

User manual highpreactor[®] BRHS



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Trademarks

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General Information on this Manual

This user manual:

- ➔ Describes the heating and stirring system BRHS from Berghof Products + Instruments GmbH. It contains product specific information.
- ➔ guides the user in the safe and proper use of the temperature controller. Familiarity with the relevant chapters of this handbook is required for safe and intended use of the equipment.
- ➔ must be read carefully prior to operating the equipment to avoid errors during operation and become familiar with the device.
- ➔ does not include repair instructions. Should repairs be required, please contact your representative or Berghof Products + Instruments GmbH.

After unpacking, the device must be checked for mechanical damage or loose parts. If any transport damage is found, the manufacturer is to be informed immediately and the device is not to be put into operation.

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Document history

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1. General information

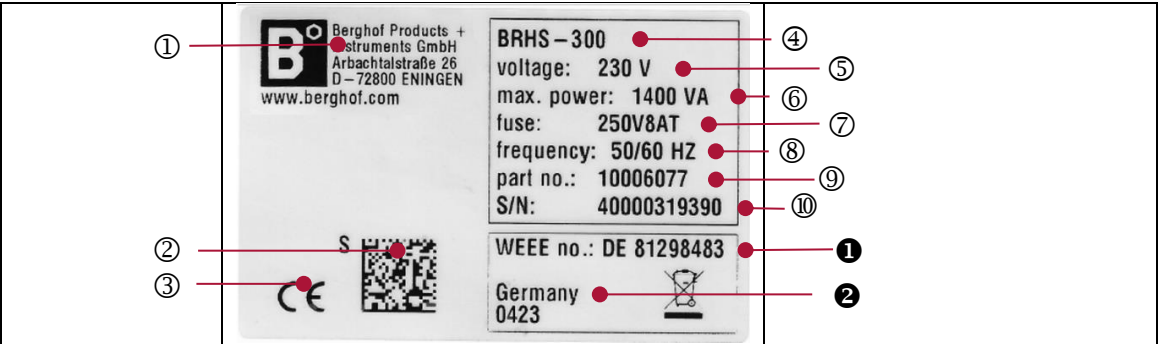
Please read these operating instructions carefully before using your BRHS. Failure to observe these operating instructions may result in damage to the equipment and injury to the operating personnel. Safety-relevant instructions and their classifications are explained in the section Danger categories and signal terms. These instructions must be observed in any case!

1.1. Information about the BRHS

No modifications may be made to the device without the written consent of Berghof Products + Instruments GmbH. Unauthorized modifications may affect the safety of the device.

1.1.1. Type plate

The type plate is located on the bottom of the device. Shown here as an example, the type plate of the BRHS-300:



① Manufacturer with address	⑦ Fuse
② QR Code	⑧ Input voltage frequency
③ CE-marking	⑨ Part No.
④ Model: BRHS-25, BRHS-40, BRHS-100, BRHS-200, BRHS-300	⑩ Serial number
⑤ Input voltage	① WEEE Registration
⑥ Maximum power consumption	② Country of origin

1.2. Warranty / Limitation of Warranty

Berghof Products + Instruments GmbH subjects each device to a functional and safety test before delivery. Provided that no modifications have been made to the equipment, Berghof Products + Instruments GmbH warrants that all its products will conform to Berghof Products + Instruments GmbH specifications and will be free from defects in material and workmanship when operated under normal conditions of use and service. Berghof Products + Instruments GmbH's obligation ends after one (1) year and is limited to repair, or at its option, replacement free of charge, of such equipment that is proven by its own judgment to be defective within the meaning of this warranty statement. No warranty is given on wear parts.

In the event of any claim, please attach a mark to the unit and a description of the defect found. Please state your name, department, address, and telephone number so that a quick settlement can be made.

The unit should be returned in its original packaging to ensure adequate security. We regret that any damage caused in transit by improper packaging is not covered by this warranty.

Except as expressly set forth in this agreement, there is no other warranty, contractual or statutory, given by Berghof Products + Instruments GmbH hereunder, including the statutory warranty of merchantability and fitness for a particular purpose. Berghof Products + Instruments GmbH shall not be liable to the customer for loss of profit, consequential damages of any kind resulting from a breach of the foregoing warranty.

2. Safety

The safety of users and personnel can only be guaranteed if the safety instructions and safety related warnings are observed and followed. Therefore, this manual must be available to all persons working with the BRHS.

Use the device only:

- As intended
- In technically perfect condition
- Without unauthorized changes
- Under supervision
- Through qualified operators

Comply with the requirements of the professional trade bodies, the technical monitoring association, the VDE regulations, or corresponding national provisions.

2.1. Qualified Users

Qualified users in the sense of the safety instructions in this documentation are appropriately trained and instructed specialists with basic chemical and technical knowledge. They should be familiar with the relevant legal regulations for handling pressure vessels and chemicals.

The device may only be used by laboratory personnel who, as a result of their education and training, have an overview of the hazards that can arise during operation of the device.

2.2. Intended use



Follow the operating instructions!

Always observe the operating instructions for the heating systems that are controlled by the process controller and for the devices that are to be heated. Care must always be taken when handling pressure vessels.

→ Scope of application of the BRHS

The BRHS is used for temperature control and mixing of Berghof's own pressure vessels. The system enables heating, stirring, and cooling of the pressure vessels on a laboratory scale and the display and storage of relevant process parameters. The BRHS is intended for use on a laboratory bench or within a fume hood but can be transported for storage purposes.

The main functions are:

- PID-controlled heating of the pressure vessel contents with an intrinsically safe 1200 W heating system based on measured temperature and, if necessary, pressure values.
- Stirring of the pressure vessel contents by means of a magnetic stirring fish.
- Accelerated cooling of the pressure vessel contents by means of a fan.
- Data logging and monitoring.

The system may only be used within the scope of the data and applications specified in this documentation and the associated user manuals. The system must never be used without a pressure device.

2.3. Safety instructions

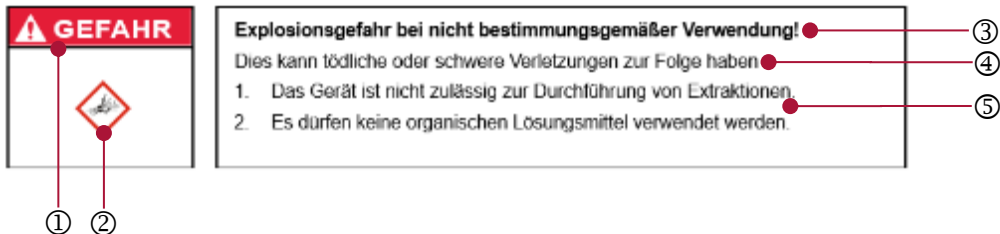
2.3.1. Danger categories and signal words

DANGER, WARNING, CAUTION and NOTICE are standardized signal words for classifying the risk and danger of suffering injury or damage to property. All signal words relating to personal injury are listed together with the general safety symbol.

For safety reasons, it is necessary that you read and understand the table of signal words and their definitions below.

Symbol	Signal word	Definition
	DANGER	DANGER means that failure to follow the safety instructions is likely to cause severe personal injury or death.
	WARNING	WARNING means that failure to follow the safety instructions may cause severe personal injury or death.
	CAUTION	CAUTION means that failure to follow the safety instructions may cause personal injury.
	NOTICE	NOTICE means that failure to follow the safety instructions may cause damage to the device.

Additional safety symbols can be indicated under the signal word.



① Signal word classifying the risk	④ Type and source of danger
② Safety symbol	⑤ Measures to avoid risk
③ Possible consequences in the case of failure to comply	

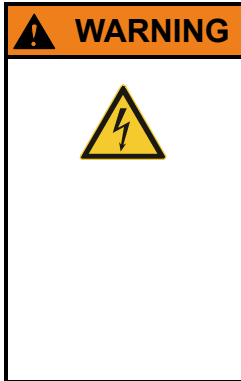
2.4. General safety instructions

In addition to the safety precautions listed below, the operation of the BRHS heating and stirring system also includes those that must be observed for the operation of the devices to be heated. These can be found in the corresponding operating instructions.

The following general safety instructions must be read carefully and observed before setting up and commissioning the system.

No liability can be accepted for damage caused by improper handling or non-observance of these instructions.

 DANGER	Only suitable for Berghof's own pressure vessels! Safety instructions from the BR reactor user manual must be observed additionally.
 DANGER 	Hot surface! Depending on the setpoint temperature, the heating area of the device can become very hot on the surface. Do not touch the marked upper area and adjacent areas with your hand to avoid burns. Use personal protective equipment.
 WARNING 	Hot surface! Depending on the setpoint temperature, the heating area of the device can become very hot on the surface. It is imperative that non-heat-resistant cables, etc. have no contact with these areas!
 WARNING	Compatible pressure vessels! The device may only be used with Berghof's own pressure vessels intended for this purpose.
 WARNING	Max. Observe operating temperatures! When operating the BRHS, always observe the maximum permissible operating temperatures of the equipment to be heated!
 WARNING	Continuous operation, overnight operation Only operate heaters overnight if they have at least one additional overtemperature switch!

**Unit uses mains voltage AC 230V!**

The device must always be connected to a protective earth conductor. The connection from the device to the power source must always be made via a three-wire cable with a protective earth conductor.

Only use approved mains cables.

The socket used must be always freely accessible.

The device must not be put into operation if it is damaged.

Repair and service work may only be carried out by appropriately trained and qualified personnel of Berghof Products + Instruments GmbH.

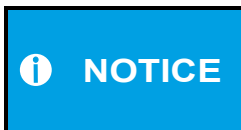
The device may only be operated at a socket with a maximum fuse rating of 10A on the building side.

**Hot air flowing out!**

During the cooling process, hot air is blown out through the upper ventilation slots. Areas must not be covered and must be kept free of obstructions (free areas, chapter Installation conditions). No heat-sensitive objects (cables, etc.) may be in this area!



The supply air in the floor area for the integrated ventilation/cooling is ensured by the adjustable feet to a level installation surface. This supply air area must not be closed and would lead to damage to the device.



The ventilation openings in the upper part of the device must be free at all times. Closing the openings can lead to damage to the device.

2.5. Product safety

2.5.1. Safety and emission und Emission

In the following cases, the unit must be disconnected from the mains supply and protected against unintentional use:

- if there is visible damage to the unit,
- if the unit has loose parts,
- if the unit does not work,
- after prolonged storage in unfavorable conditions (e.g., outdoors or in a very humid environment)

2.5.2. Safety instructions on the unit



This safety notice is located on the bottom of the unit.

2.5.3. Safety regulations in the EU

This appliance has been designed and tested in accordance with the following standards:

Title	Standards
Safety requirements for electrical equipment for measurement, control and laboratory use Part 1: General requirements	IEC 61010-1:2010/AMD1:2016
Safety requirements for electrical equipment for measurement, control and laboratory use – Part-2-010: Particular requirements for laboratory equipment for the heating of materials	IEC 61010-2-010:2019
Electrical equipment for measurement, control, and laboratory use – EMC- requirements Part 1: General requirements	EN 61326-1:2013 IEC 61326-1:2012 Class A device Professional equipment. The equipment is suitable for use in all establishments other than domestic and those directly connected to a low voltage power supply network which supplies buildings used for domestic purposes.

