Report on the investigation of

the fire on board the canal boat

Lindy Lou

at Lyme View Marina, Adlington

resulting in 1 fatality

20 January 2007

Marine Accident Investigation Branch
Carlton House
Carlton Place
Southampton
United Kingdom
SO15 2DZ

Report No 23/2007
October 2007

Extract from

The United Kingdom Merchant Shipping

(Accident Reporting and Investigation)

Regulations 2005 – Regulation 5:

"The sole objective of the investigation of an accident under the Merchant Shipping (Accident Reporting and Investigation) Regulations 2005 shall be the prevention of future accidents through the ascertainment of its causes and circumstances. It shall not be the purpose of an investigation to determine liability nor, except so far as is necessary to achieve its objective, to apportion blame."

NOTE

This report is not written with litigation in mind and, pursuant to Regulation 13(9) of the Merchant Shipping (Accident Reporting and Investigation) Regulations 2005, shall be inadmissible in any judicial proceedings whose purpose, or one of whose purposes is to attribute or apportion liability or blame.

Further printed copies can be obtained via our postal address, or alternatively by:
Email: maib@dft.gsi.gov.uk
Tel: 023 8039 5500
Fax: 023 8023 2459
All reports can also be found at our website:
www.maib.gov.uk

Front cover photograph courtesy of the vessel owners

CONTENTS

GLOSSARY OF ABBREVIATIONS AND ACRONYMS

AINA	-	Association of Inland Navigation Authorities
BMF	-	British Marine Federation
BS	-	British Standard
BSi	-	British Standards Institution
BSS	-	Boat Safety Scheme
CEN	-	Comité Européen de Normalisation (European Committee for Standardization)
CO	-	Carbon Monoxide
EC	-	European Communities
EEA	-	European Economic Area
EN	-	European Norm (standard)
GMT	-	Greenwich Mean Time
hp	-	horsepower
INREM	-	Inland Water Related Emergency Monitoring Database
ISO	-	International Organization for Standardization
kW	-	kilo Watts
LAV	-	Leisure Accommodation Vehicle
LPG	-	Liquefied Petroleum Gas
MDF	-	Medium Density Fibreboard
mg	-	milligrammes
ml	-	millilitres
NCC	-	National Caravan Council
RCD	-	Recreational Craft Directive
RNLI	-	Royal National Lifeboat Institution
RoSPA	-	Royal Society for the Prevention of Accidents
RYA	-	Royal Yachting Association
UTC	-	Universal Co-ordinated Time
V	-	Volts

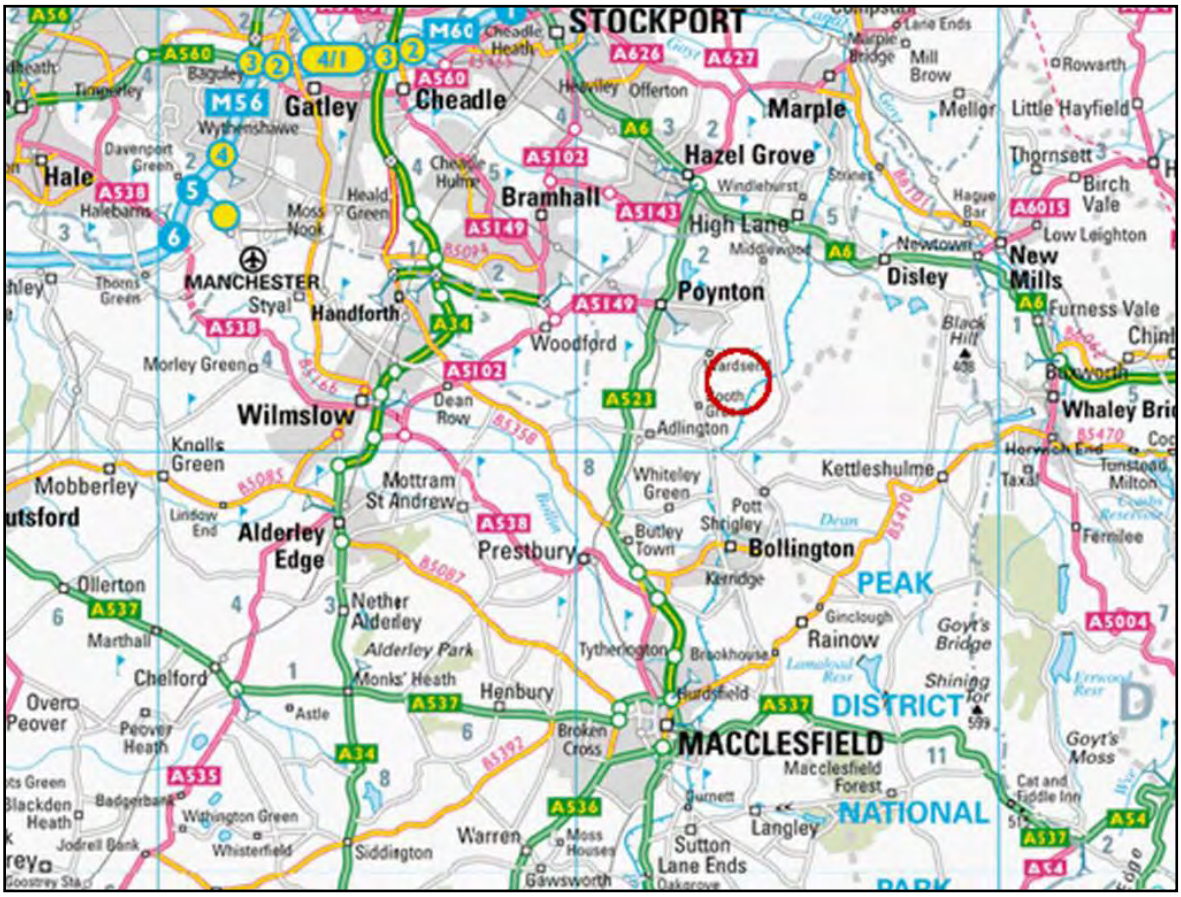
Photograph reproduced courtesy of owners

Figure 1

Lindy Lou at Lyme View Marina, August 2005

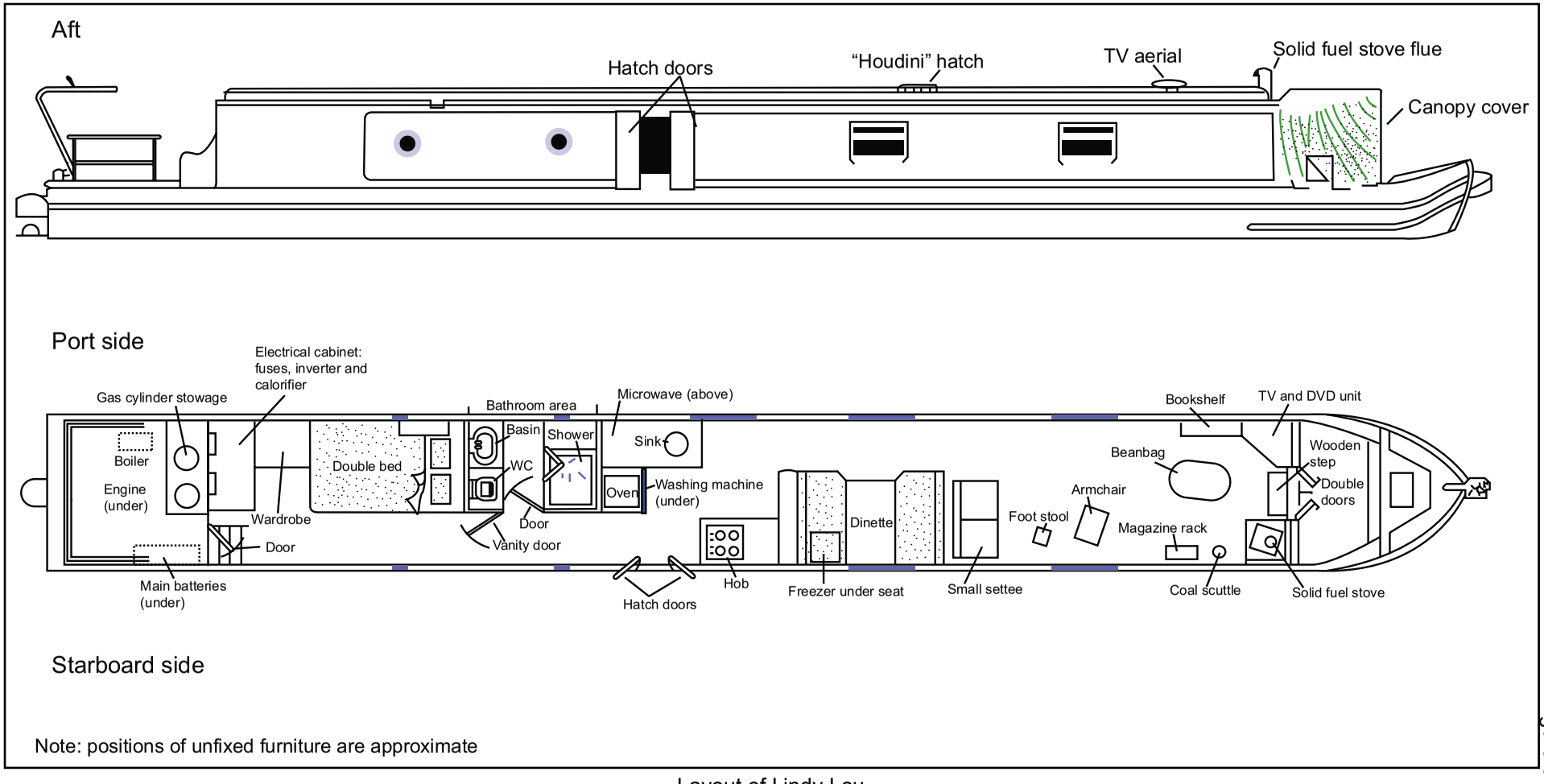
Reproduced from www.multimap.com

Figure 2a and b



Reproduced from www.maps.live.com

Map and aerial photograph showing location of Lyme View Marina, Adlington



Note: positions of unfixed furniture are approximate

Figure 3

Layout of Lindy Lou

SYNOPSIS

At about 0245 on 20 January 2007, a fire broke out on board the narrowboat *Lindy Lou* which was moored at Lyme View Marina, Adlington. One person died as a result of the inferno, which quickly swept through the boat. The other occupant, the owner of the boat, suffered from serious burns and effects of smoke inhalation.

It was a cold, wet and windy night. The interior of the boat was cosy when the couple arrived back on board, and the owner added some more fuel to the stove to keep the boat warm overnight. They opened a bottle of vodka, and drank this between them before going to bed.

During the night, the owner woke and found the air in the boat to be extremely warm and stuffy. He got up to open the double hatch doors on the starboard side of the boat to let some air in, and then also opened the aft door. Having stepped outside onto the aft deck to cool off, he became aware of an orange glow from the forward external covered deck, and walked along the towpath to investigate. As he approached, he realised that the canopy was burning, and that flames seemed to be emanating from inside the boat. He turned to go back aft, and at the same time, the forward port window shattered and flames leapt out of the saloon.

Despite his desperate attempts, the owner was unable to re-enter the boat, and as his girlfriend had not appeared, he ran to a nearby boat to seek help. A “999” call was made and the first of three fire engines arrived on scene at 0302, and the fire was extinguished by 0319. The body of his girlfriend was later discovered in the bathroom area, and a postmortem established that she had died from the inhalation of smoke and fumes.

