

Operating Instructions

Stirling Generator Type Gen70-00-100-00
Experimental Edition I
alphagamma® Technologie

www.frauscher-motors.com

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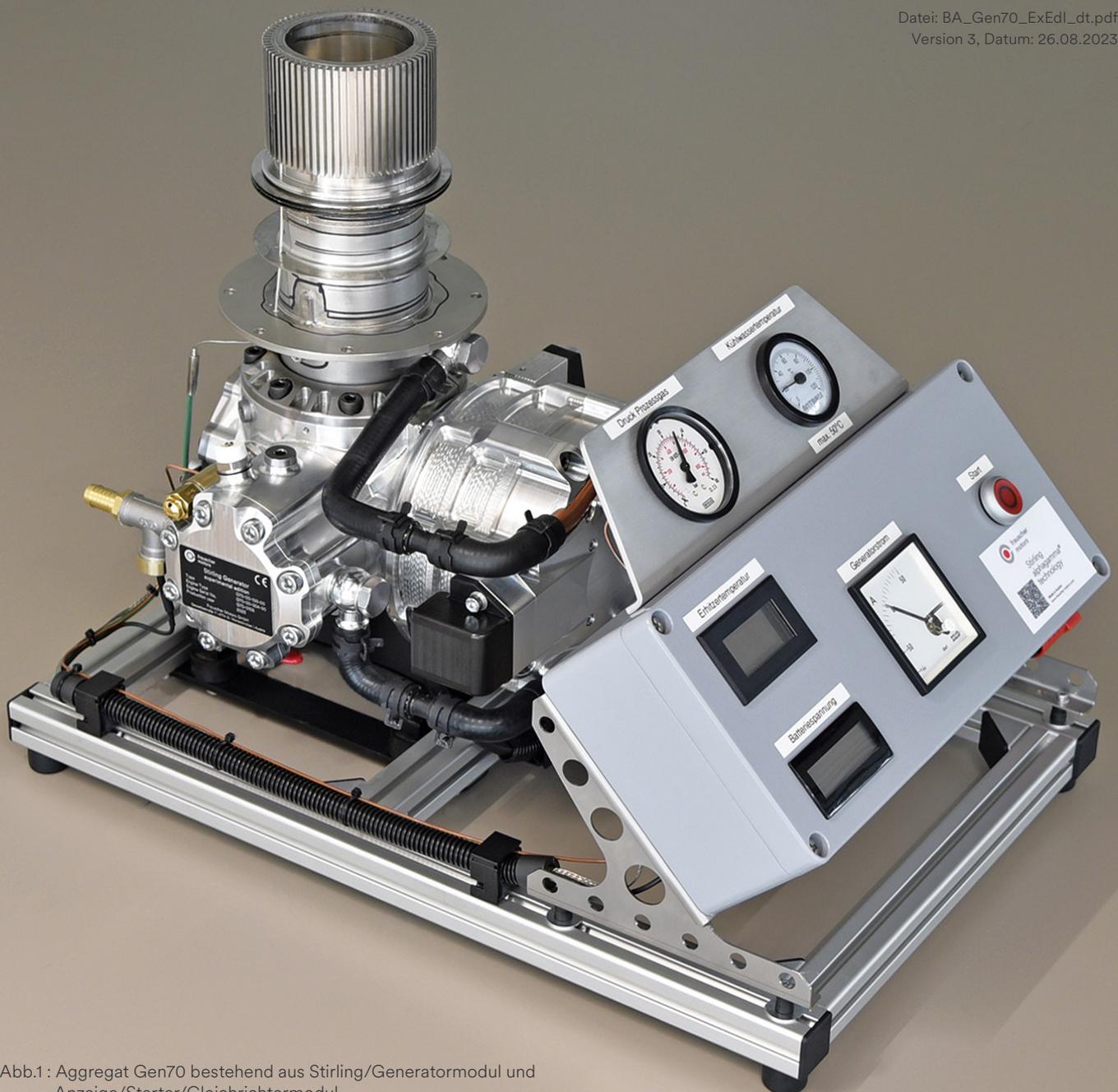


