

Water Heater

Workshop Manual

Thermo E 200
Thermo E 320
with Control Unit 1587

1 Introduction

1.1	Content and purpose	101
1.2	Workshop manual validity	101
1.3	Meaning of highlighted content	101
1.4	Additional applicable documentation	101
1.5	Installation and safety regulations	101
1.5.1	Legal installation regulations	101
1.5.2	General safety regulations	101
1.5.3	Combustion air supply	104
1.5.4	Exhaust line	104
1.5.5	Temperature sensor	104
1.6	Suggestions for Improvement and change	104

2 Technical Data

2.1	Electrical components	201
2.2	Fuel	201

3 Description of assemblies and components

3.1	Burner	302
3.1.1	Combustion air fan	302
3.1.2	Fuel pump	302
3.1.3	Nozzle block preheater	303
3.1.4	Control unit	303
3.1.5	Electronic ignition unit with ignition electrodes	304
3.1.6	Temperature sensors with water temperature sensor and integrated overheating protection	304
3.2	Heat exchanger	304
3.3	Combustion chamber	305
3.4	Circulating pump	306
3.4.1	Aquavent 5000 (U4814) and Aquavent 5000S (U4854) circulating pumps	306
3.4.2	Aquavent 6000C (U4855) and Aquavent 6000SC (U4856) circulating pumps	307
3.5	Fuel filter	307

4 Heater functions

4.1	General heater functionality description	401
4.2	Operational heater sequence	402
4.2.1	Switching on and start	402
4.2.2	Heating operation	402
4.2.3	Switching off	403
4.3	Malfunction interlock and heater interlock	404
4.4	Malfunction interlock	404
4.4.1	Malfunctions during switching-on and start procedure	404
4.4.2	Malfunctions during heater operation	404
4.4.3	Malfunctions during purge cycle	404
4.4.4	Malfunction interlock release and error clearance	405
4.5	Heater interlock	405
4.5.1	Heater interlock release	405
4.6	Error output	405

5 Troubleshooting and error correction

5.1	General	501
5.2	General error symptoms	501
5.3	Malfunction code output via flash code	503
5.4	Error symptoms during functional tests with malfunction code output	505
5.4.1	Error symptom "No start within safety period"	505
5.4.2	Error symptom "Flame interruption"	505
5.4.3	Error symptom "Low voltage"	507
5.4.4	Error symptom "Extraneous light detected prior to ignition or during purge cycle"	508
5.4.5	Error symptom "Flame detector defective"	509
5.4.6	Error symptoms "Temperature sensor / overheating protection defective" and "Overheating"	509
5.5	Individual component tests	510
5.5.1	General visual inspection	510
5.5.2	Heat exchanger visual inspection	510
5.5.3	Combustion chamber visual inspection	510
5.5.4	Resistance check of the temperature sensor with integrated overheating protection	510
5.5.5	Fan and combustion air intake line visual inspection	511
5.5.6	Burner motor inspection	511
5.5.7	Electronic ignition unit inspection	511
5.5.8	Ignition electrode inspection	512
5.5.9	Flame detector inspection	512
5.5.10	Fuel pump inspection	513
5.5.11	Solenoid valve inspection	514
5.5.12	Nozzle block preheater inspection	514

6 Wiring diagrams

6.1	General	601
-----	---------	-----

7 Servicing

7.1	General	701
7.1.1	Heater servicing	701
7.2	Servicing	701
7.2.1	CO ₂ Measurement and setting	701

8 Burner, components and heater removal and installation

8.1	General	801
8.2	Burner removal and installation	802
8.3	Removal and installation of the temperature sensor with integrated overheating protection	803
8.4	Hood removal and installation	803
8.5	Burner motor removal and installation	803
8.6	Electronic ignition unit and ignition electrode removal and installation	805
8.7	Control unit removal and installation	807
8.8	Fuel pump removal and installation	807
8.9	Solenoid valve removal and installation	808

8.10	Atomizer nozzle removal and installation	808
8.11	Combustion chamber removal and installation	809
8.12	Heat exchanger removal and installation	809
8.13	Heater removal and installation	810
8.14	Start-up after burner, heater or heat exchanger installation	810
8.14.1	Bleeding of the fuel system	810
8.14.2	Bleeding of the water circuit	810

9 Modifications and retrofits

10 Packing / storage and shipping

10.1	General	1001
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Appendix A 1

	Periodic heater maintenance	A-2
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1 Introduction

1.1 Content and purpose

This workshop manual is used to support personnel briefed and/or trained by Spheros during maintenance and repair of water heaters Thermo E 200 and E 320.

1.2 Workshop manual validity

The workshop manual applies to heaters listed on the title page of this document.

It may be subjected to modifications and amendments. The respectively currently valid version is binding. This version can be found on the Spheros homepage under Service / Technical Documents.

1.3 Meaning of highlighted content

In this manual sections highlighted with CAUTION, ATTENTION and NOTE have the following meaning:

CAUTION

This caption is used, if improper adherence or non-adherence to instructions or procedures may cause injuries or fatal accidents.

ATTENTION

This caption is used, if improper adherence or non-adherence to instructions or procedures may cause component damage.

NOTE

This caption is used, if a distinctive feature is pointed out.

1.4 Additional applicable documentation

We recommend the use of additional documentation. References are provided in the workshop manual at appropriate locations.

The following documents can be consulted during operation and maintenance of the heaters listed on the title page:

- Operating instruction
- Installation instruction
- Technical communications
- Technical information
- Spare parts list
- Accessories catalog

1.5 Installation and safety regulations

1.5.1 Legal installation regulations

For the heaters exist type approvals according to the ECE Regulations:

R10 (EMV)	No. 03 5742 and
R122 (Heater)	No. 00 0265 for Thermo E 200 No. 00 0266 for Thermo E 320

Installation is governed above all by the provisions in Annex VII of the ECE Regulation R122.

NOTE

The provisions of these Regulations are binding within the territory governed by ECE Regulations and should similarly be observed in countries without specific regulations!

Extract from ECE Regulation R122, Annex VII:

„7.1 A clearly visible tell-tale in the operator's field of view shall inform when the combustion heater is switched on or off.“

NOTE

For information and rules regarding installation of heating devices in vehicles, see the installation instructions.

1.5.2 General safety regulations

General accident prevention regulations must be observed.

"General safety regulations" beyond the scope of these regulations are listed below.

The safety regulations must be observed during operation, maintenance and repair of heaters of the Thermo E series.

ATTENTION

Failure to follow the installation instructions and the notes contained therein will lead to all liability being refused by Spheros GmbH and its companies. The same applies if repairs are carried out incorrectly or with the use of parts other than genuine spare parts. This will result in the invalidation of the ECE Type Approval for the heater.

For heaters in vehicles, which are not subjected to the European Directive, inspection and approval by the respective inspection authority is required, if applicable regulations are in place.

The year of first start-up must be permanently marked on the type plate by removal of not applicable dates.

The heaters are registered and licensed for the use in vehicles according to the respective EU Directive 2007/46 (e.g. 2001/56/EC). When using the heater for other applications not subjected to this EU Directive (e.g. ships), respective applicable regulations must be fulfilled.

ATTENTION

The heaters are not approved for vehicles subjected to Directive 94/55/EC (ADR, TRS) or rail applications.

The heater may only be installed in the driver's cab or passenger compartment, if an installation box is used, which can be tightly sealed vs. the vehicle interior. The installation box must be sufficiently vented from the outside.

If the temperature within the installation box exceeds the permissible ambient temperature of the heater, the venting opening must be increased after consultation with Spheros.

ATTENTION

Prior to opening the heater it must be disconnected from the vehicle electrical system.

NOTE

The heater should always be disconnected from the vehicle electrical system prior to disconnecting the temperature sensor plug.

If this order is reversed, the heater will automatically be interlocked.

Prior to removing the burner from the heat exchanger, the temperature sensor plug must be removed.

ATTENTION

A temperature of 85°C may not be exceeded in the heater areas (max. operating temperature). Exceeding this temperature may cause heater malfunctions and permanent damage to the electronics.

Electrical cables must be routed avoiding isolation damage (e.g. by pinching, heat development, bending, fraying, etc.).

CAUTION

For risk of poisoning and suffocation the heater may not be used in closed rooms such as garages or workshops without exhaust fume extraction. This also applies when pre-set times/timers are used. This also applies for burner operation during adjustment of the CO₂ content in the exhaust fumes.

The heater may not be operated close to inflammable materials such as dry grass and leaves, cartons, paper etc.

If the heater is operated without coolant (overheat-

ing), the outer shell of the heater may reach a temperature equalling the ignition temperature of diesel fuel! Any dripping or evaporating fuel must neither collect nor be ignited by hot components or electrical equipment. To prevent this, if necessary, a drip pan with defined drain holes is to be installed in the area below the interface burner housing/fuel line connectors/heat exchanger.

At petrol stations and other fuel filling facilities the heater must be switched off due to the explosion hazard. An appropriate self-adhesive label is to be affixed next to the filler neck.

For explosion risk the heater must be switched off, when combustible fumes or dust can be generated (e.g. in the proximity of fuel, coal, wood dust, grain storage/silos or similar).

ATTENTION

The heaters may only be installed in horizontal position. (see Installation instruction).

The heater should be installed as low as possible to ensure automatic venting of heater and circulating pump. This in particular applies for the non-self-priming circulating pump.

After coolant replacement sufficient purging of the cooling system must be ensured. Insufficient venting during heating operation can cause malfunctions due to overheating.

Proper venting can be recognized by almost noise-free operation of the circulating pump.

The opening pressure in the vehicle cooling system, usually indicated on the cooler lid, may not exceed 2.0 bar working overpressure (also applies to separate heating circulations).

Hose connections must be secured with hose clamps against slipping.

ATTENTION

The tightening torques of the used hose clamps must be observed.

Water heating circulation system - wall heater and roof channel heater

- 1 Wall heater with fan
- 2 Heat exchanger at the entrance
- 3 Heater
- 4 Circulation pump
- 5 Roof heat exchanger
- 6 Vehicle engine
- 7 Shut-off valve
- 8 Driver seat heater
- 9 Control element

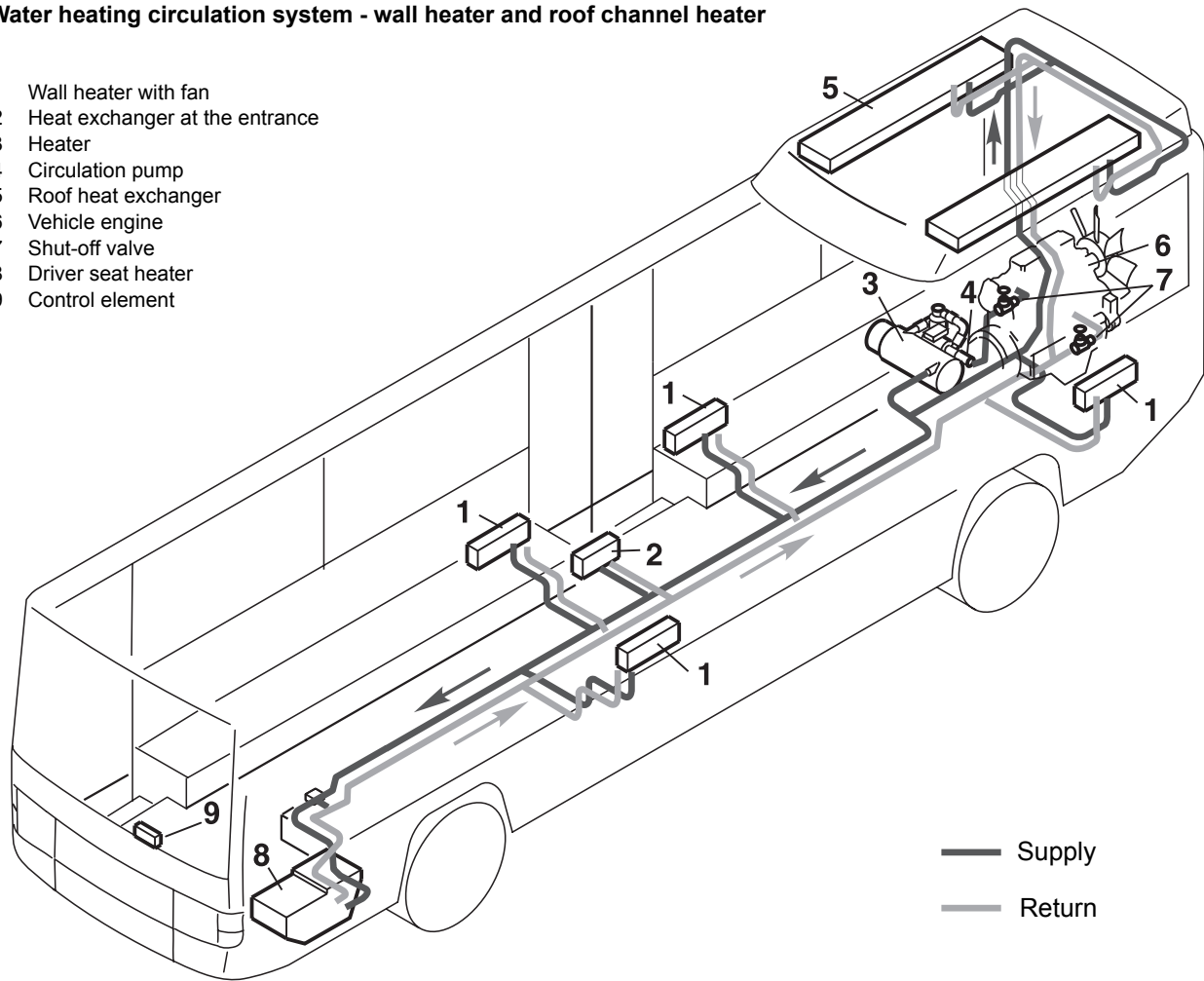


Fig. 101 Heater installation example in a bus

Coolant level verification and cooling system purging must be performed according to the vehicle manufacturer's specifications. The coolant in the heating circulation system should contain at least 20 % of an anti-freezing agent recommended by the vehicle manufacturer. The anti-freezing agent content should not exceed 60 %.

Fuel hoses may not be bent or twisted during installation. In order to avoid sagging, they should be secured using clamps in 25 cm distances. Fuel lines must be protected against temperature exposure.

Permissible fuel line dimensions must be obtained from the installation instruction.

It is to be ensured that the fuel is supplied to the heater clean and without bubbles.

If a shut-off fitting is installed in the return line, an information placard must be installed at a well visible location.

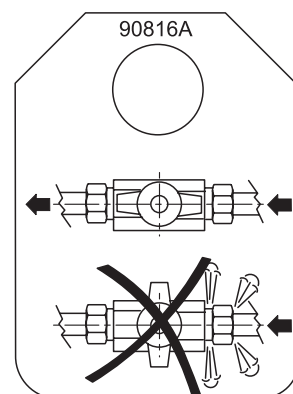


Fig. 102 Information placard

1.5.3 Combustion air supply

ATTENTION

The combustion air intake opening may not point into driving direction. It should be arranged to effectively avoid contaminations as well as snow plastering and splash water intake. Furthermore the combustion air intake opening should be protected against object penetration by installing a grid or other suitable measures.

Combustion air intake and exhaust fume outlet must be arranged to ensure that no air pressure difference (e.g. suction) will occur in any vehicle operating condition. Permissible dimensions of the optional, application-dependent combustion air intake line must be obtained from the installation instruction. Condensation water accumulations must be drained. If necessary, a condensation water drain hole with a diameter of 4 mm must be implemented.

1.5.4 Exhaust line

The exhaust pipe must be secured to the heater using e.g. a clamp.

Permissible dimensions of the optional, application-dependent exhaust line are to be obtained from the installation instruction.

ATTENTION

The heater exhaust pipe port may not be partially or completely obstructed by leaves, soil, snow, mud, etc. (this may occur when the vehicle is driving in reverse). The exhaust pipe port may not point into driving direction.

Combustion air intake and exhaust fume outlet must be arranged to ensure that no air pressure difference (e.g. suction) will occur in any vehicle operating condition.

If the exhaust line is installed in close proximity to temperature-sensitive parts, then it must be insulated.

If exhaust fumes exit downwards under the vehicle, an exhaust gas deflection is absolutely necessary.

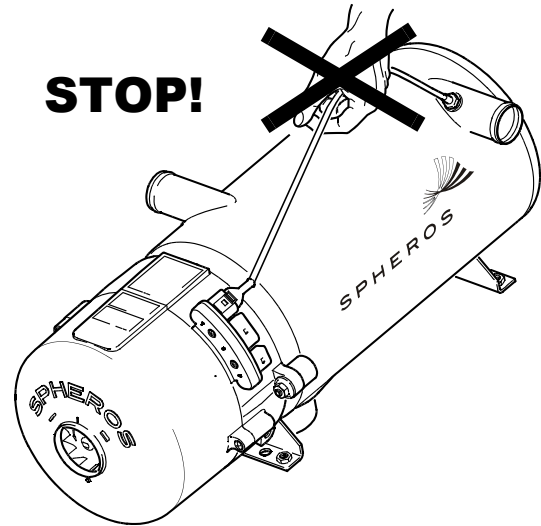
CAUTION

For permissible exhaust gas deflections for the Thermo E 200 heater, see Installation instruction.

1.5.5 Temperature sensor

ATTENTION

The temperature sensor cable may not be mechanically stressed (pull on the cable, carry the heater at the cable etc.).



1.6 Suggestions for Improvement and change

Please direct any complaints, improvement or modification suggestions regarding this manual to:

service@spheros.de

2 Technical Data

Unless limiting values are defined, the technical data should be understood with tolerances of $\pm 10\%$ common for heaters at an ambient temperature of $+20^{\circ}\text{C}$ and at nominal voltage.

Table 201 Technical Data

Heater		Thermo E 200	Thermo E 320
Design		High-pressure atomizer	
Heat flow rate	kW	20	32
Fuel		Diesel / light fuel oil	
Fuel consumption	kg/h / l/h	2.0 / 2.7	3.2 / 4.1
Nominal voltage	V (DC)	24	
Operating voltage range	V (DC)	20.5...30.0	
Electrical power consumption at 24 V *	W	55	100
Combustion air intake temperature	$^{\circ}\text{C}$	-40...+ 85	
Ambient temperature during operation	$^{\circ}\text{C}$	-40...+ 85	
Storage temperature	$^{\circ}\text{C}$	-40...+ 90	
Operating pressure	bar	max. 2.0	
Heat exchanger filling volume	l	1.8	
Minimum water flow	$\pm \dots$ l/h	2400 \pm 200	2700 \pm 200
Minimum coolant circulation volume	l	min. 25.0	
CO ₂ in exhaust at nominal voltage	Vol %	9.5 \pm 0.5	10.0 \pm 0.5
Heater dimensions (tolerance \pm 3 mm)	mm	Length 593 / Width 247 / Height 224	
Weight	kg	16.5	17.3

* without circulating pump

Max. continuous current of the circulating pump 8.75 A, max. peak current for 0.5 s duration = 90 A - We recommend the use of Spheros circulation pumps for highest efficiency and reliability! In order to reduce starting currents the circulating pump can be synchronized by the control unit for a short time period during activation.

