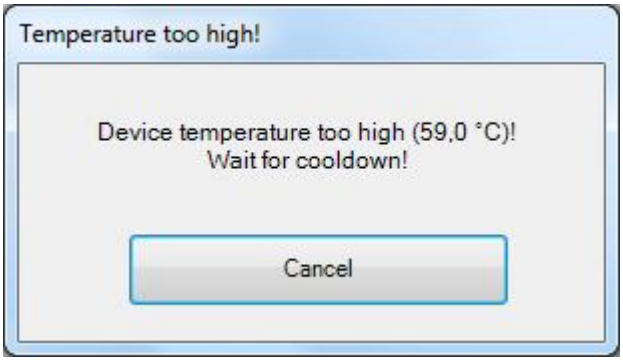
Start single measurement will start immediately the measurement with the actual tolerance.

Before starting a measurement, be sure to have a valid actual tolerance!

Pressing on the green button beside the yoke has the same effect.

Since with the small yoke only flux hysteresis measurements are possible, always this type of measurement is executed if the small yoke is connected to the Robograph RE.

The Robograph RE will only start a measurement if transistor temperature is below 50 °C. If temperature is too high, this window will appear:

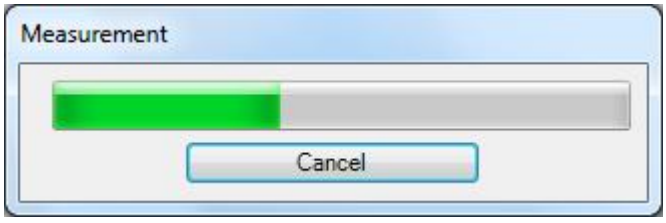


Temperature warning

The actual temperature is always shown and when it falls below 50 °C measurement will start. If **Cancel** is pressed, the measurement is stopped.

Under normal circumstances this error message will never appear for measurements with the small yoke. If this error message is shown, check whether the fan is blowing and the air slots on the top of the Robograph as well as the blow out opening at the backside are not covered. At temperatures higher than 50 °C the fan must blow at highest speed and make a considerable noise.

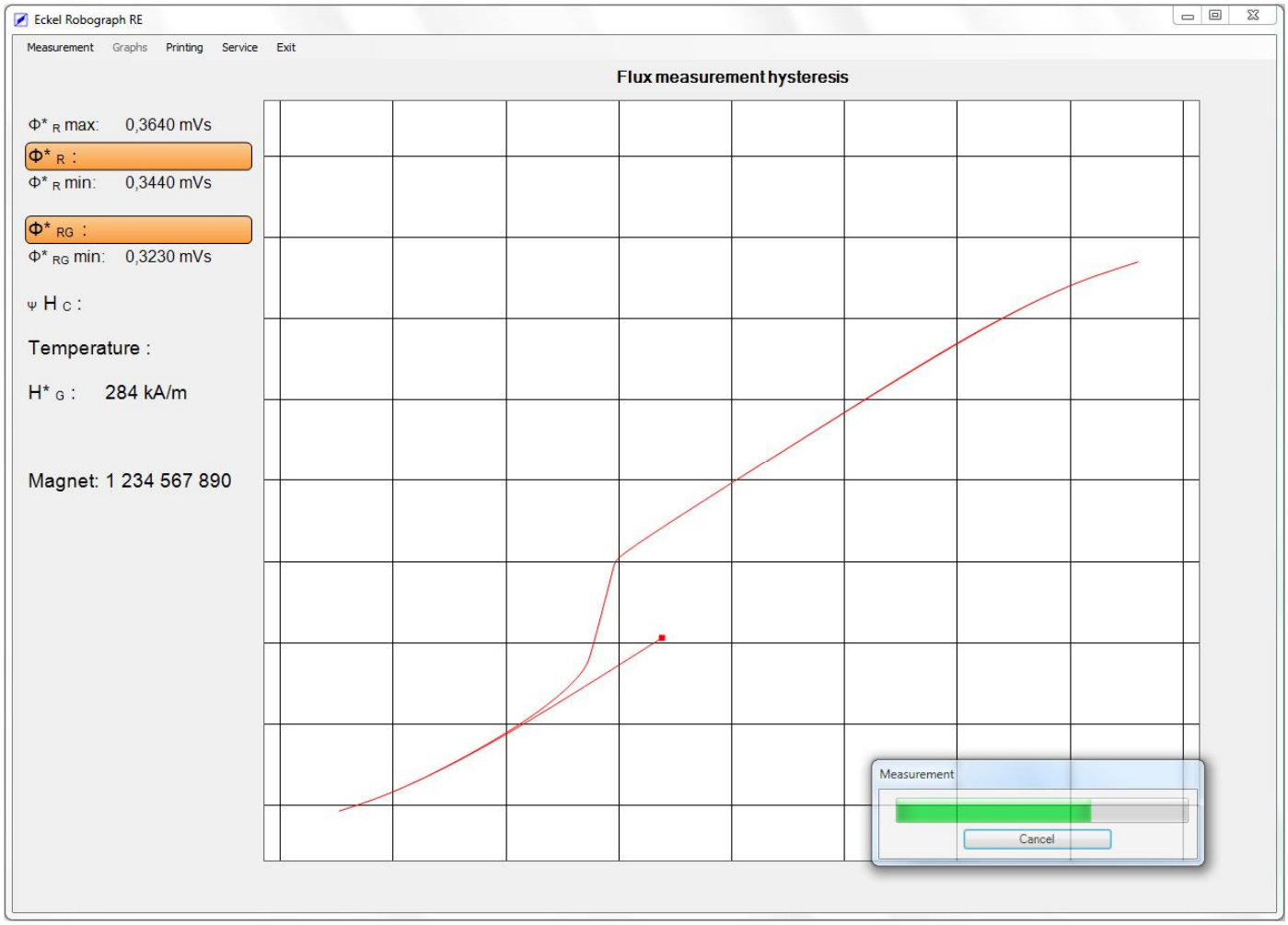
At first measurement the power amplifier will be activated, the fan will be set to standard speed and a progress bar will show the progress of the measurement.



Progress bar

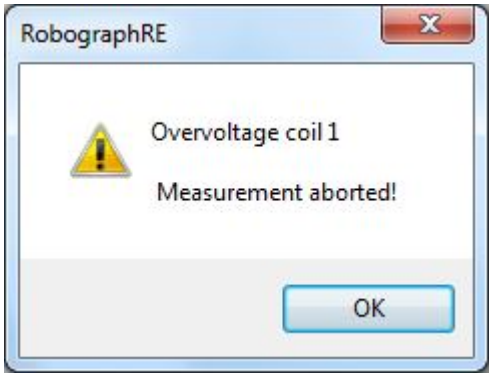
Cancel will stop the measurement immediately.

During measurement the main window will show a real time graph of the hysteresis. This graph is calibrated and centred after measurement is finished.



Real time hysteresis

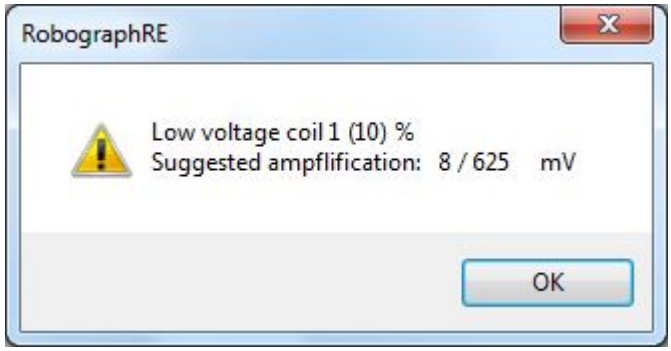
If input amplification has not been set correctly there are two possible error messages:



Input overload warning

If one of the inputs has got overvoltage during measurement, the signal has not been recorded correctly. The result would be wrong and the evaluation is aborted.

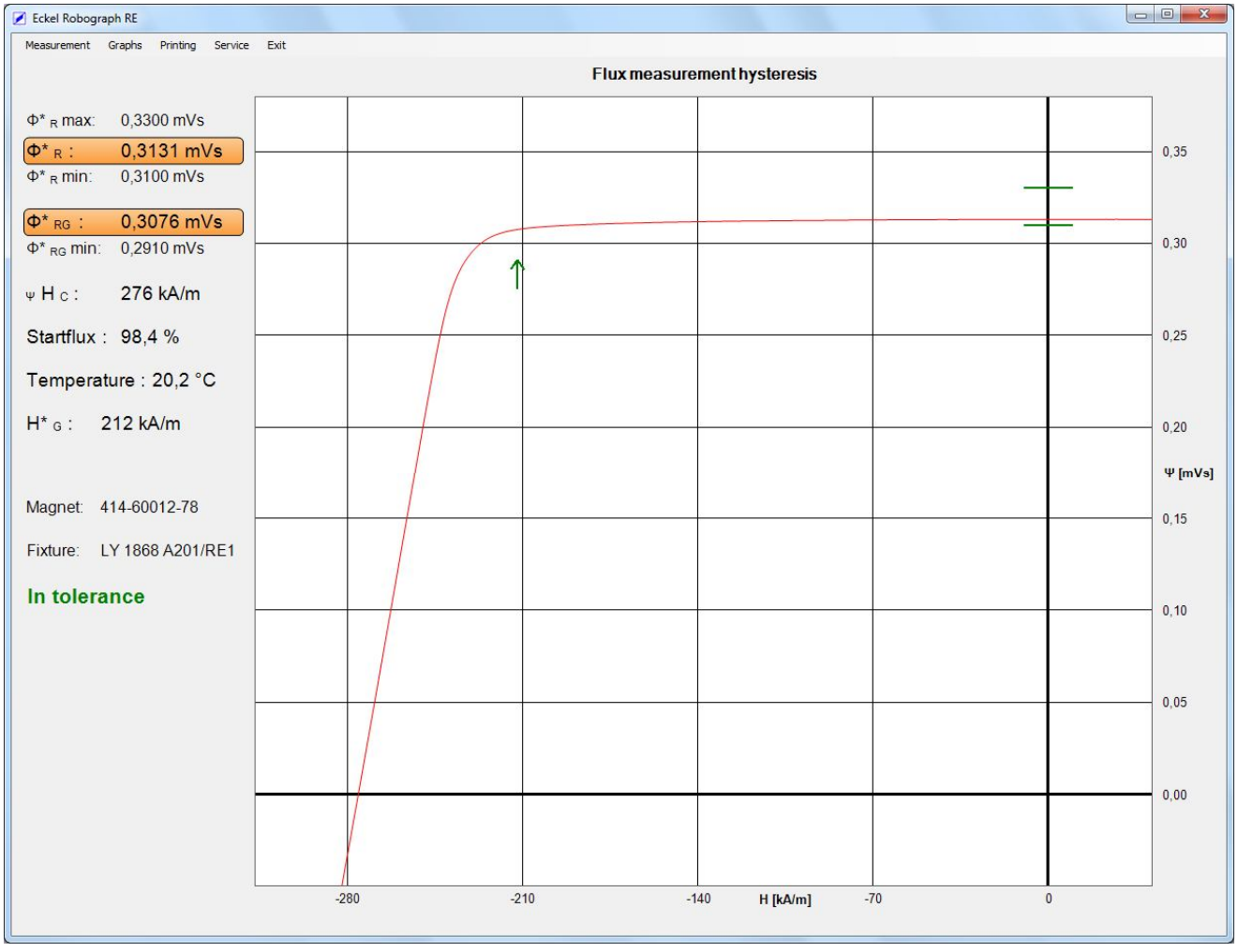
Reduce input amplification of the mentioned input in the actual tolerance and try again. If amplification was correct this time, save this tolerance again if this measurement was made with a standard magnet for this fixture.
For a Robograph 2 fixture just save the actual tolerance. For a Robograph RE fixture it is necessary to edit the content of the fixture EEPROM by using the Service routine. Change the amplification to desired value and write it to the EEPROM.



Low input voltage warning

If this message is shown, the input amplification is too low. The result is evaluated anyway but the accuracy is reduced. Change the amplification of the mentioned input to the suggested value and save the tolerance the same way as described before.

After 8 seconds the measurement is finished, results and graph are shown and 1 minute later the fan is set back to power save mode.



Result window

Default graph is Demagnetisation Ψ. But the graph type can be changed at **Graphs**.

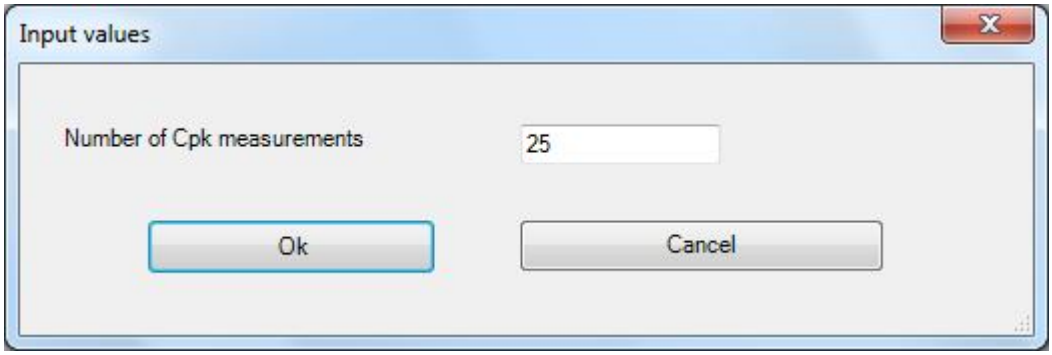
The results and tolerances are shown. The results are always temperature compensated to 20 °C. The temperature coefficients can be set at the tolerance window.

The tolerance bars in the graph and the numerical tolerance limits will change from green to red if they are exceeded.

Above tolerance, in tolerance or below tolerance is indicated.

Measurement will be saved by default if activated in **Program options**.

Start Cpk measurement will open a window to enter the number of measurements for Cpk measurement. The Cpk measurement is a statistical evaluation according to Bosch standard.

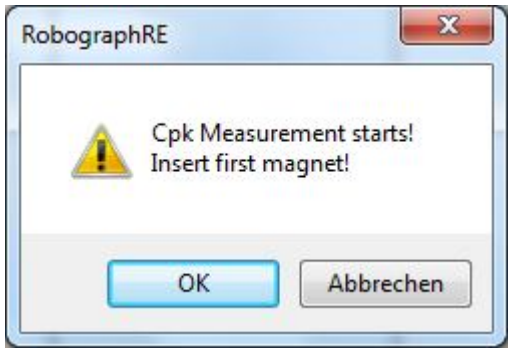


Number of Cpk measurements

Default number of measurements for Cpk is 25.

Remember that there are 2 different evaluation options for Cpk measurements. They can be selected at the tolerance window.

Then the first magnet has to be inserted



Insert first magnet

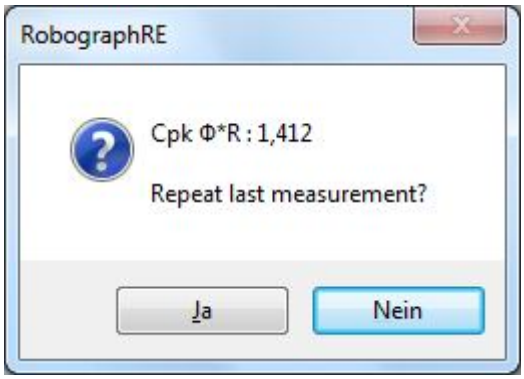
After each measurement the last measurement can be repeated if the magnet moved during measurement or something else was wrong. **It is not possible to repeat a measurement later**. Next measurement is started by clicking “No” (not repeat last measurement), press ENTER or the green button at the yoke.
If you want to repeat last measurement, press the red button at the yoke or click “yes”.

Repeat measurement?

From now on the actual Cpk value is shown.

With Cpk value

Window of the last measurement.

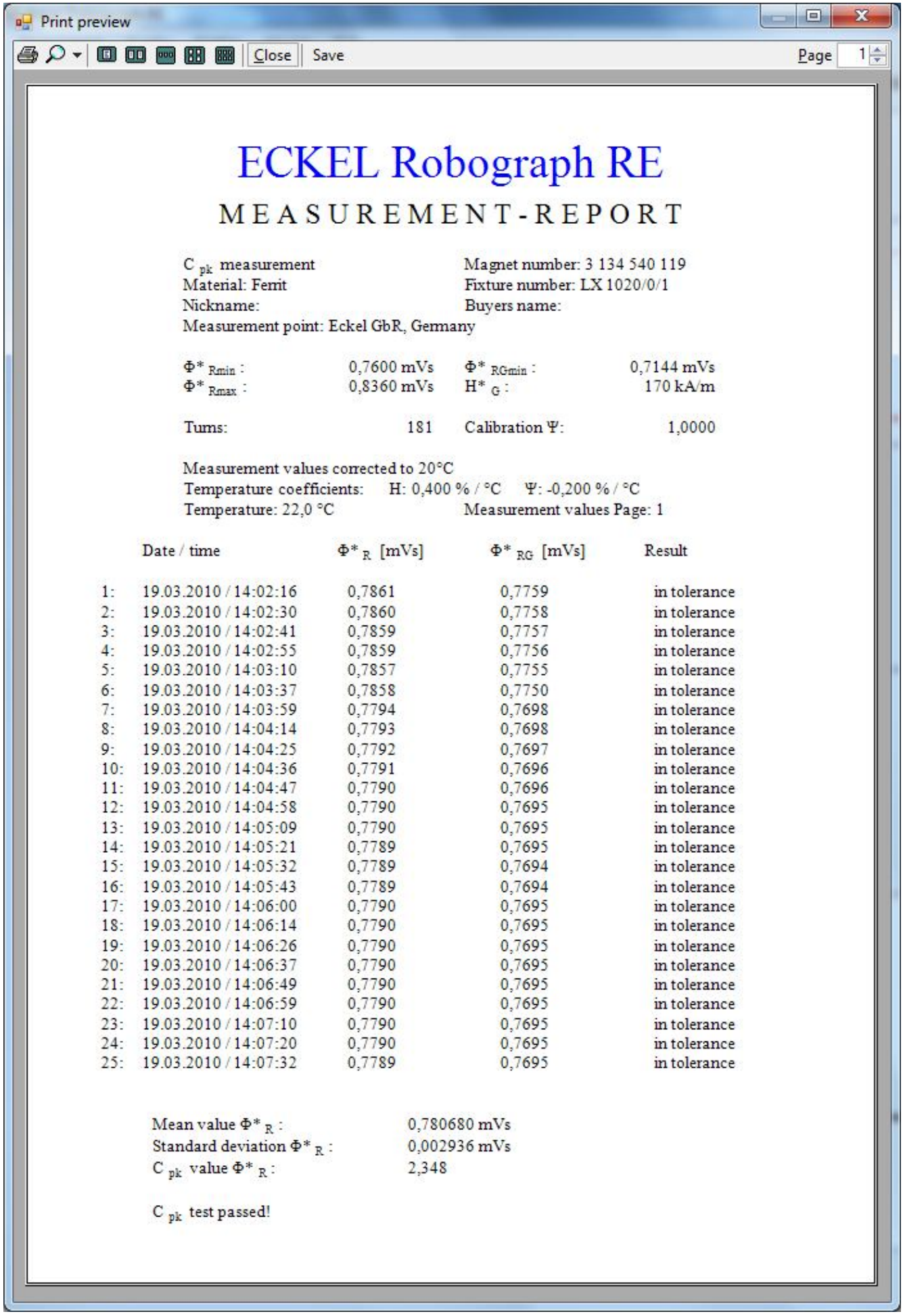


Last Cpk window

After the last Cpk measurement a window showing the results will open. This is already the print preview and can be printed by clicking on **the printer symbol**.

If necessary, next page can be shown by **Page**. Also view of several pages together is possible.

If selected at measurement options it will be saved by default. If not, you can save it now with the button **Save**.

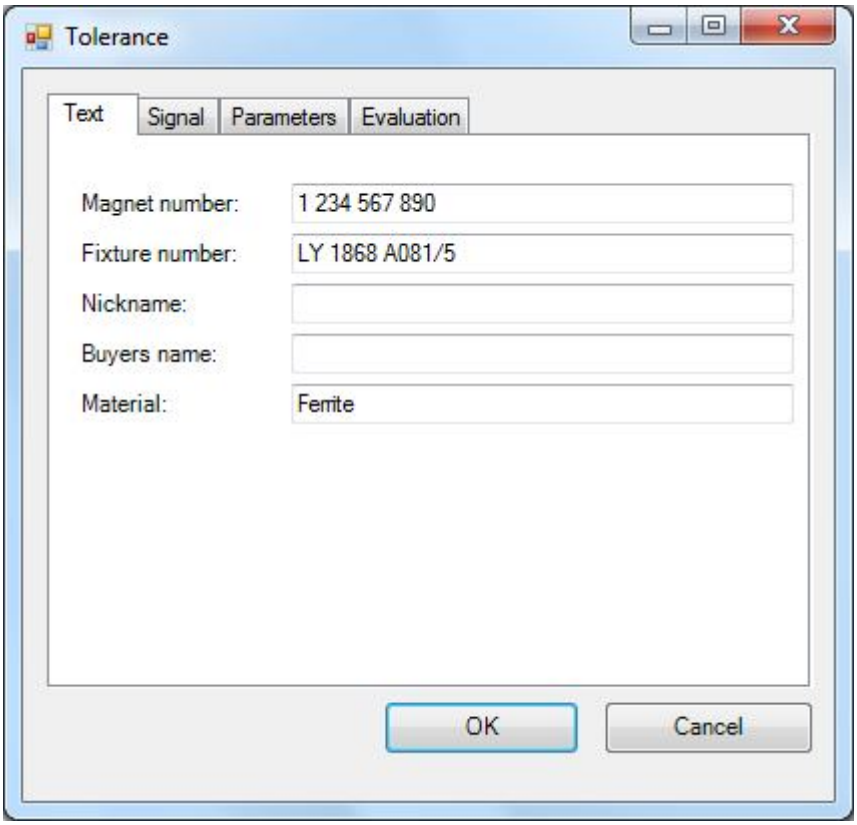

Print preview
Close
Save
Page 1
ECKEL Robograph RE
MEASUREMENT-REPORT
C pk measurement
Material: Ferrit
Nickname:
Measurement point: Eckel GbR, Germany
Magnet number: 3 134 540 119
Fixture number: LX 1020/0/1
Buyers name:
Φ* Rmin : 0,7600 mVs
Φ* Rmax : 0,8360 mVs
Φ* RGmin : 0,7144 mVs
H* G : 170 kA/m
Tums: 181
Calibration Ψ: 1,0000
Measurement values corrected to 20°C
Temperature coefficients: H: 0,400 % / °C Ψ: -0,200 % / °C
Temperature: 22,0 °C
Measurement values Page: 1
Date / time Φ* R [mVs] Φ* RG [mVs] Result
1: 19.03.2010 / 14:02:16 0,7861 0,7759 in tolerance
2: 19.03.2010 / 14:02:30 0,7860 0,7758 in tolerance
3: 19.03.2010 / 14:02:41 0,7859 0,7757 in tolerance
4: 19.03.2010 / 14:02:55 0,7859 0,7756 in tolerance
5: 19.03.2010 / 14:03:10 0,7857 0,7755 in tolerance
6: 19.03.2010 / 14:03:37 0,7858 0,7750 in tolerance
7: 19.03.2010 / 14:03:59 0,7794 0,7698 in tolerance
8: 19.03.2010 / 14:04:14 0,7793 0,7698 in tolerance
9: 19.03.2010 / 14:04:25 0,7792 0,7697 in tolerance
10: 19.03.2010 / 14:04:36 0,7791 0,7696 in tolerance
11: 19.03.2010 / 14:04:47 0,7790 0,7696 in tolerance
12: 19.03.2010 / 14:04:58 0,7790 0,7695 in tolerance
13: 19.03.2010 / 14:05:09 0,7790 0,7695 in tolerance
14: 19.03.2010 / 14:05:21 0,7789 0,7695 in tolerance
15: 19.03.2010 / 14:05:32 0,7789 0,7694 in tolerance
16: 19.03.2010 / 14:05:43 0,7789 0,7694 in tolerance
17: 19.03.2010 / 14:06:00 0,7790 0,7695 in tolerance
18: 19.03.2010 / 14:06:14 0,7790 0,7695 in tolerance
19: 19.03.2010 / 14:06:26 0,7790 0,7695 in tolerance
20: 19.03.2010 / 14:06:37 0,7790 0,7695 in tolerance
21: 19.03.2010 / 14:06:49 0,7790 0,7695 in tolerance
22: 19.03.2010 / 14:06:59 0,7790 0,7695 in tolerance
23: 19.03.2010 / 14:07:10 0,7790 0,7695 in tolerance
24: 19.03.2010 / 14:07:20 0,7790 0,7695 in tolerance
25: 19.03.2010 / 14:07:32 0,7789 0,7695 in tolerance
Mean value Φ* R : 0,780680 mVs
Standard deviation Φ* R : 0,002936 mVs
C pk value Φ* R : 2,348
C pk test passed!

Cpk result

Show actual tolerance opens the **Tolerance** window.

The first card shows text that can be entered like Magnet number, **Fixture** number, Nickname of the magnet, Buyers name and Material. This all is only text shown on the screen and on the printout.

If the tolerance is saved (only for Robograph 2 tolerances), the magnet number is used as file name with extension .RTO.



Tolerance: Text

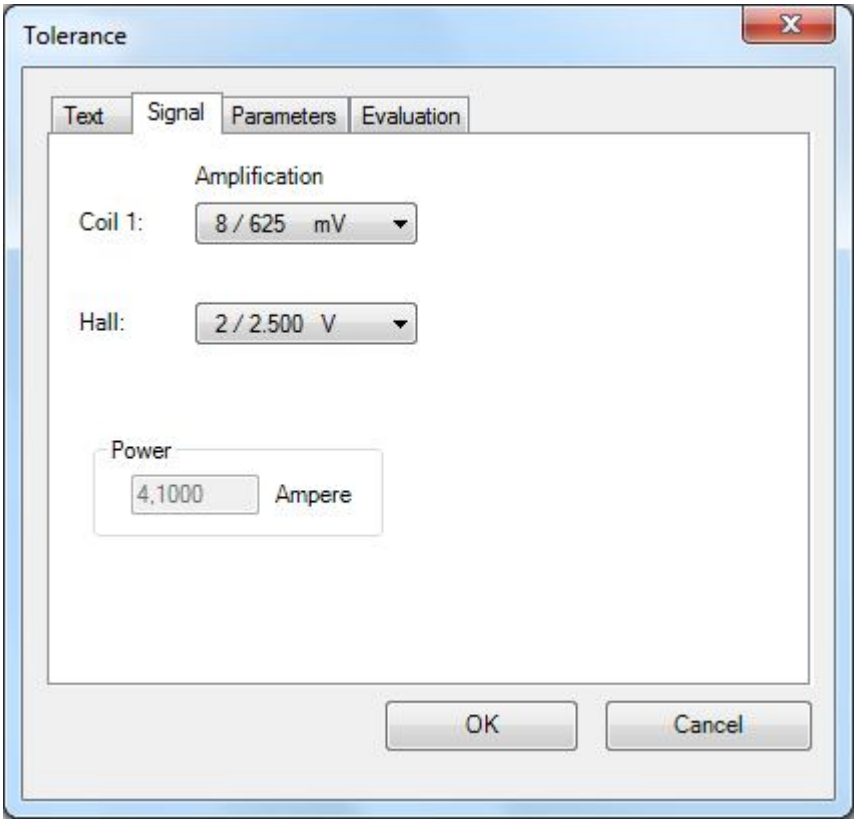
For Robograph RE fixtures all values are read from the fixture.

For Robograph 2 fixtures these values have to be entered by hand for new tolerances or imported from Robograph 2 tolerances.

The **Signal** card shows the input amplifications. Amplifications can be set for coil 1 and Hall probe.

Input amplification and maximum input voltage is shown. For the Hall probe always amplification 2 will be correct for flux measurements. Amplification for coil 1 depends on number of turns and magnet size.

Power shows the maximum current in the in the coils of the yoke during flux measurement. Since the flux measurement is a standardized measurement, the current is fixed to 4.1 Ampere.



Tolerance: Signal

If amplification is not optimal, a warning will be shown after measurement asking the user to change amplification.

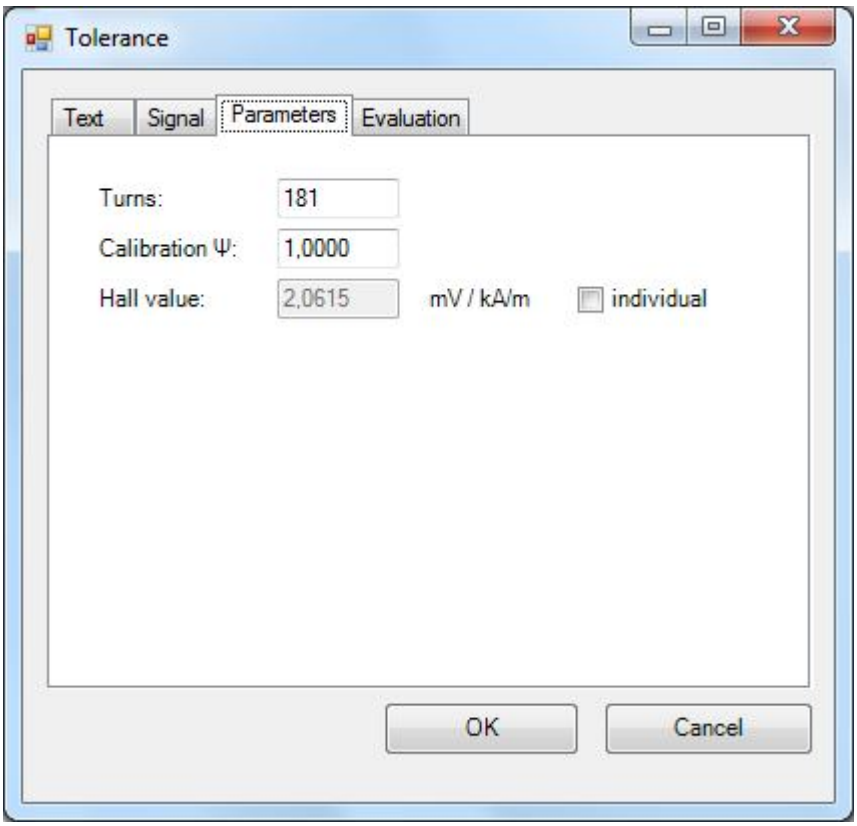
For Robograph RE fixtures all values are read from the fixture.

The third card shows the **Parameters** of the Fixture.
The number of **Turns** is shown. It is the same for all Robograph RE fixtures (50) but has to be copied from the text written on the fixture for Robograph 2 fixtures.

Calibration Ψ is for eliminating the differences between various fixtures of the same magnet type.

The **Hall value** is individual for all Robograph RE fixtures and for Robograph 2 fixtures with inbuilt Hall probe.

For Robograph 2 fixtures with external Hall probe, the value is always the same. This standard value is entered at **Program options**.



Tolerance: Parameters

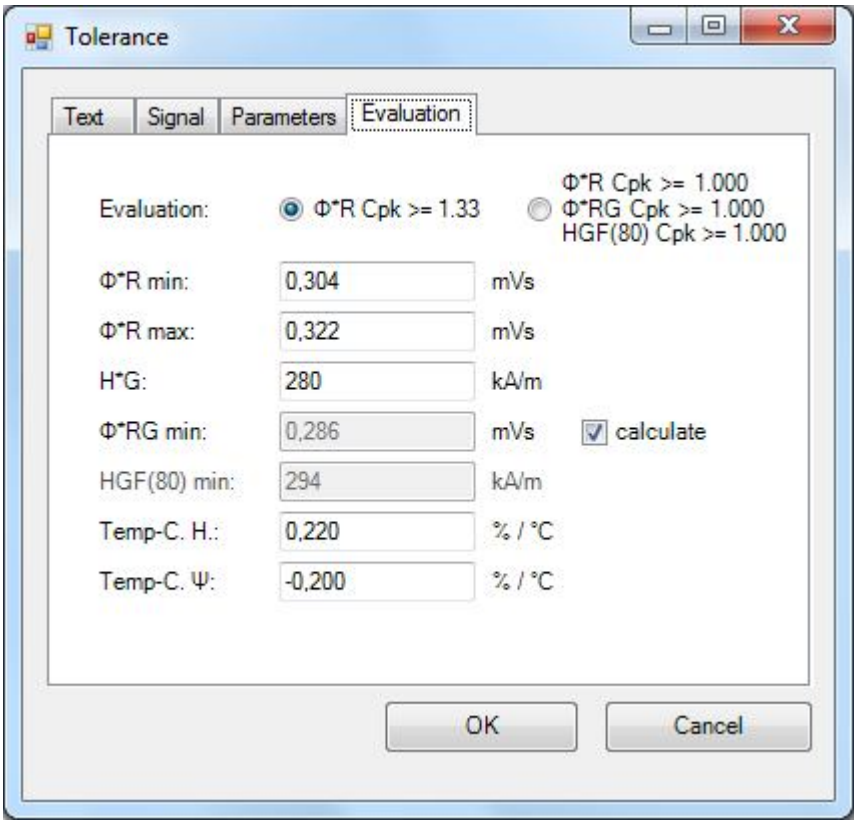
For Robograph RE fixtures all values are read from the fixture.

The fourth card shows the **Evaluation** tolerances and parameters.

First it has to be selected between 2 possible Cpk evaluations, former known as K4 and K9 version. These were different departments of Bosch. K9 (Cpk >=1.000) is for starter magnets. K4 (Cpk>=1.33) is for all other magnets.

The limits $\Phi^*_{R\ min}$, $\Phi^*_{R\ max}$, $\Phi^*_{RG\ min}$ and (for starter magnets) $H_{GF(80)\ min}$ as well as the Opposing field are given in the magnet drawing.

The temperature coefficients are taken from the material table. Standard values are 0.400% for H and -0.200% for Ψ but modern materials often have a lower temperature coefficient for H.



Tolerance: Evaluation

For Robograph RE fixtures all values are read from the fixture.

Select other magnet from fixture opens a small window where the user can select a tolerance for another magnet type, if there are more than one magnet types stored in the Robograph RE fixture.

Load tolerance is only necessary for Robograph 2 type fixtures. When a Robograph RE fixture is inserted in the yoke, the tolerance will be automatically read from the fixture.

New tolerance for old fixture opens an empty measurement options field to create a new tolerance for Robograph 2 type fixtures.

Save tolerance is depending on if a Robograph RE fixture is inserted or not. For Robograph 2 fixtures the tolerance is only saved as a file on the PC.

For a Robograph RE fixture it is necessary to edit the content of the fixture EEPROM by using the Service routine. Change the desired values and write it to the EEPROM. Fixture number, number of turns and Hall value are fixed and are not allowed to be changed.

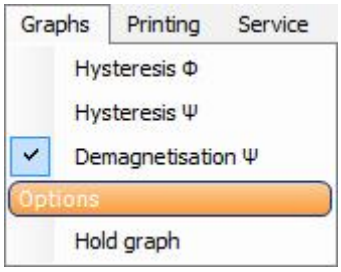
Import Robograph 2 tolerance allows the user to copy Robograph 2 tolerances to Robograph RE tolerances without the need to write it by hand. A file selector box opens, the Robograph 2 tolerance is selected and converted to a Robograph RE tolerance.
The new Robograph RE tolerance must be saved by hand.

Load measurement will load a formerly saved measurement to review and print it. A standard file selector box will open.

Save measurement will save the complete measurement for later use. A standard file selector box will open.

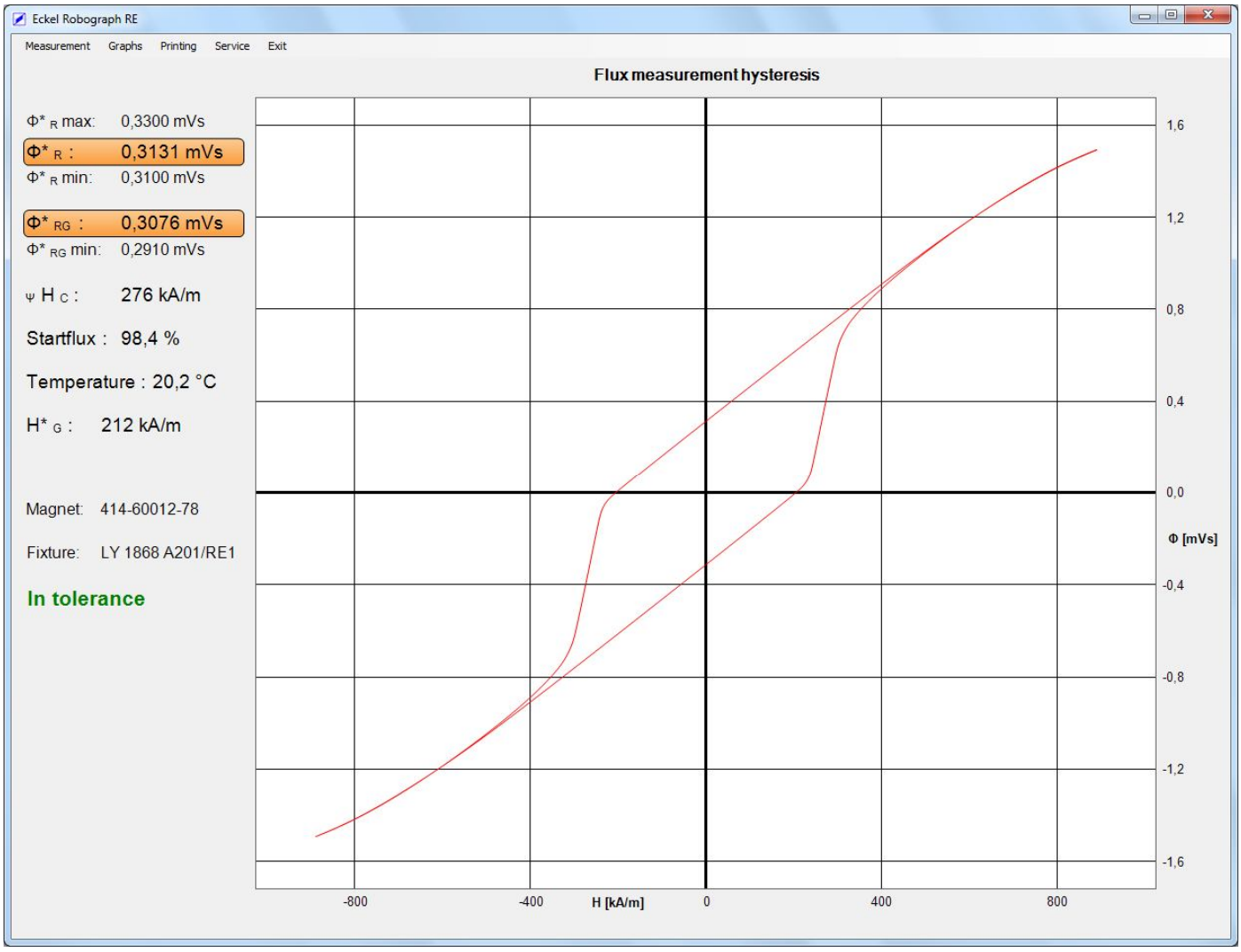
A 4.2. Flux graphs

By moving the mouse to “Graphs” at the task bar the drop-down menu is opened.



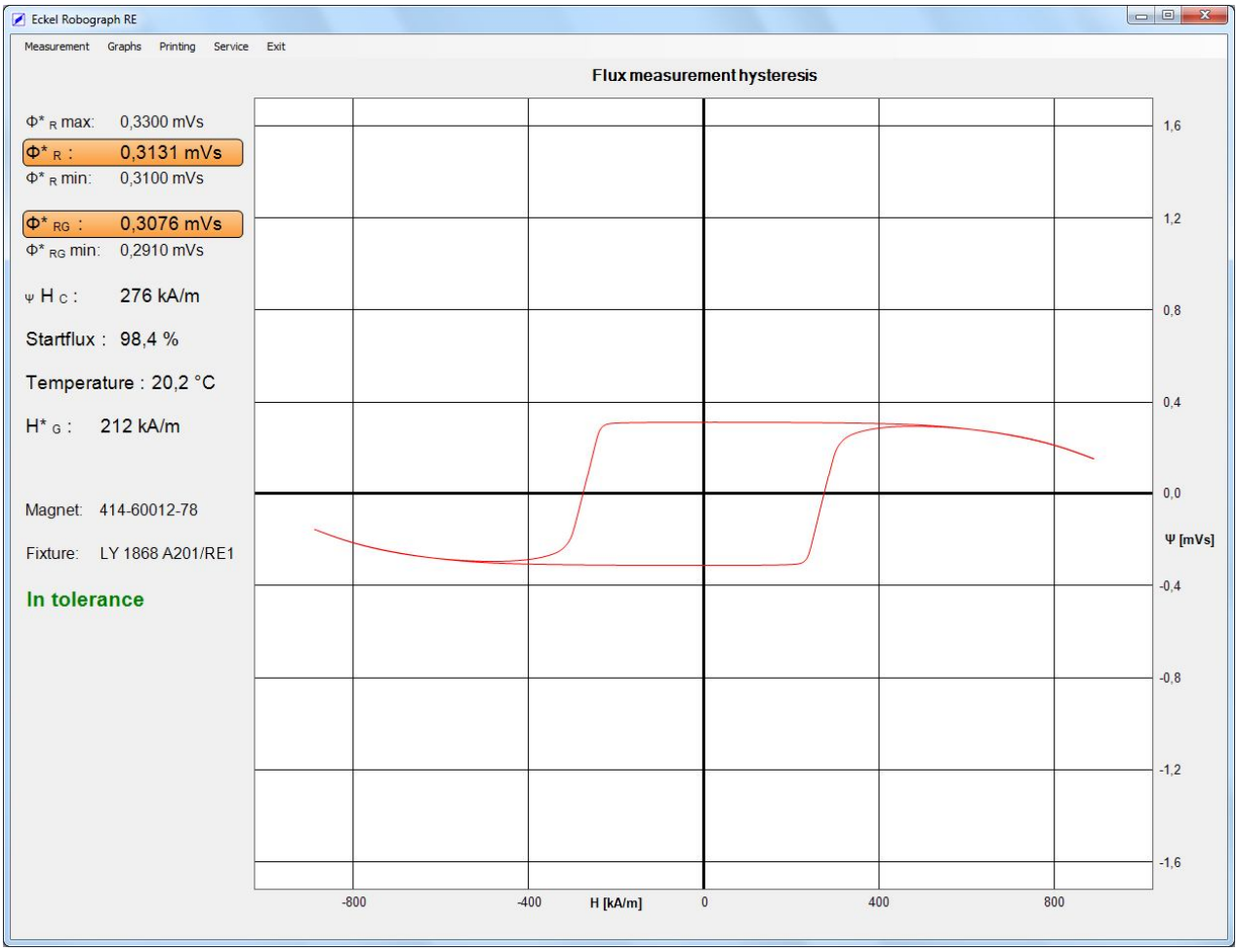
Drop-down menu for graphs

Here different graphs for result can be selected. Other graphs can be shown by clicking on them.