2.5.4. CE-mark

The products from Berghof Products + Instruments GmbH comply with the VDE directives and European Standards. The conformity tests performed by Berghof Products + Instruments GmbH comply with the currently prescribed standards of safety for electrical measuring, control, regulation and laboratory equipment, as well as their EMC requirements (Class A).

Declaration of conformity

See Chapter 7.1

2.6. Disposal instruction

→ Disposal
within the
EU

The product is made of high-quality, recyclable, and reusable materials and components. Correct disposal is essential for environmental protection.

European Union

Electrical and electronic devices must not be disposed via domestic waste. Berghof Products + Instruments GmbH takes back its electrical and electronic products from business customers for free disposal, raw material recovery and recycling. Contact your dealer or Berghof Products + Instruments GmbH directly, if you are intending to dispose of electrical and electronic devices.

The form "WEEE return of old devices" describes the return of old devices. Customers must fill this out and return it with the device. We will be happy to send you the form or you can download it from our website:

<https://www.berghof-instruments.com/de/downloads/>

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Important note!

Customers wishing to return instrumentation and/or associated materials to Berghof Products + Instruments GmbH or regional dealer are advised that all returned goods must be certified as clean and free from contamination. Therefore, clean and decontaminate your old device before returning it.

Countries outside the European Union

Outside the European Union, the relevant regional and local laws regarding proper disposal must be complied with.

→ Disposal
outside of
the EU



Environmental hazard in case of incorrect disposal!

This can result in minor or moderate injuries.

1. The device must be disposed of in accordance with the requirements of the European Union.
2. The relevant regional and local laws regarding proper disposal must be complied with.
3. To ensure proper disposal, you can contact Berghof Products + Instruments GmbH.

3. Device description

3.1. Basic instrument

The highpreactor BRHS (heating-stirring system) can be used for Berghof's own reactors in 5 different sizes as a controller with integrated heating, cooling and stirring. Temperatures of up to 300°C (572°F) can be set in the reactor.

The highpreactor BRHS is offered in 5 variants for the following reactor sizes:

1. BRHS-25 for reactor BR-25
2. BRHS-40 for reactor BR-40
3. BRHS-100 for reactor BR-100
4. BRHS-200 for reactor BR-200
5. BRHS-300 for reactor BR-300



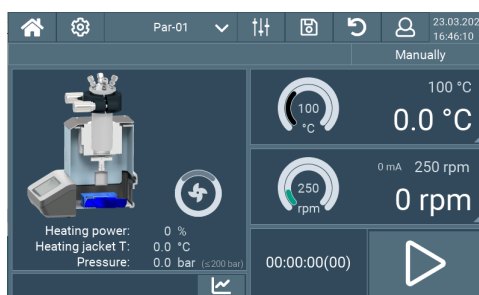
These different variants differ in the design of the built-in heater, but have the same performance data.

The PID control parameters can be freely programmed for different temperature ranges. The system may only be used within the scope of the data and applications specified in this documentation and the associated user manuals.

BRHS



User interface



3.1.1. Electrical connections



No.	Function
1	Main switch
2	Fuse drawer (2x AC 250 V / 8AT slow blow)
3	Mains cable connection
4	P-1: Connection pressure sensor (4...20mA / RS485)
5	T-R: Connection temperature sensor reactor (PT-100)
6	USB (PC): Mini-USB connection. Connection to a computer.



Only devices certified according to the standard may be connected.

3.1.2. Technical data

BRHS without reactor	
Power supply	230 V, 1400 VA, 50/60 Hz
Maximum heating power	1200 W
Fuse protection	2x: AC 250 V / 8 AT (slow blow), 5x20mm
Temperature sensor	PT-100 (2-/4-wire)
Measuring range	0...+400°C (32...752 °F)
Type of control	PID controller
Weight approx.	18 kg (33,07 lbs)
Dimensions approx. (W x D x H)	250 x 360 x 345 mm (9,8 X 14,2 X 13,6 inch)
Volume	≤ 66 dB(A) with activated cooling fan

3.2. Data logger function

By connecting an external PC, the BRHS process controller can also be used as a data logger for documenting the temperature and pressure curves or other standard signals. With the aid of the software supplied, the temperature, pressure, heating power, speed and motor current curves can be recorded via the BRHS. See chapter 5.10 BRVI Datalogging.

→ [Documentation with PC application](#)



The graphs include the set temperature, current temperature, current pressure and current heating power, motor speed and motor current.

4. Setup and commissioning



The security of a system into which the BRHS is integrated is the responsibility of the operator of the system.

4.1. Scope of delivery

See the scope of delivery list enclosed with the unit.

4.2. Setup and commissioning

4.2.1. Ambient conditions

When selecting the installation location, the corresponding regulations and conditions of the devices to be heated (e.g., high-pressure laboratory reactors) must also be observed.

The BRHS is intended for indoor use and must not be placed in wet areas (no splash water resistance).

BRHS	
Ambient temperature	+5°C (41°F) to +40°C (104°F). Furthermore, it should be - 40°C (-40°F) to +70°C (158°F) during transport or storage
Maximum relative humidity	Maximum relative humidity 80% at temperatures up to 31°C, decreasing linearly to 50% relative humidity at 40°C. Non-condensing.
Altitude	Up to 2000 m
Electrical connection	230 V, 1400 VA, 50/60 Hz Fluctuations of the mains supply voltage up to ±10% of the nominal voltage. Overvoltage category II.
Pollution level	Pollution degree 2: Non-conductive soiling only, although occasional temporary conductivity caused by condensation is expected.
Sound pressure level	≤ 66 dB(A)
Space requirement (W x D x H)	approx. 29 cm x 40 cm x 55cm (incl. reactor) (approx. 11.4 x 15.8 x 21.6 inches)
Load capacity	Minimum 28 kg (40 lbs) (incl. reactor)
Outdoor areas	To ensure sufficient internal ventilation, at least 200 mm must be kept free all around.
Building protection	The unit may only be operated from a socket with a maximum fuse rating of 10A on the building side.

4.2.2. Positioning

First position the unit in the designated place. The footprint must be statically sufficient for the weight of the BRHS incl. Reactor (approx. 28 kg; 40 lbs) and be approx. 29 cm x 40 cm (11.4 x 15.8 inch; L x W).

i NOTICE

The supply air in the floor area for the integrated ventilation/cooling is ensured by the feet to a level installation surface. This supply air area must not be closed and would lead to damage to the unit.

i NOTICE

The ventilation openings in the upper part of the unit must be free at all times. Closing the openings can lead to damage to the unit.



4.2.3. Unpacking / Inspection

Carefully open and remove the transport packaging. Please keep it so that you can return the unit in its original packaging to the manufacturer in case of service.

Also remove the other accessories and check the delivery for completeness.

Check the system for transport damage such as cracks, scratches, dents, etc.

**Visible damage!**

For safety reasons, do not operate the unit if any damage has been detected. Contact your local dealer or Berghof Products + Instruments GmbH directly to obtain the appropriate service (for contact address, see section 6.4 Repairs / Customer service).



If any parts are missing or damaged, contact your local dealer or Berghof Products + Instruments GmbH directly (for contact address, see section 6.4 Repairs / Customer service).

4.2.4. Software

The process values of the BRHS can be logged in a file via the PC programme "BRVI" supplied on a USB stick.

System requirements: Windows 7 SP1 or newer and USB connection.

5. Operation



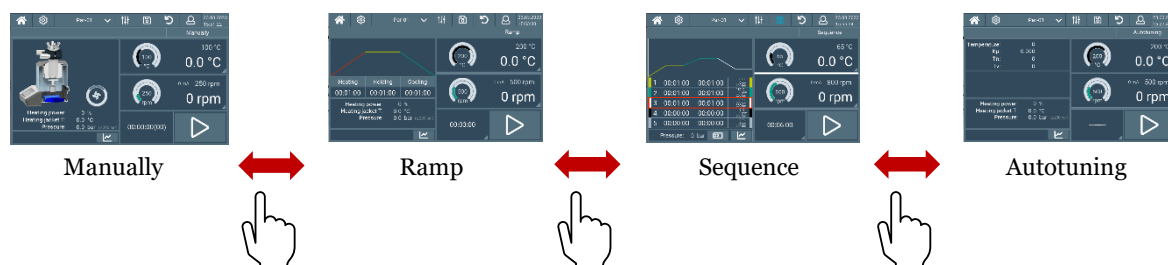
WARNING

Max. Observe operating temperatures

When operating the BRHS, always observe the maximum permissible operating temperatures of the units to be heated!

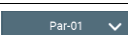
5.1. General

The capacitive 5" touch display can be used to navigate through the various screens of the user interface by swiping.



There are a total of four modes to choose from. The interfaces of these modes are all similarly structured. At the top is the menu bar with the status bar below it. On the right-hand side, the control values for reactor temperature, stirring speed and internal reactor pressure are displayed. Below this are the buttons for starting and stopping the program. Depending on the mode, various overviews or monitoring values are displayed on the left-hand side.



Button	Description	Function
	Home-Screen	By pressing the home screen button twice, you can switch to the start screen at any time. The home screen can be set individually under System parameters → General . Pressing once calls up the previous main screen..
	System parameters	This is used to call up the system parameter settings . Global settings can be made for the entire system.
	Selected parameter set	The drop-down menu allows you to choose between ten different parameter sets .
	Parameter settings	In the parameter settings , the currently selected parameter set can be edited. An individual name can be assigned, the controller sets can be managed, and other settings can be made. The settings made only apply to the active parameter set and not to the entire system.
	Save	The save button can be used to save changes to the control values (times, temperatures, speeds, pressure limits) in the active parameter set. Only the changes of the currently selected mode 'Ramp' or 'Sequence' are saved. Changes must be saved separately in the parameter set for each of these two modes. The symbol is displayed in blue if there are changes that have not yet been saved. Values in 'Manually' and 'Autotuning' mode cannot be saved.
	Undo	The undo button can be used to undo changes made to the control values and restore the initial state (only mode 'Ramp' or 'Sequence').
	User settings	User types with different rights can be selected in the user settings. Password protection for the user types can be activated via System parameters → User manager and corresponding passwords can also be assigned for the various roles.

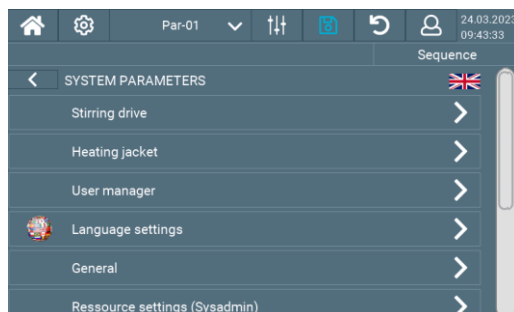
The menu bar is permanently displayed in the upper area and contains buttons for standard functions. The status bar shows the last actions and message as well as the currently selected mode. The status bar lights up briefly in yellow if a new message has been added. Pressing the current message displays the system's messages with a time stamp.