Confirm compatibility in case pumps provided by different manufacturers are used!

2.1 Electrical components

All heater components as well as the circulating pump and the timer are designed for 24V nominal voltage. The temperature sensor voltage is regulated by the control unit.

NOTE

Circulating pumps must be assigned to the heaters according to the flow resistance in the coolant circulation system.

2.2 Fuel

Only fuels listed on the type plate as well as fuels approved by Spheros may be used. The fuel use limitations in the heater listed below must be observed.

- Diesel fuel according to DIN EN 590 and DIN 51628: The limitations of use of the standard apply, hence winter diesel down to -20°C , Arctic diesel down to -40°C
- Light fuel oil according to DIN 51603 (above 0°C)
- Mixture of 70 Vol-% diesel fuel (winter diesel) according to DIN EN 590 or DIN 51628 and 30 Vol-% Bio-diesel according to DIN EN 14214: $-5 \dots -10^{\circ}\text{C}$ without preheating system, -15°C with nozzle block preheater and heated fuel filter (use limitations depending on fuel quality).

At temperatures below 0°C commercially available winter diesel should be used. This especially applies for fuel extraction from a separate fuel tank. The use of lubrication and flow improving additives is permitted. No negative impact is known at time of the preparation of this workshop manual.

ATTENTION

The listed temperature ranges, hence minimum permissible temperatures strongly depend on the respective fuel quality. In case of bad-quality fuel the use limitations may deviate, e.g. in case of too high water content.

When fuels are used, their respective limitations of use must be observed and appropriate measures (nozzle block preheater, electrically heated filter) must be applied as needed.

In case fuel is extracted from the vehicle tank, the vehicle manufacturer's mixing regulations shall apply.

3 Description of assemblies and components

The water heaters Spheros Thermo E 200 and E 320, are used in conjunction with the vehicle heating system

- to heat the passenger compartment
- to defrost the windows as well as
- to preheat water-cooled vehicle engines.

The water heater operates independently from the vehicle engine and is connected to the cooling system, the fuel system and the electrical system of the vehicle. It is bolted to the vehicle chassis or is secured using an additional cross beam.

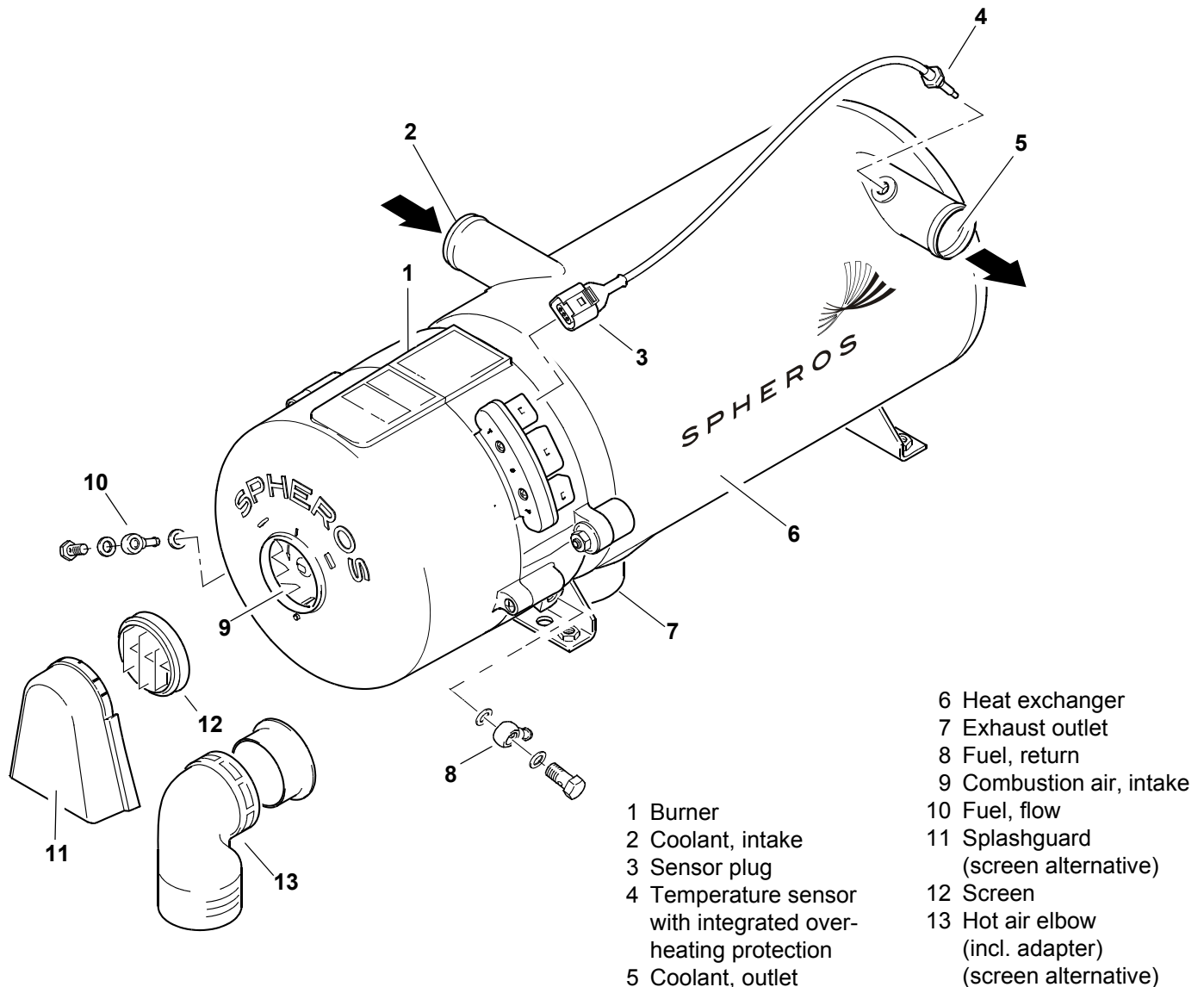
Heat is generated by combustion of liquid fuels. The heat it transferred to a coolant circulation system via the

heater's heat exchanger. Intermittent operation adjusts the heater to changing heat demand. The control unit controls heater activation and deactivation based on the temperature sensor signals.

The heaters of the Thermo E series mainly consist of the following main components:

- Burner
- Combustion chamber
- Heat exchanger

A circulating pump, preferably controlled by the control unit, is externally installed in the system, or for compact devices directly on the heater. An external control of the circulating pump (UPFA) is for the Thermo E not provided.



3.1 Burner

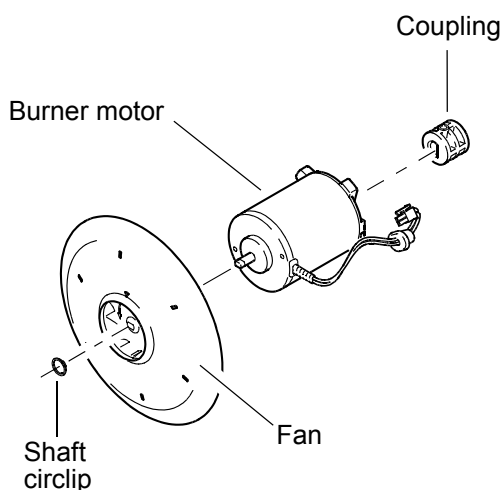
The burner consists of components

- Burner motor
- Combustion air fan
- Fuel pump with solenoid valve
- Atomizer nozzle
- Electronic ignition unit with ignition electrode
- Control unit with flame detector
- Disc with inspection glass
- Nozzle block preheater (optional)

3.1.1 Combustion air fan

The combustion air fan transports the air required for combustion from the combustion air intake to the combustion chamber.

The combustion air fan consists of burner motor and fan. Air is drawn in through the air intake opening in the hood. The air intake opening is equipped with a splashguard, a protective screen and a hot air elbow.



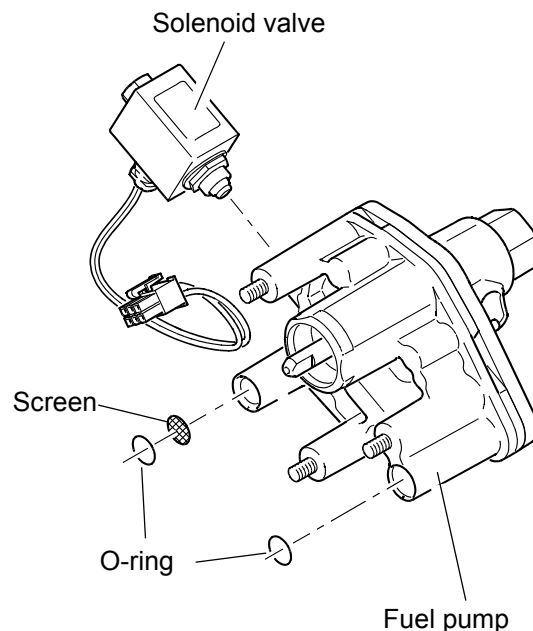
Two different motors are assigned to the different heating capacity classes of the Thermo E series. This assignment is clearly beyond the material number. The motors must not be interchanged.

NOTE

The positioning of the engine to the housing is safely defined by a pin and a hole (see Fig. 803).

3.1.2 Fuel pump

The fuel pump is responsible for fuel supply. The pump is driven by the burner motor via a coupling. Fuel is compressed in the fuel pump to approx. 10 bar and atomized via the atomizer nozzle. The solenoid valve integrated into the fuel pump opens and closes the fuel supply to the atomizer nozzle. Identical fuel pumps are installed in heaters of both heating capacity classes.



The fuel pump is designed for dual-line operation (fuel supply and return line).

ATTENTION

If the heater is operated with

- a long fuel supply line (> 15m)
- check valves in the fuel supply and return line (> 0,07 bar)
- a fuel filter in the fuel supply line

the fuel supply line and fuel filter are to be filled prior to first heater start-up (see 8.14.1).

3.1.3 Nozzle block preheater

In case of very low temperatures fuel may exhibit severely modified viscosity. Due to insufficient fuel atomization functional heater malfunctions may occur.

Depending on the fuel used, these temperatures vary. When used in cold regions or if fuels different from diesel fuel are used, we recommend the use of a nozzle block preheater.

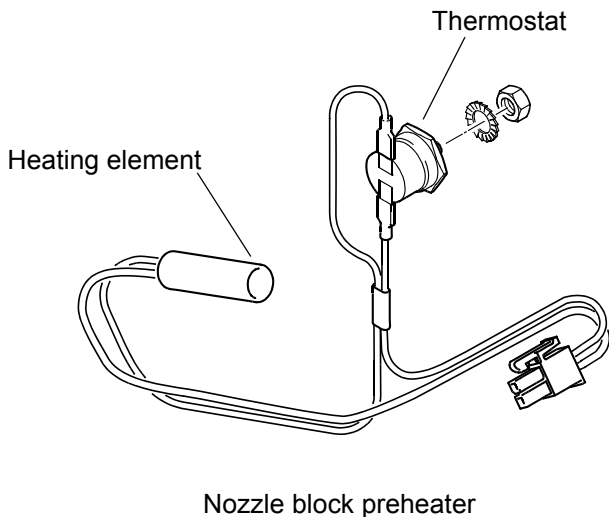
The nozzle block preheater consists of a heating element with an integrated temperature sensor.

At a temperature of < 5°C the heating element heats the nozzle holder and thus, fuel and atomizer nozzle. Fuel viscosity is reduced and atomization improved.

The heating duration depends on the intake air temperature and on the reflected by the burner heat.

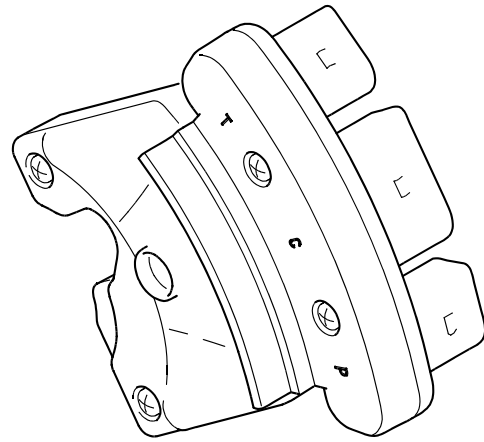
Above 8°C the thermostat turns the preheater off.

The use of the nozzle block preheater is optional. It is possible to retrofit this capability without modifications to the control unit.

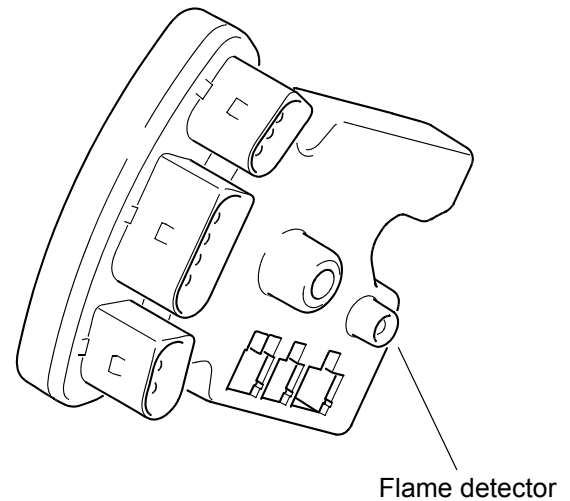


3.1.4 Control unit

The control unit 1587 ensures the operating sequence and burner operation monitoring. The flame detector is integrated into the control unit.



Control unit 1587

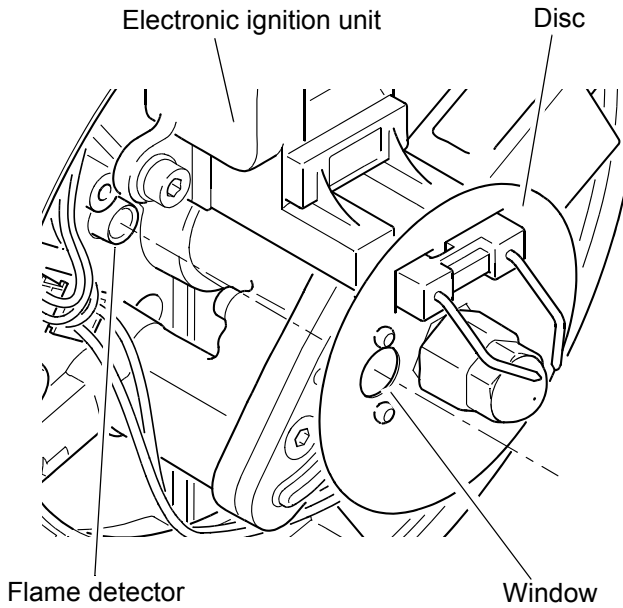


Flame detector

3.1.4.1 Flame detector

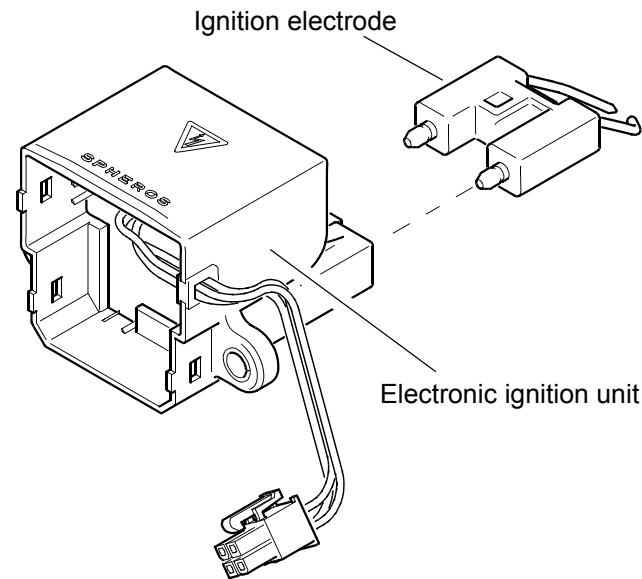
The flame detector monitors the flame conditions during heater operation.

The flame detector is a photo transistor, which changes its resistance as a function of flame luminous intensity and thus, the voltage applied.



3.1.5 Electronic ignition unit with ignition electrodes

The electronic ignition unit induces the high voltage required for ignition of the fuel-air mixture. Ignition is triggered by a high voltage spark, which is initiated on the ignition electrode.

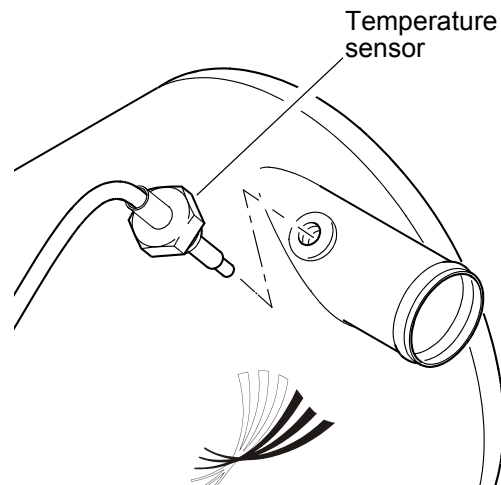


3.1.6 Temperature sensors with water temperature sensor and integrated overheating protection

The water temperature sensor captures the coolant temperature at the heat exchanger outlet as electrical resistance. This signal is transmitted to the control unit, where it is processed.

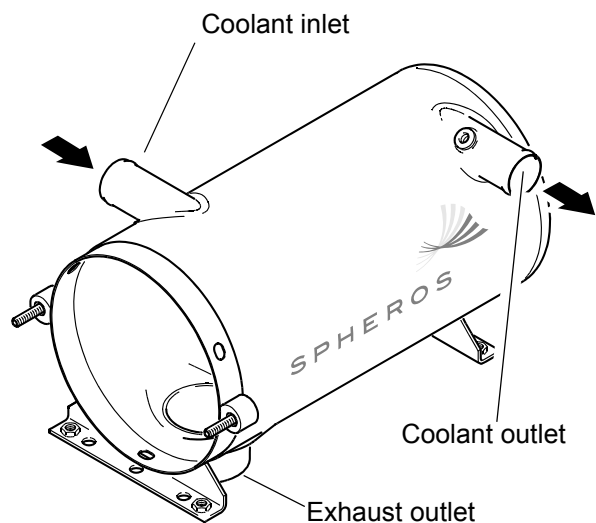
The overheating protection integrated into the temperature sensor is responsible for temperature limitation. Similar to the water temperature sensor, the coolant temperature is captured at the heat exchanger outlet as electrical resistance and transmitted to the control unit. Overheating protection prevents inadmissibly high heater operating temperatures. At a temperature greater than 125°C heater deactivation and interlocking is initiated.