Abb.1: Aggregat Gen70 bestehend aus Stirling/Generatormodul und Anzeige/Starter/Gleichrichtermodul

Preliminary remarks:

Congratulations on the purchase of a world first product in the Stirling engine sector. It is the result of more than 20 years of research, which we have released for the market after many thousands of operating hours on our test benches. Maintenance-free continuous operation without complex oil lubrication is just one of several remarkable properties. The quiet operating noise and the outstanding efficiency for this performance class underline the uniqueness of this innovation. In addition, the extensive freedom in the choice of heat source also offers the possibility of using regenerative fuels. Since the combustion takes place under atmospheric conditions, exhaust gas values can be achieved which, in a positive sense, differ greatly from those of internal combustion engines.

We developed the Experimental Edition product series to support knowledge building in Stirling engine technology and its energy-related applications. We want to provide research-based companies as well as schools and universities with a highly available small unit that allows numerous experiments and further developments. Starting with the simple structure of the basic equipment, the interaction of the parameters process pressure, heater temperature, cooling water temperature, generator output and efficiency can be experimentally determined and analyzed. We have chosen a proven machine that can continuously deliver more than 1 kilowatt. This should create an incentive to develop functional supplements, for example to concentrate heat in the heater head. This creates the basis for a powerful micro CHP.

For transport safety reasons, the unit is only partially charged when delivered. The level of the process pressure determines the heat absorption at the heater head and, as a result, the electrical output power. At this point we would like to state that we are always at your side with advice and action and our greatest interest is that you find a satisfactory way of operating.

Please read these operating instructions before commissioning. Please be sure to observe the safety regulations. Handling exhaust gases, hot fuel gases, high gas pressures and glowing surfaces requires care and relevant specialist knowledge.

We thank you for the trust. If you would like more detailed information about our engines and in particular about the **alphagamma® technology**, we refer to our website www.frauscher-motors.com

I wish you every success in your experiments

Josef Frauscher and his team

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Measurement data on the test stand with liquid gas burner:

Description	Value	Unit	Comment
Motor			
Process gas			Helium
Upper process gas temperature	652	°C	
Medium process pressure	57	bar	
Swept volume	70	cm ³	Expansionsvolumen
Cylinder phase angle	90	degrees	
Power	1,46	kW	at the crankshaft
Number of revolutions	1970	1/min	
Cooling capacity	3,23	kW	
Inflow of cooling medium	30,6	°C	Range up to 50 degrees C
amount of cooling water	0,39	m ³ /h	Range 0,3 – 0,5 m ³ /h
Motor efficiency	31	%	mechanical power : heat input
Generator			
Design	3-phase		
Electrical power	1,24	kW	at 27.45 volt battery voltage
Brenner			
System			muzzle-mixing gas burner
Power	5,17	kW	lower calorific value
Fuel			propane gas
Gas pressure	50	mbar	
Air mass	17,4	kg/h	
Fan pressure	30	mbar	
Exhaust temperature	217	°C	at 25 degrees intake temperature
Emission value O ₂	8%		
Emission value CO	1,8	g/kWh	with propane operation
Emission value NO _x	1,3	g/kWh	with propane operation
Aggregat			
Typenbezeichnung			Gen70 Nr.#101
El. Gesamtwirkungsgrad	24	%	DC-power: LHV propane gas

Table 1: Measurement data, 09.08.2022 10:15, Tester Dipl. Ing. Jürgen Brandt

Safety Precautions:



The Stirling generator type Gen70-00-100-00 was developed exclusively for experimental purposes and therefore for supervised operation. The display elements on the starter/rectifier module show the physical values. Please ensure that the limit values mentioned in the following instructions are not exceeded.