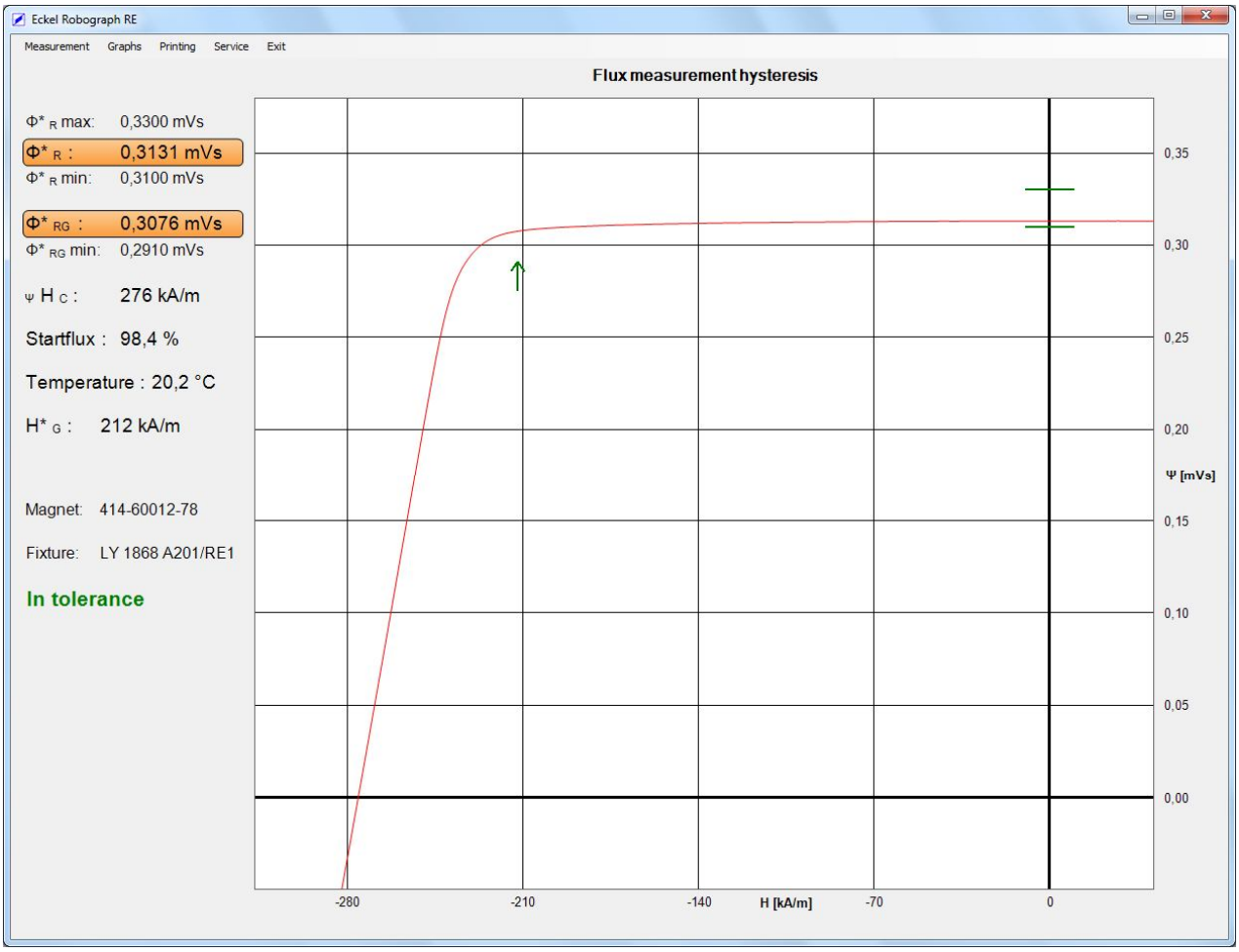


Graph hysteresis Φ

Parts of the graphs can be magnified by drawing a window around desired area with the mouse. At high magnifications the single samples will be shown as dots.
Clicking the right mouse button reduces the view one step back.

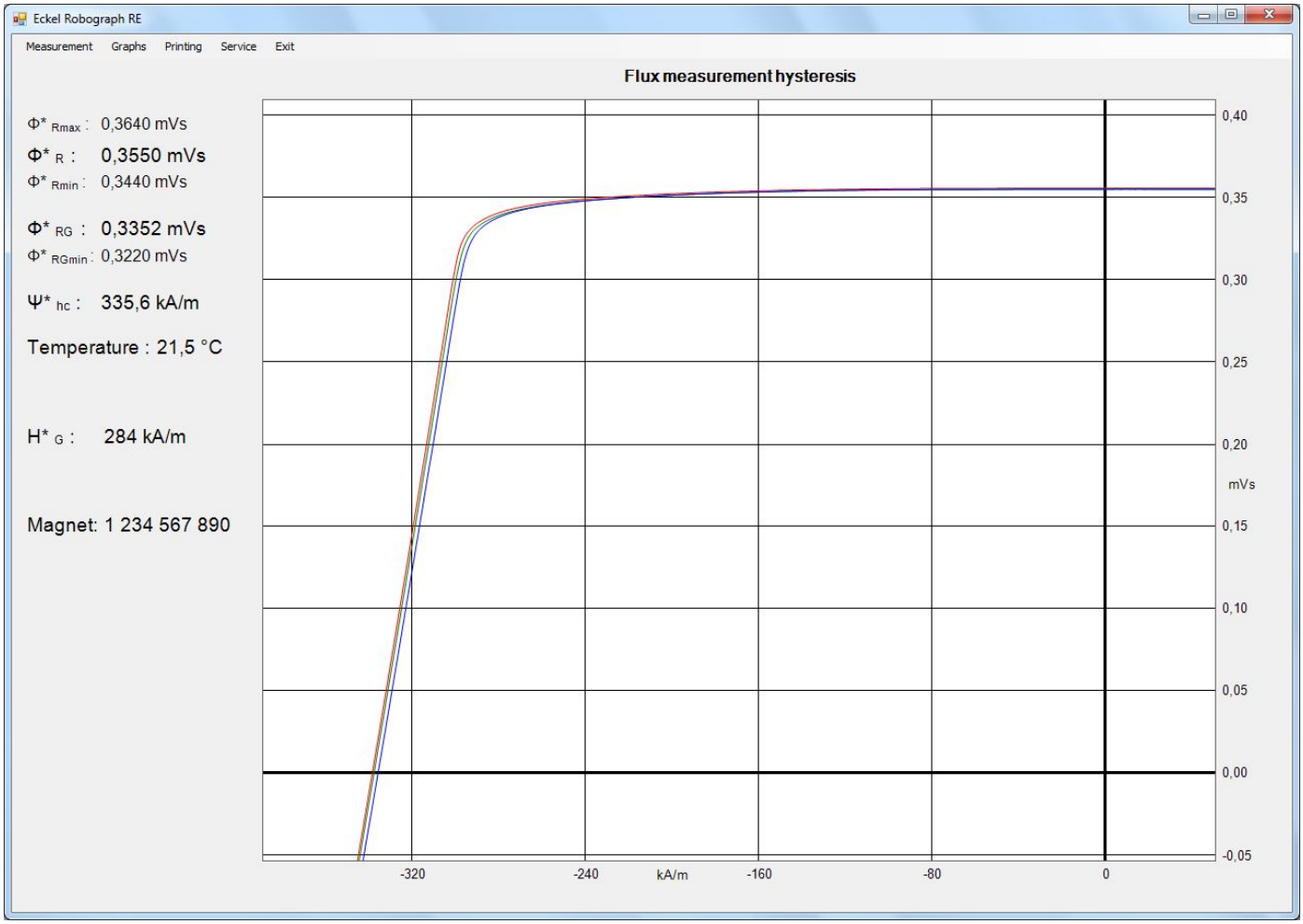


Graph hysteresis Ψ



Graph demagnetisation Ψ

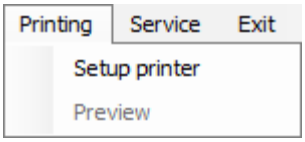
Hold graph is an option. If Hold graph is selected, the actual graph will stay in the window and after performing another measurement, both graphs will be overlaid in different colours and can be easily compared. This function is repeatable.



Three graphs in one window

A 4.3. Printing flux graphs

By moving the mouse to “Printing” at the task bar the drop-down menu is opened.



Printing drop-down menu

Setup printer opens the printer setup window of the operating system. A printer and properties can be selected.

Preview opens the preview window. The page can be printed by clicking on **the printer symbol**.

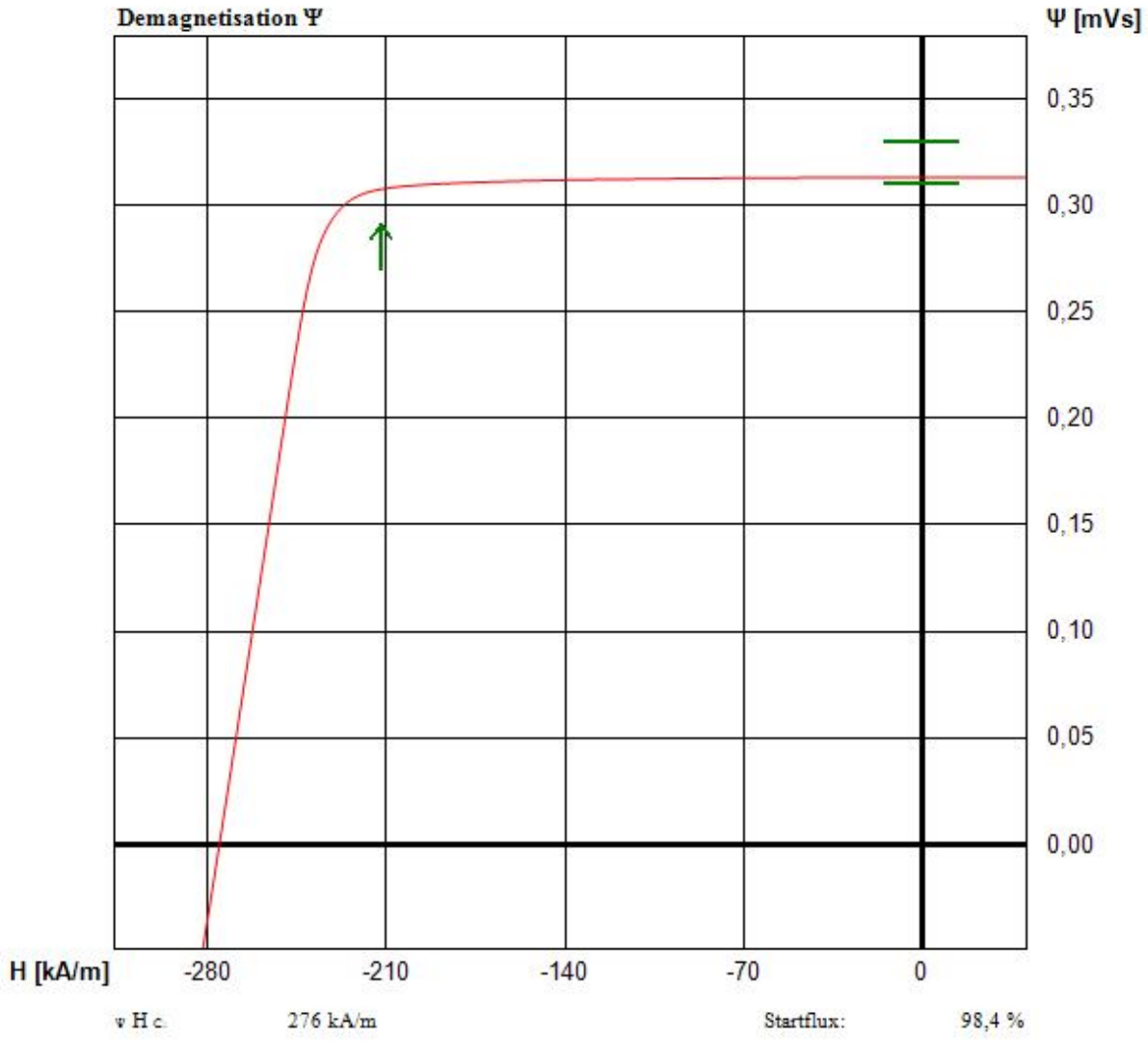
The Cpk measurement ends with the printer preview by default.

Print preview

Close

ECKEL Robograph RE

Flux measurement 27.04.2011 / 09:58:15
Measurement point: Brose Shanghai
Magnet number: 414-60012-78
Fixture number: LY 1868 A201/RE1
Hall sensor value: 1,9471 mV / kA/m
Material: Ferite
Nickname:
Buyers name:



v H c. 276 kA/m Startflux: 98,4 %

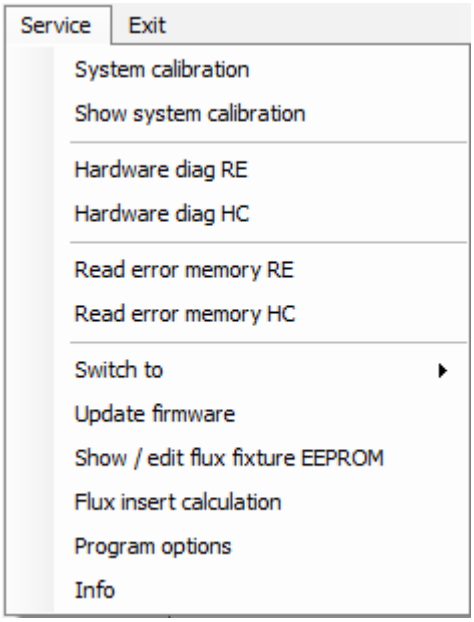
Temperature coefficients: H: 0,400 % / °C Ψ: -0,200 % / °C
Temperature: 20,2 °C / Measurement values corrected to 20 °C Turns: 050

Φ^*_{Rmin} :	0,3100 mVs	Φ^*_{R} :	0,3131 mVs	Φ^*_{Rmax} :	0,3300 mVs
Φ^*_{RGmin} :	0,2910 mVs	Φ^*_{RG} :	0,3076 mVs	H^*_{G} :	212 kA/m
in tolerance				Calibration Ψ:	0,9930

Preview window for printing

A 4.4. Service flux

By moving the mouse to “Service” at the task bar the drop-down menu is opened.



Drop-down menu for service

System calibration is necessary for correct operation of the Robograph RE. It sets the calculation factors for software since exact hardware values are unknown before.

The system calibration has to be performed once after combining a Robograph RE unit with a PC and software.

Start system calibration by clicking on it.

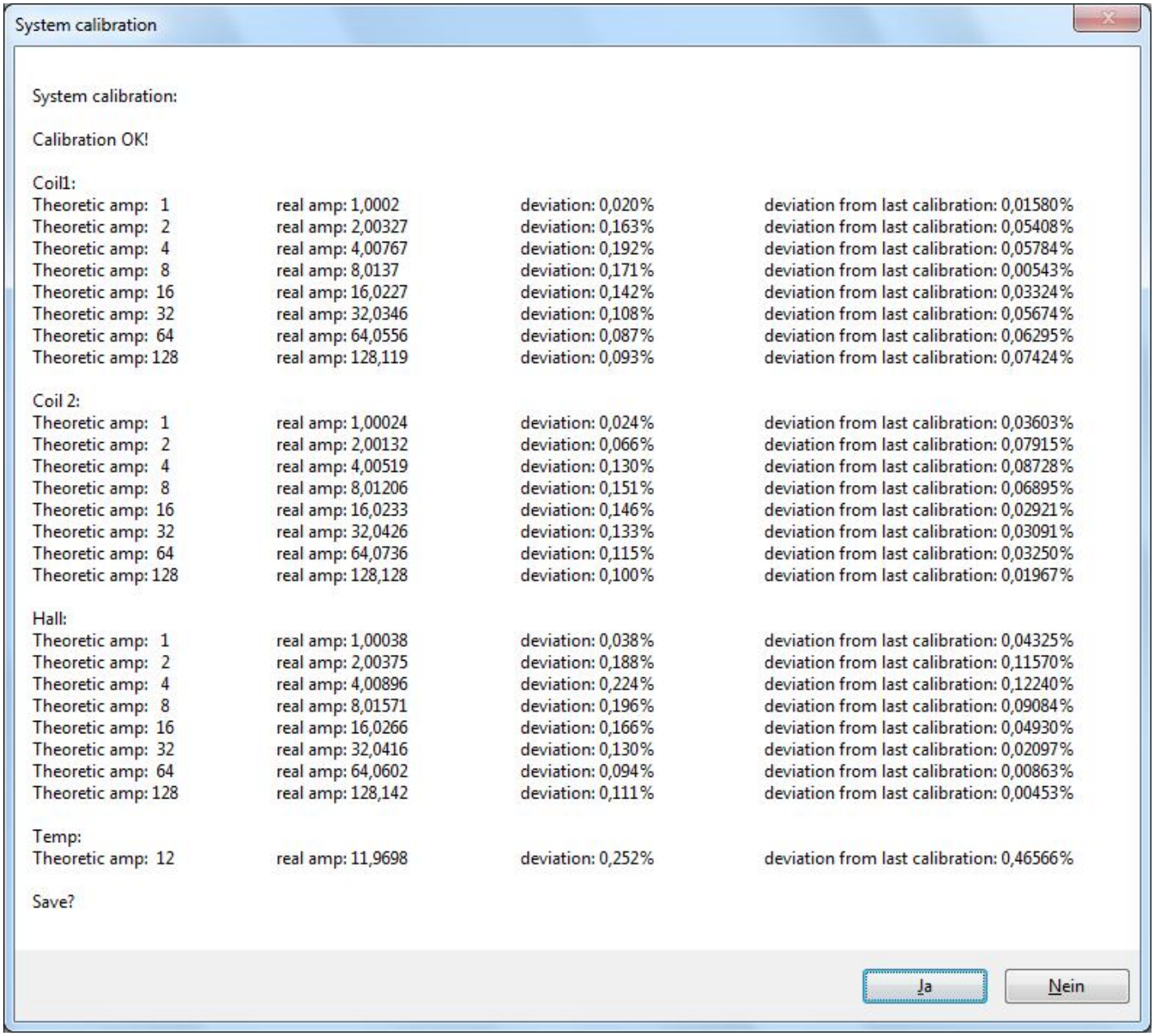
During system calibration exactly defined test voltages are connected to the inputs to calculate exact amplifications and later after measurement the exact input voltages. Calibration will take some seconds and the clicking of the relays can be heard.

After the calibration a result window opens. It shows the theoretical and real amplifications of all inputs. If this is a repeated calibration also the deviations from the last calibration are shown. These deviations should be very low.

The deviations between theoretic amplification and real amplification are compensated by this calibration procedure. Thus for result calculation only the real amplification values are used.

If something is not like expected an error message will be shown.

Save the calibration if it is OK.



System calibration result window

Show system calibration will open this window again later.

Hardware diag RE opens a hardware diagnostic window. If ever the Robograph RE should not work as expected anymore, this will help to find the reason.

This function should only be used if something is wrong and we ask you to do this test.

The Robograph RE has total control over the temperature, current, voltage and power loss of each transistor.

There are 2 amplifiers, 1 for each coil of the yoke. Each amplifier has a voltage regulator, a positive and a negative transistor. The upper 3 graphs at the left and the center show the temperature, power loss and maximum allowed power loss at actual temperature for these transistors.
Further graphs show the temperature of the 2 power op-amps, the regulated and unregulated positive and negative power supply voltages, the output voltages and the output currents.

If any of these values ever should run out of expected tolerances, the measurement will be stopped and maybe even the amplifier shut down to protect the hardware. The necessary calculations are made inside the Robograph RE itself.

The large window on the right side is the large version of one graph selected from the small graphs by clicking on it.

Hardware diagnostic window

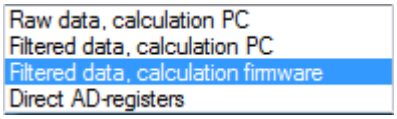
At the right bottom there is the choice between different data:

Raw data, calculation PC gives the pure calibrated A/D converter data from the unit.

Filtered data, calculation PC gives filtered and calibrated A/D converter data from the unit. This filtering improves signal quality eliminating noise and getting better readable results.

Filtered data, calculation firmware gets the loss power values completely calculated from the Robograph RE itself. This is default.

Direct AD-registers gives the original A/D converter data from the unit.



Data selection

First of all the **graph has to be started**. Parallel operation to normal measurement is not possible. Then the graph starts to run.

The power amplifier can be **powered up**. Relay status for fan, output stage, output relay and power-up delay are shown. A bar shows the fan voltage.

A maximum current is entered and sample frequency is selected. Sample frequency of standard flux measurement is 2000 Hz. The number of samples stays the same. Thus the measurement duration becomes longer with lower sample frequencies.

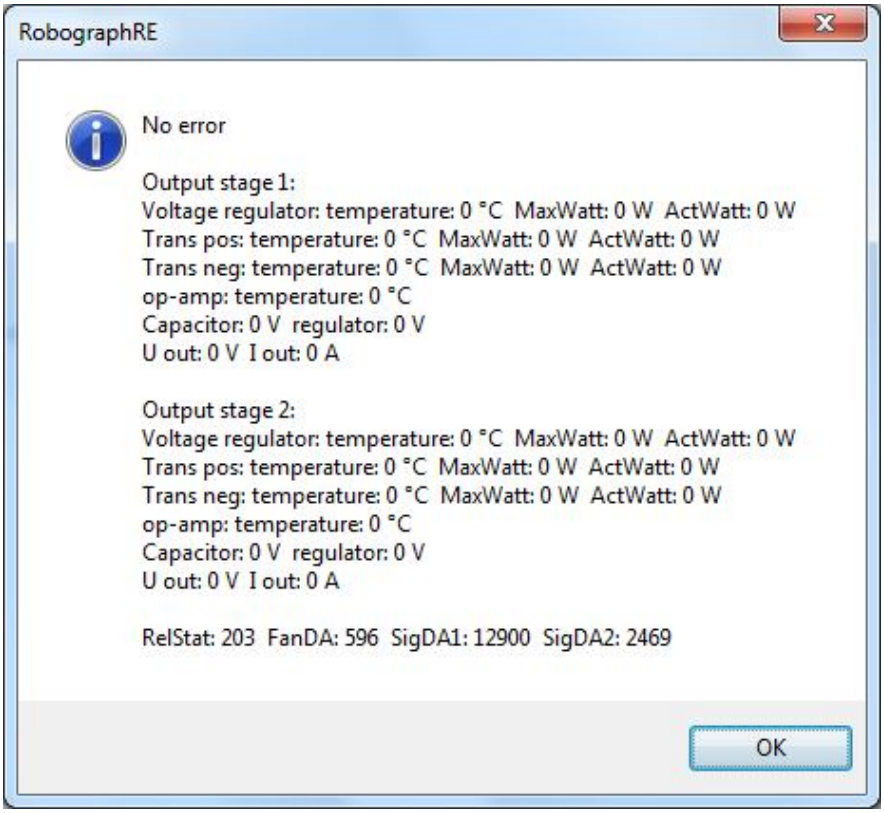
Then the **measurement can be started** and all internal processes are shown numerically and graphically. The values of the D/A converters are shown as bars in positive and negative. They should always correspond to the output current values.

Hardware diag HC is valid only if a Robograph HC is connected. See part B.

Read error memory can help to find the reason for a shutdown of measurement or the complete power amplifier.

The Robograph RE unit will always register the reason and the actual internal situation when executing a shut down. By reading this error memory the reason for shut down becomes visible.

If you need to do this, please contact us before for further instructions.



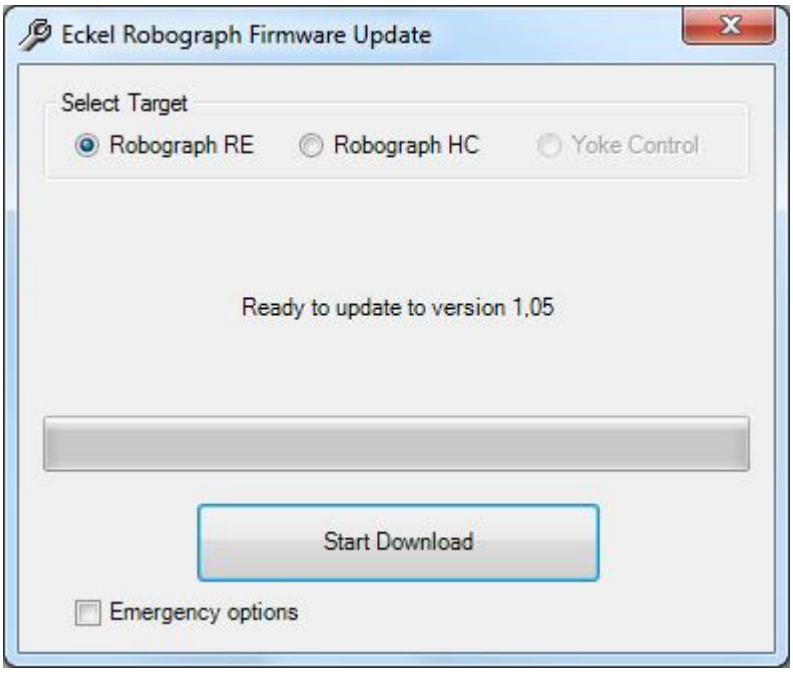
Read error memory

Switch to is used to switch the Robograph Sw switch to another yoke.

Update firmware allows the user to update the internal program of the Robograph RE and Robograph HC unit.

The newest firmwares are always part of the newest software for PC. If your actual firmware in the unit is older than the firmware in the PC program and you are authorized to use this update, you will be asked to update.

Update is made by standard USB connection. Select **Update firmware** and an update window will open.



Update window

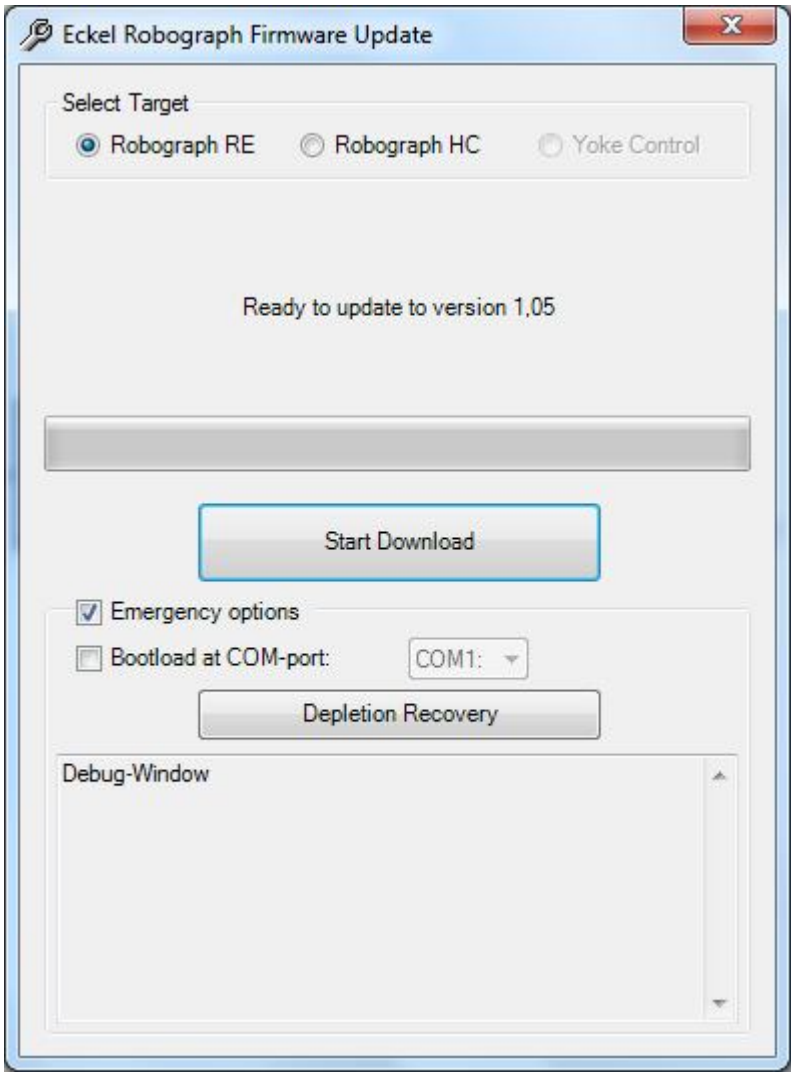
Select the unit, start the download and the firmware is updated.

New features may be added. So look at www.eckelgbr.com for a new operating manual version.

If somehow internal program is corrupted (power fail or switch off during update) there are the **Emergency options**. This will open a debug-window where the complete process is listed during update. If this process cannot be finished successfully, the new program must be loaded by COM-port.

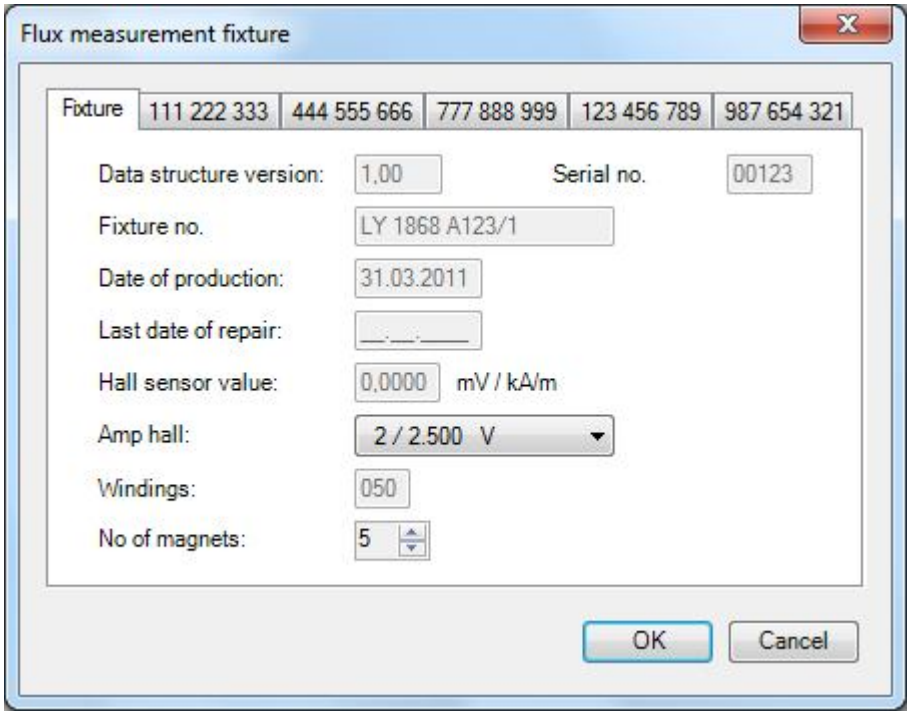
Using this feature allows to restore the internal program even if the program is not running anymore and USB connection fails.

If even this fails and there is an error message of erase or program error, the **Depletion Recovery** must be executed. This resets the internal Flash memory. Then repeat the update via COM-port.



Firmware update with emergency options

Show / edit flux fixture EEPROM opens a window showing the content of the fixture EEPROM. This option is only selectable if a Robograph RE fixture is inside the yoke.

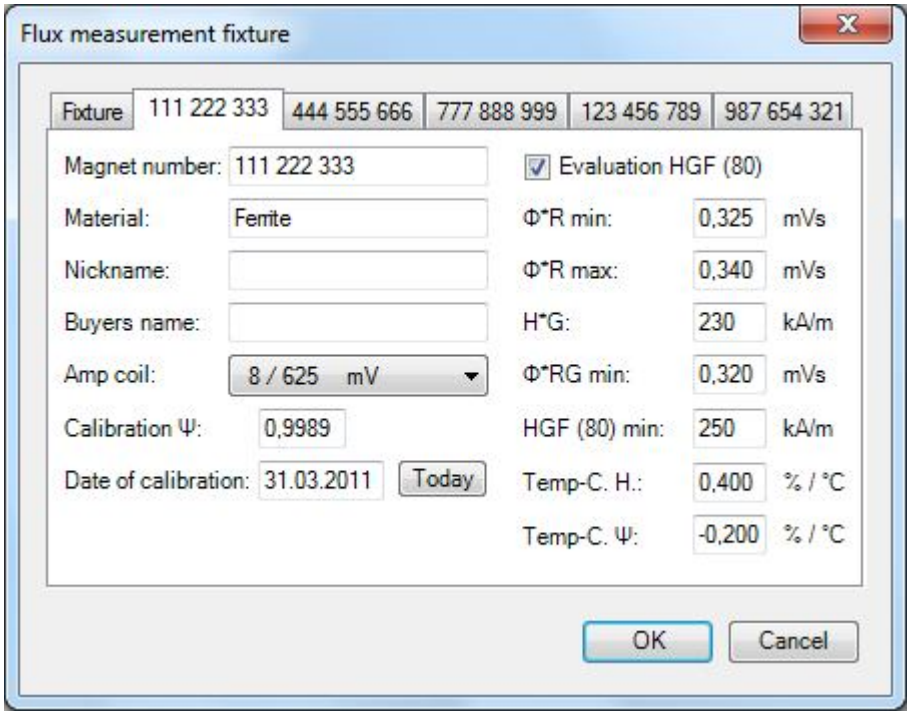


Content of the fixture EEPROM (Fixture)

This window shows general parameters of the fixture. Only amplification of the Hall signal can be changed but “2 / 2.500 V” should always be correct for flux measurements.

By “No of magnets” new sheets can be created to add new magnets. Reducing the number will deactivate but not delete the last sheets. The sheets can be sorted by moving by mouse before reducing the numbers.

By clicking on a magnet number this sheet will open.



Content of the fixture EEPROM (Magnet)

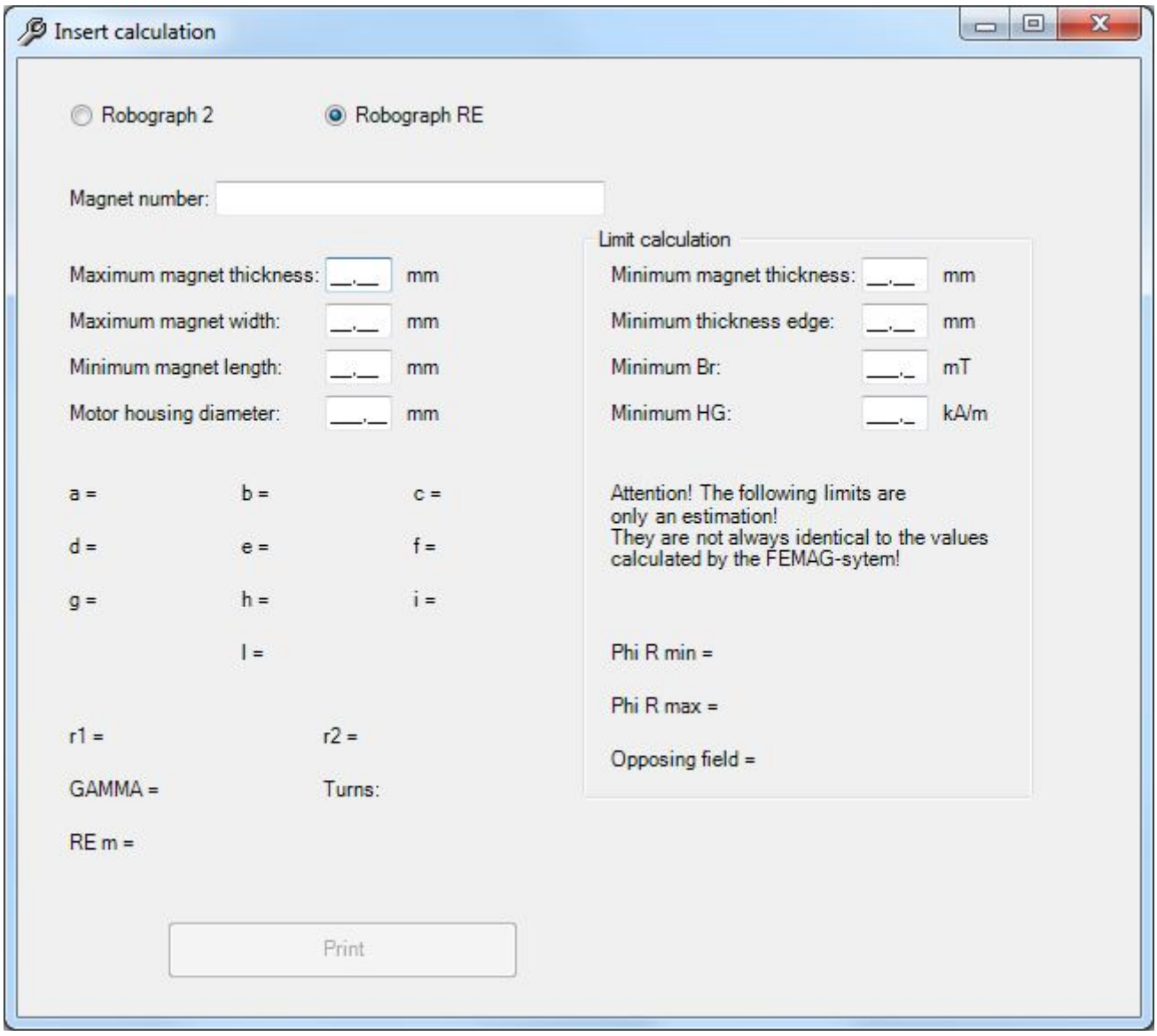
Here all tolerances, coefficients, amplifications and calibrations for this magnet are shown. Since different magnets may have different length and thus signal may be different, amplification for fixture coil can be selected individually.

Also calibration factors can be defined individually for different magnet types. Actual standard is to use one calibration factor for all magnets of the fixture.

All values can be changed in advanced mode. In restricted mode no changes are possible.
If a password for flux fixtures has been entered at program options, after pressing the OK button, this password must be entered to execute writing.

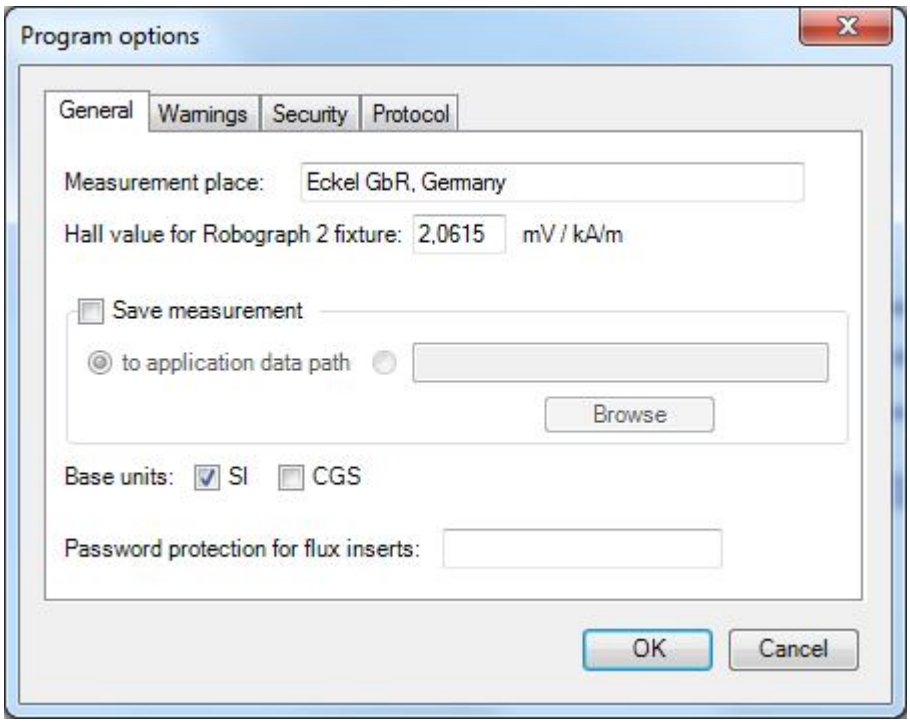
By pressing the OK button all values are written to the fixture EEPROM. The old values are lost and cannot be recovered. So be careful when changing values. Important information may be lost.

Flux insert calculation opens a window to enter magnet dimensions. Here the production dimensions for flux fixtures are calculated. Also estimation for flux limits will be given.



Calculation of fixture dimensions

Program options opens the program options window.



Program options General

At "**General**" the following information can be entered:

Measurement place is written on the printout.

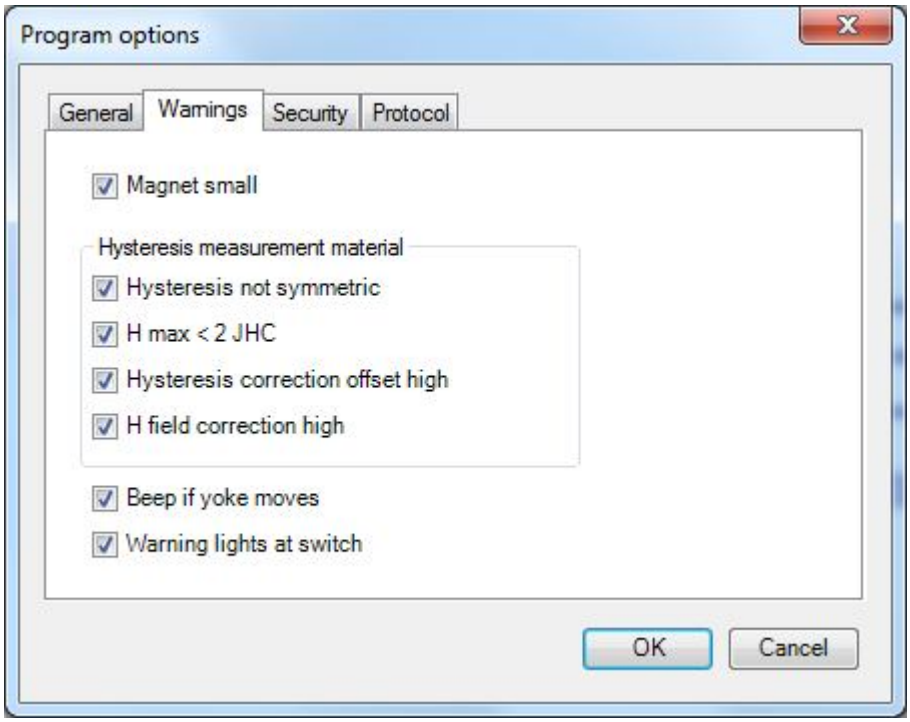
Hall value for Robograph 2 fixture: If for flux measurements of ferrite segments old type Robograph 2 fixtures without inbuilt Hall probes are used, the calibration value of the exchangeable Hall probe must be entered here.

Save measurement is for automatic storing of all measurements. **Application path** is where also the Robograph RE program is located. Other possibility is to enter a path for the archive. Inside the folder there will be generated a path structure with magnet number, date and time.

Base units selects if SI units (T, kA/m, mVs) or CGI units (Gauss, Oerstedt, Maxwell) are shown.

Password protection for flux inserts !!! : If a password is entered here, changing flux fixture parameters is only possible after input of this password. The actual password is not visible here. To change the actual password, the old password must be entered one more timer after pressing the OK button.

At “**Warnings**” different options for message boxes and acoustic or visual warnings can be activated:



Program options Warnings

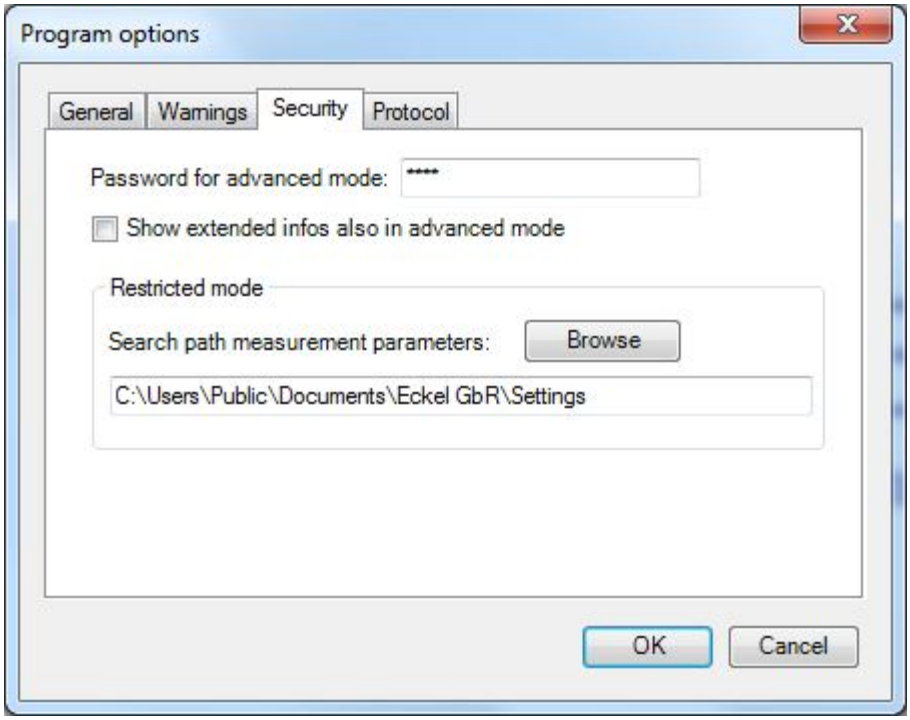
Magnet small: Due to high pressure by magnetic force (5000 – 10000 N) it can be dangerous for magnet and pole shoe to measure magnets with small surface. If the magnet is smaller than 0.5 cm² a warning will be given that magnet or pole shoe may be damaged. If it is even smaller than 0.25 cm² the warning will say that there is a high probability that magnet and/or pole shoes will be damaged.