It is not necessary to manually reset the overheating protection.



3.2 Heat exchanger

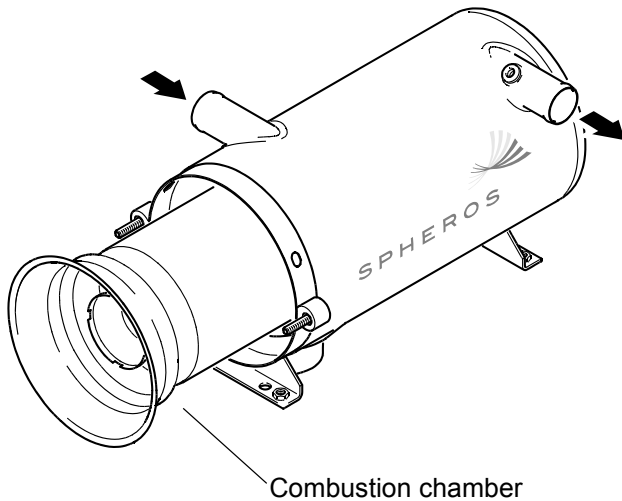
The heat exchanger transfers the heat generated by combustion to the coolant circulation system.



3.3 Combustion chamber

The combustion chamber is used for generation and combustion of the fuel air mixture. The generated exhaust gas heats the coolant flowing through the heat exchanger.

Depending on heating capacity class, different combustion chambers are used. They have different swirler (E 200 sheet metal, E 320 cast iron). The combustion chamber of the Thermo E 320 is additionally equipped with a flame stabilization pipe. The combustion chambers have an identification stamp according to the associated heater (E 200 or E 320).

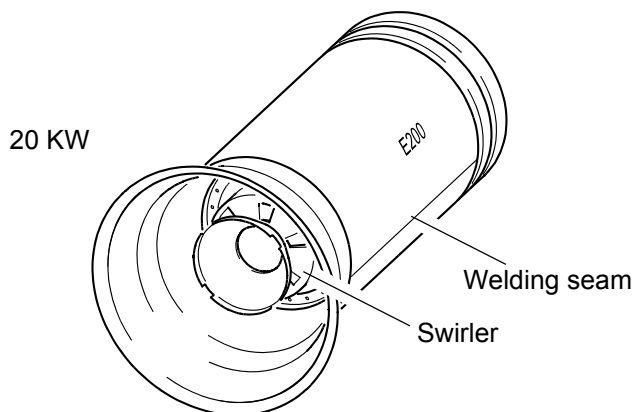
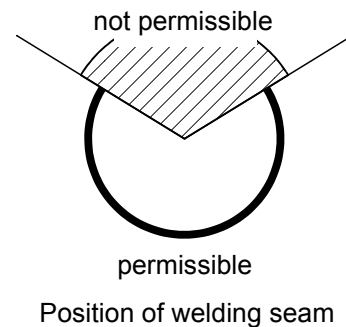


CAUTION

Heater operation with a combustion chamber of a other heating capacity class is not permitted.

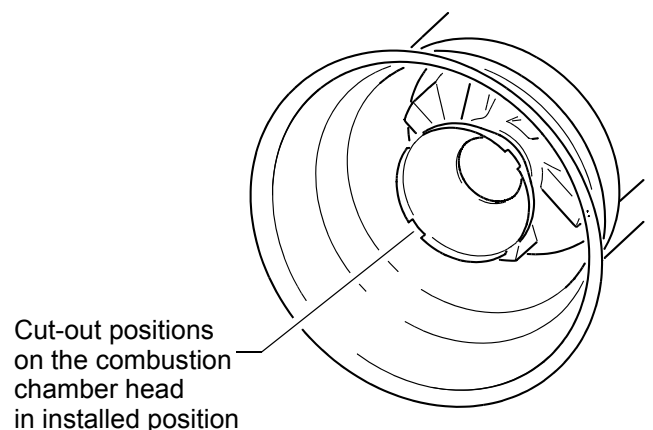
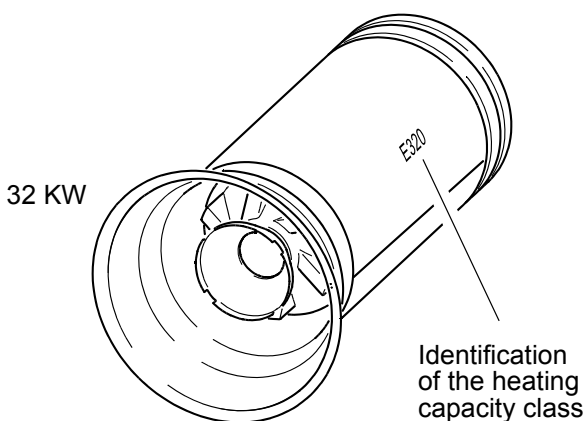
NOTE

The combustion chamber should be inserted into the heat exchanger in such a way that its welding seam is positioned between 2 and 10 o'clock (not upwards!). A position change during maintenance is permissible and affects the expected service life of the combustion chamber positively (see graphic below).



NOTE

It should be ensured that none of the 4 cut-outs of the combustion chamber head points vertically downwards (see graphic below). Dripping from nozzle fuel is so collected in a reservoir between disc and burner head and will be burned at the next burner operation instead to soil the heater.

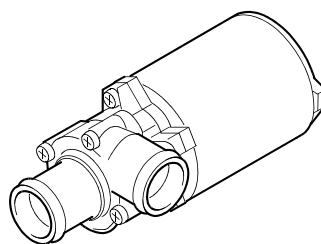


3.4 Circulating pump

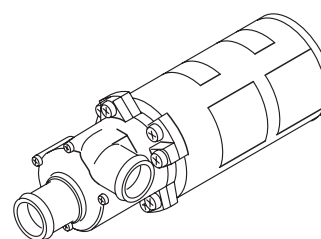
The externally arranged circulating pump ensures coolant transport within the vehicle and/or heater circulation system.

Depending on the application, the circulating pump is switched on via the control unit or directly via the vehicle electrical system and operated during the entire heater operation duration.

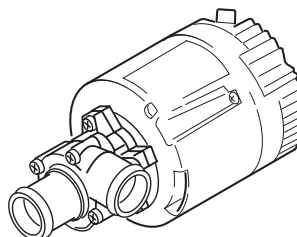
Heaters can be operated with Aquavent 5000 (U4814), Aquavent 5000S (U4854), Aquavent 6000C (U4855) or Aquavent 6000SC (U4856) circulating pumps.



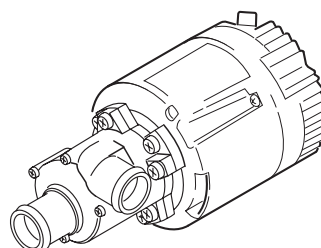
Aquavent 5000
(U4814)



Aquavent 5000S
(U4854)



Aquavent 6000C
(U4855)



Aquavent 6000SC
(U4856)

Circulating pump	Flow rate l/h	Nominal voltage V =	Operating voltage range V =	Nominal power consumption W	Weight kg
U 4814 Aquavent 5000	5000 (against 0.2 bar)	24	20...28	104	2.1
U 4854 Aquavent 5000S	5000 (against 0.2 bar)	24	20...28	104	2.2
U 4855 Aquavent 6000C	6000 (against 0.4 bar)	24	20...28	210	2.4
U 4856 Aquavent 6000SC	6000 (against 0.4 bar)	24	20...28	210	2.5

ATTENTION

The circuit breaker of the circulating pump may never be pulled, while the pump is running, and may not be replaced, when the pump is switched on.

3.4.1 Aquavent 5000 (U4814) and Aquavent 5000S (U4854) circulating pumps

The Aquavent 5000 (U4814) and 5000S (U4854) circulating pumps are equipped with a brush motor.

NOTE

Aquavent 5000 (U4814) with floating-ring type shaft seal

Aquavent 5000S (U4854) with magnetic drive (no seal)

ATTENTION

The circulating pump motor is not equipped with an internal inverse-polarity protection.

3.4.2 Aquavent 6000C (U4855) and Aquavent 6000SC (U4856) circulating pumps

The Aquavent 6000C (U4855) and Aquavent 6000SC (U4856) circulating pumps are equipped with a brushless motor.

HINWEIS

The Aquavent 6000C (U4855) has a floating-ring type shaft seal.

The Aquavent 6000SC (U4856) is equipped with a magnetic coupling (no seal)

Soft start

The circulating pump motor starts slowly and gently. Max. rotational speed is only reached after approx. 5 seconds.

Protection against dry running

Protection against dry running is integrated into the circulating pump motor.

If the circulating pump motor consumes within a time period of approx. 45 minutes significantly less current, dry running is detected. The circulating pump motor is switched off.

After approx. 2 minutes and circulating pump motor reactivation, the operation can be continued.

Blocking protection

If the pump wheel is blocked, the motor will be switched off via the error mode directly prior to standstill of the pump wheel.

Overload protection

Overload protection is activated after the soft start is completed. The current consumption will be limited. In case of hydraulic overpressuring of the circulating pump, the circulating pump motor will not be damaged.

Error mode

In case of malfunctions the circulating pump motor is switched off via the error mode. After approx. 5 seconds the error mode switches the circulating pump motor into energy-saving sleep mode.

Sleep mode

In sleep mode internal electronics consumers of the circulating pump motor are switched off.

Reactivation of the circulating pump motor

It is possible to reactivate the circulating pump motor from sleep mode. For this purpose the power supply is disconnected for > 2 min. After the power supply is reconnected, the circulating pump motor restarts in soft-start mode.

Inverse-polarity protection

ATTENTION

The circulating pump motor is not equipped with an internal inverse-polarity protection.

3.5 Fuel filter

A heatable fuel filter is available as an option.

The integrated filter heating is switched on below of a fuel temperature of 0.5°C and off at a temperature of 5.5°C. When the heater is operated at temperatures below of -30°C the usage of this heatable fuel filter is absolutely necessary.

4 Heater functions

4.1 General heater functionality description

The heater principle is based on a high-pressure atomizer burner and is monitored by an integrated control unit.

The burner motor powers the fan and the fuel pump. The fuel pump is coupled to the motor using a coupling. The fan produces the required combustion air, the combustion air volume is impacted by the burner motor speed.

The first CO₂ adjustment was made at Spheros. For adaption to different applications (extension of combustion air intake or exhaust line) and after any maintenance and repair the CO₂ content is to be readjusted in a workshop.

The fuel pressure is generated in the fuel pump and reduced to the required pressure using a pressure limiting valve.

A solenoid valve releases the fuel via the atomizer nozzle for combustion in the combustion chamber.

As an option, the fuel pump can be equipped with a nozzle block preheater. The nozzle block preheater heats the nozzle holder with the atomizer nozzle at temperatures below 5°C and thus the fuel. The fuel air mixture is ignited in the combustion chamber via a high-voltage ignition spark.

The flame is monitored by a optical flame detector integrated into the control unit.

Depending on the equipment, the heater is switched on and off using a

- digital timer
- switch
- or climate control.

During heating operation the burner is automatically switched on and off. For regulation a temperature sensor is installed in the coolant outlet of the heat exchanger. The heater is switched on, when the temperature falls short of a lower temperature threshold (72°C), and is switched off, if the upper temperature threshold is reached (82°C). A distinction between parking heating and auxiliary heating mode does not exist.

For overheating protection of the heater the switching thresholds are modified by the control unit, if specified temperature gradients are exceeded (gradient evaluation).

An operating display is available for monitoring the operating status. The operating display is also used to output error messages in flash code.

4.2 Operational heater sequence

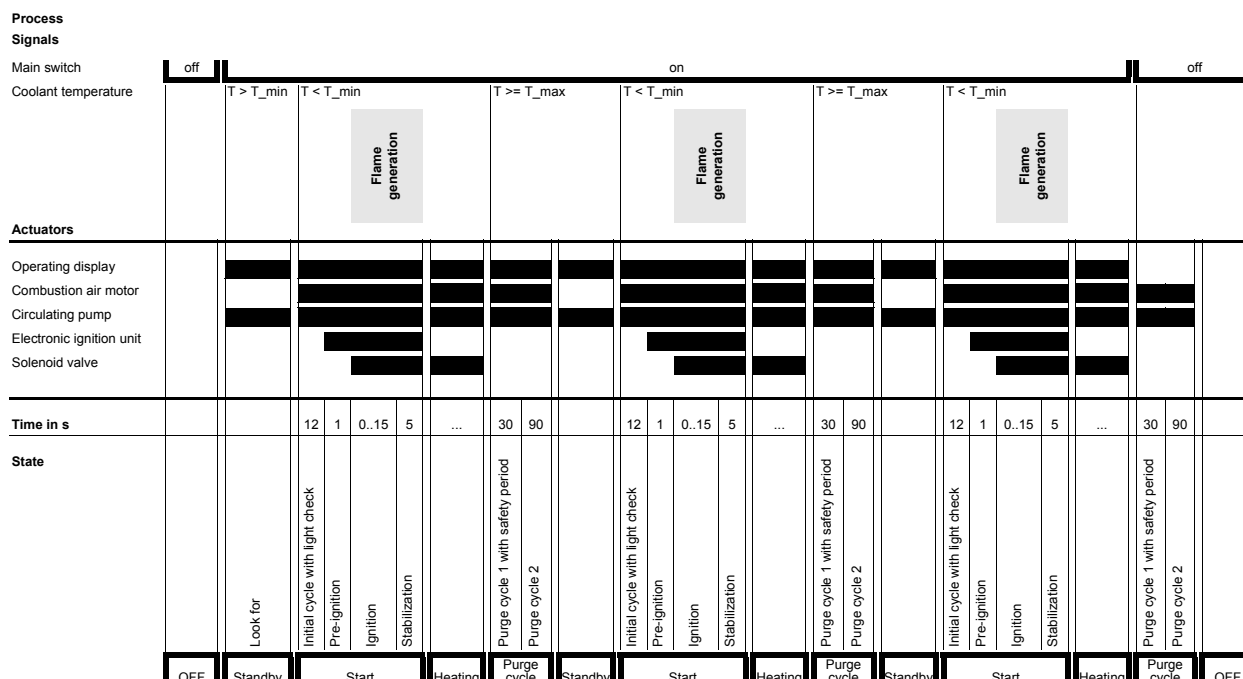


Fig. 401 Operational sequence

4.2.1 Switching on and start

When switched on, the operating display is illuminated, the control unit starts controlled operation and checks the coolant temperature.

If the coolant temperature is below the upper temperature threshold, the initial cycle starts. Combustion air fan and circulating pump are switched on.

After approximately 12 seconds (initial cycle time) the high-voltage spark is ignited. Approx. 1 second later the solenoid valve in the fuel pump is opened. The fuel injected via the atomizer nozzle and mixed with the air of the combustion air fan, is ignited by the ignition spark and burned in the combustion chamber. The flame is monitored by a flame detector integrated into the control unit. Approximately 5 seconds after a flame is detected, the control unit switches the electronic ignition unit off. Until then the flame is stabilized. The heater is not yet in heating mode.

With optional nozzle block preheater:
The heating element is in the control device in parallel connected with the motor output and is activated by the thermostat at temperatures below 5°C.

4.2.2 Heating operation

After the flame is stabilized, the heater is in controlled operation.

Once the upper switching threshold is exceeded, heating operation is finished and purge cycle initiated. The solenoid valve is closed, the flame expires, however the combustion air fan and circulating pump continue running. The purge cycle ends approx. after 120 seconds. The combustion air fan is switched off. The heater is in a controlled break. The operating display is illuminated.

Once the temperature falls short of the lower switching threshold, the heater restarts burner operation. It runs through the same sequence as the switching-on sequence.

4.2.2.1 Gradient evaluation

In case of low coolant flow or poor coolant circuit venting the temperature may quickly increase during heating operation. The control unit recognizes the quick temperature increase and automatically sets the upper switching threshold to a lower value. The quicker the temperature increases, the lower the

switching threshold for starting the controlled break is set.

In addition, the burner is also switched back on again after the controlled break at a lower switching threshold.

This prevents residual heat triggering the overheating protection.

If the temperature rise (temperature gradient) is again within permissible limits, the thresholds are reset to normal values immediately (lower threshold 72°C, upper threshold 82°C).

4.2.3 Switching off

Switching the heater off ends the combustion process. The operating display expires and purge cycle is initiated. The solenoid valve closes, the flame expires, the combustion air fan and circulating pump continue running. The purge cycle ends approx. after 120 seconds. The combustion air fan is switched off.

If a malfunction occurs during purge cycle (e.g. flame detection), the purge cycle may be shorter than 120 seconds.

During purge cycle it is permitted to switch the heater back on. The burner will restart after a purge cycle time of 30 seconds and subsequent initial cycle time.

4.3 Malfunction interlock and heater interlock

Malfunction interlocks and heater interlocks are distinguished.

The interlocks protect the heater and the surrounding vehicle assemblies against sequence errors after failure of individual heater components and particularly against impermissible thermal loads.

Thermal loads can be triggered by:

- Coolant flow too low
- Coolant circuit not or only partially filled (dry overheating)
- Circulating pump failure.

The control unit software detects overheating. Overheating is also detected by hardware (overheating protection), independently from software.

4.4 Malfunction interlock

If one of the malfunctions listed below occurs, the heater will initiate a fault shut-down, followed by malfunction interlock.

Depending on the error time, a purge cycle up to 120 seconds duration can be executed.

An error code is outputted by means of flash impulses via the operating display.

In case of several sequential malfunction interlocks a heater interlock is initiated (see 4.6).

4.4.1 Malfunctions during switching-on and start procedure

NOTE

If malfunctions occur during switching-on or during the start process prior to ignition, the heater will be switched off without purge cycle.

The heater is in malfunction interlock. The motor stops immediately or does not start.

Malfunction criteria:

- Short circuit and/or interruption of electrical components:
 - Burner motor (stops immediately)
 - Electronic ignition unit
 - Optional nozzle block preheater
- Interruption of circulating pump operation
- Flame or extraneous light detection by the flame detector prior to ignition of the high-voltage ignition spark.
- No start: No flame detection within 15 seconds after opening the solenoid valve.
- Temperature sensor delivers unacceptable temperature values.

- Heater operation outside the permissible temperature range.
- Voltage falling short of the low voltage threshold of approx. 20.5 V at motor start or within a duration of 20 seconds after a heating request.
- Voltage exceeding the high voltage threshold of approx. 30 V at motor start or within a duration of 6 seconds (purge cycle only, no malfunction interlock).