When a sequence has been started, symbols show the status:

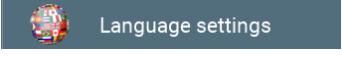
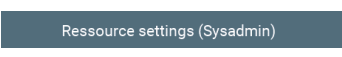
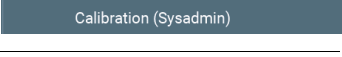
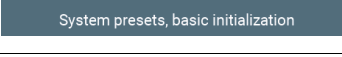
Symbol	Description	Explanation
	Cooling active	The symbol indicates that cooling is currently active and the fan is being activated.
	Heating active	The symbol indicates that the signal for heating is issued by the controller.
	Power limit active	The symbol indicates that a set power limit is currently in effect and that the output heating power is being limited. The specified temperature may not be reached due to the limitation.
	Pressure limit active	The symbol indicates that a set pressure limit is currently effective and that no heating power is currently being output. This typically results in a temperature drop, i.e. the set temperature may no longer be reached.

By pressing the English language icon in the top right-hand corner , the system language in this display area can be temporarily changed to English to facilitate navigation in certain situations.

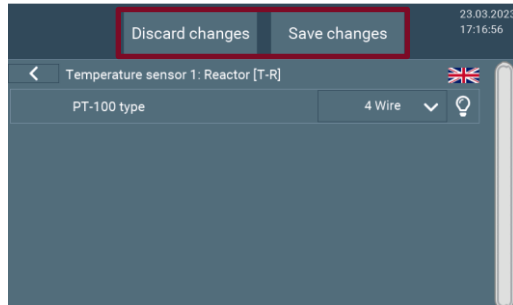
In the System Parameters menu, global settings for the entire system can be made.



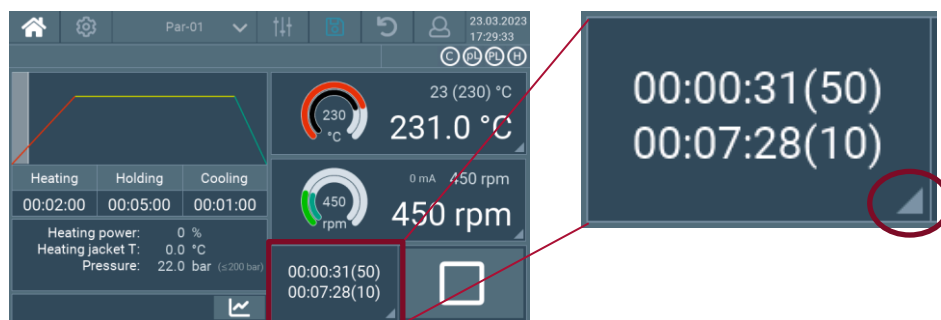
The light bulb symbol  in the respective submenus can be used to call up information on the setting options. This system runs through all menus and setting options.

Sub menu	Function
 Stirring drive	Configuration stirring drive (see 5.9) - Acceleration - Deceleration
 Heating jacket	Heating jacket configuration - T-Limitor jacket (service): Here, trained service personnel can configure the switching temperature of the built-in temperature safety switch so that it is not exceeded by the controller during normal operation. - Max. Delta-T above T-set (see 5.7.1)
 User manager	The user management can be activated here and the passwords for the rights levels <i>Sysadmin</i> and <i>Admin</i> can be managed.
 Language settings	In the language settings submenu, you can choose between the different system languages.
 General	General settings of the unit can be made here - Start screen after switching on the device - Active parameter set after switching on the device - Base temperature - Start temperature is the base temperature (see 5.8.3)
 Ressource settings (Sysadmin)	In the resource settings submenu, the connected sensors (temperature, pressure) can be configured. The type of PT-100 (2-wire / 4-wire) and the interface to the pressure sensor (4...20mA / RS 485) can be defined (see 5.4.2 and 5.5.2). The right level <i>Sysadmin</i> is required to access this menu.
 Calibration (Sysadmin)	The temperature and pressure sensors can be calibrated here (see 5.4.3 and 5.5.3).
 Date and time (24.03.2023 09:43:44)	The date and time of the system can be set here. These settings are also used for the time stamp in the log file, which is created via the BRVI, and for the status messages on the device.
 System informations	The serial number of the device and the software version used can be viewed in the system information.
 System presets, basic initialization	The basic initialization and the selection of whether the system is operated with or without PTFE insert can be made here (see 5.3).

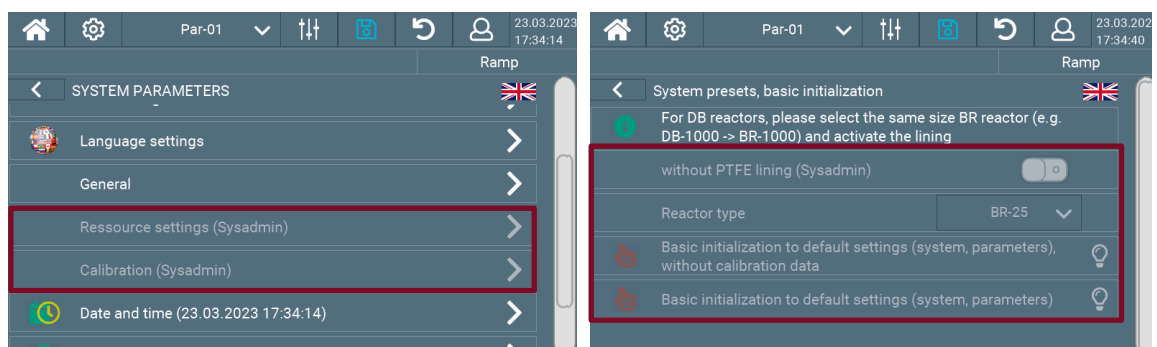
Changes in the settings are discarded or confirmed by pressing the **Discard changes** or **Save changes** button. Pressing the buttons completes the editing of the settings and returns to the main screen. Several settings can be adjusted before completing the editing by exiting the submenu through the arrow .



The -symbol indicates that the corresponding data field can be switched. Here the running time of a ramp program. It is possible to choose between the remaining running time and the time that has already passed.



Selection options are inactive (greyed out) if the currently set rights level is not sufficient. Select the necessary rights level via the -button.



5.2. User management

On the device, the user administration controls access to setting options. There are four hierarchy levels:

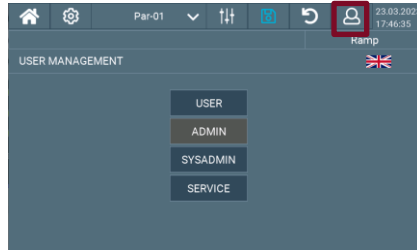
1. USER

(Only if user management is activated)

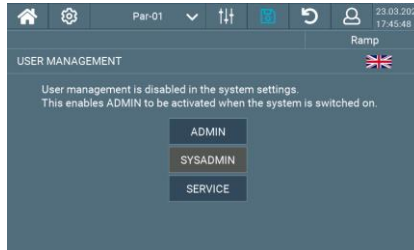
2. ADMIN

3. SYSADMIN

4. SERVICE



User management is activated
(see system parameters)



User management is deactivated
(see system parameters)

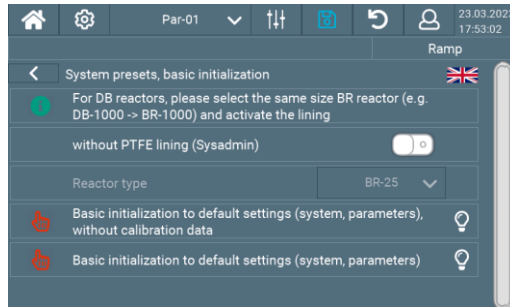
If the user management is deactivated, the system is started as "Admin" by default. Some global settings are blocked here and are displayed in grey. As "Sysadmin", these settings are available.

If user management is activated, the system is started as "User".

To call up the user "Service", a password entry is necessary. Further setting options are available as "Service". These may only be changed by appropriately trained service personnel.

5.3. Reactor configuration

The reactor size is preset at the factory and preassigned with standard control values. Via the menu **System parameters** → **System presets, basic initialization**, it can be selected whether the reactor is operated with or without PTFE insert. This automatically presets the reactor configuration for each parameter set and retrieves the default values of the control sets.

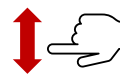
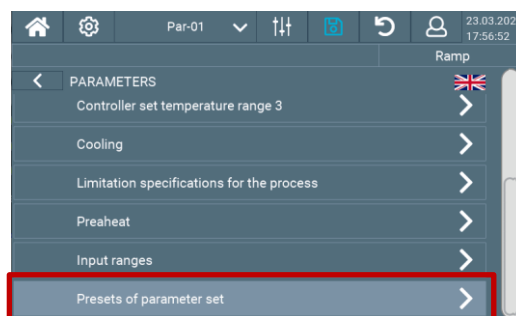


You can select whether or not the calibration values entered for the temperature and pressure measurement should also be reset during the basic initialization.



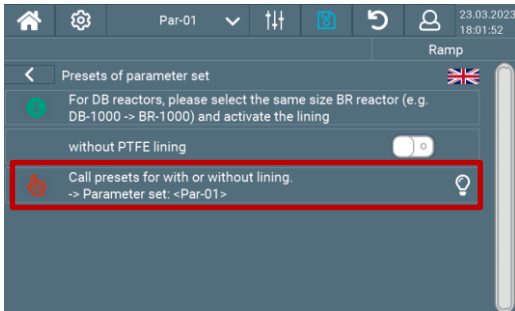
Calling up the basic initialization resets all parameter sets and sequence values to factory settings!

The **parameter settings menu**  can be used to make individual changes to the different parameter sets. Set control parameters for different reactor equipment and configurations can be called up or existing parameter sets can be edited. A total of ten different parameter sets can be stored in the memory. These can be selected via the menu bar at the top.



To retrieve the default parameter sets, the option “**Call presets for with or without lining**” can be selected in the lower area of the **parameter settings**.

It can be selected whether a PTFE insert is used.

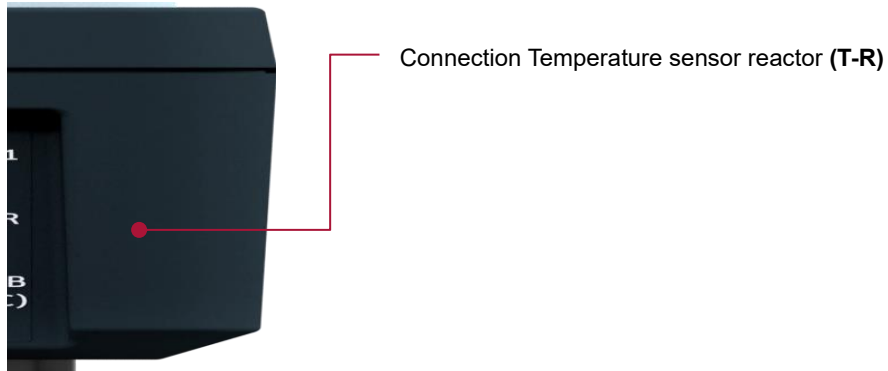


The default values for this reactor configuration can then be called up as pre-settings for the selected parameter set. These default values can be used to obtain good temperature control even without an autotuning procedure. These are valid for standard applications with an aqueous medium and approx. 3/4 filled vessels.

