Report on the investigation of the intake of exhaust gas fumes into the cabin spaces of the motor cruiser *Chapter Two* while transiting the River Medway on 31 December 1999

MAIB 1/10/198

Marine Accident Investigation Branch
First Floor, Carlton House
Carlton Place
Southampton
SO15 2DZ

Report No 36/2000

Extract from

The Merchant Shipping

(Accident Reporting and Investigation)

Regulations 1999

The fundamental purpose of investigating an accident under these Regulations is to determine its circumstances and the causes with the aim of improving the safety of life at sea and the avoidance of accidents in the future. It is not the purpose to apportion liability, nor, except so far as is necessary to achieve the fundamental purpose, to apportion blame.

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GLOSSARY OF ABBREVIATIONS, ACRONYMS & TERMS

CO	-	Carbon monoxide
ETA	-	Estimated Time of Arrival
GRP	-	Glass Reinforced Plastic
m	-	metre
ppm	-	Parts per million

Cable Loom	-	Collection of electric cables bound together but with individual ends leading off at required positions
Cockpit	-	A sunken part, or well, in the deck of a yacht, in which the helmsman sits to steer
Eberspächer	-	Name of German boiler manufacturer
Helm	-	Steering control
Hyperbaric chamber	-	A chamber containing oxygen at high pressures, in which patients are placed for decompression or treatment for certain forms of poisoning
Transom	-	Flat vertical thwartship plate at stern

SYNOPSIS

This accident was notified to the Marine Accident Investigation Branch (MAIB) by the owner of *Chapter Two* (a 9.45m Targa 28 motorised pleasure craft), at the beginning of January 2000. Following an incident involving carbon monoxide poisoning on board his vessel, the owner arranged for a senior engineer from the cabin heater manufacturer, Messrs Eberspächer to inspect the installation. On receipt of the manufacturers report, the owner contacted the MAIB and an investigation started shortly afterwards.

On the morning of Friday 31 December 1999 the owner, together with his wife, his two children aged fourteen and ten, another couple and their eight year old daughter, boarded the boat at Medway Bridge Marina with the intention of sailing up the Thames to celebrate the New Year at Tower Bridge.

The boat was moved to the fuel pontoon where the potable water tanks were filled. As it was rather cold, the canvas hood covering the cockpit area was left up and the cabin heater started. They left the marina at 0815 and started down the River Medway.

During the early part of the passage, the children complained of being ill, and by 0845 the majority of the passengers were feeling seasick and complaining of headaches. The boat was, by that time, close to buoy 31, with the owner at the helm. Within the next few minutes one of the children collapsed, followed shortly afterwards by the owner's wife. Realising that they all appeared to be suffering from carbon monoxide poisoning, he ordered everybody out on deck before informing the emergency services by a 999 telephone call that an ambulance would be needed on arrival at the marina. The owner turned the boat around and headed back to the Medway Bridge. On arrival, they were met by the police, fire and ambulance services when all on board were treated with oxygen before going to hospital for a check-up. Following further checks and blood tests, three of the passengers were sent for further treatment in a hyperbaric chamber at Portsmouth. All fully recovered.

The carbon monoxide poisoning was the result of exhaust fumes from the main engines being drawn in by the cabin heater air intake and being circulated throughout the accommodation. When the boat was stationary or moving slowly, the main engine exhaust gas emissions seeped into this area, were sucked into the heater system, heated, and discharged throughout the boat.

SECTION 1 - FACTUAL INFORMATION (all times GMT)

1.1 PARTICULARS OF VESSEL (Figure 1)

Name	:	*Chapter Two*
Official No	:	07717
Port of Registry	:	Medway Bridge Marina Sheerness
Dry Weight	:	3861kg
Overall Length	:	9.45m
Breadth	:	3.10m
Maximum Draught	:	0.97m
Year of Build	:	1994
Type	:	Fairline Targa 28
Main Engines	:	2 x Volvo 4.3 GS/DP Petrol
Owners	:	David Tanti 39 Augustine Road St Pauls Cray Orpington, Kent BR5 3JY
Date and Time	:	0900 GMT 31 December 1999
Place of Incident	:	Buoy 31, Short Reach River Medway
Injuries	:	Four adults and three children affected, one adult, two children taken to hospital for treatment in a hyperbaric chamber.

Figure 1

Chapter Two

1.2 BACKGROUND

The present owner had bought *Chapter Two*, a 9.4m motor cruiser, second-hand from Marine Sales, Port Solent, about two weeks before the incident. Having inspected the boat, he asked for a boat heating system to be fitted before the boat was delivered to his berth at the Medway Bridge Marina, Rochester, Kent. An Eberspächer air heater was suggested and accepted, and was installed by Krueger Ltd, of New Milton, Hampshire. The boat was subsequently delivered to the marina in Rochester on 17 December by road transport and floated on to her berth later that day.

1.3 NARRATIVE

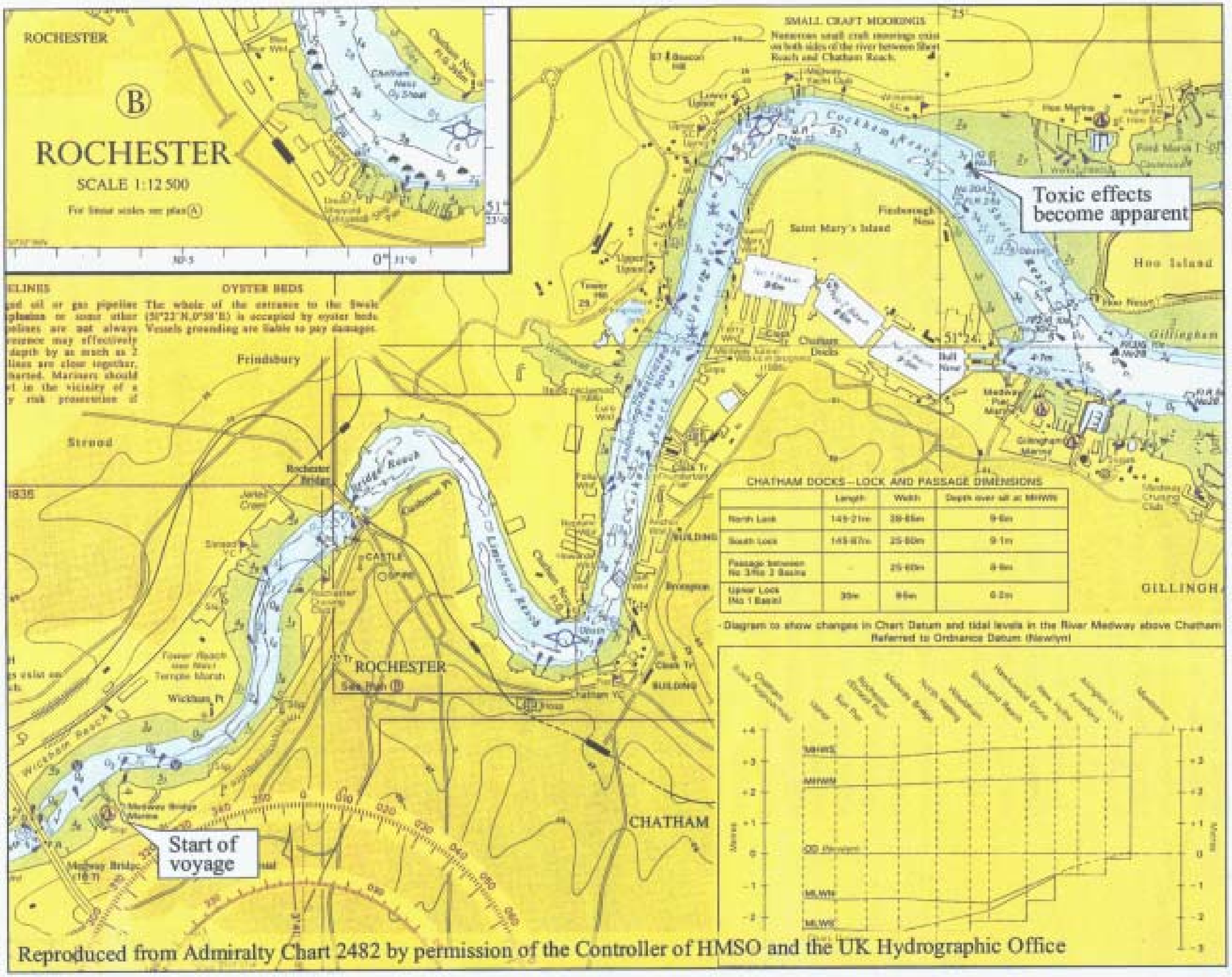
1.3.1 The owner, his family, and three friends boarded *Chapter Two* at the marina on the evening of 30 December 1999, and stayed on board overnight. The intention was to take the boat down the Medway River to the Thames Estuary, and then upriver to London Bridge for the New Year festivities.

Pre-start checks were carried out on both main engines with all oil levels being recorded as satisfactory. The log sheet shows that the running hours on each main engine prior to starting were in the order of 161-164 hours, with the port engine running temperature recorded as 150°F (65.5°C), and the starboard at 100°F (37.8°C). The engine log also records that the starboard main engine temperature gauge was not working correctly, and that this engine seemed to be running with the choke on at all times.

With all checks having been carried out, the boat was moved across to the fuel pontoon where the potable fresh water tanks were filled. At 0815, it left the pontoon and started down the River Medway towards the Thames Estuary. At that time, with the weather being so cold, they elected to travel downriver with the two-part cockpit hood in the raised position. The aft centre section of the rear hood was initially open, but was closed once they were underway on the river. The cabin heater system was also started and warm air circulated throughout the boat.

1.3.2 At 0845, *Chapter Two* had progressed downriver until she was close to buoy 31, at the start of Short Reach, off Port Werburgh. David Tanti, the owner, was at the helm with Les Smith, a friend, in the cockpit with him. The other passengers, Michaela Tanti, the owner's two children, Claire and Luke, together with Roz Smith and her daughter Natasha were all in the main cabin. During the early part of the voyage downriver, the children complained of not feeling well, but this was initially put down to the motion of the boat, excitement etc. By now however, the majority of the passengers were feeling seasick and complaining of headaches. One of the children, seven year old Natasha, suddenly came out of the main cabin into the cockpit saying that she felt sick, and collapsed. Her father went to help her, while David Tanti remained at the helm.

Roz Smith, who had been in the bathroom, went out to help her daughter after being told by Michaela Tanti that she had collapsed. Shortly after this, Claire Tanti called out to her father that Michaela Tanti was not well. He looked down into the main cabin through the open door and saw Michaela lying unconscious on the cabin deck floor



Reproduced from Admiralty Chart 2482 by permission of the Controller of HMSO and the UK Hydrographic Office

adjacent to one of the heating outlets. Immediately handing the helm over to Les Smith, he pulled his wife out of the cabin into the cockpit.

1.3.3 David Tanti had by this time realised that they were all suffering from the effects of carbon monoxide poisoning, so ordered everybody out of the main cabin. He opened up the cockpit hood. The boat was turned round immediately and the authorities were informed through a 999 call that the boat was heading back to Medway Marina, where an ambulance would be needed. This was at about 0900.

As everybody was still feeling the effects of the gas, David Tanti made everyone go forward on to the foredeck and into the fresh air, while he navigated the boat back to the marina. David Tanti's wife, Michaela, lost consciousness again and had to be revived. Although still feeling ill, the other passengers remained conscious.

1.3.4 At about 0930 *Chapter Two* arrived back at the Medway Bridge Marina and was secured alongside the fuel pontoon with help from the marina staff. The police, fire brigade, and ambulance were there. Everybody on the boat was immediately treated by the ambulance staff and given oxygen (except David Tanti as there were not enough oxygen cylinders), before being driven to Medway Hospital for a full examination and treatment. With both children and adults being involved, further advice was sought on the effects of carbon monoxide poisoning, and what specialist treatment might be required for children.

Blood tests were carried out as a precaution and, after further consultation, it was decided that the two who had lost consciousness, plus one other adult, should be sent to Portsmouth for treatment in the hyperbaric chamber. All three left by ambulance at 1600 that day.

Following a number of hours in the chamber all fully recovered and returned to the Medway area and their homes.

1.4 DESCRIPTION OF MOTOR CRUISER

1.4.1 *Chapter Two* is one of a range of open-cockpit offshore cruisers sold by Fairline Boats plc, and is designated as a Targa 28. The GRP hull is of a very deep Vee design with rounded chines, and provides a good sea boat, good manoeuvrability, and living accommodation for four people. It has an extended stern, providing not only a bathing platform, but also protection for the outdrives when going astern. A moulded non-slip deck is fitted on all upper surfaces including the cockpit.

The cruiser is divided into three main areas below deck with the engine compartment aft. The two main areas forward have a clear headroom of 1.88m. The forward cabin or saloon is fitted with "U" shaped daytime seating with a central table, which can readily be converted into a double berth if required. Four portholes, two either side, plus a large circular deck hatch, provide daylight and fresh air. Immediately aft is the galley, together with the shower and toilet compartment. The galley, fitted on the starboard side, has a two burner gas cooker with oven and grill, plus refrigerator and sink unit. The 12volt electrical battery/shore power switchboard, together with the Calor gas

detection alarms is contained within this area, so too is a hot air outlet positioned just above deck level (**Figure 2**). The shower compartment, on the port side, has standard shower fittings, and there is a chemical toilet.

Aft of the galley/shower area, and under the cockpit, is a double berth cabin. Access to this area is via a door adjacent to the aft or main cabin. This cabin is also fitted with a hot air outlet positioned just above floor level between the entrance door and the bed (**Figure 3**).

On the centre line, between the access door to the aft cabin and the galley area, is a three-step access to the cockpit (**Figure 4**).

1.4.2 The cockpit deck is split-level; the aft section about 400mm lower than the forward section fully upholstered and protected by a curved toughened glass windscreen. On the forward upper section, starboard side, is a single forward-facing helm seat together with a three seat L-shaped settee and table on the port side. The helm position is fitted with full engine instrumentation; control and steering together with remote control of bilge pump, fans, and deck winch. Just above the cockpit deck level, and next to the helmsman's position, is a hot air outlet (**Figure 5**).

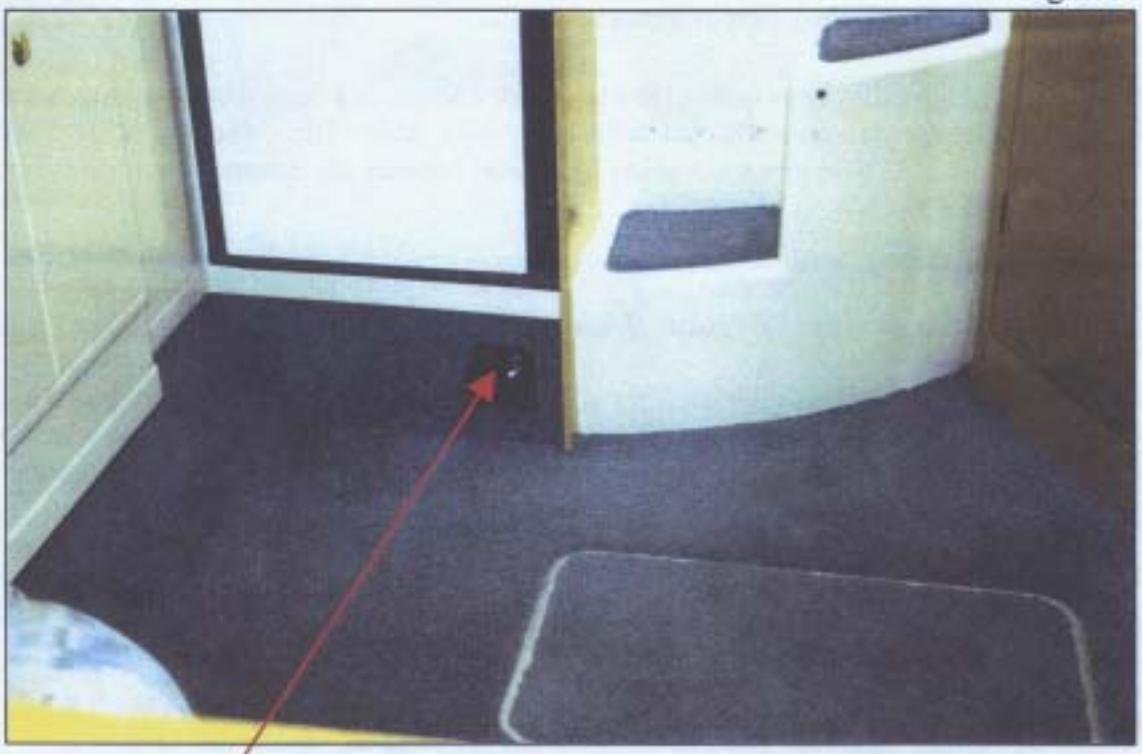
Aft, on the lower section, port side, is a large settee/double sunbed. A small sink unit and drinks cabinet is fitted on the starboard side, just forward of the transom gate. The heater air intake is positioned on the starboard side just above deck level, facing inboard and aft of the drinks cabinet. It is about 1m forward of the transom gate. The polyglass transom gate, which has a clearance of about 15mm between the bottom of the gate and the deck, gives access to an integral bathing platform across almost the beam of the craft at the stern (**Figure 6**).

Above the cockpit is a GRP arch fitted with cockpit lights under, together with stern light and whip aerial. The cockpit is fitted with a two-part cover mounted on a stainless steel frame, the forward half being designed to act as a sun canopy. The canvas cover is clipped to the boat at the top of the windscreen and at intervals along the cockpit perimeter, including the transom. The canvas cover is fitted with clear view panels across the front side and rear. A zipped panel above the transom gate allows access with the hood fully fitted (**Figure 7**).

1.4.3 The engine compartment is fitted with twin Volvo 4.3GS/DP petrol engines, each developing 153kW, giving the boat a speed of between 33 and 36 knots. The compartment is soundproofed, and fitted with an extractor fan and an auto fire-extinguisher system. Forward of the engine compartment is a cofferdam containing the 418 litre fuel tank. The bulkhead forward of the cofferdam is sealed to prevent fuel and engine smell contamination of the accommodation.