4.4.2 Malfunctions during heater operation

NOTE

In case of malfunctions during heater operation, first a 120 seconds purge cycle will be performed. Then the heater is switched into the malfunction interlock.

Malfunction criteria:

- Short circuit of the circulating pump.
- Short circuit or interruption of other electrical components (motor, solenoid valve, electronic ignition unit, nozzle block preheater).
- Water temperature greater than the upper switching threshold.
- Temperature sensor delivers unacceptable temperature values.
- Heater operation outside the permissible temperature range.
- Flame interruption (combustion interruption for longer than 15 seconds).
- Voltage falling short of the low voltage threshold of approx. 20.5 V at motor start or within a duration of 20 seconds after a heating request.
- Voltage exceeding the high voltage threshold of approx. 30 V at motor start or within a duration of 6 seconds (purge cycle is applied, but no malfunction interlock).
- Control unit malfunction.

4.4.3 Malfunctions during purge cycle

Malfunction causes:

- Short circuit or interruption of the burner motor (stops immediately)
- Interruption of circulating pump operation
- Heater operation outside the permissible temperature range.
- Voltage falling short of the low voltage threshold of approx. 20.5 V at motor start or within a duration of 20 seconds after a heating request.
- Voltage exceeding the high voltage threshold of approx. 30 V at motor start or within a duration of 6 seconds (purge cycle is applied, but no malfunction interlock).
- Control unit malfunction.

4.4.4 Malfunction interlock release and error clearance

The malfunction interlock is released when the heater is switched off.

After that it will be immediately ready for operation.

4.5 Heater interlock

The heater interlock overrides the standard malfunction interlock.

If the heater interlock is active, neither start nor purge cycle are executed after switching the heater back on. Prior to restarting the heater troubleshooting must be performed by personnel trained by Spheros in order to identify the root cause.

After that the heater interlock can be released (see 4.6.1).

Here it is differentiated between interlocks caused by overheating and interlocks caused by other errors.

NOTE

If malfunctions occur during switching-on or during the start process prior to ignition, the heater will be switched off without purge cycle.

The heater is in heater interlock state.

The burner motor stops immediately or does not start. Besides that a purge cycle between 30 seconds and 120 seconds is performed depending on error type and timing. Subsequently the heater status is switched to heater interlock.

Heater interlock causes:

- Short circuit and/or interruption of electrical components:
 - Solenoid valve
 - Flame detector
 - Overheating protection
 - Water temperature sensor
- Flame not expired within 30 seconds after purge cycle started (Burner motor stops)
- Overheating protection triggered
- Control unit error or programming error
- Repeated malfunctions (8)
- Repeated flame interruptions (5)

4.5.1 Heater interlock release

Temperature sensor, overheating protection errors or errors causing overheating cause a heater interlock in software and hardware.

CAUTION

The heater interlock release is permitted by Spheros trained personnel only.

The interlock must be released also in software and hardware.

For this purpose the heater must be disconnected from the vehicle electrical system twice.

The heater interlock release is performed using the following sequence:

1. Correct the cause of the heater interlock.
2. Switch interlocked heater on.
3. Disconnect the switched on heater for > 10 seconds from the vehicle electrical system.
4. Reconnect the switched on heater to the vehicle electrical system.
5. Within 120 seconds disconnect the switched on heater **again** from the vehicle electrical system.
6. Reconnect the switched on heater to the vehicle electrical system **again**.

NOTE

The heater automatically starts after connecting it to the vehicle electrical system.

The heater can be switched off in the initial cycle.

4.5.1.1 Release of a heater interlock triggered by other malfunctions

1. Correct the cause of the heater interlock.
2. Switch interlocked heater on.
3. Disconnect the switched on heater for > 10 seconds from the vehicle electrical system.
4. Reconnect the switched on heater to the vehicle electrical system.
5. Within 120 seconds disconnect the switched on heater **again** from the vehicle electrical system.
6. Reconnect the switched on heater to the vehicle electrical system **again**.

NOTE

The heater automatically starts after connecting it to the vehicle electrical system.

The heater can be switched off in the initial cycle.

4.6 Error output

If the heater is equipped with the standard timer, an error output is displayed on the digital timer after a malfunction occurs, otherwise via flash code at the operating display.

5 Troubleshooting and error correction

5.1 General

This section describes troubleshooting and error correction for Thermo E 200 and E 320 heaters.

ATTENTION

Troubleshooting and error correction may only be performed by briefed and competent trained personnel.

In case of doubt functional connections can be obtained in chapters 3 and 4.

Error detection is usually limited to localizing the faulty component.

The following malfunction causes are not taken into account and should basically always be verified and/or a malfunction due to these reasons should be excluded:

- Corrosion on plugs
- Loose plug connections
- Crimp failures on plugs and/or pins
- Corrosion on cable and fuses
- Corrosion on battery terminals
- Cable insulation damage

ATTENTION

Prior to replacing a fuse troubleshooting needs to be performed. The heater must be disconnected from the vehicle electrical system and the fuse is to be replaced when the heater is in currentless state.

A properly dimensioned fuse must be inserted (see chapter 6 Schematic diagrams).

After each error correction a functional test must be performed in the vehicle.

5.2 General error symptoms

The following table lists possible, general error symptoms.

Table 501: General error symptoms

Error symptom	Possible cause
<p>Error in the electronics</p> <p>Operating display is not illuminated and the heater does not function.</p> <p>Fuse F1 triggered.</p> <p>Fuse F2 triggered.</p> <p>Heater is functional, however the operating display is not illuminated</p>	<ul style="list-style-type: none"> • No supply voltage • Fuses • Supply cable to the plug contacts of plug A of the control unit <p>Short circuit or overload of cables, heater components or of the circulating pump Check cables, connectors and components and replace if required.</p> <p>Short circuit in the supply cable to the main switch or, if installed, in the digital timer</p> <p>Operating display defective to cables to the operating display interrupted or shorted</p>

Table 501: General error symptoms

Error symptom	Possible cause
<p>Error in the water system</p> <p>Circulating pump not operating (Aquavent 6000S and Aquavent 6000SC only).</p>	<ul style="list-style-type: none"> • Error mode activated. <p>In case of malfunctions the motor is switched off via the error mode.</p> <p>Reactivation of the circulating pump motor For this purpose disconnect the power supply for > 2 min. After the power supply is reconnected the motor performs a soft start.</p>
<p>Heater stops as the connected heat exchanger provides insufficient heat.</p> <p>Approximate flow rate determination:</p> <p>Flow rate in [l/h] =</p>	<p><u>Flow rate too small, because</u></p> <ul style="list-style-type: none"> • Air in the heater, heat exchanger or in system sections. • Taps/valves (flow controllers) throttled, contaminated, closed. • Contaminations in the system, e.g. filters or at bottlenecks. • Circulating pump delivery rate insufficient (air in pump housing), • Insufficient frost protection. • System resistance too high (especially high in the cold). • Circulating pump defective. <p><u>Heat exchanger provides not enough heat, because</u></p> <ul style="list-style-type: none"> • Air in the heat exchangers and/or system sections. • Contaminated heat exchanger. • Insufficient air entry or air exit. • Fan: Insufficient delivery rate / incorrect direction of rotation / resistance too high. • Antifreeze content too high. $\frac{\text{Heat flow [kW] according to type plate}}{\text{Temperature difference } \Delta t \text{ in [K] or } [^{\circ}\text{C}] \text{ measured on the heater between water inlet and water outlet (e.g. using contact thermometer)}} \times 860$

Table 501: General error symptoms

Error symptom	Possible cause
<p>Error in the fuel supply</p> <p>No fuel delivery to the heater.</p>	<ul style="list-style-type: none"> • Fuel tank empty. • Bent, closed, clogged or leaking lines. • Paraffin deposits or frozen water entrapments in fuel lines or lines. • Venting opening in tank closed. • Fuel lines mixed up. • Fuel filter contaminated. • Fuel screen (filter) in pump contaminated.
<p>Error in the combustion</p> <p>CO₂ value cannot be adjusted to nominal value. Irregular combustion.</p>	<ul style="list-style-type: none"> • Air bubbles in fuel supply line (leaking fuel supply line). • Fuel filter contaminated or leaking. • Fuel integration leaking (suction lift, low pressure in tank), observe installation instruction. • Fuel pump defective (pump pressure). • Screen (filter) in fuel pump contaminated. • O-ring seal on fuel pump ineffective (leaky or lack of O-ring). • Atomizer nozzle defective. • Combustion air and exhaust lines throttled or closed. • Burner motor speed too low. • Coupling defective.

5.3 Malfunction code output via flash code

The error cause is outputted as a flash code via the operating display.

After five short signals the long flash signals are counted.

The number of long flash impulses corresponds to the respective flash code. Flash codes and their respective error meaning are presented in Table 502.

Table 502: Blinkcode

No. of impulses	Error	Error description
0	Control unit error	Control unit error
1	No start within safety period	No start within safety period
2	Flame interruption	Flame interruption in burner operation, repeated starts unsuccessful
3	Low Voltage / high voltage	High voltage (> 30V, at least 6 seconds)
		Low Voltage (< 20.5V, at least 20 seconds)
4	Extraneous light in initial or purge cycle	Extraneous light (flame detector "Bright" in purge cycle 2)
		Extraneous light (flame detector "Bright" prior to ignition)
5	Flame detector defective	Flame detector short circuit
		Flame detector interruption
6	Temperature sensor / overheat protection defective	Temperature sensor short circuit
		Temperature sensor interruption
		Temperature sensor / overheat protection non-plausible
		Overheat protection short circuit
		Overheat protection interruption
7	Solenoid valve defective	Solenoid valve short circuit
		Solenoid valve interruption
8	Combustion air fan motor / nozzle block preheater defective	Combustion air fan motor short circuit
		nozzle block pre-heater short circuit
9	Circulating pump defective	Circulating pump short circuit
10	Overheat protection triggered	Overheating T>125°C
11	Electronic ignition unit defective	Electronic ignition unit short circuit
		Electronic ignition unit interruption
12	Heater interlock	Flame interruption counter threshold exceeded
		Heater interlock - release required
		Malfunction counter threshold exceeded

5.4 Error symptoms during functional tests with malfunction code output

5.4.1 Error symptom "No start within safety period"

If due to a malfunction the heater unsuccessfully attempted to start eight times in a row, it will be interlocked.

No further start attempts will be tried.

The heater interlock overrides the standard malfunction interlock.

The procedure for releasing the heater interlock can be found in point 4.5.1.

The "No start within safety period" error symptom does not always indicate that no ignition took place. This symptom occurs as well, if the heater fails to enter heating operation (heating or auxiliary heating state) after successful ignition, e.g. in case the fuel supply is interrupted.

5.4.2 Error symptom "Flame interruption"

If due to a malfunction flame interruption occurs during heating operation five times in a row, the heater will be interlocked.

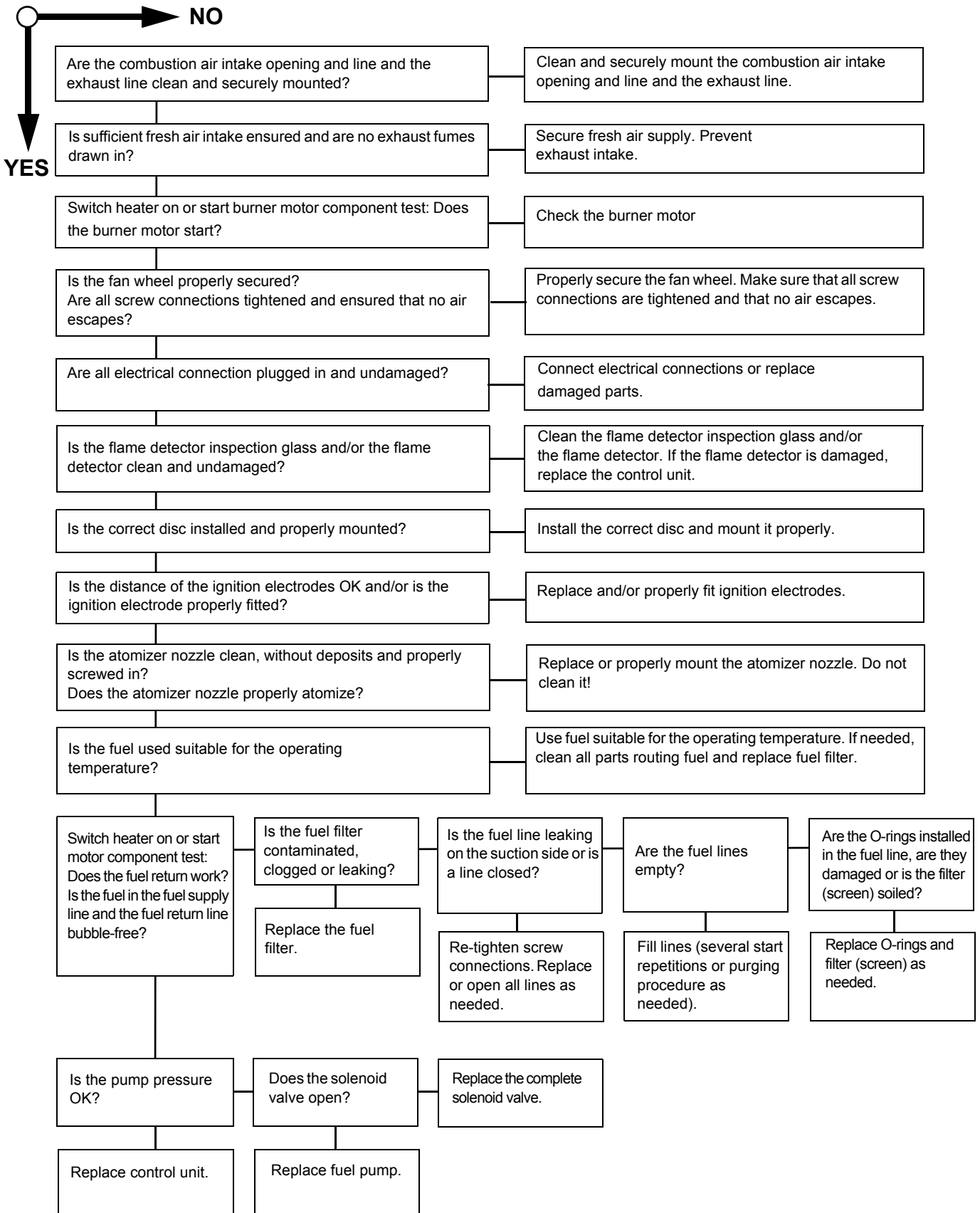
No further start attempts will be tried.

The heater interlock overrides the standard malfunction interlock.

NOTE

After above mentioned error symptoms occur, troubleshooting according to page 506 is recommended.

The procedure for a heater interlock release is outlined in point 4.5.1.

