# FIXED VENTILATION ON SMALL CRAFT

Time to reconsider?

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# Fixed Ventilation on Small Craft – Time to Reconsider?

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## Introduction

Fixed ventilation provision on small leisure craft is extremely important for the welfare of the vessel and occupants; the grandfather of gas installation standards for boats explaining in 1979:

> *All compartments of a vessel should have adequate ventilation to prevent excessive condensation, build-up of products of combustion and other unhygienic or toxic conditions occurring* (BS 5482-3:1979).

*Figure 1 - Extract from BS 5482-3:1979*

The formula used to calculate required ventilation in today's extant standards (and in-use by the Boat Safety Scheme (BSS) (and others) first appears in BS 5482-3:1979. Some 46 years later the industry is using the same calculation yet is arguably facing a very different set of environmental and social conditions.

Boats are now very often homes, used year-round and daily. Estimates of population size vary wildly, from 15,000 (RBOA, 2024) to 30,000 (Smith, A. 2024). CRT (2022) found around 31.5% (3002 of 9530) of respondents to their census are liveaboard boaters. Bryant (2021) reported the population afloat rose from 15% of all boats in 2011 to 25% in 2021; an estimated 20,000 dwellings. CRT data is similar, reporting the proportion of liveaboard boaters has risen from 15% in 2011 to 27% in 2020 (CRT, 2021). It's a growing number even if the total is not clear; 30% seems about right.

As boat use changes so does appliance use; appliances are used 365 days a year. Boats are commonly clumped together in large marinas, their neighbours often also liveaboards. However, no standard or guide has moved to review or alter the way ventilation is calculated since 1979, and on private leisure vessels undergoing a BSS examination, meeting a minimum level of fixed ventilation is advisory only. Note: hire boats are mandated to meet the minimum requirements, no advisory requirements exist for hire vessels (BSS 2024a).

Ventilation is not so much designed but is merely present, with often no thought given to positioning and function. The formula used to calculate required fixed ventilation is based on a “Christmas Day event”; a full quota of people aboard and all fuel-burning appliances operating flat out. In this scenario full ventilation is necessary of course, but in most cases that same amount of ventilation remains present and open at 3am, when generally people are long to bed and only background heating is operating. Having spent the last 46 years using the same calculations for ventilation, there is evidence that openings into vessels are now serving to let poor air from the crowded local environment in to the living space. The pollution being expelled by an increasingly large and compact liveaboard community is entering boat cabins; this paper details three events of CO ingress, including one of acute CO poisoning, caused by neighbouring boats.

It’s possible then that the balance is wrong, and this paper aims to start a new conversation about how the sector best looks after boaters. This is timely given that BSI aim to review PD 54823:2016 in the near future, meaning the industry has an approaching opportunity to reconsider fixed ventilation requirements on small craft.

 

## 1. Calculating fixed ventilation requirements

Requirements for fixed ventilation in accommodation spaces on small leisure craft are found in British Standards and other associated guidance documents. The calculation in BS 5482-3:1979 is virtually the same as the very latest in-force standard (ISO 10239:2017), and industry guidance document (PD 54823:2016). The only change to the formula since 1979 comes in BS EN ISO 10239:2014 and PD 54823:2016 which instructs that consideration shall be given to any other air consuming appliance in the accommodation space, burning other types of carbon fuel (ISO 10239:2014).

In the UK, PD 54823:2016 gives us a full formula to use, as shown in Figure 2:

> The effective area of fixed ventilation for accommodation spaces containing an LPG appliance, V, in mm2, should be calculated from the following equation:
>
> V = (2200 × U) + (650 × P) + (440 × F) + (550 x H)
>
> where:
>
> U   is the input rating of unflued appliances, in kilowatts (kW);
>
> P   is the number of persons for which the accommodation space is designed;
>
> F   is the input rating for all open flued appliances in kilowatts (kW)
>
> H   is the nominal output rating of solid fuel appliances, in kilowatts (kW), as defined in BS 8511:2010

*Figure 2 - Ventilation calculation formula, PD 54823:2016*

Figure 3 shows how this formula is applied to a typical small leisure craft:

V = (2200 × U) + (650 × P) + (440 × F) + (550 x H)

| | | |
|---|---|---|
| Cooker, unflued,10kw | (10 x 2200) | = 22000mm2 |
| 6 persons | (6 x 650) | = 3900mm2 |
| Diesel central heater, flued, cabin, 5kw | (5 x 440) | = 2200mm2 |
| Solid fuel stove | (5 x 550) | = 2750mm2 |
| | V | = 30850mm2 |

*Figure 3 - Example small craft ventilation requirement as calculated*

As common with all later standards, BS 5482-3:1979 points out:

> 14.3.2 The area calculated by the above formula should be divided equally between high and low level, the top ventilators being as high as practicable and those at low level positioned so that they cannot be inadvertently obstructed

*Figure 4 - Extract from BS 5482-3:1979 detailing ventilator location*

The actual ventilation aboard is calculated by measuring the fixed openings, grilles and ducts as required.

## 2. Enforcing ventilation requirements

Hire boats and liveaboard boats are subject to the Gas Safety (Installation and Use) Regulations 1998 (GSIUR). GSIUR requires ventilation to be adequate (GSIUR, 1998), as shown in Figure 5 below:

> 2 Gas engineers carrying out installation, commissioning, maintenance or safety check work should ensure that:
>
> (c) the room or space where the appliance is located is adequately ventilated, and that the means of ventilation is suitable to provide a sufficient permanent supply of air to the appliance for safe combustion of gas. Account needs to be taken of:
>
> (i) the volume of the room or space;
> (ii) whether draught exclusion or new windows have been fitted, or other changes that could affect ventilation have been made to the room containing the gas appliance(s);
> (iii) the location, type, size and configuration of airbricks and other permanent air vents;
> (iv) whether air inlet ducts of room-sealed appliances are correctly located and remain unobstructed; and
> (v) any other factors which could affect the adequacy of the air supply;

*Figure 5 - Extract 1 from GSIUR 1998 – Appendix 3*

The requirement is repeated in Regulation 34, as shown in Figure 6:

> 279 A responsible person must not use or allow the use of any appliance which it is known or suspected could constitute a danger to any person, and in particular danger of fire/explosion arising from gas leakage or carbon monoxide poisoning arising from inadequate flueing arrangements or fixed ventilation.
>
> 280 An unsafe/dangerous appliance in this context means any appliance where both (a) and (b) which follow apply:
>
> (a) there is a design, construction, installation, modification, servicing/maintenance deficiency or other fault (e.g. maladjustment) in the gas appliance, associated flue/ventilation arrangement or a gas fitting/other works for the gas supply to the appliance, which has or is likely to result in:
> (i) incomplete gas combustion; or
> (ii) products of combustion not being safely removed; or
> (iii) _ insufficient oxygen being available for the occupants of the room/space where the appliance is located; or
> (iv) an accidental gas leakage; or
> (v) other danger, e.g. of fire;
>
> (b) the resulting leakage, inadequate combustion, inadequate removal of the products of combustion, insufficiency of oxygen or other danger has caused or is likely to cause death or serious injury.

*Figure 6 - Extract 2 from GSIUR 1998 – guidance from Reg 34*

A registered gas engineer is guided by industry-specific guidance (GSIUP) to take action where provision is seriously deficient, as shown in Figure 7:

6.1 **IMMEDIATELY DANGEROUS (ID) APPLIANCES/INSTALLATIONS**

An ID appliance/installation is one which is an immediate danger to life or property.

Broadly, these will be appliances/installations that fail tightness tests, appliances that fail spillage tests, or appliances which have serious flueing and/or ventilation and/or combustion deficiencies.

Some ID situations will meet the criteria of RIDDOR and will require reporting (see clause 8.3).

With the gas user/responsible person's agreement, the engineer shall make every endeavour to rectify the situation(s) and make the appliance/installation safe to use at the time of the visit. Where this is not possible, the following actions shall be taken:

a) Explain to the gas user/responsible person:
   - that the appliance/installation is Immediately Dangerous
   - why the appliance/installation is Immediately Dangerous
   - that the appliance/installation MUST NOT BE USED
   - that the appliance/installation must be disconnected from the gas supply until the situation has been rectified and that further use would contravene the law e.g., GS(I&U)R Regulation 34.