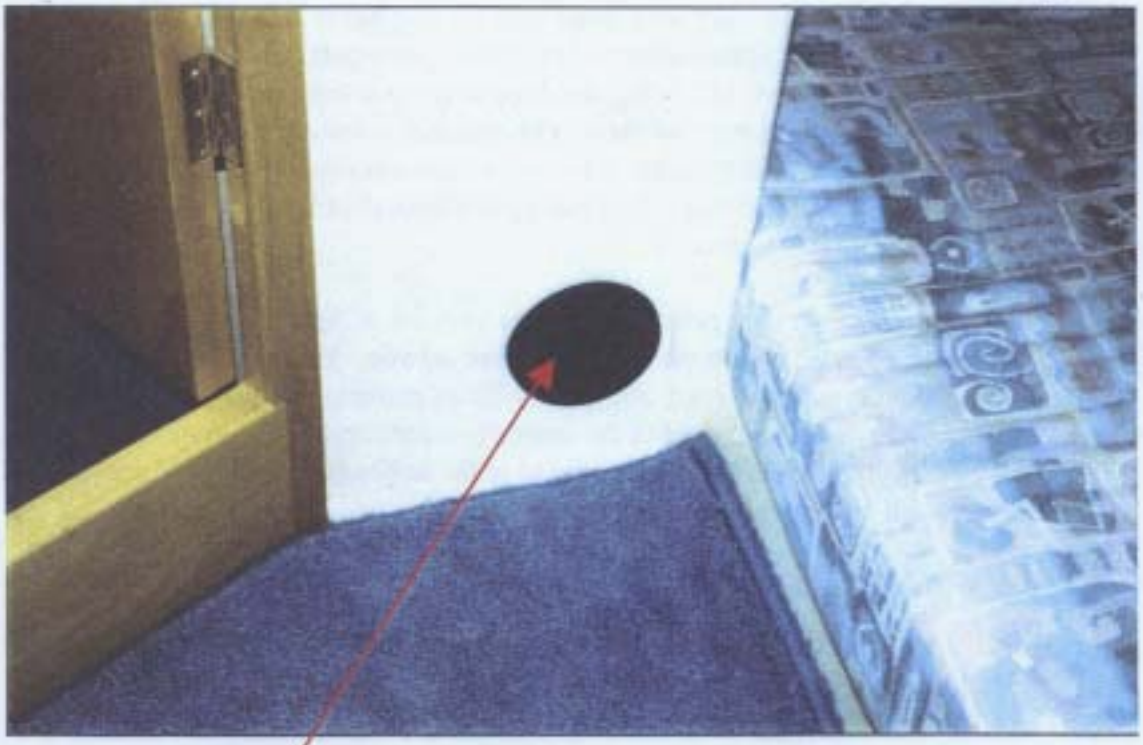
With both engines in operation, the boat is capable of speeds in excess of 30 knots, the boat moving on to the "plane" at about 15 knots.

Figure 2



Hot air outlet in galley area

Figure 3

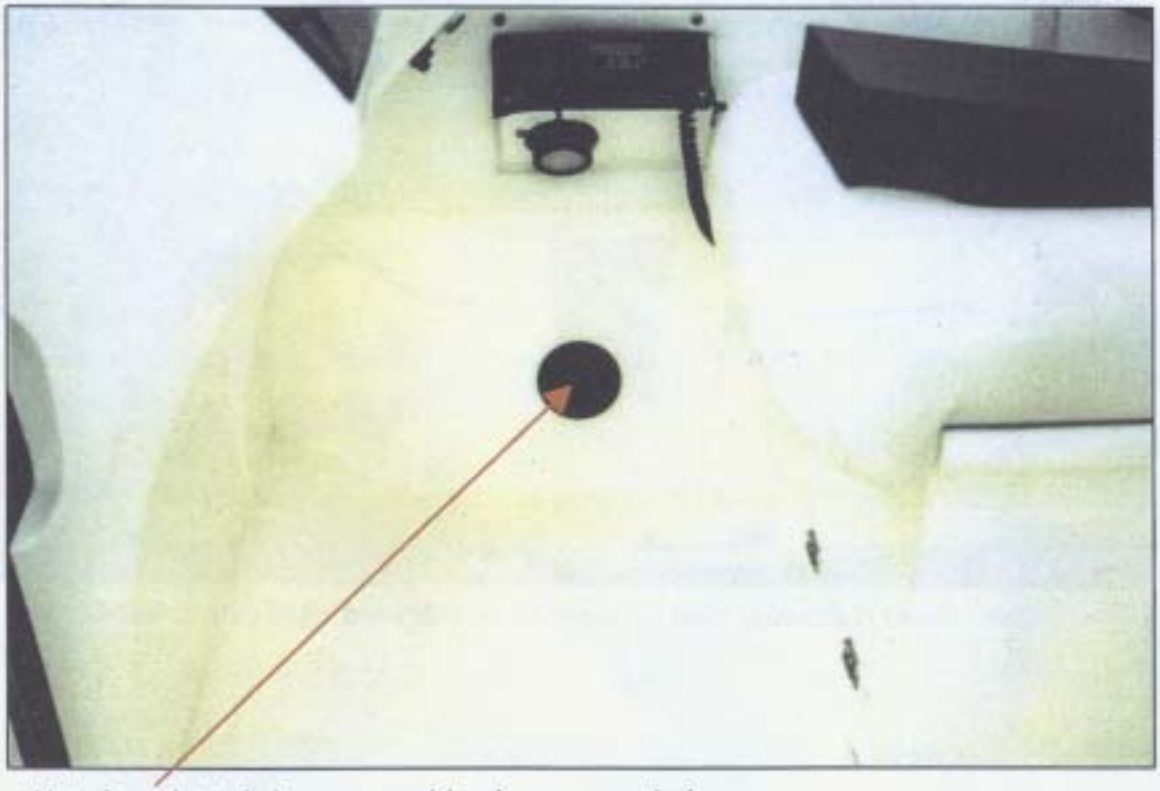


Hot air outlet in double berth cabin

Figure 4

Three step access aft to cockpit

Figure 5



Hot air outlet at helmsman position in upper cockpit area

Figure 6

Lower cockpit area with heater air intake and polyglass transom gate

Figure 7

View from aft showing clear view panels on sides and aft of canvas hood

1.5 DESCRIPTION OF CABIN HEATER

1.5.1 The boat heater fitted in *Chapter Two* is based on the Eberspächer D3L'C' Compact diesel fired air heater. The system is an indirect burner unit for delivering warm air to areas of the boat which require heating.

The unit burns diesel in a sealed combustion chamber/heat exchanger, over which ambient air is passed to collect the heat from the walls of the heat exchanger for distribution through ducting to the cabins.

Combustion air, drawn from outside, is mixed with diesel fuel supplied by the fuel metering pump and ignited by a glow plug fitted in the unit. The products of combustion pass through a flexible stainless steel exhaust tube to the hull skin fitting, and are discharged into the atmosphere.

Control of the heater is by means of a Mini programmer and modulator with remote sensor, all sited in the cabin area. Safety features include a flame monitoring device, a timed restart shutdown device, an overheating thermal cut-out, low voltage shutdown, and a glow plug/fuel metering pump cabling fault shutdown.

1.5.2 The heater is supplied with a mounting plate and has to be installed with the exhaust, fuel and combustion air manifold pointing vertically downward. The heater body should not be fitted more than 2m from the exhaust hull skin fitting, nor within the cabins.

The heating air intake can be either re-circulated air from the cabin, or fresh air. The fresh air intake must be sited so as to prevent the entry of water or sea spray.

The hot air outlet ducting, 75mm rounded section, should be as straight as possible, to avoid crushing the duct, or areas where damage could occur. Outlets should preferably be low down or close to cabin floors.

The exhaust hull skin fitting should be mounted in a dry area with the flexible exhaust ducting connected so as to form a swan neck close to the skin fitting. The exhaust needs to be placed where the exhaust fumes cannot reach cabins or the heater fresh air intake. It must not be connected to any other engine exhaust system.

The combustion air intake must be sited to avoid water or spray intake and not be more than 2m long.

The fuel and electrical systems come complete with all necessary connections and fittings. The fuel system lines are flexible, the only requirement being that the fuel metering pump is fitted at an angle of 15° to the vertical, with a maximum of 2m between pump and fuel tank, and 6m between pump and heater. The electrical system comes as a cable loom with one-way connectors for the equipment.

1.5.3 The introduction of the Eberspächer Installation and Operating Instructions for a D3L'C'Compact boat heating kit states the following:

The D3L'C' Compact is designed for boats requiring heating within the range of 3.2 to 3.5kW. The instructions must be read carefully, prior to installation and followed exactly. Any deviations or proposed changes must be approved by one of the dealers listed under the service maintenance section.

Messrs Krueger is listed as an approved main dealer under the London and South section.

The installation manual produced by Eberspächer, and used by Krueger, has an illustration where the heater air intake is facing just forward of the transom. The installation notes in this manual relating to the air intake, include the following:

When using air from outside, care must be taken to ensure that no water may enter the heater. Siting of the fixed air intake should be carried out particularly in cockpit areas with due regard to protecting against an ingress of water at sea or during cockpit cleaning operations.

Although it is understood that the owner expressed a preference on the siting of the warm air outlets, the siting of the heater, exhaust outlet, and air inlet, would be left to the discretion of the installer. In this installation, the exhaust was sited forward of the starboard engine room air intakes, while the air intake was sited in the cockpit at the lower level, starboard side, about 1m from the transom gate.

1.6 EBERSPÄCHER SERVICE ENGINEER'S REPORT

1.6.1 After the incident, a manufacturer's service engineer visited *Chapter Two* and carried out a full inspection of the installation. He reported the following:

1. *Heater mounted on support bracket in engine room on starboard side.*
2. *Fuel for heater taken from own separate diesel fuel tank.*
3. *Cold air for heating by the Eberspächer D3LC Compact heater is supplied through a louvre intake/rotary type.*
4. *The position of the intake being located on the starboard side uprise panel approximately 150mm above floor level (to centre line of louvre)*
5. *There are three hot air outlets installed;*
   a. *In the helm*
   b. *In the saloon*
   c. *In the bedroom*
6. *The heater is controlled by a mini seven day timer and mini modulator. The mini timer display is faulty and requires replacing.*
7. *The insulating boots on the two fuel metering pump electrical terminals are not in place (although fitted on two wires). Rectified at time of inspection.*
8. *The fuel system is of plastic material for sea going operation and not Inland Waterways.*
9. *Heater combustion air pipe has been extended with APK duct to terminate by the engine room air intake vent.*
10. *The heater exhaust skin fitting is installed forward of the air intake vents for the engine room.*

11. The transom lower section of door (see through plastic) has a gap between it and the deck floor of approximately 20mm.

All the above comments confirmed that correct practice had been followed in these areas.

1.6.2 *The customer commented that when the incident occurred the rear awning was in place and the transom door closed. He has since purchased a CO meter after the incident and using this without the engines in operation, no CO reading was recorded in the saloon area. Upon starting the engines (with the starboard engine having difficulty to start and upon so producing excessive smoke and a petroleum smell in the boat) a reading of 999ppm (parts per million). Following an engine warm up period, this reading decreased to 210ppp.*

With the heater in operation, any CO fumes entering the saloon area would be dispersed throughout the boat via the air intake – hot air outlet ducting.

With the boat on the move and a following wind, exhaust gas ingress into the boat (with the awning in place) would be increased considerably.

Although a second Fairline Targa 28 nearby was examined, the siting of the heater, its outlets and exhaust skin fitting were positioned differently (probably a factory installation at build). It was not possible to determine the air inlet position on this boat and therefore could not be used as a guide.

RECOMMENDATIONS

Due to the incident and upon the boat engines being tested and if necessary rectified (on CO exhaust output) it would be advisable to relocate the heater air inlet. Further discussions with the installer (Krueger) and the customer to take place on this issue.

Faulty timer to be replaced.

1.7 MAIB VISIT TO BOAT

1.7.1 The boat was inspected in July 2000 while alongside at Medway Bridge Marina, and the incident was discussed with the owner, Mr David Tanti. The boat was starboard side alongside with the full canvas hood in place. Since the incident, both main engines have been overhauled, choke mechanisms repaired and engines re-tuned (24 January 2000). A CO meter, bought to check out the boat after the incident, is now a permanent feature in the galley area.

Following a general discussion and survey of the general features of the boat, a commercially available CO meter bought by Mr Tanti after the incident, was placed on the rear section of the cockpit deck between the boat heater intake and the transom door. This meter shows a CO reading with an alarm sounding if the gas level is maintained over a fixed time period. The ranges shown on the instrument were:

45ppm - 60 minutes
150ppm - 10 to 30 minutes
350ppm - 6 minutes

The main engines were then started, and the CO readings noted. These showed a reading in the order of 30 - 40ppm after about 4 - 5 minutes of operation when the engines were in idling mode. At the time, the boat was stationary alongside, with the wind on the starboard bow, no heater working, and the canvas hood fully closed.

1.7.2 The main engines were then shut down and, after a few minutes to allow any residual CO to disperse, the cabin heater was started. This heating system was run for a few minutes with the CO meter placed in the same position as before, ie close to the air intake. The boat remained stationary alongside under the same conditions as the canvas hood being fully closed up. No reading was obtained during this short test.

1.7.3 Following this demonstration, the owner confirmed that on 31 December 1999, due to the cold weather, he had started downriver with the canvas hood fully closed and the heater on. Prior to this he thought that the rear part of the canvas hood was probably open to allow boarding, and manoeuvring the boat to and off the fuel jetty.

He also stated that before reaching a decision as to what they should do following the illness of the people, three possible courses of action were discussed:

1. to anchor and wait for help to reach them,
2. to try and find a berth near their current position, or
3. to return to the marina.

Despite some reservations from some of the passengers about continuing to use the main engines (some thought the gas was coming from them), he decided that the best option was to return to the marina with the emergency services waiting for them on arrival.

1.7.4 Subsequent to the MAIB visit, Fairline Boats plc, the builders of the boat, were asked to comment on where the heater air intake would normally be fitted when Eberspächer heaters were installed during building. They stated that when the air heater system is installed during boat construction, the air intake is fitted under the back seat in the forward cockpit position ie under the helmsman's seat on the starboard side. This position is remote from the rear part of the cockpit, is at a higher level, faces forward, and is about 3.5m from the transom.

The existing intake is also on the starboard side, but is fitted in the lower, rear part of the cockpit, faces into the deck area, and is about 1m from the transom gate.

1.8 EXHAUST GAS SOURCES

1.8.1 Two differing types of liquid fuel are used on this boat: petrol and diesel oil. The products of combustion, whether they are exhausted from a compression ignition engine or a fan assisted burner, will include a percentage of carbon monoxide. The main difference however, is that exhaust emissions from a petrol-based combustion process

will contain a much greater percentage of carbon monoxide than those from a diesel-based combustion process. Toxicity tests carried out by the manufacturers show that the percentage of carbon monoxide present in diesel exhaust is less than 0.1% by volume.

With the passengers confirmed as suffering from carbon monoxide poisoning, the position of the exhausts, and the amount of CO being generated by the respective sources, needed to be established.

The main engine petrol exhaust emissions are combined with the engine cooling water outlet and are discharged underwater at the stern, the gases coming to the surface at, or close to, the stern depending on the forward speed of the boat. The diesel oil burner exhaust from the cabin heater discharges on the starboard side of the vessel just forward of the engine compartment air intake **(Figure 8)**.

1.8.2 Both these exhaust emissions contain CO although the diesel exhaust would not provide a sufficient volume of gas to create a poisonous atmosphere within the confines of the boat. The main engines however, generate by far the greatest amount of carbon monoxide gas due to the fact that:

a. They are petrol driven; and
b. Their higher fuel consumption results in a greater volume of gas.

Given the very simple tests applied while alongside at Medway Bridge Marina, there is no doubt that the source of the CO gas found in the boat interior was from the main engine exhaust emissions.

Figure 8

Diesel oil burner exhaust from cabin heater, forward of engine compartment air intake

SECTION 2 - ANALYSIS

2.1 SITING OF HEATER AIR INTAKE

2.1.1 Messrs Krueger Ltd, a local firm who are agents for Eberspächer, fitted the heater and associated equipment, and have considerable experience of such installations.

After being instructed by the owner to install a heating system, the air intake was sited in the lower part of the cockpit and within reasonable distance of the transom gate. It is understood that the installer chose this position, as it was not advisable to fit the air intake in the usual position under the helmsman's seat. This was because the owner, very reasonably, had requested a hot air outlet at his feet. It is important that hot air is not re-circulated through the heater otherwise overheating can occur.

The decision to install the air intake in the lower area of the cockpit close to the transom gate was unusual as this area gives direct access to the bathing platform and sun deck, and is therefore likely to be washed down during cockpit cleaning operations. To avoid this potential problem, a swan neck was formed in the intake ducting.

2.1.2 It was noted earlier, when the heating system is installed during build, the air intake is positioned under the helmsman's seat, well away from the bathing platform, and in an area unlikely to be washed down. Although the owner wanted an air heating outlet by his feet, the installer should have been sufficiently experienced to fit the air intake in the higher level part of the cockpit, as well as satisfying the owner's request for local heating.

That this would have been possible is suggested by the examining Eberspächer engineer's final comment (see 1.6.2) where he recommends that it would be advisable to relocate the heater air inlet. Krueger have subsequently suggested that they would recommend extending the ducting to relocate the air intake into the main saloon via an acoustic silencer. This modification would be applicable to petrol engined craft, and would significantly reduce the risk of any engine exhaust gas entering the heating system.

2.2 CONDITION OF MAIN ENGINES AND OTHER EQUIPMENT

2.2.1 The condition of the main engines at the time of the incident is uncertain. What is known is that when the Eberspächer engineer visited *Chapter Two* on 24 January 2000, the starboard main engine choke was giving trouble, with the result that excessive smoke and petroleum fumes were present around the stern of the boat during the first few minutes of operation. This subsequently reduced in intensity once the engines had warmed up with the CO reading decreasing from 999 to 210 ppm.

As stated earlier, the main engines were serviced following the incident in December. When the engines were started during the MAIB visit in July 2000, no smoke or petroleum fumes were evident during the start-up period or subsequently during a short test run.

2.2.2 The heating system had not been touched since the incident and had only been run on a very few occasions. The comments of the service engineer remain valid, with all the suggested modifications and replacements still outstanding. The exhaust from the heating boiler is not considered as being the source of the CO fumes.

2.3 OPERATIONAL CONSIDERATIONS

2.3.1 One of the main points that became apparent during the various static test runs was that CO fumes found their way into the lower cockpit. The earlier test run, when the starboard main engine was badly tuned, produced the highest results. Even after both engines had been serviced and tuned, CO readings could still be recorded in the lower cockpit area.