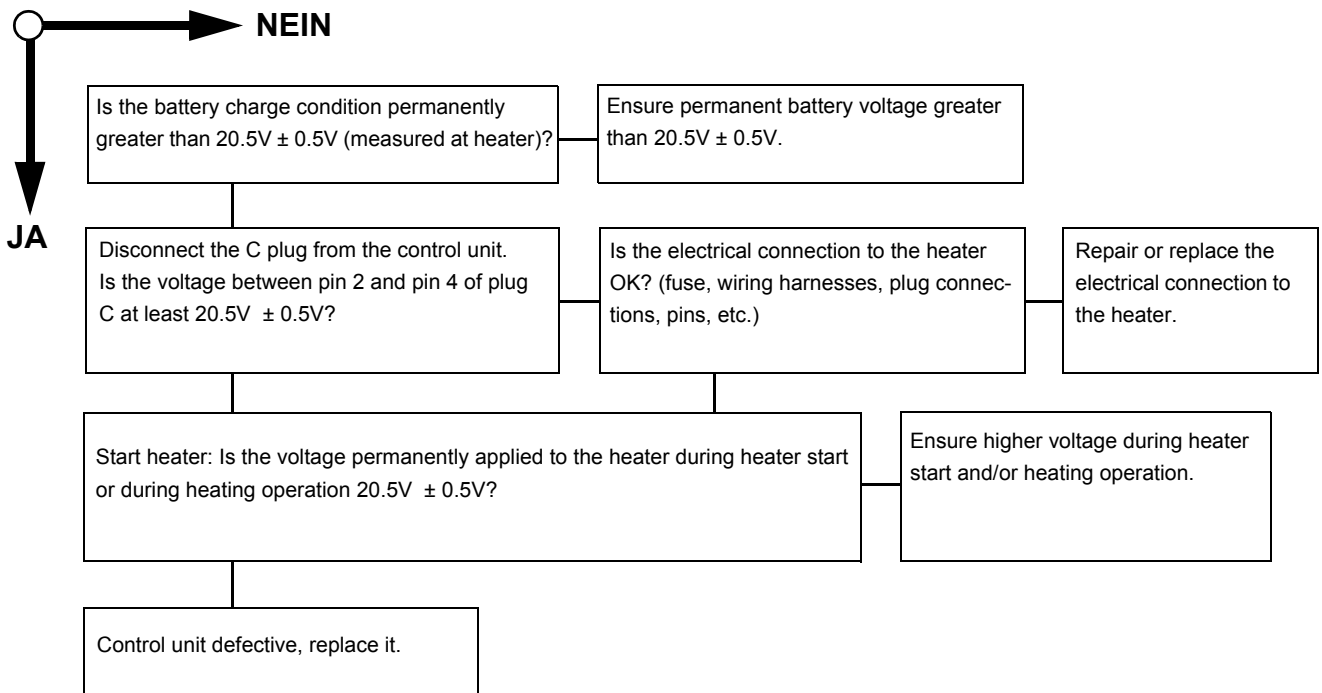


5.4.3 Error symptom "Low voltage"

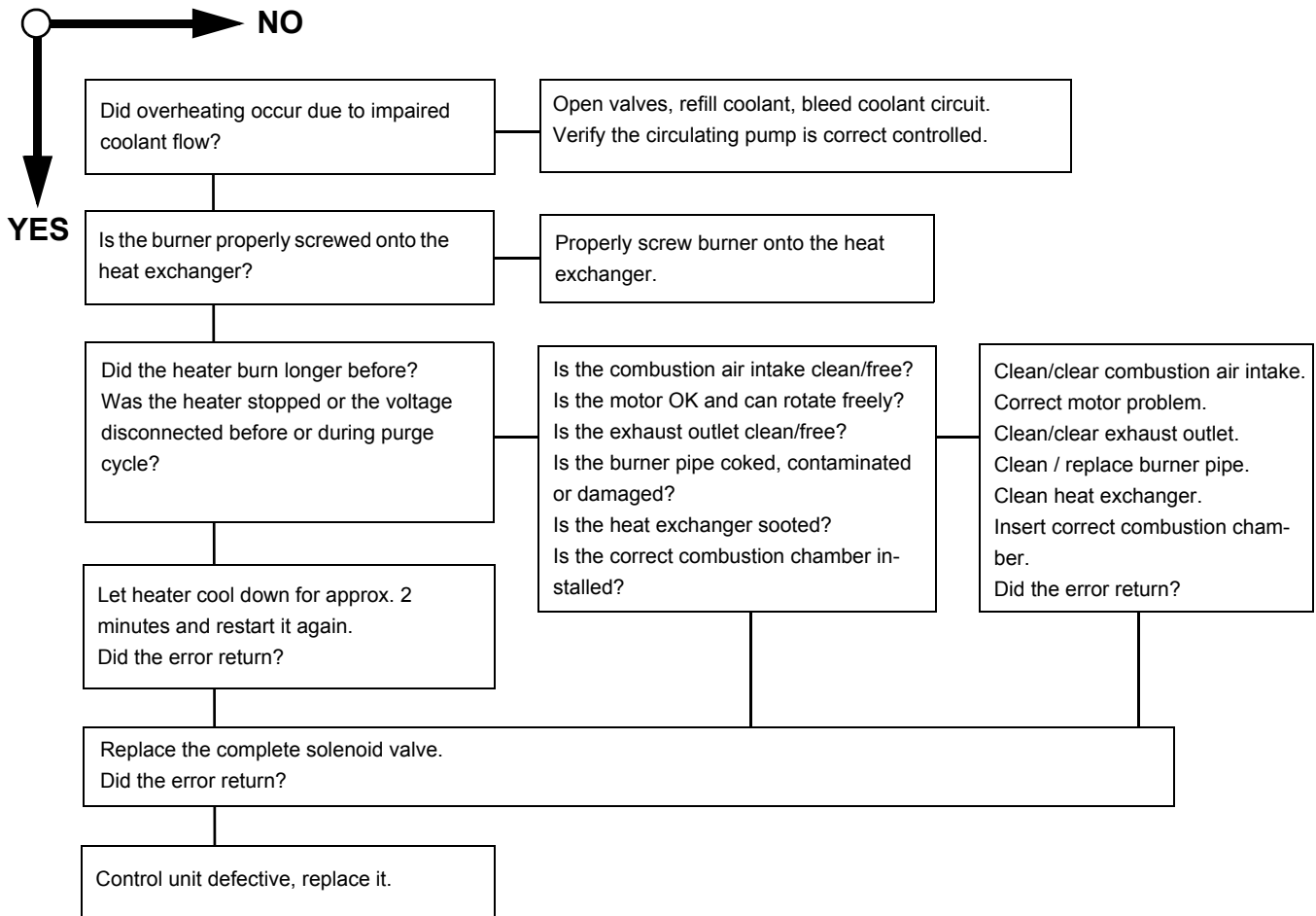
A value is stored in the control unit as smallest "permissible low voltage".

It must be noted that the voltage may be lowered during heater start, and that the "low voltage" threshold may be violated.

Among others this depends on the vehicle electrical system, the temperature of optional components, such as the nozzle block preheater, circulating pumps or heatable filters.



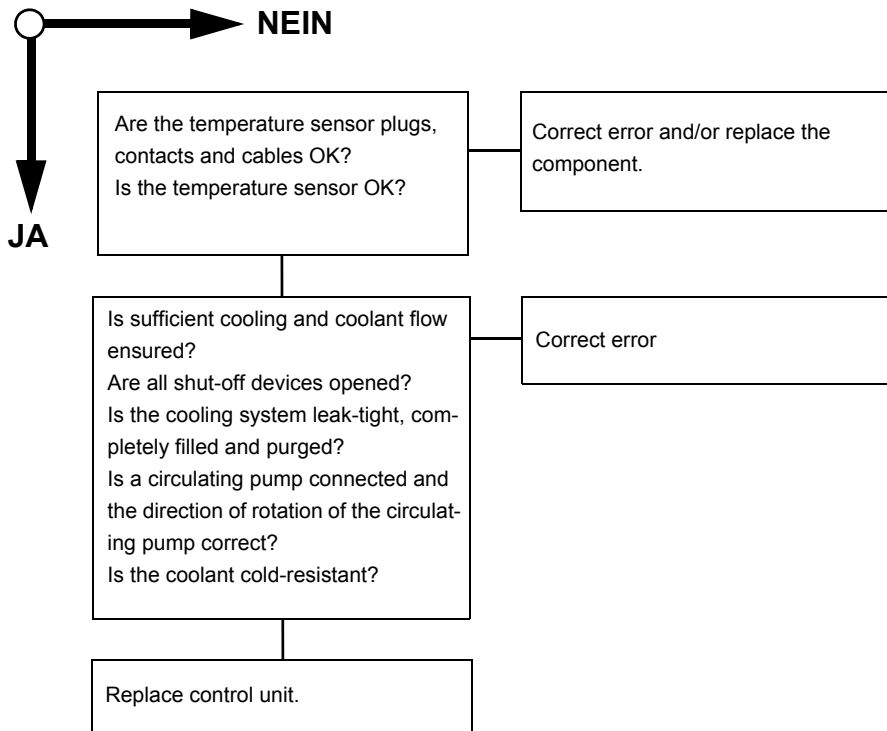
5.4.4 Error symptom "Extraneous light detected prior to ignition or during purge cycle"



5.4.5 Error symptom "Flame detector defective"

The flame detector cannot be replaced. Optionally the control unit is to be replaced.

5.4.6 Error symptoms "Temperature sensor / overheating protection defective" and "Overheating"



5.5 Individual component tests

Individual components can basically be tested using visual inspection or manual electrical testing.

NOTE

Prior to disconnecting the temperature sensor plug connection, disconnect the heater from the vehicle electrical system.

ATTENTION

The general safety regulations according to Chapter 1 must be observed.

5.5.1 General visual inspection

- Inspect components for damages (cracks, deformation, leaks, discolourations, etc.) and replace as needed.
- Inspect plugs and cables for corrosion, contact and crimp errors and repair as needed.
- Check plug contacts for corrosion and tight fit. Repair as needed.

5.5.2 Heat exchanger visual inspection

- Inspect heat exchanger interior for damage, corrosion, sooting and deposits.
- Inspect heat exchanger for outer damage, corrosion, moisture, deformations, deposits, discolourations, etc.

ATTENTION

Soot and deposits in the heat exchanger must be removed, as they impact the heat transfer to the coolant.
Severe outer deformations may impact coolant flow.

5.5.2.1 Visual inspection of exhaust outlet and exhaust line

Inspect exhaust outlet and possibly available exhaust line for conditions, tight fit, contamination and deposits. Use only exhaust gas deflections according to Installation instruction.

5.5.3 Combustion chamber visual inspection

- Remove combustion chamber (see 8.11).
- Inspect swirl plate and combustion chamber head for damage and tight fit.
- Check and remove combustion chamber for scalings and coke deposits as needed.

- Inspect combustion chamber for deformation and moisture.
- Inspect combustion chamber for cracks.

NOTE

Cracks in longitudinal direction at the end of the welding seam shorter than 80 mm are permissible.

- After the inspection is completed, reinstall the combustion chamber (see 8.11).

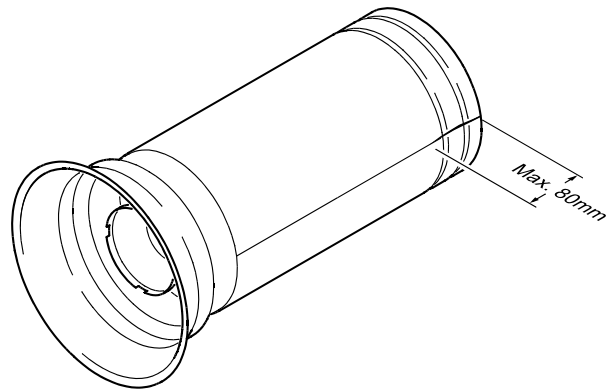


Fig. 501

5.5.4 Resistance check of the temperature sensor with integrated overheating protection

CAUTION

Prior to removing the temperature sensor, the overpressure in the cooling system must be released by opening the cooling lid. Observe the risk of injuries due to increased coolant temperature. Possibly let heater additionally cool down and have collecting container ready for discharged coolant.

Inspection

- Inspect temperature sensor, plug and cable for damage and proper fit.
- Remove temperature sensor (see 8.3).
- Perform the electrical test using a measuring device suitable for resistance measurements.
- The electrical resistance between pin 1 and pin 3 (see Fig. 502) is at 0°C 500 Ohm, between pin 2 and pin 3 2000 Ohm. Both resistances change depending on temperature. The ratio should be at tempered through sensor 1:4.
- Install temperature sensor (see 8.3).

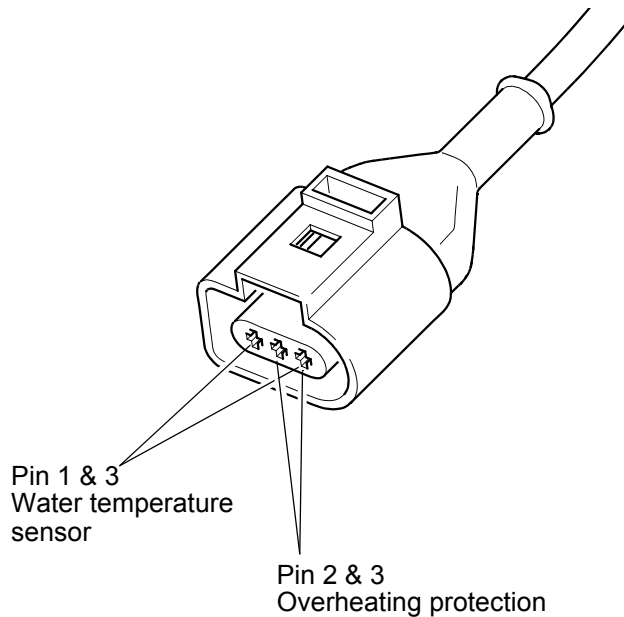


Fig. 502

5.5.5 Fan and combustion air intake line visual inspection

- Inspect a possibly available combustion air intake line for contamination, condition and deposits.
- Remove hood (see 8.4).
- Inspect fan channels for contamination and deposits.
- Inspect fan and motor shaft mount for cracks, stress marks and deformations.
- Check circlip for proper fit.
- Install hood (see 8.4).

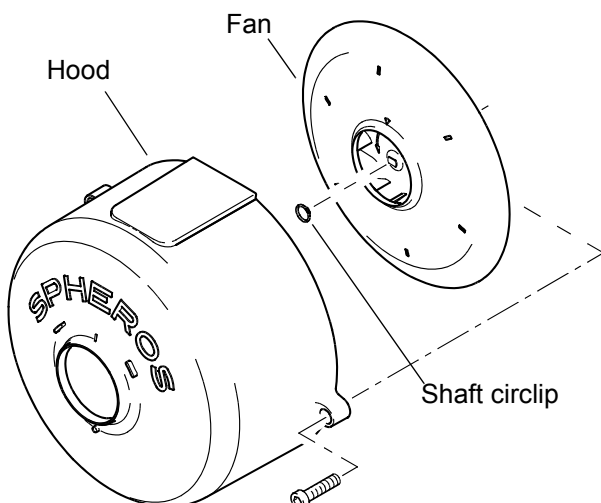


Fig. 503

5.5.6 Burner motor inspection

The motor can be checked by applying 24V DC voltage. The electrical connection to the control unit must be disconnected first.

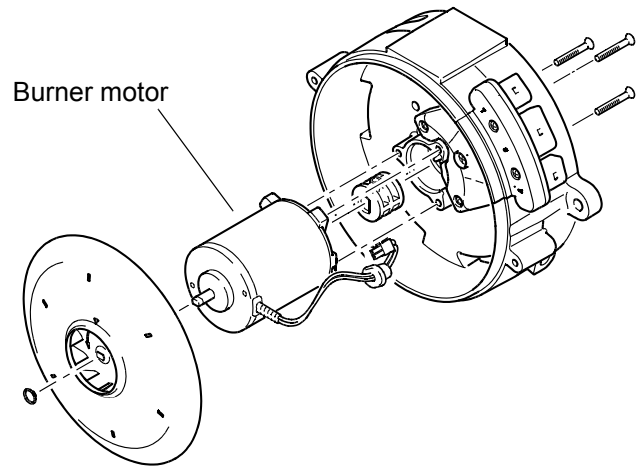


Fig. 504

- Disconnect the heater from the vehicle electrical system.
- Check whether the motor used corresponds to the heating capacity class.
- Inspect the motor for bearing conditions (stiffness). For this purpose remove hood as needed (see 8.4).
- Reconnect the heater to the vehicle electrical system.

5.5.7 Electronic ignition unit inspection

NOTE

It can only be verified by visual inspection of the ignition electrode, whether the ignition spark jumps over to the ignition electrode.

CAUTION

High voltage: The voltage received by the ignition electrode is >13,000 Volt.
During operation or testing of the electronic ignition unit, the ignition electrode may not be contacted by persons or items.

ATTENTION

Do not test or apply voltage to the electronic ignition unit without an ignition electrode.

Inspect the electronic ignition unit for housing and end cover damage.
No mechanical damage may be caused or be present on housing and end cover.

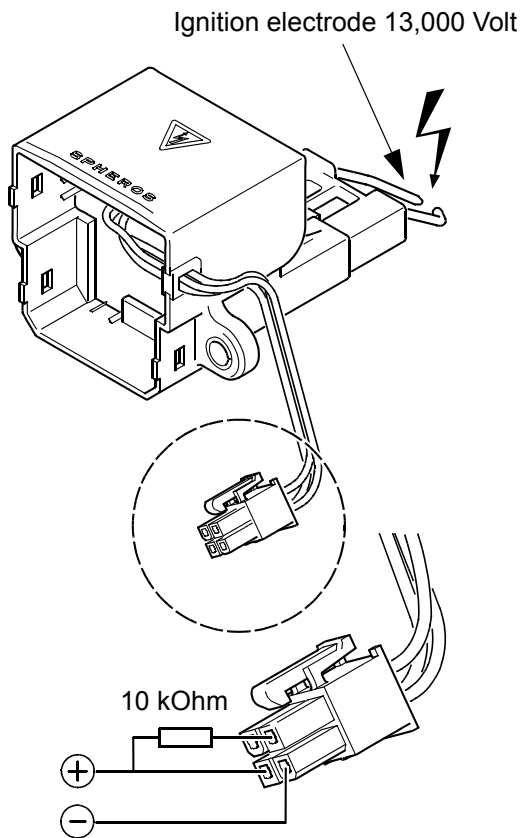


Fig. 505

Manual functional test when disassembled

- Remove electronic ignition unit (see 8.6).
- Connect ignition electrode.
- Apply 24V direct voltage according to Fig. 505.
- Nominal condition: Ignition sparks the ignition electrode jump over with a rate of 6Hz.
- After the test is completed, install the electronic ignition unit (see 8.6) and attach the ignition electrode.
- Install burner (see 8.2).

5.5.8 Ignition electrode inspection

NOTE

The ignition electrode insulation may not be damaged. Ignition electrodes not functioning properly must be replaced.

ATTENTION

Do not damage the electronic ignition unit when removing the ignition electrode.

Inspection

- Remove burner (see 8.2)
- Check distance of the electrode tip to the atomizer nozzle (see Fig. 506).
- Check the distance between the electrodes (see Fig. 506).

NOTE

The distance between the electrodes may be measured using checking gauge, item number 310646.

- If needed, lift off ignition electrode (3, Fig. 805) from the electronic ignition unit by twisting a screwdriver sideways (see Fig. 804).
- Inspect the ignition electrode insulation for damage.
- Functionality is verified while inspecting the electronic ignition unit.

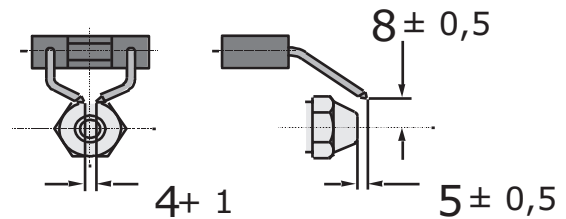


Fig. 506

5.5.9 Flame detector inspection

NOTE

In case of contamination the glass body of the flame detector and the inspection glass in the disc (see Fig. 507) must be cleaned.

The flame detector is permanently integrated into the control unit and cannot be replaced.

The error diagnosis is possible only via the flash code (error code 5).

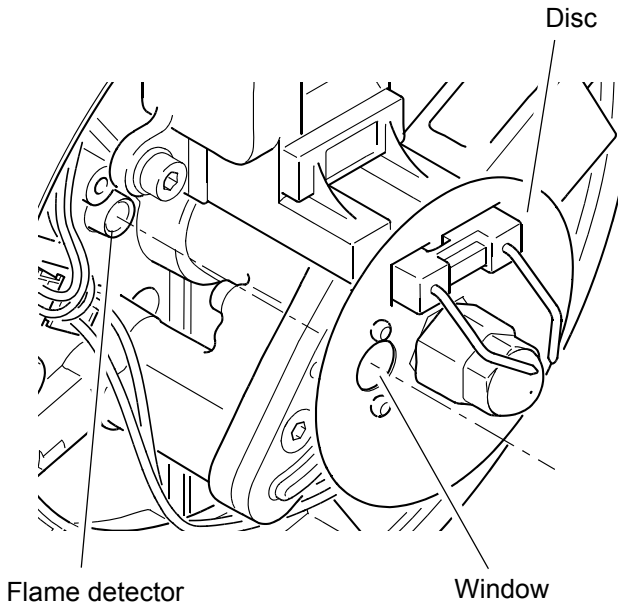


Fig. 507

- Are the filters (screens) in the pump inlet clean?
- Is the fuel delivered without bubbles? Attach a transparent hose for testing.
- If the specified exhaust values cannot be reached after inspection and consideration of this error sources, the fuel pump is to be replaced.

The pump pressure can be checked as follows. The pump pressure adjustment is not permitted.

- In a workshop (not in the vehicle) fix the burner head.
- Disconnect motor and solenoid valve connectors from control device.
- Ensure fuel supply.
- Screw a pressure gauge into the nozzle holder.
- Hook-up the motor and the solenoid valve with a 24V power supply (Observe the rotation direction of the motor! Pointer on the fan wheel).
- Read the pressure at the pressure gauge.
- Dismantling in reverse order.

5.5.10 Fuel pump inspection

ATTENTION

The pump pressure of the fuel pump is adjusted to a fixed value in the factory. It is not permitted to change the pump pressure.

The fuel pump and fuel hoses must be replaced after 5 years.

An admixture of up to 30% FAME to Diesel fuel is permitted.