5.4. Temperature measurement

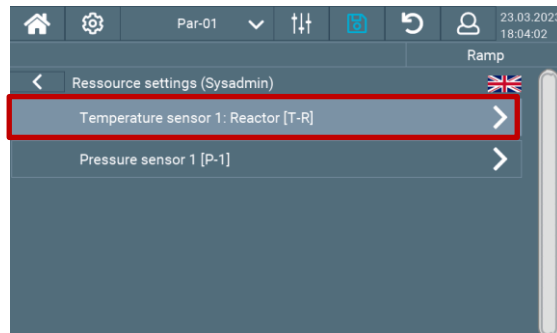
5.4.1. Connection

The BRHS has an external connection for a PT-100 temperature sensor (2-/4-wire) and an internally installed PT-100, which detects the heating block temperature. The sensor for the internal reactor temperature is connected to the T-R input on the rear of the device. If no temperature sensor is connected, a temperature of 99°C is displayed.

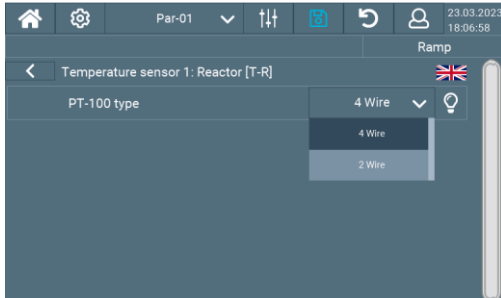


5.4.2. Configuration

The temperature channel can be configured under **System parameters** → **Resource settings**.

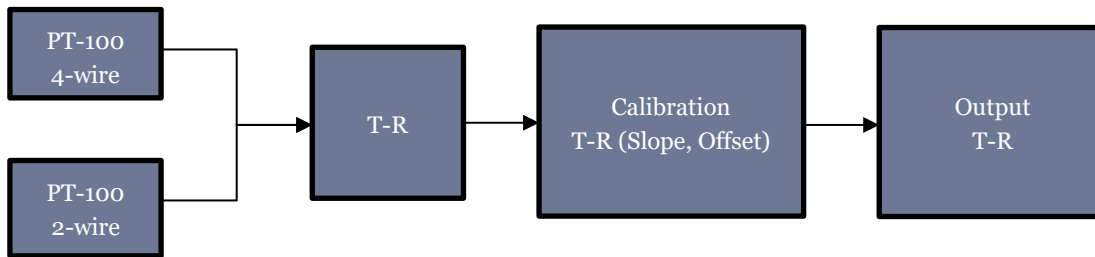


The type of PT-100 temperature sensor (2-/4-wire) can be selected for the channel (standard is 4-wire). The temperature sensor for the reactor cannot be deactivated. A measured value must be present here in order to start a sequence.

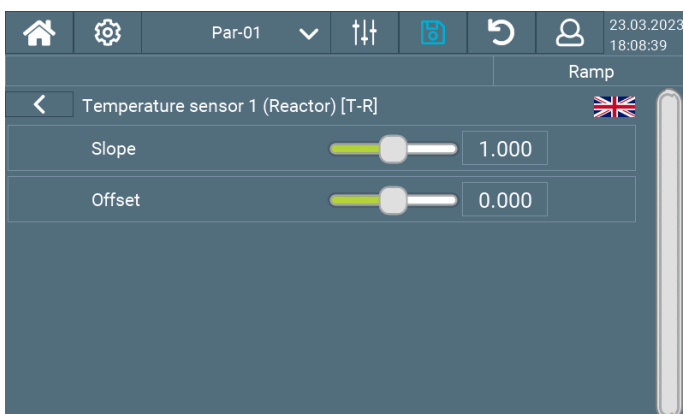


5.4.3. Calibration

The temperature channel for the reactor temperature can be calibrated with the appropriate tools. The schematic of the signal processing is shown below:



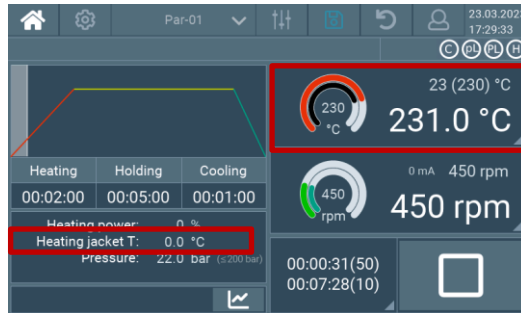
To set the calibration values, the user must be logged in as **SYSADMIN**. Under **System Parameters** → **Calibration**, the menu for calibration and the corresponding channel can be selected.



The measuring chain can be calibrated by changing the values for slope and offset. It is necessary to recalibrate the temperature input when changing the temperature sensor from 2-wire to 4-wire or vice versa.

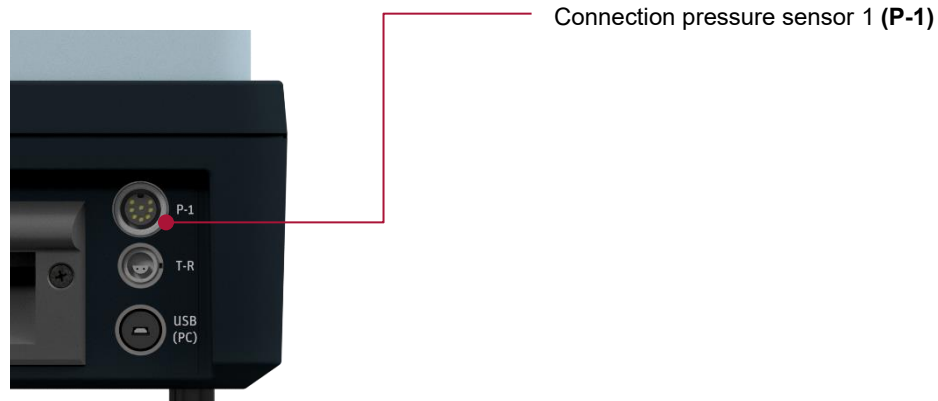
5.4.4. Usage

The measured values are displayed on the surface. The reactor temperature and the setpoint (upper, greyed value) are displayed on the right. The heating jacket temperature T-H at the bottom left as a monitoring value.



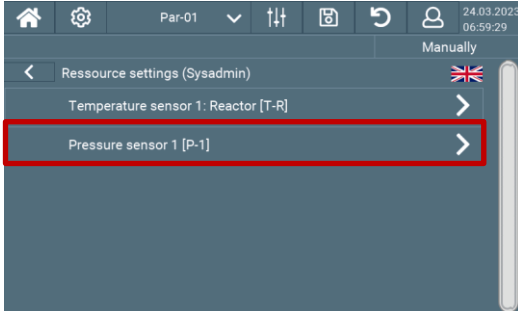
5.5. Pressure measurement

5.5.1. Connection

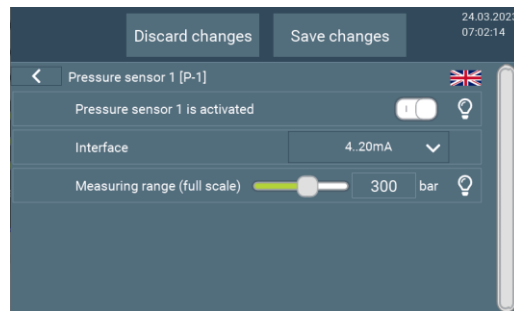
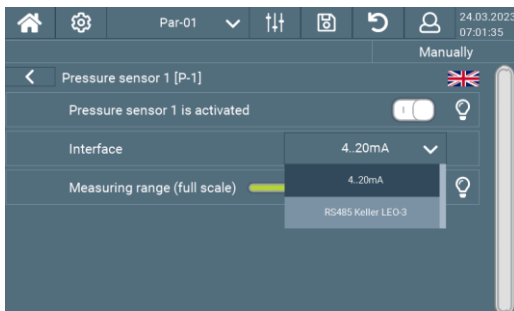


The BRHS has an input for connecting pressure sensors. You can choose between a 4...20mA or a RS 485 interface (for special sensors from Keller). If no pressure sensor is connected, a pressure of 99 bar is displayed in the data logging.

5.5.2. Configuration

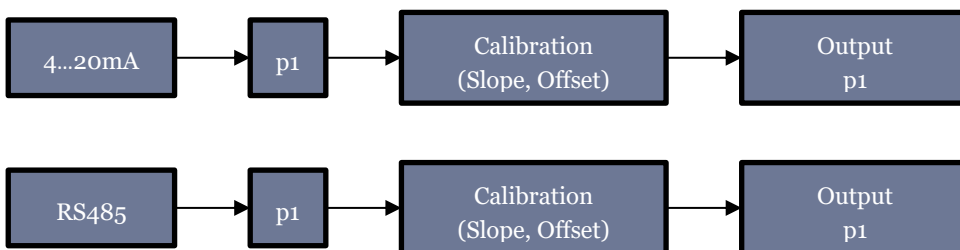


The input can be configured via **System parameters** → **Resource settings**. You can choose between a 4...20 mA and an RS485 interface for the pressure sensor LEO-3 from Keller. For each sensor, the measuring range of the sensor used must be specified (see technical data sheet).



5.5.3. Calibration

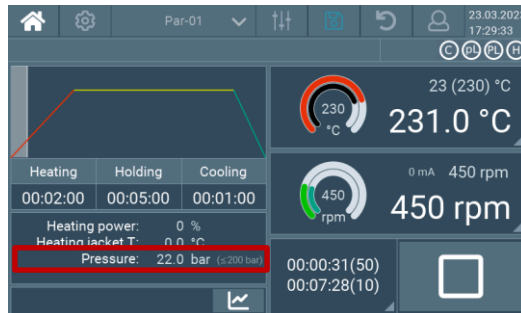
The channel for pressure measurement can be calibrated either for the 4...20mA or for the RS485 interface with the appropriate tools. The schematic of the signal processing is shown below:



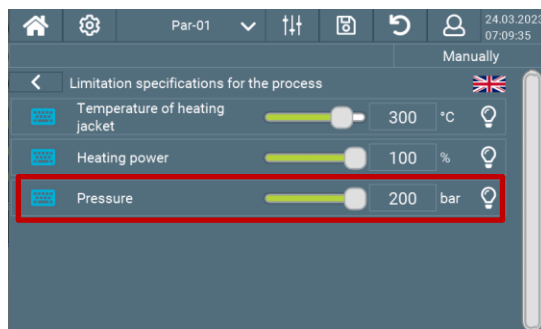
To set the calibration values, the user must be logged in as **SYSADMIN**. Under **system Parameter** → **Calibration**, the menu for calibration and the corresponding channel can be selected. By changing the values for slope and offset, the measuring chain can be calibrated.

5.5.4. Usage

The measured values of the pressure sensor are displayed in the monitoring area.