When making way, the airflow round the sides of the boat will create a pressure reduction at the transom, the extent of which depends on the speed of the boat. Although an increase in speed should theoretically increase the pressure differential, it will also have an effect on where the centre of the low pressure lies in relation to the transom. At low speeds, up to about 10 knots, the low-pressure centre is likely to be at, or close to, the transom, whereas at higher speeds it will be further aft.

Exhaust fumes from the main engines are discharged under water at the stern, and it is the CO component of these fumes which has caused the problem on this boat. When these gases break the surface, they are attracted into the low-pressure area before dispersing. It is during this period that the gases enter the lower level of the cockpit via the small gap between the bottom of the transom gate and the cockpit deck. At higher speeds, it is probable that the increased air movement aft disperses the gas and prevents it entering the cockpit.

2.3.2 In the normal course of events, seepage of CO gas on to the lower cockpit deck would not, and does not, cause a problem. Running the main engines for an extended period while the vessel is stationary is unlikely to happen. Even with the canopy fully erected and the aft cover secured in place, gases seeping in at deck level would remain in the lower cockpit area. As this vessel is one of a series, all with the same basic design, the seepage of CO must have occurred before without causing a problem.

Although a change in the aerodynamic design features of the hull form may well eradicate the problem by moving or reducing the low-pressure effect at the stern, such measures would be prohibitively expensive and ignore the basic problem: the position of the air intake to the cabin heater.

2.3.3 The presence of an air intake connected to an electrically-driven induction impeller close to deck level in the lower cockpit inevitably changes the situation. With exhaust gas entering the lower cockpit, fumes would be drawn in by the induction fan, heated, and circulated throughout the boat.

If, however, the air intake had been positioned in the higher cockpit area, similar to those installed during the boat-building period, no problem would have been

experienced. It is possible, although unlikely, that exhaust gas fumes would have built up in the lower area to such an extent that they would have spilled over into the upper part of the cockpit, even with the hood in place.

Motoring of the vessel with the cockpit canvas hood fitted in place would affect air circulation as well as reducing the number of air changes taking place within that space. Nonetheless, the hood is designed to be used in place as is evident from the see-through panels inserted to give an all round view. Operating the boat in this condition was, however, a contributory factor in the incident.

Undoubtedly the poorly tuned starboard main engine was another contributory factor in the subsequent series of events. The main cause of the carbon monoxide reaching the cabins/saloon was, however, the positioning of the cabin heater air intake in the lower cockpit area.

SECTION 3 - CONCLUSIONS

3.1 FINDINGS

3.1.1 *Chapter Two* is a standard Targa 28 boat, originally built without a cabin heater, and fitted with two Volvo 4.3 GS/DP petrol engines.
(Ref: 1.4.1 & 1.4.3)

3.1.2 On purchase, the new owner arranged for a cabin heater system to be fitted before the boat was delivered to Medway Bridge Marina. The cabin heater system recommended was a diesel oil burner type, manufactured by Eberspächer and installed by Messrs Krueger Ltd.
(Ref: 2.1.1)

3.1.3 The owner had indicated his preferences for the heater outlets, but the positioning of the air intake for the heating system was left to the installer, Messrs Krueger Ltd.
(Ref: 2.1)

3.1.4 Main engine exhaust fumes, on reaching the surface, seep into the lower cockpit area under the transom gate when the boat is stationary and at speeds up to about 10 knots, due to the development of a low air pressure centre at, or close to, the stern of the boat.
(Ref: 2.3.1)

3.1.5 With exhaust gas entering the lower cockpit, the fitting of the air intake close to deck level enabled fumes to be drawn in by the induction fan, heated, and circulated throughout the boat.
(Ref: 2.3.3)

3.1.6 Operating the boat with the canvas hood fully fitted was a contributory factor in the incident.
(Ref: 2.3.3)

3.1.7 The poorly tuned starboard main engine was a contributory factor in the volume of carbon monoxide.
(Ref: 2.3.3)

3.2 CAUSES

3.2.1 The cause of the carbon monoxide poisoning was the distribution within the cabin/saloon of main engine exhaust gas fumes drawn in by the air intake fitted close to deck level in the lower cockpit area.

3.2.2 Contributory causes of the accident were:

1. Operating the boat with the canvas hood fully fitted

2. The poorly tuned starboard main engine

SECTION 4 - RECOMMENDATIONS

Krueger Ltd is recommended to:

1. Reposition the heater air intake to recycle air from the saloon/cabin area.

2. Ensure that all staff fitting heating systems are aware of this incident and the importance of ensuring the air intakes are fitted in a safe area.

Fairline Boats plc is recommended to:

3. Identify within their sales literature the importance on petrol engined boats of the position of air intakes in the retro-fitting of air heating systems.

4. Consider and take into account the dangers of exhaust gas flow when developing new hull forms and boat designs.

Eberspächer (UK) Ltd is recommended to:

5. Identify in its installation instructions the possible dangers of siting air intakes in areas where air turbulence can cause a build-up of exhaust fumes.

Marine Accident Investigation Branch
November 2000

ANNEX 1

1. Outline information of "TARGA 28"

■ Full length moulded spray deflectors ■ Isophthalic gelcoat backed by isophthalic resin-rich powder-bound glassmat to prevent any risk of osmosis ■ Gelcoat and glassfibre laid up by hand with directional and woven rovings ■ Transverse and longitudinal strengthening stringers throughout hull ■ Hull/deck joint bolted and bonded ■ Optional coloured hull top band.

Deck

Stainless steel stem head roller ■ 12kg anchor ■ 20/30 fathoms chain ■ Bow locker ■ Anodised alloy fairleads and bow, spring and stern cleats ■ Stainless steel pulpit and pushpit ■ White anodised alloy rubbing strake with plastic insert ■ Fuel cap ■ ICO navigation lights ■ Riding light ■ Electric anchor winch ■ Water and fuel fillers ■ Moulded non-slip deck surface ■ Integral teak-lined, extended bathing platform with concealed telescopic bathing ladder stowage ■ Hot and cold transom shower ■ 4 fenders ■ Transom/wheelhouse cover.

Helm Position

GRP dashboard with burr elm veneer instrument panel ■ Single helm seat to starboard ■ L-shaped triple helm seat to port ■ White anodised alloy framed windscreen with curved, toughened glass ■ Full engine instrumentation including: tachometer(s), oil pressure gauge(s), temperature gauge(s) and battery condition indicator(s) ■ Power steering ■ Helm position indicator ■ Engine level throttle and gear control(s) ■ Outdrive trim control(s) and position indicator(s) ■ Trim tab controls ■ Anchor winch controls ■ High speed compass ■ Echosounder and speedometer/distance log with sea water temperature read-out ■ Chart table ■ Chart stowage ■ Fuel contents gauge ■ Domestic water contents gauge ■ Engine hour meter(s) ■ Waterproof switches for navigation and riding lights, windscreen wipers, bilge pump and engine extractor fan ■ Twin windscreen wipers ■ Passenger grab rail ■ Drinks holders ■ Sliding door to saloon.

Maple.

Electrical Systems

All 12v circuits protected by circuit breakers on main electrical control panel in saloon ■ Isolating switches to all batteries ■ 80 amp circuit breaker for anchor winch.

SINGLE ENGINE BOATS:

1 x 65 a.h. deep cycle battery supplying domestic services ■ 1 x 135 a.h. battery (or as recommended by engine manufacturer) exclusively for engine starting.

TWIN ENGINE BOATS:

1 x 165 a.h. deep cycle battery supplying domestic services and port engine starting ■ 1 x 135 a.h. battery (or as recommended by engine manufacturer) exclusively for starboard engine starting ■ Domestic battery charge from both engines ■ Emergency battery coupling system permits starboard engine battery to start port engine if domestic battery accidentally discharged.

240v system (if fitted) comprises: 10 metre shoreline and inlet socket, 40v control panel in saloon with earth leakage protection and polarity check, automatic changeover, 12 amp regulated charger for domestic battery, immersion heater for calorifier and 2 x 240v sockets over galley.

Engines

GRP engine access hatch with stainless steel pneumatic support struts ■ Engine bay sound-proofing ■ Electric engine bay extractor fan ■ Automatic engine bay fire extinguishers ■ Electric bilge pump ■ Engine manufacturer's handbook.

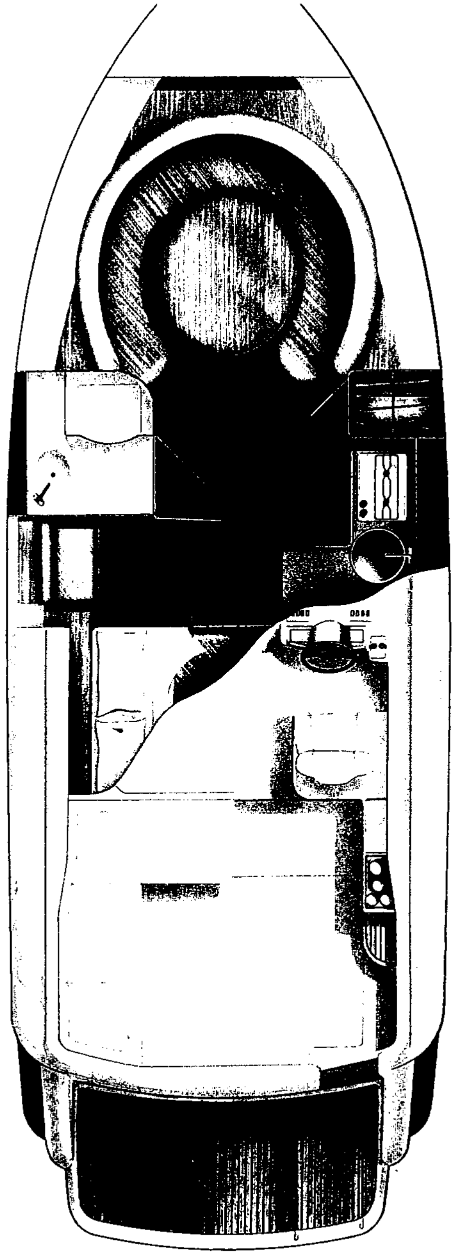
Fuel System

92 gallon marine grade alloy fuel tank ■ On/off control accessible in cockpit ■ Tank access through hatch in cockpit floor ■ Fuel tank isolated between full height bulkheads ■ Fuel filler and vent outside deck ■ Aircraft grade fuel filler and vent pipes ■ High capacity water separator(s) and fuel filter(s) on diesel installations.

Automatic pressurised supply.

Gas

All gas burners fitted with flame failure protection devices ■ Gas bottle stowage in self-venting locker ■ Copper, polythene-sheathed supply pipe ■ Single tail feed with regulator and gas low system test meter.



Shower and Toilet Compartment
Shower with hot and cold water ■ Shower curtain ■ Automatic shower tray pump out system ■ Chemical WC or sea toilet with seacocks to outlet and inlet ■ Hand basin with hot and cold water ■ Opening porthole with flyscreen ■ Halogen ceiling light ■ Towel and toilet paper holders ■ Toothbrush and glass holder ■ Mirror ■ Cupboards.

Aft Cabin
6'2" headroom in dressing area ■ 6'6" x 4'0" double bed ■ Wardrobe ■ Dressing table and mirror ■ Two stainless steel opening portholes fitted with flyscreens.

Cockpit
Self-draining ■ Transom gate to integral bathing platform ■ U-shaped cushioned rear seating to port, converting to 6'3" x 4'0" double sunbed ■ Cockpit table on bed base ■ Stowage lockers under seats ■ Stainless steel pushpit ■ GRP arch with cockpit lights ■ Drinks holders ■ Moulded non-slip surface ■ Cockpit carpet ■ Radio speakers ■ Two part cockpit hood stainless steel frame, with forward cut off hood convertible to canopy.

Saloon
Headroom 6'2" ■ U-shape[d] converting to 6'3" x 5'10" berth ■ Table ■ Wardrob[e] ■ Stowage lockers under ■ Glass and bottle rack ■ forward deck ■ Halogen ■ Control panel for 12v d[c] electrical circuits ■ Stainl[ess] opening portholes fitted w[ith] flyscreens.

Galley
Recessed two-burner gas with oven and grill ■ Opt[ional] cupboard/drawer unit in ■ 2.3 cu.ft. refrigerator wi[th] changeover when shoreli[ne] connected to 240v suppl[y] steel sink with hot and co[ld] ■ Ceiling light ■ Fire exti[nguisher]

This specification may be changed at any time without notice.

TECHNICAL INFORMATION AND EQUIPMENT

(PROVISIONAL)

HULLFORM AND CONSTRUCTION
Designed by Bernard Olesinski and the Fairline design team • Deep V forward 20° deadrise aft • Full length moulded spray deflects • Isophthalic gelcoat backed by isophthalic resin-rich pre-bond glass to prevent any risk of osmosis • All gelcoat and glassfibre laid up by hand, with unidirectional and woven rovings • Transverse and longitudinal strengthening stringers throughout hull • Hull/deck joint bolted and bonded.

DECK
Stainless steel bulkhead • Black anodised alloy rubbing strake • Stainless steel cockpit and pulpit • Stainless steel mooring cleats • Stainless steel rubbing strake with plastic insert • Navigation lights • Riding light • Moulded non slip deck surface • Integral anchor locker with concealed transom bathing platform • Stowage for fenders with transom locker • Stowage.

HELM POSITION
Single helm seat to starboard • L-shaped triple seat to port with cocktail table • Stainless steel framed windscreen with curved, toughened glass • Full engine instrumentation including: tachometer(s), oil pressure gauge(s), temperature gauge(s) and battery condition indicator(s) • Power steering • Helm position indicator for Single-lever throttle and gear control(s) • Outdrive trim control(s) and position indicator(s) • Trim tab controls • High speed compass • Speedometer and distance log • Echosounder • Remote control anchor winch with • Chart table and light • Chart wag • Fuel/water gauge • Domestic water contents gauge • Engine hour meter • Circuit breaker switch for navigation lights, windscreen wiper, bilge pump and engine extractor fan • Twin windscreen wipers • Co-pilot grab rail.

COCKPIT
Self-draining transom gate integral bathing platform • Cushioned rear seat to port, converting to 6' 3" x 1' double sunbed • Cushions to enable saloon table to be used for cockpit dining • Stowage lockers • Stainless steel guard rails • GRP arch with light holders • Moulded non slip floor surface • Grey ribbed waterproof carpet • GRP bar with sink, and space for optional refrigerator • Two-part cockpit hood on stainless steel frame, with forward part converting to canopy.

INTERIOR FURNISHINGS
Choice of co-ordinating carpets, upholstery and curtain fabrics • Joinery and woodwork in Teak or American Ash.

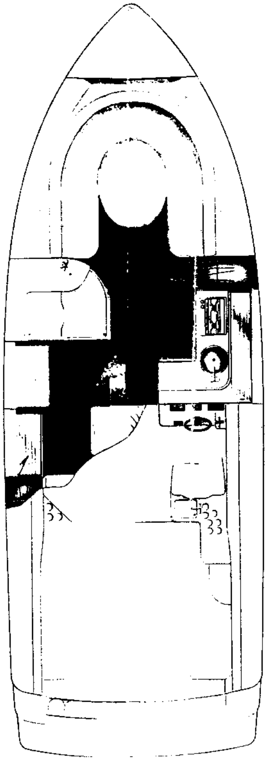
SALOO
Forward saloon with U-shaped dinette converting to 6' 3" x 5' 9" double berth • Table (dismountable) • Drop-in cockpit • Wardrobe • Stowage for towels • Furniture pot, starboard and forward • Bottle rack • Escape hatch to fore deck • Reading lights • Companion light • 12 240v domestic electrical circuits.

GALLEY
Two burner cooker with oven and grill • Optional cupboard with unit in place of oven • 2.3 cu.ft refrigerator with automatic 24/240v ... • Stainless steel sink with hot and cold water • Chopping board cover for sink • Lamp • Ventilator • Ceiling light • Fire extinguisher • Cupboards, drawers and crockery stowage • Grack rack.

AFT CABIN
6' 3" headroom in dressing area • Two 6' 8" x ... berths • Wardrobe • Large cupboard with shelf • Ceiling lights • Recessed reading light • Opening hatch to cockpit • Dressing table • Berths ... can be used as a 6' 8" x 4' 8" double if required.

SHOWER TOILET COMPARTMENT
Shower with hot and cold water • Shower curtain • Automatic shower tray pump out system • Chemical WC, or toilet with sea cocks to outlet and inlet • Hand basin with hot and cold water • Opening porthole • Ceiling light • Towel and toilet paper holders • Toothbrush and glass holder • Mirror.

ELECTRICAL SYSTEMS
All 240 volt and 12 volt circuits protected by circuit breakers on main electrical load centre in saloon. Isolating switches to all batteries. 80h. circuit breaker for anchor winch



12 Volt
SINGLE ENGINE BOATS
1 x 125 a.h. battery supplying domestic services 1 x 50 a.h. battery (or as recommended by engine manufacturer) exclusively for engine starting.

TWIN ENGINE BOATS
2 x 125 a.h. batteries wired in parallel supplying domestic services and port engine starting • 1 x 50 a.h. battery (or as recommended by engine manufacturer) exclusively for starboard engine starting • Domestic batteries of twin engine boats accept charge from both engines • Emergency battery coupling system permits starboard engine battery to start port engine if domestic batteries accidentally discharged.

240 Volt
240v shorepower supply • Socket outlets in saloon, galley and cabins • Wiring diagram provided in handbook.

ENGINES
GRP engine access hatch with pneumatic support struts • Engine bay soundproofing • Electric engine bay extractor fan • Automatic engine bay fire extinguisher • Electric bilge pump • Engine manufacturer's handbook.

FUEL SYSTEM
120 gallon marine grade alloy fuel tank • On/Off control in accessible in cockpit • Tank accessible through hatch in cockpit floor • Fuel tank located between full height bulkheads • Fuel filler and vent on side deck • Aircraft type fuel filler and vent pipes • Copper fuel lines • High capacity water separator(s) and fuel filter(s) on diesel installations.

FRESHWATER SYSTEM
35 gallon water tank • Filler and vent on side deck • 6 gallon Calorifier hot water system 1kw 240v shorepower immersion heater • Automatic pump and filtered pressurised supply.

GAS
All gas burners fitted with flame failure protection devices • Gas bottle stowage in self-venting locker • Copper, polythene sheathed supply pipe • Single tail feed with regulator.