When delivered, the Stirling generator is filled with working gas (helium) to approx. 20 bar; this pressure may be filled up to a maximum of 50 bar. Although the pressurized elements (housing, etc.) have been calculated and tested for multiple safety, the following safety measures must be observed:

Provide good ventilation if you install the unit in a room. Place the unit on a solid base and take precautions so that it cannot fall or be damaged by any other cause. If helium escapes during the filling process or due to improper operation or damage, you and any other people present should leave the room immediately and wait until the room is well ventilated again. Although helium is not toxic, it can displace the oxygen in the air we breathe. Helium is lighter than air and therefore rises and can be disposed of through ventilation.



The Stirling generator and the control elements are operated with low voltage and are therefore harmless if live parts are touched. However, the unit requires a battery supply, which is why the safety regulations of the battery manufacturer must be observed. In particular, the charging regulations must be observed and any gas leakage or other damage caused by overcharging the batteries must be taken into account. Ensure that the room is adequately ventilated.



The Stirling generator is not equipped with a heat generating device. According to the supply contract, the customer or user is responsible for supplying and bringing in the heat. If a burner device is used as a heat source, the customer must ensure that only an authorized company and trained personnel handle the burner device. In particular, it must be ensured that exhaust gases are routed to the outside and cannot be inhaled by people. Regional safety regulations for handling flammable gases must be observed.

Harmonization information

The Stirling Generator Type Gen70-00-100-00 Experimental Edition meets the following relevant harmonization regulations of the European Union:

- | | |
|--------------------|------------------------------|
| - EN60204 | Safety of Machines |
| - 2006/42/EG | Machinery Directive |
| - 204/68/EU | Pressure Equipment Directive |
| - <u>IEC</u> 61140 | Low Voltage Directive |

Based on this, the unit was CE marked. These operating instructions are an integral part of the declaration of conformity.



Picture 2: Type level of the engine

Explanation of terms:

Type:	Type designation of entire aggregate
Engine Type:	Type designation of the Stirling engine
Engine Serial No.:	Stirling engine serial number

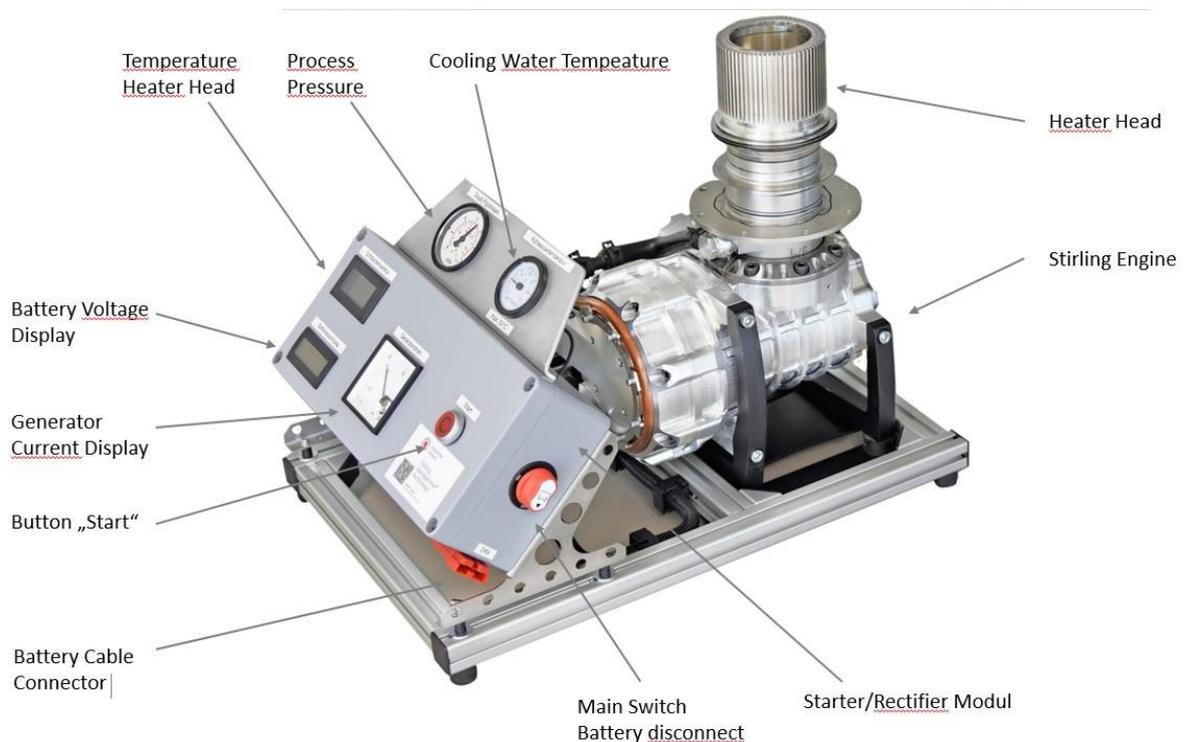
Summary information:

The Stirling generator Gen70-00-100-00 consists of the Stirling engine with built-in synchronous generator and a starter/rectifier module. The unit generates charging current for a 24 volt battery, which is also used to start the unit. A battery set consisting of 2x12 volt vehicle lead batteries with a capacity range of min. 75 Ah to max. 225 Ah is recommended. The batteries are also used to limit the speed of the unit so that operation without a battery set is not possible.

When delivered, the Stirling aggregate is filled with approx. 20 bar of helium. In this condition, the charging power will settle at around 10-15 amps once the heater core has reached its rated temperature of 650 degrees C.

Advanced users can increase the charging pressure when the unit is cold up to 50 bar. The charging capacity increases to approx. 40 amps. In this condition, the process gas inside the machine extracts a significant amount of heat from the heater head, so maintaining the appropriate 650 degree temperature rating with the added heat can be a challenge. Frauscher Motors uses specially developed nozzle-mixing gas burners, which are supplied with combustion air preheated by the exhaust gas.

Definition of terms and part designation:



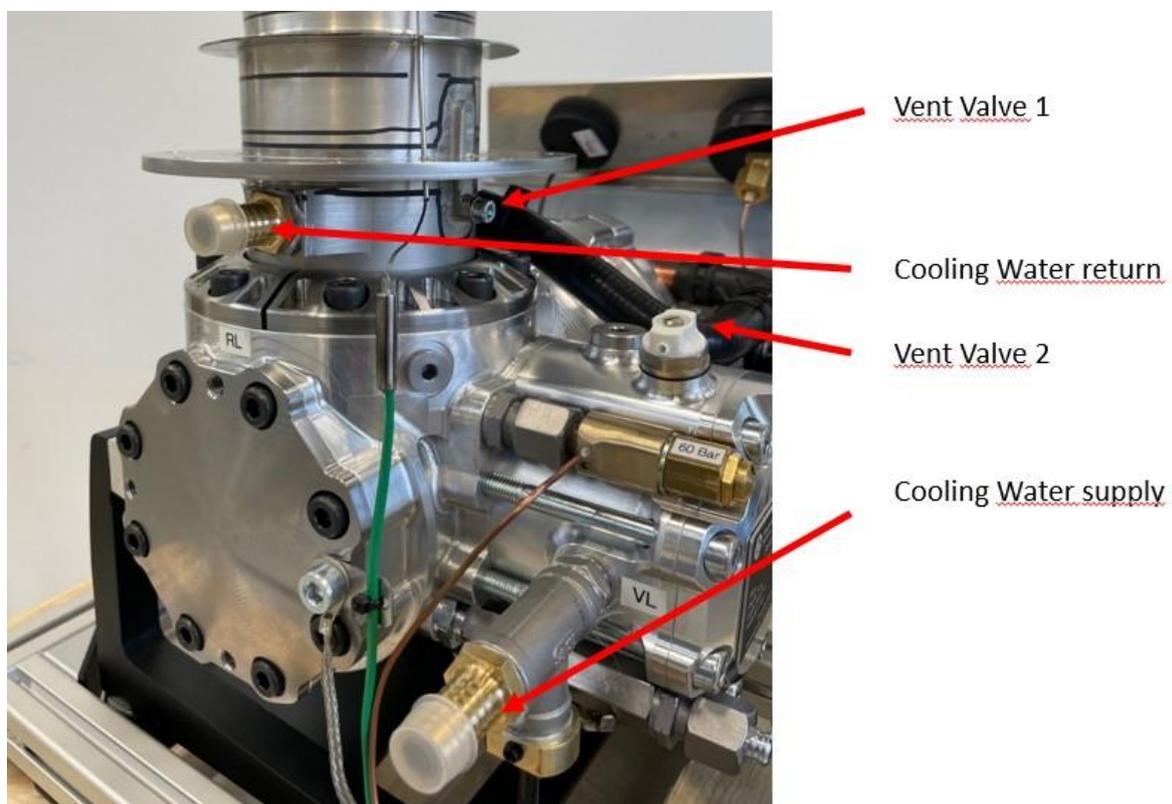
Picture 3: Definition of terms and part designation of the Stirling generator