A pressure limit can be set under **parameter settings** → **Limitation specification for the process**. The value set here is displayed in brackets behind the pressure value in the monitoring values area (see above). **bar (≤ 200 bar)**



As a result, the controller switches off the heating power when the pressure limit is reached and activates cooling if necessary. A delayed reaction of the temperature curve can lead to temperature overshoots and undershoots and thus possibly also to the pressure limit being exceeded. Overshoots can be reduced by using slow temperature curves, e.g. a temperature ramp as a default.



The function "pressure limit" is **not** an exact **pressure control** but a **cut-off**. The pressure limit must be selected with a sufficient distance to the maximum permissible pressure (due to rupture disc, reactor specification, ...), as exceeding the set pressure limit cannot be guaranteed.

5.6.

5.6. Autotuning/ Control parameters

**Observe max. operating temperatures**

When operating the BRHS, always observe the maximum permissible operating temperatures of the pressure vessels to be heated!

**Heating of pressure vessels with PTFE lining**

Pressure vessels with PTFE lining may only be heated to higher temperatures under a minimum pressure of approx. 5 bar. This pre-pressure can be generated with nitrogen or other gases.

**Hot Surface!**

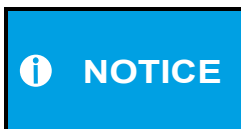
The heating area of the device can reach very high temperatures on the surface, depending on the setpoint temperature. Do not touch the marked upper area and adjacent areas with your hand to avoid burns. Use personal protective equipment.

**Hot Surface!**

The heating area of the device can reach very high temperatures on the surface, depending on the setpoint temperature. It is essential that non-heat-resistant cables, etc. do not come into contact with these areas!



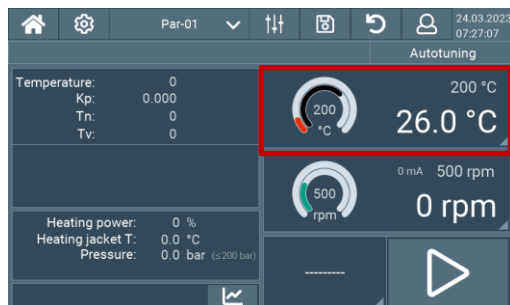
The supply air in the floor area for the integrated ventilation/cooling is ensured by the feet to a level installation surface. This supply air area must not be closed and would lead to damage to the device.



The ventilation openings in the upper area of the device must be free at all times. Closing the openings may cause damage to the device.

Autotuning is a procedure for determining the PID parameters of a given system at a given temperature. This makes it possible to take into account the versatile configuration options of reactor, heating, stirring, medium, PTFE lining, lid assemblies, etc.

An oscillation around the set temperature value is induced and the PID parameters are determined from the process. For this purpose, the desired target temperature is set in auto-tuning mode and the run is started.



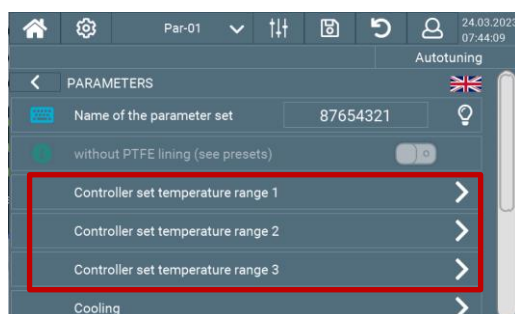
Depending on the dynamics of the system and the set temperature, autotuning can take between a few minutes and several hours. During autotuning, set pressure limits and jacket temperature limits are also taken into account and the heating is switched off if necessary. If the control has to intervene when limit values are exceeded, the PID control set can still be useful for the later applications.

⚠ DANGER

Due to the way in which the control parameters are determined in auto-tuning, possibly high overshoots can occur, depending on the dynamics of the system and the selected temperature range. The maximum permissible temperatures of the components used and the maximum permissible pressure of the reactor must be taken into account. Limits can be set for the heating jacket temperature (option) or the internal pressure.

It is advisable to start with lower temperatures in order to recognise the level of overshoots and then increase the temperature in small steps if the overshoots do not pose a problem.

Once the run is complete, the PID values are displayed on the left-hand side. The controller sets can be configured via the **Parameter settings** button . A total of three different controller sets for different temperatures can be entered, saved, and activated or deactivated depending on the application. At least one controller set must be active.



Each parameter set consists of the temperature and the three PID values (Kp, Tn, Tv).



The parameter set that is closest to the current setpoint temperature is always used for control. When running a ramp, the setpoint temperature is the temperature after the ramp. This means that the active controller set changes during a sequence with different holding temperatures. If a sequence is run with several holding temperatures, it makes sense to carry out an autotuning for exactly these temperatures and to store the PID values as controller sets (up to 3).

The PID parameters define the temperature control characteristics of the system. A distinction is made whether a reactor is operated with or without a PTFE lining, as this has a major influence on the controllability of the system.

For the various reactor sizes and types, standard values are already stored, which can be used to achieve useful results even without autotuning procedures. These apply to standard applications with an aqueous medium, approx. 3/4 filled containers and stirring switched on.



The control of PTFE-lined autoclaves requires completely different control parameters due to the very slow response of the controlled system. Corresponding PID parameters can be called up for the individual reactor types in the BRHS.

5.7. Heating and Cooling

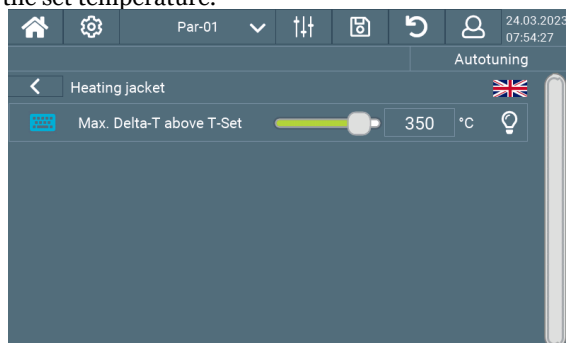
5.7.1. Heating

Settings for the heating jacket can be made via **System parameters** → **heating jacket**.

The integrated heating has a self-resetting, independent safety temperature switch. This interrupts the heating current at a heating block temperature of approx. 350°C. The heating current is reactivated as soon as the temperature has dropped by approx. 100°C.

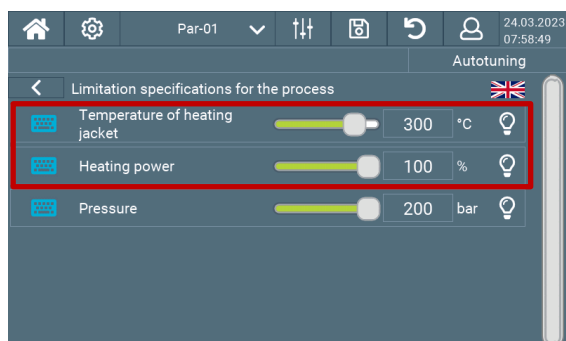
This safety temperature switch ensures that the heating system is intrinsically safe and that no uncontrolled heating can take place. The controller reduces the heating power in time so that the switching temperature of the safety temperature switch is not exceeded during normal operation. This results in a maximum heating jacket temperature of 350°C.

Furthermore, it is possible to set a maximum temperature difference between the reactor temperature and the set temperature.



This ensures that the heating jacket temperature and the reactor temperature are not too far apart, especially in very slow systems, so that overshooting can be avoided.

Limit values for the maximum permissible heating jacket temperature and the heating power can be set via **parameter settings** → **Limit settings**.



In addition to the control parameters, these setting options can be used, for example, to avoid overshoots by limiting the heating power or jacket temperature. In particular, if temperature increases are caused by the reaction of the medium.

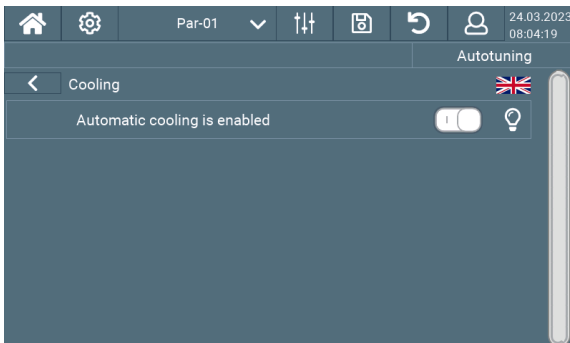
Furthermore, it can be prevented that installed PTFE components are overheated and damaged (e.g. limitation to 230°C).

The limit of the heating jacket temperature must be higher than the setpoint for the reactor temperature to be reached (approx. 50°C higher), otherwise the desired temperature in the reactor cannot be reached.

5.7.2. Cooling

The BRHS has an internal fan that can be switched on for active cooling of the heating block if required. As counter-cooling for fast control operations, the cooling is then also switched on when the heating is still active. In terms of sustainability and energy saving, please check whether these fast control processes are required for your system.

The use of the fan can be configured via **parameter settings → Cooling**. You can select whether the automatic cooling should be used in this parameter set.



If the automatic cooling is deactivated, this applies to all modes (Manually, Ramp, Sequence, Autotuning). With automatic cooling deactivated, other PID values are determined in Autotuning, as the cooling behavior of the system changes as a result.

5.8.

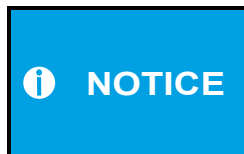
5.8. Process Configuration / Control

5.8.1. General



Observe max. operating temperatures

When operating the BRHS, always observe the maximum permissible operating temperatures of the pressure vessels to be heated!



Heating of pressure vessels with PTFE lining

Pressure vessels with PTFE lining may only be heated to higher temperatures under a minimum pressure of approx. 5 bar. This pre-pressure can be generated with nitrogen or other gases.



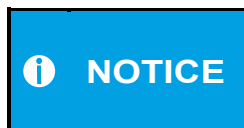
Hot Surface!

The heating area of the device can reach very high temperatures on the surface, depending on the setpoint temperature. Do not touch the marked upper area and adjacent areas with your hand to avoid burns. Use personal protective equipment.

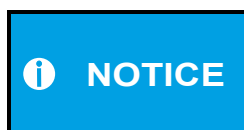


Hot Surface!

The heating area of the device can reach very high temperatures on the surface, depending on the setpoint temperature. It is essential that non-heat-resistant cables, etc. do not come into contact with these areas!

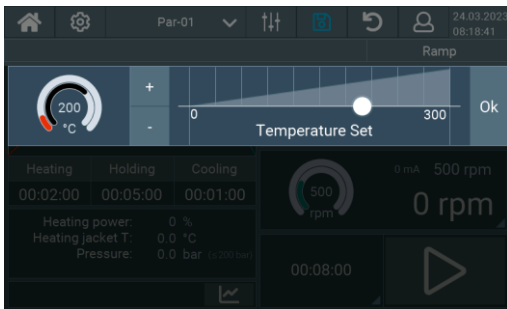


The supply air in the floor area for the integrated ventilation/cooling is ensured by the feet to a level installation surface. This supply air area must not be closed and would lead to damage to the device.



The ventilation openings in the upper area of the device must be always free. Closing the openings may cause damage to the device.