PERFORMANCE ESTIMATES

Diesel:	
1 x Volvo AD42/DP230 hp	22–26 knots
2 x Volvo AD31/DP130 hp	24–27 knots
2 x Volvo AD41/DP200 hp	35–40 knots
2 x Volvo AD42/DP230hp:	40 knots plus
Petrol:	
1 x Volvo 570/DP 275hp	28 knots
1 x Volvo 740/DP 330hp	30 knots plus
2 x Volvo 500/DP 210hp	33 knots plus
2 x Volvo 570/DP 275hp	40 knots plus

STANDARD FEATURES

Reversible 1000 watt electric anchor winch • Integral bathing platform with transom gate • Electro-hydraulic trim tabs with cathodic protection • Echo sounder with audible shallow water alarm • Stereo radio/cassette player with saloon and cockpit speakers • Hot and cold water transom shower • Two-part cockpit hood on stainless steel frame • 15lb anchor • 15 fathoms chain • 4 fenders • Horn • Mooring warps • Waterproof cockpit carpet.

RECOMMENDED EXTRAS

Antifouling • Regulated charger for domestic battery bank • Radio telephone • Refrigerator for cockpit bar complete with 10 amp regulated battery charger.

PRINCIPAL DIMENSIONS

LENGTH OVERALL	32' 5"	9.88m	NO. OF BERTHS		4
LENGTH OF HULL (bow to aft face of transom)	28' 9"	8.76m	FUEL CAPACITY	120 gals	545 L
BEAM	11' 1"	3.38m			
DRAUGHT (APPROX. WITH STERNDRIVES DOWN)	3' 2"	0.97m	WATER CAPACITY, INCL. CALORIFIER	41 gals	186 L
HEIGHT ABOVE WATERLINE (including GRP arch)	8' 9"	2.67m			
DRY WEIGHT (APPROX. WITH 2 x 500 DP)	4.5 tons	4572 kg	H.P. RECOMMENDATIONS		230hp to 550hp

Performance estimates are given in good faith, but are in no way guaranteed for any particular boat. Dirt on the bottom of the boat damage to the propellers, engine tuning, external water and air temperatures and the weight of fuel, water and stores carried can all adversely affect performance. For these and other reasons we can give no performance guarantees.

This specification may be changed at any time without notice

2. Marine specification for Eberspächer air heating system

Eberspächer

MARINE SPECIFICATION FOR THE INSTALLATION OF EBERSPÄCHER AIR HEATING SYSTEMS IN BOATS

Aug 1995 Issue A

Pt N° 20220

Eberspächer

INDEX

1. **Heater Location**

1.1 The heater can be located in the engine room, sea locker, sail locker or storage void which offers unrestricted movement in the operation of the vessel. Note - Do not install the heater in the accommodation area.

1.2 Where the heater is fixed to a wood bulkhead, a stainless mounting plate should be used to secure the heater in a horizontal position with the exhaust outlet directed vertically downwards.

1.3 Where it is intended to fix the heater to the glass fibre hull a 20 - 25mm thick ply-wood plate of suitable dimensions should be glassed to the hull for the purpose of fixing the heater as detailed in 1.2.

1.4 The heater should be fixed in a position that allows access for routine maintenance and removal of the glow plug and printed circuit board.

1.5 The position chosen for locating the heater should be dry and protected against the ingress of moisture with due regard for other aspects of the installation, i.e. exhaust, fuel lines, ducting, electrics, etc ..

1.6 When the heater is located in a sail locker, the heater must be protected against the possibility of the sails, ropes, any item that may be affected by heat coming into contact with the heater and its exhaust system.

1.7 When the heater is fitted inside an engine room, sail/sea locker or storage void, the unit must be protected against physical damage. The protection must maintain ease of access for routine maintenance and fast replacement of parts.

Petrol Engines - Note: Use Only Diesel Fuel Heaters.

1.8 When it is intended to locate the heater in the engine room the heater must be installed in a steel box, sealed to avoid the ingress of petrol vapour with provision to duct the combustion air to an external source.

2. **Ducting**

Intake

2.1 The internal diameter of the air intake duct must not be below the minimum specified (see page 4).

D1L'C' - 60mm Diameter
D3L'C' - 75mm Diameter
D5L'C' - 100mm Diameter
D8L'C' - 100mm Diameter
D12L - 100mm Diameter (if length exceeds 2 mtrs then 125mm ducting must be used).

2.2 If a fresh air system has been adopted, the air must be taken from a position avoiding water ingress, sea spray, heat influence, exhaust fumes, diesel / engine fumes, etc.

2.3 If a re-circulated air system has been adopted, the air must be taken from a clean, dry area avoiding the direct influence of heat from hot air outlets.

2.4 The air intake must be protected by a mesh or louvered grill which provides an adequate amount of free air (see below).

D1L'C'	$36cm^2$ minimum
D3L'C'	$56cm^2$ minimum
D5L'C'	$100cm^2$ minimum
D8L'C'	$100cm^2$ minimum
D12L	$156cm^2$ minimum

Note The air intake mesh or grill must be fitted in a position to avoid blockage by curtains, bed linen and cabin doors, etc.

2.5 The ducting must be routed in the least restricted way possible with the minimum amount of bends and offsets.

2.6 The duct must be adequately supported and fixed in position throughout its length.

Note During this section, references are made to fresh and recirculate air systems. Eberspächer recommend a recirculated air system as it reduces the possibility of corrosion to electronic components contained within the heater body.

Output

2.7 The ducting must be secured (using a Jubilee Clip) to the heater and all duct components (i.e. "Y" Branches, outlets, heater, etc).

2.8 The ducting must maintain its full internal diameter throughout (not crushed).

2.9 All ducting should be run in protected areas to avoid crushing or impact damage.

2.10 Only APK grade ducting or ducting of similar specification should be used for hot air as it is manufactured to withstand the high temperatures produced by the heater. Minimum temperature specification 150°C.

2.11 One hot air outlet must remain permanently open (not manually closeable) at all times. i.e. D1L'C' 60mm outlet, D3L'C' 75mm outlet, D5L'C' 100mm outlet, D8L'C' 100mm outlet, D12L 2 x 100mm outlets.

2.12 Hot air outlets must be positioned to avoid as far as possible, blowing onto the back of peoples legs or any item that is likely to be damaged by heat.

3. **Exhaust**

3.1 The exhaust length should not exceed the maximum length detailed below unless authorized by Eberspächer (UK) Limited.

	I/D	LENGTH
D1L'C'	24mm	2 Metres
D3L'C"	24mm	2 Metres
D5L'C'	24mm	2 Metres
D8L'C'	40mm	3 Metres
D12L	40mm	3 Metres

3.2 The exhaust must be adequately insulated throughout its length. Note: The minimum insulation would be sleeved within a G.R.P woven sock and sleeved overall with APK ducting.

3.3 The exhaust must be securely clamped at both heater and hull fitting using the correct Eberspächer exhaust clamp (not Jubilee Clip).

3.4 The exhaust should be adequately supported throughout its length. By stand off support clips. Note minimum stand off 25mm.

3.5 The exhaust must be routed away from any components likely to be damaged by heat.

3.6 An adequate swan neck must be formed in the exhaust pipe prior to it exhausting to atmosphere at the hull fitting. Note: This is to prevent water ingress.

3.7 An exhaust elbow with pig tail drain should be fitted to the heater exhaust stub allowing any water that may have entered the exhaust pipe, to drain away.

3.8 The exhaust hull fitting should be positioned at a minimum height of 300mm above the waterline.

3.9 The exhaust hull fitting should be mounted vertically so as to ensure any water that may enter the exhaust can be drawn away.

4. **Combustion Air**

4.1 The combustion air must be taken from a clean dry area not from the accommodation or a sealed void.

4.2 The combustion air must be taken from an area that is well ventilated and not contaminated by engine heat or exhaust fumes.

Note The combustion air must never be taken from the same area as the air for heating.

4.3 If the combustion air tube requires to be increased in length from standard to comply with 4.1 and 4.2 approval must be obtained from Eberspächer (UK) Limited.

5. **Fuel System**

5.1 The fuel metering pump should be mounted in an inclined position (between 15° and vertical) with the delivery side uppermost.

5.2 The fuel lines supplied in the installation assembly are designed to give optimum heater performance. The fuel lines must not be increased in length without first consulting Eberspächer (UK) Limited for approval.

Note If the fuel lines require shortening, they should be cut with a sharp blade or the correct fuel line cutters (not side cutters).

5.3 The fuel lines must be adequately supported throughout their length.

5.4 All fuel lines must be butted together at all joints to prevent air locks and incorrect fuel delivery.

5.5 The fuel line must be routed clear of the exhaust or any hot components.

5.6 Where fuel lines come in to contact with uneven surfaces, sharp corners or pass through bulkheads, they must be protected against abrasion.

5.7 When installing the fuel standpipe care must be taken to ensure that no steel, fibre-glass or debris particles enters the fuel tank.

Note: Any debris drawn into the system could cause fuel blockage.

5.8 When the standpipe requires shortening it should be terminated 25mm minimum from the bottom of the fuel tank, cut at a 45° angle and de-burred.

5.9 With the fuel pump correctly installed as per 5.1, the electrical connections should terminate above the fuel line, protected with grease and the rubber boots fitted to avoid moisture being trapped.

6. **Electric's**

6.1 The power cables if not supplied by Eberspächer (UK) Limited should be calculated to ensure that a maximum volts drop of 1 volt (24v) and 0.5 volts (12v) is not exceeded with a component load of 22 amps.

Note: It is the boatbuilders responsibility to ensure that the interconnecting cables between the batteries and the distribution point (fuse box) are of sufficient cross-sectional area to carry the total electrical load of all components fitted to the finished vessel.

6.2 The power loom must be fused at its source using one of the following in the positive line:
16A - Ceramic Fuse
25A - Blade Fuse
25A - Miniature Circuit Breaker

6.3 All heater looms (power, pump and switch) must be adequately supported throughout their length and secured in position.

6.4 Where the cables pass through bulkheads, they must be protected against abrasion with a grommet or by further oversleeving.

6.5 All male and female terminal housings must be securely connected to ensure good electrical continuity.

6.6 The switched modulator should be mounted in a position to avoid direct sunlight or components radiating heat. There should also be sufficient air movement around the switched modulator.

6.7 The switched modulator should be wired as follows:

Terminal 1	-	Brown / White
Terminal 2	-	Grey / Red
Terminal 3	-	Blue / White
Terminal 4	-	Black / White
Terminal 5	-	Red
Terminal 6	-	Yellow
Terminal T	-	Grey

6.8 When fitting a switched modulator, the internal sensor of the heater must be disconnected (small miniature housing) at the heater end, and substituted by the remote sensor (small miniture housing) of the switched modulator wiring loom.

Note: The miniature housings that should be connected together are normally identified by a red spot on each.

Note: Should the vessel be used on the National Rivers Authorities / inland waterways. The heating system must be installed in conjunction with the NRA /inland waterways specification Part N° 20221.

ANNEX 3

3. Eberspächer installation and operating instructions

Eberspächer

D3L'C' COMPACT

Boat Heating Kit

Installation and Operating Instructions

For Heaters:

25 1906 05 00 00 (12v)
25 1967 05 00 00 (12V)
25 1980 05 00 00 (12v)
25 1907 05 00 00 (24v)
25 1968 05 00 00 (24V)
25 1981 05 00 00 (24v)

Part N° 20237 Issue D September 1997

Contents

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Introduction

The D3L'C' Compact is designed for boats requiring heating within the range of 3.2 to 3.5kW. The instructions must be read carefully, prior to installation and followed exactly. Any deviations or proposed changes must be approved by one of the dealers listed under the service maintenance section.

Technical Description

The boat heater kit is based on the Eberspächer D3L'C' diesel fired air heater.

The unit burns diesel in a sealed combustion chamber and heat exchanger over which ambient air is passed to collect the heat from the walls of the heat exchanger for distribution through ducting to the cabins. Combustion air, drawn from the outside, is mixed with the diesel fuel supplied by the fuel metering pump and ignited by an integral glow plug in the unit. The products of combustion pass through a flexible stainless steel exhaust tube to the hull fitting for escape to atmosphere. The system is an indirect burner unit for delivering warm air to the various areas of the boat requiring heat.

Operation

The heater is started by pressing the control switch on the rheostat The integral operational lights (Red and Green) will illuminate.

Switch-on
The green & red operational lights come on when the heater is switched on. The glow plug is switched automatically on and the blower starts up at a low speed.

Note: If the heat exchanger still contains residual heat, only the blower runs (cold-blowing phase). The start-up procedure commences after residual heat has dissipated.

Start-up procedure
Fuel feed starts after approx. 30 seconds. The fuel/air mixture ignites. Blower speed and fuel delivery is increased continuously. Once a flame has been detected and the combustion process has stabilised, the glow plug is switched off. The heater is heated up rapidly in the >BOOST< setting until the heat exchanger reaches its operating temperature.

Note: The duration of maximum heat flow is dependent upon ambient temperature .

Control during heating
During heating, the cabin temperature or the intake heating air temperature is measured constantly and compared with the temperature set at the operating unit. If the measured temperature exceeds the desired cabin temperature, the heater switches to the >LOW< setting and continues to run at low blower motor speed. If the heating capacity in the >LOW< setting is insufficient, the heater switches to the >MEDIUM< setting. The blower continues to run at low speed. In most cases, the LOW-MEDIUM-LOW control sequence at low blower speed will supply the required heat. If the >MEDIUM< setting is not sufficient, the heater switches back to>HIGH< This again entails full blower speed. If, in special cases, an even lower heating capacity is required than the heater delivers in the >LOW< setting, the heater switches to the >OFF< setting. Restart is generally in the >MEDIUM< setting at low blower motor speed.

Switch -off
When the heater is switched off, the green & red pilot lights go out and the fuel feed is shut off.
The glow plug is automatically switched on for another 15 seconds to clear the heater of combustion residues.
The blower continues to run to cool down the heater.

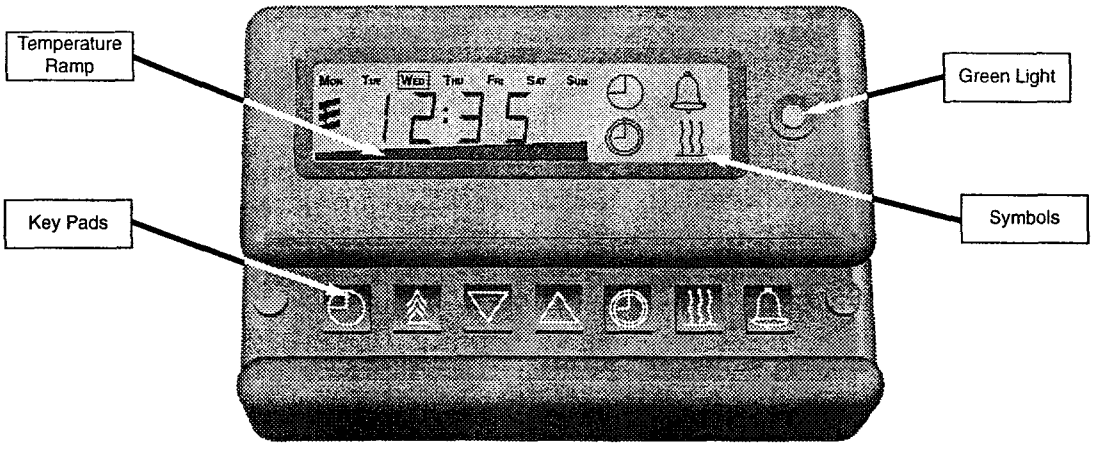
Note: If no fuel is delivered during the start-up procedure or if the heater is in the >OFF< setting, the heater is switched off immediately without afterrun.

Once the normal afterrun period has elapsed, the heater is constantly after-ventilated at minimum blower speed (in recirculated-air operation only) until the heater is restarted.

Timer Modulator Operating Instructions

For Part N°S

401 00 190 (24v), 401 00 191 (12v)



To set clock time

Press key then, while symbol is flashing:

a) Press once for each day to set present day.

b) Press or to set exact time.

Note: If no adjustment is made for 5 seconds, then the symbol will stop flashing & the present day or time will be set.

To switch heater on (continuous running)

Press .Heater will start. Display will show 00:00. If no adjustment is made within 5 seconds, the symbol will stop flashing. Heater is now set for continuous running. Display will revert to show present time. symbol will stay on.

To switch heater on (timed duration operation)

Press . Heater will start. symbol flashes and display shows 00.00. Press to set required time from 8 hours (max) to 30 mins. (Min). Adjust time using or . Five seconds after last adjustment, the symbol stops flashing and stays on. The display shows the duration time and counts down to zero, when the heater automatically switches off.

During count down, it is possible to view real time by pressing . Real time is displayed for **5** seconds then display reverts to count down.

To switch heater off (timed and continuous running modes)

Press once. symbol will switch off. The heater will continue to run for 2 minutes, then automatically shut down.

To pre–program timer

Press , then while symbol is flashing:

a) Set "Required switch on time" by pressing or keys to adjust time.

b) Set required switch–on day by pressing . *Note:press once to advance symbol around required day*

Note: If no adjustment is made for 5 seconds will stop flashing. Preset time and day are now stored.

will remain on to indicate timer is now set. Display reverts to present time and day.

When the heater switches on in the pre-programmed mode, the pre-set time is copied over to the next day and may be pre-selected if required.

To review switch on time and day

Press key once. Display will show set time & day for **5** seconds then revert to present time & day.

To cancel advanced switch on time

Press key twice. symbol will switch off.

To set heater–on duration time (when used in pre–programmed mode)

Note: If no adjustment is made timer automatically sets for 2 hours.

Press key once, then while is flashing, adjust required "heater-on duration time" (from 30 min to 8 hours duration) by pressing or . If no adjustment is made for **5** seconds, the symbol will stop flashing and duration time is now stored. The display reverts back to present time.

To set Alarm

Press and while Q symbol is flashing set alarm 'on' time by pressing or .

Five seconds after last adjustment, symbol **stops** flashing and stays on. The display reverts back to time. To review alarm set time, press key once.

To cancel alarm set time, press twice.

Temperature Display

This timer incorporates a temperature ramp display.

Press or to set the required temperature (approximate) between 5°C and 25°C in 1°C increments.

Ventilation (blower only) to activate press key until no segments are shown on display. (D5LC / D8LC only)

To stop ventilation (blower only) press key until segments return to display. (D5LC / D8LC only)

Always switch **off** the heater when filling the **fuel** tank.

Controls and Safety Equipment

The flame is monitored by the flame sensor, and the maximum permissible temperature by the safety thermal cutout switch.
Both affect the control unit, which shuts down the heater in the event of faults.