*Figure 7 - Extract from GSIUP*

The above regulations do not apply to private leisure vessels or workboats, as made clear in guidance notes 67 and 68 (GSIUR 1998). Most liveaboard vessels do not receive any professional input from gas engineers, status and ownership changes, as well as DIY seem to prevent gas engineer input.

Private leisure vessels that are subject to the BSS have their requirement appraised as outlined in Figures 2 and 3. If the ventilation aboard does not meet the minimum calculated, then an Advisory fail point against check item 8.9.1 is recorded. No rectification work is required for the vessel to get a new BSS certificate, but the advisory fail point is noted on the certificate. If the provision is less than 50% of the requirement, a warning notice is issued and a CO safety leaflet is given to the customer.

Boat Safety Scheme Ltd (2024b) reports that out of 15083 pass certificates issued in a 12 month period 2023-2024, there were 2497 boats that failed to meet the minimum recommendations for private leisure vessels; 16.5% of all boats issued with a pass.

This figure perhaps requires further thought; it's probable that most vessels with a ventilation shortfall have gas cooking appliances aboard as these, being unflued, require a huge amount of ventilation compared to flued appliances such as solid fuel or diesel fuel heaters. Most boats with only flued appliances will meet BSS ventilation requirements through gaps in doors and opening alone, let alone fixed ventilators. The author previously established (2022) that around 76% of boats have gas aboard. So if 76% of the 15,083 have gas, that makes the number to measure against 11,463. This in turn means a possible 21.7% of all boats with gas have a ventilation shortfall. BSS figures for 2023-24 are higher but mirror the the author's research for the period 2016-2019; which were 14% of all passes and 19% of adjusted passes (boats with gas).

For the purpose of this discussion paper, considering that around 20% of all boats with gas have a ventilation shortfall is probably realistic.

## 3. Considering ventilation design

Design of ventilation – as opposed to simply considering the volumetric requirement – is given little time in any available industry resource. The Canal Boatbuilding Association (1999) did not cover it. British Marine (2022) in their *Inland Boatbuilding Code of Practice* make brief reference to it as shown in Figure 8, stating:

> *Adequate ventilation must be provided to prevent hazards from leaks and products of combustion….Sufficient cabin ventilation is required and the Boat Safety Scheme is a useful guide to the requirement. (British Marine).*

*Figure 8 - Extract from British Marine, boatbuilding guidance*

However as the BSS (2024c) makes clear it's remit is limited to safeguarding 3rd parties as shown on Figure 9, stating:

> *The BSS is in place to help minimise the risks to all visitors to the waterways and the waterways' workforce, and to help protect adjacent property*

*Figure 9 - Extract from BSS webpage about scope of scheme*

The ventilation checks completed by BSS examiners are then a simple volumetric check of required amounts and actual amounts (as per Figures 2 and 3). There is no consideration of the design or test of the effectiveness of the ventilation, perhaps because that is not within the remit of the BSS, in the same way as a car manufacturer designs a window wiper system, but the MOT tester just sees that it clears a screen at a moment in time.

However, Figure 8 shows boatbuilders are being guided to use the BSS system as a design aid, yet the BSS system does consider design in any detail. A generic assessment tool is a dubious aid to design as it does not assess suitability or measure effectiveness which are responsibilities of a manufacturer. The BSS, as it must, falls back on the published standards, but as discussed these have their root in a system established 46 years ago for a small, light-use leisure industry. The BSS and their examiners are now assessing requirements for what is now a small residential town; suddenly the Navigation Authorities are responsible for something very significant indeed.

Industry workers conscientious to look for other help will find no design guidance from other classes of vessel. The Inland Waters Small Passenger Boat Code (2007) at section 21.5 simply states compartments should be ventilated and references the standards discussed above.

PD 54823:2016 provides some limited design guidance as seen in Figure 10:

**JMENT** **PD 54823:2016**

Ventilation should be supplied by at least two equally sized fixed openings in the accommodation space, with one opening as high as practicable and one as low as practicable. Both openings should be positioned or shielded such that they cannot be inadvertently obstructed.