Damaging the pole shoe will occur if the complete magnet or parts of it are pressed into the surface of the cobalt steel. Though cobalt steel is very hard, this may happen, resulting in a not flat surface. Then measurements will not be as precise as before. Grinding the surface will repair this damage, but due to the platform and mechanics connected to the pole shoes other work and adjustments will be needed to reach complete functionality again. Also grinding will only be possible few times and then a new pole shoe must be used.

Hysteresis measurement material: When measuring a hysteresis at material measurement, it is necessary to saturate the material to both directions. Sometimes it is not clearly visible if saturation is reached or not. In this case some tests are performed to check the hysteresis.

Hysteresis not symmetric: A normal hysteresis will be point symmetric to the centre of the coordinate system. If symmetry is poor, saturation probably was not reached sufficiently.
H max < 2 jHc: If the maximum field is less than 2 times jHc, saturation probably was not reached sufficiently.
Hysteresis correction offset high: With a hysteresis measurement, it is presumed that same values are reached at second circle. Thus the hysteresis is closed to eliminate small offset errors. If offset error correction is high, it is no offset but indicates that same values were not reached due to insufficient saturation.
H field correction high: The hysteresis is centred also in H direction. Normally this effect should be very low. If not, positive and negative jHc did not have the same value.
Beep if yoke moves: If activated the computer will give a beep warning signal before the yoke starts to move.

Warning lights at switch: If activated the additional relay board inside the Robograph Sw switch will be used to switch external warning light at different situations.



Program options Security

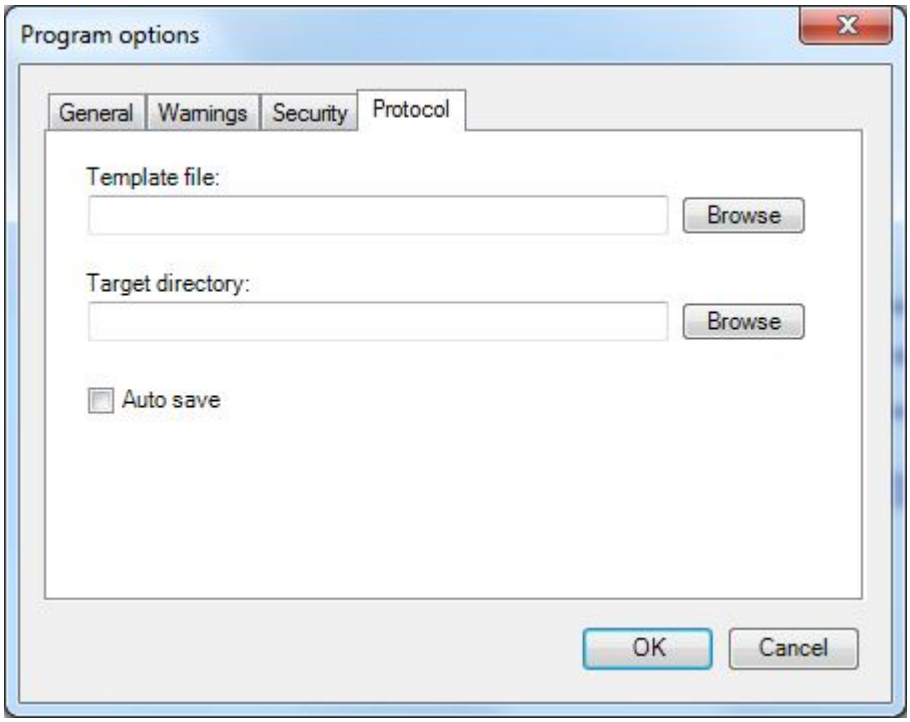
At **Password for advanced mode** a password can be entered. If a password has been defined, a window will open at program start to enter this password. If the correct password cannot be entered, only restricted mode will be available.

To change the password, another password can be entered here. But at closing the window the old password is asked again to confirm authorisation.

If no password is entered here, the program will always be in advanced mode.

Show extended infos also in advanced mode: In restricted mode many warnings and instructions are given to support the user and prevent errors or damage. The advanced mode user may be annoyed by these messages and can deactivate them here.

Search path measurement parameters: For restricted mode all setting files (tolerances) are located in a folder defined in this line.

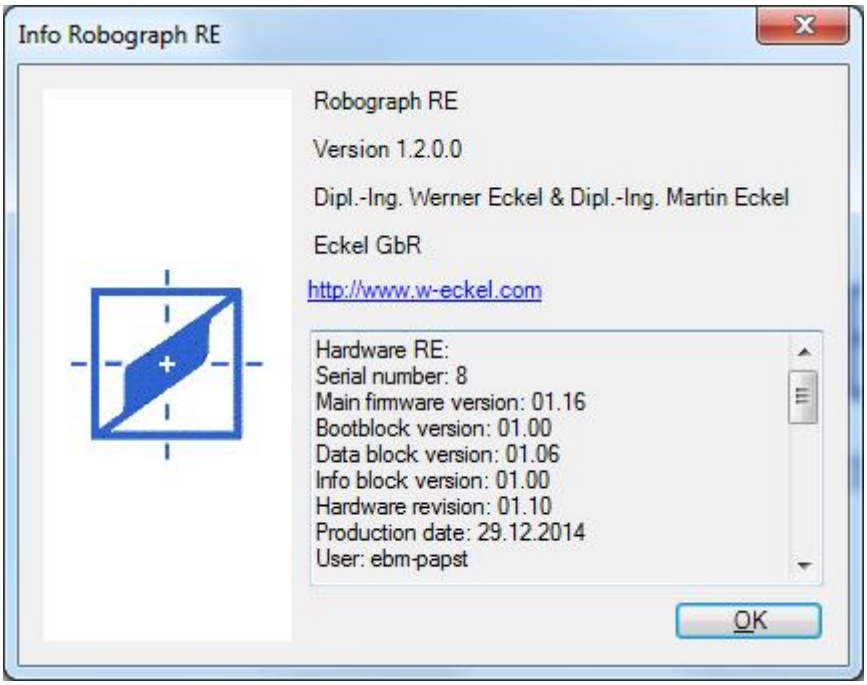


Program options Protocol

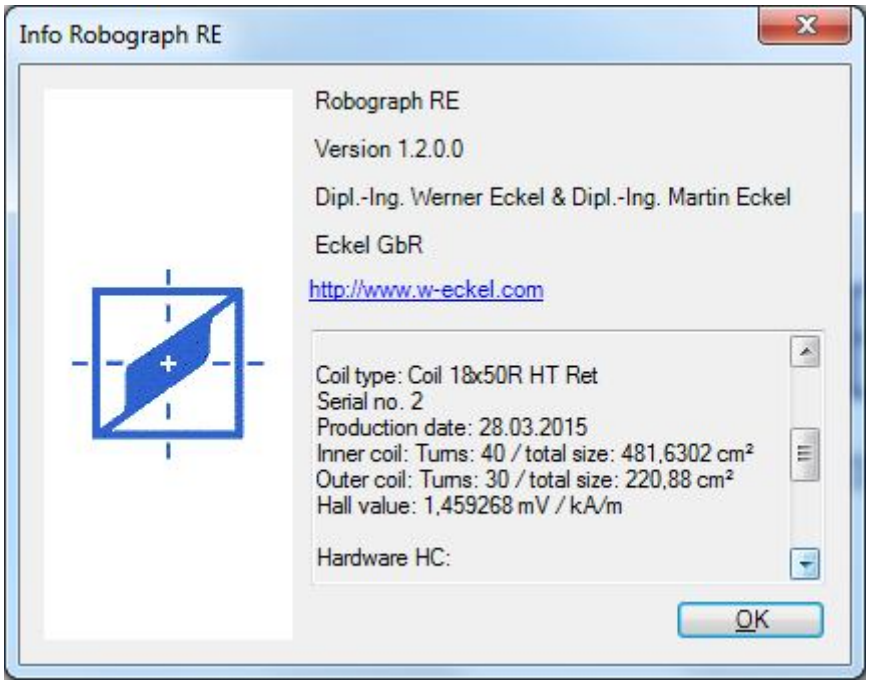
At **Protocol** the template file for extended protocol and the target directory for created protocols are defined.

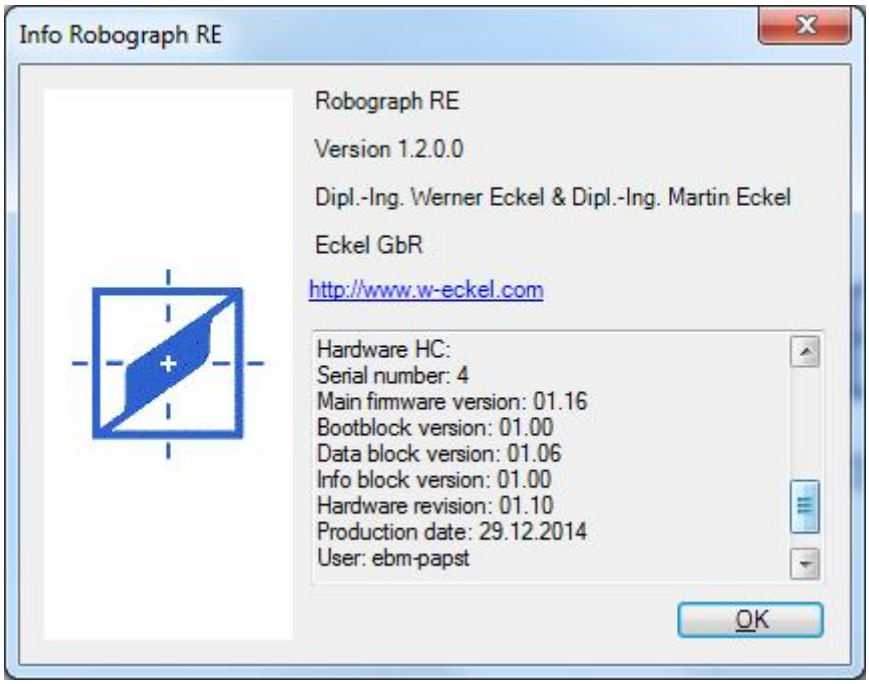
Auto save activates automatic storing of all protocols.

Info opens the information window, showing all versions of different program parts and, if powered on and connected, also the versions of the internal software and hardware.



Information window

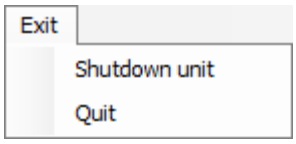




Scrolling down information

A 4.5. Exit flux

By moving the mouse to “Exit” at the task bar the drop-down menu is opened.



Drop-down menu for exit

Shutdown unit shuts off the power amplifier of the Robograph RE. The other parts of the Robograph stay powered on.

Quit ends the execution of this program and returns to the desktop.

A 5. Errors flux

Most errors changing the result come from errors in temperature. If magnet temperature is not room temperature, the result will be not exact.

Take care to have the magnets in the same room as the Robograph RE long enough (1/2 to 1 hour).
No direct sun on the magnets or the connector box at the yoke.
Do not hold the magnets in the hand for a longer period.
Do not store the fixtures at other temperature as the Robograph RE.

Remember that during repeated measurement of the same magnet this magnet becomes warm from magnetisation. Full hysteresis energy is transformed to temperature.

Check if all parameters of the tolerance are correct. Have a special look on the Hall probe value if not read from the fixture.

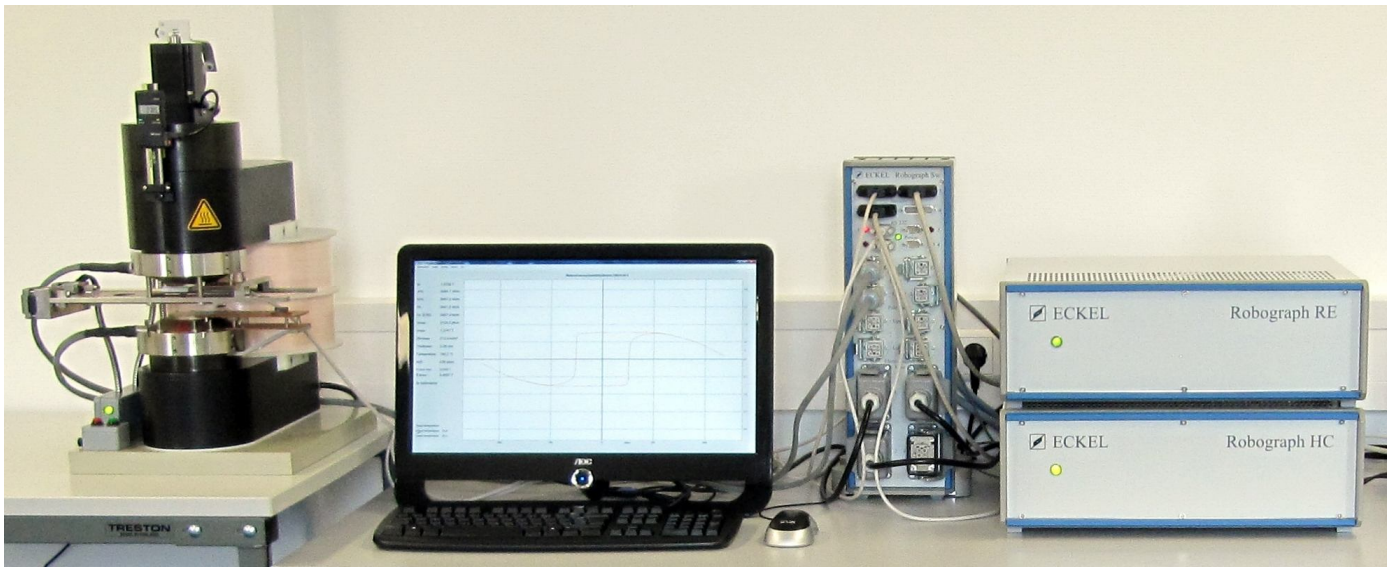
Other errors may occur from insufficient fixing of the magnet. Listen and look if the magnet is moving during measurement.

Changing the insertion direction may slightly vary the results since the magnets are not perfectly symmetric in shape.

Also errors may occur if the power or the sensors plug of the yoke is not correctly inserted.

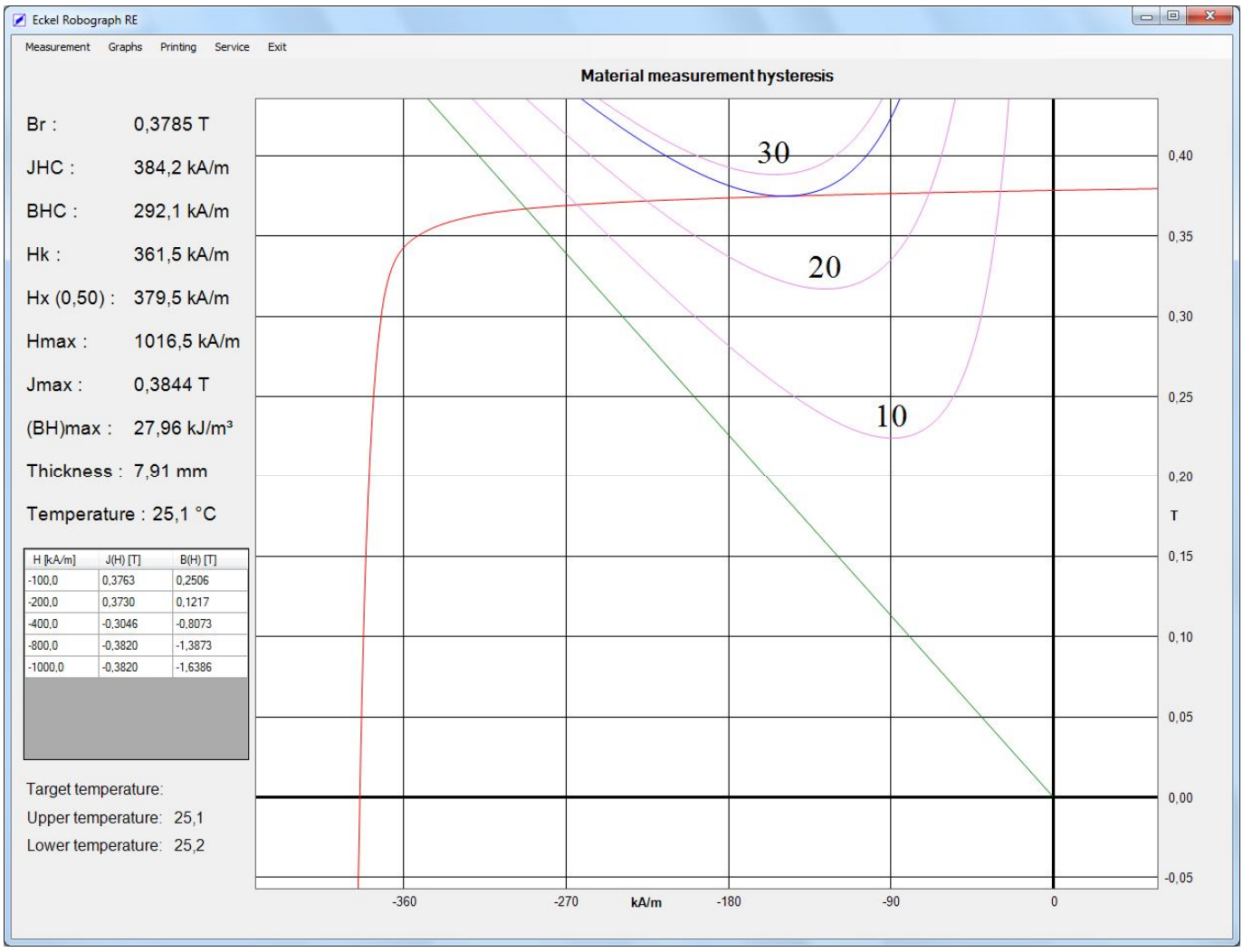
Hardware errors leading to interruption of measurement have to be checked by appropriate test programs. In general message boxes will explain the errors.

B 1. Material measurement of flat magnets (ferrite, AlNiCo and Rare Earth)



Robograph RE for material and flux measurement of flat Rare Earth and ferrites

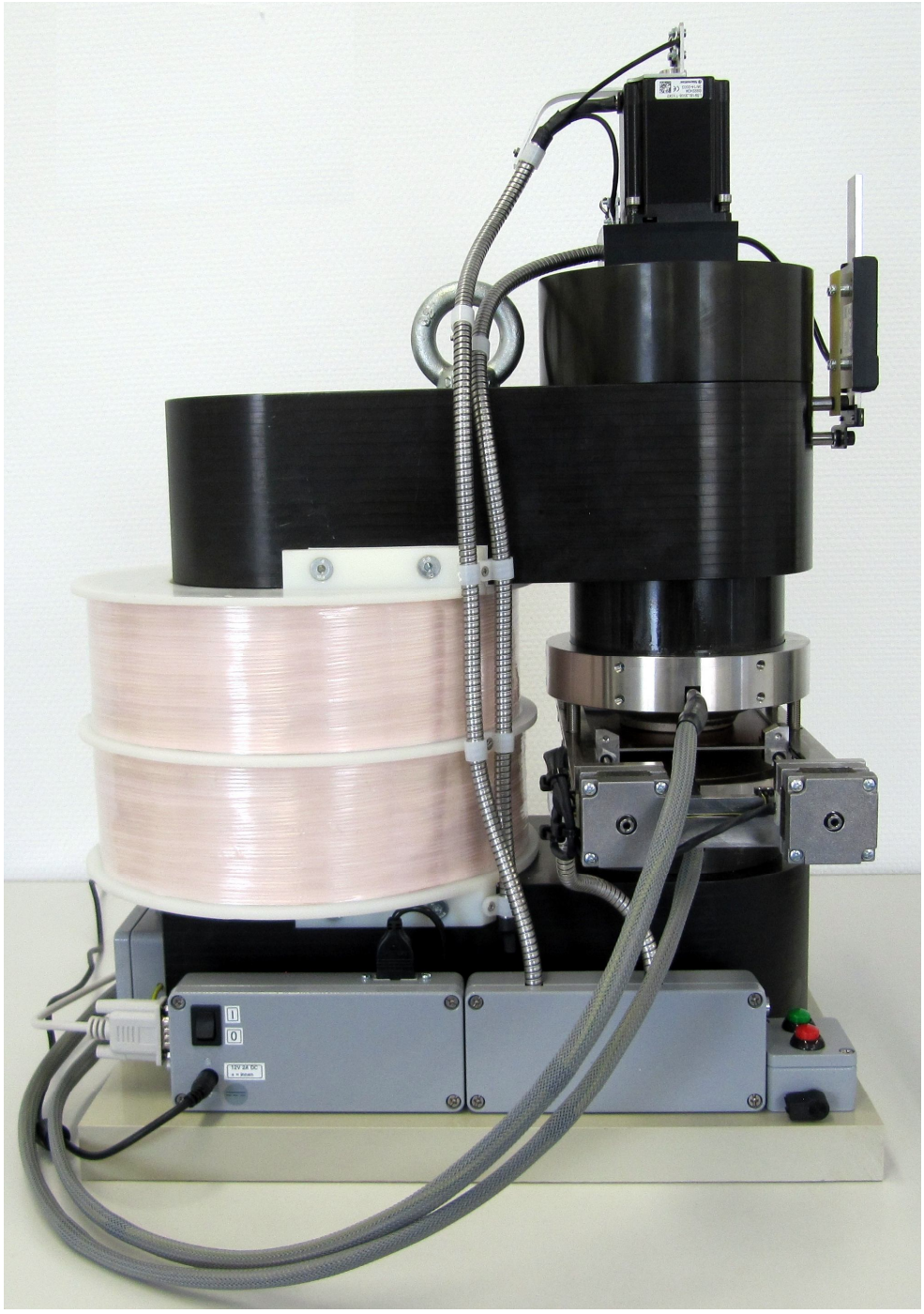
With the big yoke also Rare Earth magnets and other flat samples can be measured. Standard measurement is material measurement (B_r, H_G, $_BH_C$, $_JH_C$, $B*H_{max}$) as hysteresis or demagnetisation. But also flux measurement (result in mVs) is possible.



Demagnetisation J

With the Robograph RE ECKEL offers the only fully motor driven electromagnet yoke in the world for completely automatic measurement of flat samples.

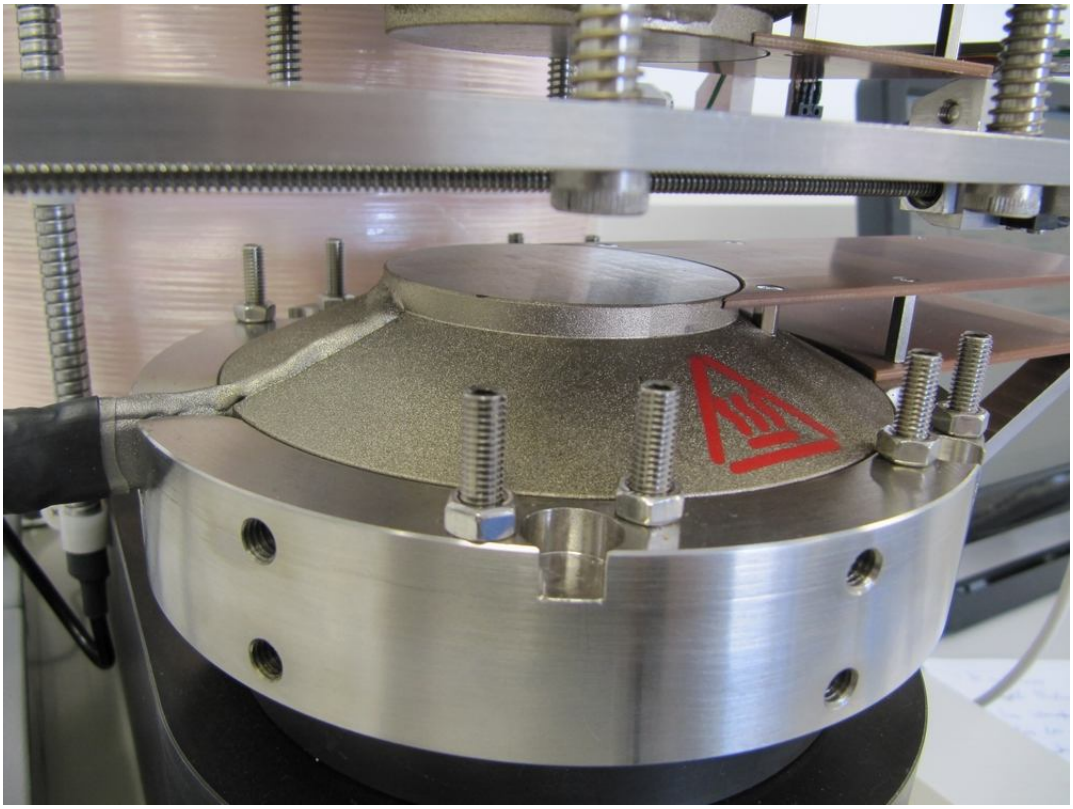
This yoke has also been optimized in size, weight and performance.



Big yoke for Rare Earth

The yoke holds a pair of flat heatable pole shoes made from cobalt steel Vacoflux 50 with a saturation polarisation of 2.35 T. The usable diameter is 64 mm by default. Other sizes are possible on request. The pole shoes are used in combination with a J-compensated surrounding coil. For evaluation surface area of the sample must be known and must be constant over thickness. Thickness is recorded automatically by digital caliper.

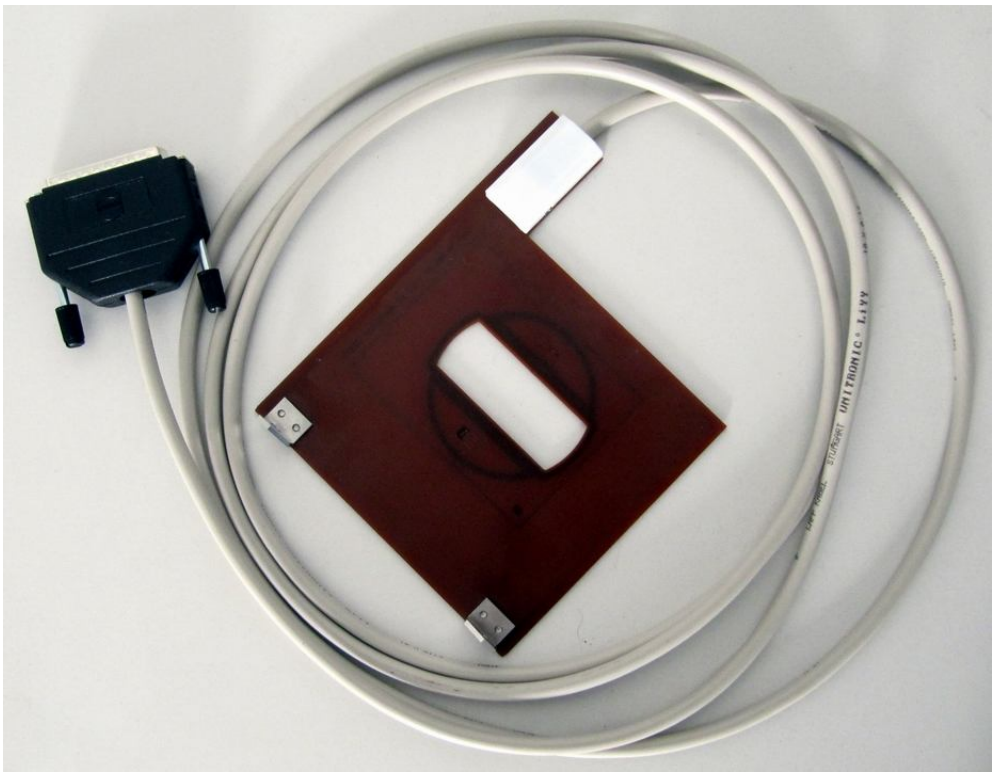
Depending on sample thickness maximum field is up to 2.200 kA/m. A $_JH_C$ can be evaluated reliably up to 1.800 kA/m.



Iron cobalt steel pole shoe

The surrounding coil consists of a 7-layer PCB with 2 printed coils and an integrated Hall probe. It is available in different diameters and shapes and is exchangeable. Parameters of the coil are read by the Robograph RE automatically. The coil is calibrated by a PTB certified comparison coil. For compensation of field widening at larger air gap a thickness dependent calibration is performed.

For measurement the magnet is clamped backlash-free between the pole shoes within the coil opening.



Surrounding coil

The pole shoes can be heated up to 250 °C by using the Robograph HC (Heat Control). The Robograph HC has two independent regulated DC current sources of up to 700 VA. After some minutes the Robograph HC reaches the selected temperature and keeps it constant also during measurement for +/- 0.2 °C. The temperature is acquired by Platinum surface sensors.

ECKEL Robograph HC

As the Robograph RE the Robograph HC is completely controlled and regulated internally. It is also connected to PC via USB and firmware can be updated.

The measurement is completely automatic even with heating up. Coil and yoke are motorized and equipped with sensors. The yoke is controlled by the PC via serial interface (RS232).

The magnet is inserted magnetized or not magnetized to the coil by hand. Measurement can be started by button at the yoke or by keyboard / mouse.

The coil is pulled in together with the magnet and the yoke is completely closed until contact detection. Then the selected measurement starts. At the end the yoke is opened and the coil is pushed out together with the magnet.

The complete automatic procedure is not only very comfortable but also ensures exact repeatable results, fast execution and temperature stability at the beginning of measurement after heating up.

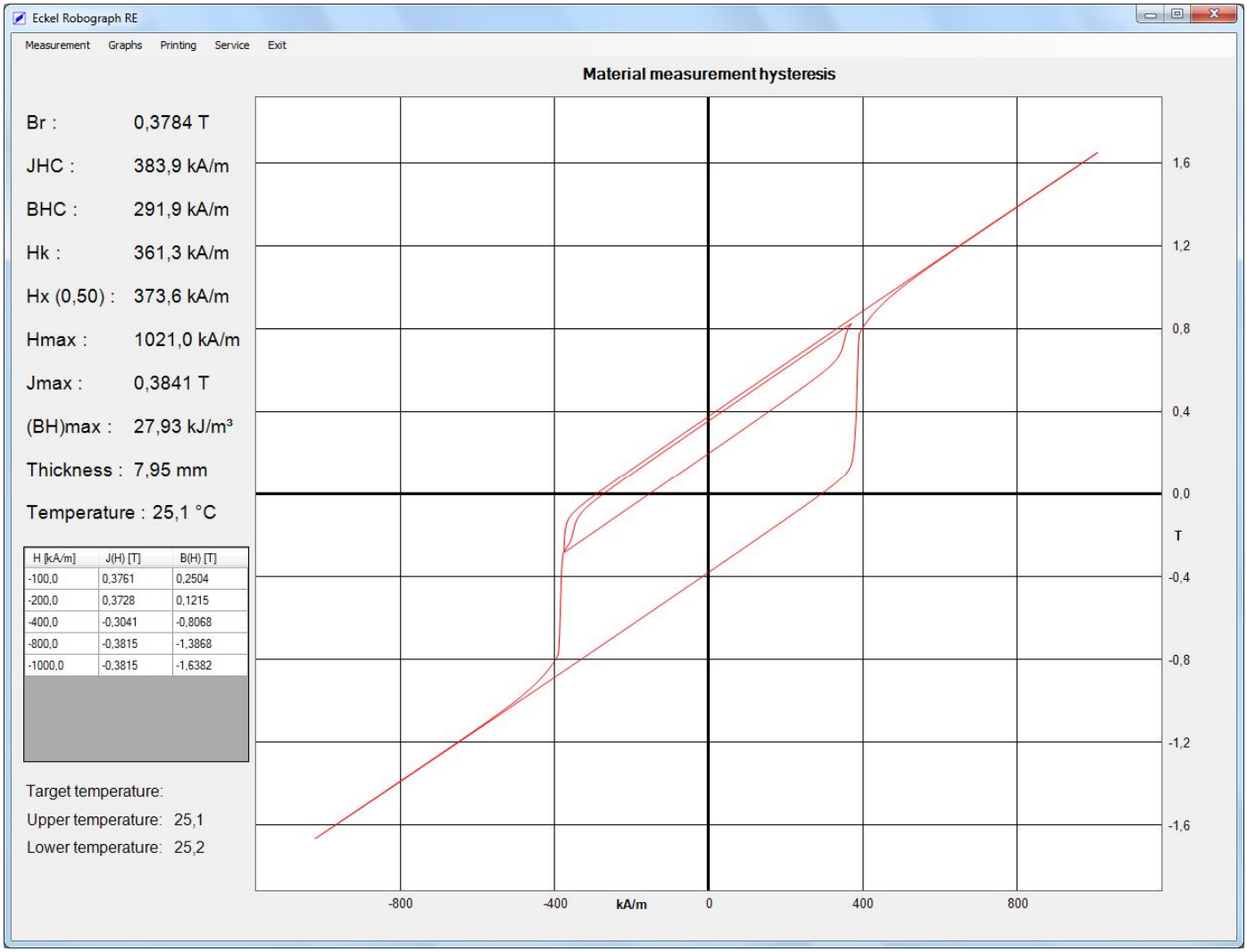
Procedure of flux measurement is mainly the same. Since flux measurement shall simulate the situation within the motor, an air gap is needed. For that there are coils that create a magnetic air gap with PCB material (e.g. 0.5 mm). The magnetic shear of hysteresis at this measurement is part of the result and is evaluated analogue to flux hysteresis measurement of ferrite segments. But flux measurement can also be performed as demagnetisation measurement and of course with heating. The user can select between standardized J curve (horizontal in Φ^*_R) and real J curve (with slight gradient in Φ^*_R).

For unheated material tests of flat ferrite or AlNiCo magnets also pole shoes with internal coils can be used. The magnet is clamped backlash-free between the coils of one of the coil pairs. The induction B is measured using this coil pair. The second coil pair is used for J-compensation. The field strength is measured using a

Hall probe. Here the surface area of the sample may be unknown and may be not constant over thickness. The coil must be covered completely be the magnet.

Sample rate, measurement speed and maximum field strength are selectable. Hysteresis, demagnetisation and 2-quadrant demagnetisation (with magnetisation at the beginning) with or without inner loops can be selected. Also New Curves of demagnetized magnets can be recorded. Even back-coupled functions with constant dH/dt as well as temperature coefficient evaluation are available.

Measurement time and number of samples are depending on the selected parameters. Measurement time is between 8 and 128 seconds. The number of samples is set to about 10.000 samples for a complete hysteresis.



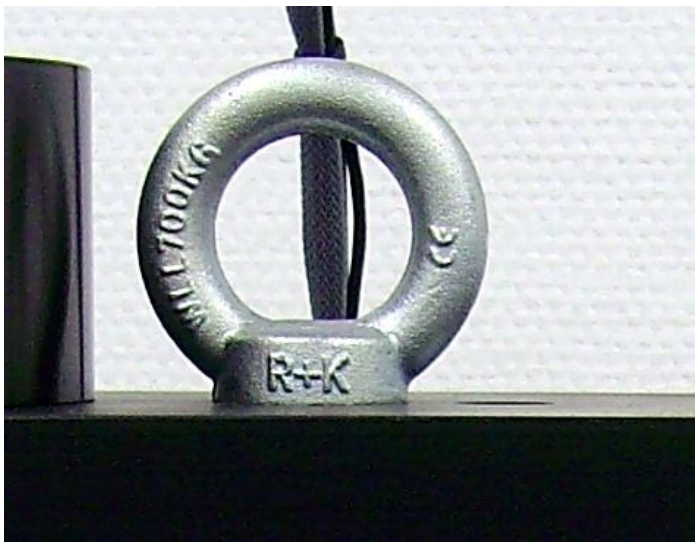
Hysteresis B

Evaluation and display of the result take less than one second. All results that can be calculated from a hysteresis or demagnetisation curve can be displayed. If desired, a tolerance can be set for all results. Of course all results can be archived, printed and exported.

A Rare Earth magnet normally cannot be magnetized by the Robograph RE at all temperatures. For demagnetisation measurement most times an external magnetizer is necessary for prior magnetisation. Also a complete physical demagnetisation is not possible with the Robograph RE. Therefore an external demagnetizer is used.

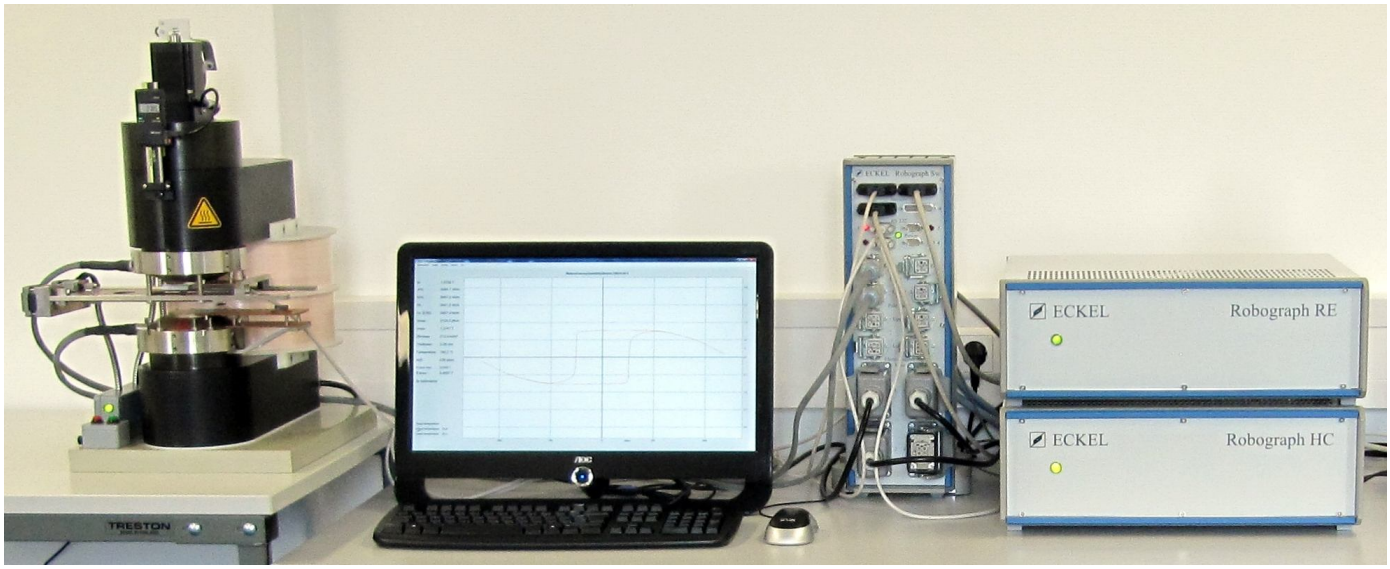
B 2. Installation of the Robograph RE for material measurement

Security information: Lift the yoke only at the iron ring!
Never lift the yoke at other construction parts!



Ring for lifting the yoke

When positioning the yoke, Robograph RE, Robograph HC and monitor on the table remember the weight of about 200 kg. Take care that the table can bear this weight!



Positioning of Robograph RE for material measurement

The yoke creates a strong DC magnetic field during measurement. This may harm your hard disk of the PC. Keep the PC away from the yoke.

The magnetic field may harm heart pacemakers. Don't stand near the yoke during measurement if you have a heart pacemaker!

Always use a LCD flat screen. A CRT monitor is disturbed by the magnetic field.

At the backside of the Robograph RE you find the connectors to line voltage, yoke and PC.

Backside of the Robograph RE

On the left side you see the line voltage input, power switch, and the electromagnet yoke connector.

Line voltage input, power switch and the electromagnet yoke connector

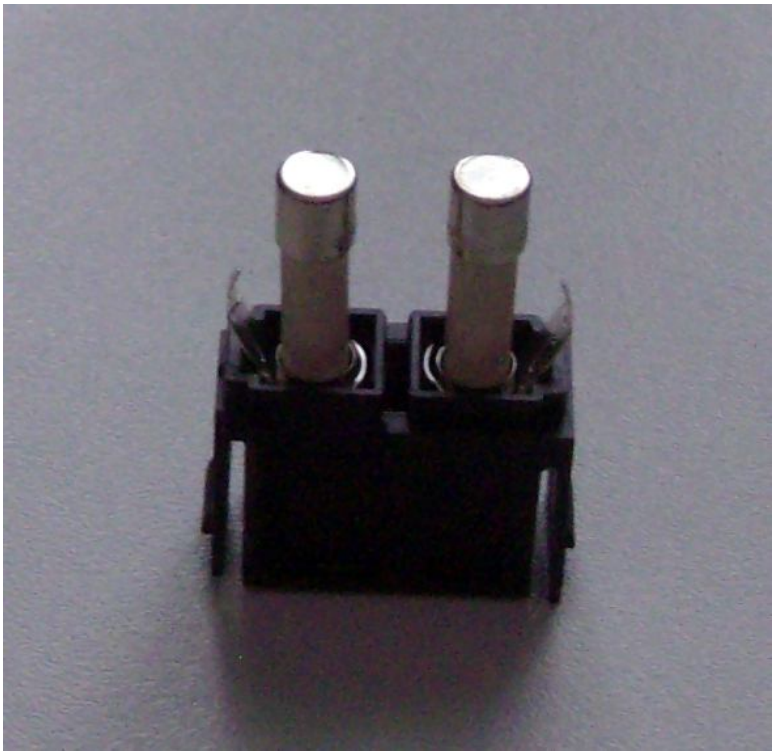
Always keep the fan, the slots at the backside and on the top uncovered!

Take care not to let any liquid soak inside the unit!

The line voltage input contents the fuses. Use a screwdriver to take them out if necessary.

Opening the fuse holder

The fuse holder contains 2 fuses 5x20 mm 8A T (slow)



Fuse holder with 2 fuses

Connect the power cable to the line voltage input. Voltage is 220-240V, 50 or 60 Hz.

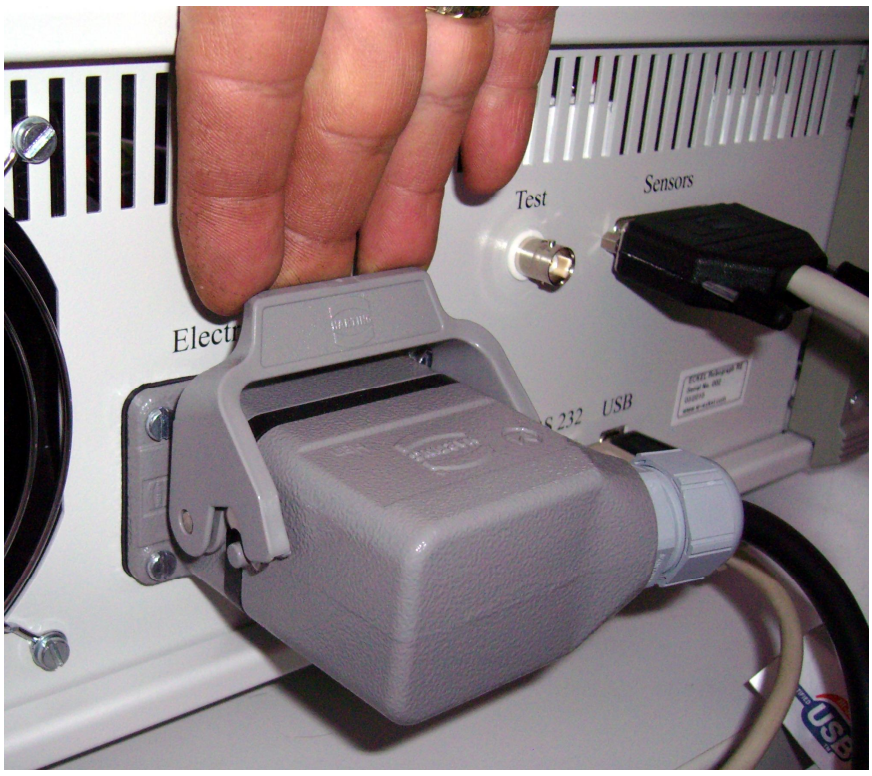
For correct and safe operation the line voltage must be combined with a protective earth.

Use the power switch to switch the unit on and off. The unit is on when “I” is pressed.