1. If the heater fails to ignite within 90 seconds of fuel delivery, starting is repeated as described.If the heater still fails to ignite after 90 seconds of fuel delivery, fault shutdown takes place.

2. If the flame goes out spontaneously during operation, a restart is first attempted. If the heater fails to ignite within 90 seconds of fuel pumping, or if it does ignite but goes out again within 10 minutes, fault shutdown takes place. The heater can be reset by switching it off and then back on again.

3. In the event of overheating the safety thermal cutout switch is operated, the fuel supply is interrupted, and fault shutdown takes place. Once the cause of the overheat has been removed, the unit can be restarted by switching it off and then back on again.

4. If the voltage drops below 10.5 or 21 V or rises above 14 or 28V as the case may be, fault shutdown takes place.

5. If the glow plug is defective and the electric cable to the metering pump is interrupted, the heater will not start.

6. When the heater starts the operation of the blower motor is checked once. If it does not start, the heater reacts as for fault. During operation, the blower motor is monitored continuously. If the motor speed is below the allowed limit, fault shutdown follows.

7. When the heater is switched off the glow plug is switched on during the delayed shutdown for about 15 seconds after-glow) to clear the heater of combustion residues.

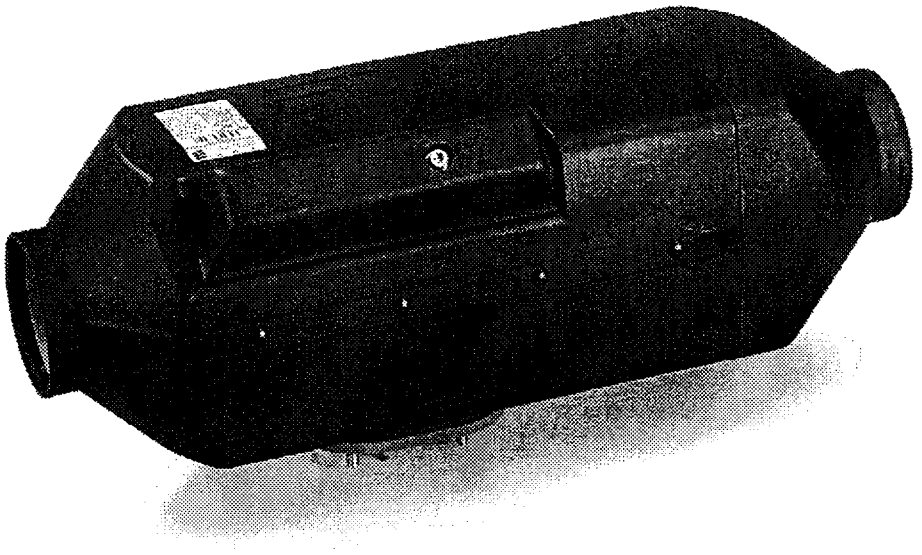
Please note:

When carrying out electric welding work on the boat disconnect the positive terminal from the battery and earth it in order to protect the control unit.

The heater must always be switched off when the fuel tank is being filled.

The heater must not be operated in a storage shed.

D3L'C' Compact Technical Specification



Specifications

Heating medium	Air
Heating capacity') W ± 10%	Boost/ High/ Medium/ Low 3500 / 3200 / 1500 / 1000
Hot air throughput without counter-pressure[4]) kg/h ± 10%	Boost/High/Medium/Low 155 / 155 / 85 / 65
Heating capacity control	Boost - High - Medium - Low - Off
Ventilation	Not Available
Fuel	Diesel fuel (commercially available)
Fuel consumption') l/h ± 10%	Boost/High/Medium/Low 0.42 / 0.37 / 0.18 / 0.12
Rated voltage	12V or 24V respectively
Operating range	
Minimum voltage[2])	10.5V or 21V respectively
Maximum voltage[3])	14V or 28V respectively
Ambient temperature	
In operation	-40 to +70°C
Not in operation	-40 to +85°C

Electric	
Power consumption')	at start for approx. 45 seconds 12V = 270 W ± 10% 24V = 240 W ± 10%
In operation	Boost/High/Medium/Low 36 / 36 / 15 / 10 W ± 10%
Radio interference suppression level 3	R.S.I additional suppression measures possible
Weight	approx. 6 kg

[1]) at rated voltage

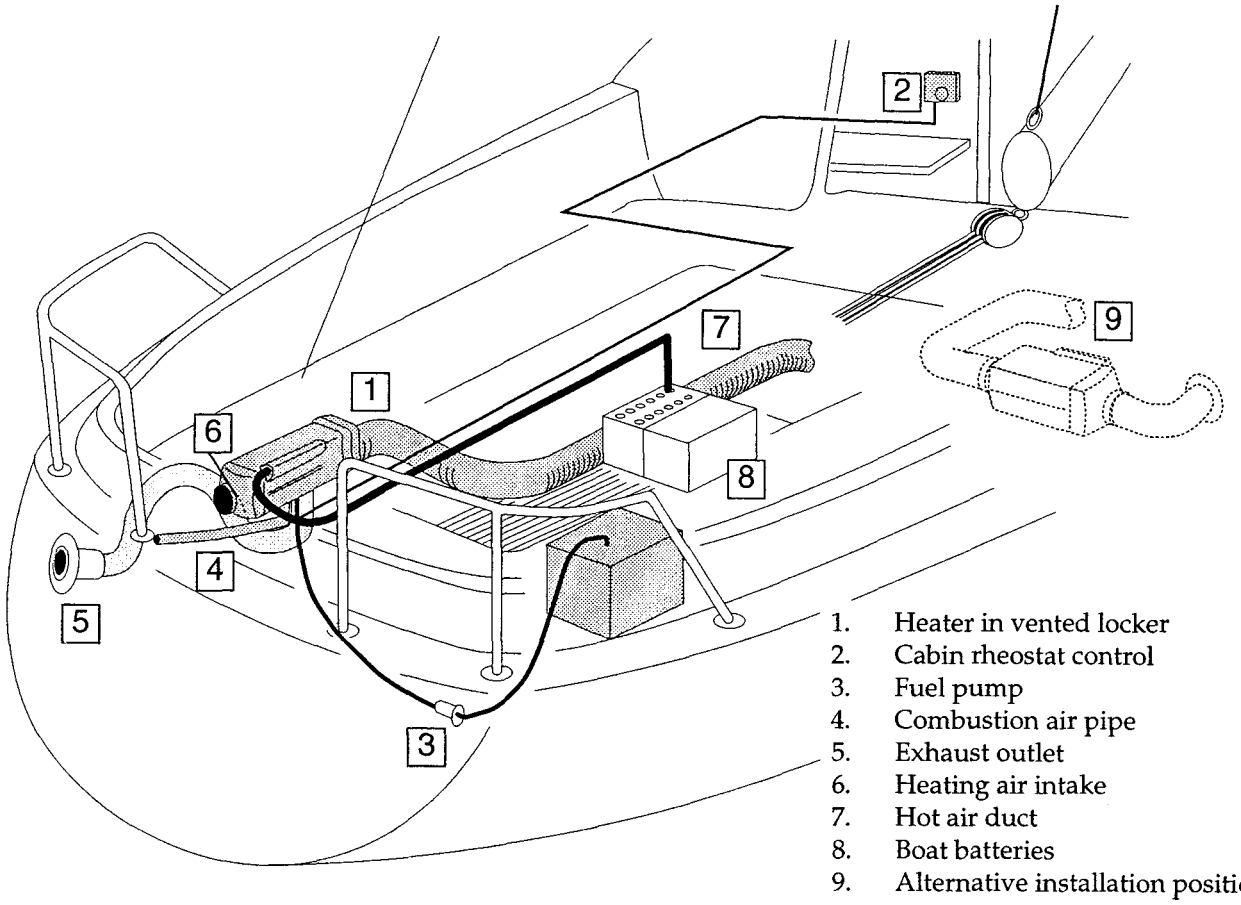
[2]) an undervoltage safety device built into the control unit switches off the heater at around 10.5V or 21V respectively.

[3]) an overvoltage safety device built into the control unit switches off the heater at around 15V or 30V respectively.

[4]) without backpressure.

Siting the Heater

Fig N°. 1



1. Heater in vented locker
2. Cabin rheostat control
3. Fuel pump
4. Combustion air pipe
5. Exhaust outlet
6. Heating air intake
7. Hot air duct
8. Boat batteries
9. Alternative installation position

Fig. N°. 1 shows the general position of the heater and associated components. The heater unit is mounted on the stainless steel mounting plate supplied in the kit and in such a way that the heater manifold is downward. See Fig. N°. 2

The mounting plate is pre-drilled to accept the heater manifold and has provisions for self tapping to bulkheads. A suitable and strong enough bulkhead will need to be provided particularly in the GRP boat where thin GRP coaming or panels will need suitable plywood support to give the heater a firm mounting. Care should be taken to avoid mounting on cabin bulkheads where vibration could be amplified through the acoustic effects of large bulkhead panels.

Mount the heater in a dry protected position but with due regard to the other aspects of the installation, i.e. exhaust, fuel line, ducting, electric's etc. For instance, the exhaust length supplied is 2 meters so the heater body must not be more than this length away from the exhaust skin fitting.

A cockpit locker is normally an ideal site. The heater should not be mounted inside the cabins. Access should be considered for servicing, particularly removal of the glow plug. See Fig. N°. **3** for dimensions.

The heater is bolted to the mounting plate by four M6 nuts and spring washers. Four self tap screws secures the mounting plate to the bulkhead.

It is important to ensure that the heater is installed with the exhaust, fuel and combustion air manifold pointing vertically downward. Failure to achieve this will affect the optimum running of the heater particularly when sailing at an angle of heel. The heater will operate in conditions of permanent 15" heel and after starting to a maximum heel of up to 30° . Deviations exceeding 30" may cause the heater to lock out under safety control but no damage of the unit can occur. See Fig. N°.3

Permissible Installation Positions

Fig N°. 2.

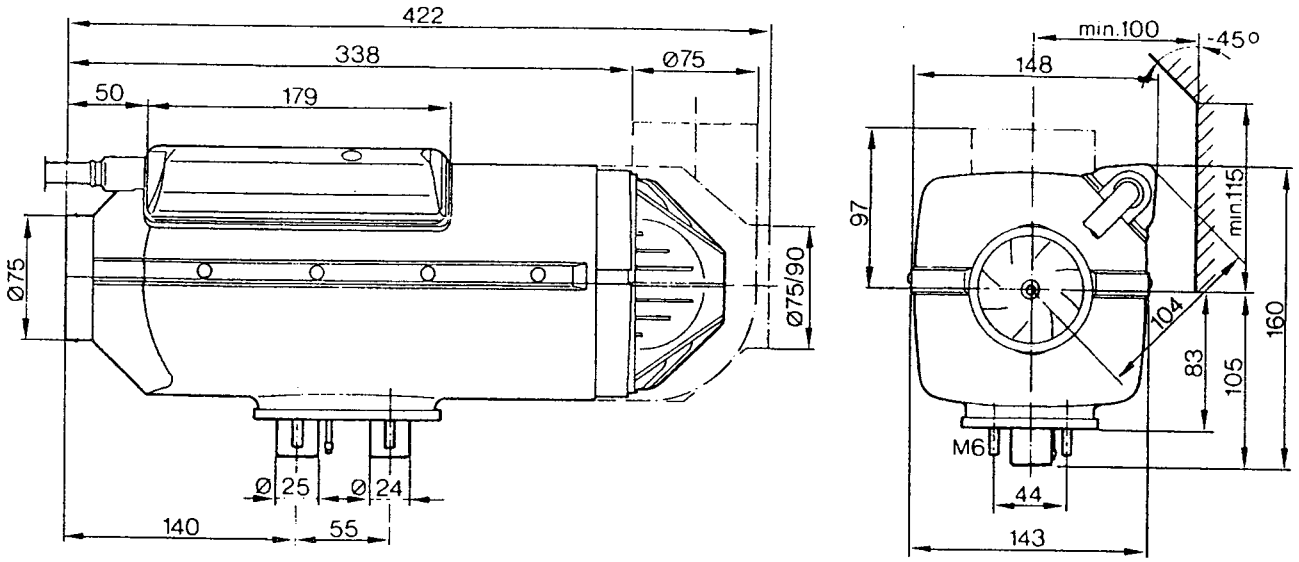
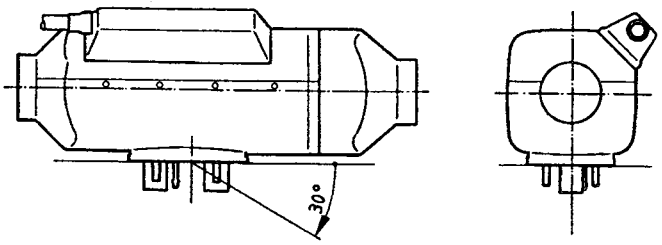


Fig N°. 3.



Ducting — (A) Air Intake

Air for heating is drawn into the heater at the intake. Re-circulated air from the cabin is introduced to the heater with ducting connected to the intake of the heater. Engine room air or air likely to be contaminated must not be used.

When using fresh air from outside care must be taken to ensure that no water may enter the heater. Siting of the fixed air intake should be carried out particularly in cockpit areas with due regard to protecting against an ingress of water at sea or during any cockpit cleaning operations.

To ensure sufficient free air reaches the heater and to avoid overheating through air starvation, the grille supplied should be used to cover a minimum 75mm diameter hole. Any existing grille in the cockpit walls etc., can be used providing the air stream to the heater is unrestricted (56.25 sq. cm.) minimum.

What ever method is chosen a sufficient supply of free, clean air must be allowed to reach the heater at all times (56.25 sq. cm.) minimum.

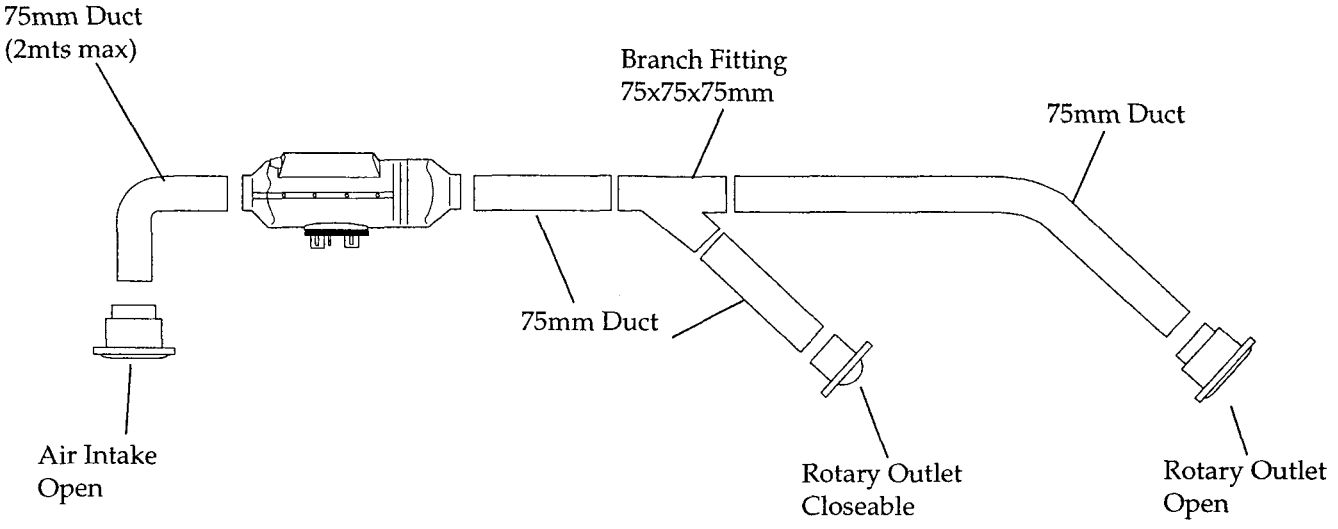
(B) Hot Air Outlet

When fitting the ducting, plan for "runs" or "routes" to be as straight as possible, and avoiding areas where ducting could be crushed or damaged.

Attempt to locate the heater outlets in a position low down and close to the cabin floor. Ideally this should be in such a position that the air will move unobstructed along the cabin floor towards the forward end of the boat. In this way the maximum heating effect is achieved with minimal loss through hatchways. See Fig. N°. 4 and 5.

Fig N°. 4

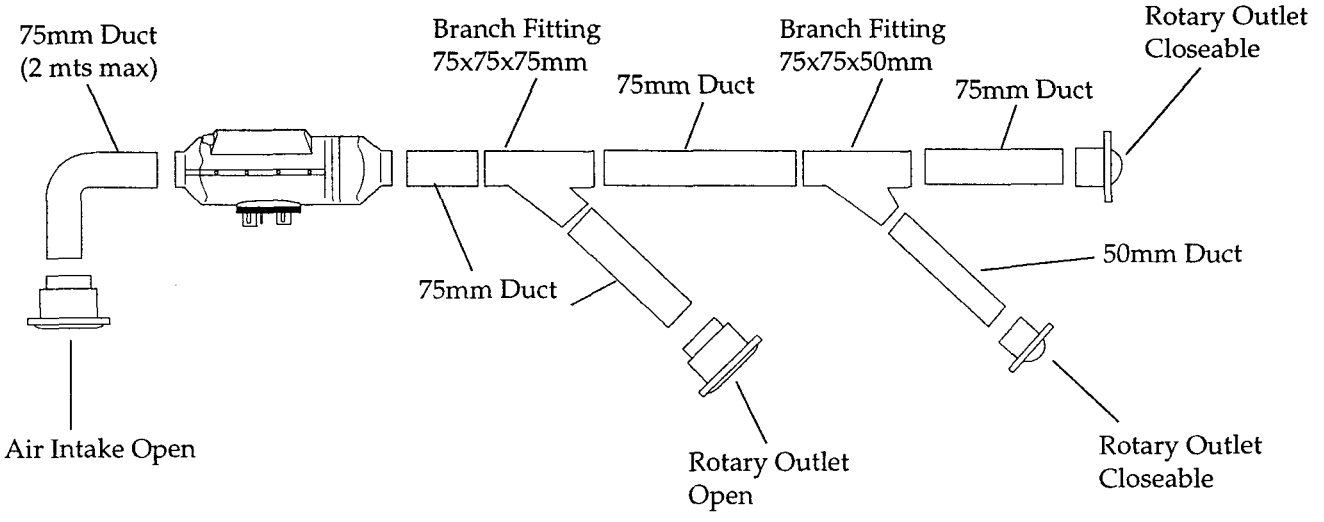
D3L'C' Compact Duct Schematic Marine 2 Outlet



Note: Open & closeable rotary outlets can be interchanged on hot air outlets only

Fig N°. 5

D3L'C' Compact Duct Schematic Marine 3 Outlet



Exhaust

The exhaust passes through the centre spigot of the skin fitting. See Fig. N°. 7.