Installation preparation:

Place the machine on a stable table in a frost-free area

Fill in the cooling water and vent (picture 4)

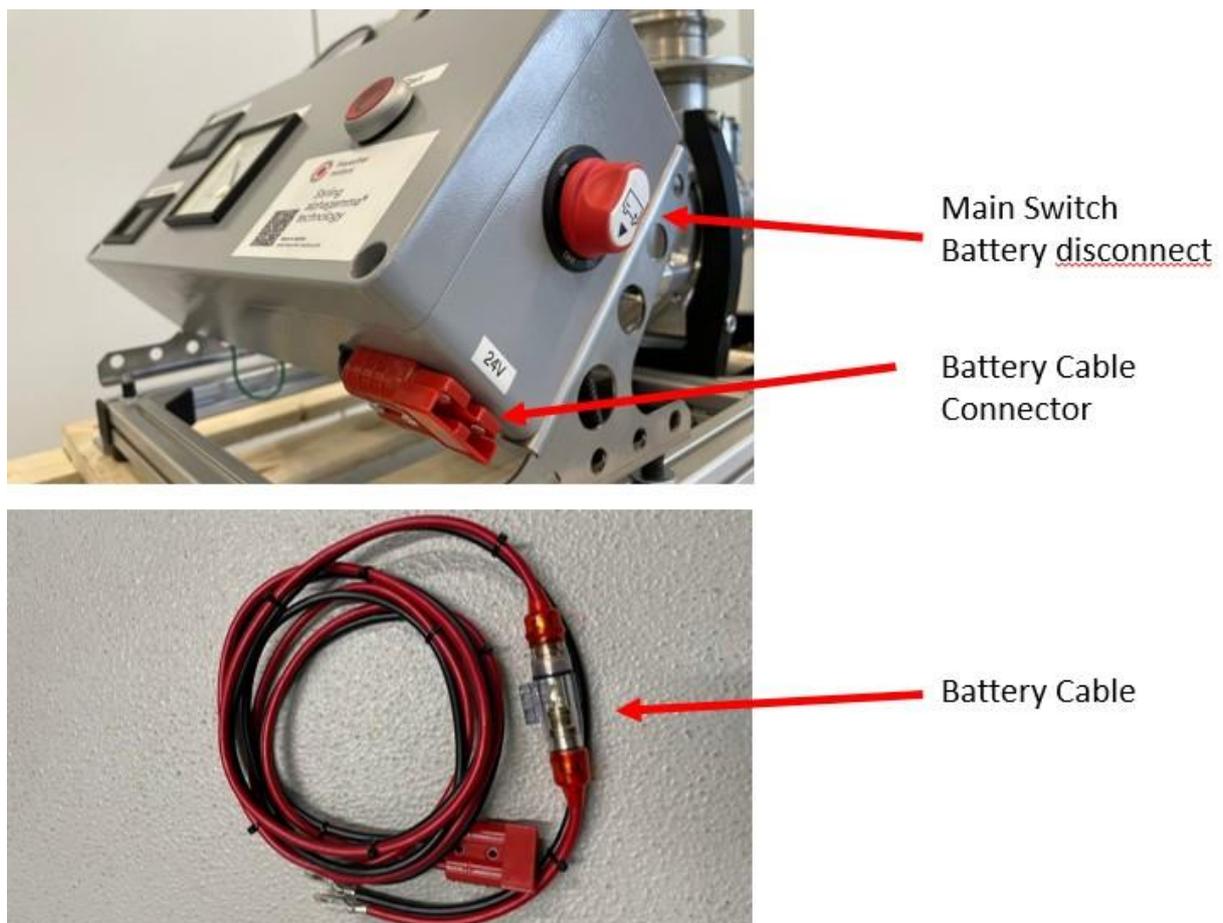
- Connect the cooling water circuit. Use pressure-resistant and heat-resistant fabric hoses on the inlet and outlet of the machine
- Make sure that the hose connections are firmly seated using the appropriate hose clamps
- Pay attention to the direction of flow inlet – outlet
- Use treated water with anti-corrosion protection, only use pure tap water for a short time
- If it is a closed circuit, use an appropriate pressure equalization tank, set a pressure of about 1-2 bar
- In the case of an open circuit (e.g. connection to mains water), ensure a back pressure of approx. 1-2 bar, for example by means of a throttle point in the drain area
- Ensure a flow of cooling water by means of a circulation pump or by opening the water tap –
- vent the machine several times at the designated points while the cooling water circuit is active at a pressure of 1-2 bar.