Line voltage connection

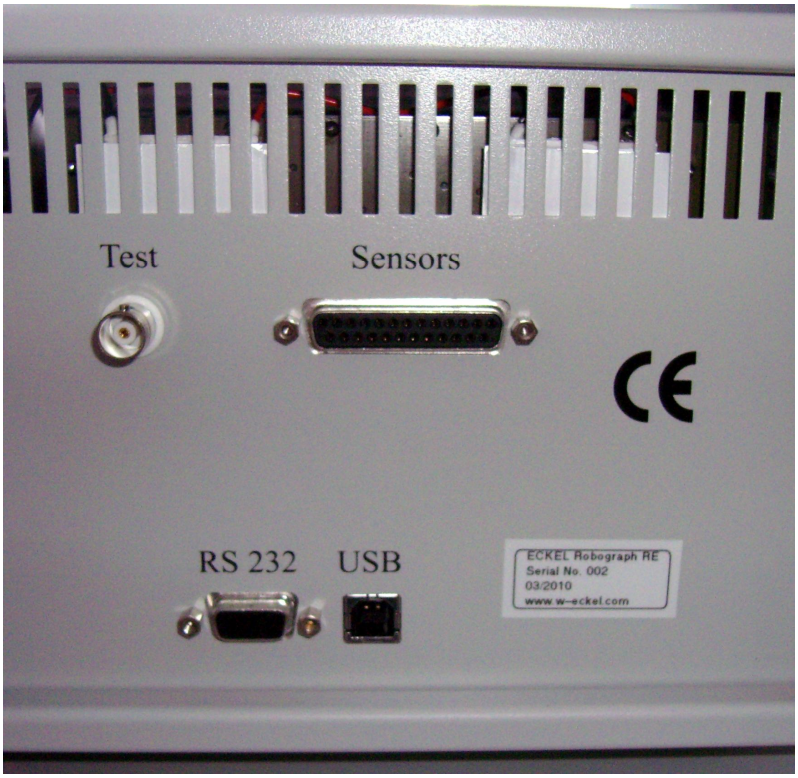
Connect the yoke power plug to the connector. It fits only in one position.
None of the yoke connector contacts may ever be connected to ground or protective earth!

Close the retaining bracket. If the connection is opened during measurement very high voltages may occur at the yoke power plug.



Closing the retaining bracket

On the right side you see the RS232, USB and Sensors input and the test output. Also serial No. and production date are marked.



Connectors on the right side

Connect the USB cable to the PC and the sensors plug of the coil. Fix the sensors plug.

The RS232 cable is only needed in emergency cases of firmware update. Do not connect for normal use.

The test output is used for external calibration test for certification.

Connections to yoke and PC

At the front of the Robograph RE there is only a 10mm LED. This LED can be on in green, red or yellow. When switching on the unit the LED will be red for a short time. After successful system test the colour changes to green.

During measurement the LED is yellow. **Do not switch off the unit or disconnect the yoke!**

If the LED flashes red there is some error.

Front of the Robograph RE

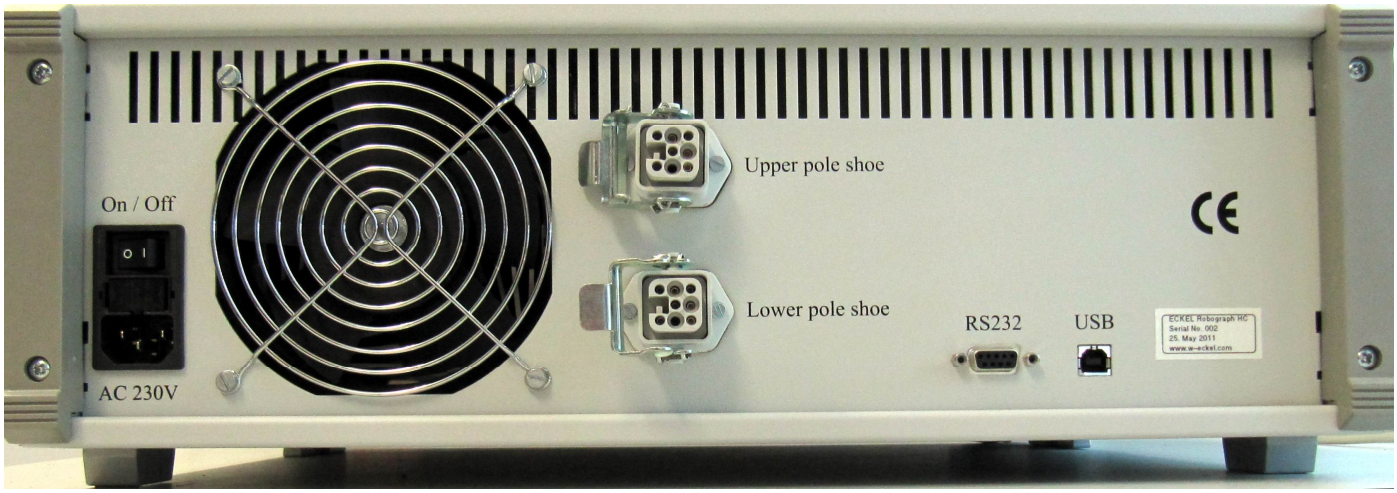
After switching on the fan will start to turn slightly. Starting the fan makes some noise. This is normal.

The fan is temperature regulated and runs during measurement and 1 minute after. If transistor temperature is above 30 °C, the fan will always run with a speed depending on temperature until temperature falls below 30 °C. Then it is reset to power save mode.

The power amplifier is not yet activated. It will be activated when first measurement is started.

The Robograph RE will recognize the yoke and the fixture (Robograph RE type) automatically.

At the backside of the Robograph HC you find the connectors to line voltage, pole shoes and PC.



Backside of the Robograph HC

On the left side you see the line voltage input.

Line voltage input

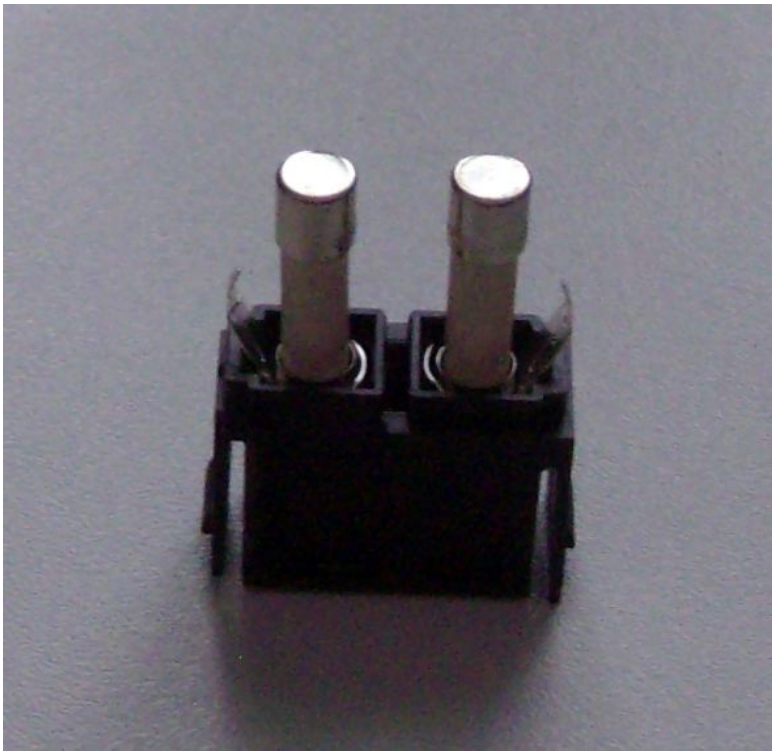
Always keep the fan, the slots at the backside and on the top uncovered!

Take care not to let any liquid soak inside the unit!

The line voltage input contents the fuses. Use a screwdriver to take them out if necessary.

Opening the fuse holder

The fuse holder contains 2 fuses 5x20 mm 8A T (slow)



Fuse holder with 2 fuses

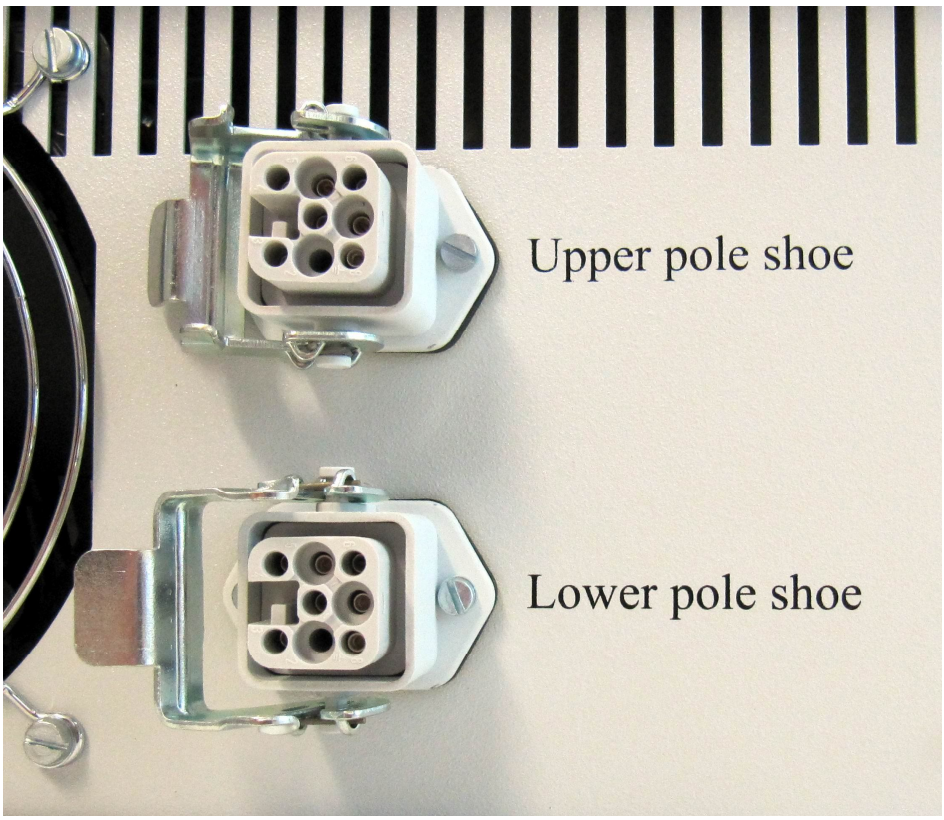
Connect the power cable to the line voltage input. Voltage is 220-240V, 50 or 60 Hz.

For correct and safe operation the line voltage must be combined with a protective earth.

Use the power switch to switch the unit on and off. The unit is on when “I” is pressed.

Line voltage connection

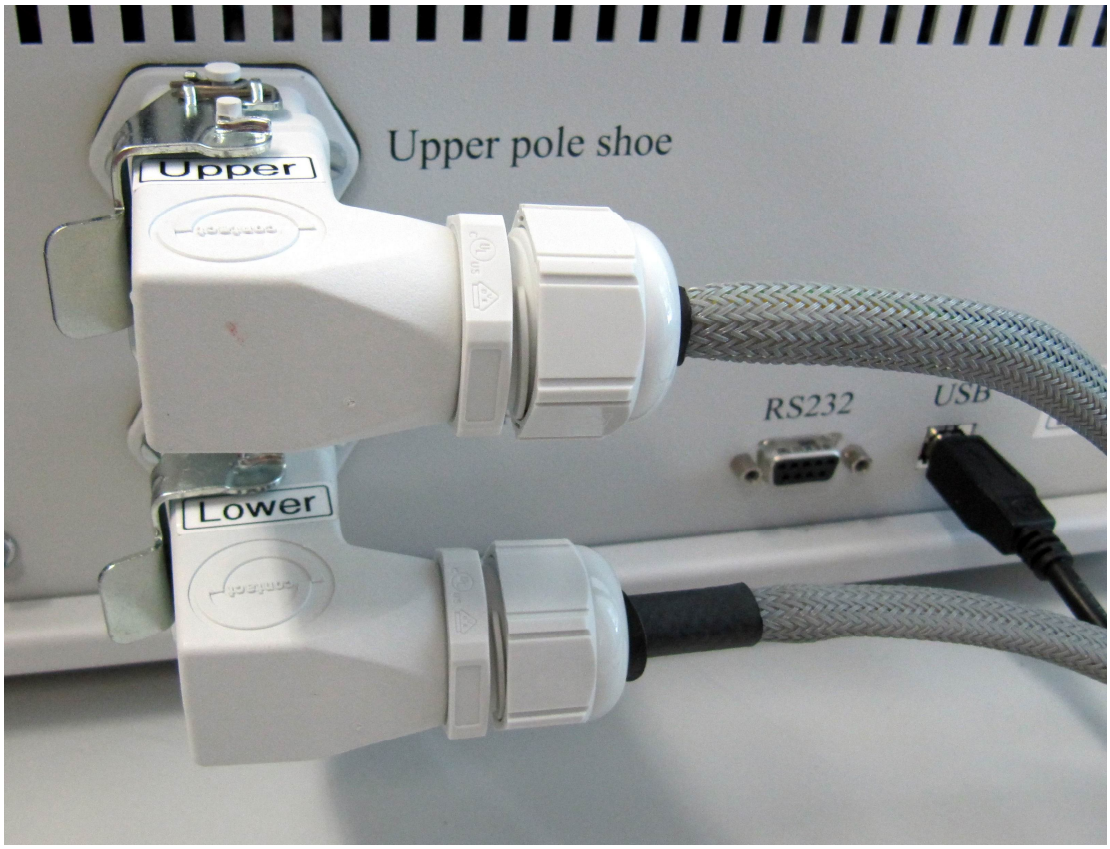
In the centre there are 2 connectors for the heated pole shoes.



Heating connectors

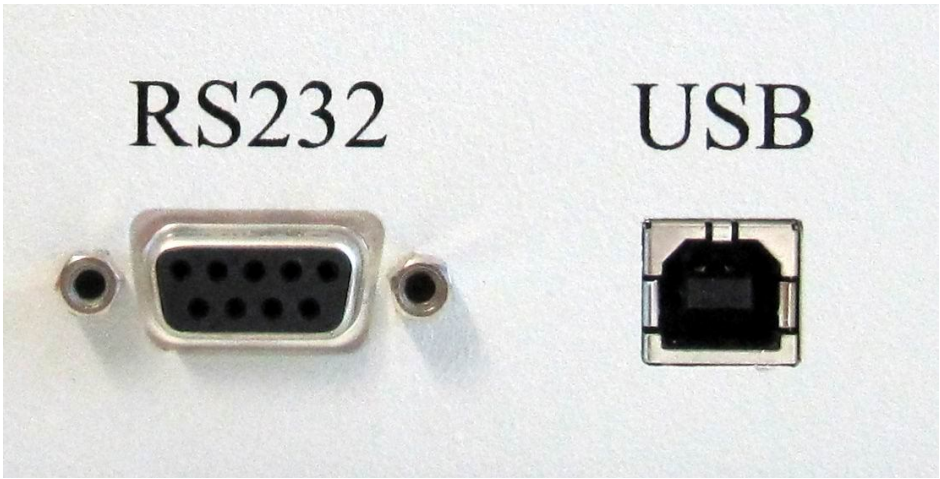
Connect the pole shoe plugs to the connectors. They fit only in one position.
Take care to connect the upper and lower plug to the corresponding connector.
None of the pole shoe heating contacts may ever be connected to ground or protective earth!

Close the retaining bracket.



Connecting of pole shoe heatings and USB

On the right side you see the RS232 and USB inputs. Also serial No. and production date are marked.



Connectors on the right side

Connect the USB cable to the PC.

The RS232 cable is only needed in emergency cases of firmware update. Do not connect for normal use.

At the front of the Robograph HC there is only a 10mm LED. This LED can be on in green, red or yellow. When switching on the unit the LED will be red for a short time. After successful system test the colour changes to green.

During heating operation the LED is yellow. **Do not switch off the unit or disconnect the pole shoes!**

If the LED flashes red there is some error.

Front of the Robograph HC

After switching on the fan will start to turn slightly. Starting the fan makes some noise. This is normal.

The fan is temperature regulated. If transistor temperature is above 30 °C, the fan will always run with a speed depending on temperature until temperature falls below 30 °C. Then it is reset to power save mode.

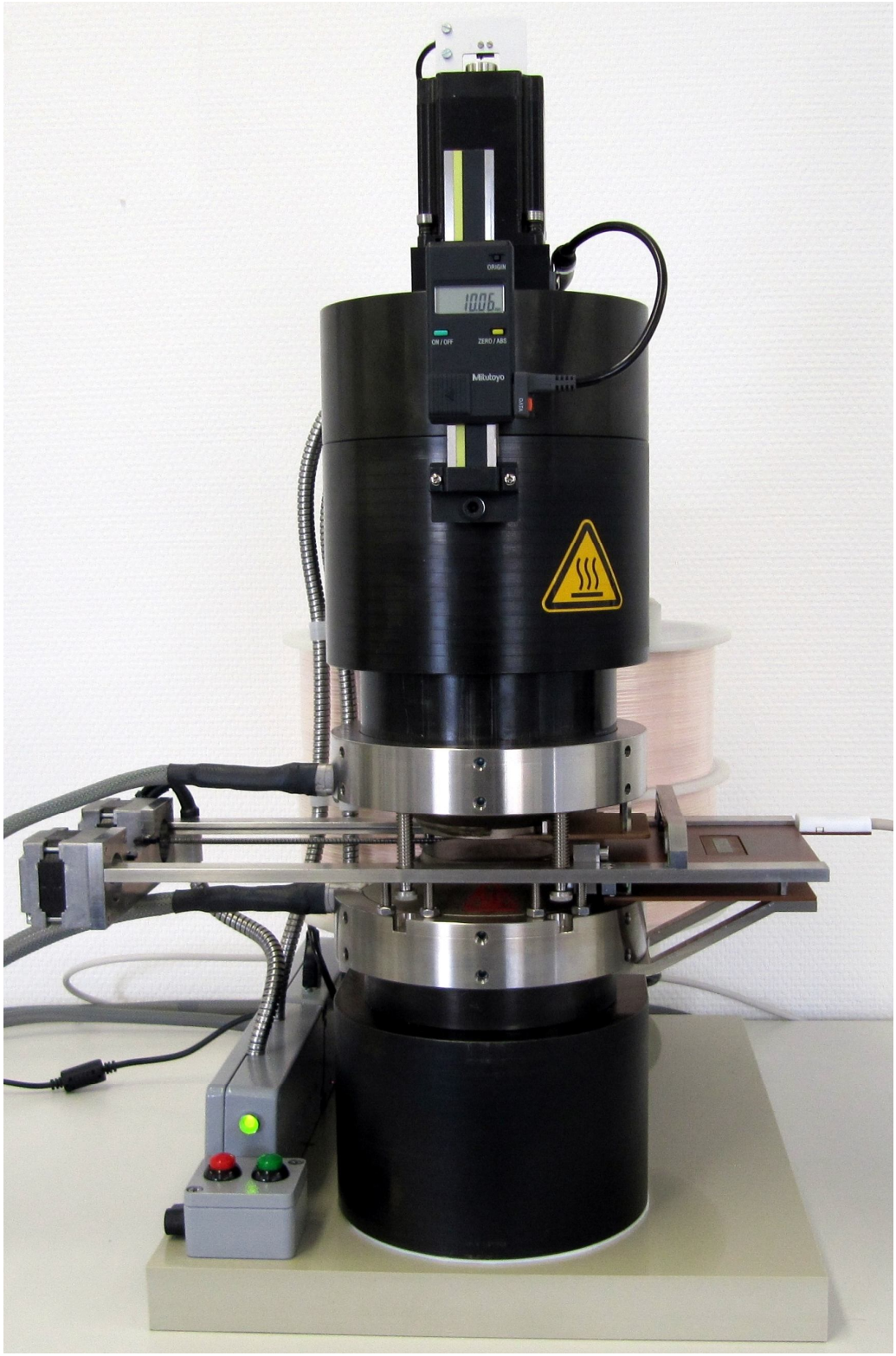
The power amplifier for heating is not yet activated. It will be activated when first measurement is started.

The Robograph HC will recognize the upper and lower pole shoes automatically.

B 3. Big yoke for heated material measurements

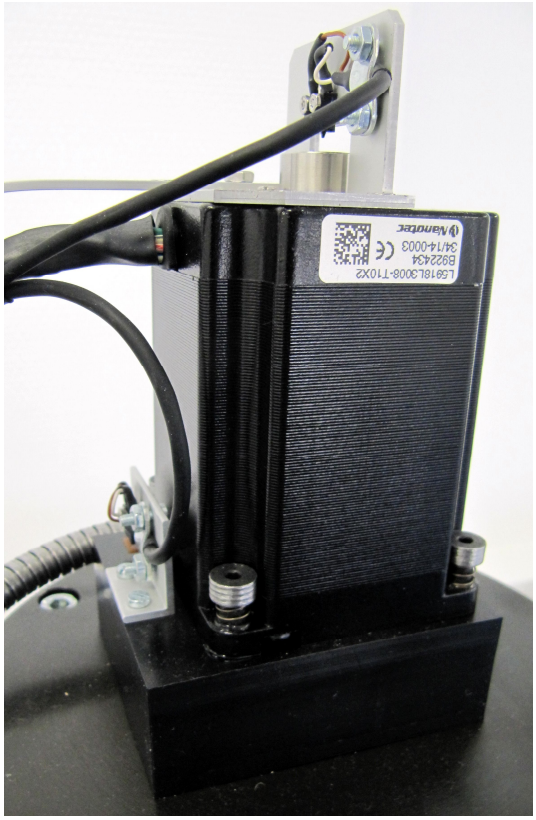
The big yoke is designed for optimal performance at minimum size and weight. It is equipped with 3 motors, a digital caliper and 8 switches. This allows the user to perform measurement fully automatically including retraction and ejection of magnets.

For control there is a box with internal microcontroller getting orders and sending alarms via RS232 connection.

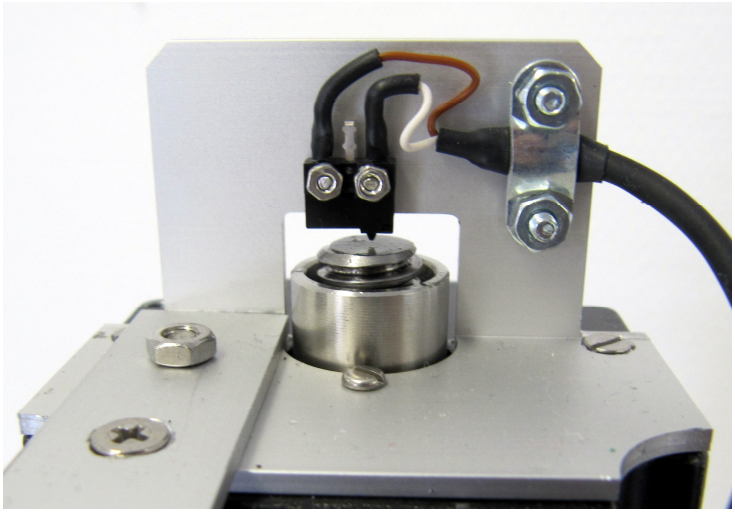


Big motorized yoke

The top motor lifts and lowers the upper cylinder of the yoke. On the top there is an end switch that is pressed by the spindle at upper position. At system start it must be contacted once to define cylinder position.

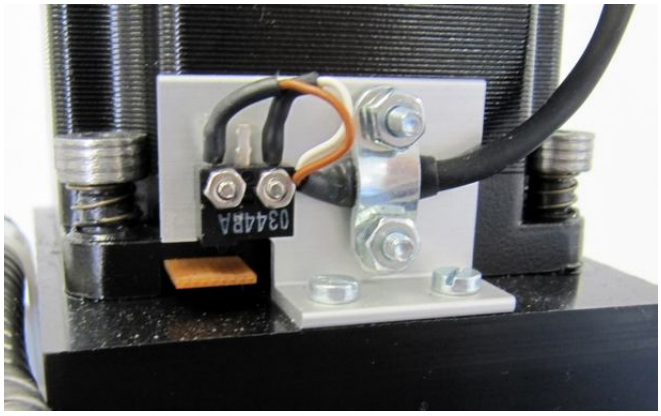


Top motor



Top switch

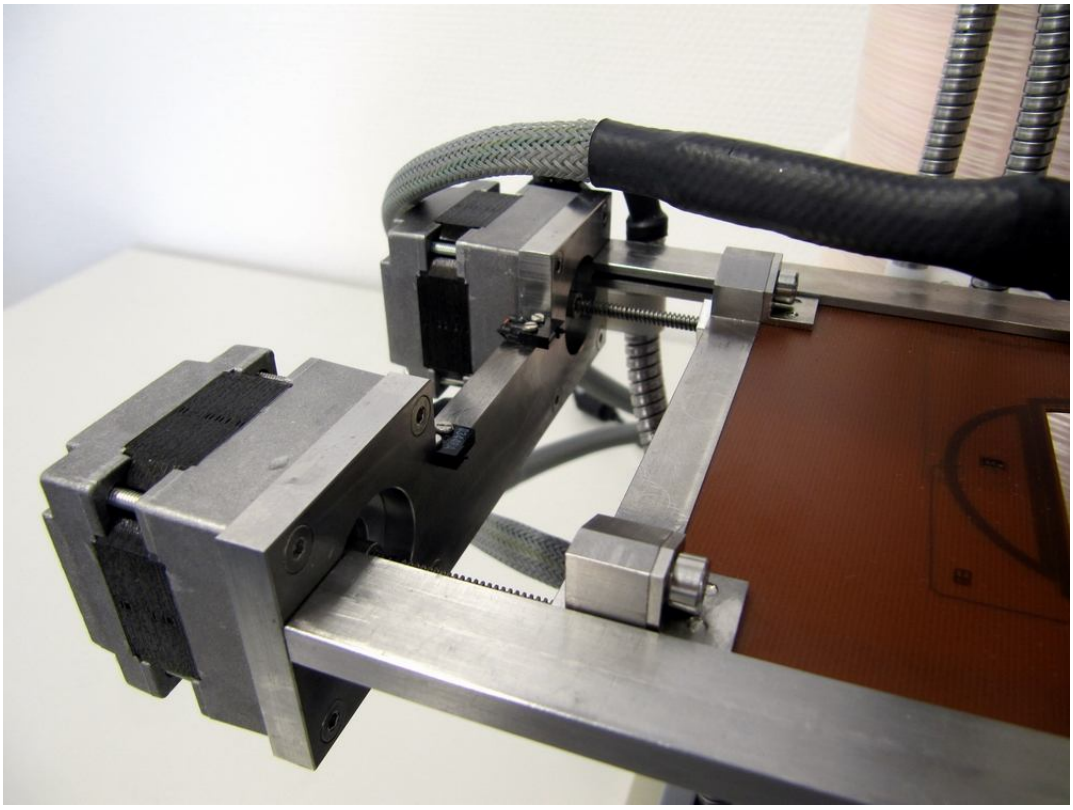
The position of contacting the surface of the magnet when lowering the cylinder is unknown since it depends on the magnet thickness. To stop the cylinder at contact without damaging the magnet, the motor can lift up itself for some millimetres. The lifting of the motor is recognized by an end switch.



End switch for contact position

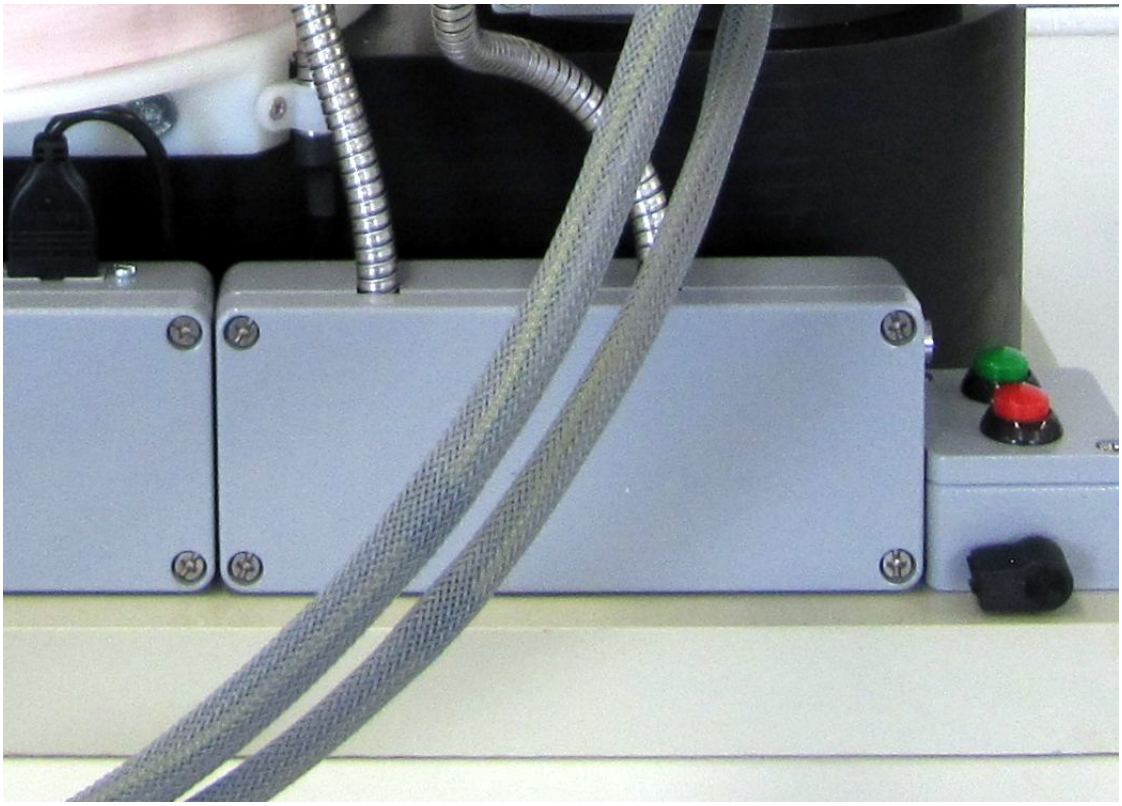
Since the motor is not really fixed in position, it may make some noise that results from step movement. Some grease will help against possible noise. See below at maintenance.

The side motors move the coil. The coil has fixed outer and inner positions. There are end switches near the motor. At system start they must be contacted once by the carriage to define coil position.



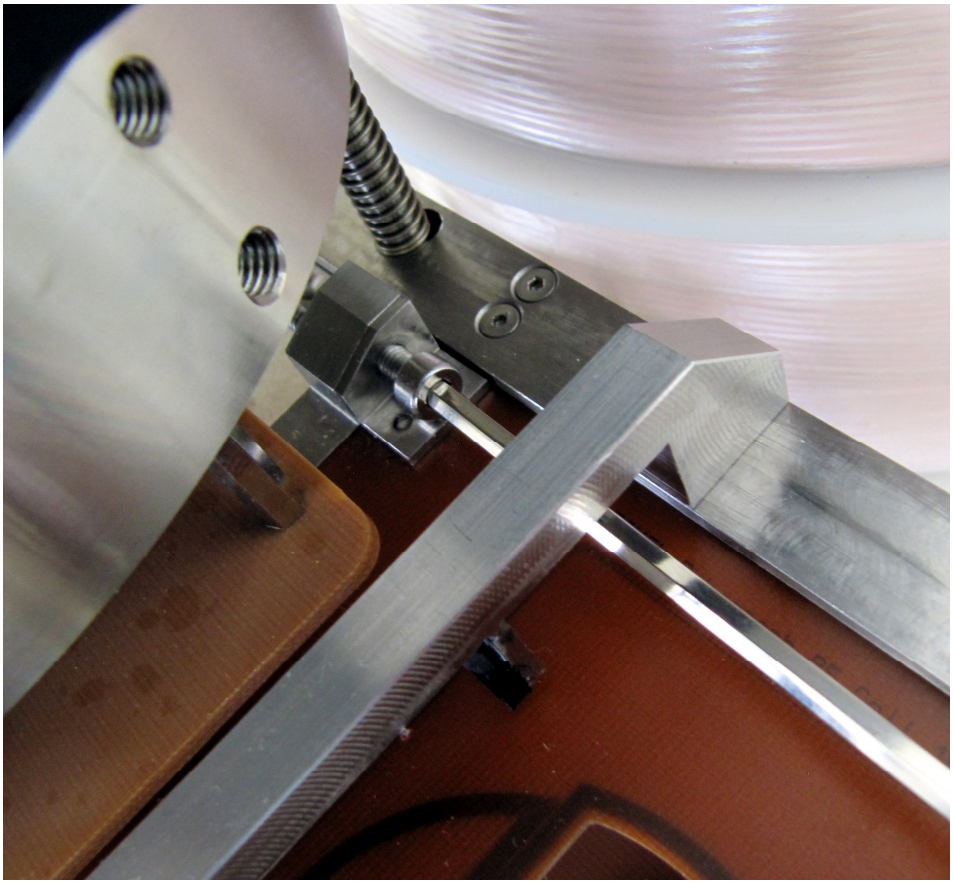
Coil motor moving the carriage and coil

All 3 motors are connected to their power stages. The power stages are connected to the control box.

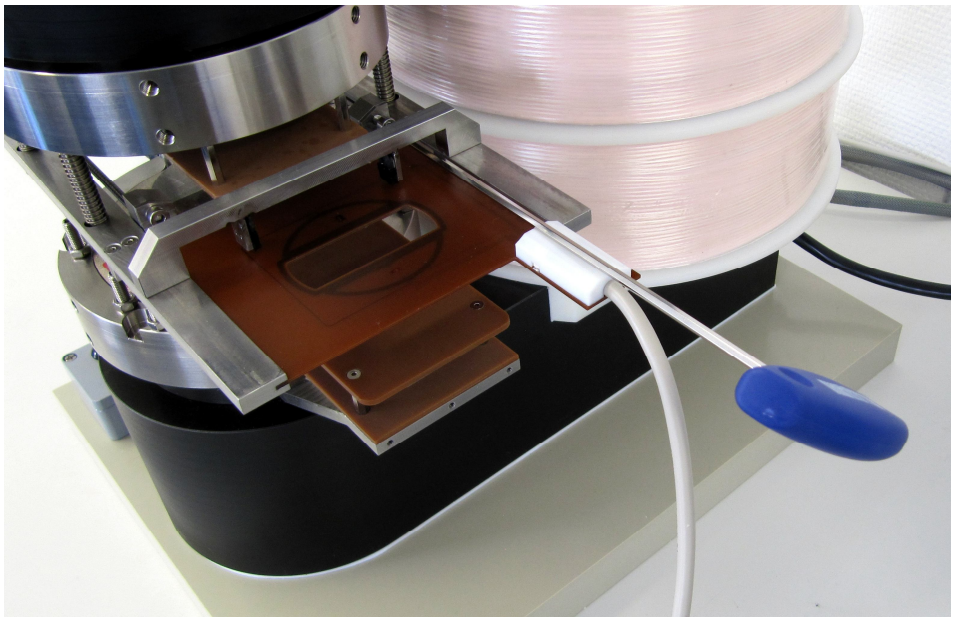


Motor power stages inside aluminium cases

The coil must be driven to drop and pick up position (right end) to change it. The coil is fixed with 2 screws M4. A special long 3 mm Allen key is needed.



Unscrew the coil

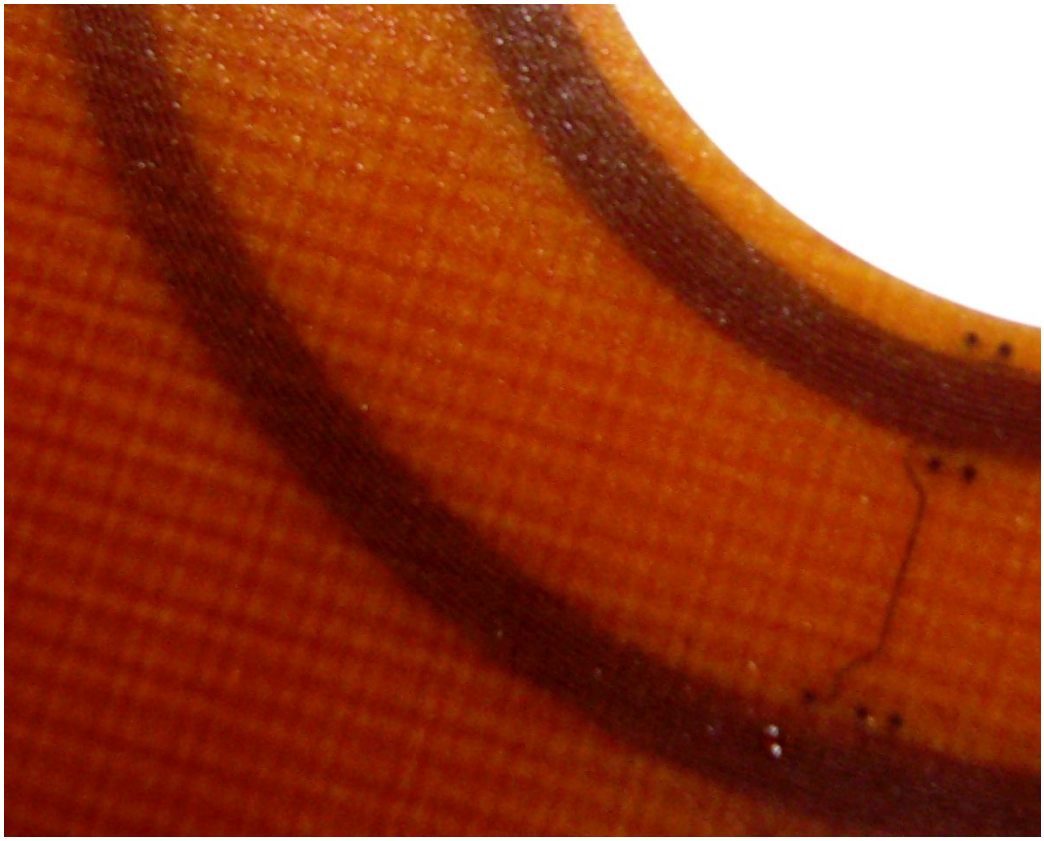


Unscrew the coil using a long Allen key

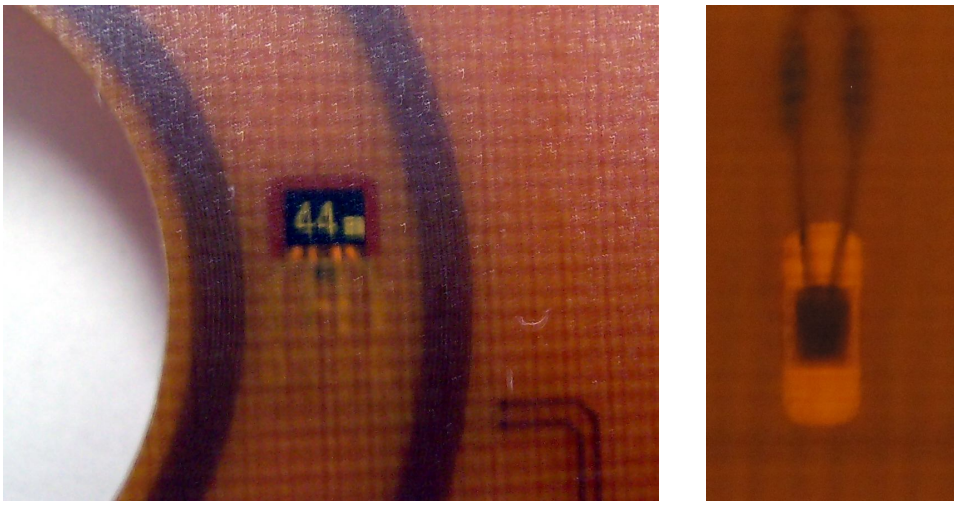
At tightening the screws the carriage must not be bent! Do not tighten too much!

Never run the carriage without coil! If ever by any reason the two motors will run not synchronously, the coil protects the spindles from being bent. But without coil serious damage may occur in that case.

The coil is not wound but a 7 layer PCB. The wires are only 0.09 mm wide. The inner coil has 40 windings and the outer coil has 30 windings. There is an inbuilt Hall sensor and a platinum temperature sensor between the coils. Total thickness is about 1.35 mm.



Micro wires of the coil

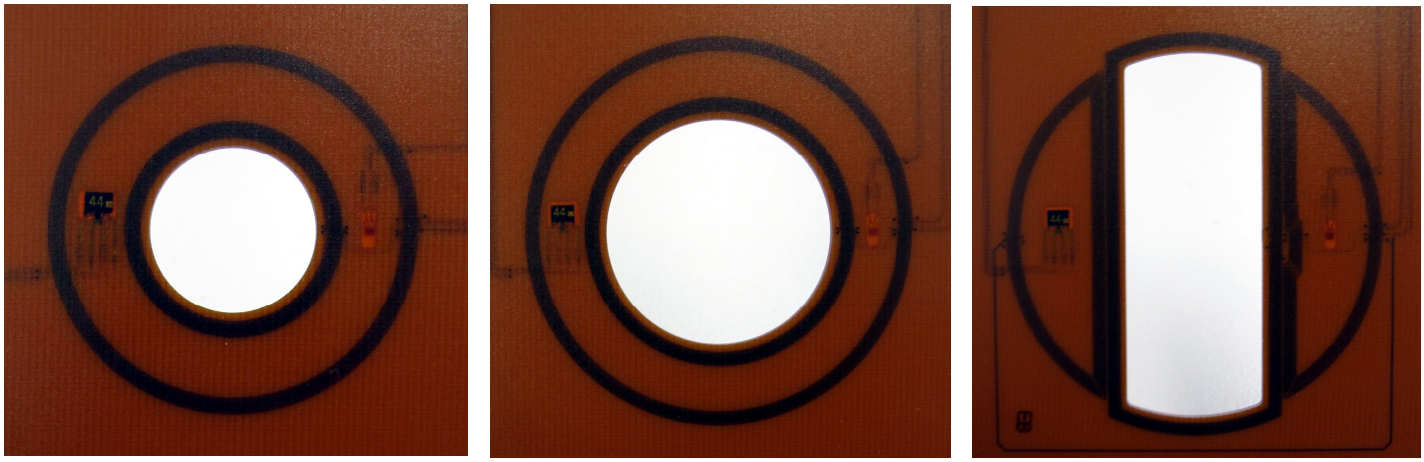


Internal Hall and PT temperature sensors

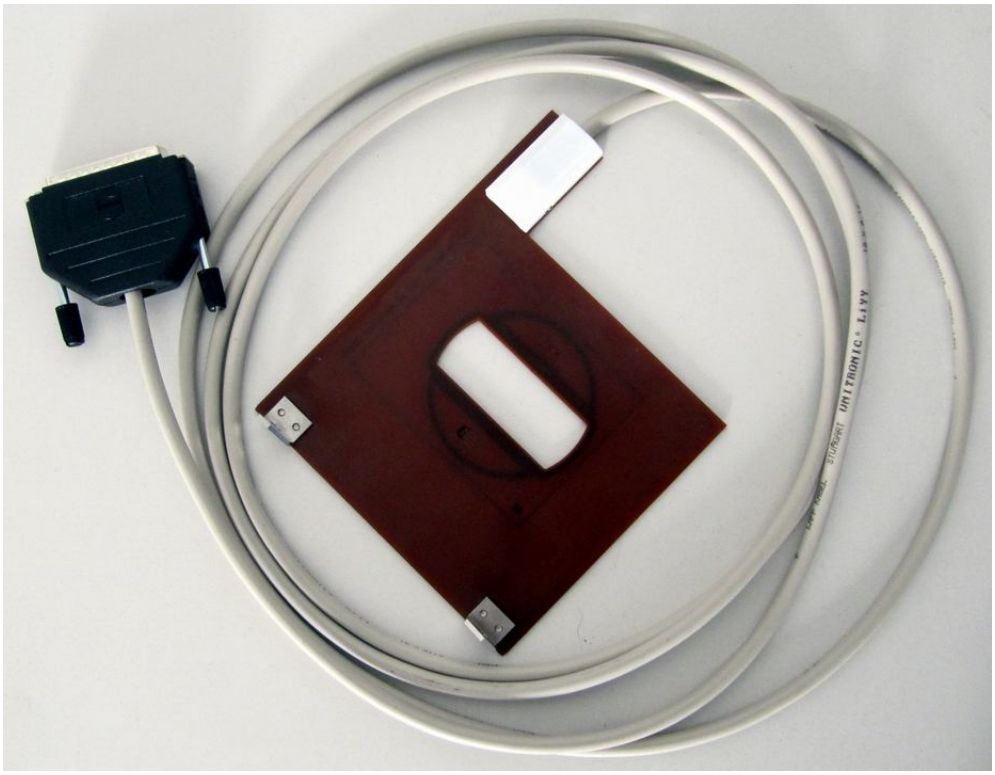
This coil is perfectly protected against damage and guarantees perfect reproducibility at coil production. The high temperature coils can work up to 250 °C. At highest temperature use they will become a little bit darker but this does not harm anything.