Mount the skin fitting in as dry an area as possible since the heater exhaust is a totally dry exhaust. The maximum length of exhaust allowed is 2 metre. The skin fitting must be in an outside surface such as transom, hull side, coaming etc., and located so exhaust fumes cannot reach cabins or heater fresh air intake. The skin fitting must not be fitted to a deck or flat horizontal surface without the use of a deck standpipe which is available as an optional extra from an approved Eberspacher dealer.
Under no circumstances connect the heater exhaust to an engine exhaust or any other exhaust system.

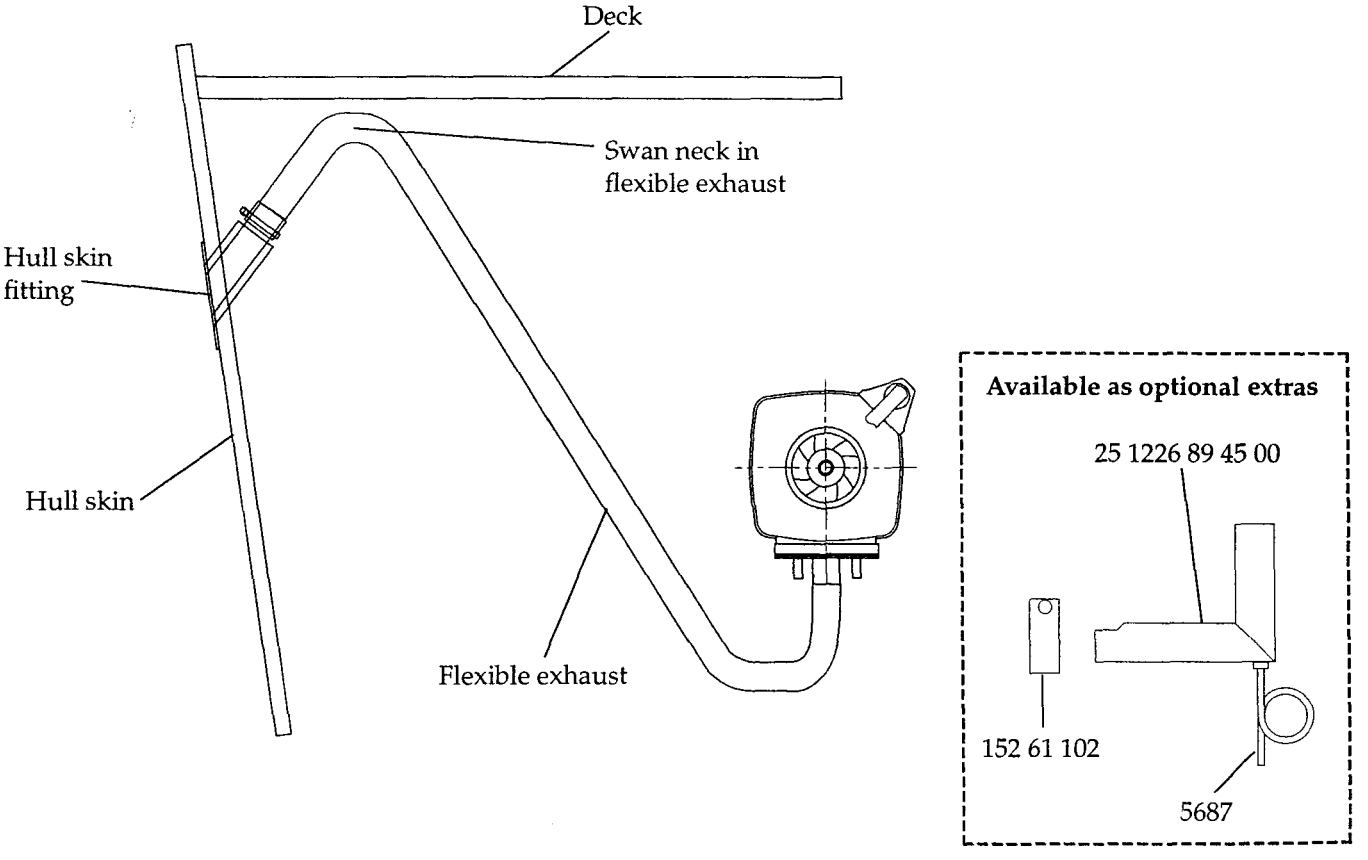
When routing the flexible exhaust tube between the hull fitting and the heater a swan neck should be incorporated immediately adjacent to the skin fitting. See Fig N°. 6.

The 2 metre flexible exhaust supplied in the kit is pre-wrapped in a fibre glass woven sock and oversleved with 50mm APK ducting. The exhaust is prepared to fit both the heater and exhaust skin fitting spigots along with two clamps for connection. Ensure these connections are tight and do not allow exhaust fumes to escape.

Note:
Ensure that the exhaust does not come into contact with electric cables, fenders, pipes or fittings that could become damaged by any increased temperature. Also ensure that the exhaust does not run too close to the control box where localised heat damage could occur.

It should not be necessary on many installations to change the length of exhaust since the 2 metre length is suitable for most applications. Should you require to shorten the exhaust for any reason please consult your nearest approved Eberspacher dealer.

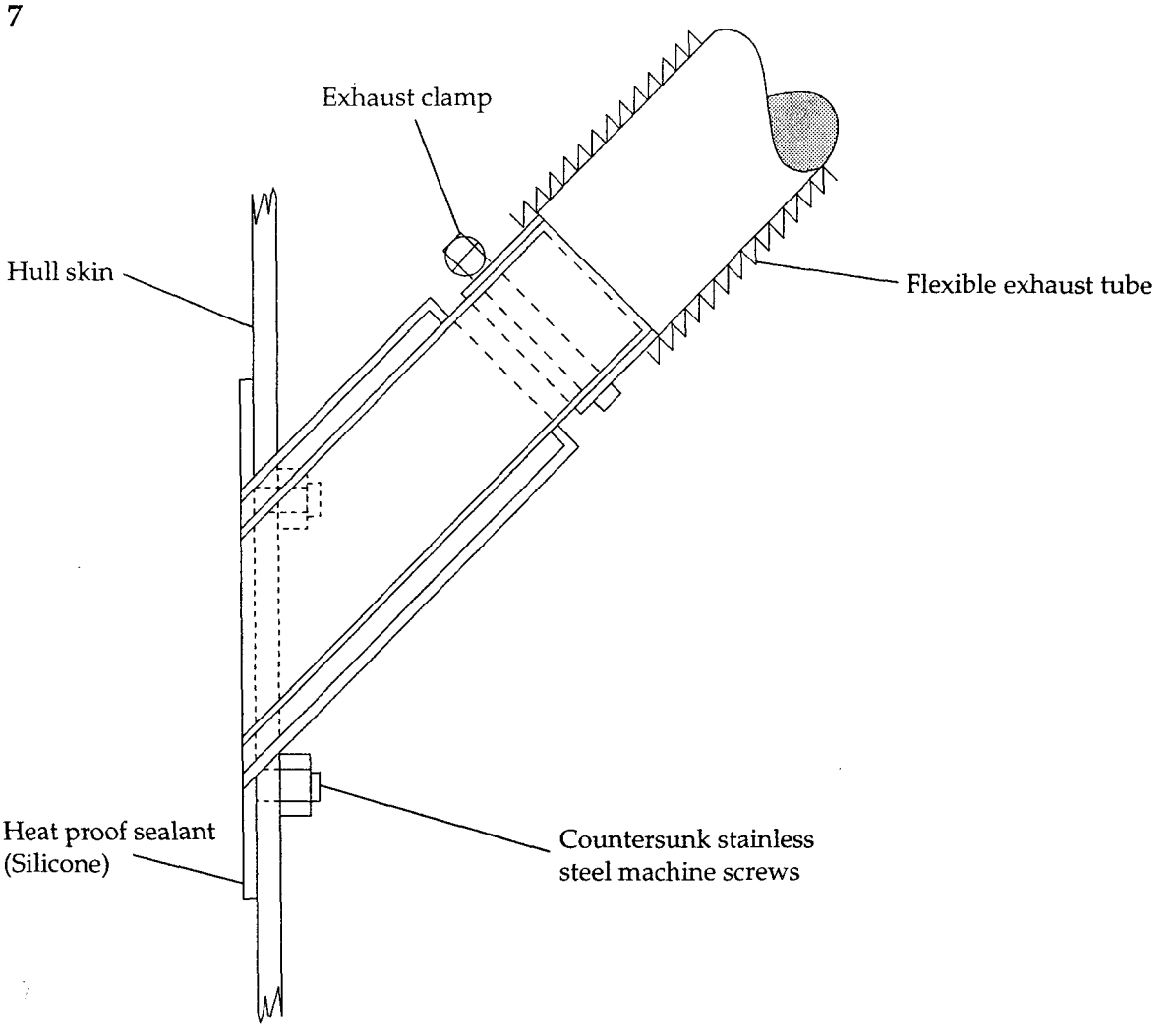
Fig N°. 6



If it is not possible to achieve an adequate swan neck on the exhaust, an exhaust elbow and drain should be fitted. **(Note exhaust elbow and drain are not supplied in kit).**

Exhaust Skin Fitting

Fig. N°. 7



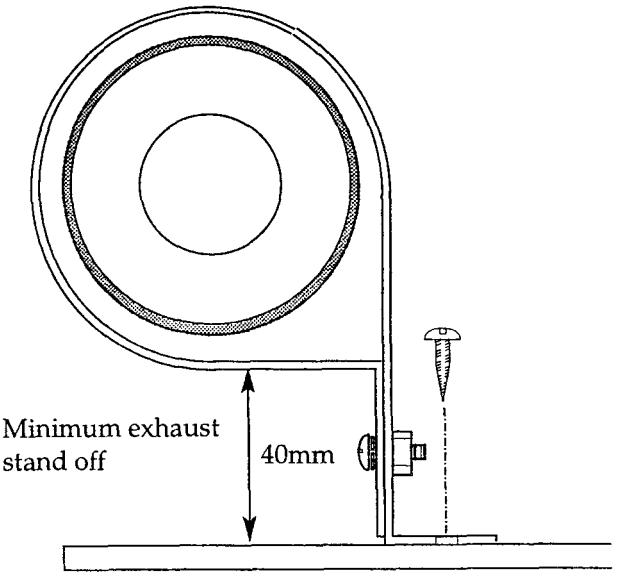
Exhaust Lagging and Fitting

The exhaust pipe will become hot in operation, and if not protected will damage plastic pipes and cables. The standard silicone/fibre & **APK** sleeving supplied with the kit is sufficient to provide adequate insulation in most applications.

However, care should be taken to run and clip the exhaust in a way to avoid "touching" any pipes.

Exhaust Stand Off Clip

Fig N°. 8



Combustion Air

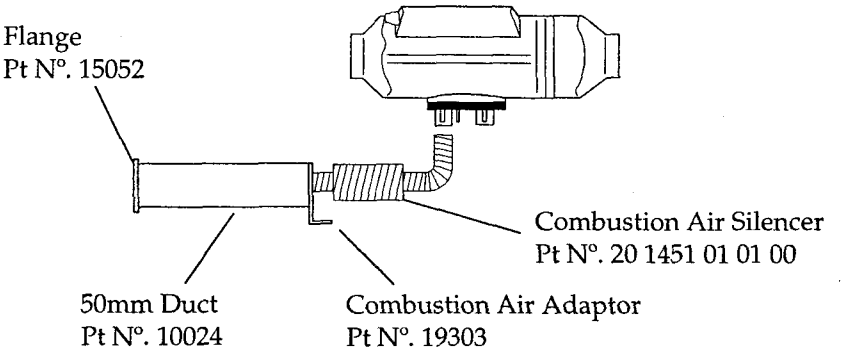
For combustion air, connect the black combustion air silencer provided with the heater kit to the combustion air spigot on the heater. Ensure that there is an adequate supply of air for the combustion process where the heater is sited.

With an inadequate air supply for combustion the site area of the heater will require additional ventilation or the combustion air tube routed to a vented source. The maximum permissable length is 2.0 metres (6'6")

Care must be taken to avoid the ingress of moisture or dirt entering the combustion air tube.

Fig N°. 9

Extending combustion air tube to a vented source



Parts available as optional extras

Flange	-	Part N° 15052
Duct	-	Part N° 10024
Adaptor	-	Part N° 19303

Fuel System

The fuel kit supplied contains all necessary fuel lines and connections to enable a tank top fuel connection to be made. See Fig.N°. 10

A variety of methods are available to achieve connection to a fuel supply. If it is necessary to deviate from that supplied please consult your nearest Eberspacher dealer for other fuel options.

Note: **Do** not adjust or interfere with the inlet or outlet ports of the fuel metering pump.

Methods of Connection

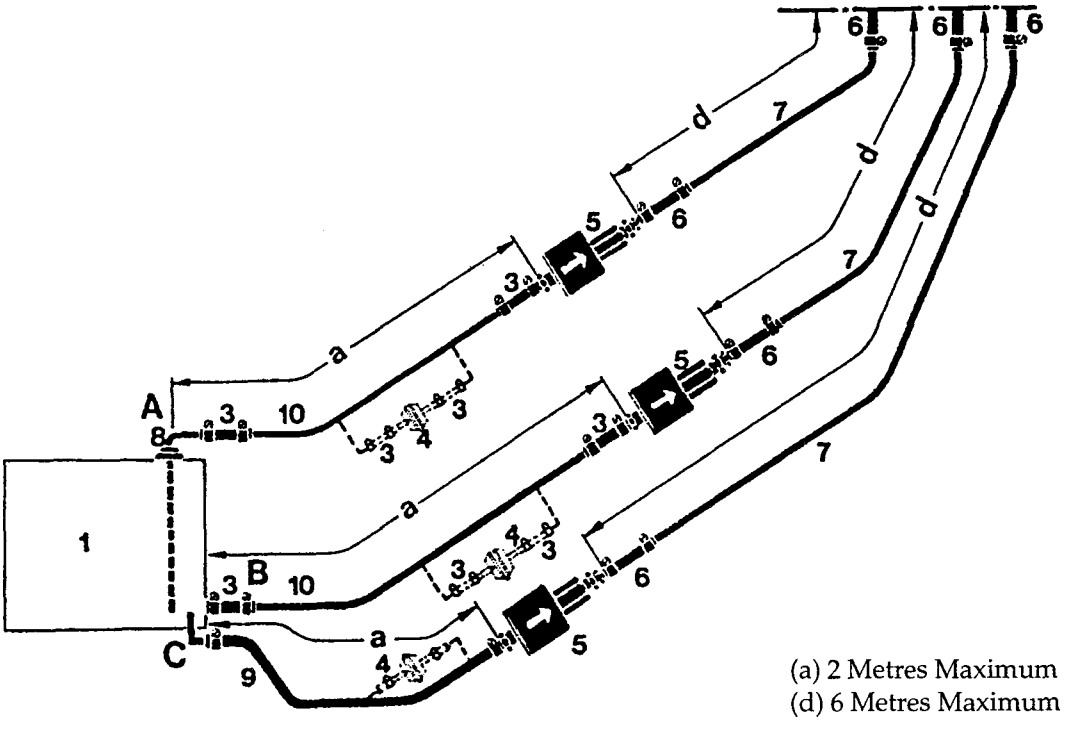
Fig. N°. 10 shows three methods of connection to the fuel tank:

* **(A)** Standpipe into the fuel tank
(B) Gravity feed from fuel tank
(C) Gravity feed from bottom of fuel tank

* Method of connection supplied with heater kit

Fig. N°. 10

1	Tank
2	Fuel branch
3	Fuel tube, internal dia 5 mm
4	Fuel prefilter Cat. No. 25 122689 00 **37,** only necessary if fuel is contaminated
5	Fuel metering pump (15" to vertical, inclined upward)
6	Fuel tube, internal dia **3.5** mm
7	Fuel pipe, plastic, internal dia.l.5 mm
8	Tank connection, internal dia.2mm
9	Tube or plastic pipe max.internal dia. 5 mm)
10	Fuel Pipe plastic



(a) 2 Metres Maximum
(d) 6 Metres Maximum

The diagram arrangement "**A**" with 2mm ID standpipe connection should be followed exactly to ensure that the fuel pump will prime the standpipe and fuel pump suction line, particularly maximum lifting capacity on the fuel inlet side to the fuel pump (dimension ***(f)***) should not be exceeded.

Fig. N°. 11 shows how the fuel metering pump (F.M.P) is assembled and secured to floor bearer or similar.

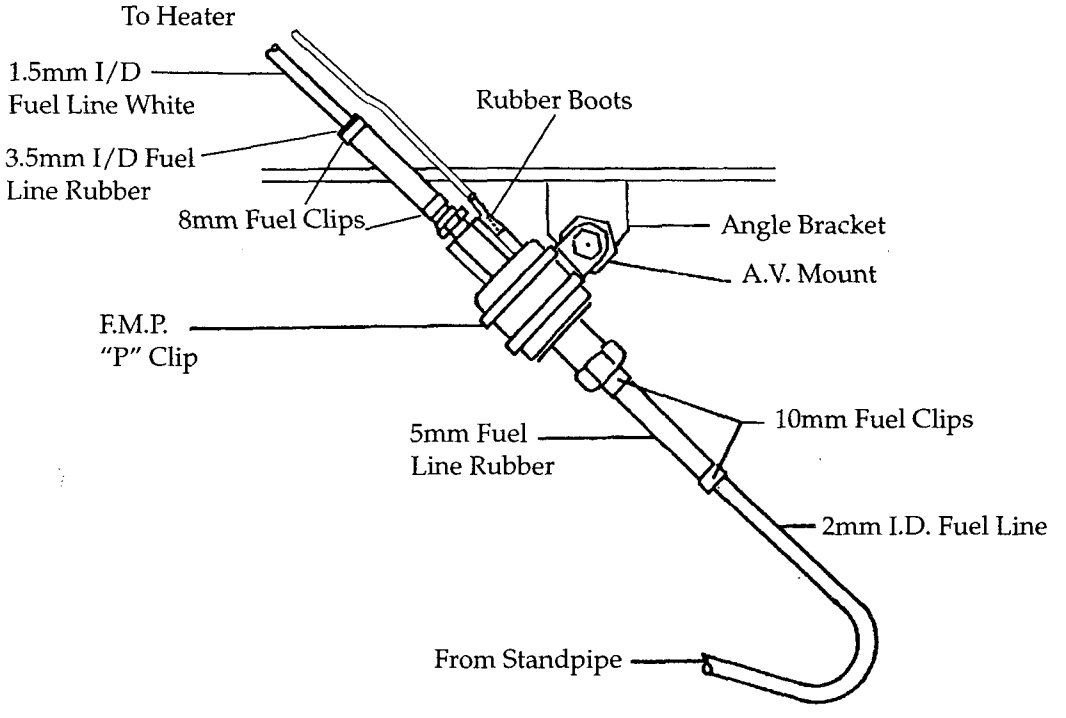
Note:

1. The angle of the fuel pump **(45°)** approximately

2. The rubber boots over the electrical connections

3. Fuel lines 1.5mm at top (output) 2mm at bottom (input)

Fig. N°. 11



Notes:

(1) If it is necessary to reduce the length of the standpipe (8)ensure that it is cut at 45 and at least 25mm from the bottom of the tank. **(Note check that internal bore of standpipe is not blocked after cutting)**

(2) Do not reduce or increase the lengths of fuel line supplied without prior reference to an authorised dealer.