To start a heating process, one of the three modes: Manual, Ramp, Sequence can be called up. On the right-hand side, pressing the upper button calls up the slider for setting the target temperature. By moving the slider, the temperature can be selected and by pressing the + or - button, the fine adjustment can be made. Pressing the buttons for a long time starts a fast run of the temperature. Pressing **Ok** ends the entry and the value is accepted. Tap next to the item in the dark area to cancel the entry. The black arc above the numerical value indicates where the temperature is in the selectable temperature range.

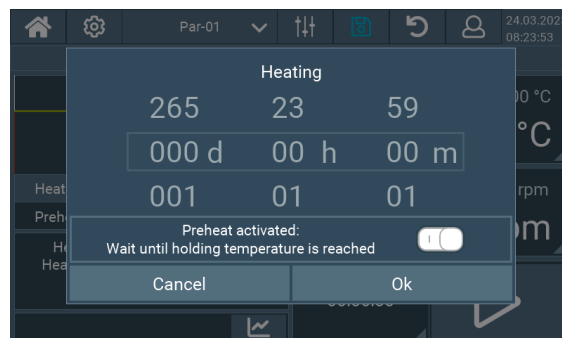
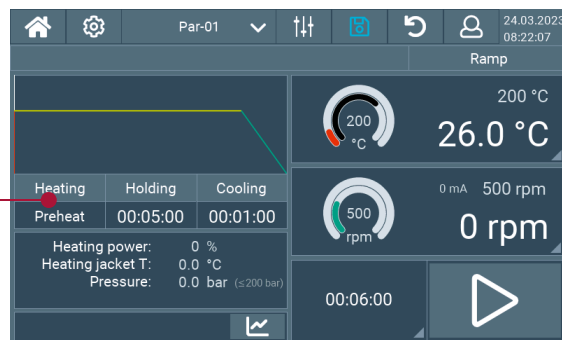


The controller will approach this temperature differently (ramp or direct) depending on the mode selected. As long as no run has been started, the current measured values of the sensors are already displayed.

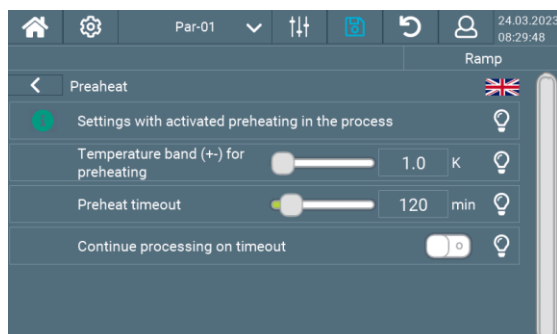
5.8.1.1. Preheating

For the ramp and sequence modes, there is the option of activating the so-called **preheating**. Preheating is used instead of a fixed ramp time to approach a target temperature. In this case, the hold time of the program only starts when the reactor temperature is within a defined temperature band around the set temperature.

Preheating activated

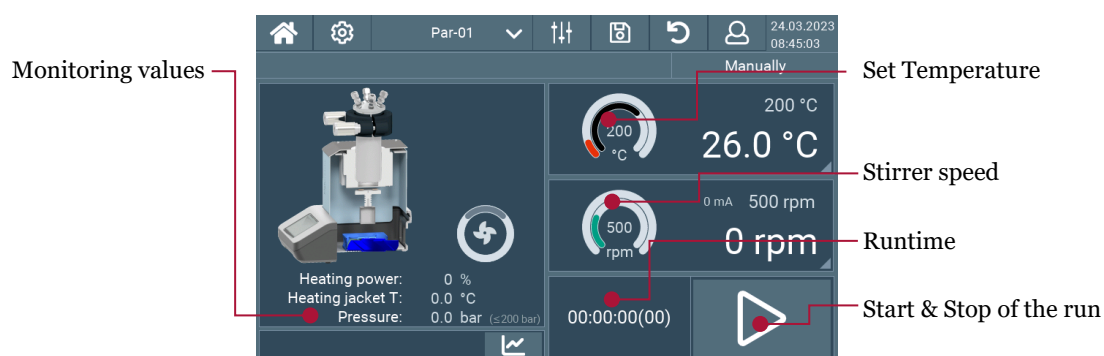


The advantage of this function is that the set temperature is reached as quickly as possible and is then maintained for the defined period (hold time). Under **parameter settings → Preheating**, the width of the temperature band from which the runtime starts can be set, as well as the termination conditions if the target temperature is not reached.



5.8.2. Mode *Manually*

In the Manually mode, simple processes can be carried out, which are started and stopped manually. For this purpose, the temperature and speed of the stirrer motor can be selected and, if necessary, also changed during the sequence. The cooling can be activated manually by pressing the  button.



The runtime in this mode is unlimited and is started and stopped manually by the user. The set temperature is approached as quickly as possible according to the PID parameters for this temperature. Overshoots of the temperature can occur.

5.8.3. Mode Ramp

In the **Ramp** mode, three phases of the sequence can be programmed: A heating phase (or preheating phase), a holding phase and a cooling phase. By pressing the buttons below the ramp graphic, the times of the individual steps can be configured.



The time can be set in each case by scrolling.



Under **System settings** → **General**, the start temperature of the ramp can be preset. You can choose between a fixed base temperature and the current temperature of the reactor. This results in different starting points for the ramp and thus also different heating rates for the same ramp time. The set temperature and the time for the heating or cooling phase determine the gradient of the heating or cooling ramp. The duration of a heating ramp must be set flatter than the fastest possible heating rate.

The set temperature of the current time step is displayed above the currently measured temperature. A set speed is approached directly according to the settings in the **system settings** → **Stirring drive** and is not taken into account in the ramp calculation.

In the area at the bottom right, the remaining running time and the current running time of the sequence are displayed. Pressing the runtime field toggles between the times. Once all setpoints have been set, the sequence can be started by pressing the start button.

By programming a ramp to a desired set temperature, overshoots can be avoided.

The current time in the sequence is indicated by a time marker in the diagram area. During the sequence, it is possible to change set values directly.

The graphical progression of various parameters can be viewed via the button .

		Resetting the graphic settings to default
	   	Scroll forwards and backwards (page by page or according to scale element)
		Zoom settings time axis

5.8.4. Mode Sequence

In **Sequence** mode, several sequence steps can be configured. There are a total of five sequence pairs, each consisting of a heating or cooling phase and a holding phase. By pressing and holding the time for the respective sequence step in the left-hand area, the time selection can be opened, and the days, hours and minutes of the step can be set by scrolling.

Sequence Steps 1-5

Remaining run time or duration of the program

Set temperature current sequence step

Set stirrer speed current sequence step

The time values in the left-hand area and the control values in the right-hand area are each represented by colored markings. A set temperature and a stirring speed can be entered for each sequence step. The control values are displayed together in the left-hand area for each step.

170 °C	0 rpm	100 bar
190 °C	300 rpm	100 bar
230 °C	450 rpm	100 bar
260 °C	450 rpm	100 bar
20 °C	450 rpm	100 bar

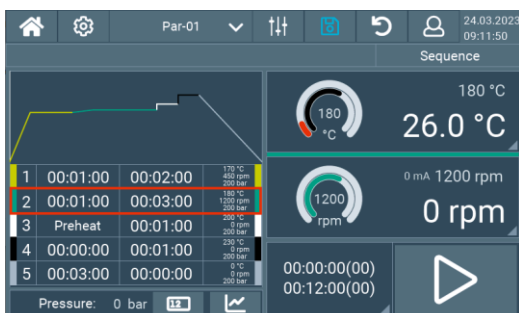
During the run, a time marker shows the current progress of the program.

The button can be used to view the graphical progression of various parameters.



	Resetting the graphics settings to default
	Scroll forwards and backwards (page by page or according to scale element)
	Zoom settings time axis

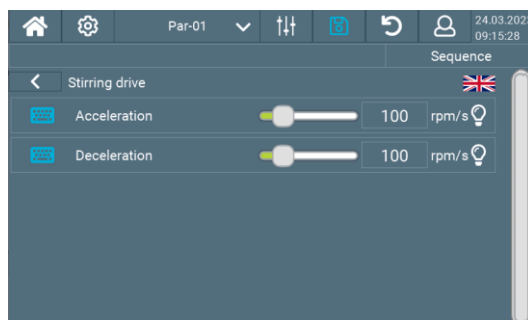
The monitoring values can be viewed via the button



5.9. Stirring

5.9.1. Configuration

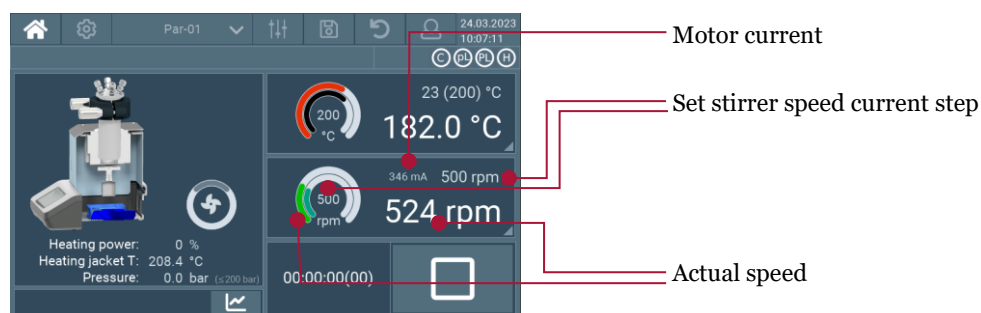
The stirrer drive can be configured via **system parameters** → **Stirrer drive**.



The acceleration and deceleration of the stirrer motor can be adjusted.

5.9.2. Usage

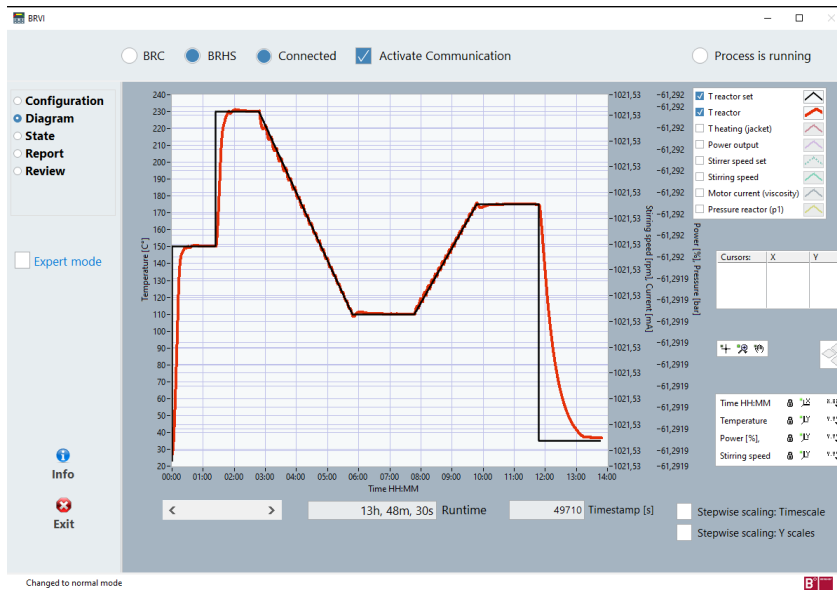
The set stirrer speed is selected analogue to the set temperature via the slider. When programming a ramp or a sequence, the speed is not increased or decreased according to the ramp time, but according to the configuration of the acceleration and deceleration ramp. For multi-step sequences, a different speed can be set for each step of the sequence. The information on the stirring is displayed in the right-hand area. The target speed below the arc is displayed in Rpm. The current motor current is displayed to the right. This can be observed as an indicator for viscosity changes. To the right above the currently measured actual speed, the target speed for the current time step is displayed.