*NOTE 4 The fixed ventilation may be divided as equally as practicable between high and low level, by singular or multiple ventilators.*

Where ventilation air is ducted to a space from an outside source, the duct cross-sectional area should be maintained throughout its length, the duct should be securely fixed and accessible for inspection, and the duct should not have forms that can trap liquids.

Ventilation systems passing through engine spaces for appliances and accommodation areas should be avoided.

Adjustable ventilation provided by openable windows, roof lights or hatches should not be included in the calculation.

Ventilators that have variable settings should only be included in the calculations at their lowest optional rating.

Ventilation should be provided through, or around, cockpit coverings over an area leading to a fixed ventilator, equivalent at least to the size of the fixed ventilator.

Ventilation systems should be designed to avoid draughts.

*Figure 10 - Design guidance from PD 54823:2016*

Here it is clear that openable sources cannot be counted, but does hint at a notion of 'dynamic' ventilation, with their volume at 'lowest optional rating' being counted. An adjustable but not entirely closeable ventilator sounds promising for our modern boater, in contrast to the current "always open" fixed ventilator common on the modern fleet. Even the closeable dispensation for sea-going boats has disappeared, last seen in PD 5482-3:2005, as shown below in Figure 11:

Ventilators should be weathertight in accordance with conditions the vessel could encounter. Vessels that regularly go to sea may be fitted with closable ventilators if severe weather conditions could be encountered. If closable ventilators are fitted, a warning should be permanently attached on or near to cooking appliances as follows: "WARNING: Open ventilator before use".

*Figure 11 - Extract from PD 5482-3:2005 sea-going ventilation*

This allowance for sea-going vessels was removed for reasons unknown in PD 54823:2016, but there many problems with PD 54823:2016 as discussed previously (Keeling, T. 2023).

At points in the past then, the industry seemed to be content with allowing boaters the discretion to manage their air space if they were going to sea, for obvious reasons, but the concept of freedom of choice is not alien to the inland leisure industry. It's perhaps worth looking at the leisure accommodation vehicle (LAV) requirements to compare. EN 721:2019 allows for LAV ventilation to either be calculated by physical size or for a vehicle to be assessed against the CO2 produced during a prescribed test. If the latter method is used the vehicle must be supplied with the following notice as shown in Figure 12:

**Annex A**
(normative)

**Warning notice**

**If the leisure accommodation vehicle is tested in accordance with Clause 6, a permanent warning notice (see Figure A.1) shall be affixed adjacent to the grill, cooker and oven in a position where it can be easily seen, and in the language of the country in which the vehicle is first sold.**

**WARNING**
When you are cooking, it is essential to provide additional ventilation, such as opening windows near the grill, cooker and oven. Do not use cooking appliances for space heating.

**Figure A.1 — Warning notice**

**The lettering of the heading shall be in capital letters, not less than 6 mm in height and in the colour red. The rest of the text shall be printed in black and no letter shall be less than 3 mm in height.**

*Figure 12 - Extract from EN 721:2019 for LAV ventilation*

While EN 721:2019 is referenced in the bibliography of ISO 10239:2017 as being a source of further information, there is nothing relative to boats in it. The CO2 test described would only be of use for a large production run of similar vehicles, as opposed to boats that are all different or made in only small batch numbers.

The closest similar discretionary advice given to consumers on boats appears with an asphyxiation warning label which first appears in ISO 10239:2000 and is reiterated in all following standards, an example of which is repeated below from PD 54823:2016 and shown in Figure 13:

> For cooking appliances, a permanent, legible warning label, with a minimum character height of 4 mm, should be affixed in a conspicuous position on or adjacent to the appliance (cooking stove or oven). This label should provide at least the following information, in a language acceptable in the country of intended use:
>
> | |
> |---|
> | **DANGER.** Avoid asphyxiation. Provide ventilation when the stove is in use. Do not use for space heating. |
>
> *NOTE 6 The label is not required if permanent unrestricted ventilation, as recommended in Annex C, is provided for all the appliances within the accommodation area.*

*Figure 13 - Extract from PD 54823:2016 showing asphyxiation warning*

This itself is a confusing and contradictory section of the PD document, because it seems to suggest that the label precludes the requirement for full fixed ventilation (for example, if there were closeable vents), yet nowhere in the document is there an allowance for closeable vents (not even for sea-going vessels). It seems to have copied the label requirement from ISO 10239:2000, but added Note 6 for sea-going boats with closeable ventilators that used to be allowed in PD 5482-3:2005, which the subject document itself no longer permits… It is impossible for a consumer to make sense of this. In short, PD 54823:2016 is again shown to be unreliable with vital safety guidance.