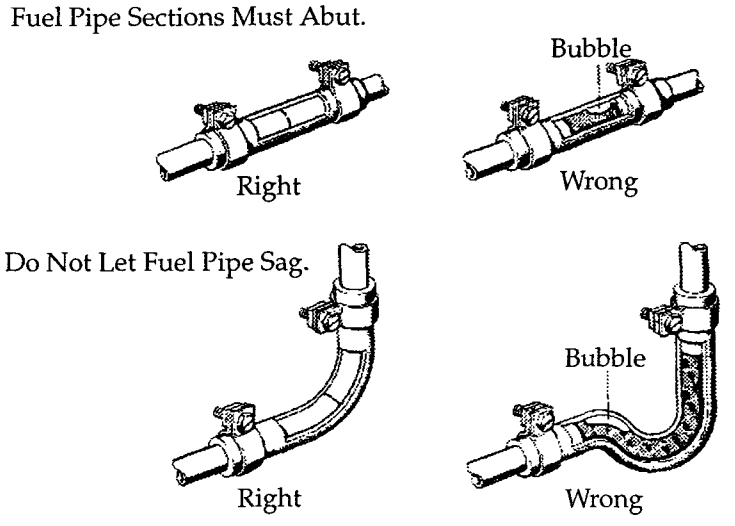
(3) Changes in the supplied fuel arrangement * **(A)** can result in the pump failing to deliver fuel to the heater.

(4) Ensure that the run of the fuel lines are as simple as possible and protected against possible damage.

(5) Keep the fuel lines clear of any hot components associated with the heater or engine.

(6) Ensure that all fuel lines are secured in position and all joints are butted and secured by clips as Fig. N°. 12

Fig. N°. 12

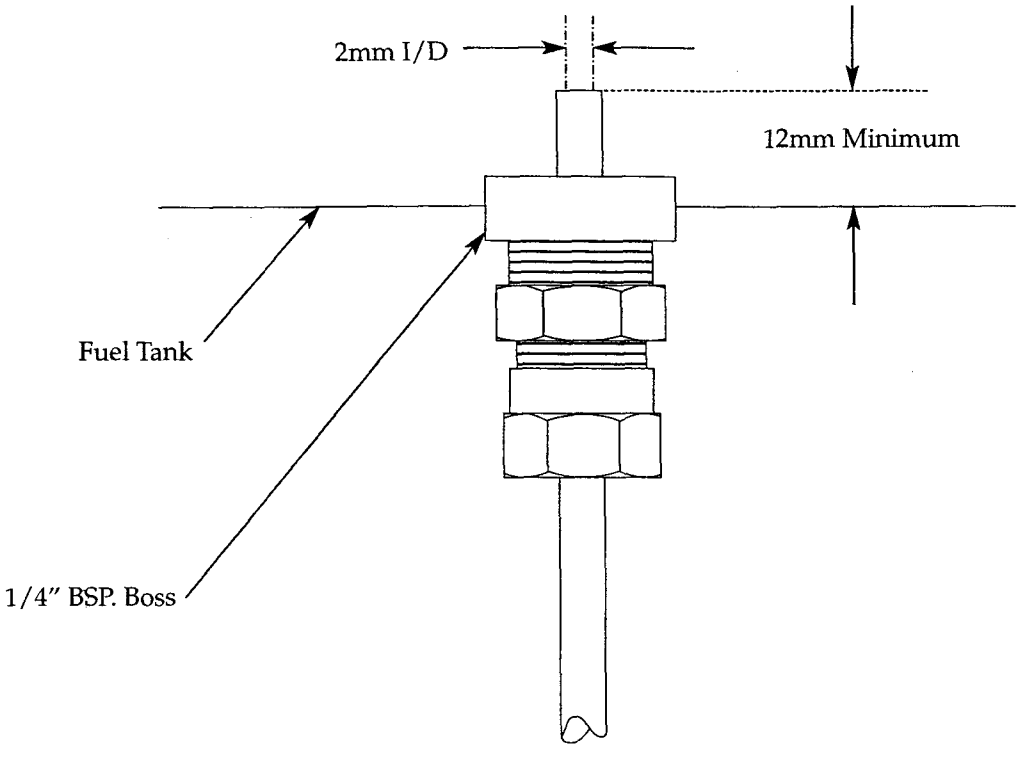


Should you require to shorten any of the fuel lines a sharp stanley knife or nylon pipe cutter (not sidecutters) should be used. After cutting check that the core of the fuel line is not obstructed in any way.

Gravity feed from bottom of fuel tank and separate fuel tanks

When using a fuel connection from the bottom of the fuel tank it is necessary to ensure that the take off comprises of an upstand as Fig. N°. 13 to minimise the ingress of dirt etc into the fuel system.

Fig. N°. 13



Initial priming of the fuel system may require several starts of the heater as described under Operating Instructions.

Electrical Connection

The appropriate wiring diagram for the equipment is shown on Fig. N°. **14** or **14A** and must be followed exactly. Note: Please ensure all electrical connections are coated with t silicone grease or petroleum jelly (not provided in kit).

Cable looms are supplied ready for connection with one way plugs to the equipment, but if extensions are necessary please contact your local dealer for advice.

Ensure polarity is correct; that is connect **RED** cable to positive **and BROWN** or **BLACK** cable to negative at the battery or isolator, otherwise serious damage will result in the inergrated control unit.

The heater will use 30 watts (2.5 amps on 12v) in normal running and an additional 18 amps for starting (normally only **45** seconds). It is important to ensure therefore that an adequate battery supply is available and one which will supply sufficient power for other electrical equipment on board and most important engine starting. **If** in any doubt please contact **a** Dealer who will recommend additional battery power as necessary and the appropriate connection required.

A main line fuse in a black push and twist connector is provided and should be installed in the positive line. Fig. N°. **14** and **14A** shows how to open up the fuse. Note: Push firmly together before twisting.

We recommend that the heater is wired to the power supply through an isolator switch in order for the equipment to be isolated when the boat is out of use. Please ensure that the heater has gone through its cool down cycle before operating the isolator switch. Failure to do so could result in serious damage.

Fig. N° . 14

Heater models:

25 1906 05
25 1907 05
25 1980 05
25 1981 05

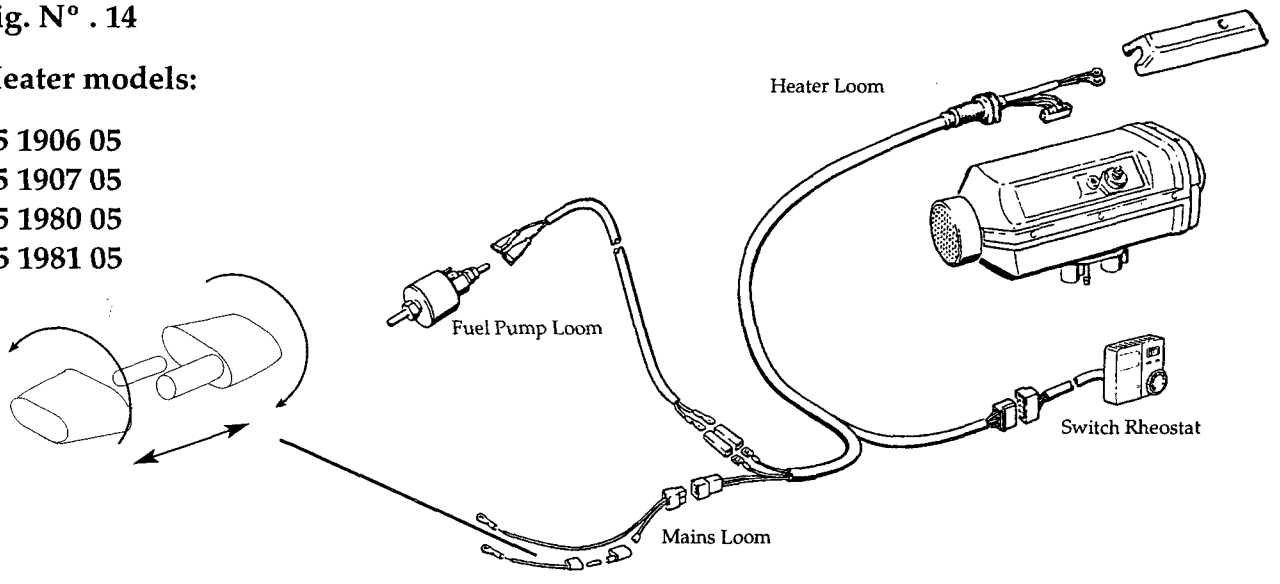


Fig. N° . 14A

Heater models:

25 1967 05
25 1968 05

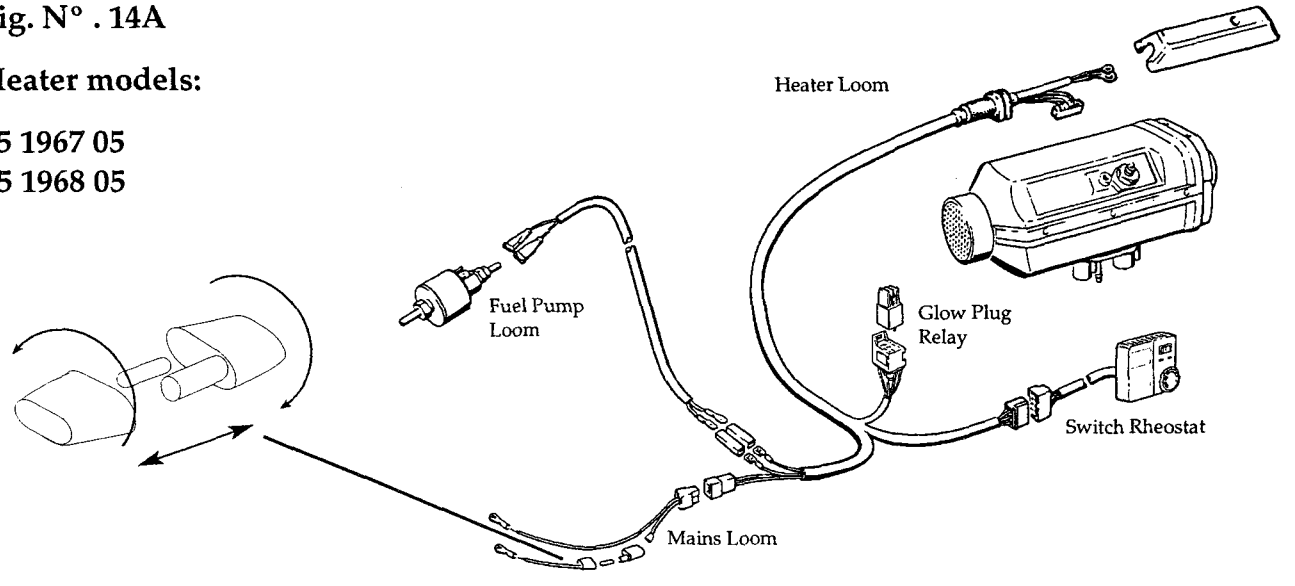


Fig N°. 15

Wiring Diagram D3L'C' Compact

Heaters: 25 1906 05 25 1907 05 25 1980 05 25 1981 05

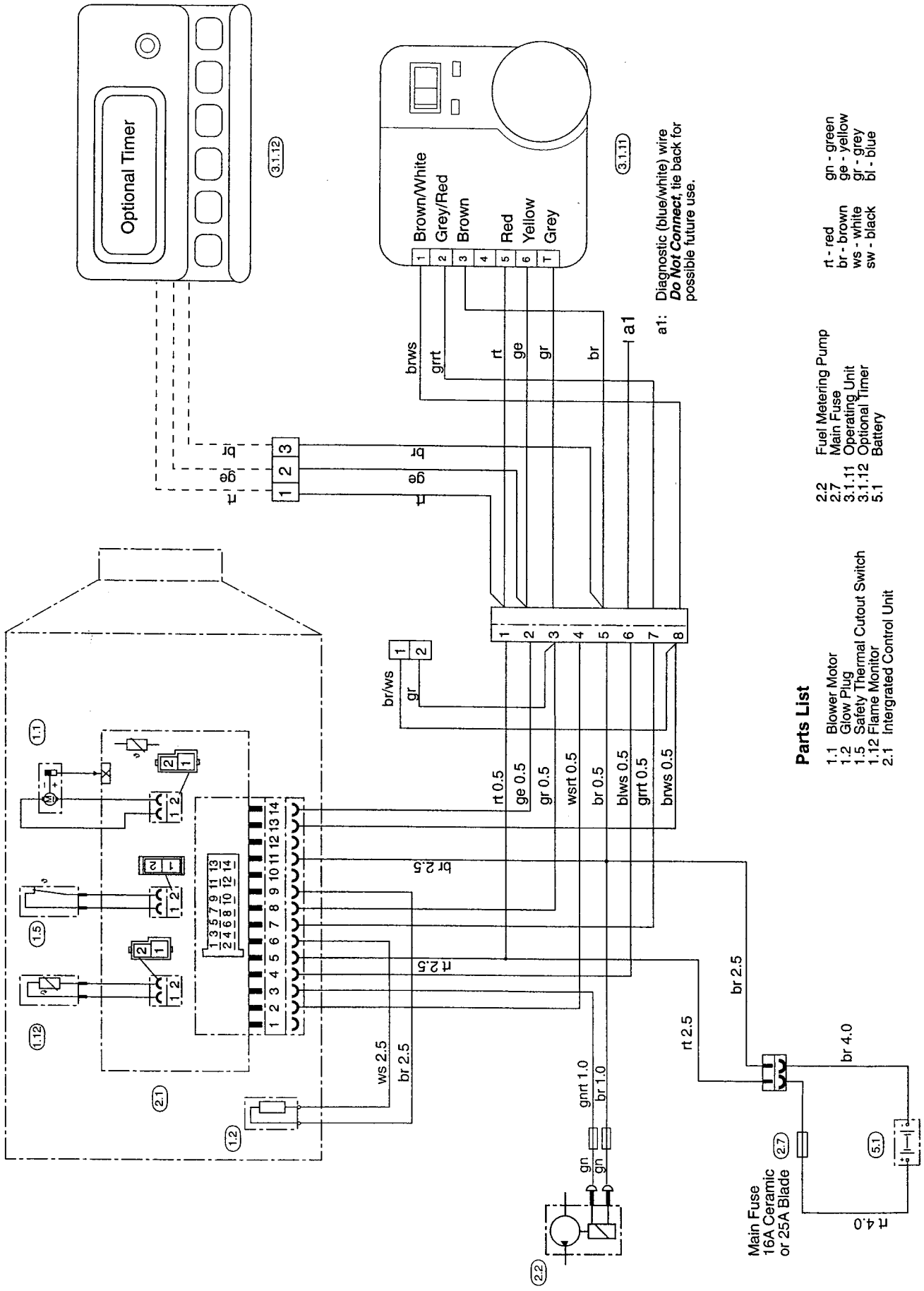


Fig N°. 15a

Wiring Diagram D3L'C' Compact

Heaters: 25 1967 05 25 1968 05

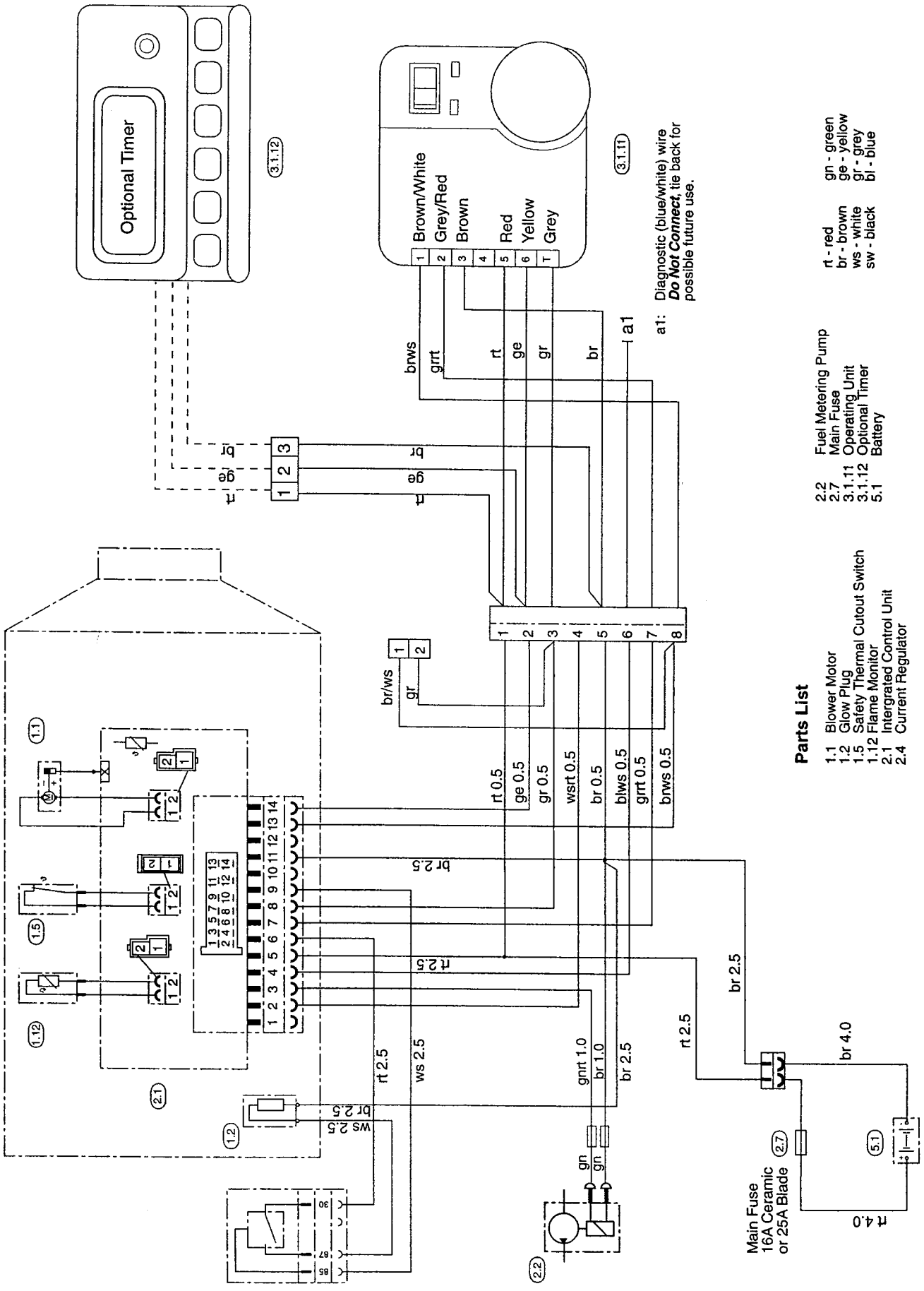
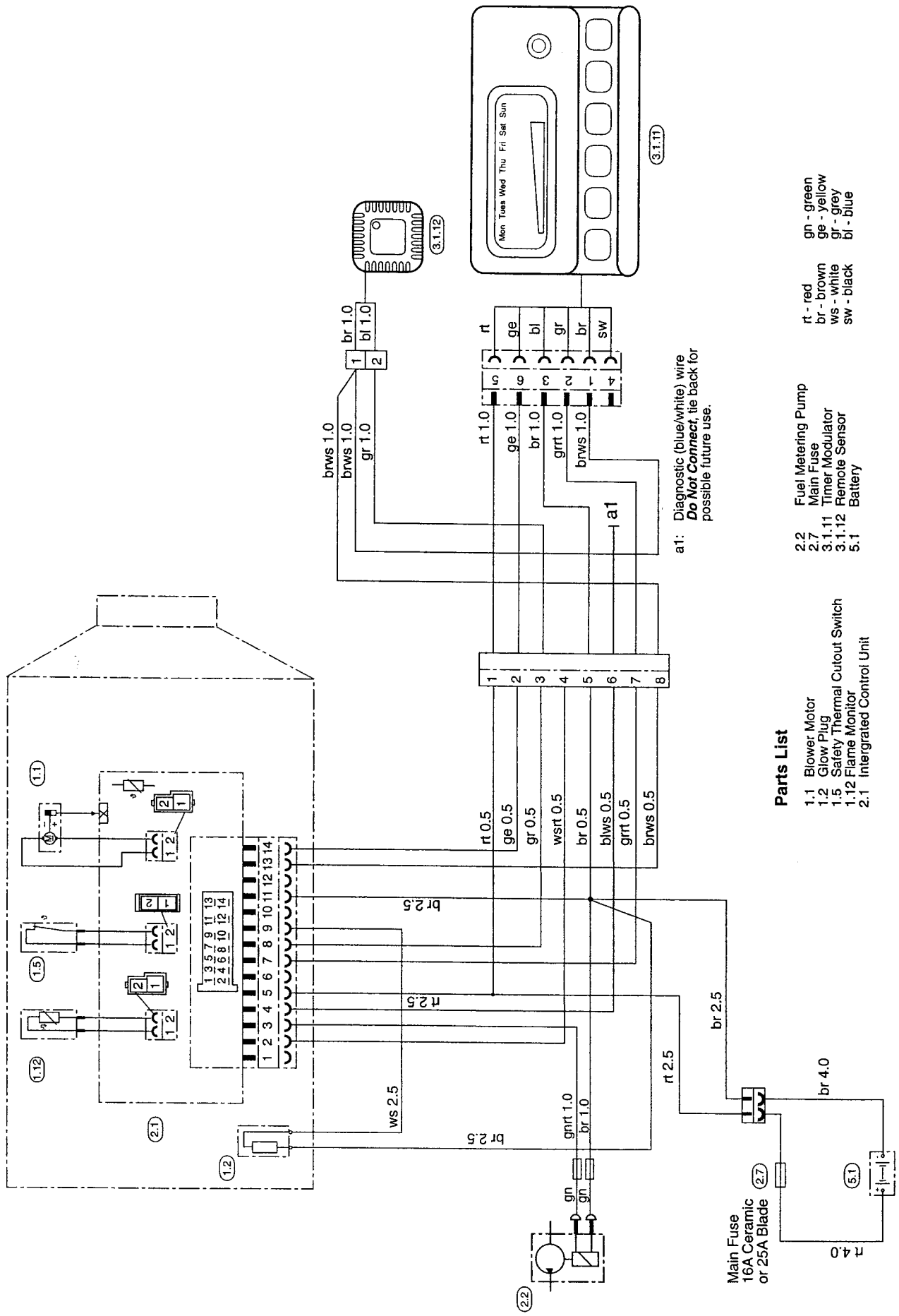


Fig N°. 15b

Wiring Diagram D3L'C' Compact (Timer Modulator with Sensor)



Checks You Should Carry Out Prior to Switching On, Following the Completion of the Installation:

1. Check that the batteries are fully charged.

2. Check there is sufficient fuel in the fuel tanks.

3. Check the mains supply for correct polarity RED - positive + BLACK/BROWN negative -.

4. Check that the setting on the modulator is turned up to its highest setting.

5. Now switch on your heater.

Service and Maintenance

At least once a season and certainly at the start of a season check all electrical connections for good contact and absence of corrosion.

Check all ducting to ensure no sections are damaged and that the heater fan intake is unobstructed.

Check exhaust connection at heater and skin fitting to ensure no damage to exhaust or combustion air pipes.

Remove and clean glow plug - taking care not to damage the glow spiral or element. Clean with fine wire brushing and emery cloth.

Depending on usage, but certainly every third season or 2,000 hours running we recommend a dealer to be contacted for a service and de-coke of the heat exchanger and replacement of the integral fuel filter.

If the heater is swamped or takes in water, contact your nearest dealer as soon as possible.

Terms of Warranty

Your Eberspacher diesel heater is covered by warranty for 12 months from date of purchase. This is deemed to cover all parts with the exception of glow plugs and fuses.

Claims for warranty will not be accepted where failure is caused by faulty installation or where the installation fails to comply with the installation handbooks. Claims for warranty will not be accepted where the equipment has been subjected to external force. pressure or ingress of sea or rain water. Owners are requested not to attempt repairs. In the event of heater failure during the warranty period only authorised dealers should be contacted immediately.

Please note warranty is only accepted for parts failing due to faulty manufacture within a 12 month period which deems to exclude fair wear and tear. Glow plugs will be replaced free of charge during the 12 months period only where genuine faulty manufacture is proved.

Claims for warranty will not be accepted for faulty installation and owners fitting their own equipment are recommended to take advice on fitting aspects, if in any doubt. A list of dealers is provided.

Eberspächer Approved Main Dealers in the U.K. & Southern Ireland

Scotland

Aberdeen	Turner Diesel	(01224) 723925
Edinburgh	Fulton Auto Electric's	(0131) 555 0396
*Glasglow**	Whitehurst Engineering	(01505) 682010
Inverness	Lucas Service	(01463) 224855

North East

Beverley	Yortec	(01482) 881141
Doncaster	Lucas Service	(01302) 342194
Grimsby	C. F. Parkinson	(01472) 358758
Scarborough	Yortec	(01723) 365321
Sunderland	A.E.S.	(0191) 5658734
Thornaby	Auto Electric's	(01642) 607901
*York**	Yortec	654513

North West

Carlisle	Cumbria Auto Elec.	(01228) 31707
*Ellesmere Port**	Tachograph Chester	(0151)3552101
Leeds	Automotive	(01924) 495726/7
Manchester	A.E.S.	*(0161) 865 0816*
Preston	Ribblesdale Auto Elec.	*(01772) 555011*
Sheffield	Oughtibridge Comm.	*(01142) 863477*

Midlands

Birmingham	Carlighting Services	(0121) 440 3663
Boston	C. F. Parkinson	(01205) 363008
Coventry	Carwood Motor Units	(01203) 449533
Derby	Derby AES	*(01332) 574836*
Gloucester	Lucas Service	(01452) 524951
Hereford	Lucas Service	(01432) 265571
Leicester	Wathes Electro Diesel	(0116) 2664101
Lincoln	C. F. Parkinson	(01522) 530176
Mansfield	C. F. Parkinson	(01623) 25682
Newark	C. F. Parkinson	(01636) 72631
Northampton	N.D.E.S	(01604) 755321
Nottingham	C. F. Parkinson	(0115) 9476624
Peterborough	C. F. Parkinson	(01733) 311222
Stoke	H. Bowers	(01782) 599990
Walsall	Electro Diesel	(01922) 33111
Wolverhampton	A. F. Glaze	(01902) 455434

East Anglia

Cambridge	Lucas	(01223) 315931
*Colchester**	C.F.I.	(01206) 862049
Ipswich	Lucas	(01473) 215931
Norwich	Panks	(01603) 629967

Wales

Caernarfon	Lucas Service	(01286) 672888
Cardiff	Lucas Service	(01222) 228361
Newtown	Grooms Industries	(01686) 626731
Swansea	Shorts Auto Electrical	(01792) 469595

South West

Avonmouth	A.T.A.C.	(0117) 9828583
Bristol	Lucas Service	(0117) 9770772
*Plymouth**	Heaters Sth. Western	(01752) 690039
Taunton	Hickley Valtone	(01823) 276041

London and South

*Brighton**	Felton Marine	(01273) 601779
*Erith**	S.E.A.E.S	(01322) 342277
Guildford	Warsop	(01483) 34222
Langley	Lunalectrics	(01753) 544118
*Leighton Buzzard**	A.E.S.	(01525) 372330
London	A23 Tacho Centre	(0181) 671 7781
*Maidstone**	SEAES	(01622) 690010
*New Milton**	Krueger	(01425) 619869
Portsmouth	Krueger	(01705) 665005
Reading	T.V.E.D.	(01734) 751199
*Shepperton**	M.M.S.	(01932) 247427
Swindon	Car & Commercial	(01793) 532111

Southern Ireland

*Dublin**	Metalcove Marine	(003531) 6686046
Dublin	Cold Chain	(00353) 45874788

Northern Ireland

*Antrim**	C J Collins	(01960) 352556
Belfast	John Robertson	(01232) 232066

Channel Islands

*Guernsey**	Seaward Marine	(01481) 45353
*Jersey**	Express Electrix	(01534) 22524

* Marine Specialists

Eberspächer Approved Service Stations in the U.K. & Southern Ireland

Scotland

Dundee	Alans Auto Electric's	(01382) 67516
Strathclyde	Argyle Diesel Electric's	(013552) 32622
Galashiels	S. Munro	(01896) 755726
Perth	Reids Auto Electronics	(01738) 622416

Midlands & North

Cinderford	Newtown Garage	(01594) 25333
Bolton	Auto S.I.D.E. Repairs	(01240) 61791
Chesterfield	E R Tomlinson & Son	(01246) 590679
Liverpool	Lucas Service	(0151) 2367063
Hexham	Hexham Auto Elec.	(01434) 607609
Tarporley	David Edge Auto Elec.	(01829) 32295
Telford	A.E.S.	(01952) 616135
Oswestry	Autolectrix	(01691) 654771
Worcester	Autostart	(01905) 29266
Doncaster	Advanced Auto Elec.	(01302) 329552
Ripon	Ripon Auto Electric's	(01765) 2253
Selby	Coatesworth Services	(01757) 288975

East Anglia

Cambridge	Camb. Battery Service	(01223) 69988
Diss	Diss Autolec Services	(01379) 6434612
Fakenham	Fakenham Auto Elec.	(01328) 51492
Ipswich	PCS Ltd	(01473) 210351
Norfolk	John Ball Commercials	(01760) 721987
*Norwich**	Brister Craft	(01603) 783783
Yarmouth	Duffields	(01493) 858632

Wales

Gwynedd	A. M Dickie & Sons Ltd	(01248) 352775

Northern Ireland

Down Patrick	A C Auto Electric	(01396) 615479
Lisnaskea	Auto Electric Refrig.	(013657) 21573
Armagh	Continental & British	(01861) 526393
Londonderry	Glenbrook Autocare	(01504)362495
Co Antrim	James McNeill Auto	(01266) 45186

Southern Ireland

Dublin	Container Refrig. Serv.	(0103531)746509
Co Kildare	Naas Refrigeration	(01035345) 76451

South West

Barnstable	Alter-Start	(01271) 42587
Bristol	Halls Auto Electrical	(01454) 319722
Chard	Tytherleigh Veh. Elec.	(01460) 64255
Redruth	Scorrier Trucks	(01209) 820820

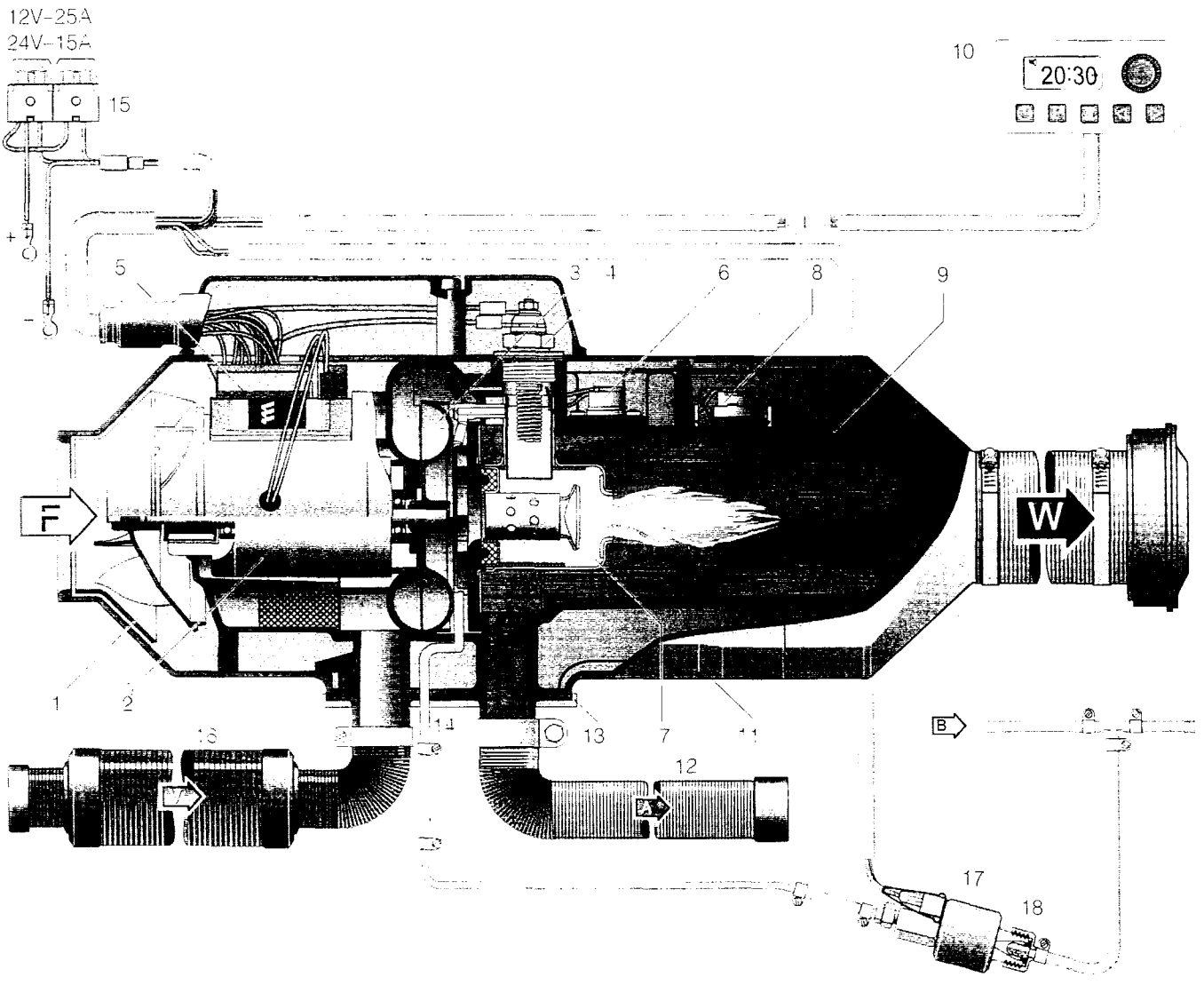
London and South

Abingdon	Cannon Transport	(01235) 835151
Andover	Trim Truk	(01264) 334334
Basingstoke	Basingstoke Comm.	(01256) 811414
Deal	Fleetcare	(01304 381288
Dover	E V R Commercial	(01304) 203057
Grays	R & T Auto Electric's	(01375) 393065
Redhill	Autosparks	(01737) 766957
Hailsham	Diplock Fuel Inj Serv.	(01323) 847282
High Wycombe	Truck Techniks	(01240) 27568
London w10	Double Drive	(0181) 968 8760
Milton Keynes	Oxon Bucks Auto Elec.	(01908)641205
Purfleet	Thames Auto Elec.	(01708) 862775
Salisbury	The Tachograph Cent.	(01722) 322004
Reading	MacDonalds Electric's	(01734) 885698
Thame	City Trucks	(01844) 218874
Worthing	Auto Electrical Serv.	(01903) 211892

* Marine Specialists

4. Detail of heater

Sectional drawing



d3LCC047

1 Hot air blower wheel
2 Blower motor
3 Combustion air blower wheel
4 Glow plug
5 Control unit
6 Safety thermal cutout switch
7 Combustin chamber
8 Flame monitor
9 Heat exchanger
10 Heater timer
11 Outercasing
12 Exhaust line
13 Flange seal
14 Fuel line
15 Main fuse, 25 A
16 Combustion air intake line
17 Fuel metering pump
18 Fuel strainer

F = fresh air

V = combustion air

B = fuel

W = hot air

A = exhaust