The boat had been extensively damaged during the fire, which had burnt fiercely and quickly. The most likely cause of the fire was the solid fuel stove, which had not been installed in accordance with the stove manufacturer’s recommendations, as the hearth dimensions, and the air gaps around the stove were less than recommended. It is possible that either an ember fell onto the nylon carpet in the saloon when the stove was stoked, or that there was radiant heat transfer from the stove and its flue to a nearby combustible item (e.g. a beanbag, a book propped up near the hearth, or a plastic loudspeaker that was attached to the wall behind the flue). Evidence was also found of possible long-term charring of the wooden hearth structure beneath the tiles, and this structure might have also ignited to cause the fire.

The investigation has identified that, although British Standards are available for the installation of solid fuel stoves and flues in buildings, park homes and transportable accommodation units, there is no such standard for their installation on boats. A draft proposal for a new standard to address this omission is currently being developed by the British Standards Institution (BSi).

No smoke alarms were fitted on *Lindy Lou*. The Recreational Craft Directive (RCD) EN ISO 9094, and the Boat Safety Scheme (BSS) do not currently require these to be fitted to recreational craft. The BSS has now strongly recommended that boats with overnight accommodation are fitted with at least one suitable and effective smoke alarm.

A recommendation has been made to the British Standards Institution to propose a change to the current ISO standards so that smoke alarms are required to be fitted on habitable small craft.

SECTION 1 - FACTUAL INFORMATION

1.1 PARTICULARS OF *LINDY LOU* AND ACCIDENT

Vessel details

Registered owner	:	Privately owned
Type	:	Square back cruiser-style narrowboat
Built	:	Hull built in Hixon, Staffordshire. Outfitted by Triton Boat Fitters, Eccles, 2005
Construction	:	Steel
Length overall	:	17.37m (57')
Breadth	:	2.08m (6' 10")
Engine power and type	:	Vetus 4.17K 42hp (31.5kW)

Accident details

Time and date	:	Around 0245 on 20 January 2007
Location of incident	:	Lyme View Marina, Adlington, Cheshire
Persons on board	:	2
Injuries/fatalities	:	1 fatality and 1 person seriously injured with burns and smoke inhalation.
Damage	:	Extensive fire damage.

1.2 BACKGROUND

Lindy Lou was a privately-owned narrowboat, used by one of its joint owners as a domestic dwelling. Since its delivery in August 2005, the boat was moored at Lyme View Marina, Adlington in Cheshire, apart from regular short weekend cruises. **Figure 1** shows the vessel as new. In the summer of 2006 the boat was moved to her permanent mooring on the Macclesfield Canal, controlled by British Waterways, but still within the confines of the marina **(Figures 2a** and **2b)**. A general description of the boat is at section 1.5, with the layout shown in **Figure 3**.

1.3 NARRATIVE

All times are GMT (UTC)

During the week commencing Monday 15 January 2007, the joint owner of *Lindy Lou*, who lived on board, was working away from the area. The boat was therefore unoccupied until the early evening of Friday 19 January, when he and his girlfriend arrived to spend the weekend on board.

During the drive to the marina from the girlfriend's house in Stockport, they stopped off at a pub for about half an hour for a drink. On arriving at the boat, the owner started the solid fuel stove, situated on the starboard side of the saloon area, to heat the boat for when they later returned from a nearby pub.

In order to light the stove, the owner added a layer of smokeless fuel, then some firelighters and kindling wood, topped off with more of the smokeless fuel. He then used a match to ignite the firelighters and closed the glass-windowed door at the front of the stove. A description of the stove and its installation is provided at section 1.5.4.

With the stove lit, they then walked to the pub, arriving there at about 2030. During the 2 hours spent in the pub, *Lindy Lou*'s owner consumed 4 pints of beer, and his girlfriend about 7 vodkas with diet coke. They also had a snack, their only food of the evening.

At around 2230 they left the pub and walked back through the marina to *Lindy Lou*. It was a wet and windy evening, with winds of around force 3 to 4 (7 to 16 knots) blowing in a westerly direction along the canal and the length of *Lindy Lou*. The temperature was near freezing.

When they arrived back they were glad that the stove was lit, as the boat was warm and cosy. At some stage the owner added more smokeless fuel to the stove to keep the boat warm overnight, again closing the stove door after this had been done. They opened a bottle of vodka, and drank this between them before going to bed, in the aft area of the boat.

The owner had been asleep on the inside of the bed, adjacent to the passageway, with his girlfriend outside of him next to the boat's side. He woke up to find the air extremely warm and stuffy. Although naked, the temperature was sufficiently uncomfortable to make him decide to get up and open the double hatch doors on the starboard side, to let some air in. Feeling groggy, he got up and felt the air getting warmer as he moved forward along the corridor, towards the galley. The boat was dark as he had not put on the lights, and he did not notice anything unusual.

Despite opening the double doors, it remained very warm so he went aft and opened the rear door, and stepped outside onto the deck to cool off, still naked. Turning around, he became aware of an orange glow, which appeared to be coming from inside the forward open deck, which was fitted with a plastic cover. Aware that he hadn't left any lights on, he stepped onto the towpath to walk forward to investigate.

When half-way along the boat's length he realised that the port side of the canopy was burning. He felt the fire must be external and was confident that he would be able to extinguish it using the fire extinguishers on board *Lindy Lou*. However, as he reached the end of the boat's superstructure, he could see the canopy was well alight and that the flames seemed to be emanating from the inside of *Lindy Lou*.

He turned to go back aft, just as the forward port window, nearest to him, shattered, and flames leapt out. As he ran aft past the window all he could see were flames in the saloon area. By now extremely anxious, he banged the side of the boat as he passed the bedroom area portholes, shouting loudly to try to wake his girlfriend, whom he believed to be still in bed.

Arriving back on the aft open deck, the ferocious heat emanating from the doorway prevented him from descending the steps to re-enter the boat to reach his girlfriend. Smoke was by now also starting to emit from the doorway and, as he continued to try to go down the steps, while frantically shouting and screaming, he could feel himself beginning to burn. Realising at this stage that he needed urgent help, he ran the short distance across the car park to the nearest boat that he knew to be occupied, *Merdeka*.

*Merdeka'*s two owners were woken by the sounds of banging on their windows and shouting, and looked out of a porthole to see a mass of orange flames coming from the area of *Lindy Lou*'s mooring. Opening their side doors, they discovered the owner of *Lindy Lou*, covered in black soot. Shaking, he asked for their help as his boat was on fire with his girlfriend still on board.

One of *Merdeka'*s owners immediately called "999", at 0248, on their mobile telephone, while the other provided the owner of *Lindy Lou* with some clothing to wear, and then went outside and across to the boat, hoping to find that the girlfriend might have escaped. *Lindy Lou'*s owner followed him out, and stood a short distance from *Merdeka*, watching the inferno. As *Merdeka'*s owner crossed the car park, he could see that the boat was engulfed in flames, which were blazing fiercely out of the windows and portholes. He managed to get no more than two thirds of the way down the sloped path towards *Lindy Lou*, before the intensity of the heat prevented him getting any closer. With no signs of life from the boat or the surrounds, he returned to *Merdeka*. Deciding that more help was required, they again called 999 at 0255 for an ambulance, to be informed one was already on its way.

The first of three fire engines arrived on scene at 0302. As they approached the scene, the fire crew reported 2 foot high (60cm) "lazy" flames emitting from the boat's windows, and the owner of *Merdeka* re-emerged to inform the fire crew that there may be a woman still on board the boat.

The fire was extinguished at 0319 using four high pressure hose reels with six firefighters wearing breathing apparatus. The two Liquefied Petroleum Gas (LPG) cylinders in a locker on the aft deck were cooled and subsequently removed from the boat. The fire crew later boarded the boat, and discovered the body of the girlfriend, lying in the toilet area of the boat. Her head was resting against the side of the boat and her right leg was partially in the shower cubicle.

An ambulance also attended and paramedics treated the owner's injuries, before transporting him to hospital.

1.4 DETAILS OF THE CASUALTIES

1.4.1 Owner's girlfriend

The owner's girlfriend was a 22 year old teaching assistant, who worked with children with learning difficulties.

A postmortem was conducted on Sunday 21 January, which established the cause of death to be *Inhalation of smoke and fire gases*. A high level of carbon monoxide was present in her blood, consistent with cases where death has been attributed to carbon monoxide poisoning. The postmortem also identified a blood alcohol concentration of 67 mg/100 ml, i.e. below the legal alcohol limit for driving in the UK[1]. The postmortem revealed no evidence of any other injuries.

1.4.2 Owner

The joint owner of the boat who survived the fire was a 37 year old joiner. He had lived on board *Lindy Lou* since August 2005, when he had also obtained his RYA Inland Waters Helmsman's Certificate.

Following the accident he was admitted to hospital for treatment to serious burns to his arm and face. Tests also revealed that he had ingested a high level of carbon monoxide during the accident.

1.5 DETAILS OF *LINDY LOU*

1.5.1 General description

Lindy Lou was built in a style typical of many modern, privately-owned narrowboats, and met the requirements of the Recreational Craft Directive (RCD), Category D, for craft on inland waterways. The boat had also been examined for compliance with the Boat Safety Scheme (BSS) and issued with a certificate. Details of the RCD and the BSS are provided at sections 1.7 and 1.8 respectively.

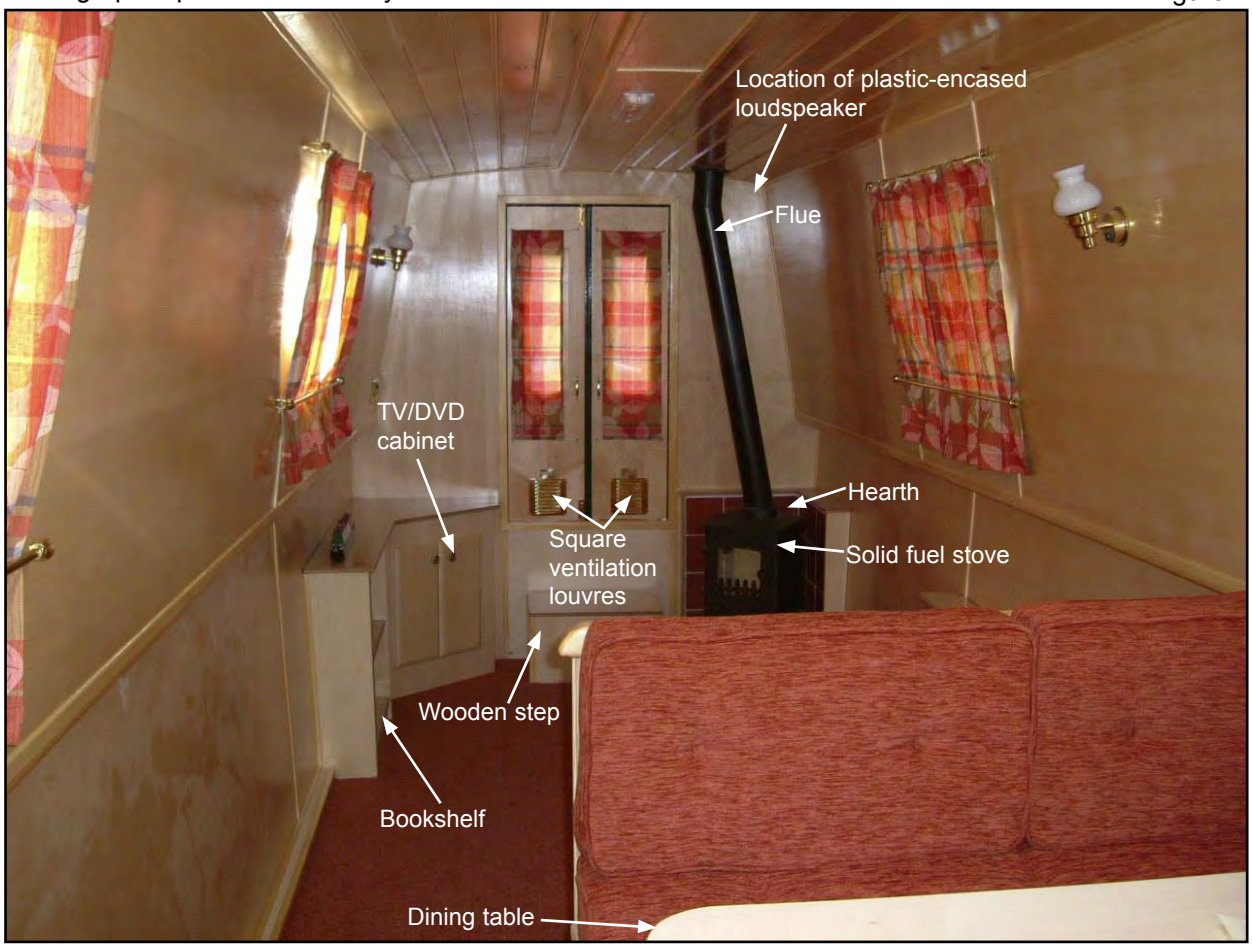
The steel hull and cabin were manufactured by Hixon Hulls, then transported to Triton Boat Fitters for fitting out. *Lindy Lou* had an open plan layout, with no permanent divisions other than wooden partitions around the toilet and shower area and a wooden privacy door between the galley and permanent berth. The general layout is shown in **Figure 3**.