A serial EEPROM is in the plug of the coil, transferring all parameters of the coil and Hall sensor to the Robograph RE.

Different diameters, shapes and constructions are available. The coils are calibrated by a PTB certified comparison coil.



Different coil sizes, shapes and constructions



Coil with special shape

For compensation of field widening at larger air gap a thickness dependent calibration is performed.

A digital caliper is used to record and transfer the thickness of the sample. Thickness information is necessary for different calibration and compensation procedures.

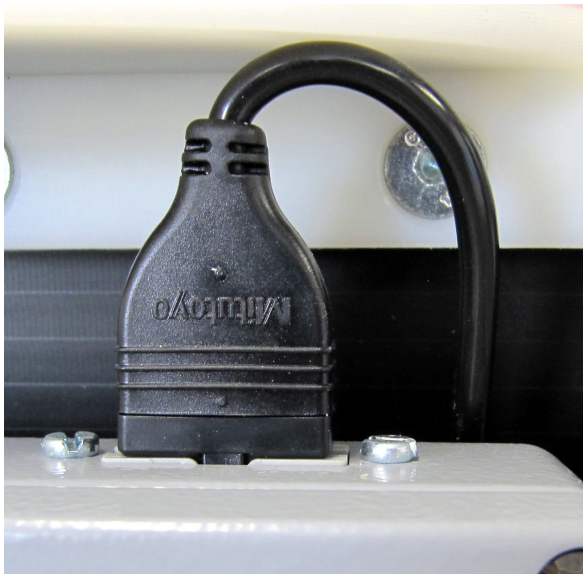
The caliper can be switched off if not used but must be on during system operation.

Digital caliper showing magnet thickness

The caliper can be recalibrated by closing the yoke with coil driven to park position (left side) and pressing the “Origin” button for 2 seconds.

If a small “B” is shown in the display, battery must be replaced. It is a SR44 or LR44 type. Open the cover marked with the arrow. Always keep a spare battery. Measurement is not possible without caliper.

The caliper is connected to the control box.



Caliper connection

The control box and the motors need an external power supply. It provides 12V at 3A.

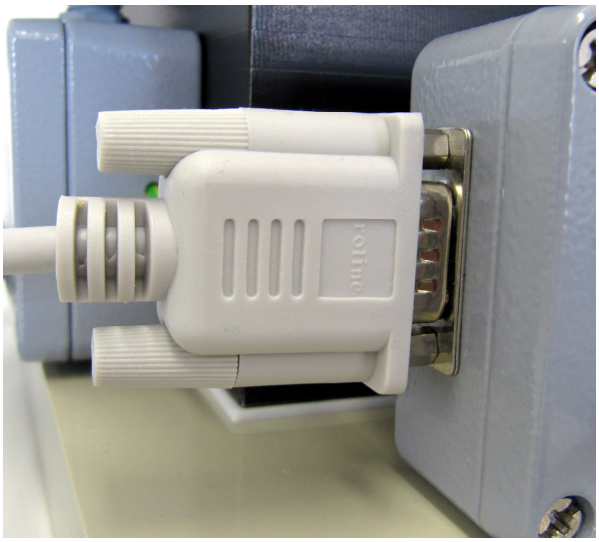
Yoke power supply

The power supply is connected to control box below the power switch.

Power supply connection

Set the switch at the control box to “On” position (I) when using the big yoke.

The control box is connected to the PC via RS232 interface. This cable is connected to an RS232 connection of the switch Robograph Sw, the PC or the Robograph RE itself. In last case a different cable (male/male cross connected) is needed.



RS232 interface connection

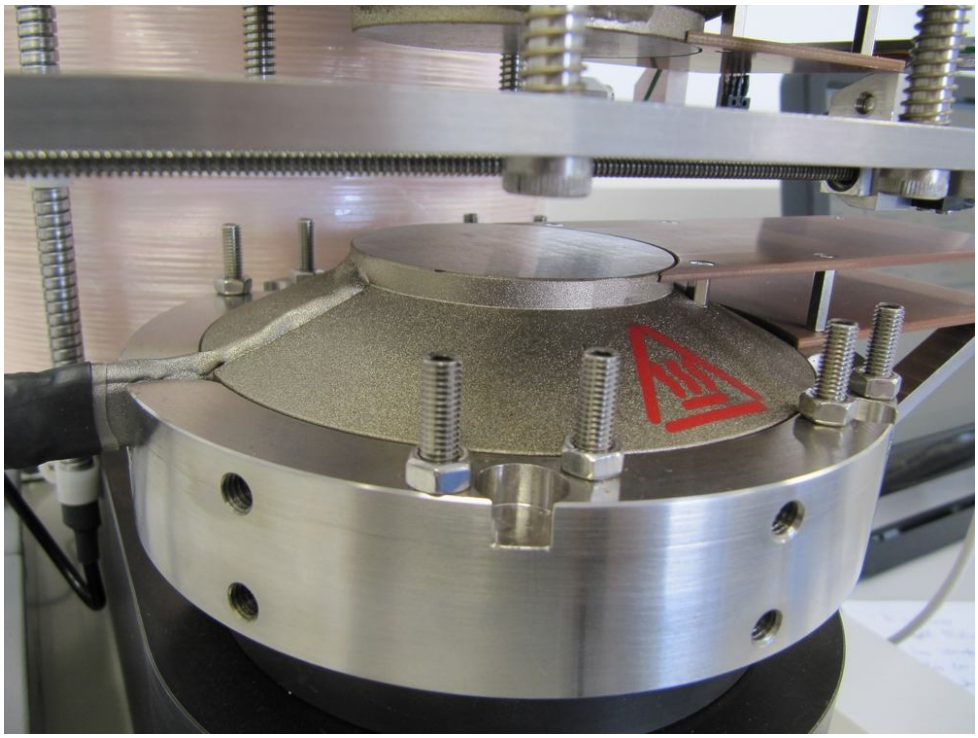
During execution of motor movements the LED changes from green to red light. After finishing the execution it becomes green again.

LED colour change during order execution

At the yoke there are two buttons. Functions are not yet implemented but pressing any button will stop yoke or coil movement immediately. The connector with plug at the side of the box is for connecting an external emergency stop button. For normal operation both inner contacts must be connected. If they are interrupted, the yoke will stop working. The outer contact is protective ground and must not be connected to the inner contacts.

Buttons at the yoke

The pole shoes are made from iron cobalt steel Vacoflux 50 with a saturation polarisation of 2.35T. There is no better material for pole shoes. They can be heated up to 250 °C. Temperature is measured by surface platinum sensors. Usable diameter is 64 mm.



Pole shoe

The pole shoes are fixed by stainless steel rings with 6 mm screws. They should not be demounted from yoke unless necessary.

Do not disassemble the rings from pole shoes since position is important for coil operation.

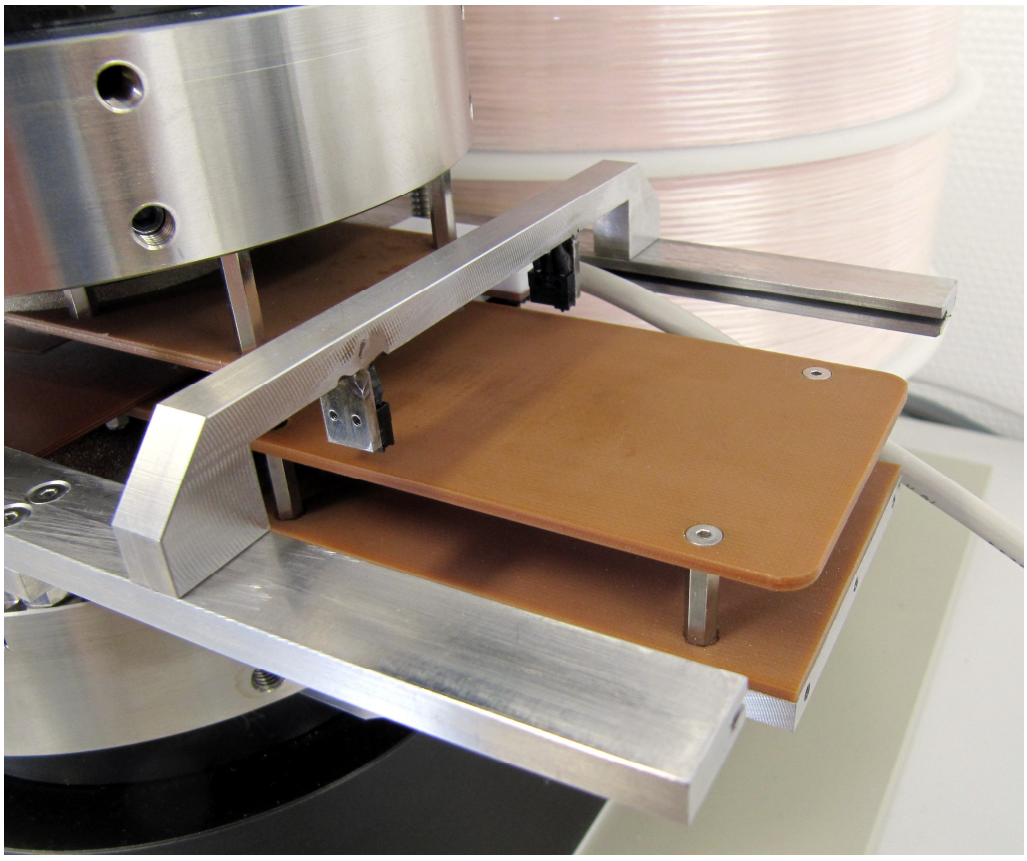
To fix them, the yoke must be closed with coil in park position (left side) to ensure parallelism and no air gap under the pole shoes.

It may be necessary to tighten the screws again at higher temperature since the pole shoes and rings will expand more than the yoke cylinders and the pole shoes may come loose.

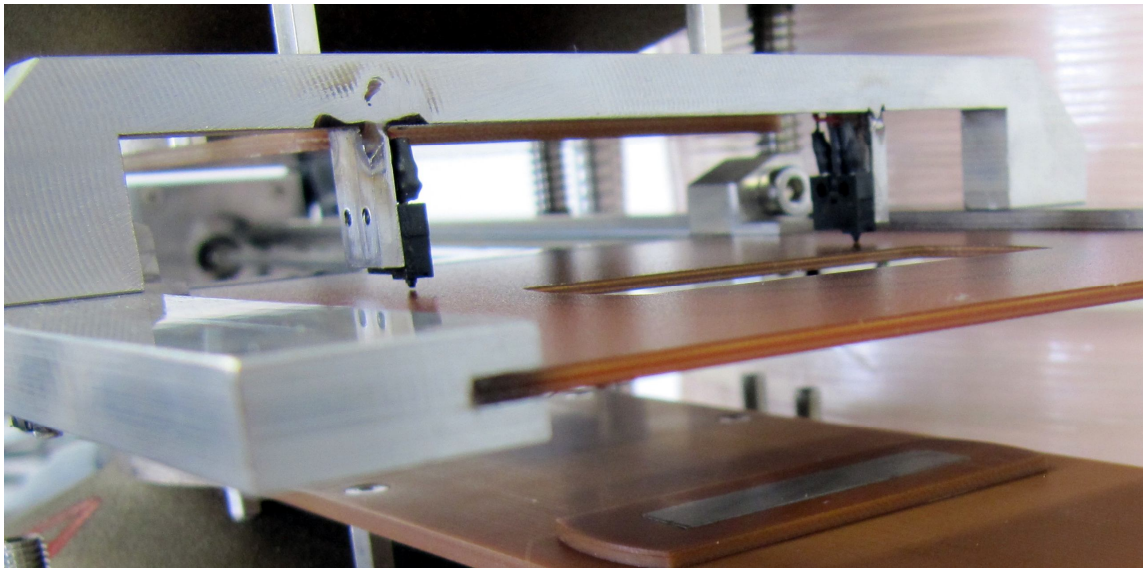
At the lower pole shoe there is a ramp to place and move the magnet. Below this ramp there is a thin steel sheet to keep the magnet in place instead of jumping or sliding to the pole shoes.

At the upper pole shoe there is also a short ramp to prevent the magnet from sticking on the upper pole shoe.

The two switches on top of the ramp are about 0.1 mm above the coil surface. If the magnet with template should be not in correct position when the upper cylinder is lowered for picking up the magnet, the coil will touch the magnet and will be bent. Thus one or both switches are pressed and the upper cylinder will stop movement to prevent any damage.

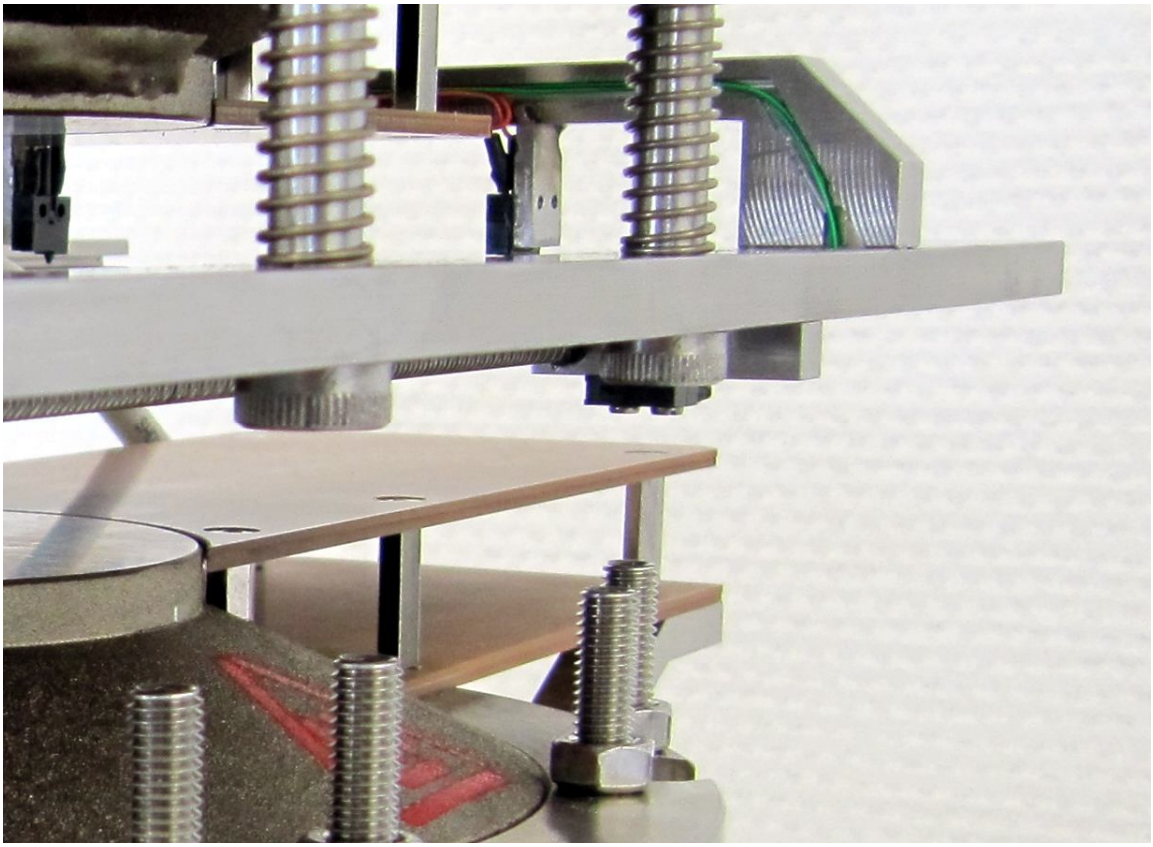


Ramp at pole shoe with two safety switches



Security switches above the coil in pickup position

Finally there are two safety switches at the ends of the spindles. In normal operation these switches will never be touched.



Safety switches at ends of spindles

The coil has 4 fixed positions:

- Park position at left side 0.5 mm from end switches. This is end position for demagnetisation measurements to be as far as possible away from the magnet.
- Measurement position with the magnet in the centre of the pole shoes.
- Drop and pick up position at the right end of the ramp.
- Open position to set the magnet free. Here the coil is driven until it is left of the right strap.

The upper cylinder also has fixed positions:

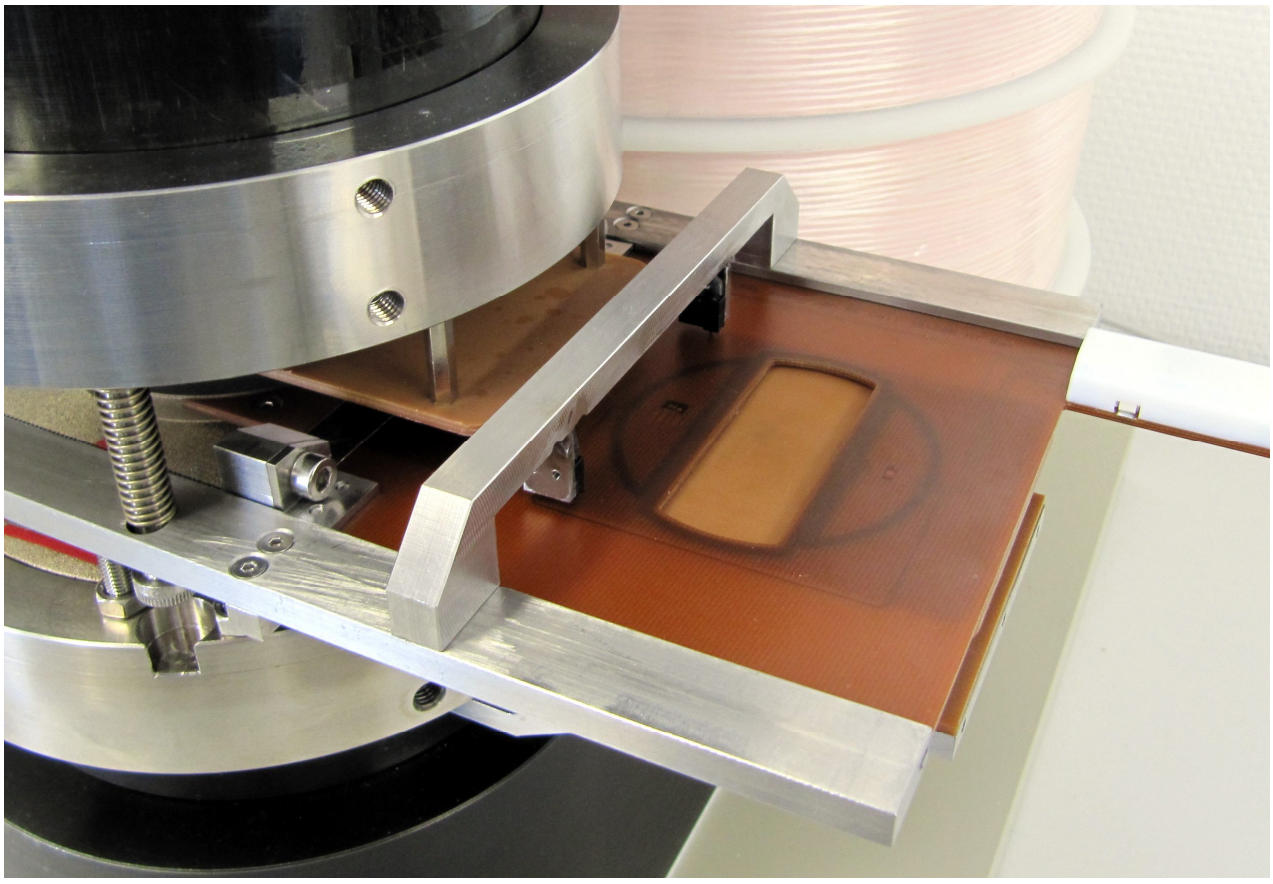
- Top position to drive the coil without magnet transport
- Pick up position to drive the coil with magnet transport
- Contact position with closed yoke depending on magnet thickness
- Drop position 0.1 mm above contact position

For manual hysteresis measurement the yoke and coil movements will be:

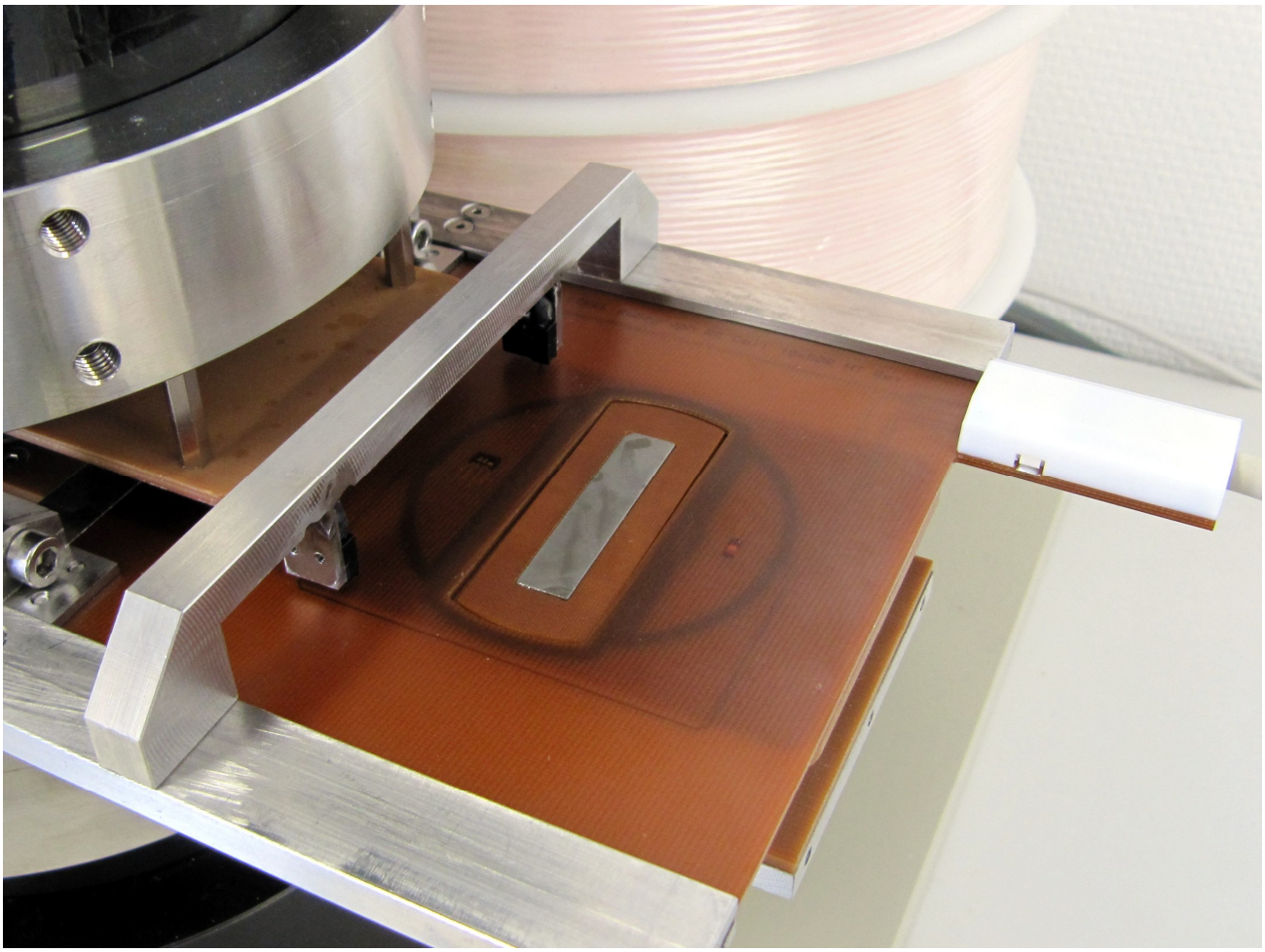
- Start with pick up position of cylinder and coil. The template and magnet can be entered to the coil.
- Coil moves with magnet to measurement position.
- Cylinder lowers to contact position. Waiting for correct temperature if needed and then measure.
- Cylinder lifts for 0.1 mm.
- Coil moves to drop position. It is same as pick up but moves 0.5 mm more far and then back. Thus the magnet with template is positioned in the centre of the coil.
- Cylinder lifts to top position.
- Coil is driven left to open position. The magnet can be extracted.

For measurements with external robot for magnet placing the measurement will start with open position. Robot placement ensures accurate positioning of template and magnet. Then same procedure will begin with start position.

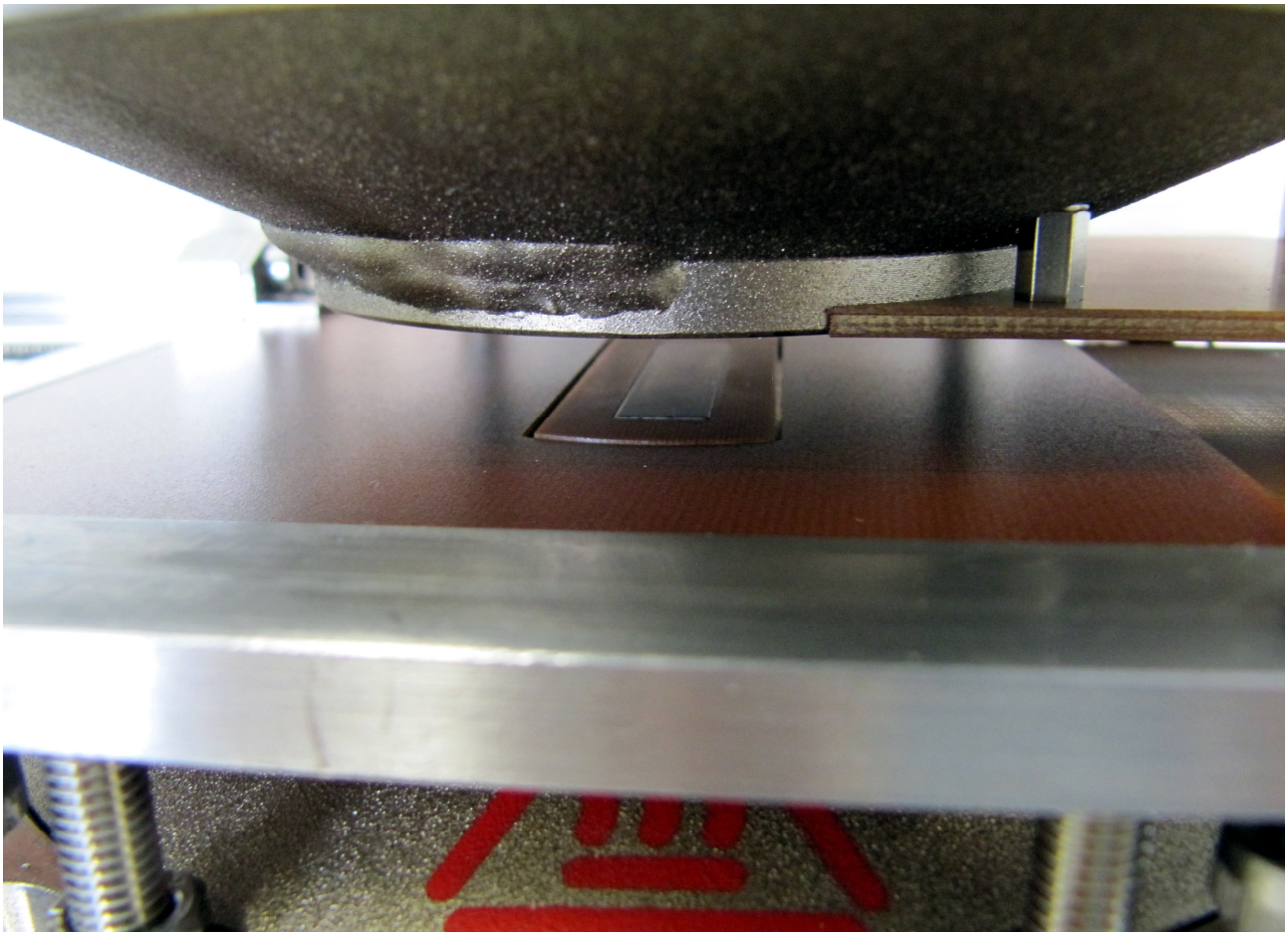
For demagnetisation measurement the final position is not directly open position but first park position to finish integration and then back to open position.



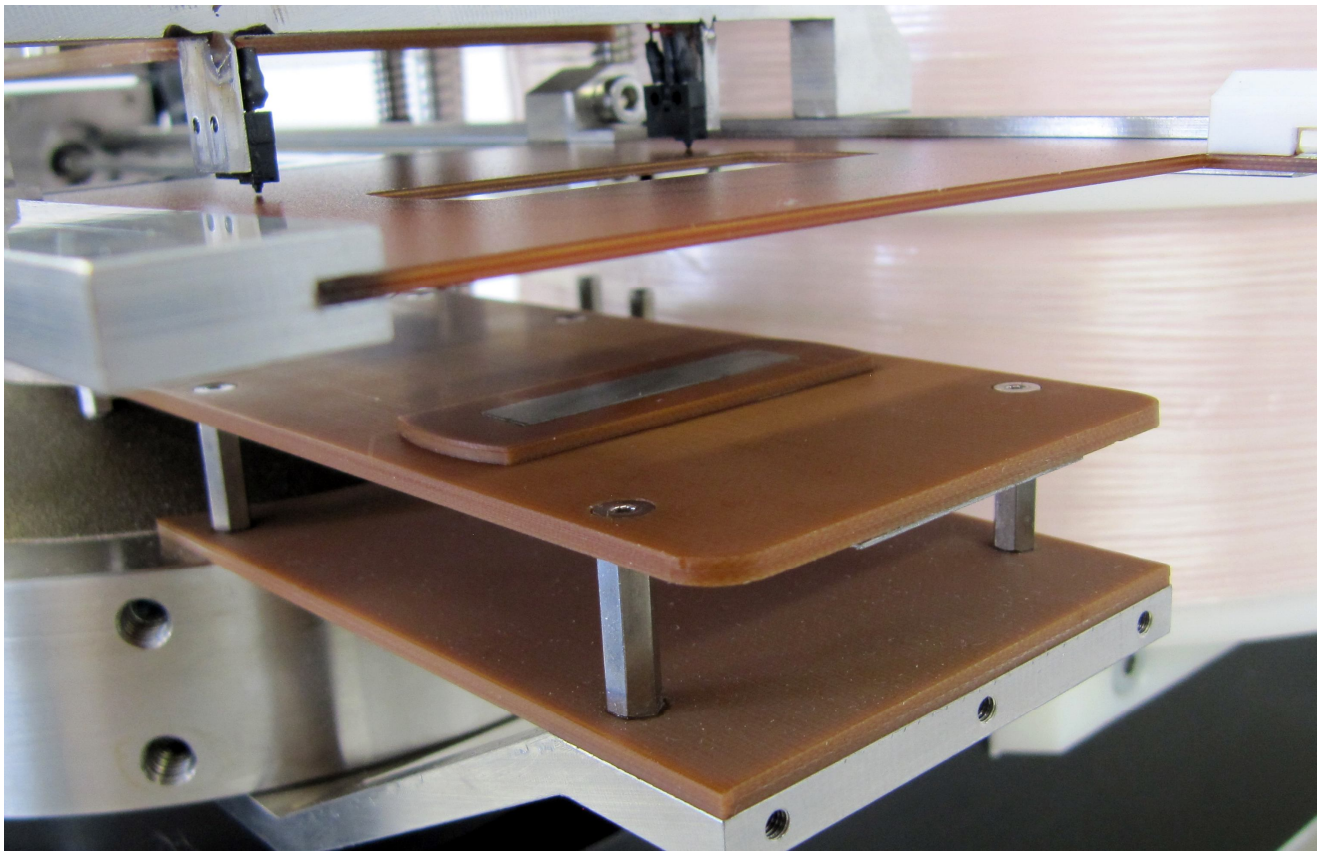
Cylinder and coil in start position



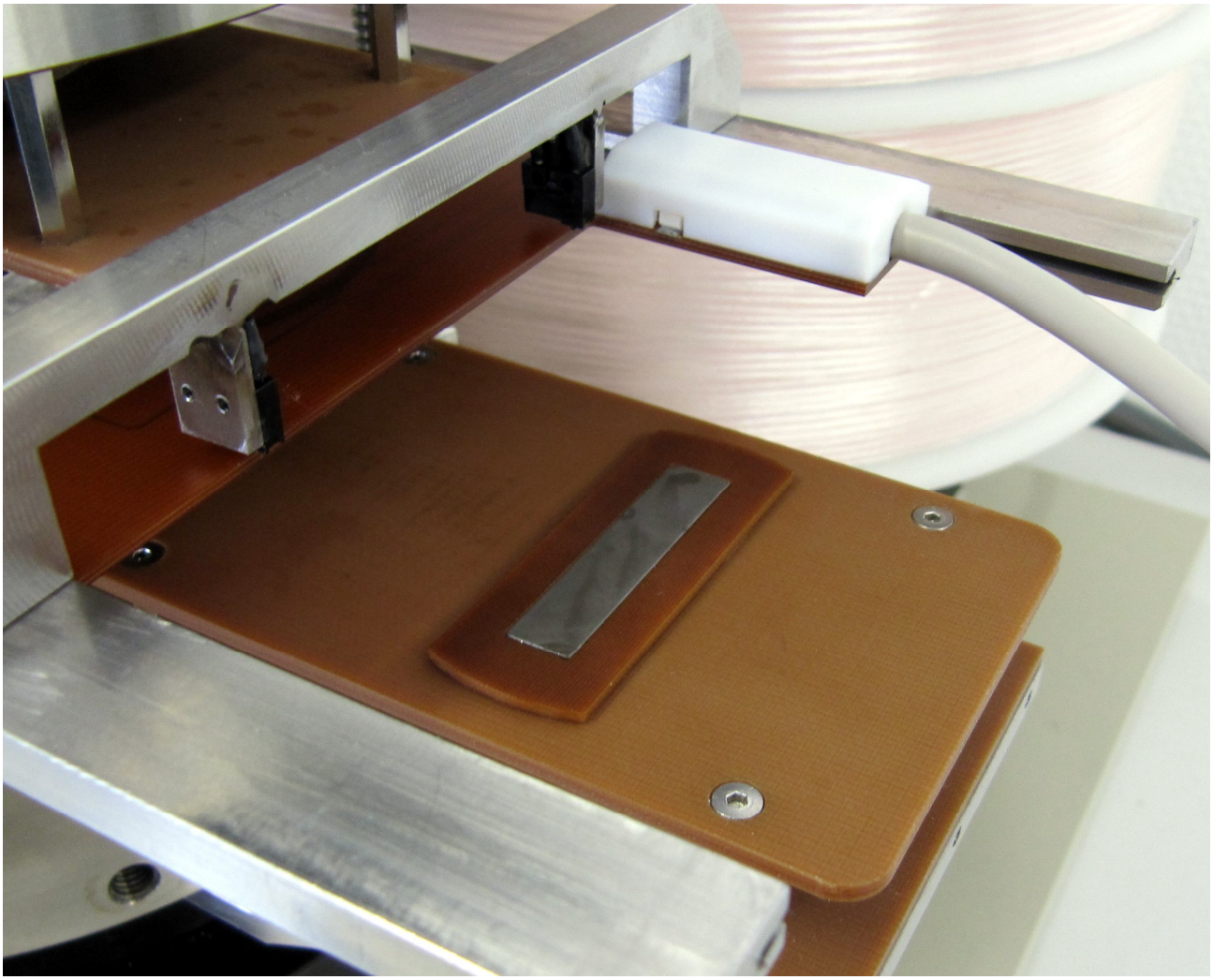
Template and magnet manually placed



Measurement position before closing the yoke



Magnet dropped and cylinder in top position



Final open position for extraction of magnet

Maintenance of the moving parts

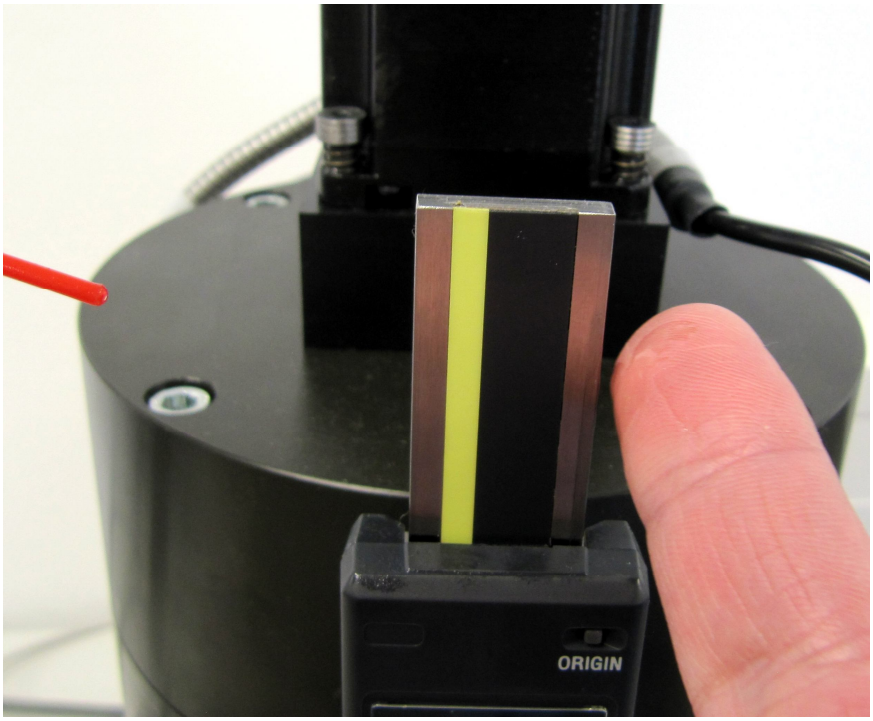
To keep the yoke cylinder moving it will be necessary to enter some high temperature oil to the open slit in the front of the top cover of the yoke sometimes. For this the cylinder must be lowered. Use only 250°C high temperature oil like OKS 3521. Also give the same oil to the spindle.

Oiling of upper cylinder

The oil will fill the small air gap between cylinder and block. Always keep some thin oil film visible when the cylinder is lowered. But do not use too much oil. It will run down on the pole shoe, make it dirty as well as the coil and will let the magnet stick on the upper pole shoe when opening the yoke.

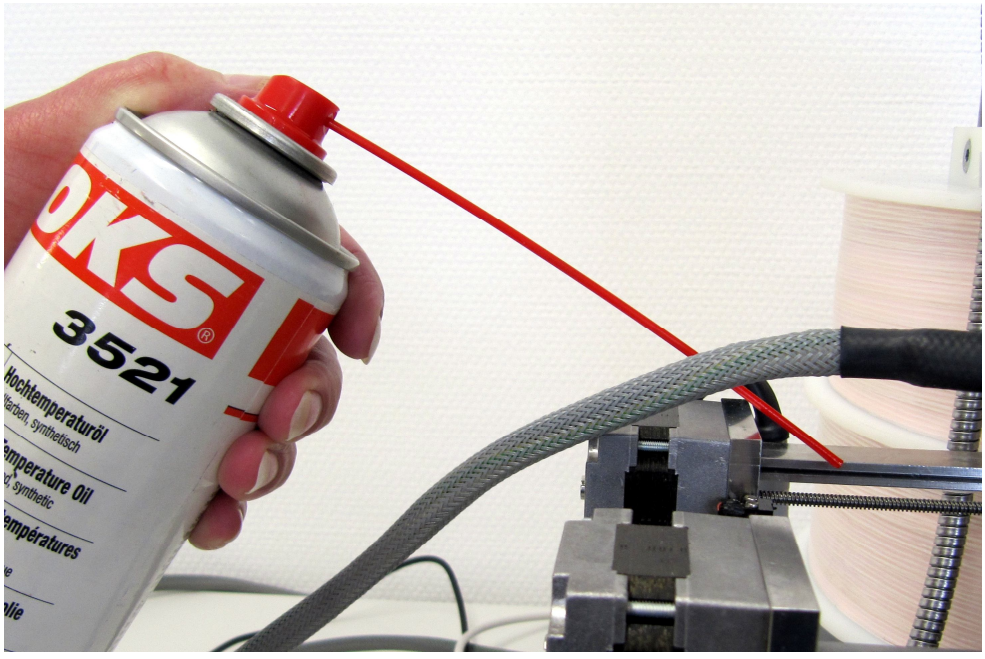
Oiling the cylinder spindle

Also put some oil on the sides of the fixed part of the caliper from time to time. Use a finger with a small drop of oil.



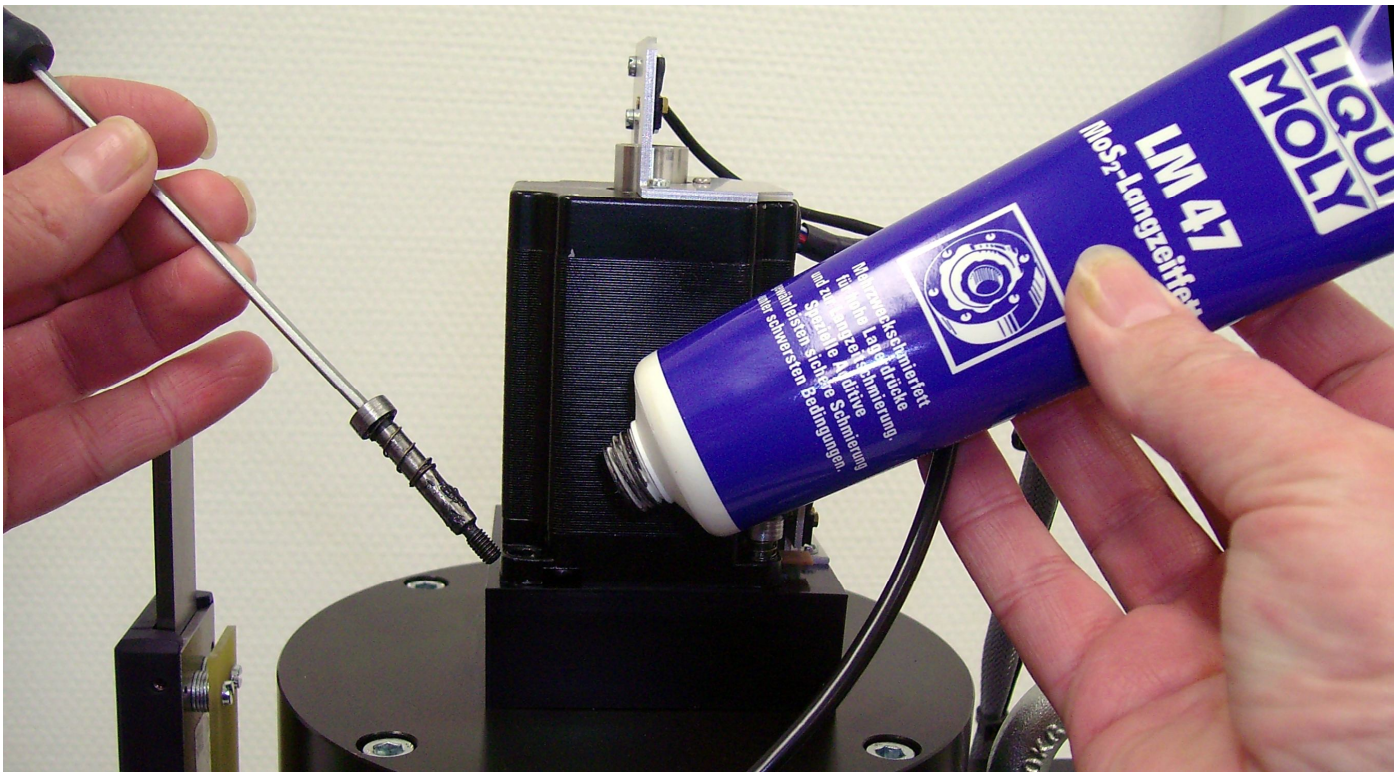
Oiling the caliper

To keep the coils moving on the spindle of the small motor also use the same oil.



Oiling the coil spindles

If the movements of the motor for the cylinder start to become noisy, put MoS_2 grease on the screws of the motor. It is necessary to unscrew them before. If there is no more grease at the screws the step motor will hit the screws at every single step movement.



Greasing the motor screws

Theory and operation of the Robograph RE according to IEC 60404-5

IEC 60404-5 determines methods of measurement of magnetic properties for permanent magnetic materials.

Magnet samples must be flat with 2 parallel surfaces and the cross-sectional area must be constant over height.

The magnet is positioned between 2 parallel poles of soft magnetic material. Thus (with some limitations) the magnetic field between the poles is considered to be constant over measurement area outside and inside the magnet sample.