Picture 4: Cooling water connections and vent valves

Electrical connection (see Picture 5):

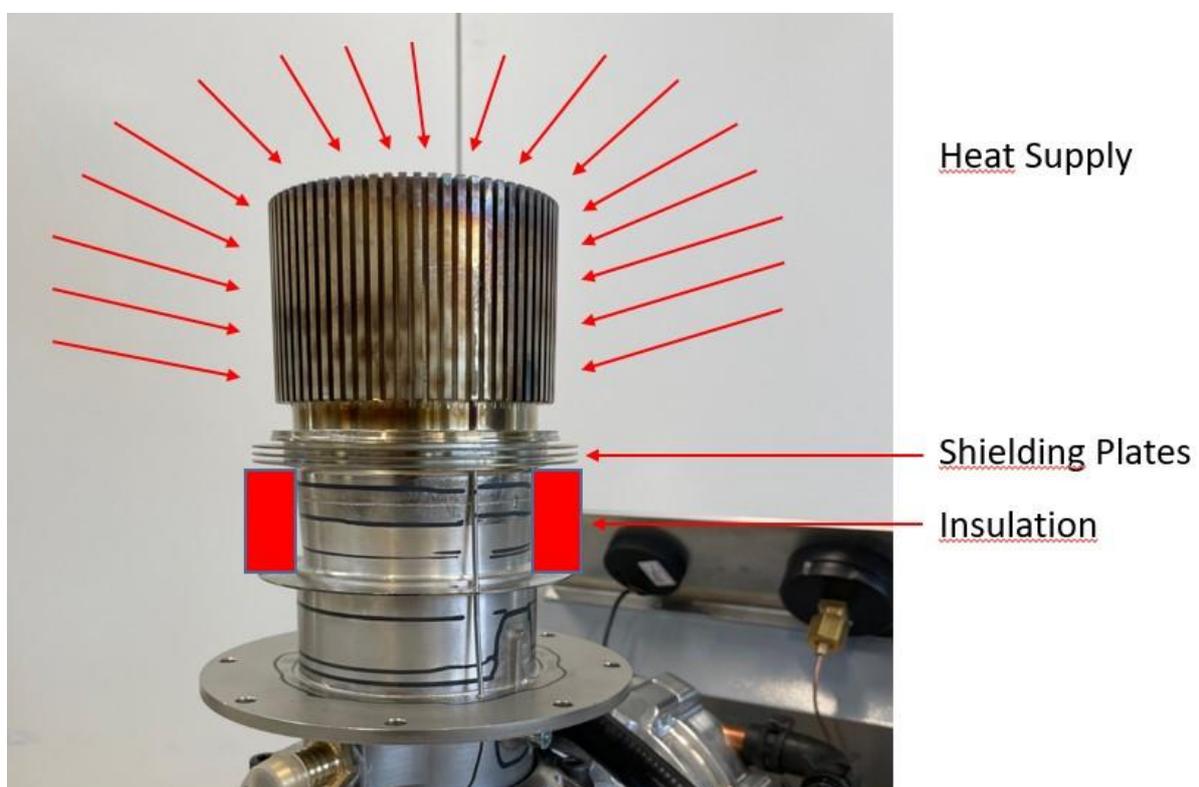
- Use two commercially available lead batteries, each 12 volts, for example from the automobile or truck sector
- We recommend a capacity of 75 - 225 Ah depending on the application and storage need
- connect the two batteries in series to produce a voltage of 24 volts
- Set the main switch to "OFF". This corresponds to the position shown in Figure 5.
- Connect the supplied battery cable to the battery poles, paying attention to the polarity: red wire with fuse = positive pole, black wire = negative pole
- Connect the cable to the connector on the starter/rectifier module
- Operate the main switch by turning it. Check whether the indicator lamp on the "Start" button lights up. The controller is ready for operation
- When you are not operating the unit, disconnect the controller from the battery again by turning the main switch to the off position. This prevents the battery from discharging in the long term.



Picture 5: Starter/rectifier module with battery cable

Put into operation (see picture 6):

- First activate the cooling water circuit and check the flow. The flow rate can be set between 0.3 and 0.5 m³/h depending on the motor power.
- Turn on the main switch. In addition to the control lamp on the "Start" button, the digital displays for "battery voltage" and "heater temperature" show the current values.
- You can also read the current values on the analog displays "Process gas pressure" and "Cooling water temperature".
- For safety reasons, the process gas pressure is set to around 15-20 bar when delivered. It is recommended to carry out the first tests with this pressure. Higher pressures require a highly concentrated transfer of heat to the heater-heat exchanger, which may only be achieved step by step in the course of the experiments.