The saloon, towards the bow (shown when the vessel was new, at **Figure 4**), was carpeted with a 100% nylon carpet, provided by the owners. They had also provided a small settee, armchair, footstool and a bean bag in this area. A TV and DVD player were fitted above a wooden cupboard and bookshelf unit in the port forward corner of the boat. The bookshelf contained a large number of DVDs and paperback books. A solid fuel stove was fitted to a hearth in the starboard forward corner. A wooden step was fitted between this and the television unit leading up through the forward double access doors onto the open deck, which had a plastic canopy fitted to provide an additional covered storage area.

[1] The legal alcohol limit for driving in the UK is 80 mg of alcohol in 100 ml of blood.

Photograph reproduced courtesy of owners

Figure 4



View of saloon area (boat as new) looking forward

The dining area was to the rear of the saloon, with bench seats either side of a table on the starboard side. This could be lowered to provide an additional sleeping berth, if required. A small chest freezer was fitted beneath the aft bench seat. The galley was to the rear of the saloon, and was constructed from standard wooden cabinets topped with granite work surfaces, with a sink on the port side and gas hob on the starboard side. It was also fitted with a gas oven, microwave and a washing machine, and a quantity of alcohol was stored in the galley. On the starboard side, aft of the hob, outwards opening double steel hatch doors were fitted above the work surface. These could be opened for additional ventilation, and also provided an additional escape route, if necessary. Plastic-type floor tiles were fitted in the galley and throughout the remainder of the aft section of the boat.

Aft of the galley on the port side was the bathroom area, accessed by an inwards opening door. The boat's permanent double berth was fitted aft of the bathroom area, with a locker and electrical cabinet aft of this. A wooden vanity door (which was always kept open) was located forward of the berth in the starboard passageway running aft from the galley to a single steel door. This led out up two steps onto the open stern deck, which acted as the boat's steering space and provided access to the engine compartment beneath. The fuel tank was fitted aft of the engine, while two LPG cylinders were fitted in a steel locker on the port side of the open deck.

1.5.2 Construction

The hull and cabin were fabricated from mild steel, welded together to form a long tube. Five rectangular windows were fitted in the saloon and dining area, with four circular portholes in the galley and aft accommodation areas.

Stone ballast was secured inside the bottom of the hull beneath a wooden (chipboard) deck. Fire resistant polystyrene insulation sheets were fitted to the lower hull sides. The safety data sheet for this polystyrene noted that at temperatures above 250°C, a flammable irritant, including styrene monomer, carbon monoxide (CO), carbon dioxide (CO_2), dense smoke, and possibly benzene & other hydrocarbons, may be emitted.

Rigid urethane insulation boards[2], incorporating composite foil facings for higher performance, were fitted to the boat's upper sides and deckhead (roof). The insulation on the sides was covered with 6mm maple-faced plywood, and the deckhead with 9mm maple "tongue and groove" planks. All the woodwork was treated with a water-based varnish, which would produce dense black smoke, containing hazardous decomposition products, including CO, CO_2 and nitrous oxides, during a fire.

The furniture was constructed from pine, plywood and medium density fibreboard (MDF). Mattresses and upholstery were of the domestic type, using the appropriate fire retardant materials, with polyester-cotton curtains fitted throughout.

1.5.3 Domestic equipment and services

A diesel fired water boiler was fitted in the engine compartment to heat water which could then be pumped through three radiators fitted in the boat. The pump for this system drew power from the 12V batteries; this system was not in use prior to the accident.

Electricity for the 240V system could be produced by a generator driven off the boat's main engine, or by an inverter powered by the 12V batteries. The main engine had not been on immediately prior to the fire, so 240V power was being supplied by the inverter. Electrical appliances were never left on, even on standby overnight, as this would drain the batteries, while if the TV and DVD were on standby, electrical interference from the inverter caused a loud buzzing noise from the speakers. The only appliance plugged in and operating at the time of the accident was a mobile phone charger, plugged into a socket in the galley area, on the work surface beneath the side hatch.

1.5.4 Solid fuel stove and hearth[3]

The solid fuel stove installed during outfitting in the starboard forward corner of the saloon, was a Villager Puffin stove, with a nominal rated output of up to 4kW. Although no photographs are available of *Lindy Lou*'s stove prior to the fire, **Figure 5** shows a Puffin stove similarly installed on another Triton narrowboat. The stove was secured to a hearth constructed of 6mm plywood attached to 50mm square pine bearers. The hearth had panels to the side and rear, also made of 6mm plywood mounted on 50mm pine bearers. The plywood was faced with 4mm thick domestic ceramic tiles, attached to the plywood with a silicone mastic compound. Air gaps of 60mm were incorporated between the tiled-plywood and the remainder of the boat's structure. A wooden shelf formed the top of the hearth; the owner had previously noticed some discolouration of this shelf in the area behind the stove.

---

[2] This met the requirements of BS 476-7:1997 with a Class 1 rating for the surface spread of flame.

[3] The hearth has been defined to include not only the horizontal base, beneath and in front of the stove, but also the vertical tiled structure surrounding the stove.

Reproduced from www.abnb.co.uk Figure 5

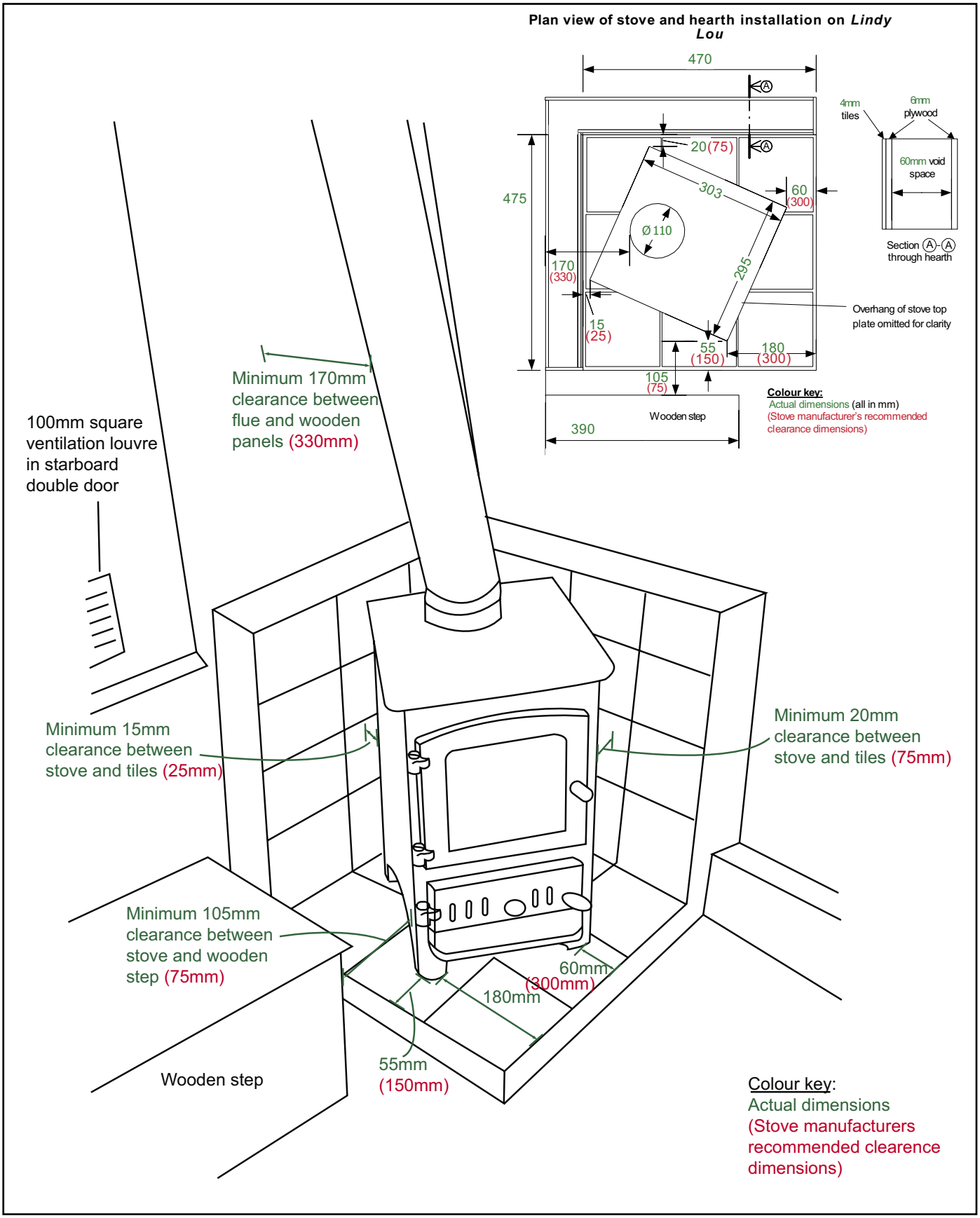
Stove installation on board another Triton narrowboat

The stove was angled on the hearth to face towards the centre of the saloon. **Figure 6** depicts the dimensions of the hearth and the clearances around the stove, and also includes the comparative recommended clearances, based on the stove manufacturer's guidance, which are described in more detail at section 1.10.3 below. The minimum clearance between the stove and the tiles was 15mm at the rear of the hearth (forward bulkhead) and 20mm at the outboard edge. The minimum projection of the hearth in front of the stove was 60mm on the stove's right side. The inboard side of the hearth finished 50mm from the wooden step leading out to the forward deck, with the stove 105mm away from this step at its closest point.

The front of the stove had two doors. The main upper door incorporated a glass window and provided access to the combustion area of the stove, which had a grate in the base and was lined with six fire bricks. The door was operated by a latch handle, which used a locknut to seal the door closed. The lower ash door provided access to the removable ashpan, where the ashes falling through the grate were collected, and was also operated with a latch handle. This door incorporated adjustable ventilation inlets, operated by a slider control knob in the middle of the door.