NOTE

If FAME is used, commonly designated as biodiesel, the fuel pump and fuel lines must be replaced according to the latest technical information / notification.

The following inspections should be performed prior to testing the pump pressure:

- Is the CO₂ content properly adjusted?
- Do the combustion chamber, atomizer nozzle and burner motor correspond to the heating capacity class?
- Does the motor reach nominal speed?
- Is the fuel temperature 15...25°C?
- Are available check valves in the fuel supply and return lines opened?
- Was the fuel filter in the fuel supply line replaced?

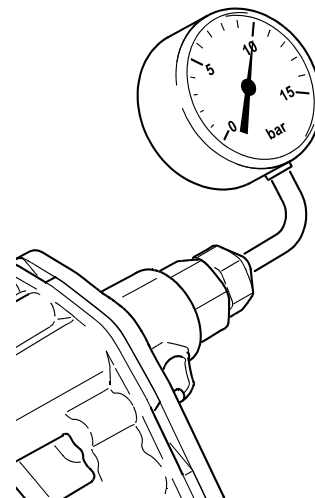


Fig. 508

At 24.0V	Pump pressure
Thermo E 200	8 +1 bar
Thermo E 320	9 +1 bar

5.5.11 Solenoid valve inspection

ATTENTION

The coil of the solenoid valve can heat up in switched-on condition.

The solenoid valve must only be completely replaced.

In case of replacement or assembly a new gasket ring must be used.

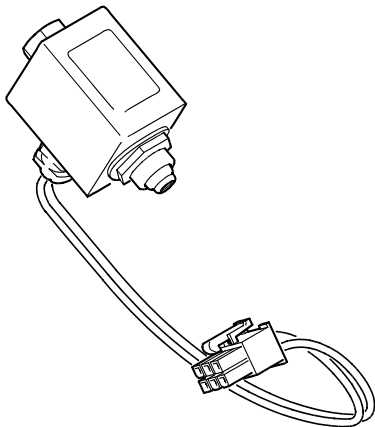


Fig. 509 Solenoid valve

NOTE

Due to system characteristics draining the space between solenoid valve and nozzle bore may cause fuel dripping from the atomizer nozzle for a short period of time.

A leaking valve seat of the solenoid valve can be indicated by smoke development in the heater during the purge cycle. Fuel drips from the atomizer nozzle.

A not closing solenoid valve may cause heater deactivation during purge cycle with heater interlock activation.

The electrical function of the solenoid valve can be checked manually.

Manual inspection:

- Remove burner (see 8.2).
- Disconnect the solenoid valve plug from the control unit.
- Apply 24V direct voltage and check electrical function:
 - Opening voltage: ab 17.0 Volt
 - Power consumption at 24V and 20°C: 9 Watt
 - Nominal current at 24V: 0.37 Ampere

The solenoid valve must audibly open, when voltage is applied.

- Reconnect the solenoid valve plug to the control unit.
- Install burner (see 8.2).

5.5.12 Nozzle block preheater inspection

NOTE

At a temperature of $< 5^{\circ}\text{C}$ the heating element in the nozzle holder is switched on via a temperature sensor. The heating duration depends on the intake air temperature and on the reflected by the burner heat. Above 8°C the thermostat turns the preheater off. The power consumption of the heating element is at 24V approx. 80W.

Inspection

- Remove burner head.
- Disconnect the nozzle block preheater plug from the control unit.
- Connect an ohmmeter to the plug.
- Bridge over the thermostat
- Resistance max. 8 Ohm.

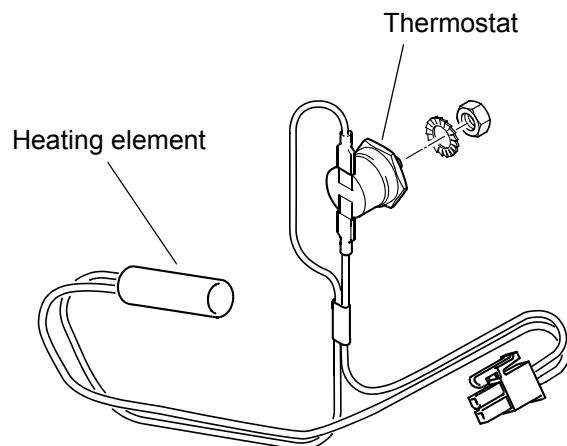


Abb. 510 Nozzle block preheater

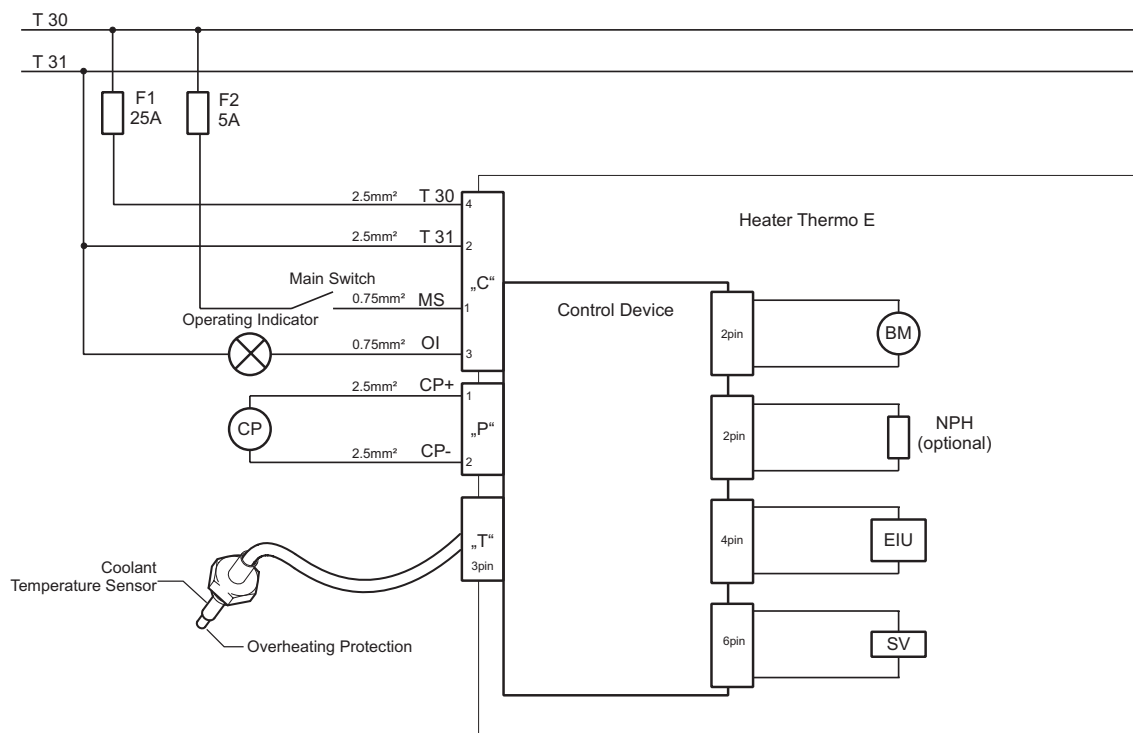
6 Wiring diagrams

6.1 General

The following figures represent heater connection options to the vehicle electrical system.

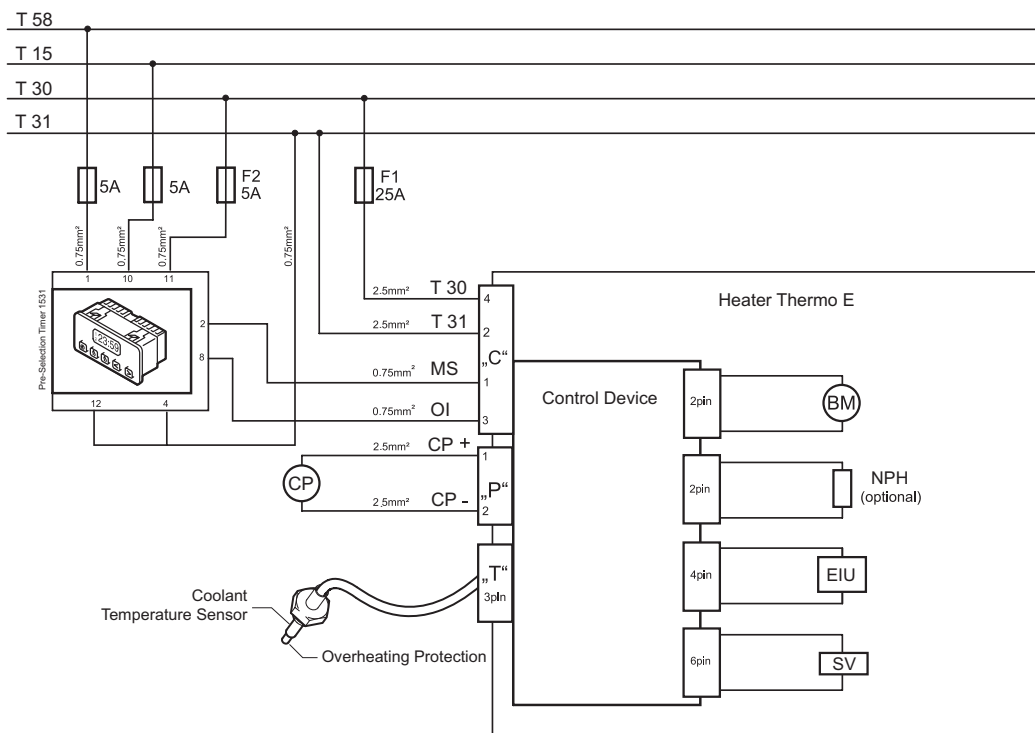
The in the table below shown cable cross-sections are to be used.

Cable length <7.5m	Cable length 7.5 - 15m
0.75 mm ²	1.5 mm ²
2.5 mm ²	4.0 mm ²



Cable cross-sections are effective for a maximum cable length of up to 7.5 m. For longer cables see table on page 601.

Fig. 601 System wiring diagram for heaters Thermo E, legend see page 603



Cable cross-sections are effective for a maximum cable length of up to 7.5 m. For longer cables see table on page 601.

Fig. 602 System wiring diagram for heaters Thermo E with pre-selection timer 1531, legend see page 603

Position	Designation
OI	Operation indicator max. 1x5W or 2x2W
BM	Burner motor
NPH	Nozzle block pre-heater
F1	Car flat-type fuse 25A acc. DIN 72581 part 3
F2	Car flat-type fuse 5A acc. DIN 72581 part 3
MS	Main switch
SV	Solenoid valve
CP	Circulating pump
EIU	Electronic ignition unit

Legend to the system wiring diagram

C	To vehicle (Power)	T	Temperature sensors
C1	Main switch	T1	Temperature sensor)
C2	Terminal 31 (-)	T2	Overheating protection
C3	Operation indicator +	T3	Ground
C4	Terminal 30 (+)	V	Nozzle block pre-heating
P	Circulation pump	V1	Nozzle block pre-heating +
P1	Circulation pump +	V2	Nozzle block pre-heating -
P2	Circulation pump -	Z	electronic ignition unit
B	Burner motor	Z1	electronic ignition unit +
B1	Burner motor +	Z2	electronic ignition unit +
B2	Burner motor -	Z4	electronic ignition unit -
M	Solenoid valve		
M3	Solenoid valve +		
M4	Solenoid valve -		

Connector pin assignment

7 Servicing

7.1 General

The general safety regulations (see 1.5.2) must be observed.

7.1.1 Heater servicing

Only briefed and/or personnel trained by Spheros may perform work on the heater.

For risk of overheating, the battery main current may not be disconnected, while the heater is operating or in purge cycle.

Make sure that the circulating pump is running while the heater is switched on for tests/inspections.

7.2 Servicing

In order to ensure long-term functional reliability, the following maintenance activities should be performed on the heater at least yearly, at the latest before the cold weather season starts.

NOTE

If FAME is used (max. 30%!), the fuel pump and fuel lines must be replaced according to the latest technical information.

You can find an actual overview of all technical information on the Spheros homepage under Service / Technical Documents.

- In order to prevent malfunctions, the fuel filter and/or strainer as well as the fuel pump filter (screen) must be replaced at least once a year, in case of heavily contaminated fuel even more often.
- Yearly visual inspection of the fuel pump, fuel and coolant lines for leakage. In case of a leakage they must be replaced immediately otherwise after 5 years service time.
- Yearly atomizer nozzle replacement.
The atomizer nozzle is a consumable thus not covered by warranty.
- Yearly visual inspection of inspection glass and flame detector glass body, clean as needed.
- Yearly visual inspection of the combustion chamber and heat exchanger interior for contamination and soot, clean as needed.
- Inspection of combustion air intake openings and exhaust port for contamination. Clean as needed.

- Outside the heating period, the heater should be operated every 4 weeks for 10 min. with the heater set to "warm" and cold vehicle engine.

7.2.1 CO₂ Measurement and setting

CO₂ Measurement

The exhaust should not be measured directly at the exhaust outlet of the heat exchanger, as this may cause inaccuracies.

Exhaust fumes should be sampled from the exhaust pipe in a distance of 350 mm after the heat exchanger. If no exhaust pipe is connected for this measurement a flexible hose of approx. 500 mm length (see accessories catalog) can be installed. At this place also the measurement of the exhaust gas temperature should be performed.

Increased exhaust temperature may indicate a sooted heat exchanger (see 5.5.2).

1. After a combustion period of approx. 3 min. measure the CO₂ content in the exhaust and compare it with the target value in Table 701.
2. Determine smoke number as needed: Target value according to Bacharach: ≤ 4.

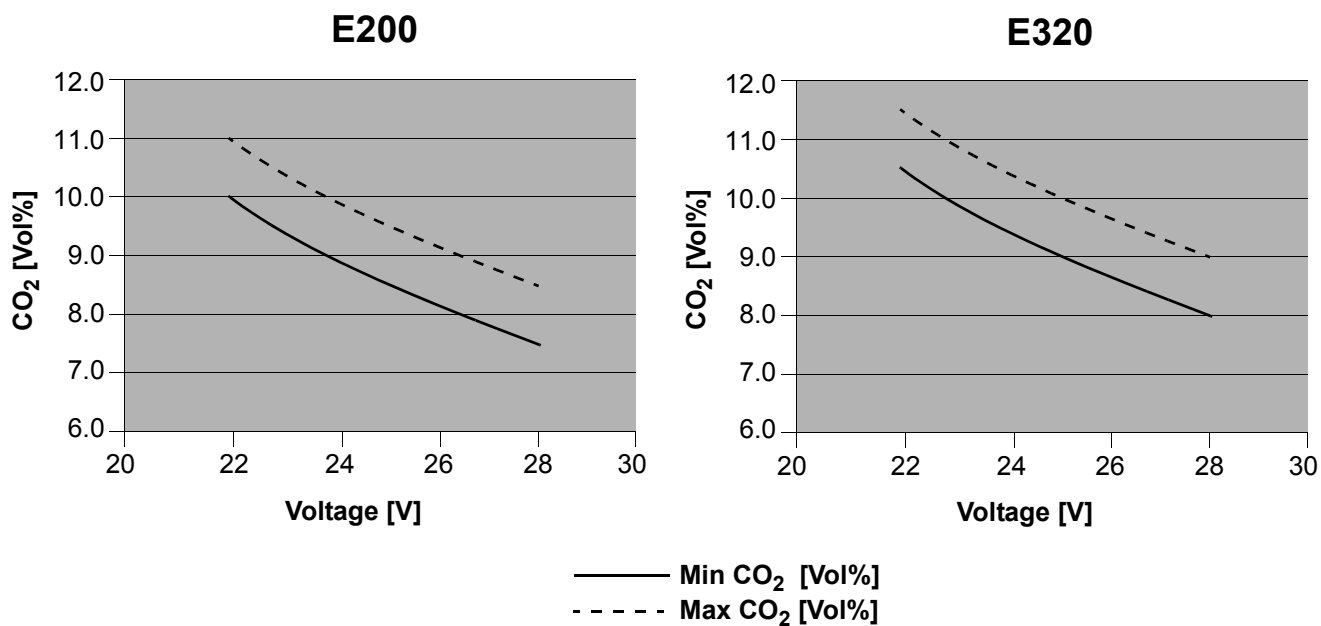
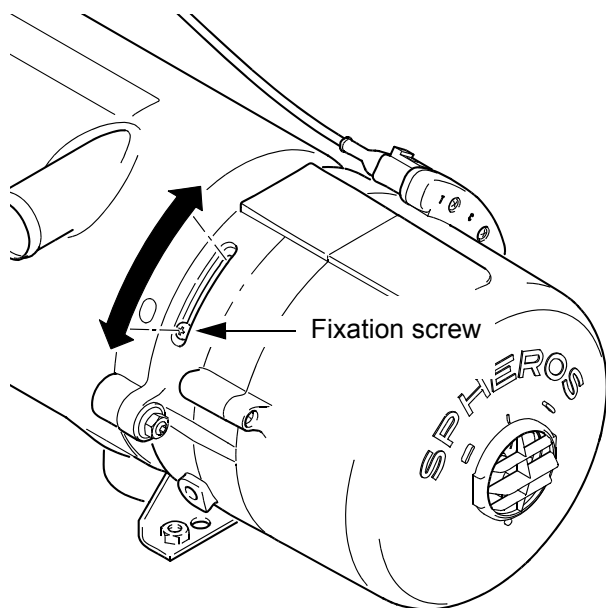
The combustion air amount change is permitted and can be achieved by rotation of the adjustment ring.

The measurement of the CO₂ content in the exhaust gas and the adjustment of the combustion air amount is to be performed:

- after repairs at the burner
- in case of combustion irregularities
- in the course of a functional inspection
- after atomizer nozzle replacement
- for application adaption
- for permanent operation at large altitudes

CO₂ Setting

1. Measure the heater input voltage
2. Operate the heater approx. 3 min.
3. Measure the CO₂ content and the smoke number and compare readings with the appropriate diagram (see Fig. 701).
4. Loosen the fixation screw (see Fig. 702) and rotate the adjustment ring with the fixation screw until the target value is reached.

Fig. 701 Diagrams CO₂ value and dependency on voltageFig. 702 Fixation screw for CO₂ setting

- Torque fixation screw to 1.0 + 0.5 Nm and apply locking compound.

NOTE

The CO₂ setting depends on the fuel (viscosity) and the height above sea level (0.1% per 100 m). If the CO₂ value cannot be adjusted to target value proceed as follows:

- Check air intake side of burner head for damage and replace, if required.
- Measure burner motor speed, replace burner motor as needed.
- Check the fuel filter and the screen in the fuel pump for contamination and replace if required.
- Check the fuel pump pressure and replace fuel pump if required.
- Replace atomizer nozzle.

8 Burner, components and heater removal and installation

8.1 General

The general safety regulations (see 1.5.2) must be observed.