- Make sure that no heat is supplied below the shielding plates (see picture). If this cannot be avoided, attach a separating plate and/or heat insulation below the shielding plates.
- Apply the heat and ensure that the heating is as even as possible in the area of the rib surface. In addition, heat can be supplied to the interior of the heat exchanger.
- As soon as the heater temperature has exceeded 400 degrees C, press the "Start" button until it runs smoothly and evenly. Repeat the process if the machine stops after releasing the button.
- Continue to heat the heater core to about 650 degrees C. The "generator current" ammeter should show about 10 - 15 amps charging current.



Picture 6: Area of heat input

Instructions for safe operation:

- Always make sure that the cooling water circuit is working and that the cooling water temperature does not exceed 50 degrees C
- Make sure the battery voltage does not exceed 28.8 volts. Load the battery with a load (e.g. inverter 24/230 volts) to keep the voltage in the 24 ... 26 volt range.
- Never disconnect the battery from the starter/rectifier module during charging. The result would be an increase in engine speed accompanied by an increase in alternator voltage, which can lead to damage to the electrical system.
- Make sure that the temperature at the heater head does not exceed 700 degrees C

Increase in Power

The electrical power output or the charging current is directly related to the mean process pressure. When the process pressure increases, the process gas inside the heater head absorbs more thermal energy. This requires more heat to be applied to the outside of the heater head to maintain the 650 degree C set point.