Overall ventilation for the stove was provided by two, permanently open, 100mm square ventilation louvres in the boat's forward double doors. The exhaust gases exited the stove via a 110mm diameter tubular flue, through a substantial transition piece in the deckhead providing the flue with support and insulation. Although the flue was unbalanced and not intended to provide ventilation, strong winds would tend to draw the exhaust gases and increase the rate of burning. Smokeless fuel, made from coke dust blended with anthracite into briquettes, was being used in the stove. The closest distance between the flue and the wooden lining was approximately 170mm. The owner had fitted a plastic-encased loudspeaker in the corner behind the flue, below deckhead level.

An Ecofan was used in conjunction with the stove to assist in the circulation of hot air around *Lindy Lou*. Designed specifically for use on solid fuel stoves, these devices sit on top of a stove and incorporate a thermoelectric module, which uses conducted heat from the stove top through the base of the fan to turn the blades. A heat sensitive spring is incorporated into the base of the Ecofan to gently tilt it back as the stove temperature increases to avoid the fan becoming overheated and damaged.



Diagrammatic representation of stove and hearth installation on *Lindy Lou*

1.6 POST-FIRE EXAMINATION OF *LINDY LOU*

1.6.1 General description

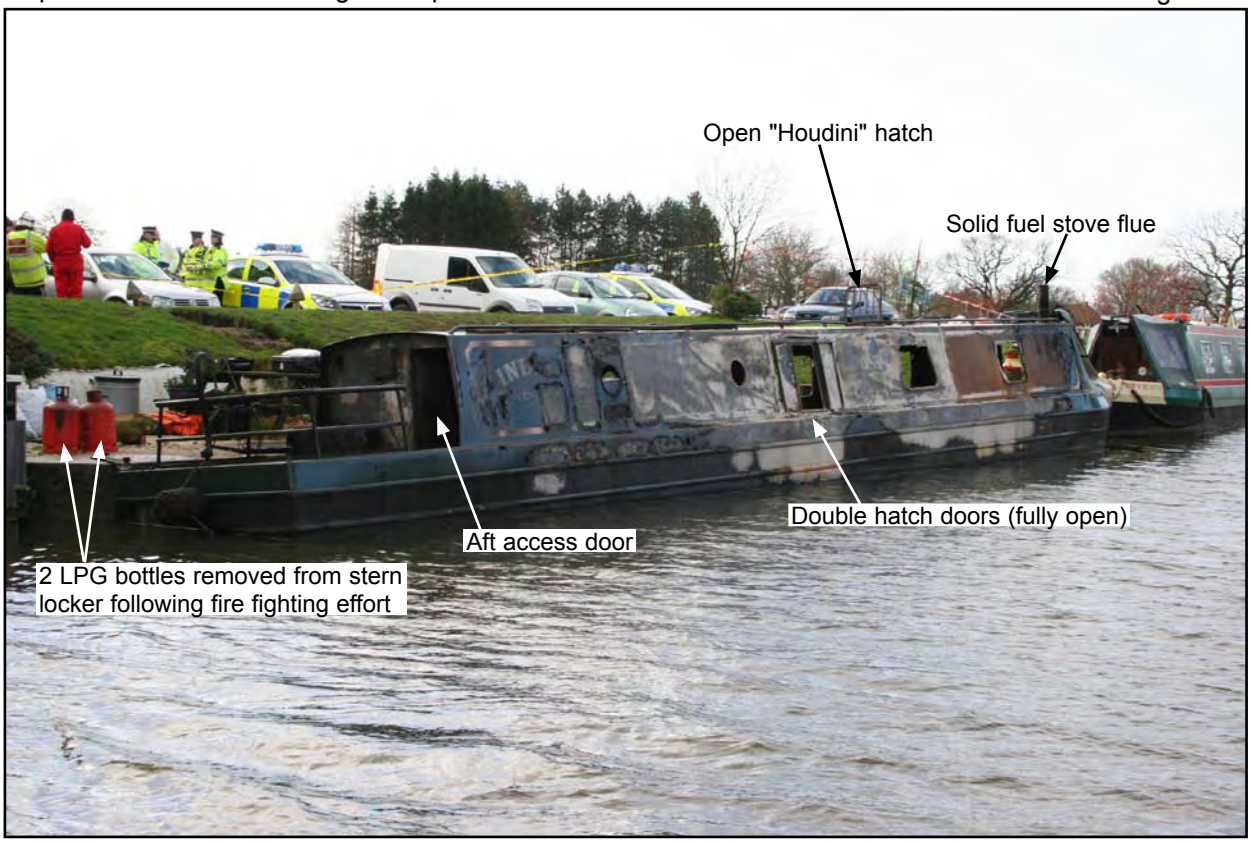
Examination of the boat following the fire revealed that it had burnt with sufficient heat to cause permanent distortion to the cabin sides and roof, as shown at **Figures 7a** and **7b**. Glass in each rectangular window and circular porthole had shattered and temperatures had been sufficiently high to melt the aluminium alloy window frames in several places. Exterior paintwork was totally burnt away on the cabin structure and had been reduced to powder on the hull in the galley area. The aft section of a circular plastic television aerial, fitted externally above the saloon area, had partially melted.

The forward open deck cover had partially melted, as seen at **Figure 7b**, while marks on the exterior of the forward double doors provided evidence of hot gases escaping through the windows and vents in these doors **(Figure 8)**. Other than the cover, no significantly burnt items were found on the forward open deck.

Wooden linings, insulation and partitions were mostly reduced to ash, other than in localised areas where materials were shielded from the fire. Furnishings in the saloon were burnt away, with only traces of metal springs and supports remaining. All the curtains had burnt, as had most of the nylon carpet, again except where it had been shielded by items standing on it. The television and DVD player were damaged, but the cupboard that they stood on was largely intact **(Figure 9)**. The bookshelf further aft had been severely burnt, with only a few, heavily charred paperback books remaining.

Reproduced from www.mengeneral.picmore.co.uk

Figure 7a

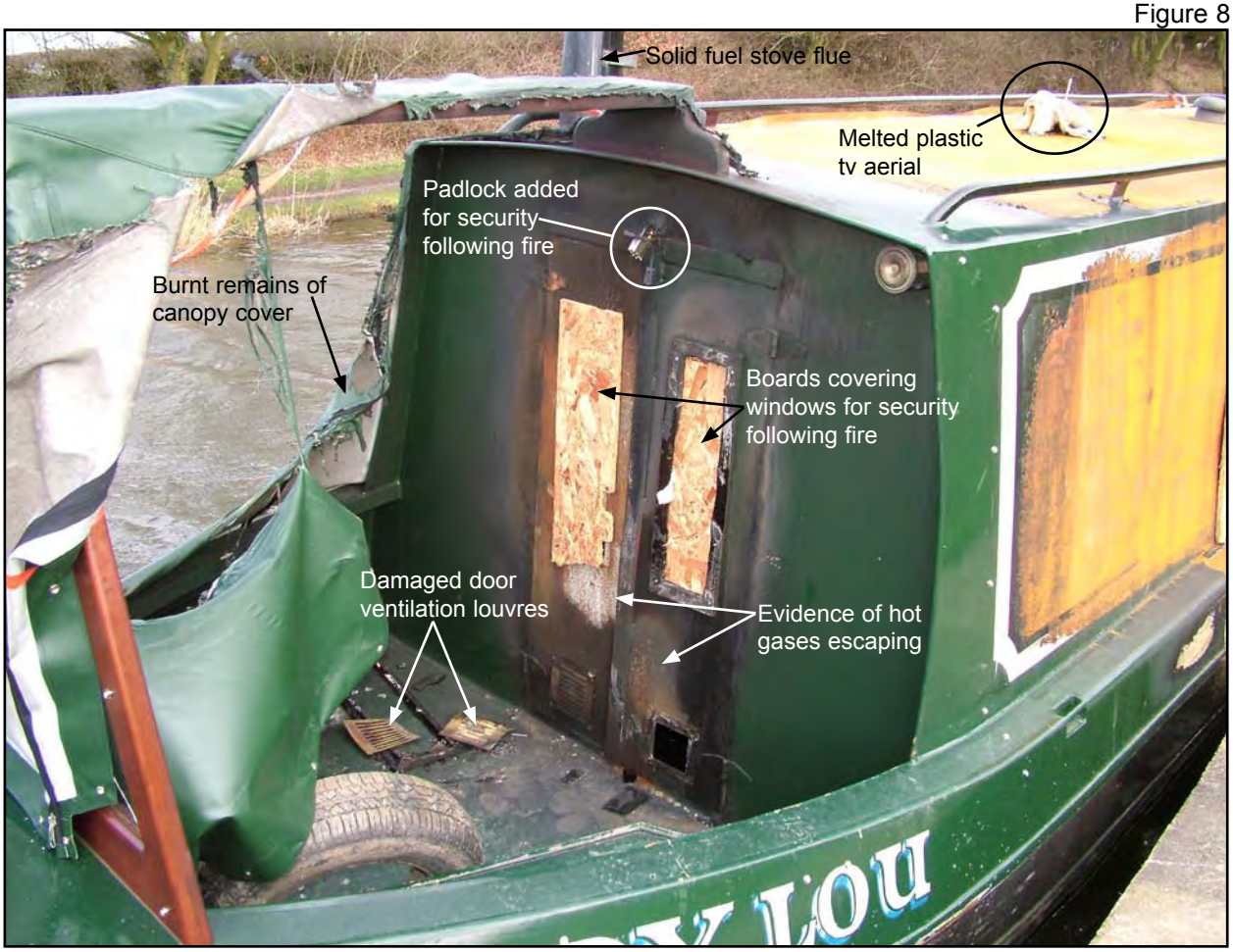


External damage to starboard side of *Lindy Lou*

Figure 7b

External damage to port side of *Lindy Lou*

Figure 8



Forward open deck of *Lindy Lou*

Figure 9

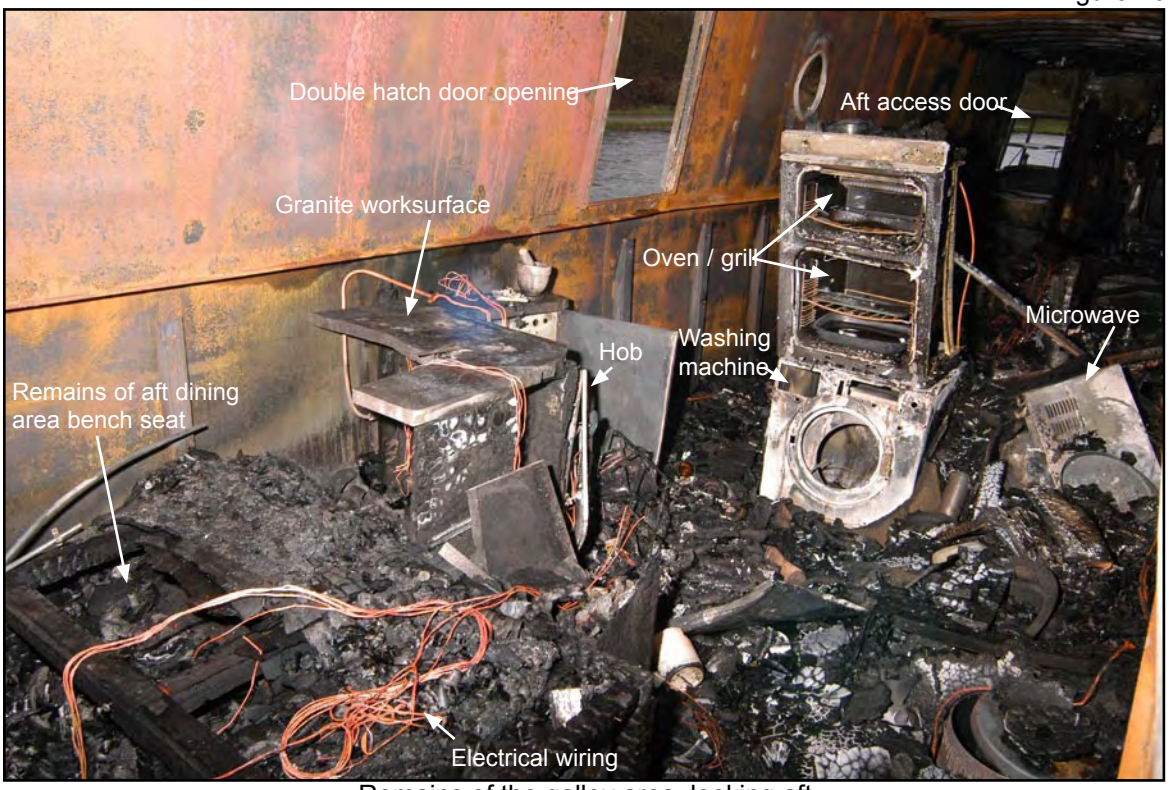
Damage sustained to the forward area of the saloon

The dining area was less severely damaged, with the foam from one of the bench seats remaining, despite the pine structure being heavily charred or burnt. However, the galley work units were severely burnt **(Figure 10)**. The plastic components of the appliances had burnt and there were small pools of solidified molten aluminium. The oven and hob controls were all found to be in the off position, and no food remains or cooking deposits were evident.