The problem this creates for UK small craft is that ISO 10239 is an over-arching international standard that provides high-level best practice guidance for numerous countries around the world. It provides a harmonised standard approach for the Recreational Craft Directive. It does not seek to deal with the liveaboard town of boats in the UK, which is why the PD document is so vitally important. The PD document feeds into gas safe engineer training and the BSS procedures and training, neither of which will be likely to change until the PD document does.

## 4. Ventilation inequality

Returning to the calculation made in Figure 3 for the example boat, 71% of the total ventilation required is mandated by the cooker, which as an attended appliance is only used for a relatively short period of time. Being attended means users are at the appliance most of the time, adjusting and working. Many open hatches and doors anyway (almost all liveaboards say this when discussing use). The requirement for ventilation is assessed on the cooker fully operating with every burner on maximum.

Overnight the user might have the solid fuel stove on when they go to bed, and maybe the diesel heater on a timer in the morning. These two combined appliances account for 16% of the requirement. However this small requirement should not drive complacency; given certain circumstances such as a faulty exhaust, an in-cabin appliance location and inadequate ventilation, deaths do still occur (MAIB, 2021).

The number of people aboard is also a factor that is unequal to reality in most cases. Most occupation is by one or two people, yet the fixed ventilation is calculated on the maximum occupancy, which on modern manufactured boats is determined by a CE plate, on older or privately built craft by number of berths. Some manufacturers stamp a plate with a number that allows day guests, for example 10 total, but again in most circumstances guests are gone by the small hours.

So in reality, at 3am on a cold night, the sole occupant who uses the solid fuel stove only requires a relatively small amount of ventilation, as Figure 14 shows:

| | | |
|---|---|---|
| 1 person | (1 x 650) | = 650mm2 |
| Diesel central heater, flued, cabin, 5kw | (0 x 440) | = 0mm2 |
| Solid fuel stove, 5kw | (5 x 550) | = 2750mm2 |
| | V | = 3400mm2 |

| | |
|---|---|
| Required amount at 3am | = 3400mm2 |
| Calculated amount from Figure 3 | = 30850mm2 |

*Figure 14 - Actual verses calculated ventilation, 3am*

The required amount of ventilation overnight in the example given is just 11% of the calculated amount. There is by any measurement an over-requirement here.

However, latest incident data published by BSS Ltd (2024) for a 12-month period within 2023-24 seems to suggest ventilation aboard small craft is successful, with only 3 CO incidents being recorded, similar to data available for other years (Keeling, 2022). Further supporting to role of ventilation is the relative lack of gas explosions versus reported gas leaks. BSS data suggests around 10% of boats have gas leaks, with a possibility that the figure is higher. Gas engineers believe leaks do not always cause explosions in part due to dilution caused by fixed ventilation (Keeling, 2022).

Many would argue that having over-ventilation, while not being directly called for at 3am, has secondary advantages to the occupiers such as assisting with condensation and scavenging bilges. These advantages might be considered to outweigh the (unresearched) disadvantages of heat loss and third party pollutant ingress.

## 5. External evidence

The impact of external 3rd-party generated pollutants affecting boat occupiers is well known and documented. It does not take a lot of research to find stories of boaters being affected by neighbours. There is also a developing interest in formal research.

The Building Research Establishment (BRE) (2018) completed an investigation into air quality on boats in 2018, finding in various scenarios that air quality aboard was affected by emissions from neighbouring boats, including:

- High concentrations of CO from a petrol-engined generator
- High concentrations of Nitrogen Dioxide from a diesel inboard engine
- Excessive concentrations of particulate matter from solid fuel stoves

*Figure 15 - Extract from BRE report on indoor air quality on boats*

In contrast, they found gas cooking hobs affected air quality aboard subject vessels but not neighbours. One recommendation made might have helped in all three of the case studies in this paper – the consideration of extension pieces to solid fuel stove chimneys for vessels in marina environments. This obviously increases the height of the discharge of pollutants, aiding dispersal, but in some situations will increase draw and aide full combustion.