The poles of the Robograph RE yoke are made from Vocoflux50 cobalt steel to get lowest possible saturation effects.

Due to special capabilities of Robograph RE system, the coil system used for measurement is different from standard coil systems for analogue integrators. Analogue integrators need voltages for H and J directly from the coil system. Therefore they need 5 coils instead of 2. But physical theory of operation remains the same.

The coil system of the Robograph RE also contains a Hall probe. When integration of voltages is started with unknown field, the Hall probe is used to find the moment where the field H is zero.

The magnet sample is surrounded by 2 coils. The inner coil is as near as possible around the hole in the coil board. The outer coil is larger but still remains inside the area that is considered to have a constant magnetic field.

During measurement the electromagnet yoke creates a slowly changing magnetic field, strong enough to magnetize the magnet to saturation, demagnetize it, magnetize to saturation in opposite polarity and then demagnetize again.

By recording the magnetic field H together with the induction B (or polarisation J) of the magnet sample, the B- or J-hysteresis can be determined and all necessary results can be calculated from it.

With

H = Magnetic field inside and outside of the magnet
B_M = Induction inside the magnet
$J_M = B_M - \mu_0 * H$ = Polarisation inside the magnet
$B_A = \mu_0 * H$ = Induction outside of the magnet
A_M = Cross-sectional area of the magnet
A_1 = Area of inner coil
N_1 = Number of windings of inner coil
U_1 = Voltage at output of inner coil
Φ_1 = Total magnetic flux through inner coil
A_2 = Area of outer coil
N_2 = Number of windings of outer coil
U_2 = Voltage at output of outer coil
Φ_2 = Total magnetic flux through outer coil

we get:

$U_1 = N_1 * d\,\Phi_1/dt = N_1 * d(A_1 * \mu_0 * H + A_M * J_M)/dt$
$U_2 = N_2 * d\,\Phi_2/dt = N_2 * d(A_2 * \mu_0 * H + A_M * J_M)/dt$

By digital integration of the signals U_1 and U_2 over the complete hysteresis we get:

$$\sum U_1 = N_1 * (A_1 * \mu_0 * H + A_M * J_M) = N_1 * A_1 * \mu_0 * H + N_1 * A_M * J_M$$
$$\sum U_2 = N_2 * (A_2 * \mu_0 * H + A_M * J_M) = N_2 * A_2 * \mu_0 * H + N_2 * A_M * J_M$$

Norming U_2 to same number of windings as U_1:

$$\sum U_2 * (N_1 / N_2) = N_1 * A_2 * \mu_0 * H + N_1 * A_M * J_M$$

Subtracting the normed integrated voltages:

$$\sum U_2 * (N_1 / N_2) - \sum U_1 =$$
$$(N_1 * A_2 * \mu_0 * H + N_1 * A_M * J_M) - (N_1 * A_1 * \mu_0 * H + N_1 * A_M * J_M) =$$
$$(N_1 * A_2 * \mu_0 * H) - (N_1 * A_1 * \mu_0 * H) = N_1 * (A_2 - A_1) * \mu_0 * H$$

Thus we can calculate the magnetic field H:

$$H = (\sum U_2 * (N_1 / N_2) - \sum U_1) / (N_1 * (A_2 - A_1) * \mu_0)$$

If H is known, J_M can be calculated:

$$J_M = (\sum U_1 - N_1 * A_1 * \mu_0 * H) / (N_1 * A_M) =$$
$$(\sum U_1 - (\sum U_2 * (N_1 / N_2) - \sum U_1) * A_1 / (A_2 - A_1)) / (N_1 * A_M)$$

By drawing a 2 dimensional graph of all H and J_M values over time, we get the complete J-hysteresis of the magnetic sample.

In reality considering the field H to be constant over area even inside and outside of the magnet sample is not correct. For low coercive and materials with low polarisation like ferrites this consideration is accurate enough, even with poles of simple soft iron. For Rare Earth materials homogeneity of the field is much lower even with poles of cobalt steel since significant saturation effects will occur inside the poles. Thus also significant errors of calculated polarisation J and / or field H will be visible.

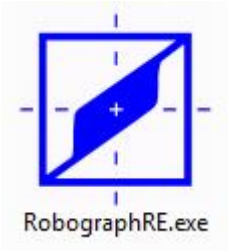
If the maximum field of the electromagnet yoke is not sufficient to magnetize the magnet to saturation in opposite direction, only the demagnetisation curve is measured and measurement is stopped after demagnetisation. Anyway all formulas and calculations are the same as for the complete hysteresis.

B 4. Material measurement software

Minimum requirement for software installation is a PC with Windows XP, Vista, 7 or 8 operating system.

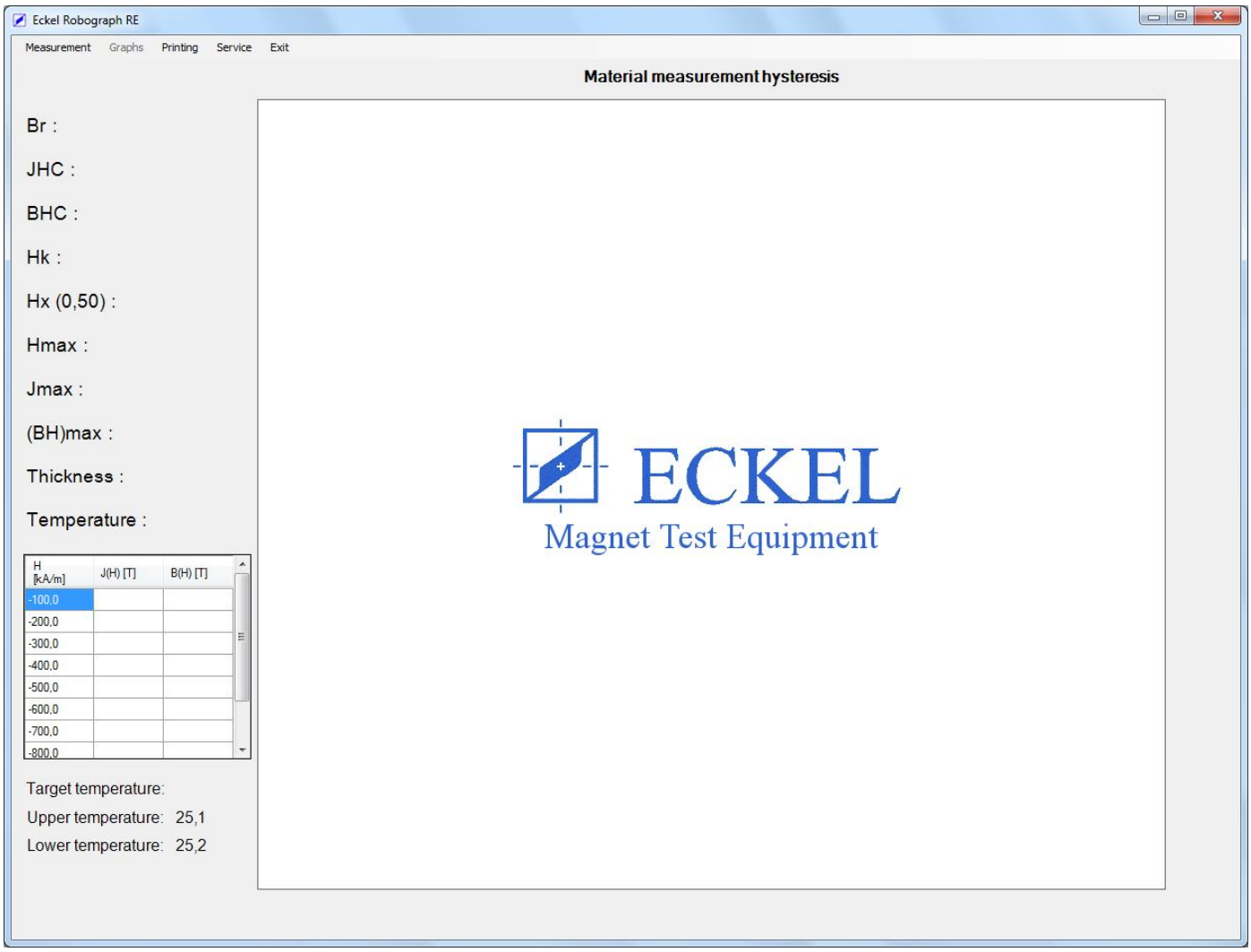
The Robograph RE software is installed by starting the program **setup.exe** on the installation CD.
Before power on of the Robograph RE unit execute the file Program Files/Eckel GbR/Robograph RE/USB Driver/**CDM20600.exe**. This will install the USB driver.

The Robograph RE program is started by double-clicking on the Robograph RE icon on the desktop.



Robograph RE icon

The main window shows the empty graph field, the result area at the left and the task bar on the top.

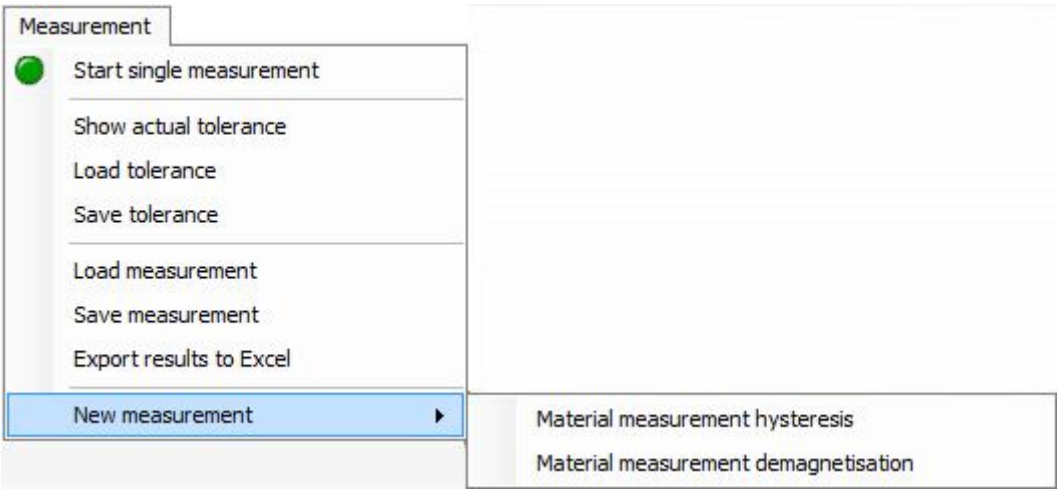


Main window

B 4.1. Material measurement

If the Robograph RE is connected to a big yoke, the menu will be set to material measurement.

By moving the mouse to “Measurement” at the task bar the drop-down menu is opened.



Drop-down menu for material measurement

A material measurement can be executed as **hysteresis** or **demagnetisation** measurement. With a hysteresis measurement it is not important if the magnet is magnetized or not and polarity doesn’t care. The magnet will be magnetized to full saturation first and then the hysteresis is measured. The measurement starts with coil inside the yoke and the yoke closed.
A correct hysteresis can only be measured if the magnet can really be magnetized to full saturation at actual maximum current / field, thickness and temperature. If the magnet is not fully magnetized the result will be too small or hysteresis is even not symmetric. A good hysteresis is always symmetric and saturation is indicated by parallel magnetisation and demagnetisation at highest fields.
With higher temperature it becomes more and more easy to saturate the magnet.

If saturation cannot be reached, only a demagnetisation measurement is useful. Here the magnet must be magnetized before measurement with an external pulse magnetizer. Measurement will start with coil outside and yoke open. Polarity is not important since it will be recognized during first passive part of measurement and demagnetisation will be started always in correct direction.

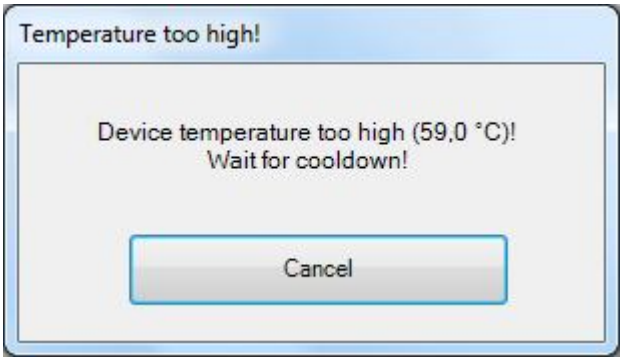
For both measurements it is possible to define inner loops. Results for inner loops can be drawn from the graph but will not be shown as numerical value in result area.

Start single measurement will start immediately the measurement with the actual tolerance.

Before starting a measurement, be sure to have a valid actual tolerance!

Pressing on the green button beside the yoke has the same effect.

The Robograph RE will only start a measurement if transistor temperature is below 50 °C. If temperature is too high, this window will appear:

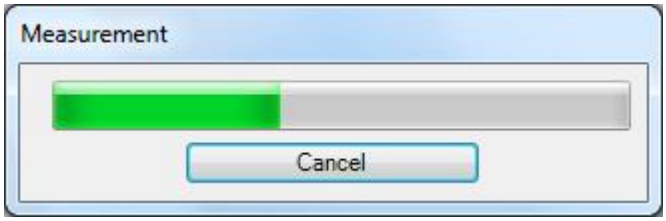


Temperature warning

The actual temperature is always shown and when it falls below 50 °C measurement will start. If **Cancel** is pressed, the measurement is stopped.

This error message may appear if several high current measurements are performed in a short time. After some seconds the transistor temperature will be below 50°C.
If this error message is shown permanently, check whether the fan is blowing and the air slots on the top of the Robograph as well as the blow out opening at the backside are not covered. At temperatures higher than 50 °C the fan must blow at highest speed and make a considerable noise.

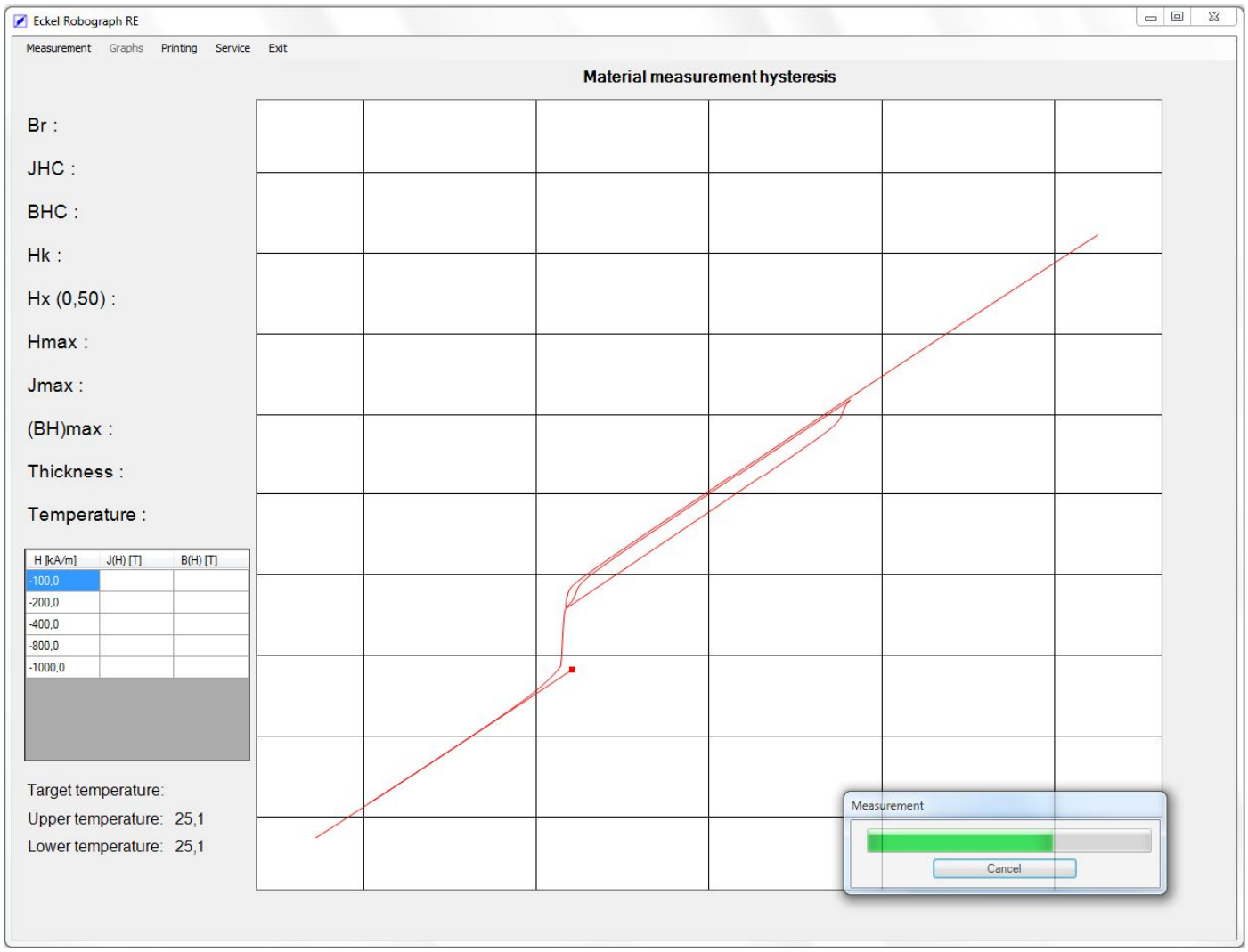
At first measurement the power amplifier will be activated, the fan will be set to standard speed and a progress bar will show the progress of the measurement.



Progress bar

Cancel will stop the measurement immediately.

During measurement the main window will show a real time graph of the hysteresis. This graph is calibrated and centered after measurement is finished.



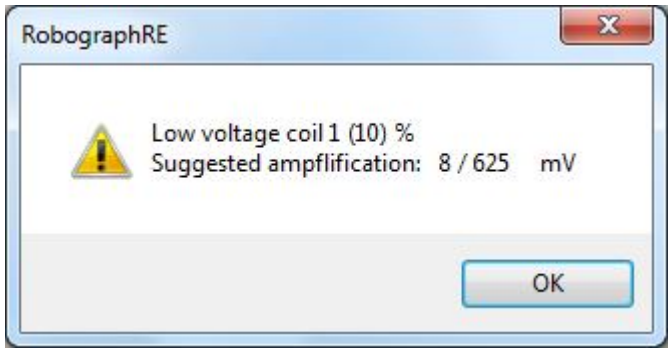
Real time hysteresis

If input amplification has not been set correctly there are two possible error messages:

Input overload warning

If one of the inputs has got overvoltage during measurement, the signal has not been recorded correctly. The result would be wrong and the evaluation is aborted.

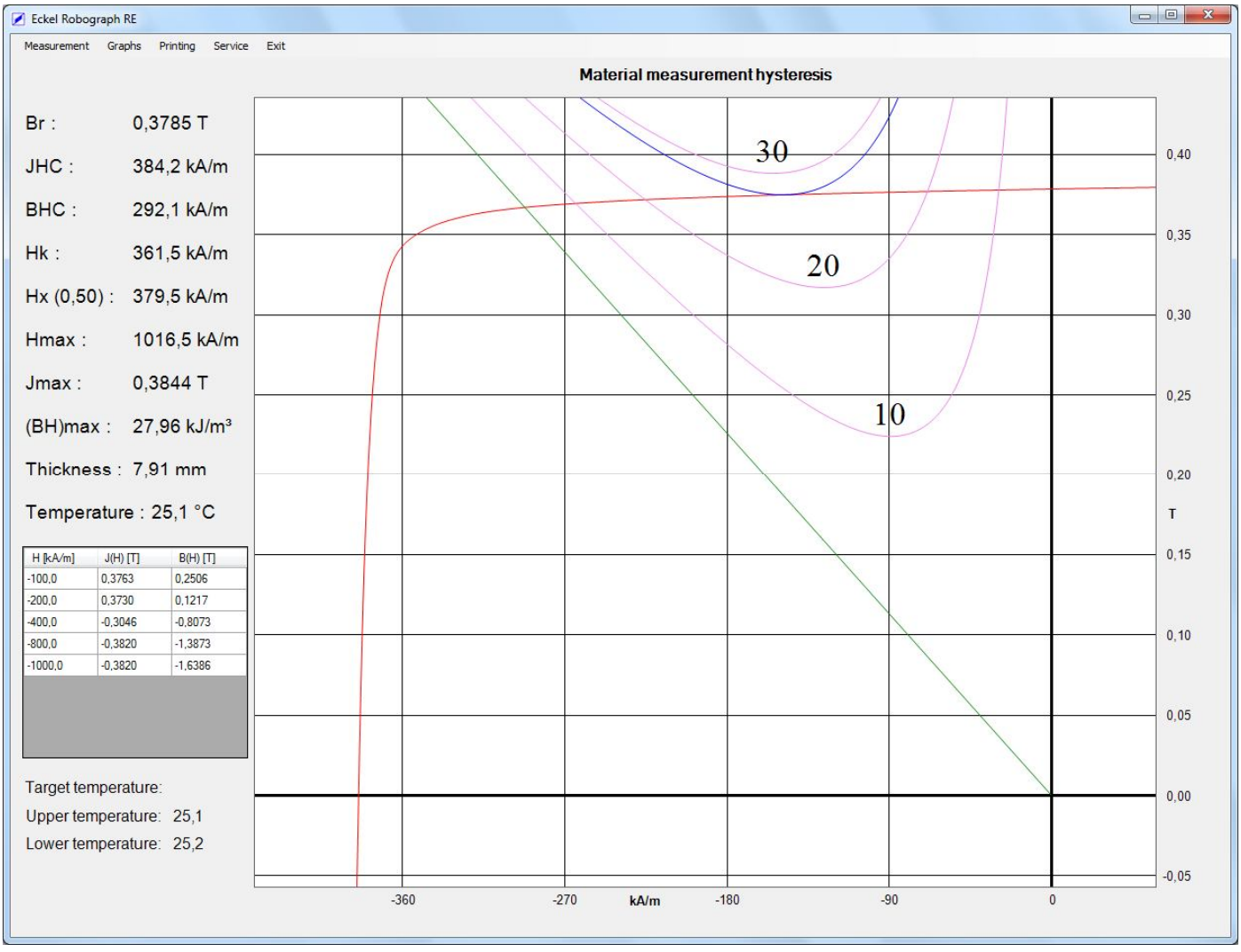
Reduce input amplification of the mentioned input in the actual tolerance and try again. If amplification was correct this time, save this tolerance again if this measurement was made with a standard magnet for this tolerance.



Low input voltage warning

If this message is shown, the input amplification is too low. The result is evaluated anyway but the accuracy is reduced. Change the amplification of the mentioned input to the suggested value and save the tolerance.

Depending on tolerance settings the measurement is finished after 1 to 128 seconds, results and graph are shown and 1 minute later the fan is set back to power save mode.



Result window

Default graph is Demagnetisation J. But the graph type can be changed at **Graphs**.

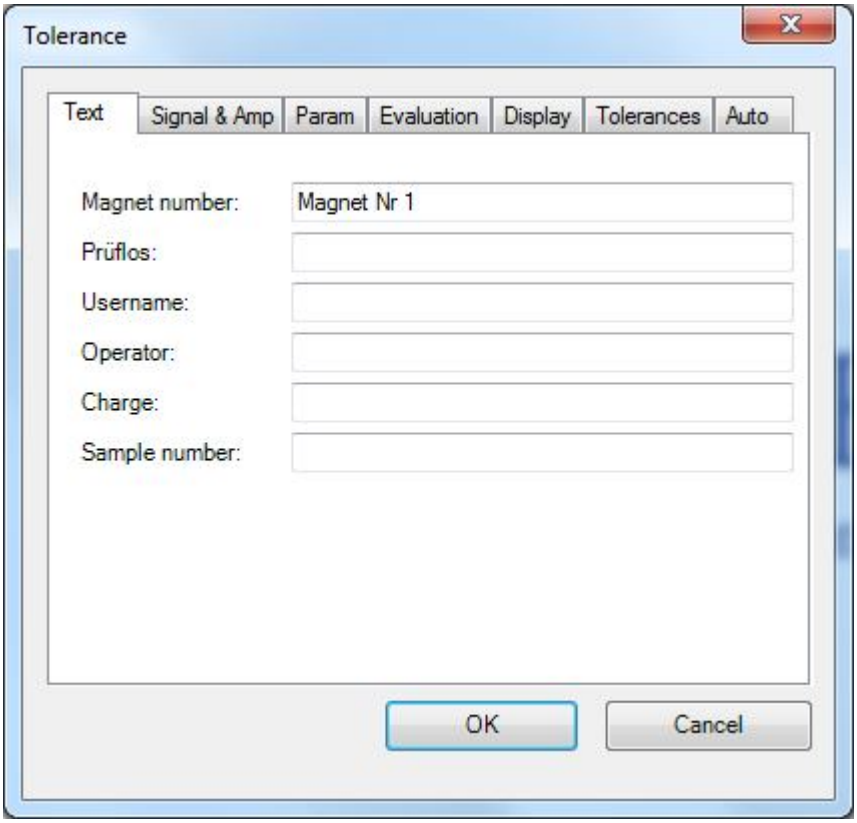
The results are shown on the left side. Depending on tolerance settings the results may be temperature compensated to any temperature. The temperature coefficients can be set at the tolerance window.

Measurement will be saved by default if activated in **Program options**.

Show actual tolerance opens the **Tolerance** window.

The first card shows **Text** that can be entered for Magnet number. This is only text shown on the screen and on the printout.

If the tolerance is saved, the magnet number is used as standard file name with extension .RTO.
A hysteresis tolerance will have an “H” in front of the magnet number; a demagnetisation tolerance will get a “D”.



Tolerance: Text

The **Signal & Amplifications** card shows the input amplifications and signal parameters. Amplifications can be set for coil 1, coil 2 and Hall probe. Coil 1 is the inner coil and coil 2 is the outer coil.

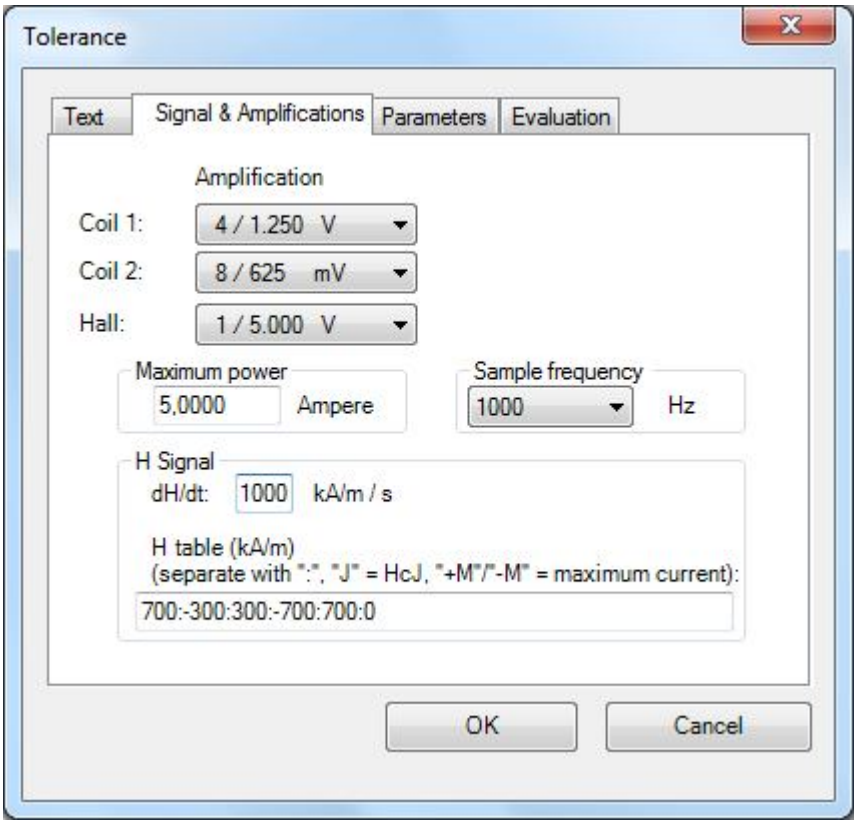
For a hysteresis tolerance the following card is shown:

Input **amplification** and maximum input voltage is shown. For the Hall probe most time amplification 1 or 2 will be correct. Amplifications for coils depend on magnet size and material as well as measuring speed dH/dt. If amplification is not optimal, a warning will be shown after measurement asking the user to change amplification.

Maximum current shows the maximum current in the in the coils of the yoke during material measurement. A value of 0 to 7.5 Ampere can be set.

The real maximum current during measurement depends on maximum field (H) set in the tolerance and magnet thickness. If maximum H cannot be reached with maximum current, a message box will inform about this problem but measurement will be executed and evaluated with maximum reachable field.

Sample frequency can be set to 2000, 1000, 500, 250 and 125 Hz. Depending on dH/dt, magnet thickness and H table values the measurement will need a specified time to finish. Multiplication with the sample frequency will give the number of samples for complete measurement. A perfect number is about 10.000 samples for a complete hysteresis. A lower number of samples will reduce accuracy. More samples will increase file size only.
Automatic sample frequency setting will follow soon.



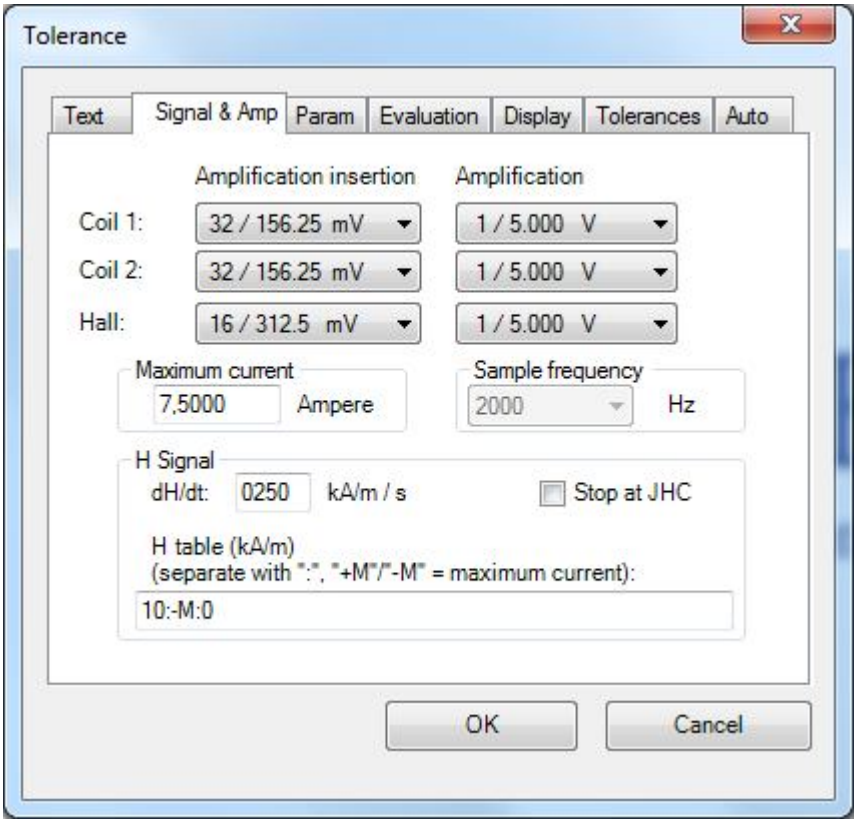
Tolerance: Signal & Amplifications hysteresis measurement

dH/dt determines the measurement speed. dH/dt is the change of field per second at B_r (H=0). Control of this value ensures the same measurement at different magnet thicknesses. If magnets of different thickness are measured with the same current, the dH/dt will be different due to air gap difference and thus the thinner magnet will see more eddy current. This will lead to different results. With fixed dH/dt the current is set depending on magnet thickness. The dH/dt value is only valid as long as the iron of the yoke or insert is not saturated. In saturation dH/dt will be significant lower but without effect on the result.

Do not set dH/dt too low. This will result in very long measurement heating up the power amplifiers and giving very low signals from the coils. The Robograph RE will estimate measurement time from dH/dt, magnet thickness and H table values. If total measurement will be longer than 128 seconds, an error message is generated.

H table defines the endpoints of the hysteresis. Depending on values entered a normal hysteresis or a hysteresis with inner loops will be generated. The first value entered will automatically generate a symmetric hysteresis with the given maximum field. If the second value is changed, inner loops can be generated. Direction will change at every value entered.
With “+M” and “-M” the direction will change at specified maximum current.
Take care to define a complete hysteresis with symmetric maximum fields if inner loops are selected. This will be supported by software at next update.
At the end of the measurement the field and current will always reach zero.

For **demagnetisation** tolerances there are some differences:



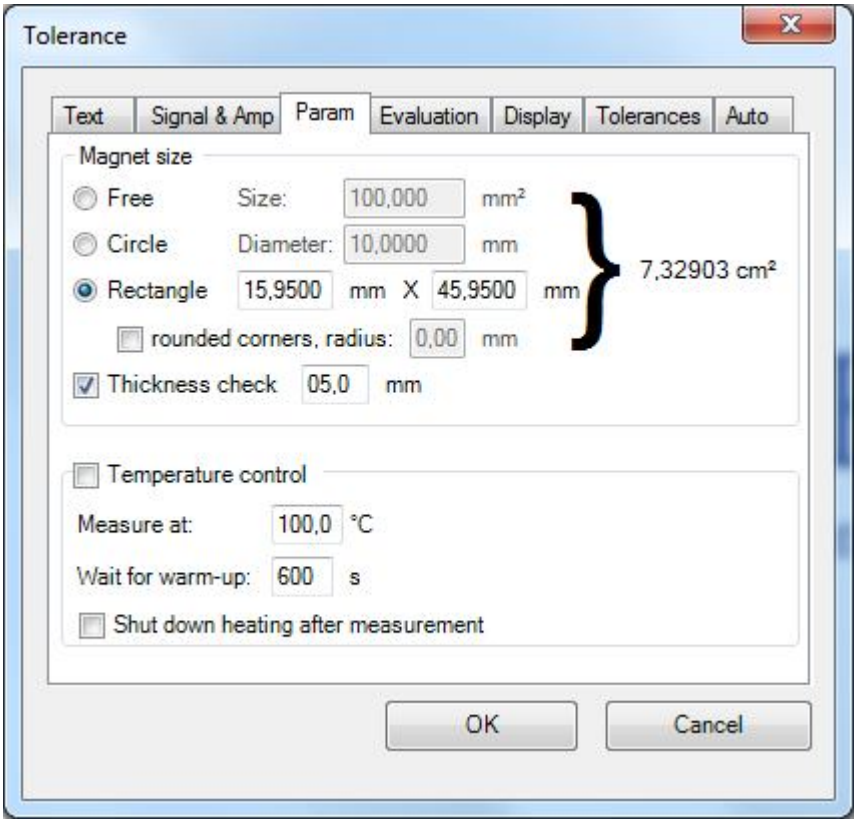
Tolerance: Signal & Amplifications demagnetisation measurement

The demagnetisation measurement is divided in two parts.
First part is measurement of the signals during movement of coil from outer to inner position and closing the yoke. This is a passive integrating flux measurement. In the end the remanence induction of the magnet can be calculated.
Second part is the active demagnetisation of the sample.
For both parts input amplifications have to be selected separately.
Amplification Insertion is for the first passive part and **amplification** for the second active part.

Stop at $_JH_C$ will finish measurement as soon as $_JH_C$ has been reached.

H table now only exists of 3 values if no inner loops are wanted. First is a small value in magnetisation direction. Without this value there is no guarantee that there will be a B_r since field inside the closed yoke is not zero but most time slightly negative. Second value is the maximum demagnetisation field and the last one is zero always. If desired also here inner loops can be defined by adding points of direction change.

The third card shows the **Parameters** of magnet and temperature.



Tolerance: Parameters

Magnet size determines the area of the magnet. This can be entered directly or by diameter of circles or sides of a rectangle. Take care with these values. Accuracy of the measurement result is directly depending on accuracy of the magnet size since the measured flux is divided by the magnet area to get induction B.

Temperature control specifies if measurement is performed with heating.
The heating will heat the pole shoes up to desired temperature and then wait for warm up of the magnet for the selected time period. Then measurement will be started automatically.
If desired, the heating can be shut down after measurement. Please remember that high temperatures stress the yoke and it should not be heated more than necessary.
If the temperature is set to more than 150°C, the temperature will be reduced to 150°C after measurement and 2 more minutes of inactivity to prevent possible damage.

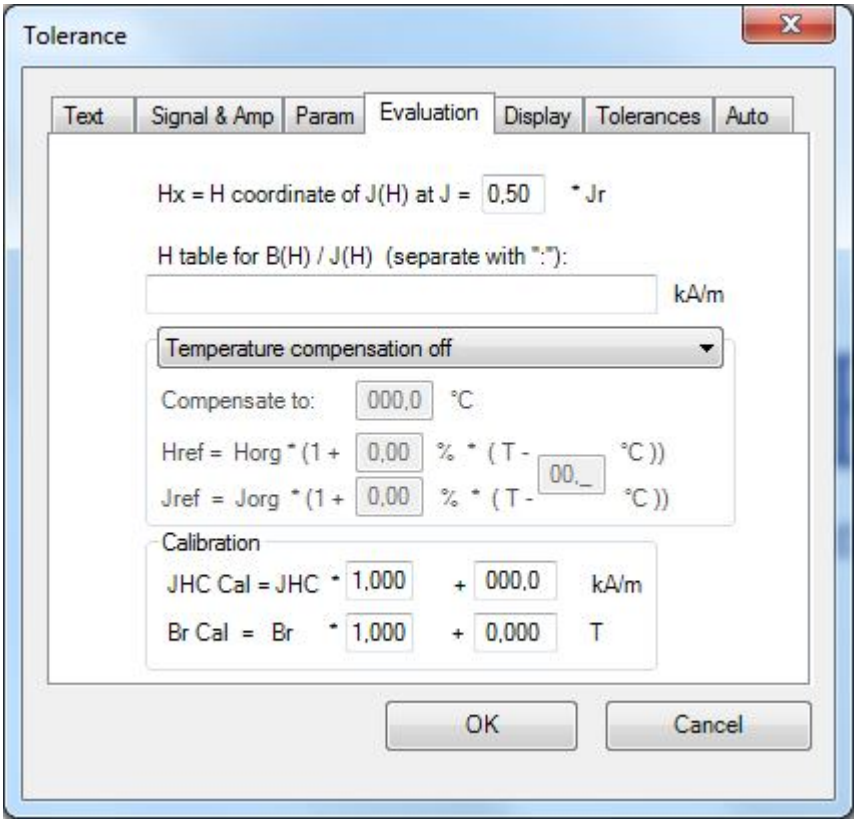
The fourth card shows the **Evaluation** tolerances and parameters.

For **Hx** the corresponding polarisation is selected relative to the remanence polarisation J_r that is identical to B_r. Hx is evaluated at the point of hysteresis where J has been reduced to the set value.

The numbers entered to the **H table** define the selected points of the hysteresis where the corresponding values of J and B will be shown.

For **temperature compensation** 3 setups can be selected:
Temperature compensation on, off or on if heating disabled.

If temperature compensation is in "on" state, temperature will be compensated to the selected temperature.

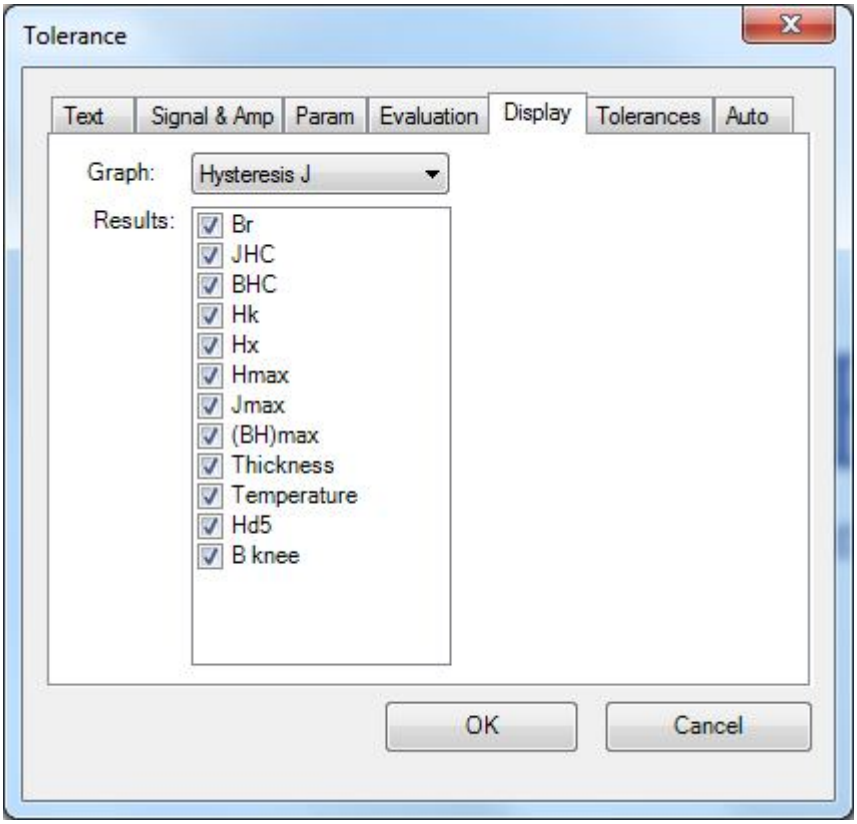


Tolerance: Evaluation

To get a correct compensation it is necessary to know the temperature coefficients of the material and to know at which temperature these coefficients have been determined. This is the reference temperature for compensation. The temperature to which the results are compensated does not need to be the reference temperature. Results will be compensated to reference temperature first and then compensated again to selected compensation temperature.
Please remember that temperature coefficients are not linear over large ranges.

"**Compensate to**" determines the temperature to which the values are compensated.
The **percentages** are the temperature coefficients for H and J for this material.
The **last field** determines the reference temperature where the coefficients have been evaluated.

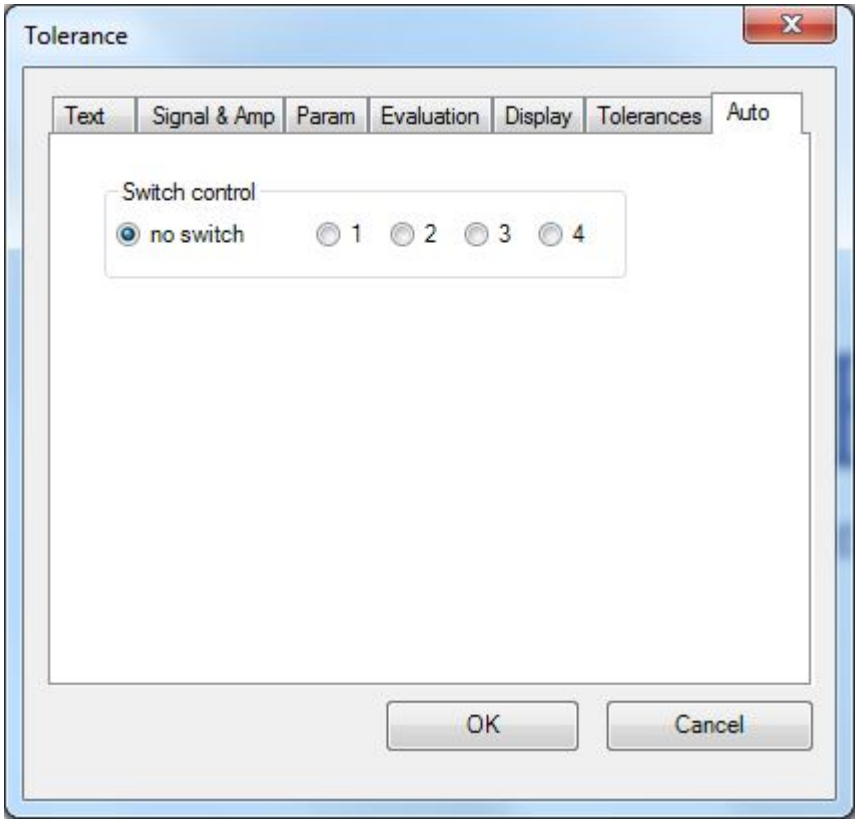
At **Display** the user can select, which result shall be shown on the screen.