Increase in the mean process pressure (see Pictures 7 and 8)

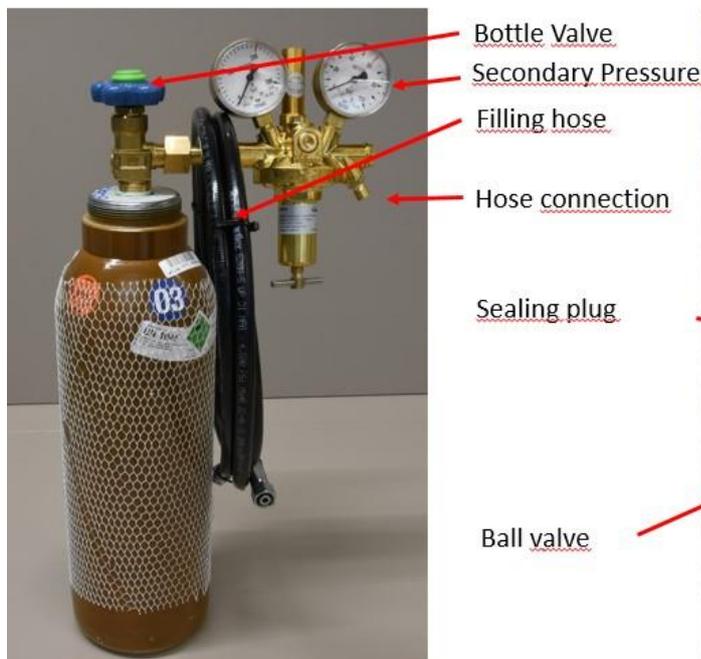
The mean process pressure corresponds to the pressure in the crankcase of the machine. In order to be able to increase the pressure, there is a connection with a ball valve shut-off. This can be used to fill or drain helium. Be sure to do the following:

- Changes to the process pressure should only be carried out when the machine is at a standstill and cold. Remember that the pressure increases when the machine is warm.
- Provide a well-ventilated room. Be aware that some helium may leak.
- Use commercially available helium from high-pressure bottles. Frauscher offers a set consisting of a 5 L high-pressure bottle, a pressure reducer and a filling hose (see Picture 7).
- Ensure that the pressure reducer is set to minimum secondary pressure by turning the pressure reducer adjustment screw to the left as far as it will go.
- Connect the filling hose to the connection on the pressure reducer and tighten the union nut.
- Remove the sealing plug on the ball valve connection of the machine. Screw the union nut of the connecting hose onto the ball valve by hand. Do not tighten the nut so that helium can escape.
- Carefully open the cylinder valve and then slightly increase the pressure on the pressure reducer by turning the adjusting screw clockwise. This flushes the hose with helium, which emerges at the connection point on the ball valve. After approx. 5-6 seconds, tighten the connection on the ball valve, whereupon the secondary pressure gauge on the pressure reducer will show the pressure actually set.
- Increase the pressure on the pressure reducer adjusting screw to the desired value, but not more than 50 bar.

- Now carefully open the ball valve on the machine and fill the machine with the preset pressure.
- Close the valves in the following order: 1) Ball valve on the machine 2) Bottle valve.
- Do not disconnect the connecting hose from the ball valve until you no longer intend to change the pressure any further

Reduction of the average process pressure (see Picture 8):

- Remove the sealing plug or the connection of the hose at the ball valve.
- Carefully open the ball valve and release the pressure to the desired value displayed on the controller.
- Close the ball valve and seal the opening again with the sealing plug.



Picture 7: Helium filling set



Picture 8: Filling connection