The BSS (2018) completed a public consultation to look at whether to introduce CO alarms on private boats which became a requirement in 2019, the BSS stating:

> ***2.2 Why now were mandatory new BSS Requirements being considered?***
>
> *In the past two years new information about the potential risk to boaters presented by CO has brought the need for action into focus. From the recent evidence collected, people and their pets aboard their own boats are at medium risk of CO poisoning from sources of CO generated outside of the boat by others e.g. the use of engines and appliances on adjacent boats.*

*The recently identified potential risk cannot be controlled by boat owners themselves. The risk is enhanced by the fact that CO is a hidden danger.*

*Figure 16 - BSS statement about external CO risks*

In closed season 2018 the author completed a series of CO detection exercises to see whether CO was entering hire boat accommodation spaces from incorrectly located gas boiler flue outlets. This involved monitoring of air within the cabins of selected boats while heaters were routinely operating. There were around 25 boats moored in close proximity to each other. In the case it was found that none of the heaters introduced CO to the cabins, however, once a month all the engines in the fleet were run up; the diesel exhaust emissions entered the cabins and a rise in CO could be seen.

A study for Imperial College by Casey, Greive and Fuller (2021) noted that as well as in-cabin activities such as cooking and fire making increasing indoor pollutants, that fumes from other sources also enter the accommodation space, as shown in Figure 17:

> Many of the highest Black Carbon air pollution measurements were during periods when the engine was in use for either charging batteries or moving the boat, resulting in emissions from a boat's diesel engine entering the indoor living area (Casey et al. 2021).

*Figure 17 - Extract from research by Imperial College*

In this example the diesel engine emissions from the boat were negatively affecting air quality aboard the owner's boat.

The BBC (2023) reported boaters complaining of being "nearly choking" as a result neighbour's emissions.

Canal and River Trust (2024) give stark guidance on the risks on pollutants to others when double mooring, stating:

> *When mooring up consider where your engine and/or generator exhausts are positioned relative to the other boats as you don't want to fill them up with toxic*

*fumes. Be very careful also about fumes from your solid fuel stove entering other boats.*

*Use your stove wisely and efficiently. Every year boaters die or become seriously ill as a result of carbon-monoxide poisoning.*

*Figure 18 - CRT warning, double mooring*

Local authorities are becoming increasingly aware that boats in their districts have a localised impact on air quality (Newham Council, 2021. Hackney Council et al, 2024). Proposals for new smoke control areas to include waterways are being proposed (Hackney Council, 2024).

Research is now underway in London, reports the CO Research Trust (2023); this can only be a positive and it is hoped the findings will help develop meaningful policy that will help safeguard boater's health.

The case studies on the next pages also indicate 3rd-party pollutants are causing both acute and chronic CO incidents.

## 6. Real world problems – Case Studies

Here are three examples of where design and circumstances have coincided to cause boats with calculated correct ventilation at risk of poisoning from neighbouring boats.

Case Study One

A rental liveaboard narrowboat in a full enclosed urban setting reported CO alarm activation in the early hours of the morning. The vessel is around 60' long, and has x 2 CO alarms, one forward one aft. The sleeping accommodation is aft, there is then a bathroom, galley amidships and saloon forward, with a diesel room heater. The heater was operating but no other fuel burning appliances were in use. The tenant called the fire brigade out who attended and conducted a check, using a meter they identify a CO concentration aboard in the galley.

The author attended the boat the next day for the owner and met the tenant, and completed some basic checks of the gas system and other systems. Batteries that are gassing are known to trigger CO alarms, but the batteries are aft in a cruiser stern and fairly well sealed from the accommodation space, and besides the first alarm to activate was in the forward saloon, not the alarm aft. Checks of the diesel room heater do not reveal any issues with the flue and no signs of poor combustion or blockage. A smoke match test shows the chimney drawing well and free of leaks.