Tolerance: Display

At **Tolerances** limits for all results can be entered

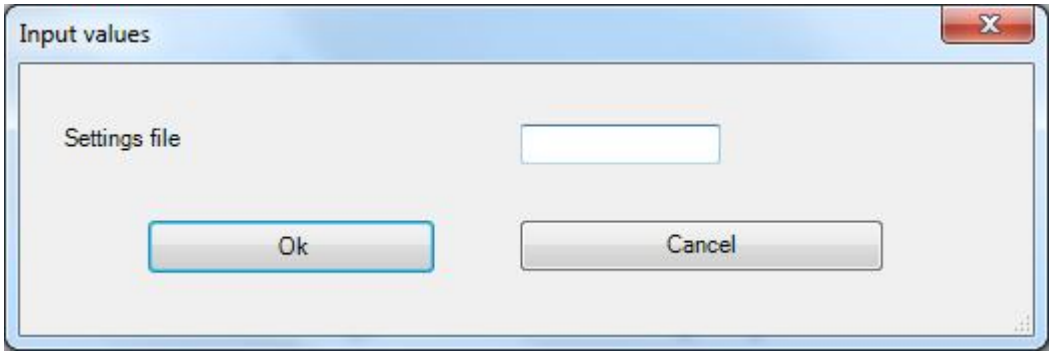
At **Auto** the user defines if it is necessary to switch the Robograph Sw to a certain position when tolerance settings are loaded.



Tolerance: Auto

Load tolerance will open a standard file selector box, where the desired tolerance file (.rto) can be loaded. Default path is the last path, where a tolerance has been loaded before.

In restricted mode it is not possible to load a tolerance by file selector box. All tolerance files for restricted mode are located in a path as entered to program options. To select the desired tolerance settings, the name of the file must be entered to a text input box. Though normally the name will be entered by scanning a 2D-matrix code, it is also possible to enter the name by keyboard.



Input of name of tolerance settings file

Save tolerance is depending on if a Robograph RE fixture is inserted or not. For Robograph 2 fixtures the tolerance is only saved as a file on the PC.

Load measurement will load a formerly saved measurement to review and print it. A standard file selector box will open.

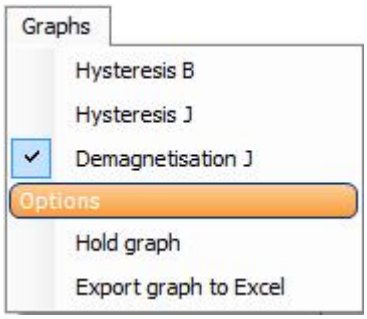
Save measurement will save the complete measurement for later use. A standard file selector box will open.

Export results to Excel creates an excel file and opens a file selector box where name and folder for the file can be selected. Only measurement results are stored.

New measurement will create a new tolerance either for **material measurement hysteresis** or **material measurement demagnetisation**. This tolerance can be modified as desired and then saved under selected name.

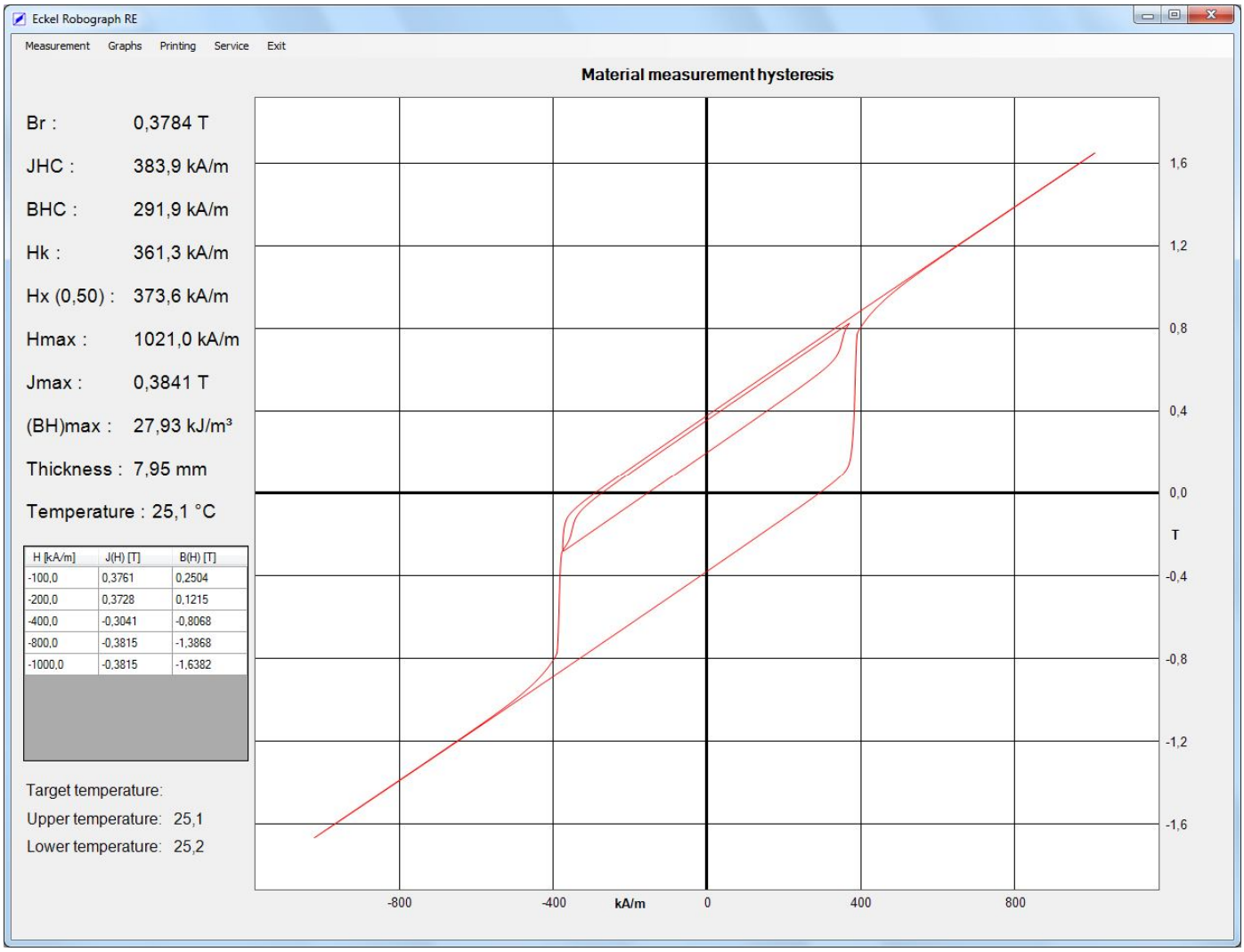
B 4.2. Material graphs

By moving the mouse to “Graphs” at the task bar the drop-down menu is opened.



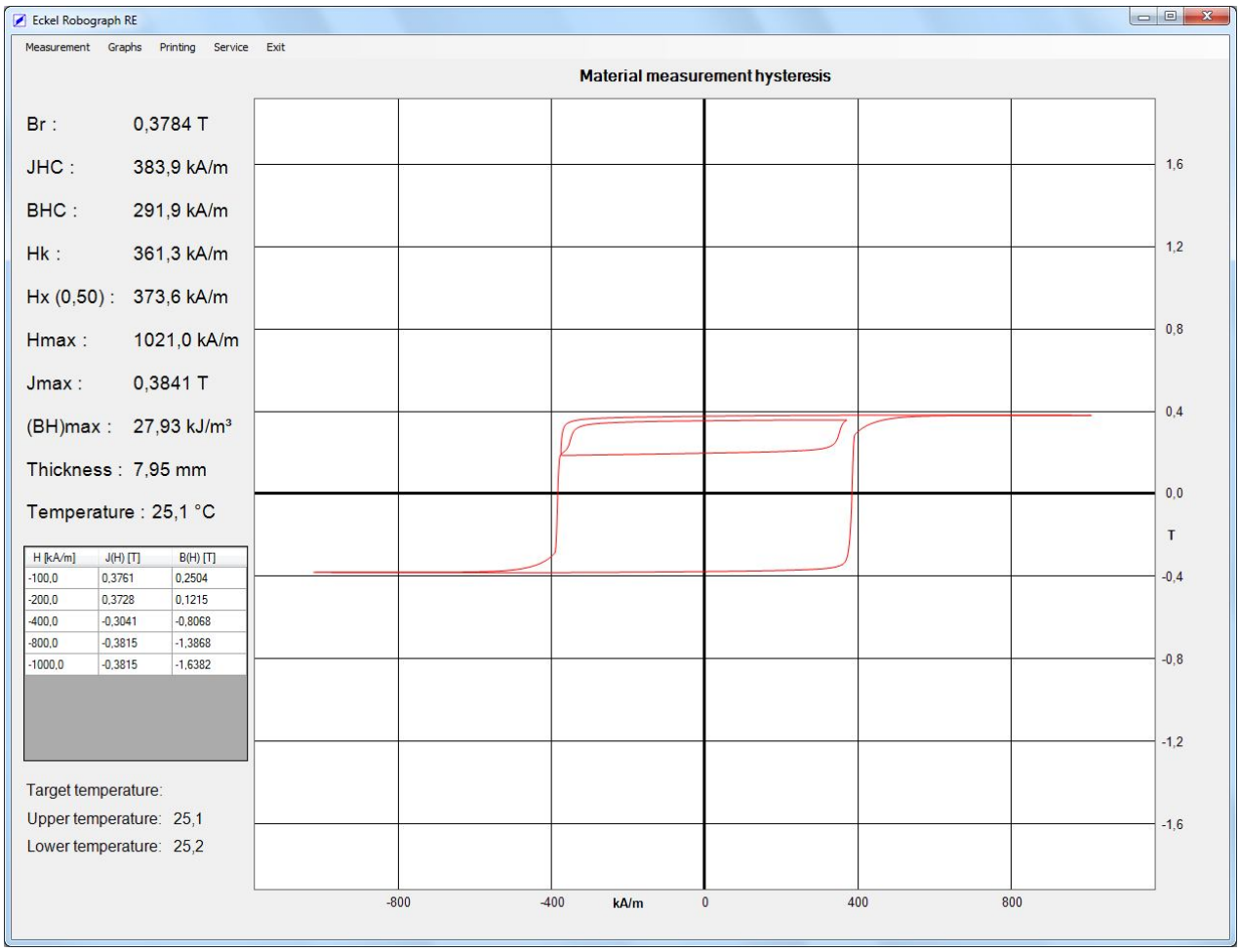
Drop-down menu for graphs

Here different graphs for result can be selected. Other graphs can be shown by clicking on them.

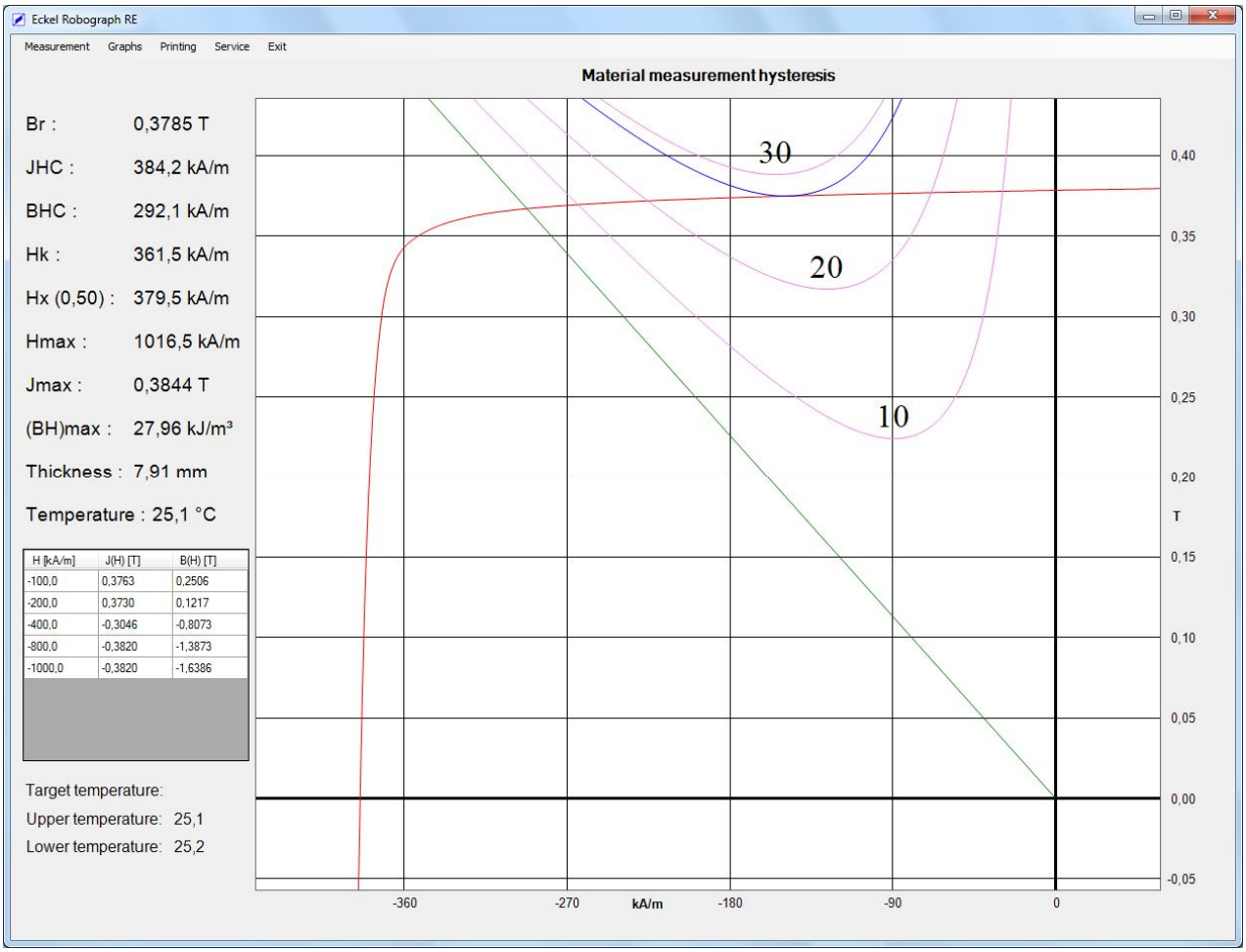


Graph hysteresis B with inner loop

Parts of the graphs can be magnified by drawing a window around desired area with the mouse. At high magnifications the single samples will be shown as dots.
Clicking the right mouse button reduces the view one step back.

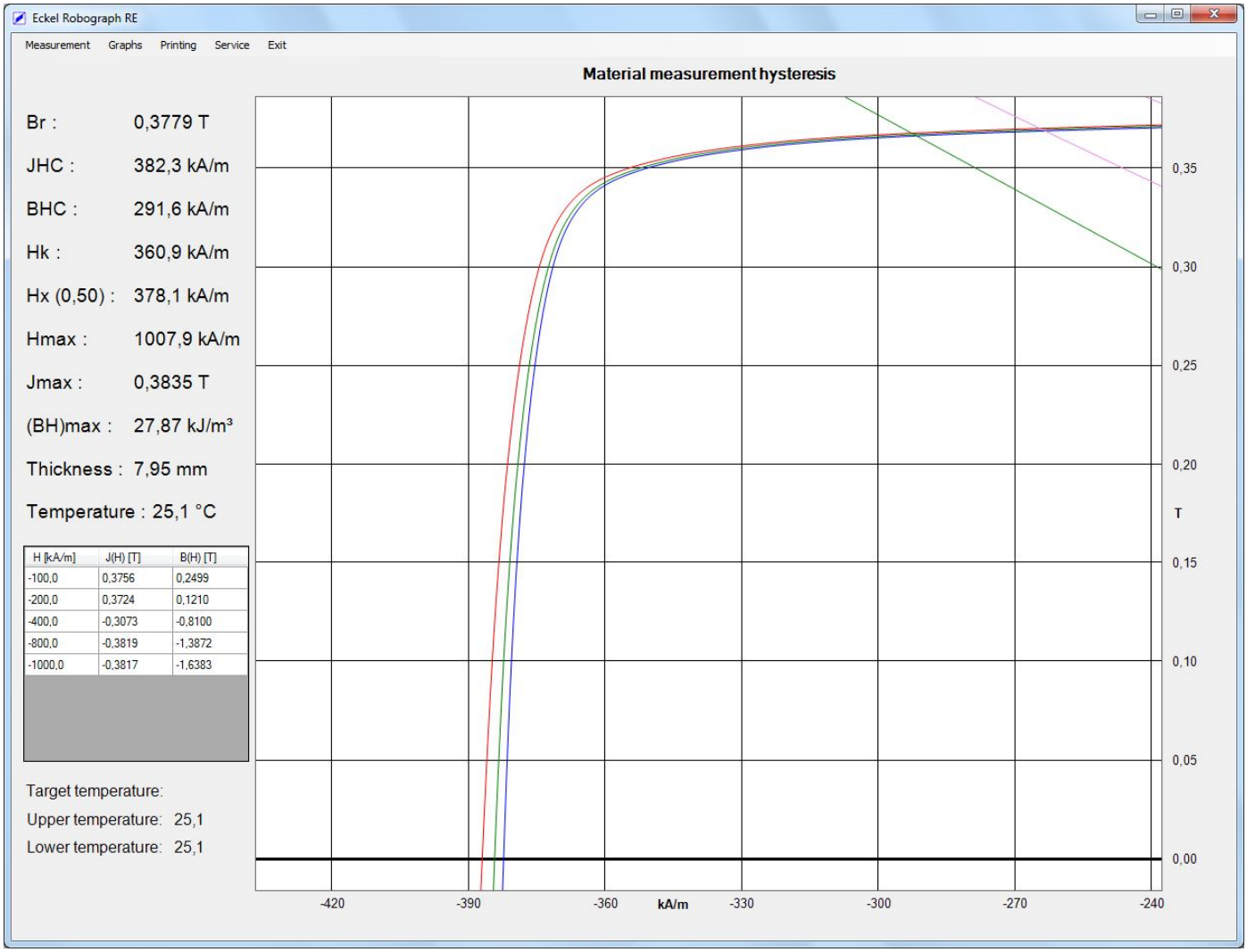


Graph hysteresis J with inner loop



Graph demagnetisation J

Hold graph is an option. If Hold graph is selected, the actual graph will stay in the window and after performing another measurement, both graphs will be overlaid in different colours and can be easily compared. This function is repeatable.

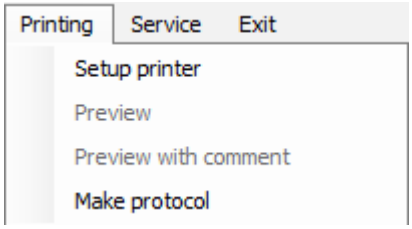


Three graphs in one window

Export graph to Excel creates an Excel file and opens a file selector box where name and folder for the file can be selected. Here all sample pairs of the visible graph are stored.

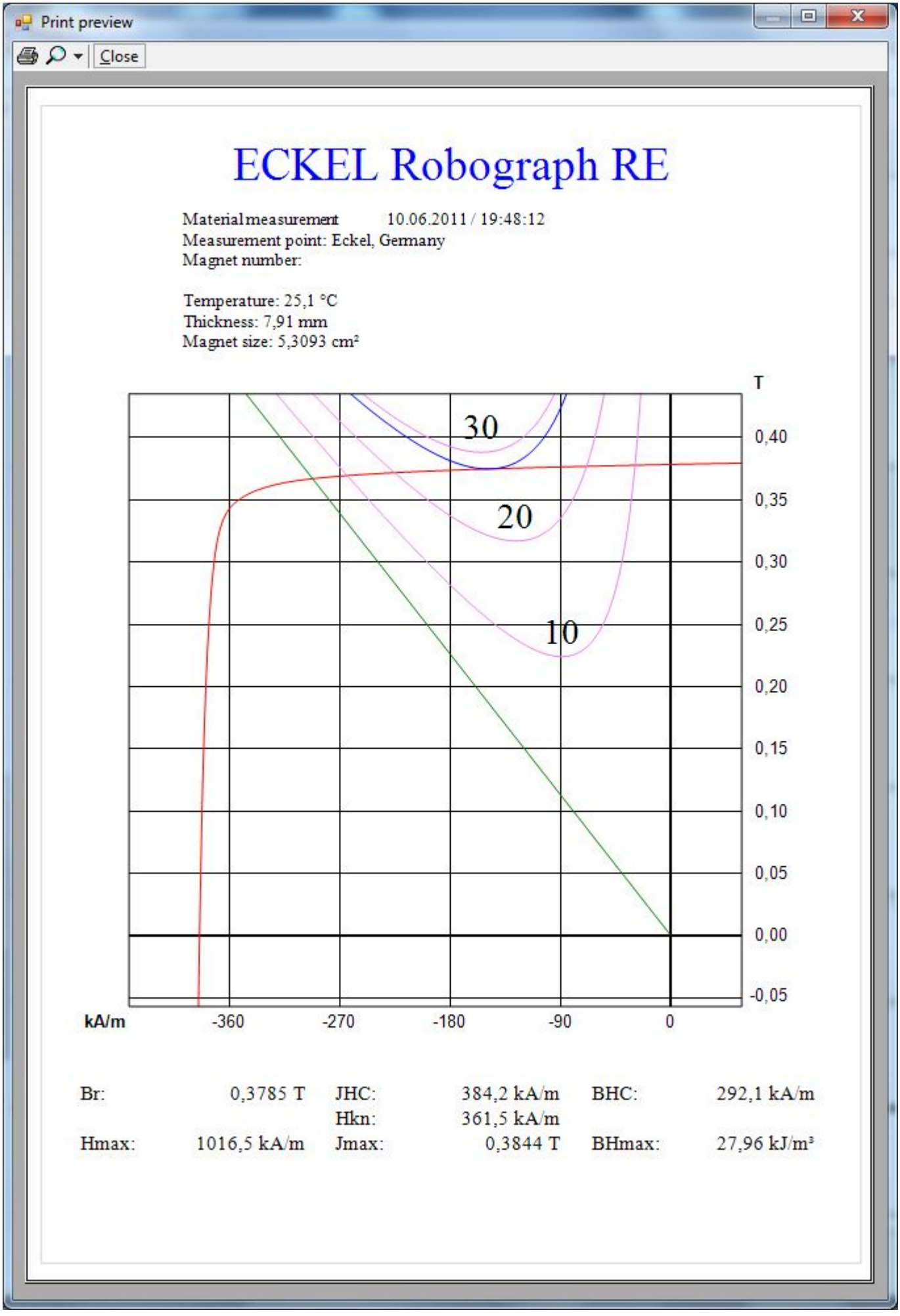
B 4.3. Printing material graphs

By moving the mouse to “Printing” at the task bar the drop-down menu is opened.



Printing drop-down menu

Setup printer opens the printer setup window of the operating system. A printer and properties can be selected.
Preview opens the preview window. The page can be printed by clicking on **the printer symbol**.



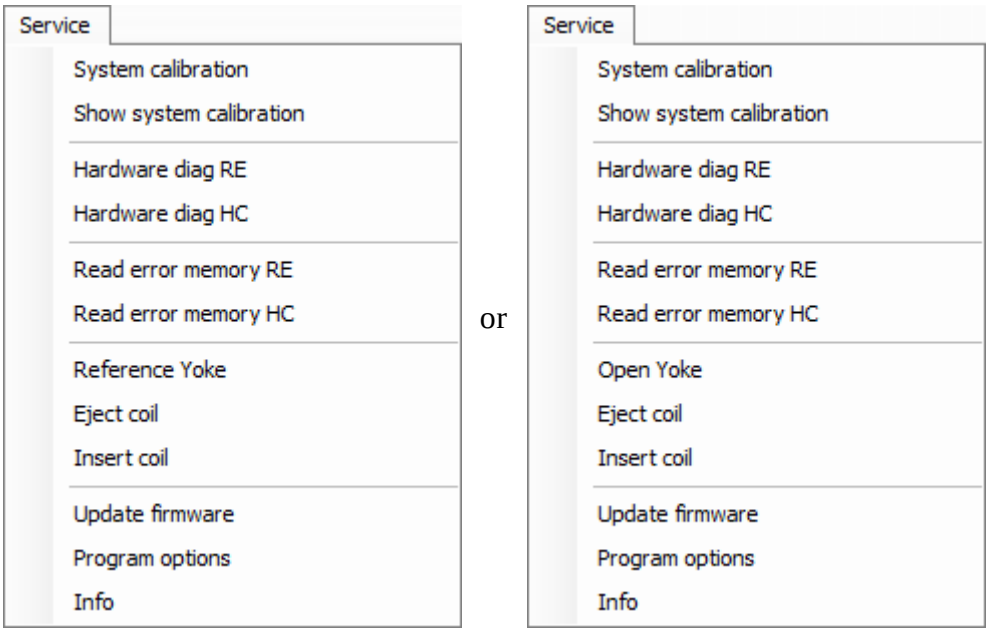
Preview window for printing

Preview with comment allows an additional comment to be added to the print.

Make protocol starts the procedure for extended measurement protocol.

B 4.4. Service material

By moving the mouse to “Service” at the task bar the drop-down menu is opened.



Drop-down menu for service

System calibration is necessary for correct operation of the Robograph RE. It sets the calculation factors for software since exact hardware values are unknown before.

The system calibration has to be performed once after combining a Robograph RE unit with a PC and software.

Start system calibration by clicking on it.

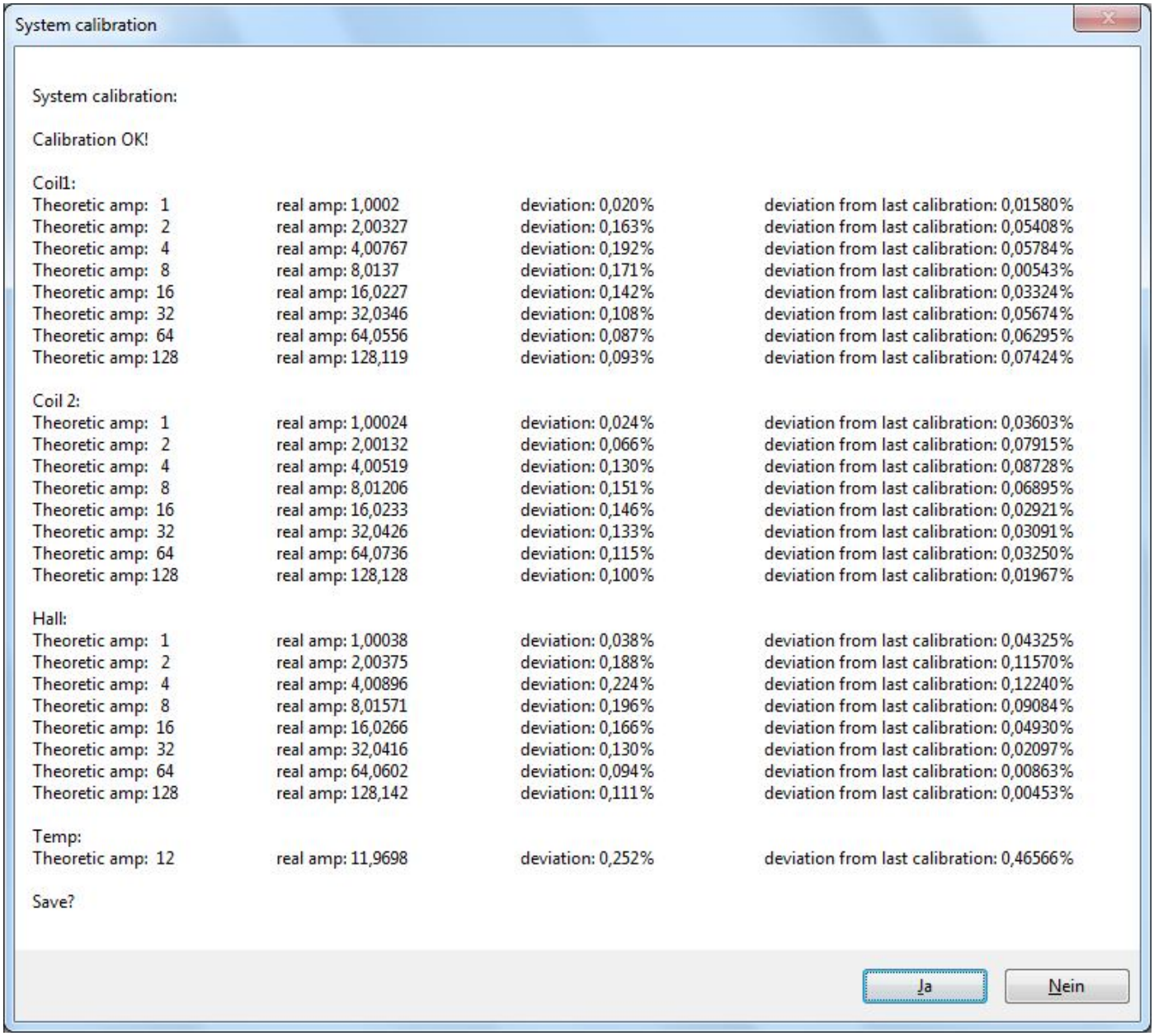
During system calibration exactly defined test voltages are connected to the inputs to calculate exact amplifications and later after measurement the exact input voltages. Calibration will take some seconds and the clicking of the relays can be heard.

After the calibration a result window opens. It shows the theoretical and real amplifications of all inputs. If this is a repeated calibration also the deviations from the last calibration are shown. These deviations should be very low.

The deviations between theoretic amplification and real amplification are compensated by this calibration procedure. Thus for result calculation only the real amplification values are used.

If something is not like expected an error message will be shown.

Save the calibration if it is OK.



System calibration result window

Show system calibration will open this window again later.

Hardware diag RE opens a hardware diagnostic window. If ever the Robograph RE should not work as expected anymore, this will help to find the reason.

This function should only be used if something is wrong and we ask you to do this test.

The Robograph RE has total control over the temperature, current, voltage and power loss of each transistor.

There are 2 amplifiers, 1 for each coil of the yoke. Each amplifier has a voltage regulator, a positive and a negative transistor. The upper 3 graphs at the left and the center show the temperature, power loss and maximum allowed power loss at actual temperature for these transistors.
Further graphs show the temperature of the 2 power op-amps, the regulated and unregulated positive and negative power supply voltages, the output voltages and the output currents.

If any of these values ever should run out of expected tolerances, the measurement will be stopped and maybe even the amplifier shut down to protect the hardware. The necessary calculations are made inside the Robograph RE itself.

The large window on the right side is the large version of one graph selected from the small graphs by clicking on it.

Hardware diagnostic window RE

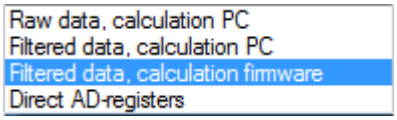
At the right bottom there is the choice between different data:

Raw data, calculation PC gives the pure calibrated A/D converter data from the unit.

Filtered data, calculation PC gives filtered and calibrated A/D converter data from the unit. This filtering improves signal quality eliminating noise and getting better readable results.

Filtered data, calculation firmware gets the loss power values completely calculated from the Robograph RE itself. This is default.

Direct AD-registers gives the original A/D converter data from the unit.



Data selection

First of all the **graph has to be started**. Parallel operation to normal measurement is not possible. Then the graph starts to run.

The power amplifier can be **powered up**. Relay status for fan, output stage, output relay and power-up delay are shown. A bar shows the fan voltage.

A maximum current is entered and sample frequency is selected. Sample frequency of standard flux measurement is 2000 Hz. The number of samples stays the same. Thus the measurement duration becomes longer with lower sample frequencies.

Then the **measurement can be started** and all internal processes are shown numerically and graphically. The values of the D/A converters are shown as bars in positive and negative. They should always correspond to the output current values.

Hardware diag HC is the same for the heat control unit.

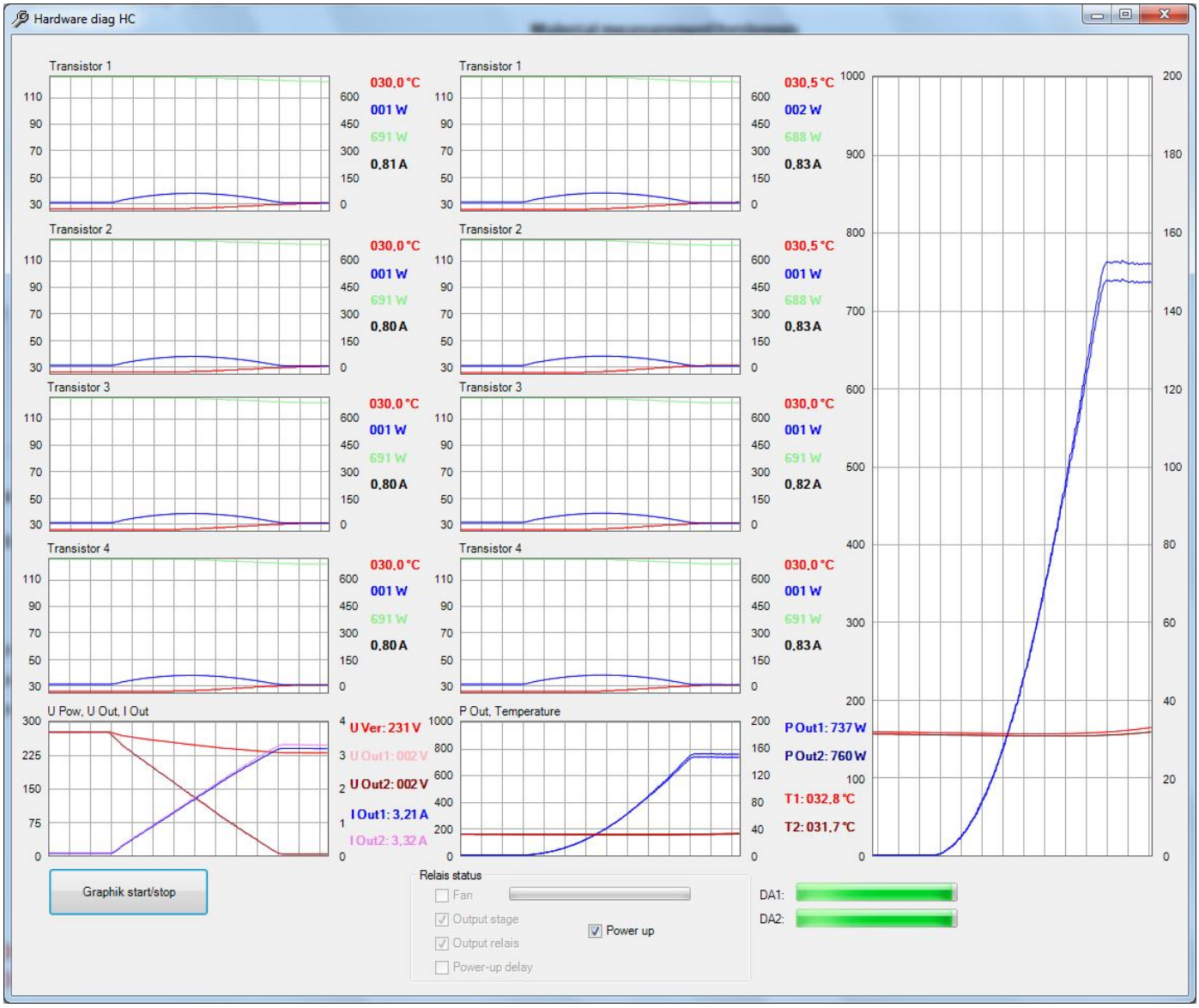
The Robograph HC also has total control over the temperature, current, voltage and power loss of each transistor.

There are 2 amplifiers, 1 for each heating of the pole shoes. Each amplifier has 4 positive transistors.

The upper 4 graphs at the left and the center show the temperature, power loss and maximum allowed power loss at actual temperature for these transistors.
The left bottom graph shows power voltage, output voltage and output current of both amplifiers. The next graph shows output power and temperature for both pole shoes

If any of these values ever should run out of expected tolerances, the heating will be stopped and maybe even the amplifier shut down to protect the hardware. The necessary calculations are made inside the Robograph HC itself.

The large window on the right side is the large version of one graph selected from the small graphs by clicking on it.



Hardware diagnostic window HC

First of all the **graph has to be started**. Then the graph starts to run. To see interesting situations, it is necessary to start the HC unit before and set a temperature.

Relay state for fan, power amplifier, outputs and power-up delay are shown. A bar shows the fan voltage.

If desired the power amplifier can be powered down and up again.

2 bars show the D/A converter voltages for current control.

Read error memory RE can help to find the reason for a shutdown of measurement or the complete power amplifier.

The Robograph RE unit will always register the reason and the actual internal situation when executing a shut down. By reading this error memory the reason for shut down becomes visible.

If you need to do this, please contact us before for further instructions.

Read error memory RE

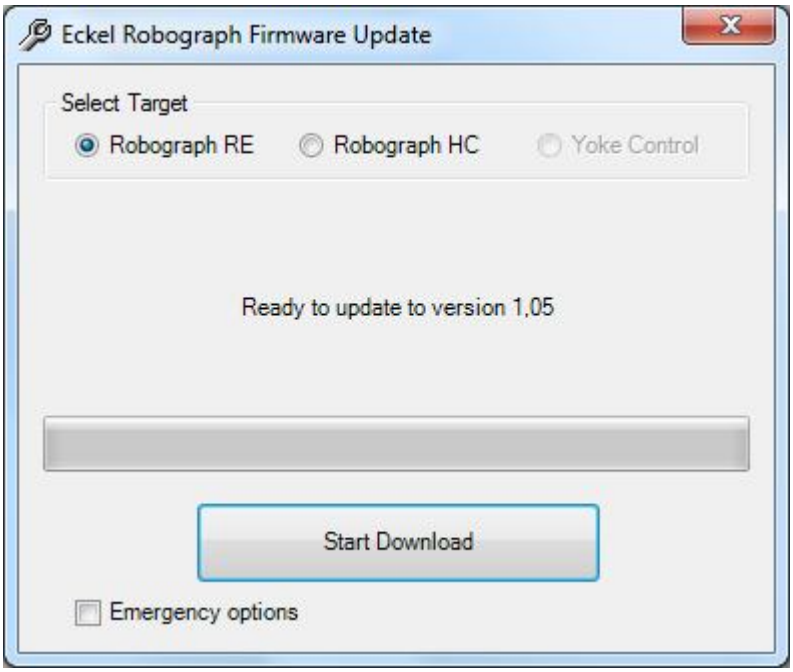
Read error memory HC is the same for the HC unit.

Reference yoke / open yoke will lift the upper cylinder of the yoke. If the yoke has not been referenced after power up, it will be driven up until end switch and the go down to open position. After this the cylinder will always stop at open position.

Update firmware allows the user to update the internal program of the Robograph RE and Robograph HC unit.

The newest firmwares are always part of the newest software for PC. If your actual firmware in the unit is older than the firmware in the PC program and you are authorized to use this update, you will be asked to update.

Update is made by standard USB connection. Select **Update firmware** and an update window will open.



Update window

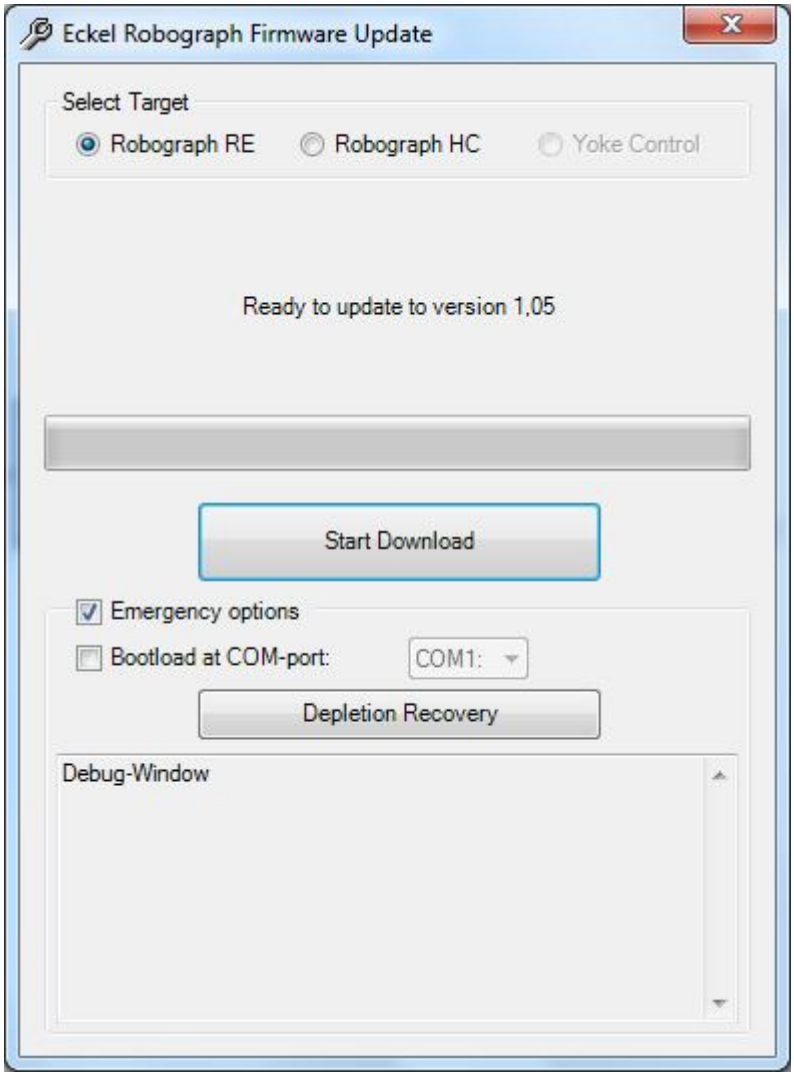
Select the unit, start the download and the firmware is updated.

New features may be added. So look at www.w-eckel.com for a new operating manual version.

If somehow internal program is corrupted (power fail or switch off during update) there are the **Emergency options**. This will open a debug-window where the complete process is listed during update. If this process cannot be finished successfully, the new program must be loaded by COM-port.

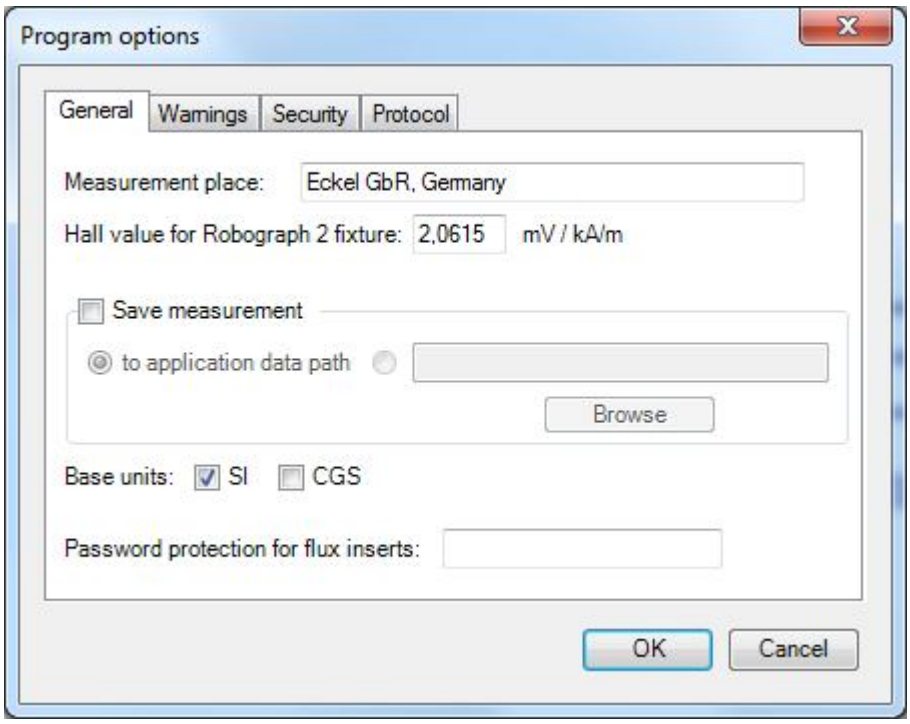
Using this feature allows to restore the internal program even if the program is not running anymore and USB connection fails.

If even this fails and there is an error message of erase or program error, the **Depletion Recovery** must be executed. This resets the internal Flash memory. Then repeat the update via COM-port.



Firmware update with emergency options

Program options opens the program options window.



Program options General

At "**General**" the following information can be entered:

Measurement place is written on the printout.