CAUTION

Prior to disassembling components the heater must be disconnected from the vehicle electrical system.

ATTENTION

Sealing elements between disassembled components must be principally scrapped and replaced. This does not apply to the temperature sensor gasket ring, as it is permanently attached. Screws with coated threads (screw locking) must be scrapped and replaced.

NOTE

If components are disassembled to a degree not covered in this workshop manual, any warranty claim shall be voided.

Only genuine Spheros spare parts should be used.

Removing the burner provides access to the following components:

- Atomizer nozzle
- Fuel pump and solenoid valve
- Electronic ignition unit and ignition electrodes
- Disc with inspection glass for flame detector
- Nozzle block preheater (option)
- Flame detector (integrated into control unit)
- Combustion chamber
- Coupling

8.2 Burner removal and installation

Burner removal

1. Disconnect the heater from the vehicle electrical system and from the circulating pump as needed.
2. Disconnect the temperature sensor plug (5, Fig. 801).
3. If necessary, disconnect the combustion air intake line from the heater.

NOTE

Make sure that any fuel leaking during the following work step is immediately bound and professionally disposed of.

4. Unscrew fuel lines and seal with blank plugs.
5. Unscrew nuts (2).
6. Remove burner (1).

NOTE

Do not bent any lines when placing the burner down.

Burner installation

1. Bring burner (1, Fig. 801) in assembly position and ensure centre alignment and correct fit.
2. Place nuts (2) and alternately tighten them slightly.
3. Tighten nuts (2) with $7.5 \text{ Nm} + 1 \text{ Nm}$ and apply screw locking paint.
4. If applicable, bolt fuel lines down with $16 \pm 1 \text{ Nm}$ using a banjo bolt and new gaskets, or slide on fuel lines and secure with hose clamps.
5. If applicable, secure the combustion air intake line to the heater.
6. Connect the temperature sensor plug (5).
7. Connect heater with the vehicle electrical system and the circulating pump as needed.

- 1 Burner
- 2 Nuts (2)
- 3 Screws (2)
- 4 Hood
- 5 Temperature-sensor plug

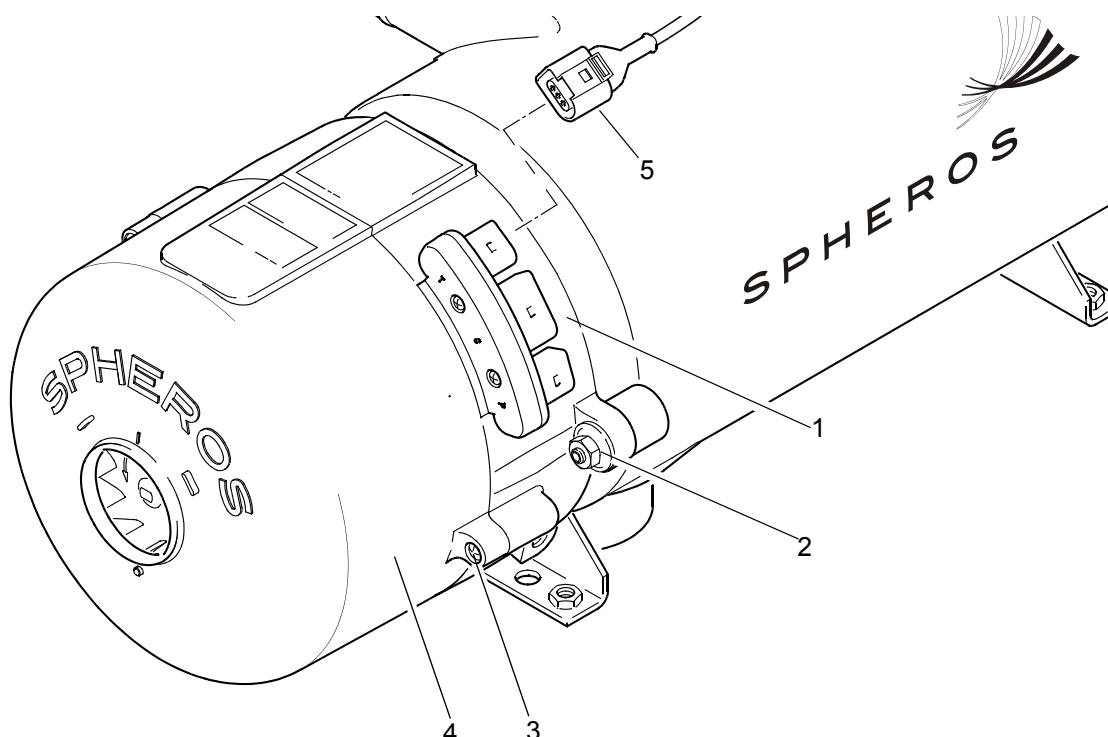


Fig. 801 Burner head / hood removal and installation

8.3 Removal and installation of the temperature sensor with integrated overheating protection

CAUTION

Risk of injuries if coolant temperature is increased.

Removal

1. Disconnect the heater from the vehicle electrical system and from the circulating pump as needed.
2. Disconnect the temperature sensor plug (5, Fig. 801).

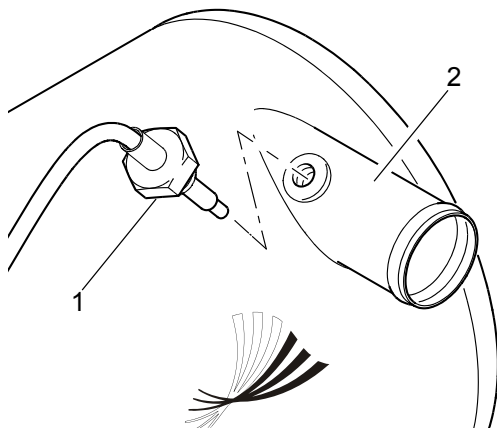
ATTENTION

The temperature sensor is positioned directly in the coolant circuit. To prevent coolant from escaping as far as possible, the coolant hoses are to be closed with pinch-off pliers (331457).

3. Unscrew and remove temperature sensor (1, Fig. 802). Collect the escaping coolant.

Installation

1. Manually screw temperature sensor (1, Fig. 802) into coolant outlet (2).
2. Tighten temperature sensor (1) with $8 \text{ Nm} \pm 0.5 \text{ Nm}$.
3. Connect temperature sensor plug (5, Fig. 801).
4. Connect heater with the vehicle electrical system and the circulating pump as needed.



- 1 Temperature sensor
- 2 Coolant outlet

Fig. 802 Temperature sensor removal and installation

8.4 Hood removal and installation

Removing the hood provides access to the following components for maintenance, inspection and repair purposes:

- Fan
- Burner motor
- Control unit
- Coupling

Removal

1. Disconnect the heater from the vehicle electrical system.
2. If applicable, disconnect the temperature sensor (5, Fig. 801).
3. Loosen screws (3, Fig. 801).
4. Remove hood (4).

Installation

1. Place hood (4, Fig. 801) in assembly position. Ensure centre alignment, proper fit and seal towards heater wiring harness.
2. Insert screws (3) and tighten with $2 \text{ Nm} + 0.5 \text{ Nm}$.
3. If applicable, reconnect the temperature sensor plug (5, Abb. 801).
4. Connect the heater to the vehicle electrical system.

8.5 Burner motor removal and installation

Removal

1. Disconnect the temperature sensor (1, Fig. 802).
2. Remove the burner (see 8.2).
3. Remove the fuel pump (see 8.8).
4. Disconnect the burner motor plug (6, Fig. 803) from control unit.
5. Remove the cable sleeve.
6. Remove the hood (1).
7. Remove the fan wheel (4). For that remove the shaft circlip using suitable pliers.

ATTENTION

Do not overstretch the shaft circlip.

8. Remove the three countersunk screws.
9. Remove the burner motor (5).
10. Remove the coupling (7).

CAUTION

If the motor is replaced due to functional failure, also all plug connections at the control unit are to be checked and replaced as necessary.

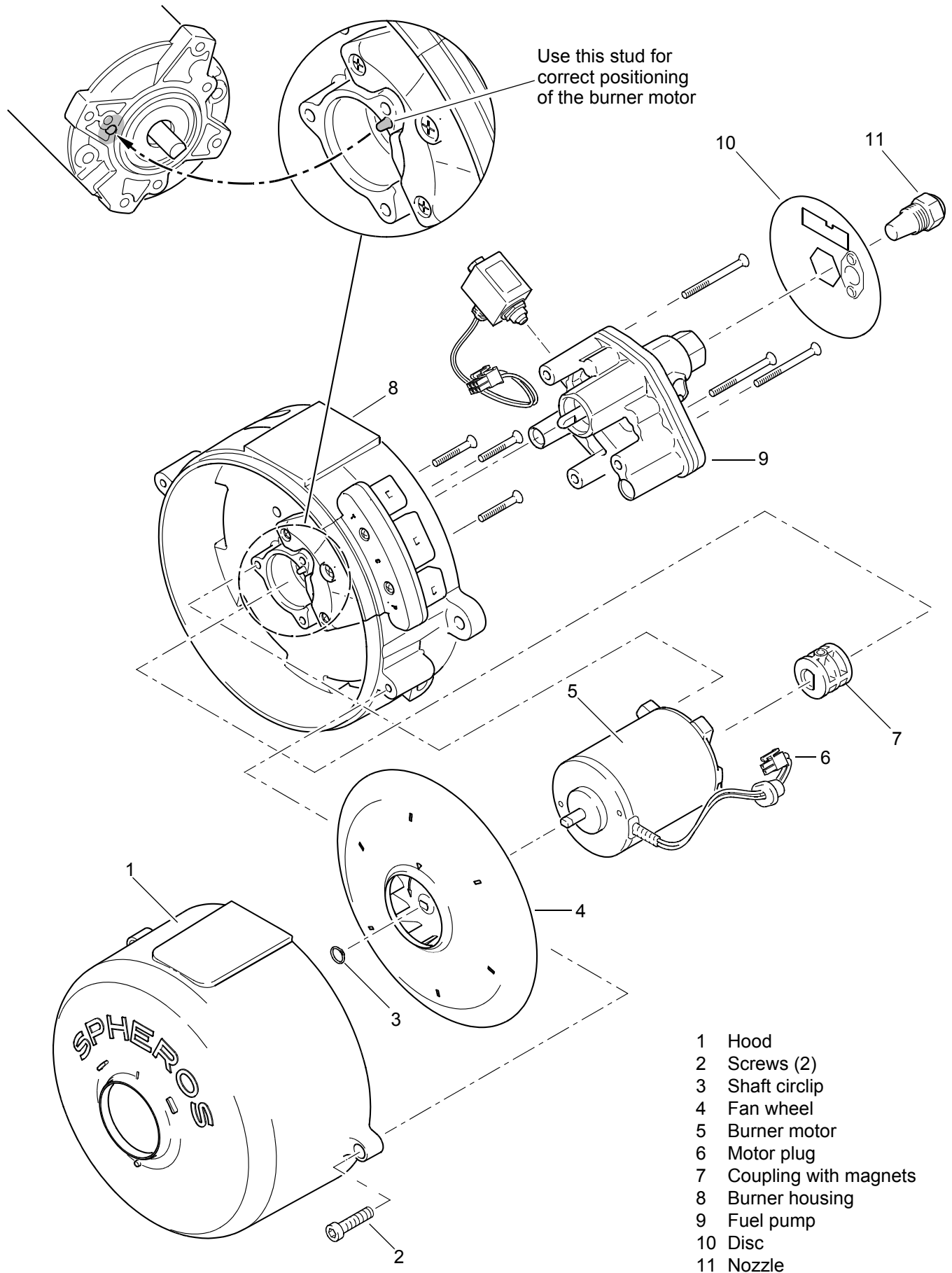


Fig. 803 Burner motor removal and installation

Installation

1. Position motor (5, Fig. 803) onto the housing (stud at the housing and hole in the motor flange).
2. Secure motor (5) with three countersunk screws M5x35 (5 +1 Nm).
3. Install fan (4). Install shaft circlip with suitable pliers.

ATTENTION

**Do not use an overstretched shaft circlip!
Ensure secure engagement of the circlip in the groove!**

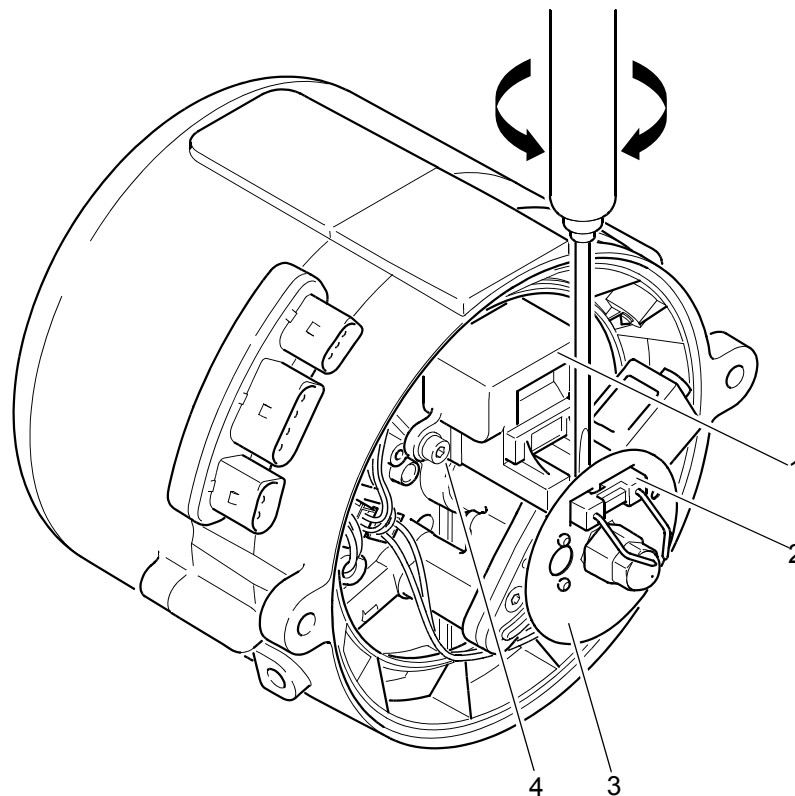
4. Put the cable through the housing hole and install the sleeve.
5. Install hood (1) (2 +0.5 Nm).
6. Connect plug (6) of the burner motor with the control unit.

NOTE

The nozzle block pre-heater plug and the motor plug may be interchanged.

7. Slide the coupling (7) onto the motor shaft and pre-position it.
8. Install fuel pump (see 8.8).
9. Install burner (see 8.2).
10. Reconnect temperature sensor (1, Fig. 802).

- 1 Electronic ignition unit
- 2 Ignition electrode
- 3 Disc
- 4 Screws (2)

**8.6 Electronic ignition unit and ignition electrode removal and installation****Removal**

1. Remove burner (see 8.2).
2. Lift off ignition electrode (2, Fig. 804) from the electronic ignition unit by twisting a screwdriver sideways.
3. Remove disc (3).
4. Remove screws (4) with retaining washers.
5. Pull electronic ignition unit (1) off and remove it.
6. If necessary, perform a general visual inspection (see 5.5.1) or test (see 5.5.7).

Installation

1. Bring electronic ignition unit (1, Fig. 804) into installation position, attach ready for connection and secure with screws (4).
2. Tighten screws (4) with 5 Nm +1 Nm.
3. Fit disc (5) onto the nozzle holder of the fuel pump (10, Fig. 805) and align with the flame detector in the control unit (15, Fig. 805) and the electronic ignition unit.
4. Fit the ignition electrode (2, Abb. 804).
5. Install burner (see 8.2).

Fig. 804 Removal of the electronic ignition unit / ignition electrode

1 Electronic ignition unit

2 Screw (2)

3 Ignition electrode

4 Atomizer nozzle

5 Disc

6 Solenoid valve

7 Heating element of the nozzle block preheater (optional)

8 Thermostat of the nozzle block preheater (optional)

9 Clamp

10 Fuel pump

11 O-rings (2)

12 Screen

13 Screws (3)

14 Burner housing

15 Control unit

16 Adjustment ring

17 Coupling

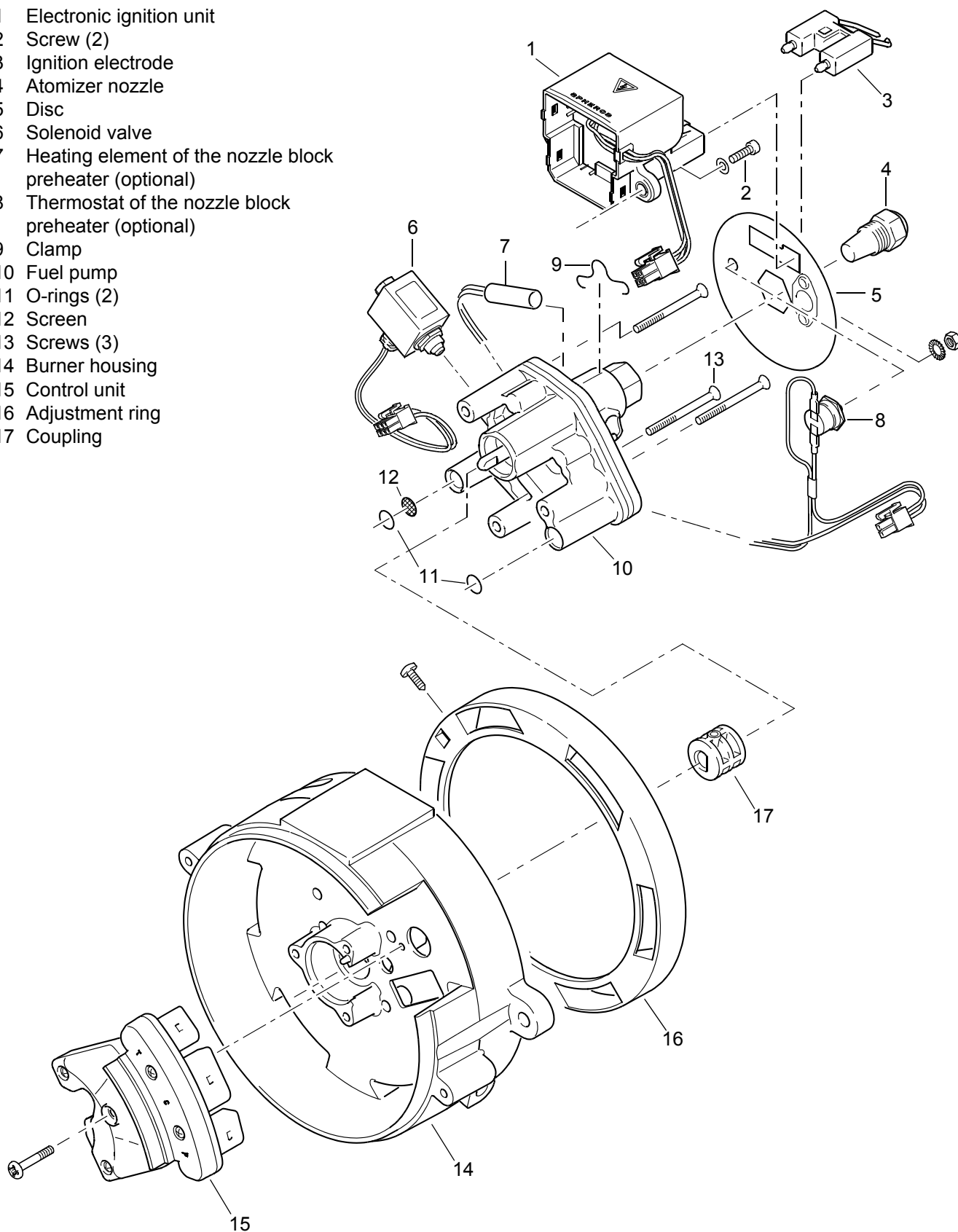


Fig. 805 Components removal and installation

8.7 Control unit removal and installation

Removal

1. Remove burner (see 8.2).
2. Disconnect all inside located plugs (motor, nozzle block preheater, electronic ignition unit, solenoid valve).
3. Remove fuel pump (see 8.8).
4. Remove electronic ignition unit (see 8.6).
5. Remove motor (see 8.5).
6. Remove control unit attaching screw.
7. Remove control unit.