Thinking on where the fire brigade found the CO concentration, which was the galley area, the main CO producing appliances were off – it was night and the user was in bed. The gas appliances operated satisfactorily with blue flames and no evidence of issue, and there seems no reason for the occupant to be dishonest about usage.

On the neighbouring boat there was a solid fuel stove with chimney corresponding to the amidships area of the subject vessel. Further investigation revealed the owner was banking up the fire with smokeless coal in the evening and letting it burn out on a low burn. The appliance is of a make and model that is extremely popular on boats but the reality is that since the DEFRA approval scheme the manufacturer only specifies that seasoned wood is a suitable fuel[1], despite previously released models of the same stove using both wood and coal, and being approved as such by the manufacturer. The appliance was operating poorly, evidenced by a heavily sooted door glass. It is possible then, that as the fire becomes cool, the products of combustion were no longer being propelled into the atmosphere but were instead coming out and settling over a localised area; an extremely still night meant no air movement. In the galley of the subject boat – as with most boats – is a roof ventilator, this is in line with the chimney of the neighbouring boat and is separated by the width of jetty and tumblehomes.

Mitigating the above scenario needs a combined approach, as simply blocking the one roof vent in the subject boat in an attempt to prevent ingress of products of combustion could be futile; there would be other openings, different winds, other faulty appliances. Relocating the boat would work, unless the new neighbour also has the same situation. It is a point worth noting though, that at the time the subject boat was being infiltrated by CO from an outside source - while asleep - the ventilator in the galley was not helping at all. Figure 19 illustrates the marina environment.

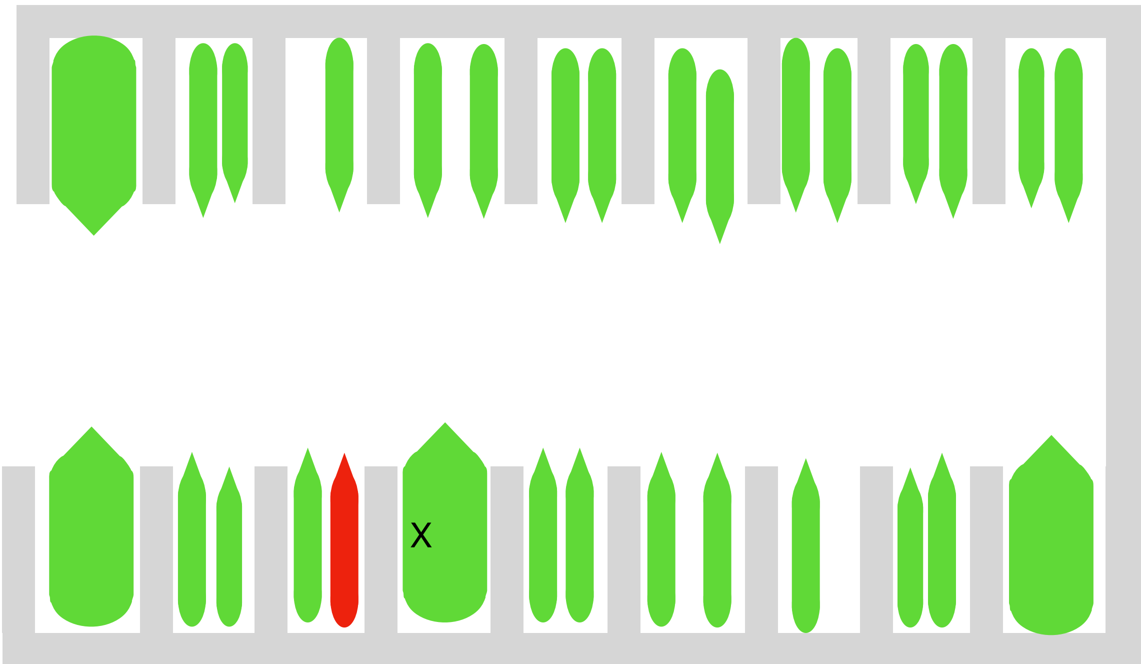


*Figure 19 - Red is subject boat, x denotes poorly operating solid fuel appliance*

[1] Despite the appliance not being recommended for use with coal, the manufacturer still sells coal inserts / economisers for the appliance. Conversations with the UK supplier of the appliance following the above incident questioned whether – with a DEFRA stove and reduced air inlets – there could ever be enough flue height for a short chimney (as is default on a boat) to draw properly in low temperature scenarios with coal.