Plastic units in the shower and toilet area were burnt away, and a wooden vanity unit and assorted bottles of toiletries were heavily charred. The permanent double berth had burnt away, but some of the structure remained due to the bed's mounting on top of the stainless steel sewage tank **(Figure 11)**. The inverter, and other electrical equipment in the locker at the stern of the cabin, had been burnt, with damage beginning on the outside of cables and enclosures and spreading inwards.

Fire had spread to electrical circuits in the engine compartment, with most of the damage confined to plastic air inlet fittings on top of the engine, and had burnt through the plywood deck on the stern. The batteries, fuel system and the LPG cylinders were not involved in the fire. The remains of the boat's three fire extinguishers were found, unused, within the accommodation.

Figure 10



Remains of the galley area, looking aft

Figure 11

Looking forward from the aft access doorway

1.6.2 Inspection of solid fuel stove and surrounds

After the fire had been extinguished, Cheshire Fire and Rescue Service investigators noted that the solid fuel stove's door was secured in the closed position, as was the lower ash door, with the ventilation grille in the latter in the half open position. Twenty five pieces of partially burnt fuel were removed from the stove's grate, and the ash collecting tray was full of ash. The remains of the broken Ecofan were to the right of the stove on the deck.

A book had been left in the gap between the steps and hearth, and would have been approximately 100mm from the closest part of the stove. The book was partially burnt away with the remaining portion heavily charred, as shown at **Figures 12a** and **12b**.

The base of the hearth was charred and the tiles were covered with soot, but otherwise undamaged. The vertical sides of the hearth around the stove had collapsed as the plywood had burnt away, although the bottom layer of vertical tiles was still attached to the remains of the sides. These tiles were removed, revealing the preserved layered structure of the plywood behind, although the wood was charred and had been reduced to charcoal. **Figure 13** depicts this charring.

Figure 12a

Damaged book, adjacent to the left side of the stove

Figure 12b

Damaged book, adjacent to the left side of the stove

Figure 13

Evidence of charring of the wooden hearth structure

The debris behind and beneath the stove was systematically removed, being mostly ashes from the burnt insulation and lining materials. Underneath this debris behind the stove **(Figure 14a)** were the remains of a loudspeaker, a wooden duck ornament and a tile that had apparently become detached from a position higher up the hearth. These were all held together in a pool of solidified molten plastic that appeared to have dripped down from the loudspeaker, no trace of which remained on the bulkhead below the deckhead. **Figure 14b** shows this debris recovered to the top of the stove for inspection. The stove was lifted off the hearth and the area behind further inspected, revealing a clear outline of soot on the tiles behind, where the molten debris had been, as shown at **Figures 15a** and **15b**.

1.7 RECREATIONAL CRAFT DIRECTIVE (RCD)

1.7.1 General description

In 1994, European Council Directive 94/25/EC, commonly referred to as the Recreational Craft Directive or RCD, was adopted by the European Commission. Its purpose is to promote the free trade of recreational craft within the Member States of the European Union and to ensure a uniform level of safety in the design and manufacture of recreational craft throughout the European Economic Area (EEA). In 2003, the original RCD was amended by Directive 2003/44/EC. This extended the RCD's scope to include personal watercraft and new provisions for exhaust and noise emissions, as well as amending some of the original essential requirements.

The RCD is implemented in UK law by the Recreational Craft Regulations[4], enforcement of which is the responsibility of local authorities' Trading Standards services. Before the regulations were introduced, no comparable national regulation existed in the UK, although some individual Navigation Authorities had long specified construction and equipment requirements for vessels using their inland waterways.

The provisions of the original RCD were applicable within the UK on a non-mandatory basis from June 1996 until becoming mandatory in June 1998. The new amending RCD came into force from 1 January 2005, with a transition period until 31 December 2005. During this period, manufacturers could apply either the original or amended RCD.

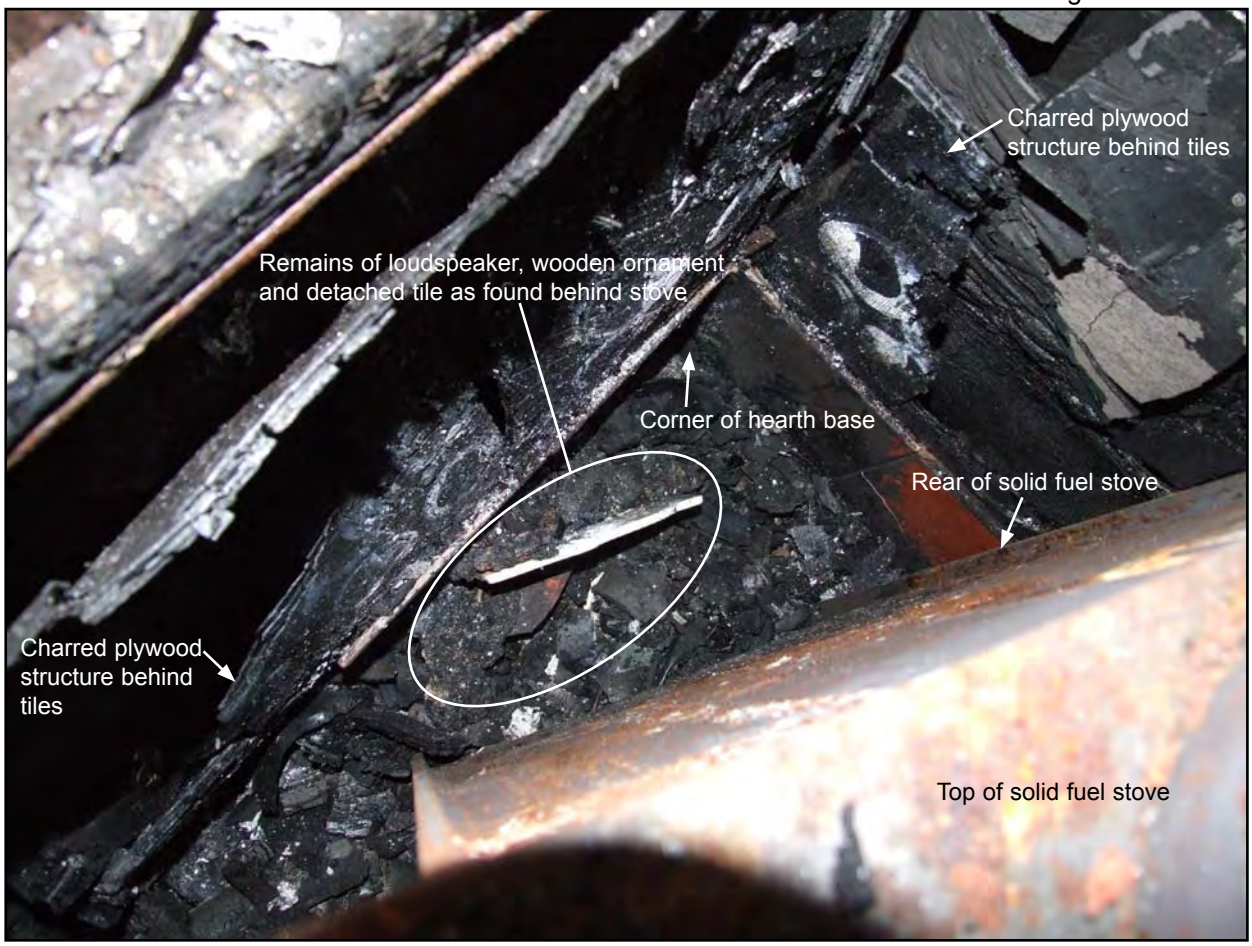
The RCD sets essential requirements for the design and construction of recreational craft. These are defined as any craft intended for sport or leisure purposes, regardless of the type or the means of propulsion, with a hull length of 2.5 to 24 metres.

Member states are unable to elaborate on the RCD's requirements in the conditions they impose on new craft, as national rules cannot require any modification to be made to craft conforming to the Directive. The RCD is a trade directive, which only applies on the first point of sale/use.

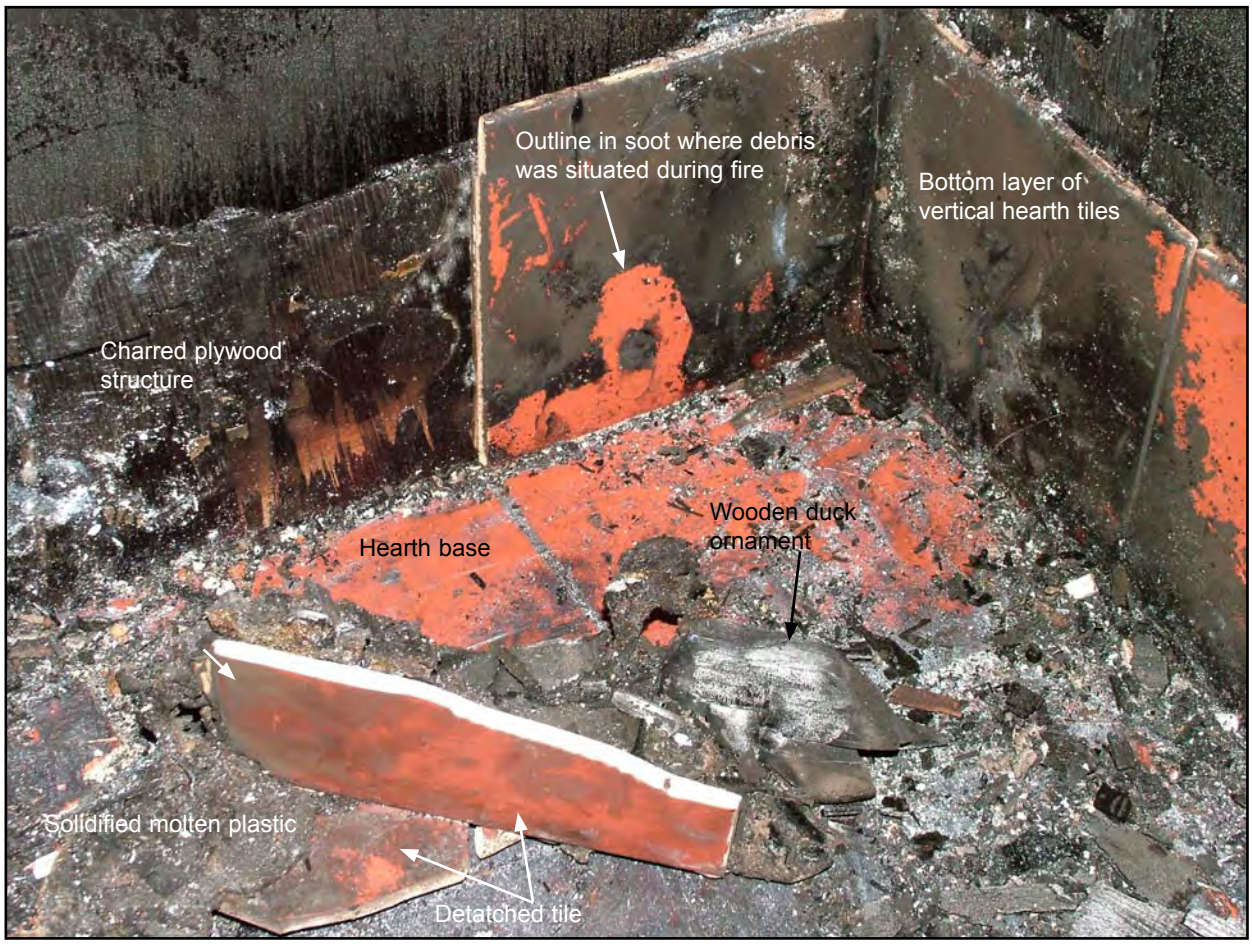
The RCD states that:

> *Member States shall take all necessary measures to ensure that products … may be placed on the market and put into service for use in accordance with their intended purpose only if they do not endanger the safety and health of persons, property or the environment when correctly constructed and maintained.*

[4] The Recreational Craft Regulations 1996, Statutory Instrument (SI) 1996/1353 2004/3201, latterly amended by the Recreational Craft (Amendment) Regulations 2004, SI 2004/3201.



Remains of loudspeaker, wooden ornament & detached tile in situ behind the stove (14a) and recovered to the stove top (14b)



Remains of loudspeaker, wooden ornament & detached tile in situ on hearth (15a) and moved from in situ position on hearth (15b), following stove removal

1.7.2 Essential requirements for fire protection

Two of the RCD's essential requirements cover the elements of fire protection. The general requirement is:

> *The type of equipment and the layout of the craft shall take account of the risk and spread of fire. Special attention shall be paid to the surroundings of open flame devices, hot areas or engines and auxiliary machines, oil and fuel overflows, uncovered oil and fuel pipes and avoiding electrical wiring above hot areas of machines.*

The requirement for fire-fighting equipment includes the statement:

> *Craft shall be supplied with fire-fighting equipment appropriate to the fire hazard, or the position and capacity of fire-fighting equipment appropriate to the fire hazard shall be indicated.* (sic)

1.7.3 Harmonised standards

Harmonised standards are European standards, adopted by European Standards organisations, following a mandate issued by the European Commission after consultation of the Member States.

Compliance with a harmonised standard provides a presumption of conformity to the corresponding essential requirements of the RCD. However, manufacturers are free to choose any other technical solution to demonstrate that an equivalent standard, or other method of compliance, has been achieved. One of the underlying characteristics of a harmonised standard, over and above ordinary European standards, is that its content must match the essential requirements of the directive to which 'it is harmonised'.

1.7.4 Harmonised standards for fire protection

The harmonised standards for recreational craft fire protection are EN ISO 9094-1:2003 and EN ISO 9094-2:2002, for craft with a hull length up to and including 15m, and over 15m respectively.

The scope of EN ISO 9094 states that it:

> …*defines procedures to achieve a practical degree of fire protection, specifies portable fire-fighting equipment and sets requirements for fixed fire-fighting systems.*

The standards provide requirements for escape routes and exits, and the installation of cooking, heating, electrical, fuel, liquefied petroleum gas (LPG) systems and appliances. The number, type and location of fire-fighting equipment are also determined, although the standards stipulate that these may also be subject to national regulations.

The standards stipulate requirements for the materials and finishes that should be used in the vicinity of open-flame cooking and heating devices, and the definition of an open flame device is any appliance where direct bodily contact with an open flame is possible. There are however no specific requirements for the installation of solid fuel stoves. A general safety provision notes that flues should be shielded to avoid overheating or damage to adjacent material or to the structure of the craft.

The standards also contain no requirements for smoke detection systems, nor the structural fire protection properties of materials used in boats.

1.8 BOAT SAFETY SCHEME (BSS)

1.8.1 General description

The Boat Safety Scheme (BSS) was jointly established by the Environment Agency and British Waterways in 1997, and works on behalf of the UK's navigation and harbour authorities to help sustain safety on the inland waterways in respect of boats, their installations and components.

Inland navigation authorities participating in the scheme generally enforce their legal requirements by requiring boat owners to submit a boat safety certificate before a navigation licence is issued. Around 60,000 boats currently possess BSS certificates, but the scheme is only a requirement on an estimated 70% (by length) of the UK's inland waterways.

A BSS certificate is issued by a registered BSS examiner following an independent examination of a craft to verify compliance with various requirements including: engines; fire prevention and extinguishing equipment; electrical equipment; LPG and appliance installations; flues and ventilation. BSS certificates are normally valid for a period of 4 years, following which a further examination is required before a new certificate can be issued. However, new craft that have been built to the RCD, are exempted from the BSS for the first 4 years.

Privately-owned boats operating on participating navigation authority waterways must comply with 31 legal requirements. Known as the BSS General Requirements, these are expressed in goal-setting terms, supported by expected means of compliance stated in the BSS Essential Guide.

1.8.2 BSS general requirements for fire protection

The BSS general requirements for fire extinguishing and escape state:

> *16 All vessels must carry specified fire-fighting equipment.*
> *17 All fire-fighting equipment must be in good condition and kept readily accessible for safe use in an emergency.*

The stated means of compliance for these requirements include checks on the number, type, capacity, condition and location of a boat's fire extinguishers, the provision of fire blankets and the adequacy of the emergency escape arrangements.

A best practice note regarding materials states that:

> *With regard to polystyrene thermal insulation, soft furnishings, fabrics and foam filling materials, we recommend checking with your supplier or the manufacturers' statements that any such material meets the latest national or international standards for fire-resistance, and for release of smoke and toxic gases in fires.*

The standards referred to in this note are however for materials used in buildings, as no such standards are applicable to boats.

The BSS currently has no requirement covering fire detection nor, apart from the above best practice note, any requirement for the type of materials used or fitted on board a boat with regards to combustibility.

1.8.3 Requirements for installation of heating devices

The two relevant BSS general requirements for appliance and flues require:

> *25 All appliances must be designed, installed and maintained in a way that minimises the risks of explosion, or of fire starting and spreading.*
>
> *28 All appliance flues must be designed, installed and maintained in a way that minimises the risk of fire.*

The stated means of compliance for these requirements include checks for any signs of heat damage on appliances, surrounding surfaces and materials near to appliances. No checks are made of the adequacy of the dimensions or location of a hearth.

A best practice note also recommends that boats meet:

> *… the fire-proofing standards for surfaces adjacent to appliances set out in BS EN ISO 9094. Also, free-hanging curtains or other fabrics are best fitted well away from appliance burners.*

1.9 SMOKE DETECTION SYSTEMS

1.9.1 General description

Although domestic-style smoke alarms are regularly fitted to boats, their use can be problematic due to the high humidity, corrosive atmosphere, extremes of temperature and battery-low warnings expiring during winter lay-up periods, all potentially experienced on boats.

Warwickshire Fire & Rescue Service has recently conducted practical evaluations to try to identify a suitable alarm for boats. Given recent technological advances in detector design and manufacture, and in the context of their formal partnership with Warwickshire Fire & Rescue Service, the BSS has sought advice from the competent body on the suitability of certain detectors for boats. The outcome of this advice has recently been published on the BSS website (www.boatsafetyscheme.com), along with a BSS statement and guidelines recommending that boats with overnight accommodation are fitted with at least one suitable and effective smoke alarm.

1.9.2 Generic requirements for smoke alarms

British Standard BS 5446-1:2000, provides a specification for smoke alarms for use in dwellings. This standard includes smoke alarms suitable for leisure accommodation vehicles (LAVs), which are subjected to additional vibration and temperature cycle testing. The standard also notes that conforming equipment may not be suitable for use in boats due to the corrosive atmosphere. A later European standard BS EN 14604:2005 for smoke alarm devices, contains no such note regarding its non-suitability for boats, although again requires additional testing for alarms to be fitted on LAVs.

The Code of Practice for the design and installation of fire detection and alarm systems in dwellings, BS 5839-6:2004, requires detectors to be fitted to all new domestic dwellings, including permanently moored boats used solely for residential purposes.

1.10 SOLID FUEL STOVES

1.10.1 Background

The use of solid fuel stoves as a traditional means of heating narrowboats dates back to the working canal boats of the 19th century, and in recent years their popularity has increased.

1.10.2 Regulatory requirements for the installation of stoves

British Standards BS 8303-1:1994 and BS 6762-2:1991 specify requirements for the installation of solid fuel fired heating in buildings, and in park homes and transportable accommodation units, respectively. BS 6461-1:1984 likewise provides for the installation of chimneys and flues for domestic solid fuel appliances. There are, however, currently no published standards covering the installation of solid fuel stoves on boats, and many such stoves are provided only with limited installation or operational instructions.

1.10.3 Villager Stoves Owner's Manual

The Owner's Manual for the Puffin stove fitted on board *Lindy Lou*, states that it should be installed in accordance with BS 8303 and BS 6461, and by a competent person, in compliance with all national and local Building Regulations and codes of practice. The manual also highlights the potential fire risks present when fitting a stove to a boat, caravan or other mobile structure, due to the combustible materials used in their construction. The importance of stoves standing on a non-combustible hearth, suitably insulated from any combustible material, with the stove itself suitably insulated from combustible materials, is also stressed.

Specifications for the hearth and stove location, are also provided, largely reflecting the requirements of BS 8303 and BS 6762. Key requirements are:

- The solid, non-combustible hearth should extend 300mm in front of the stove and 150mm on each side and to the rear, although the hearth width can be less, provided it extends to suitable heat resistant or non-combustible walls.
- The clearance around the stove to non-combustible materials should be 75mm either side, 150mm above and 25mm from the rear wall. These are ideal recommended measurements, but if the integrity of the services (i.e. marble, tiles, etc.) is in doubt, heat resistant material should be used to clad the hearth.
- The clearance from the flue to any wooden beam must be at least 3 x the flue diameter, unless the wood is shielded with a non-combustible material.

1.11 FIRE SAFETY REGULATIONS FOR CARAVANS

1.11.1 Regulatory requirements

Despite being land-based, caravans in many respects represent a similar environment to boats, given their mobile nature and accommodation with confined internal volume.

The habitation requirements relating to the health and safety on caravans, motor caravans and caravan holiday homes are covered by standards BS EN 1645, 1646 and 1647 respectively. None contain any requirement for the provision of smoke alarms or structural fire protection.

In 1998, the National Caravan Council (NCC) published a Code of Practice for Touring Caravans manufactured by NCC members for sale within the UK. This Code sets certain requirements over and above those stipulated in the standards as a condition of membership of the NCC. This includes a requirement for a smoke alarm, complying with BS 5446:1, to be fitted in touring caravans. The NCC, under its Certification Scheme, inspects these additional requirements whenever an NCC member requests approval of a UK caravan model.

The Furniture & Furnishings (Fire) (Safety) Regulations 1988, covering the fire safety of materials used in upholstered furniture, apply to caravans, but not to boats or other vessels.