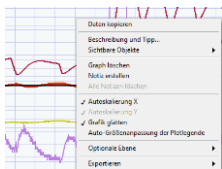
5.10. BRVI Datalogging

After starting the BRVI program, the following display appears on the screen.

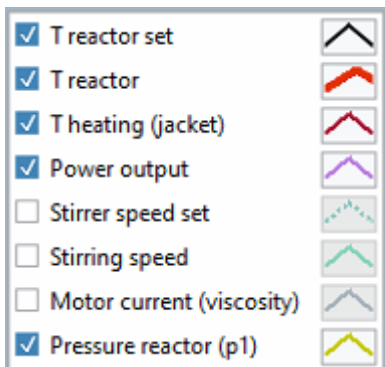
Temperature, pressure and power curves can be viewed individually, enlarged or reduced on the screen using the magnifying glass functions and copied to the clipboard for transfer to other programs (e.g. word processing).



During a sequence, an advanced display can be achieved through a stepwise scaling adjustment.



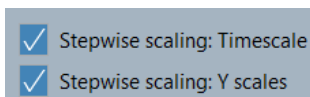
Right-clicking on the diagram gives access to display and export functions.



Select which curves are to be displayed in the diagram by activating the monitoring value ☒.

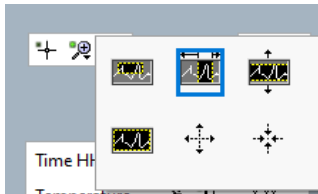
A basic setting (after starting the program) can be made in the "Configuration" area.

Clicking with the left mouse button on the diagram symbol  enables the individual display of the respective data curve.



During a sequence, an improved complete display can be achieved by adjusting the scaling step by step.

If a zoom operation is to be carried out in the diagram during the sequence, the respective element (Timescale, Y) should be deactivated beforehand.



Zoom options are available via the palette shown.
By performing a zoom, the automatic scaling of the diagram is deactivated. This can be recognized by the open lock symbol .

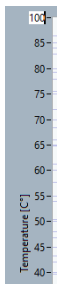
Time HH:MM			8.88
Temperature			9.99
Power [%]			9.99
Stirring speed			9.99



With  and holding the left mouse button in the diagram, the display area can be shifted during a zoom display.

Time HH:MM			8.88
Temperature			9.99
Power [%]			9.99
Stirring speed			9.99

Click on the lock symbol  to automatically scale the corresponding axis again so that the symbol  (completed lock) appears.



Change the scale range by entering values directly in the scale.

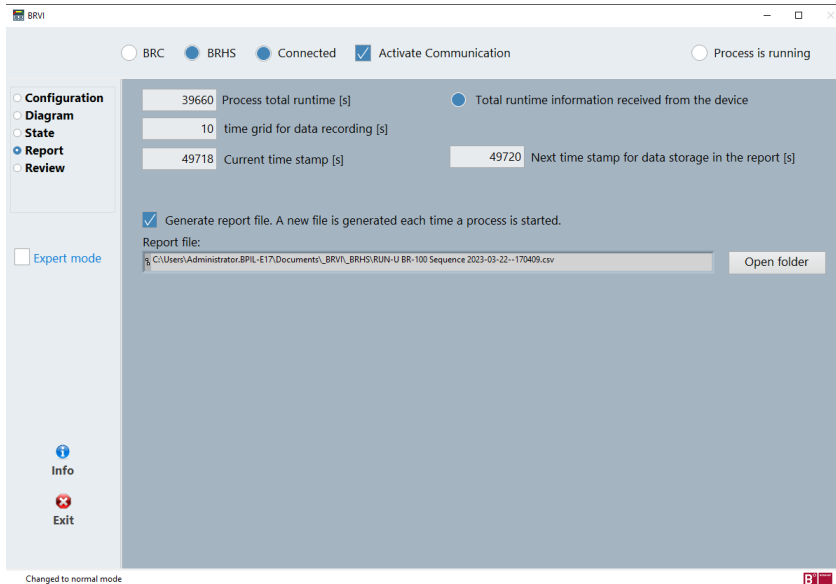


Cursors:	X	Y
 Cursor	00:00	0

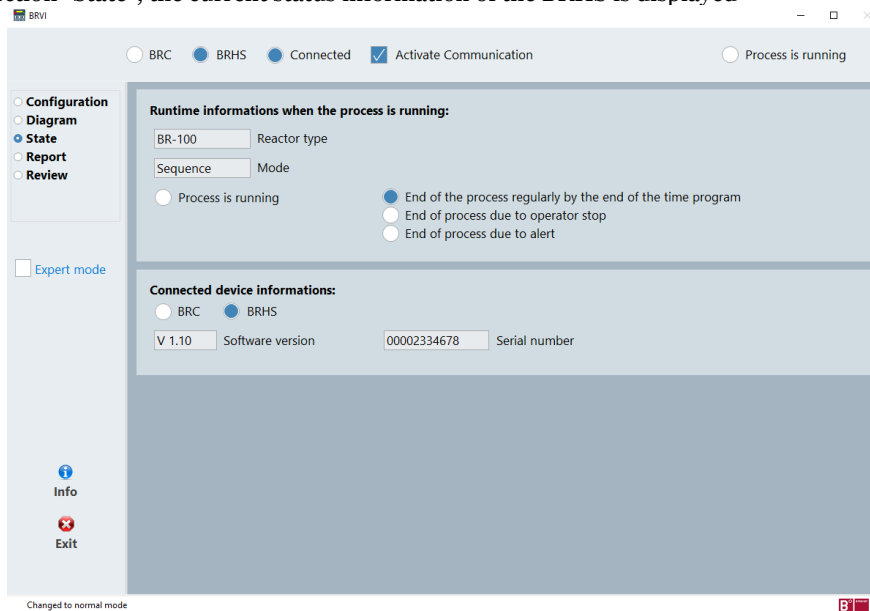
Create a cursor (right mouse button on the field) that can display single values of a selected axis.

The cursor position can be moved with the elements .

The recorded data is continuously stored in a .csv file in the specified storage location. Each program start creates a new .csv file. The .csv file can also be read in and evaluated with MS-Excel®, for example.



With the selection "State", the current status information of the BRHS is displayed



By selecting "Review", report files that have already been saved can be read in again. However, files saved in expert mode cannot be opened here (see following chapter).

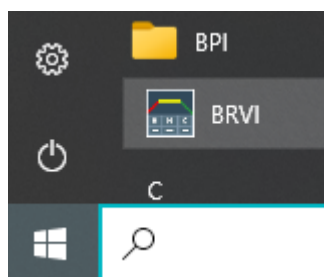


5.10.1. Installing BRVI

The PC application for Windows is supplied on a USB stick and can be installed by executing the file "setup.exe". The system requirements are Windows 7 SP1 or newer and a USB connection. Follow the installation instructions. Administrator rights are required for the installation.

5.10.2. Starting BRVI

Start the application by clicking on  and the icon  in the Windows start bar in the BPI directory.



5.10.3. Connect BRHS

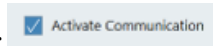
To establish a connection between the PC software BRVI and the BRHS, it may be necessary to adjust the COM port of the software.

To do this, the BRHS is connected to the computer via a mini-USB cable.

Under Windows, the number of the COM port can be found via **Settings → Devices >→ Device Manager**. By switching on the BRHS, the COM port appears in the device manager and disappears again after switching off the BRHS.

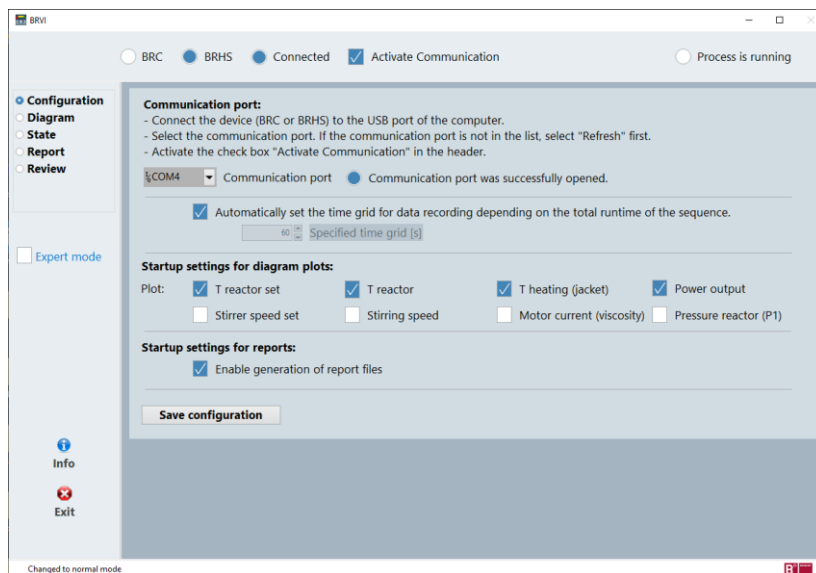
The COM port number can be set in the **Configuration** menu.

After setting the correct COM port, the connection must be activated once in the header



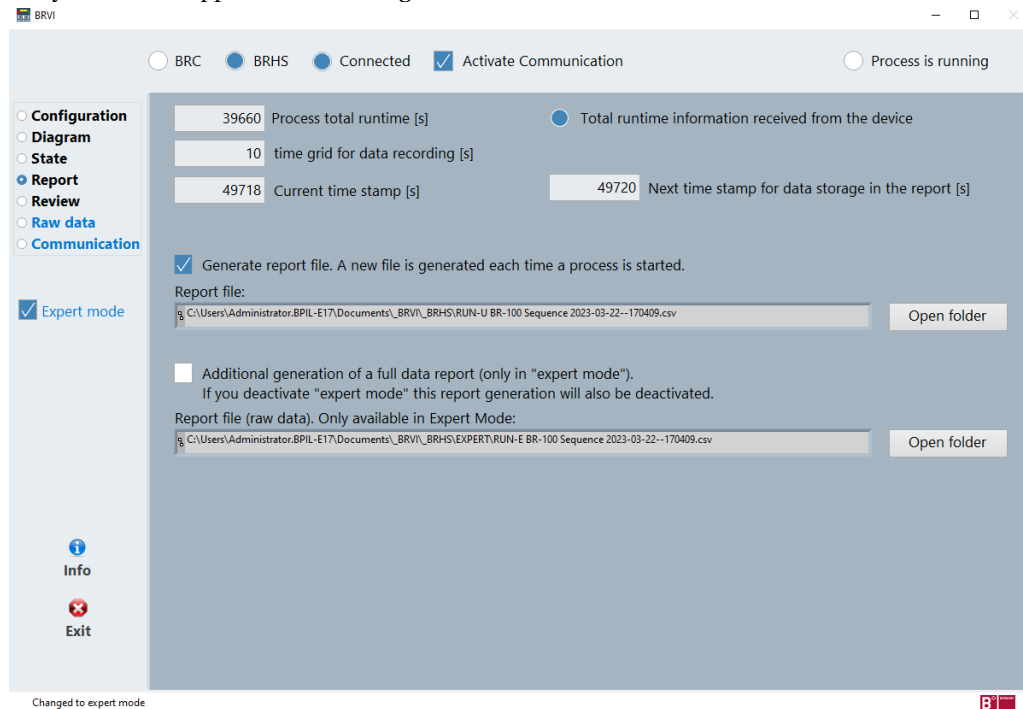
5.10.4. Configuration menu

In the **Configuration** menu, program settings can be made and saved.