Installation

1. Position control unit.
2. Tighten control unit attaching screw (2 +0.5 Nm).
3. Install motor (see 8.5).
4. Install electronic ignition unit (see 8.6).
5. Install fuel pump (see 8.8).
6. Reconnect all inside located plugs (motor, nozzle block preheater, electronic ignition unit, solenoid valve).
7. Install burner (see 8.2).

8.8 Fuel pump removal and installation

NOTE

Make sure that any fuel leaking is immediately collected, bound and professionally disposed of.

Removal

1. Remove burner (see 8.2)
2. Lift off ignition electrode (2, Fig. 804) from the electronic ignition unit by twisting a screwdriver sideways (see Fig. 804).
3. Remove disc (3).
4. Disconnect the solenoid valve plug (6, Fig. 805) and the optional nozzle block preheater (7) from the control unit (15).
5. Remove screws (13).
6. Pull fuel pump (10) with solenoid valve (6) off and remove it.
7. If applicable, remove the nozzle block preheater (7). For this purpose, remove clamp (9) from the nozzle holder using suitable tools.
8. If necessary, remove the solenoid valve (6) from the fuel pump (10) (see 8.9).

Installation

1. If necessary, attach solenoid valve (6, Fig. 805) to the fuel pump (10) (see 8.9).
2. If applicable, install nozzle block preheater (7) and secure with clamp (9) to the nozzle holder using suitable tools.

3. If required, attach new O-rings (11) and a new screen (12) to the fuel pump (10).
4. Slide the coupling (17) with magnets onto the fuel pump (10) shaft.

ATTENTION

In order to avoid damage to the O-rings, do not twist fuel pump (10) during assembly.

New screws with coated threads must be used for installing the fuel pump.

5. Align fuel pump (10) with the burner housing (14) and bring it into installation position. Align the coupling with magnets (17) with the burner motor by turning the burner motor shaft.
6. Mount the fuel pump (10) using new screws (with coated threads) (13) and tighten the screws with 5 Nm +1 Nm.
7. Connect solenoid valve plug (6) and, if applicable, the optional nozzle block preheater (7) to control unit (15).
8. Fit disc (5) onto the nozzle holder and align it with the flame detector in the control unit (15) and the electronic ignition unit (1).
9. Fit ignition electrode (3).
10. Install burner (see 8.2).

8.9 Solenoid valve removal and installation

NOTE

The solenoid valve must be completely replaced and may not be further dismantled! In case of replacement or assembly and disassembly a new gasket ring must be used.

It is not absolutely necessary to remove the fuel pump to disassemble the solenoid valve.

Make sure that any fuel leaking is immediately collected, bound and professionally disposed of.

Removal

1. Remove burner (see 8.2)
2. Lift off ignition electrode (2, Fig. 804) from the electronic ignition unit by twisting a screwdriver sideways (see Fig. 804).
3. Remove disc (5, Fig. 805).
4. Disconnect the solenoid valve plug (6) from control unit (15).
5. Using suitable tools loosen the hexagon, wrench size 16 (6, Fig. 806) of the solenoid valve (6, Fig. 805) from the fuel pump (10) and unscrew the solenoid valve (6).

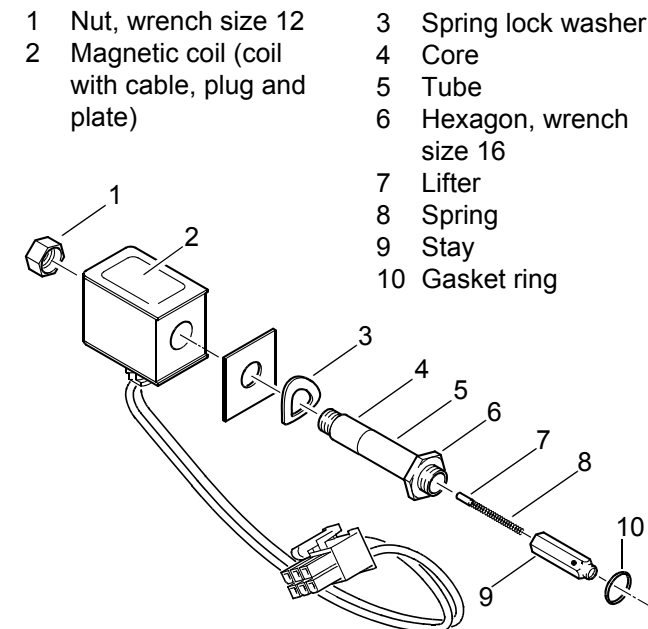


Fig. 806 Solenoid valve

Installation

1. Gasket ring (10, Fig. 806) towards the fuel pump must be replaced. Make sure stay, spring and lifter are correctly assembled, observe installation position (see Fig. 806).

2. Attach solenoid valve (6, Fig. 805) to the fuel pump (10).
3. Using suitable tools, tighten hexagon, wrench size 16 (6, Fig. 806) of the solenoid valve with $5 \text{ Nm} \pm 0.5 \text{ Nm}$.
4. Connect the solenoid valve plug (6, Fig. 805) to the control unit (15).
5. Fit disc (5) onto the nozzle holder and align with the flame detector in the control unit (15) and the electronic ignition unit (1).
6. Fit ignition electrode (3).
7. Install burner (see 8.2).

ATTENTION

If the nut, wrench size 12 (1, Fig. 806) was loosened, then it must be tightened with a tightening torque of $1.5 \text{ Nm} + 0.3 \text{ Nm}$ and subsequently secured using locking paint.

8.10 Atomizer nozzle removal and installation

Removal

1. Remove burner (see 8.2).
2. Lift off ignition electrode (2, Fig. 804) from the electronic ignition unit by twisting a screwdriver sideways (see Fig. 804).
3. Remove disc (5, Fig. 805).

NOTE

We recommend to use nozzle wrench item no. 66971_ for nozzle disassembly and assembly.

4. Unscrew atomizer nozzle (4). If no nozzle wrench is used, a tool must be used to counter on the hexagon of the fuel pump nozzle holder (10).

Installation

1. Screw in the atomizer nozzle (4, Fig. 805) and tighten with $20 \text{ Nm} \pm 2 \text{ Nm}$. If no nozzle wrench is used, a tool must be used to counter on the hexagon of the fuel pump nozzle holder (10).
5. Fit disc (5) onto the nozzle holder and align with the flame detector in the control unit (15) and the electronic ignition unit (1).
6. Fit ignition electrode (3).
7. Install burner (see 8.2).

8.11 Combustion chamber removal and installation

Removal

1. Remove burner (see 8.2).
2. Pull combustion chamber (1, Fig. 807) out of the heat exchanger (2).

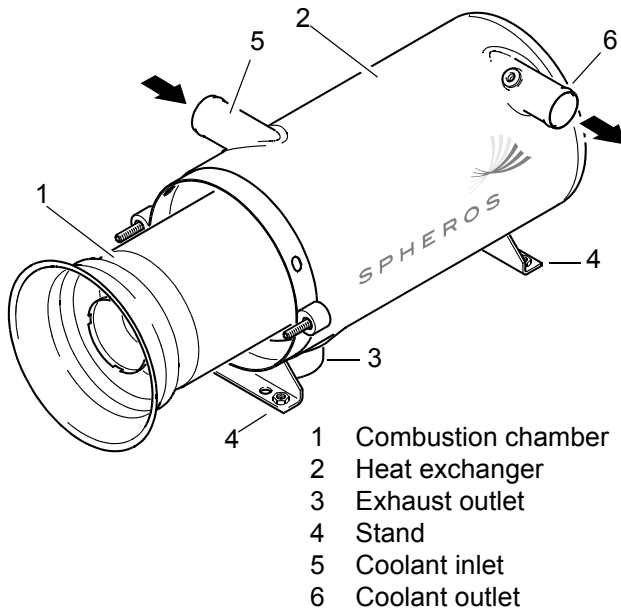


Fig. 807 Combustion chamber disassembly and assembly

Installation

1. Slide combustion chamber (1, Fig. 807) into the heat exchanger (2) as far as it goes.

NOTE

- The combustion chamber should be inserted into the heat exchanger in such a way that its welding seam is positioned between 2 and 10 o'clock (not upwards!). A position change during maintenance is permissible and affects the expected service life of the combustion chamber positively.

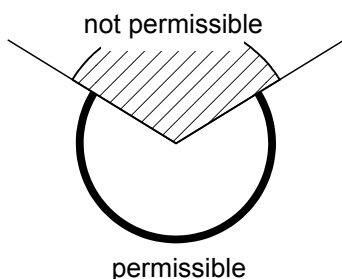
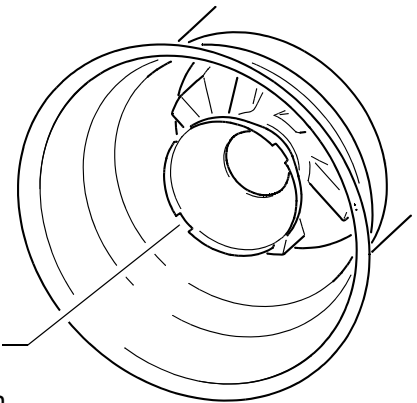


Fig. 808 Combustion chamber welding seam position

- It should be ensured that none of the 4 cut-outs of the combustion chamber head points vertically

downwards (see graphic below).

Dripping from nozzle fuel is so collected in a reservoir between disc and burner head and will be burned at the next burner operation instead to soil the heater.



Cut-out positions on the combustion chamber head in installed position

Fig. 809 Cut-out positions on the combustion chamber head

2. Install burner (see 8.2).

8.12 Heat exchanger removal and installation

CAUTION

Combustion chamber and heat exchanger can be very hot. If necessary, let them cool down.

Removal

1. Remove burner (see 8.2)
2. If necessary, remove temperature sensor (see 8.3).
3. Pull combustion chamber (1, Fig. 807) out of the heat exchanger (2) (see 8.11).
4. If necessary, loosen the exhaust line clamp on the exhaust outlet (3).
5. If existing, close water taps.
6. Loosen hose clamps on the coolant hoses, pull coolant hoses from the coolant inlet (5) and the coolant outlet (6) and seal with blank plugs. Caution if coolant temperature is increased.
7. Remove screws and washers of the heat exchanger stand (4).
8. Remove heat exchanger from the vehicle.

Installation

1. Bring heat exchanger (2, Fig. 807) into installation position and mount stand (4) using screws, nuts and washers to the vehicle according to the mounting points used.
2. If necessary, secure the exhaust line using a clamp to the exhaust outlet (3).
3. Fit coolant hoses onto the coolant inlet (5) and the

coolant outlet (6) and secure with hose clamps applying a tightening torque of 6 ± 0.6 Nm.

4. If existing, open water taps.
5. Install burner (see 8.2)
6. Purge coolant circuit (see 8.14.2).

8.13 Heater removal and installation

NOTE

The fuel supply system must be subsequently bled (see 8.14.1).

The coolant circuit must be subsequently bled (see 8.14.2).

Removal

1. Remove burner (see 8.2)
2. Remove heat exchanger (see 8.12).

Installation

1. Install heat exchanger (see 8.12)
2. Install burner (see 8.2)
3. Bleed coolant circuit (see 8.14.2).
4. Bleed fuel supply system.

8.14 Start-up after burner, heater or heat exchanger installation

Coolant and fuel connections must be checked for leak-tightness and tight fit during the test run.

If a malfunction occurs during heater operation, troubleshooting must be performed (see chapter 5).

8.14.1 Bleeding of the fuel system

If combustion does not start when the heater is started for the first time, the heater must be switched off and on again.

Small air bubbles in the fuel line are released via the atomizer nozzle in the combustion chamber.

Until the fuel line is completely bled, flame extinction may occur.

The flame will be re-ignited up to 5 times. After that the heater will be interlocked.

For operation using a long fuel supply line, check valves and/or a fuel filter in the fuel supply line, we recommend to fill the supply line prior to first heater start-up.

8.14.2 Bleeding of the water circuit

NOTE

The water circuit must be principally bled according to manufacturer specification.

CAUTION

Risk of injuries for coolant with increased temperature.

The Aquavent 5000 (U4814) and Aquavent 6000S (U4855) circulating pumps may only be switched on for bleeding, after dry operation can be excluded.

The Aquavent 5000S (U4854) and Aquavent 6000SC (U4856) circulating pumps may even in dry operation be switched on for bleeding.

Adjust the vehicle heating system to "warm" and refill coolant.

As soon as it is confirmed that the vehicle engine is filled with coolant, run vehicle engine with increased idle speed. Once the cooler thermostat opens, switch the vehicle engine off and check the coolant level. Refill coolant as needed.

While the vehicle engine is switched off, switch on the heater with the circulating pump and the vehicle heating fan.

After the engine motor cooled down, the heater must automatically start and stop as soon as the upper switching threshold is reached.

If the heater does not start automatically, it must be verified, whether the heater overheating protection is triggered and the heater is interlocked.

Release the heater (see 4.5) and repeat the bleeding process.

9 Modifications and retrofits

For further optimization the heaters are continuously improved. Units in the field can usually be upgraded or retrofitted. For this purpose respective modification kits will be available. For Information refer to the category "Service" of the Spheros homepage.

10 Packing / storage and shipping

10.1 General

The heater or its components, which are sent to Spheros for inspection or repair, must be cleaned and packaged to ensure that handling, transport and storage will not damage them.

ATTENTION

If a complete heater is sent back, it must be completely drained. Packaging and/or shipping must ensure that no fuel or coolant can leak.

Coolant inlet and outlet fittings as well as the fuel lines must be plugged and sealed using blank plugs.

The temperatures described in Chapter 2 may not be exceeded during storage.

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Appendix A

Periodic maintenance

Periodic heater maintenance

The heater should be inspected in periodic time intervals, latest at the beginning of the heating period (time of increased heater usage due to present weather conditions).

The maintenance intervals mentioned below refer to common applications and requirements in omnibuses. If heaters should be used in other vehicles and/or applications, the maintenance intervals may be shortened or extended.

In such cases please contact your dedicated Spheros partner for further information.

Inspection / maintenance activities	Important information	Inspection result		Measured values Executed repairs
		OK	not OK	
<p>1. Electrical connections</p> <p>a) Loosen electrical plug connections to the wiring harness, inspect for oxidation, spray and reconnect after completing point 5.</p> <p>b) Inspect electrical fuses for oxidation and/or contact resistances.</p>	<p>Use suitable contact spray, e.g. special contact spray (order no. 101322).</p>	<input type="checkbox"/>	<input type="checkbox"/>	
<p>2. Heat exchanger</p> <p>a) Inspect for dark burn marks on the paint (local overheating).</p> <p>b) Inspect for leak marks.</p> <p>c) Clean heater exterior and interior.</p>	<p>Determine overheating cause as needed (e.g. water circulation system); check overheat temperature limiter.</p>	<input type="checkbox"/>	<input type="checkbox"/>	
<p>3. Fuel system</p> <p>a) Inspect fuel lines and connections for leakage.</p> <p>b) Replace fuel filter insert with gasket.</p> <p>c) If available, open fuel shut-off valves</p> <p>d) Fuel pump and fuel lines.</p> <p>NOTE: Observe technical information if biodiesel or FAME is used!</p> <p>e) Replace fuel screen with gasket in the pump.</p>	<p>Ensure connections to fuel flow and return lines are sealed tight!</p> <p>Re-tighten screw connections and hose clamps.</p> <p>Replace pump and pipes every 5 years.</p> <p>Observe technical biodiesel / FAME information!</p>	<input type="checkbox"/>	<input type="checkbox"/>	
<p>4. Burner head</p> <p>a) Inspect combustion air intake opening for clear passage.</p> <p>b) Inspect hood for damage.</p> <p>c) Inspect housing interior for fuel accumulations caused by leaking.</p> <p>d) Clean flame detector inspection glass.</p> <p>e) Inspect condition of the ignition electrodes.</p> <p>f) Replace atomizer nozzle (wear part).</p> <p>g) Check nut-and-washer assemblies M8 (2ea) for burner attachment for tight fit (torque to 7.5 +1 Nm) and secure with locking paint.</p>	<p>Replace damaged hood</p> <p>Replace bent electrodes.</p> <p>In case of coke build-up shorten fuel filter replacement interval.</p>	<input type="checkbox"/>	<input type="checkbox"/>	
<p>5. Exhaust system</p> <p>a) Inspect exhaust line for clear passage, clean as needed.</p> <p>b) Remove combustion chamber from heat exchanger, inspect both parts for damage and contamination, clean and replace as needed.</p> <p>c) Insert combustion chamber and mount burner head. Ensure tight connection to heat exchanger.</p> <p>d) Reconnect electrical plug contacts.</p>		<input type="checkbox"/>	<input type="checkbox"/>	
<p>6. Water system</p> <p>a) Clean filter insert, if available.</p> <p>c) Open water shut-off valves, if available.</p>		<input type="checkbox"/>	<input type="checkbox"/>	
<p>7. Functional check</p> <p>a) Open shut-off valve of the return line, if available.</p> <p>b) Check heater functionality.</p> <p>c) Check for smoke development during purge cycle, replace nozzle as needed.</p>	<p>after at least 10 min. heater operation.</p>	<input type="checkbox"/>	<input type="checkbox"/>	