1.12 INLAND WATERWAYS BOATING FIRES INCIDENT DATA

1.12.1 Background

Given the extensive nature of the UK's inland waterways network, data for accidents involving boats is provided by various inland organisations to a number of bodies who collect this information for statistical purposes.

1.12.2 Marine Accident Investigation Branch (MAIB)

Prior to this accident, 11 fires on recreational craft in UK inland waterways have been recorded by the MAIB since 1991, involving 1 fatality and 4 injuries. The MAIB's regulations[5] do not require the reporting of privately-owned pleasure vessel accidents, and the MAIB will therefore not be made aware of many inland waterways boating accidents.

1.12.3 Inland Water Related Emergency Monitoring Database (INREM)

The INREM system was established by the Royal Society for the Prevention of Accidents (RoSPA) and the Royal National Lifeboat Institution (RNLI), and has been capturing inland waterways accident data since March 2004. Various bodies including the police, fire and ambulance services and the Association of Inland Navigation Authorities (AINA) provide data. Data provision is, however, not compulsory and only 15 fire services (out of a possible 62 within the UK), and 9 police authorities (out of a possible 50) currently contribute to INREM. As such, only limited data has been collated for inland boating fires, as detailed below:

	Fires	Fatalities	Injuries
2003	5	0	0
2004	20	1	0
2005	13	0	0
2006	1	0	0

[5] The Merchant Shipping (Accident Reporting & Investigation) Regulations 2005

1.12.4 Department for the Communities and Local Government

The Fire Statistics and Social Research Branch of the Department for the Communities and Local Government, compiles statistics on fires and deaths and other casualties resulting from fires, based on returns provided by all local authority Fire Brigades in the UK. Data[6] for the period 2003 to 2005 for inland waterways leisure boats, including houseboats (used solely as a full-time dwelling), is detailed below:

	Fires	Fatalities	Injuries
2003	56	1	7
2004	105	0	12
2005	81	2	11

1.12.5 Boat Safety Scheme (BSS)

The BSS also collates inland waterways accident data from various sources, including regular reviews of media reports, and maintains a database of such incidents. Their summarised data for leisure boat fires is:

	Fires	Fatalities	Injuries
2003	24	3	3
2004	47	1	12
2005	37	2	4
2006	49	1	3

1.12.6 Similar accidents

Some recent fires on privately-owned narrowboats include:

1.12.6.1 Shardlow, January 2007

About a week after the fire on *Lindy Lou*, another fatality occurred during a fire on board an 18.3m long narrowboat at Shardlow in Derbyshire. The 66 year old owner had been cooking some food under the grill, when he apparently fell asleep. He woke during the early stages of the fire, and died due to the inhalation of smoke and fumes. The fire caused only limited damage to the boat, as it had self-extinguished due to lack of oxygen. No smoke alarm was fitted to this boat, which had been built in 2005 to comply with the RCD.

[6] The 2003 and 2004 values for the number of fires had been sampled and statistically weighted to Fire & Rescue Service totals, although the numbers of fatalities and injuries are actual

1.12.6.2 Brinklow, March 2006

A 15 year old girl was sleeping on board a 12.2m long narrowboat at Brinklow in Warwickshire, when she was woken by the sound of a fire developing in the area of the solid fuel stove that had been left operating overnight. Flames could be seen to the rear of the stove and, after an unsuccessful attempt to extinguish the fire using a fire extinguisher, she left the boat, having suffered from smoke inhalation. The solid fuel stove had been fitted by the owner, and tiles had been bought but not yet fitted to protect the timber lining of the boat behind the stove, which had gradually dried out, then ignited. The boat was extensively damaged. No smoke alarms were fitted.

1.12.6.3 Wrenbury, February 2007

The owner of a narrowboat moored at Wrenbury in Cheshire had lit the on board solid fuel stove to heat the boat. He then left the boat unoccupied. On his return he discovered the boat to be on fire, which caused extensive damage to the interior. The boat had previously been involved in a heavy contact during a mooring incident, resulting in a number of tiles being dislodged from the stove's hearth. These had yet to be replaced and it is believed that the exposed timber framework of the hearth had ignited due to radiant heat transfer from the stove.

SECTION 2 - ANALYSIS

2.1 AIM

The purpose of the analysis is to determine the contributory causes and circumstances of the accident as a basis for making recommendations to prevent similar accidents occurring in the future.

2.2 CAUSE OF ACCIDENT

2.2.1 Seat of the fire

The description of the early stages of the fire points to the fire having started in the forward saloon area. This is consistent with the air becoming increasingly warm as the owner walked forward to open the hatch in the galley area. Although he was unaware of anything unusual at this stage, it is possible that the fire might have only been smouldering, as the first observation of flames was the burning canopy, outside the boat. On approaching this area, the owner noticed the flames appeared to be emanating from inside the boat. This is substantiated by the evidence of the escaping hot gases on the exterior of the forward double doors **(Figure 8)**, which would have built up beneath the plastic cover and ignited it. Likewise, the absence of any significant burnt items on the forward open deck that could have instigated the fire precludes an external fire source.

The shattering of the forward port window and the subsequent flames bursting through the window and enveloping the saloon is not only consistent with the fire starting in this area, but also of flashover[7] having occurred, with comprehensive combustion of the boat's fittings and contents. The window would have shattered due to thermal shock, signifying that this would have been the warmest part of the boat at this stage.

In opening the hatch and aft door, the owner unknowingly fed the fire with oxygen. When the window shattered, this would have enhanced the draught through the boat, given the wind direction along the boat from forward to aft.

Simple computer fire modelling conducted by Cheshire Fire & Rescue Service for a moderate fire within a compartment similar to that of *Lindy Lou*'s cabin adds weight to this scenario. The model showed that after around 4 minutes the smoke layer produced by a moderate fire would have reached deck level, with temperatures in the area of around 200°C, and the fire would have become constrained due to a lack of oxygen. Within a minute of oxygen being re-introduced to the compartment, the temperature would have rapidly risen to 600°C and flashover would have occurred.

2.2.2 Causes that can be discounted

Examination of the boat's electrical system following the fire, although indicating the system was switched on prior to the fire, revealed no suggestion of arcing or electrical failure.

---

[7] Flashover represents a rapid change from a localised fire in a compartment to a fire involving all the surfaces of combustible objects in the compartment.

Electrical equipment and wiring had burned from the outside inwards, and damage had tracked back aft into the engine space. All electrical items, including the TV and DVD player in the saloon, were switched off, apart from a mobile phone charging near the double hatch. The gas oven and hob were likewise switched off. *Lindy Lou*'s owner was also insistent that candles were never used on board the boat, and there was no evidence of arson.

An Ecofan, used to circulate the hot air generated by stoves, had been operating on the stove top, and its remains were found in the vicinity of the stove. The possibility that this fan could have tilted too far, and fallen off the stove to ignite the carpet has been discounted. Basic testing of the Ecofan has indicated that the metallic strips on its base would not have risen sufficiently to over balance the fan. It seems more likely that the fan was knocked off the stove during either the flashover or the fire-fighting efforts.

The owner's girlfriend was a smoker, but had not been smoking inside the boat before they went to bed. It is possible that if she had got up from bed to have a cigarette, this might have in some way led to the fire starting. However, the owner is insistent that his girlfriend never smoked inside the boat. No evidence of cigarette ends or ashtrays was found among the debris following the fire, and if she had got up out of bed before the owner, it is likely that he would have been aware of this; when he got up he believed that she was still in bed.

It is evident that she must have got up at some stage, given that her body was discovered in the bathroom area. The position of her body, in particular with her leg partially in the shower cubicle, is consistent with her having closed the inward opening door into the bathroom area behind her. The possibility of her smoking in this area and causing the fire can again be discounted, particularly given that the fire did not appear to start in this area. It is possible that once she woke up, she moved forward to investigate the commotion associated with the flashover, or simply became disorientated and went the wrong way. At some stage she probably tried to seek shelter in the bathroom area, but was overcome by the smoke and toxic gases emitted during the early stages of the fire.

2.2.3 Possible causes

The only item in the saloon that was operating at the time of the fire was the solid fuel stove. Both the main door and lower ash door on the stove had been secured closed, while the air vents in the latter were half-open, thus minimising the discharge of a spark or ember directly from the stove. After the fire, the stove and the door seals were found in good condition, apart from some cracking in the internal fire bricks.

Capable of emitting up to 4kW of power, the stove had been installed on board *Lindy Lou* during the original fit out, but not in accordance with the guidance in the stove's owner's manual.

Figure 6 provides a comparison of the actual stove/hearth installation dimensions with those recommended by the stove manufacturer. The projection of the hearth in front of the stove was considerably less than the 300mm recommended by the manufacturers to provide a non-combustible zone to catch sparks while the door was open. The absence of such a buffer would have increased the possibility of an ember falling onto the carpet and smouldering when the fire was stoked up before the occupants went to bed.

The air gaps from the stove to the hearth tiles and the wooden step were also less than recommended, as was the gap between the flue and the wooden-faced sides of the boat. These gaps would have increased the likelihood of radiant heat transfer from the stove to these structures, and subsequent ignition. The owner's previous observation of discolouration of the wooden shelf on top of the hearth, appears to confirm that heat damage of the structure had been occurring.

Combustible items near the stove and flue, such as the beanbag and chair, the book propped up next to the step, or the plastic-encased loudspeaker behind the flue, would have been susceptible to radiant heat transfer. The book was left particularly close to the stove, and was burnt from the top down, while little or nothing remained of the beanbag and chair. It is possible that one of these items could have ignited, forming the seat of the fire. A larger hearth would have discouraged the placing of objects too close to the stove.

The dislodged vertical hearth tile, and wooden ornament found embedded into the melted plastic remains of the loudspeaker behind the stove, confirm that the speaker had begun to drip molten plastic onto the hearth before the tile and duck fell. This molten plastic would have increased the risk of ignition of any combustible items that it dripped onto, such as the wooden shelf on top of the hearth. Given the gaps around the flue, the fitting of a plastic speaker in this area would have also increased the risk of it sustaining heat damage or ignition; the owner however reported no problems with the speaker in this location.

The dislodged tile was cleaner than the other soot-covered tiles in the area, suggesting that it possibly fell off the hearth at an early stage in the fire, or simply fell into a particularly well-protected location. The owner had not been aware of any loose or missing tiles, but these might not have been readily visible behind the stove. Once this and other tiles had become dislodged, the wooden structure behind would have quickly ignited.

Evidence also exists to suggest that pyrolysis[8] had been occurring in the wooden structure behind the hearth tiles. The remaining lower sections of this 6mm plywood were charred, but with the layers of ply still clearly identifiable. *Kirk's Fire Investigation*[9] confirms that although wood may not ignite at lower temperatures, prolonged exposure to lower temperatures in the absence of oxygen can cause wood to degrade to charcoal by distillation and pyrolysis, then ignite when a non-combustible barrier has suddenly failed.

The wooden hearth structure on *Lindy Lou* could therefore, possibly, have been charring for some time beneath the tiles, until the heated charcoal produced by pyroylsis came into contact with air, and ignited. The tiles used were standard domestic ceramic tiles, with minimal insulation properties, and although they survived the fire, they would have readily conducted heat to the wood behind.

---

[8] Pyrolysis is the chemical decomposition of organic materials by heating in the absence of oxygen, and often precedes combustion. Although such processes are carried out in a normal atmosphere, the outer layers of the material keep its interior oxygen-free.