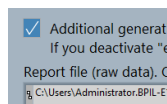


5.10.5. Expert mode

By activating the expert mode ☒ **Expert mode** in the left sidebar, further selections are available. These are particularly useful for support from the Berghof Products + Instruments GmbH service.



Under **Report** an extended report file can be recorded as a .csv file. Since this file generates a lot of data, it must be selected after each program start (BRVI).



Please note that this file cannot be opened with **Review**. The evaluation and viewing can be done e.g., with MS-Excel© or other text editors. The files can be identified by the file name "RUN-E....".

Under **Raw data** the raw data received from the BRHS are displayed

BRVI

☐ BRC ☒ BRHS ☒ Connected ☒ Activate Communication ☐ Process is running

Configuration
Diagram
State
Report
Review
Raw data
Communication

☒ Expert mode

Header raw data 1 **Raw data 1** **Header raw data 2** **Raw data 2** **Header raw data 3** **Raw data 3**

60 s

Changed to expert mode

Under **Communication**, the communication between BRHS and BRVI is logged and displayed for diagnostic purposes.

BRVI

☐ BRC ☒ BRHS ☒ Connected ☒ Activate Communication ☐ Process is running

Configuration
Diagram
State
Report
Review
Raw data
Communication

☒ Expert mode

Communication read buffer:

#1(24.03.2023@10:41:46.453 [5] LEO3: Value: 19.312866

Communication data:

#1(24.03.2023@10:41:43.199 [5] LEO3: Value: 19.341448
 #1(24.03.2023@10:41:43.980 [5] >> #NWMCW:10
 #1(24.03.2023@10:41:44.000 [5] LEO3: F73 ... [OK]
 #1(24.03.2023@10:41:44.000 [5] LEO3: Channel: 1
 #1(24.03.2023@10:41:44.808 [5] LEO3: Value: 19.398615
 #1(24.03.2023@10:41:44.808 [5] LEO3: F73 ... [OK]
 #1(24.03.2023@10:41:44.808 [5] LEO3: Channel: 1
 #1(24.03.2023@10:41:44.808 [5] LEO3: Value: 19.341448
 #1(24.03.2023@10:41:45.617 [5] LEO3: F73 ... [OK]
 #1(24.03.2023@10:41:45.617 [5] LEO3: Channel: 1
 #1(24.03.2023@10:41:45.617 [5] LEO3: Value: 19.341448
 #1(24.03.2023@10:41:46.453 [5] LEO3: F73 ... [OK]
 #1(24.03.2023@10:41:46.453 [5] LEO3: Channel: 1
 #1(24.03.2023@10:41:46.453 [5] LEO3: Value: 19.312866

Delete data display ☒ Automatic data scroll Save communication data to file

Process cycle data (1s cycle):

Last destroyed message:

Data logging path:
 C:\Users\Administrator\BPI-E17\Documents\BRVI\SYS\Log\Common

Open folder

Message Error Count: 0

Changed to expert mode

6. Maintenance, troubleshooting and service



Hot surface!

The heating area of the device can reach very high temperatures on the surface, depending on the setpoint temperature. Do not touch the marked upper area and adjacent areas with your hand to avoid burns. Use personal protective equipment.



Hot surface!

The heating area of the device can become very hot on the surface depending on the setpoint temperature. It is imperative that non-heat-resistant cables, etc. have no contact with these areas!

6.1. Maintenance

The BRHS does not require any maintenance.

6.2. Cleaning

Do not use aggressive cleaning agents to clean the device, but only wipe it with a dry or damp cloth.

Clean the air inlet openings on the underside of the appliance with a lint-free cloth, Hoover or hand brush.

6.3. Error notes

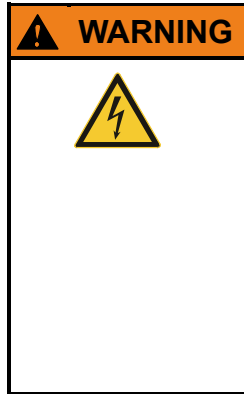
Error description	Cause	Remedy
Device does not heat	Overtemperature switch in the heating system has switched off.	Do not set the target temperature too high (<250°C for reactors with PTFE lining).
	Heating system not connected to controller	Check connection cable and plug
Instrument fuse triggers	Short circuit in the device	Send device to the manufacturer for inspection.
Strong control deviations, strong overshoot	Unfavorable choice of parameters	Optimize control parameters with autotuning
	Temperature sensor defective	Replace defective parts

Technical support is available from your regional Berghof dealer or directly from Berghof Products + Instruments GmbH at:

Berghof Products + Instruments GmbH
 Arbachtalstraße 9/2
 72800 Eningen
 Germany
 T +49.7121.894-170
 F +49.7121.894-300
 E-Mail: service.bpi@berghof.com
www.berghof-instruments.com

Please state the serial number of your device in all repair enquiries or repair orders. You will find it on the type plate.

6.4. Repairs / customer service



Device uses mains voltage AC 230V!

The device must always be connected to a protective earth conductor. The connection from the device to the power source must always be made using a three-wire cable with a protective earth conductor.

Only use approved mains cables.

The socket used must be freely accessible at all times.

The device must not be put into operation if it is damaged.

Repair and service work may only be carried out by appropriately trained and qualified personnel of Berghof Products + Instruments GmbH.

The device may only be operated at a socket with a maximum fuse rating of 10A on the building side.

Technical support and information on spare parts (order no. and prices) can be obtained from your regional Berghof dealer or directly from Berghof Products + Instruments GmbH at:

Berghof Products + Instruments GmbH
Arbachtalstraße 9/272800 Eningen
Germany
T +49.7121.894-170
F +49.7121.894-300
E-Mail: service.bpi@berghof.com

Please state the serial number of your device in all repair enquiries or repair orders. You will find it on the type plate.

7. Appendix

7.1. Declaration of conformity

DECLARATION OF CE-CONFORMITY		P. 1/1								
BRHS Berghof Heating-Stirring-System										
Manufacturer	Berghof Products + Instruments GmbH Arbachtalstraße 26 D - 72800 Eningen									
Product	BRHS – Berghof Heating-Stirring-System Part numbers: 10006072 BRHS-25, 10006073 BRHS-40, 10006074 BRHS-100, 10006076 BRHS-200, 10006077 BRHS-300									
This declaration of conformity is issued under the sole responsibility of the manufacturer. The object of the declaration described above is in conformity with the relevant Union Harmonisation Legislation: Low Voltage Directive (LVD) 2014/35/EU EMC Directive 2014/30/EU RoHS Directive 2011/65/EU The following harmonized standards and technical specifications have been applied: <table border="1"> <tbody> <tr> <td> Safety requirements for electrical equipment for measurement, control and laboratory use Part 1: General requirements </td> <td>IEC 61010-1:2010/AMD1:2016</td> </tr> <tr> <td> Safety requirements for electrical equipment for measurement, control and laboratory use Part 2-010: Particular requirements for laboratory equipment for the heating of materials </td> <td>IEC 61010-2-010:2019</td> </tr> <tr> <td> EMC – Generally </td> <td> Professional equipment. The equipment is suitable for use in all establishments other than domestic and those directly connected to a low voltage power supply network which supplies buildings used for domestic purposes (Class A). </td> </tr> <tr> <td> Electrical equipment for measurement, control and laboratory use – EMC- requirements Part 1: General requirements </td> <td> EN 61326-1:2013 IEC 61326-1:2012 </td> </tr> </tbody> </table>			Safety requirements for electrical equipment for measurement, control and laboratory use Part 1: General requirements	IEC 61010-1:2010/AMD1:2016	Safety requirements for electrical equipment for measurement, control and laboratory use Part 2-010: Particular requirements for laboratory equipment for the heating of materials	IEC 61010-2-010:2019	EMC – Generally	Professional equipment. The equipment is suitable for use in all establishments other than domestic and those directly connected to a low voltage power supply network which supplies buildings used for domestic purposes (Class A).	Electrical equipment for measurement, control and laboratory use – EMC- requirements Part 1: General requirements	EN 61326-1:2013 IEC 61326-1:2012
Safety requirements for electrical equipment for measurement, control and laboratory use Part 1: General requirements	IEC 61010-1:2010/AMD1:2016									
Safety requirements for electrical equipment for measurement, control and laboratory use Part 2-010: Particular requirements for laboratory equipment for the heating of materials	IEC 61010-2-010:2019									
EMC – Generally	Professional equipment. The equipment is suitable for use in all establishments other than domestic and those directly connected to a low voltage power supply network which supplies buildings used for domestic purposes (Class A).									
Electrical equipment for measurement, control and laboratory use – EMC- requirements Part 1: General requirements	EN 61326-1:2013 IEC 61326-1:2012									
Eningen, March 21, 2023 Date	 Dr. Dieter Gutwerk CEO									



Berghof Products + Instruments GmbH | Arbachtalstraße 26 | 72800 Eningen | www.berghof.com
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7.2. Conversion of units

Conversion of units			
Description	Units	Conversion	
Temperature	°C =	$(^{\circ}\text{F} - 32^{\circ}) / 1.8$	
	°F =	$1.8 * ^{\circ}\text{C} + 32^{\circ}$	
Length	1 cm =	0.3937 inch	
	1 inch =	2.540 cm	
Volume	1 ml =	0.06102 inch ³	= $2.642 * 10^{-4}$ gallon
	1 inch ³ =	16.387 ml	= $43.29 * 10^{-4}$ gallon
	1 gallon =	3785 ml	= 231 inch ³
Pressure	1 bar =	14.504 psi	= 0.1 MPa
	1 psi =	0.06895 bar	= 0.0068948 MPa
	1 MPa =	10 bar	= 145.04 psi
Weight	1 kg =	2.2046 lb.	
	1 lb. =	0.4536 kg	

7.3. Abbreviations

Plastics	
Abbreviation	Full name
PE	Polyethylene
PEEK	Polyether ether ketone
PFA	Perfluoralkoxy
PTFE	Polytetrafluoroethylene
TFM TM -PTFE	modified Polytetrafluoroethylene
PP	Polypropylene