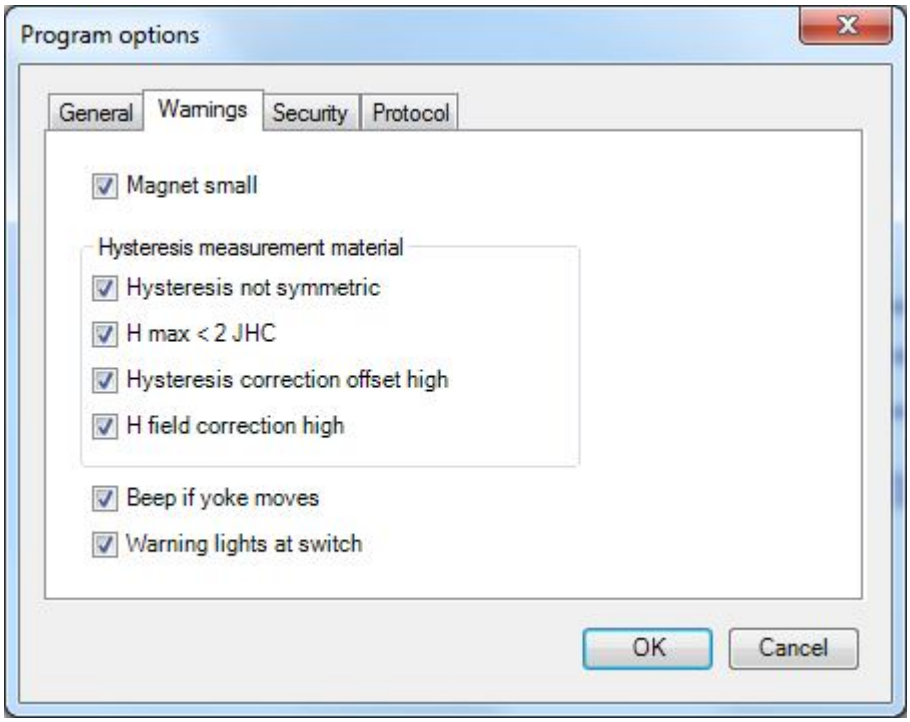
Hall value for Robograph 2 fixture: If for flux measurements of ferrite segments old type Robograph 2 fixtures without inbuilt Hall probes are used, the calibration value of the exchangeable Hall probe must be entered here.

Save measurement is for automatic storing of all measurements. **Application path** is where also the Robograph RE program is located. Other possibility is to enter a path for the archive. Inside the folder there will be generated a path structure with magnet number, date and time.

Base units selects if SI units (T, kA/m, mVs) or CGI units (Gauss, Oerstedt, Maxwell) are shown.

Password protection for flux inserts !!! : If a password is entered here, changing flux fixture parameters is only possible after input of this password. The actual password is not visible here. To change the actual password, the old password must be entered one more timer after pressing the OK button.

At “**Warnings**” different options for message boxes and acoustic or visual warnings can be activated:



Program options Warnings

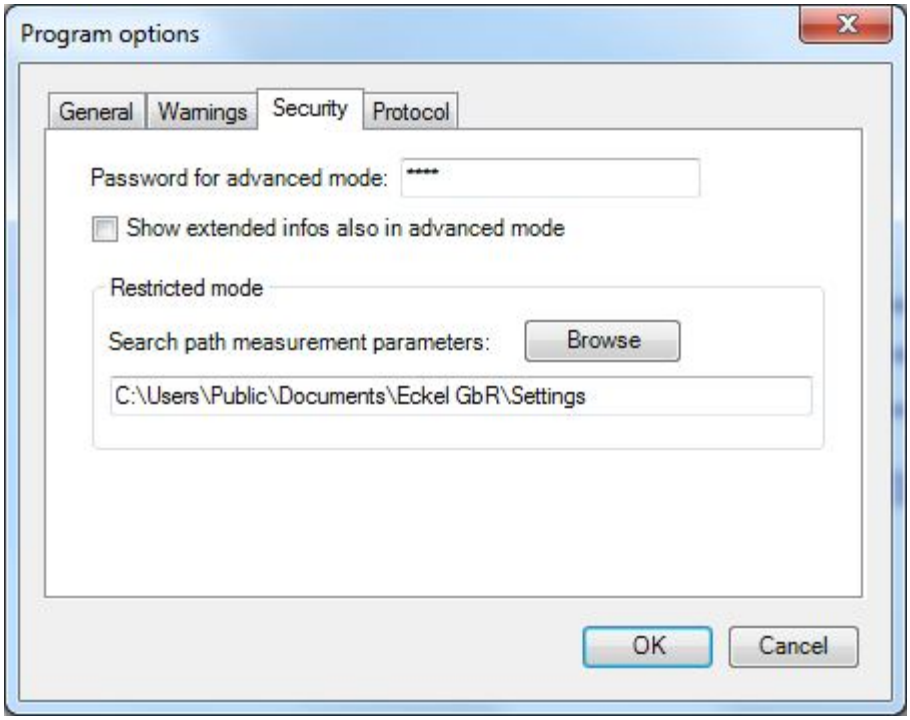
Magnet small: Due to high pressure by magnetic force (5000 – 10000 N) it can be dangerous for magnet and pole shoe to measure magnets with small surface. If the magnet is smaller than 0.5 cm² a warning will be given that magnet or pole shoe may be damaged. If it is even smaller than 0.25 cm² the warning will say that there is a high probability that magnet and/or pole shoes will be damaged.

Damaging the pole shoe will occur if the complete magnet or parts of it are pressed into the surface of the cobalt steel. Though cobalt steel is very hard, this may happen, resulting in a not flat surface. Then measurements will not be as precise as before. Grinding the surface will repair this damage, but due to the platform and mechanics connected to the pole shoes other work and adjustments will be needed to reach complete functionality again. Also grinding will only be possible few times and then a new pole shoe must be used.

Hysteresis measurement material: When measuring a hysteresis at material measurement, it is necessary to saturate the material to both directions. Sometimes it is not clearly visible if saturation is reached or not. In this case some tests are performed to check the hysteresis.

Hysteresis not symmetric: A normal hysteresis will be point symmetric to the centre of the coordinate system. If symmetry is poor, saturation probably was not reached sufficiently.
H max < 2 jHc: If the maximum field is less than 2 times jHc, saturation probably was not reached sufficiently.
Hysteresis correction offset high: With a hysteresis measurement, it is presumed that same values are reached at second circle. Thus the hysteresis is closed to eliminate small offset errors. If offset error correction is high, it is no offset but indicates that same values were not reached due to insufficient saturation.
H field correction high: The hysteresis is centred also in H direction. Normally this effect should be very low. If not, positive and negative jHc did not have the same value.
Beep if yoke moves: If activated the computer will give a beep warning signal before the yoke starts to move.

Warning lights at switch: If activated the additional relay board inside the Robograph Sw switch will be used to switch external warning light at different situations.



Program options Security

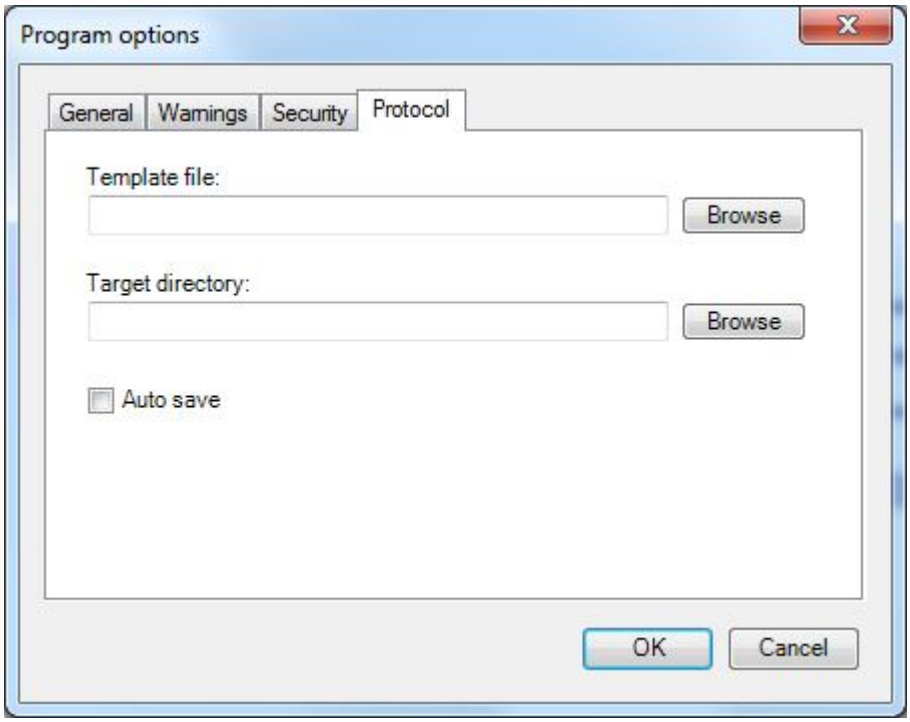
At **Password for advanced mode** a password can be entered. If a password has been defined, a window will open at program start to enter this password. If the correct password cannot be entered, only restricted mode will be available.

To change the password, another password can be entered here. But at closing the window the old password is asked again to confirm authorisation.

If no password is entered here, the program will always be in advanced mode.

Show extended infos also in advanced mode: In restricted mode many warnings and instructions are given to support the user and prevent errors or damage. The advanced mode user may be annoyed by these messages and can deactivate them here.

Search path measurement parameters: For restricted mode all setting files (tolerances) are located in a folder defined in this line.

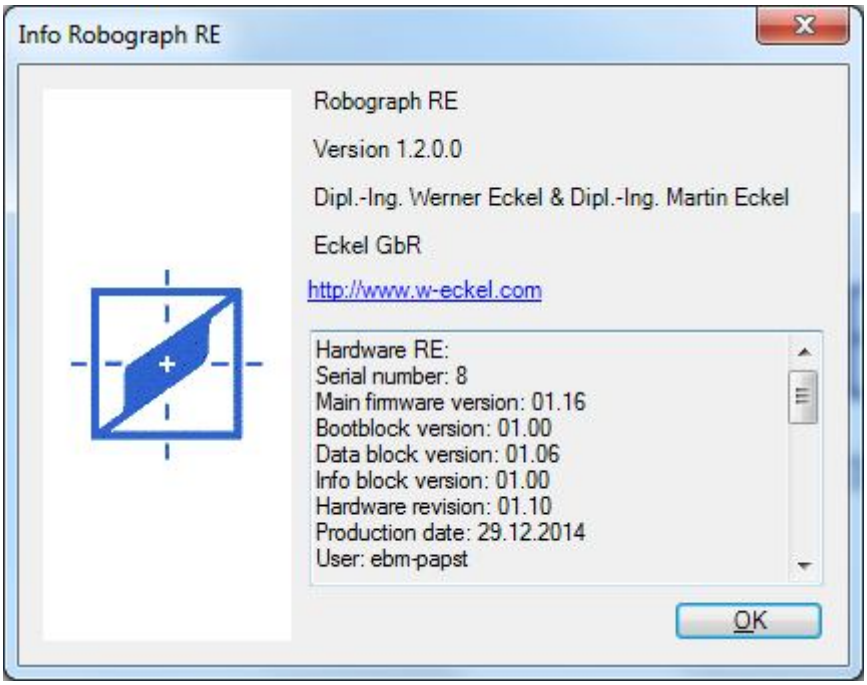


Program options Protocol

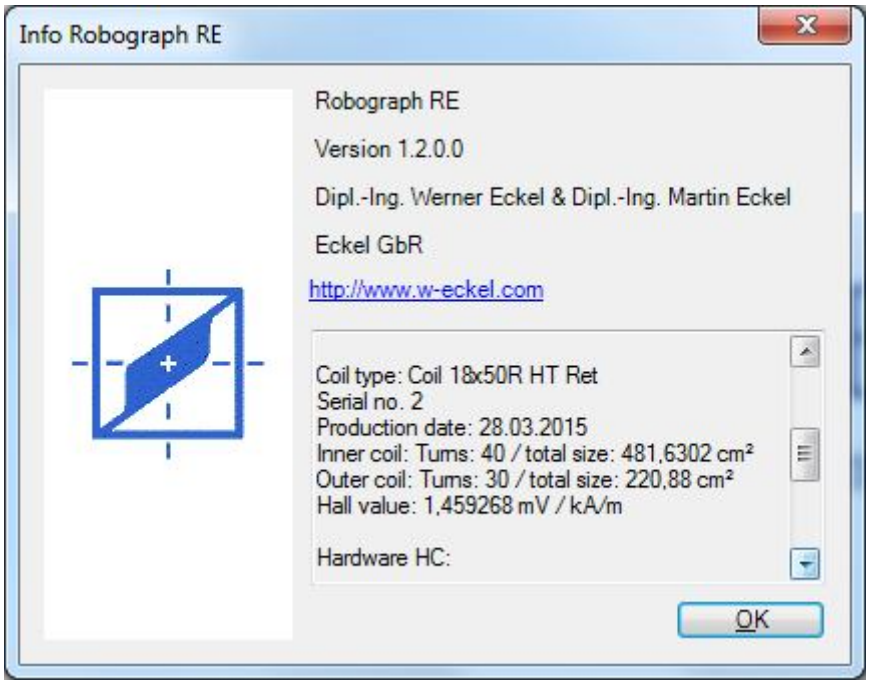
At **Protocol** the template file for extended protocol and the target directory for created protocols are defined.

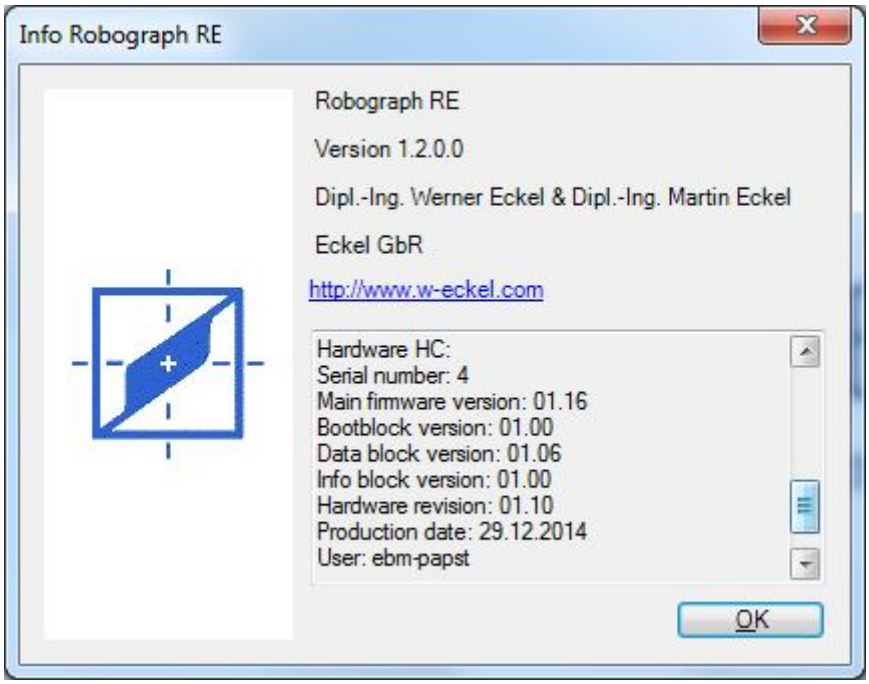
Auto save activates automatic storing of all protocols.

Info opens the information window, showing all versions of different program parts and, if powered on and connected, also the versions of the internal software and hardware.



Information window

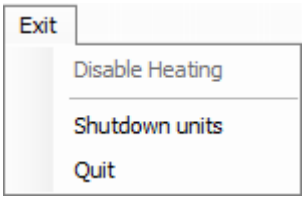




Scrolling down information

B 4.5. Exit material

By moving the mouse to “Exit” at the task bar the drop-down menu is opened.



Drop-down menu for exit

Disable Heating shuts off the power amplifier of only the HC unit.

Shutdown units shuts off the power amplifier of both the Robograph RE and the Robograph HC. The other parts of the Robograph units stay powered on.

Quit ends the execution of this program and returns to the desktop.

B 5. Errors material

For room temperature measurements without heating most errors changing the result come from errors in temperature. If magnet temperature is not room temperature, the result will be not exact.

Take care to have the magnets in the same room as the Robograph RE long enough (1/2 to 1 hour) or keep each magnet for some minutes between the pole shoes to adapt pole shoe temperature.
No direct sun on the magnets or the pole shoes.
Do not hold the magnets in the hand for a longer period before measurement.

Remember that during repeated measurement of the same magnet this magnet becomes warm from magnetisation. Full hysteresis energy is transformed to temperature.

For measurements with heating the temperature error is less significant. But it is important to set wait time for magnet warm up long enough to ensure the same temperature for pole shoe and magnet. Thinner magnets need less time than thicker magnets and Rare Earth needs less time than ferrite.

Eddy currents need special attention. Depending on selected dH/dt more or less eddy current will occur in yoke, pole shoes and Rare Earth magnets. Higher measurement speeds with higher dH/dt will create more eddy current. This will change measurement result in relation to measurements with lower speed. Normally the eddy current increases values for B_r as well as ${}_JH_C$. For very high dH/dt this error can become significant.
Also the eddy currents inside the yoke lead to errors in meeting the desired field for direction change of the hysteresis or inner loops. Though these errors are compensated, this compensation cannot be perfect since it depends on too many nonlinear factors.
In principle very slow measurements are the most exact measurements regarding the eddy currents. But not only the time waiting for the result is the problem. Also output signal of the measurement coil is reduced with slower speed. Thus signal quality is reduced for low speed measurements affecting accuracy. Also high

current low speed measurements increase transistor temperature and stress the hardware. So a compromise has to be found.

Check if all parameters of the tolerance are correct.

Also errors may occur if the power or the sensors plug of the yoke is not correctly inserted.

Hardware errors leading to interruption of measurement have to be checked by appropriate test programs. In general message boxes will explain the errors.

C 1. Material measurement of flat ferrites with embedded coils

This chapter is still under construction

Pole shoes with embedded coils can be used to measure flat samples of ferrite or plastoferrite. The advantage is that the area of the sample may be unknown or even irregular. Also it is possible to measure ferrites that are too large to fit in any coil.

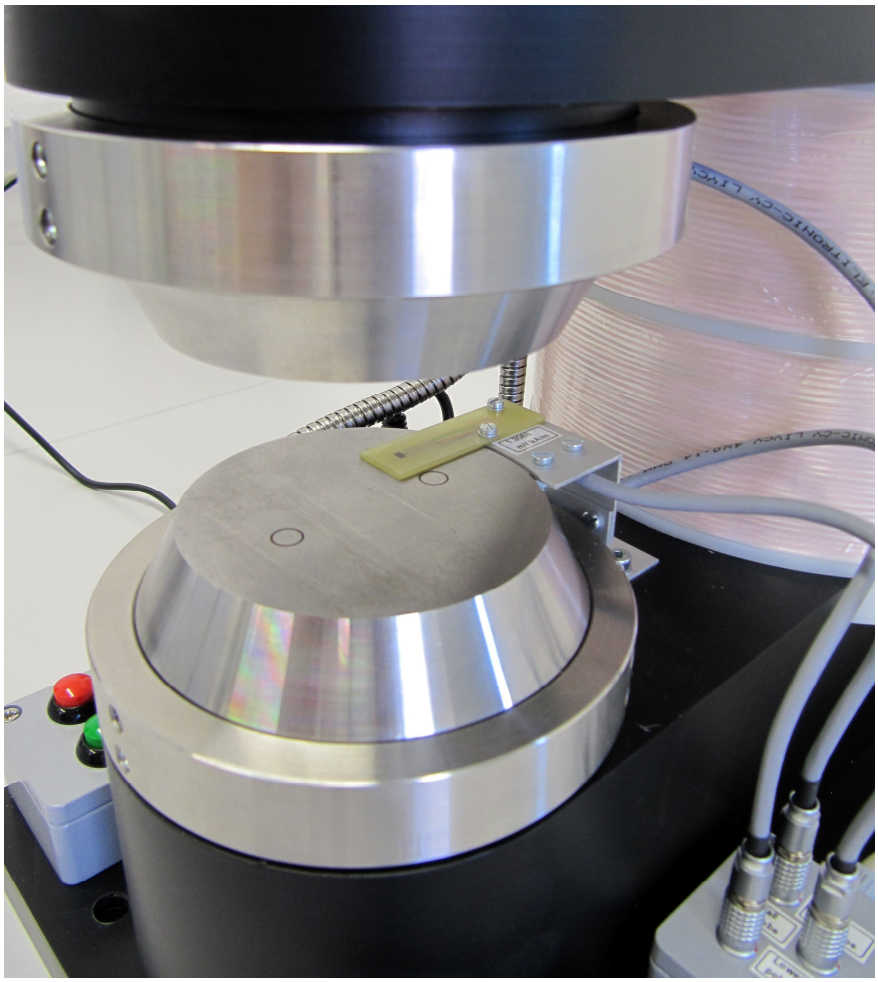
Though these pole shoes are produced of Vacoflux50 cobalt steel for the ECKEL Robograph RE, only ferrites can be measured. The inevitable space needed for coils leads to inhomogeneity inside of the pole shoes and thus to saturation effects, that are visible only at much higher fields when using surrounding coils.

Flat pole shoes with embedded coils

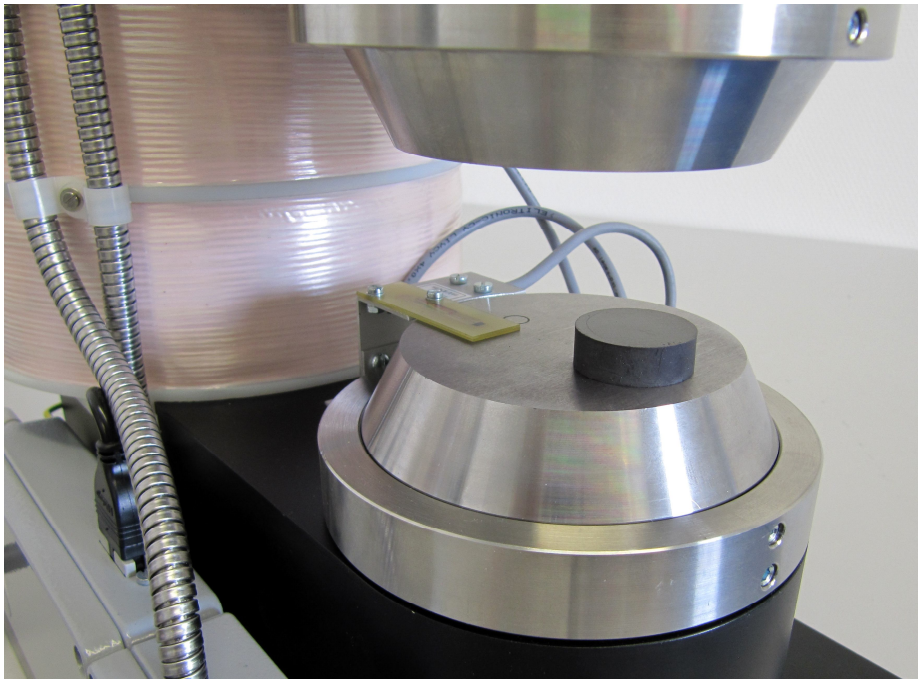
Both the upper and lower pole shoes contain 2 coils. The front coil is the B-coil. The magnet sample is placed on it. The sample should be at least 10 mm wide to cover the 6 mm coil sufficiently.
The back coil is the H-coil. The signal of this coil J-compensates the signal of the B-coil.

Field strength is measured by a Hall probe. It is only 1.3 mm thick. Thus also very thin samples can be measured.

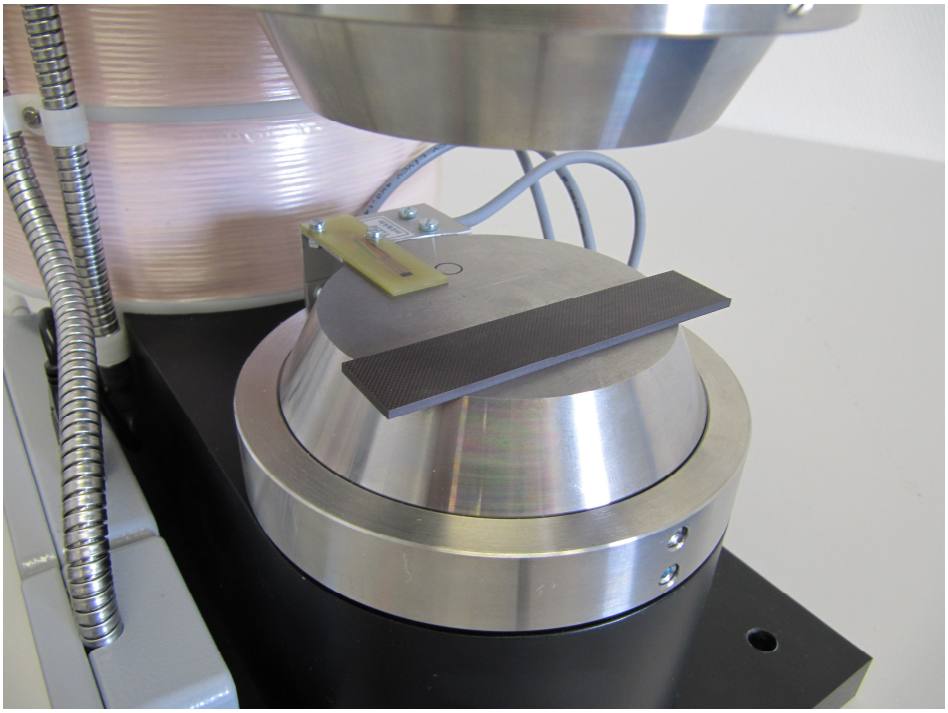
The coils and the Hall probe are calibrated by a PTB-certified coil.



Flat pole shoes with embedded coils and Hall probe mounted a the yoke



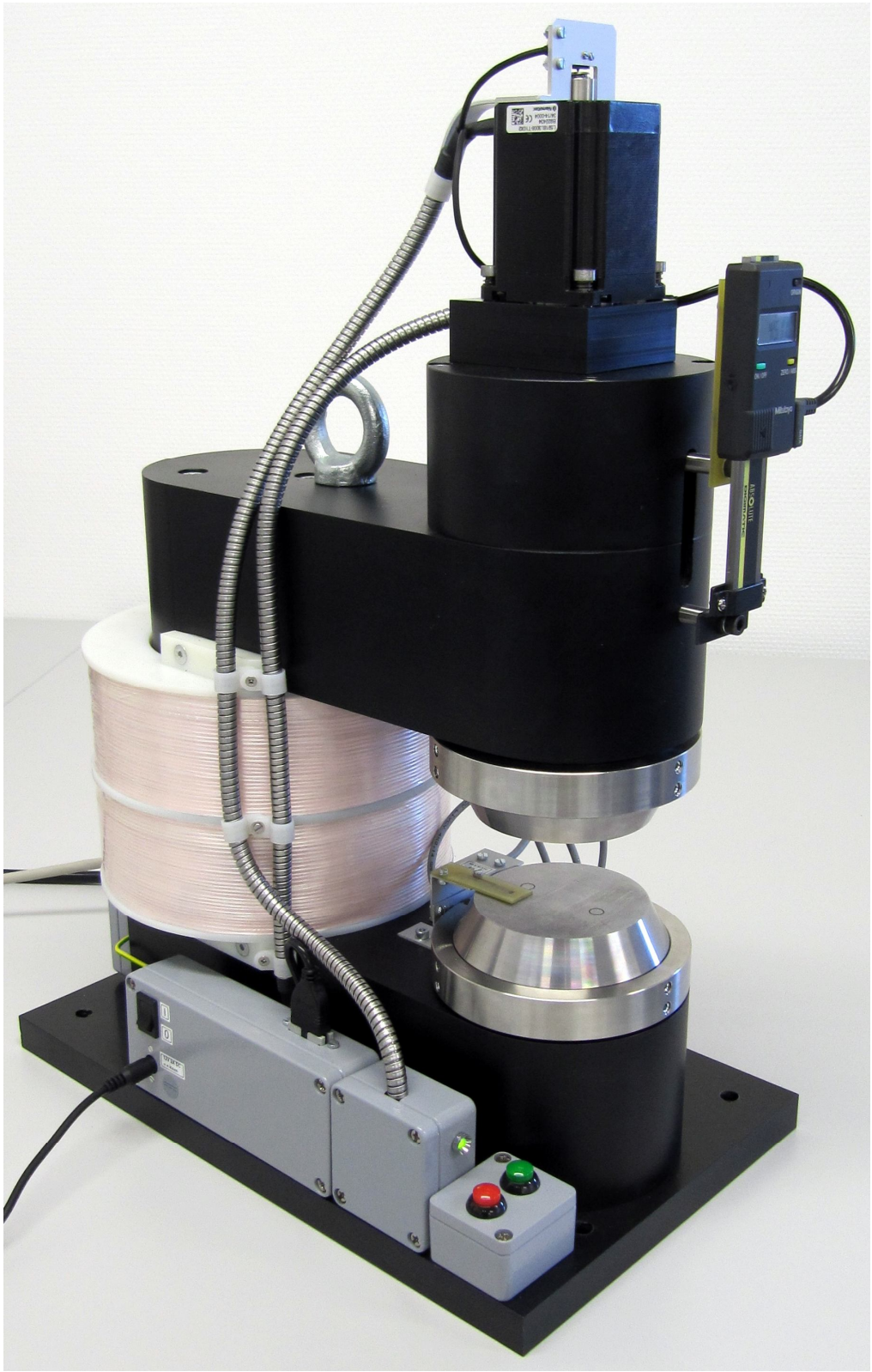
Placing a ferrite magnet on the B-coil



Placing a plastoferrite magnet on the B-coil

For this measurement a motorized version of the small electromagnet yoke is used. Annoying and time consuming cranking is not required.
The movement of the yoke is controlled by software.

Small motorized yoke



Small motorized yoke

Results of material measurement are remanence polarisation J_R, coercive fields ${}_BH_C$ and ${}_JH_C$ as well as $B*H_{max}$. These results are compared to limits calculated for this magnet.
As standard the demagnetisation curve will be shown including the tolerances.

The pole shoes and the Hall probe are connected to a box at the right side of the yoke.

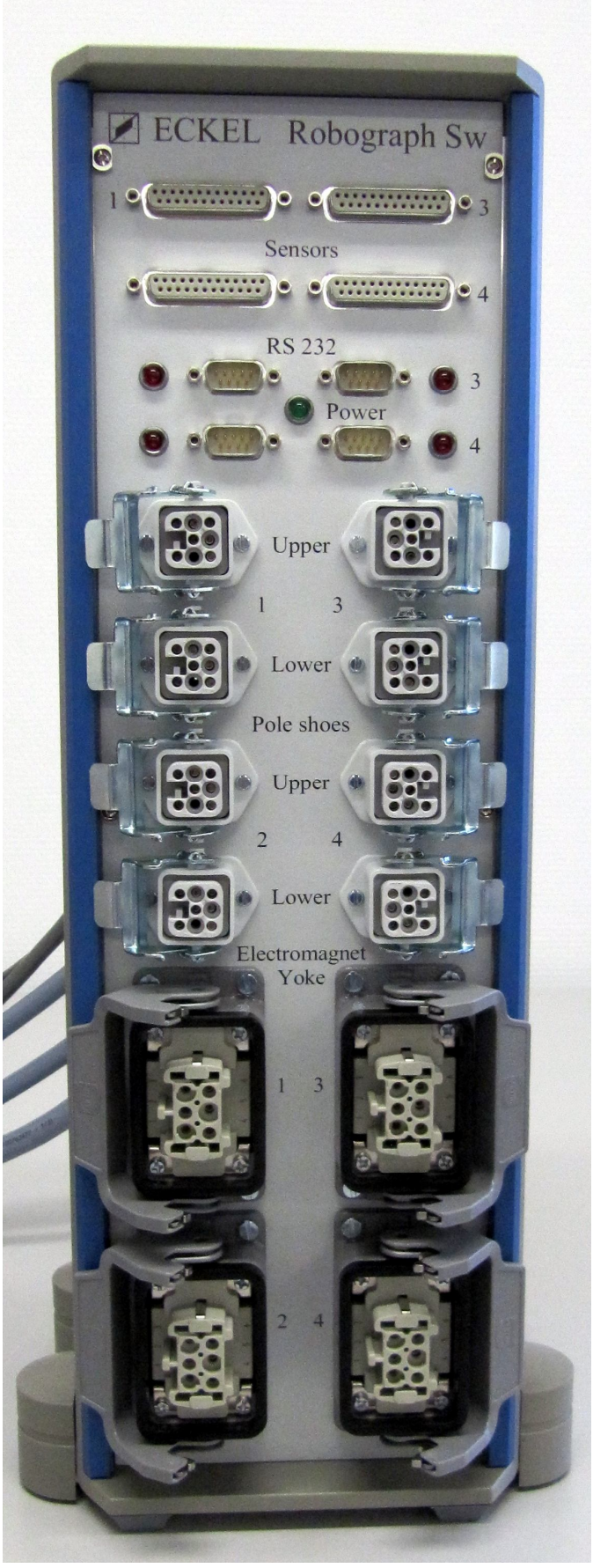
Connector box for pole shoes and hall probe

The calibration parameters of Hall probe and pole shoes are stored in an EEPROM inside the sensors plug, connecting this box to the Robograph RE unit.

All other information regarding yoke construction and technology and software operation are analogue to Chapters B and can be found there.

D 1. Using the Robograph Sw switch

This chapter is still under construction



Robograph Sw switch for 4 yokes

To connect several electromagnet yokes to one Robograph RE and/or Robograph HC the automatic switch Robograph Sw can be used.

Signal inputs, yoke control, pole shoes and yoke power connections are switched simultaneously.

Switching is initiated by software at selection of appropriate measurement.

The additional relay output has the following functions:

Input:	1-6
Output 1:	2-7
Output 2:	3-8
Output 3:	4-9
Output 4:	5-10

All relays are 250V 16A type.

E. Technical Specifications:

Requirements:
Pentium PC, LCD monitor, Windows XP – Windows 7.
The completely installed PC (Windows 7) is included.

Robograph RE Desktop:
2 controlled 750 VA bipolar power current sources suitable for continuous operation with thermal protection and forced ventilation
Sampling of 4 measuring inputs with up to 2.000 Hz at 24 bit resolution
Max. measuring error: +/- 0.2 %. Magnets must be inserted carefully!
Typical device-related measuring error: < 0.1%
Data transmission to PC via USB interface at 12 Mbit/s
Microprocessor control for all internal processes
Self-calibration by means of internal reference
Power supply: 1.600 W, 230 V or 115 V (please specify when ordering)
Dimensions: 19", 3HE (height units), W47 x L44 x H17 cm
Weight: 22.5 kg

Robograph HC Desktop:
2 controlled 700 VA power current sources suitable for continuous operation with thermal protection and forced ventilation
Data logging and regulation for 2 temperature measuring inputs with 625 Hz at 16 bit resolution
Regulation accuracy: +/- 0.2 °C
Data transmission to PC via USB interface at 12 Mbit/s
Microprocessor control for all internal processes
Power supply: 1.600 W, 230 V or 115 V (please specify when ordering)
With 230 V 16 A fuse or with 115 V connecting the Robograph RE and the Robograph HC to separated mains power circuits is recommended.
Dimensions: 19", 3HE (height units), W47 x L44 x H17 cm
Weight: 20 kg

Small measuring yoke:
Modulation up to approximately +/- 1.000 kA/m at magnet thickness of 6 mm
No measurement of Rare Earth magnets!
Seating for new and old and flux measurement fixtures
Built-in temperature sensor (PT) for temperature compensation
Weight: 78 kg
The measurement fixtures are depending on the dimensions of the magnets.

Large measuring yoke:
Modulation up to approximately +/- 2.200 kA/m at magnet thickness of 2 mm
Acceptance of heated and unheated pole shoes.
Maximum opening about 40 mm
Temperature proof for pole shoe temperatures up to 200 °C
Temperature sensors (PT) for temperature measurement and/or compensation on the pole shoes
Motor control and sensor evaluation by microcontroller
Data transmission to Robograph RE via RS232 at 115.000 Kbit/s
Power supply 12 V, 3 A DC
Weight: 150 kg

A visit at the customer for local training normally is not necessary but can be ordered optionally.
The Robograph 2 unit comes with a two-year guarantee and a 10 year service guarantee as well as an optional software update service including updates of the operating manual.

Appendix 1: Bosch standard 3 139 918 950

Unfortunately we are not allowed to reproduce the Bosch standard 3 139 918 950 exactly for copyright reasons. Thus we offer a considerable enlarged version.

The Bosch standard 3 139 918 950 is a test instruction for non destructive flux measurement of hard magnetic magnet segments made from ferrite for small motors. Using this measurement, finished magnet segments are subjected to quality tests at random after production.

The basic idea of this test instruction is, that in the motor only the real magnetic flux is decisive, and not how it was realized. The flux is depending on: Length, width and thickness of the segment, the remanence induction B_r of the ferrite material as well as the radial orientation inside of the segment. The flux measurement is performed as hysteresis measurement, since in a motor not only the remanence flux Φ^*_R but especially the stability of the flux under the influence of opposing fields is important. From the hysteresis curve 2 or 3 numerical results are evaluated. By this the complete operation curve of the magnet in the motor is tested. These results are compared to limit values.

To test the magnet segment a measuring insert is needed, that resembles the situation in the motor as exactly as possible. The measuring insert has an extremely exact air gap between two soft iron radiuses. The larger lower radius, where the segment lies on, corresponds to the inner radius of the motor housing. The smaller upper radius corresponds to the rotor. Between magnet and upper radius there is a standard air gap of 0.7 mm.

The magnet segment is surrounded by a flux measurement coil with n turns that is embedded in the upper part of the insert, and only fills part of the length of the air gap in the measurement insert. Behind the magnet segment a Hall sensor is positioned in the center of the air gap to measure the field strength.

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 loaded 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. During measurement the segments are magnetised by the yoke in sequence in both directions well above the saturation level.

The voltage induced in the coil is calculated as follows:

$$\mathbf{u_\Phi = -n * d\Phi/dt}$$

where

Φ = magnetic flux
dt = sampling time interval
$d\Phi/dt$ = change in magnetic flux per time interval

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

$$\mathbf{\Phi = -1/n * \int u_\Phi * dt}$$

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 Φ against H of the segment is recorded. It can be viewed under graph Φ and supplies the value of the remanence flux Φ^*_R at H = 0.

Furthermore the remanence flux Φ^*_{RG} is to be calculated after the influence of a specified opposing field H^*_G to find how much the segment has been demagnetised by this opposing field. For this purpose a tangent to the hysteresis curve is placed through the point Φ^*_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 at H = 0 gives the desired value Φ^*_{RG}. The value Φ^*_{RG} is the flux of the magnet segment after partial demagnetisation by H^*_G and return to the field H = 0.

Additionally if desired a value $H_{GF(80)}$ can be evaluated. $H_{GF(80)}$ the field strength that is necessary to demagnetize the segment to 80% of Φ^*_R.

Transformation of the Φ to Ψ hysteresis:
The method mentioned above for calculation of Φ^*_{RG} is difficult to understand visually from the Φ curve. Therefore the Φ curve is transformed to the Ψ curve. The idea behind this method is to obtain a statement on the pure material characteristics of the segment at H^*_G which cannot be read direct from the Φ curve.

In physical terms the flux can be calculated as follows:

$$\mathbf{\Phi = B * A}$$

and with $B = J + \mu_0 * H$
the result is $\Phi = A * J + A * \mu_0 * H$

where

B = magnetic induction within the coil
J = magnetic polarisation of the segment
A = area of the coil
μ_0 = magnetic field constant

The magnetic properties of the segment material are shown in the polarisation J. In the flux Φ, however, there is still the linear part $A * \mu_0 * H$ which distorts the hysteresis curve diagonally. The polarisation is not linear and has the desired hysteresis form. Multiplied by the area A of the segment we obtain the polarisation flux Ψ.

$$\mathbf{\Psi = A * J}$$

To obtain Ψ the linear part $A * \mu_0 * H$ is subtracted from Φ.

$$\mathbf{\Psi = \Phi - A * \mu_0 * H}$$

Since the area 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 J of the segment material in the area around H = 0 is constant, and therefore that the hysteresis curve of Ψ runs horizontally. Therefore the gradient of the tangent of the Φ curve corresponds to the value A * μ_0. By subtracting a straight line through the zero point with this gradient from the Φ curve, we can obtain the Ψ curve.

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

The hysteresis curve of the polarisation flux Ψ represents the pure material properties of the segment and is much more informative in its form than the Φ curve. The parallel straight line through the flux Φ at opposing field H^*_G now become a horizontal line so that the value of Ψ^*_G at the opposing field H^*_G which can be read directly off the Ψ demagnetisation curve is identical to the required value Φ^*_{RG}. This also applies if the segment is not sufficiently hard magnetic.

The rectangular shape of this demagnetisation characteristic curve is decisive for the stability of the permanent magnets under the influence of strong opposing fields. It corresponds to the from material measurement well known J curve when using a J compensated coil. At the Robograph 2 the results Φ^*_R, Φ^*_{RG} and $H_{GF(80)}$ are automatically evaluated and compared to given limits.

The results are evaluated as follows:

Φ^*_R must lie within the tolerances Φ^*_{Rmin} and Φ^*_{Rmax}.
Φ^*_{RG} must be at least 0.94 * Φ^*_{Rmin}.
$H_{GF(80)}$ must be at least $H_{GF(80)min}$.

If no 100% test is performed, an evaluation by the Cpk method is necessary.

Appendix 2: Cpk value

Calculation of the processability index Cpk

The Cpk value is determined from:

μ = average value of all measurements
s = standard deviation of the measurements
D represents the smaller interval of the average value μ to one of the limit values. With real magnet measurements the interval to the lower limit value represents, in most cases, the smaller interval.

Cpk = D / 3s

A fail-safe production with a theoretical overshooting of the tolerance by no more than 64 ppm (or 32 ppm for one side respectively) can only be guaranteed for Cpk >= 1,33.

Appendix 3: Continuous calibration system

Unfortunately we are not allowed to reproduce the Bosch test instruction exactly for copyright reasons. Thus we offer a changed version in own words.

Magnet measurement with the Robograph RE:
The design data for the flux measuring insert are calculated from the drawing of the magnet segment. From this geometry of the flux measuring insert and under consideration of the magnet dimensions and material values the flux and the limits are determined using a finite element program.

The Robograph RE software includes the calculation of the measuring inserts and an approximation of the flux calculation. If possible a finite element program should be preferably used as it provides more accurate results.

The flux calculation is made as follows.

- Data entry of magnet geometry.
- Design of measuring insert.
- Calculation of the magnetic flux related to B_r min.

Takeover of calculation into magnet drawing.

Φ^*_{Rmin} = calculated flux - 1%
$\Phi^*_{Rmax} = \Phi^*_{Rmin} + 10\%$
$\Phi^*_{RGmin} = \Phi^*_{Rmin} * 0.94$

The mentioned numerical values can be varied by the user.

Since the accuracy of the test air gap has great influence in the result, it is produced by wire erosion.

Continuous calibration system:
To test the quality of the magnets processed within the production, magnets that have been measured with the Robograph are integrated in a polehousing. As a result it is possible to establish a relation of the magnet drawing related single segment measurement to the flux measurement of the pole housing.

Flux data obtained from Robograph measurements cannot be directly converted to pole housing measurements since the measurement is performed with different geometry. Thus magnet segments are measured by means of the Robograph unit and are classified in groups with equal flux data for one pole housing. This pole housing is marked with a value in percent related to the Φ^*_{Rmin} specification given in the drawing.

Example:

Φ measured = 0.300 mVs, Φ^*_{Rmin} = 0.294 mVs.
$\Phi\% = 100 / 0.294 * 0.300 = 102\%$

This pole housing with flux equalling magnet segments and a corresponding labelling can be used for calibration of flux meters.

Calibration of flux meters:
The calibration pole housing is entered to the normal production process.

- Move calibration pole housing into magnetizing station
- Magnetization to saturation
- Flux measurement

Evaluation of the flux measurement: The display of the flux meter corresponds to the %-reading at the calibration pole housing, e.g. measured value 0.300 mVs = 102%

Setting of limits at the flux meter:
Lower limit = 100%, upper limit = 110%

Example:

Pole housing labelling = 102%
Measured value = 0.300 mVs
Lower limit = 0.300 / 102 * 100 = 0.294 mVs
Upper limit = 0.294 * 1.1 = 0.323 mVs

At the ECKEL DFM flux meter this process is automatically performed. After the measurement of the calibration pole housing and after data entry of the indicated percentage value the upper and lower limits are set automatically.