[9] DeHaan, John D., "Kirk's Fire Investigation", 4th Edition, Prentice-Hall Inc., New Jersey, 1997

Given the severity of the damage sustained, and the lack of eyewitness evidence, the exact mechanism and sequence of initiating events for the fire are difficult to ascertain. It however seems likely that the solid fuel stove was the most probable source of the fire, given the manner of its installation, the evidence of pyrolysis and the proximity of readily combustible materials.

2.2.4 Fire propagation

Both the eyewitness accounts and the damage sustained by the boat confirm the extreme ferocity and speed of the fire. The melting of aluminium fittings confirms that temperatures would have exceeded 550°C during the fire. The damage evident to the steel structure of the vessel and the transformation to powder of the external paintwork in places is testament to this immense heat, as shown at **Figures 7a** and **7b**. However, the heat damage around the stove appears to be less than further aft in the boat, particularly in the galley area.

Kirk's Fire Investigation describes a fire test in a wooden-framed building, where the origin of the fire was less damaged than other areas to which the fire had been driven by a strong wind blowing through openings. It is likely that this was also the case for *Lindy Lou*. The flow of air and oxygen through the boat would have promoted a greater horizontal spread of fire, exacerbated by the relatively strong winds blowing along the length of the boat from forward to aft. The flashover would also have been directed aft towards the galley area, where the wooden cabinets, and alcohol stored in this area, would also have provided enhanced fuel for the fire.

2.3 SOLID FUEL STOVE INSTALLATION

Had the solid fuel stove on *Lindy Lou* been installed in the manner recommended by the manufacturers, the risk of a fire starting would have probably been reduced. However the stove and hearth arrangement on *Lindy Lou* is not dissimilar to many modern canal boats, where the constrained dimensions pose challenges for the provision of stoves with adequate hearth surroundings.

Although standards exist for installing solid fuel stoves in buildings, park homes and transportable accommodation units, no such standard currently exists for boats, despite the risk of fire being at least as great.

The harmonized standards for recreational craft fire protection, EN ISO 9094, do not include specific requirements for the installation of solid fuel stoves. These standards do include requirements for materials and finishes in the vicinity of open flame cooking and heating devices and it could be argued that solid fuel stoves are effectively open flame devices during periods when their doors are open. However these generic requirements do not appear to be completely relevant to solid fuel appliances and their particular installation. The issue of fire protection for solid fuel stoves and the substrate material being suitably fire resistant or protected from heat in the EN ISO 9094 standards was raised during the June 2007 ISO Plenary Working Group Meeting. The ongoing review of these standards in this respect is an extremely positive development.

Following a series of canal boat fires involving solid fuels stoves, Warwickshire Fire & Rescue Service and the Boat Safety Scheme (BSS) submitted a draft proposal, in late 2006, to the British Standards Institution (BSi) for a standard to be developed for their installation on boats. This standard is currently being developed by BSi, and its accelerated introduction to provide guidance and regulation to those installing stoves on

boats is much needed. The active support by solid fuel stove manufacturers and boat builders for the development of this standard, along with their adoption of it upon its publication, would be beneficial in preventing recurrences of this type of accident.

In the ongoing absence of such a standard, it is essential that careful consideration be given to the safe and sensible design and maintenance of hearths, especially given the high power outputs of some stoves. The use of alternative materials, offering restricted combustibility or better thermal resistance to radiant heat transfer, should be considered wherever practically possible.

Boat owners should try to check for unseen charring of the hearth structure, where possible, and refer to the detailed advice regarding limiting the risks from solid fuel stoves, provided on the BSS website, entitled 'Keeping Safe with Solid Fuel Stoves'.

2.4 REQUIREMENTS FOR FIRE DETECTION

It is quite possible that, had a basic functioning smoke alarm been fitted to *Lindy Lou*, the fatality resulting from this accident could have been prevented. The high level of carbon monoxide (CO) ingested by the owner suggests the fire had been smouldering for some time, and an earlier warning of this danger would have increased the chance of both occupants safely escaping.

There is currently no requirement to fit smoke alarms in a boat in either the Recreational Craft Directive's (RCD) essential requirements, or the relevant harmonised standard, EN ISO 9094. Further, the BSS currently does not require the fitting of smoke alarms, partly because the BSS requirements aim not to exceed those of the RCD. However, despite this, the BSS could have recommended the fitting of smoke alarms in boats, but did not, due to its concerns regarding the use of domestic alarms on board boats, in view of humidity and potential false alarms. The BSS has, however, recently announced on its website (www.boatsafetyscheme.com) its strong recommendation that at least one suitable and effective smoke alarm be fitted to boats with overnight accommodation, along with guidelines regarding suitable alarm types. This is a welcome development, as is the proposed support of this initiative by the British Marine Federation (BMF) in some of its publications.

British and European standards also exist for smoke alarms that are considered suitable for leisure accommodation vehicles. Indeed, the National Caravan Council requires its members to fit smoke alarms in touring caravans being manufactured in the UK. The BMF does not impose a similar requirement on its members for boats manufactured in the UK, but various boat user associations do recommend that inland cruising craft fit smoke alarms, including the RYA and, following this accident, the Association of Waterways Cruising Clubs. Triton has also begun fitting smoke alarms as standard on all its boats following this accident, a practice that should be emulated throughout the industry.

It is also noted that BS 5839-6 requires detectors to be fitted to all new domestic dwellings, including permanently moored boats used solely as a residential dwelling. Although *Lindy Lou* was predominantly used for accommodation, her occasional cruises thus excluded her from this requirement. This apparent anomaly adds weight to the arguments for a review of EN ISO 9094 to include requirements for fire detection systems on boats.

2.5 REQUIREMENTS FOR FIRE PROTECTION

The tubular nature of narrowboats, uninterrupted by bulkheads or divisions, facilitates the rapid spread of fire, while the typically low deckhead heights provide for extremely rapid fire development and flashover conditions. The risks associated with this geometry are exacerbated by the materials commonly used to fit out narrowboats. The extensive use of combustible materials, including wood linings, varnishes, and some types of insulation not only maximises the fire loading but also, as seen on *Lindy Lou*, can include materials that produce toxic products on thermal decomposition, thus reducing the chances of survival during a fire.

The RCD states that products should not endanger the safety and health of persons, property or the environment. It is arguable that the omission of any essential requirement within the RCD or its harmonised standards for the restricted use of combustible materials, or materials with toxic thermal decomposition products, fails to enact this over-arching principle.

Alternative materials offering reduced combustibility and toxic decomposition do exist, and their use should be seriously considered by those fitting out boats, as suggested by the BSS best practice note. The fire loading associated with many domestic items, such as a bookcase containing books and DVDs is also extremely high, with the plastic cases for the latter again emitting toxic gases during combustion. Careful consideration should be given by canal boat users to the fire risks associated with storing such items in bulk, given the relatively high fire loading compared with the restricted volumes of narrowboats. Boat users should also consider minimising the inclusion of potentially flammable materials on their boats, such as nylon carpets.

2.6 FATIGUE

Despite the occupants being asleep during the early stages of the fire, fatigue is not considered to be a relevant factor to this accident. Although the delay in conducting the postmortem means that the blood alcohol level recorded for the owner's girlfriend can not be considered an accurate representation, both had consumed a significant amount of alcohol prior to going to bed. It is possible that this, combined with the effects of the carbon monoxide present during the early stages of the fire, might have caused disorientation and affected their decision-making during the early stages of the fire.

2.7 SIMILAR ACCIDENTS

The statistics collated for inland waterways boat fires confirm that this tragic accident was not an isolated case. Fires do occur on a regular basis, particularly on narrowboats, often resulting in tremendous damage, as well as fatalities and injuries.

A review of the available data has also highlighted that, although incident data is collected by organisations to varying degrees for inland waterways recreational craft, there is no definitive source for this data. The importance of accurate, comprehensive accident data, to allow safety issues and trends to be identified and acted upon is essential, and it is to be hoped that a new version of INREM, currently being developed for the National Water Safety Forum, will provide this.

The implementation of this new database is, however, subject to appropriate and adequate funding being obtained to ensure a future firm basis for data collection and analysis. Furthermore, the support of key organisations, in particular fire services and police authorities, in providing quality data, both to INREM and its replacement, is vitally important to ensure the success of these databases.

SECTION 3 - CONCLUSIONS

3.1 SAFETY ISSUES

3.1.1 Safety issues directly contributing to the accident which have resulted in actions being taken and/or a recommendation being made:

1. There is no standard available for the installation of the solid fuel stoves on boats, leading to the stove on *Lindy Lou* being installed too close to combustible materials. [2.2.3, 2.3]

2. Smoke alarms were not fitted on board *Lindy Lou*, and the Recreational Craft Directive, EN ISO 9094, and the Boat Safety Scheme do not require these to be fitted to recreational craft. [2.4]

3.1.2 Other safety issues identified during the investigation, also leading to actions being taken:

1. Incident data for inland waterways recreational craft is collected by various organisations, but there is no definitive source for this data, thus restricting opportunities for the identification and monitoring of accident trends as a basis for improving safety. [2.7]

3.1.3 Other Safety Issues:

1. The geometry of narrowboats facilitates the rapid spread of fire and flashover conditions, and these risks are exacerbated by the materials commonly used to fit out narrowboats. [2.5]

2. There is no essential requirement within the RCD or its harmonised standards relating to the restricted use of combustible materials, or materials producing toxic fumes on decomposition. [2.5]

3. The fire loading associated with many domestic items can be extremely high, and may introduce additional fire risks if stored in bulk within the restricted volumes of narrowboats. [2.5]

SECTION 4 - ACTION TAKEN

Following the accident, various actions have been taken by organisations involved both directly and indirectly in this accident. These include:

The **Boat Safety Scheme (BSS)** has:

- Issued a statement on its website (www.boatsafetyscheme.com) confirming that it now strongly recommends the fitting of at least one suitable and effective smoke alarm to boats with overnight accommodation. It has also published guidelines regarding the choice and positioning of suitable alarm types on its website.

The **British Marine Federation (BMF)** has:

- Confirmed its intention to support the BSS initiative regarding smoke alarms in its quarterly technical report and the trade publication 'Boating Business'.

Triton Boat Fitters has:

- Commenced fitting smoke alarms on all its new boats.
- Replaced the plywood, used as the tile-facing material in their stove hearths, with a fire barrier material.
- Confirmed its intention to install oil fired central heating, where possible, to replace solid fuel stoves.

Cheshire Fire & Rescue Service has:

- Confirmed its intention to introduce a Boat Fire Safety check scheme similar to that already underway with Warwickshire Fire & Rescue Service. This scheme is intended to help boat owners understand the on board hazards of fire, and identify simple preventative actions that can reduce the risk.

The **Association of Waterways Cruising Clubs** has:

- Recommended to its member clubs, through its magazine and website, that all boaters should fit smoke alarms and CO detectors to their boats and should consult their local Fire & Rescue service for technical advice.
- Issued a press release containing the same recommendation to the waterways press.

The **National Water Safety Forum** has:

- Continued to develop, through its REMTECH (Rescue Emergency Technical) group, a new web-based UK water-related incident database to replace INREM and other databases.

The **CEN (European Committee for Standardization[10]) Consultant RCD** has:

- Raised the issue of fire protection for solid fuel stoves and the substrate material being suitably fire resistant or protected from heat in the EN ISO 9094 standards, during the June 2007 ISO Plenary Working Group Meeting.

[10] CEN is the Comité Européen de Normalisation or European Committee for Standardization.

SECTION 5 - RECOMMENDATIONS

The **British Standards Institution** is recommended to**:**

2007/183 Propose to the International Standards Organisation that BS EN ISO 9094 Parts 1 and 2 should be reviewed regarding the fitting of smoke alarms on habitable small craft.

Marine Accident Investigation Branch
October 2007