 

Case Study Two

A private liveaboard boater stopped the author in a marina to ask for advice; his boat class is familiar to the author. He had recently had numerous CO alarm activations and was concerned about their on board appliances. The male, in his middle age, appeared with cold like symptoms and a slightly red face and reported suffering headaches. When asked he was pretty confident he is suffering from CO poisoning. The vessel has a proprietary diesel heater aboard in a separate cruiser stern engine room, with no faults reported. There is no solid fuel stove aboard. The single gas appliance – a cooker - was not in use at the time of alarm activation, the owner also stated he had stopped using it altogether as he was becoming increasingly concerned for his welfare and was new to boats.

The boat is moored in a line of liveaboard boats in a marina environment though it is not urban. The neighbouring vessel uses a solid fuel stove, as do others in the marina. After discussing various factors to do with his own boat, he agreed to relocate the vessel away from the marina environment and also purchased x 2 new CO alarms, and later confirms no alarm alerts at all. He returns to the mooring and moors the boat the different way round and no further problem is reported. He believes that the products of combustion from his neighbour's solid fuel stove were entering his boat through the aft doors and hatch gaps, which are reported to be considerable in size (at least 12000mm2). The front of the vessel is altogether better sealed up and the smoke from the neighbouring vessel does not have as many places to enter the subject vessel. In a photo submitted to the author, the neighbouring boat's chimney is at the forward most, and aligned with the cabin of the subject boat. It is easy to see how with the vessel moored the other way round and with large gaps how the smoke can enter, it can only be a distance of 2.5m maximum between the solid fuel stove chimney top and aft hatch.

Figure 20 shows a photo submitted by the owner, with neighbouring boat showing solid fuel stove smoke. The subject vessel is shown after being turned round, with the gaps in the aft hatch now far away from the smoke.

*Figure 20 - Case study 2 is the centre left, shown after the vessel had been turned around*

Case Study Three

A Webasto service agent attends a boat for a pre-winter service, which he completes. The next day the owner calls and reports a CO alarm activation. The agent returns to the vessel, feeling there is a duty of care, although the heater unit is located at the other end of the vessel to the alarm and the likelihood of any CO emission being the heater is slim. On returning to the vessel the agent assesses the heater with laptop and software and finds the combustion levels and emissions are correct, and looking around notes the proximity of an adjoining vessel's solid fuel stove chimney, and the very short chimney on the roof. It had been a damp foggy night and the emissions from the neighbouring boat in the marina had caused the CO alarm to activate.

Reflection

All three boats exceed the minimum requirements for ventilation according the relevant International and British Standards, and local BSS requirements. Two boats have had gas landlord certificates and all three had BSS certificates. All boats are in good order with conscientious and careful occupiers. All boats have been subject to infiltration of CO from third party sources through their fixed openings, and all had CO alarm activations aboard as a result. One of the boaters was actually poisoned. Relocating the vessels in two of the cases resolved the problem, the outcome for Case Study three is not known.

Note: The BSS introduced mandatory CO alarms on all vessel with accommodation spaces in 2019 (BSS, 2019). The three examples above prove their worth without doubt, although CO alarms do not detect long-term low-level CO (Kidde Safety, 2021) which can cause chronic health issues (Croxford et. Al, 2008). Furthermore, the BSS (2024) reports that of 22,000 examinations completed, 1900 recorded a lack of a CO alarm (8.6% of all boats examined). The data for how many had CO alarms but did not operate was not included.

The BSS does not assess the design of flues on boats, but looks at whether they are free of damage and holes etc, which could introduce products of combustion into a cabin space of the boat being examined. Solid fuel stove manufacturers rarely specify design requirements (or even express suitability) for use on boats. There is some guidance available (BS 8511:2010 *Code of practice for the installation of solid fuel heating and* *cooking appliances in small craft*) which various outlets publish (Guild of Master Chimney Sweeps, unknown date). They advise various steps to increase combustion efficiency such as insulated chimneys. They also specify requirements for the external part of the chimney as shown in Figure 21 below:

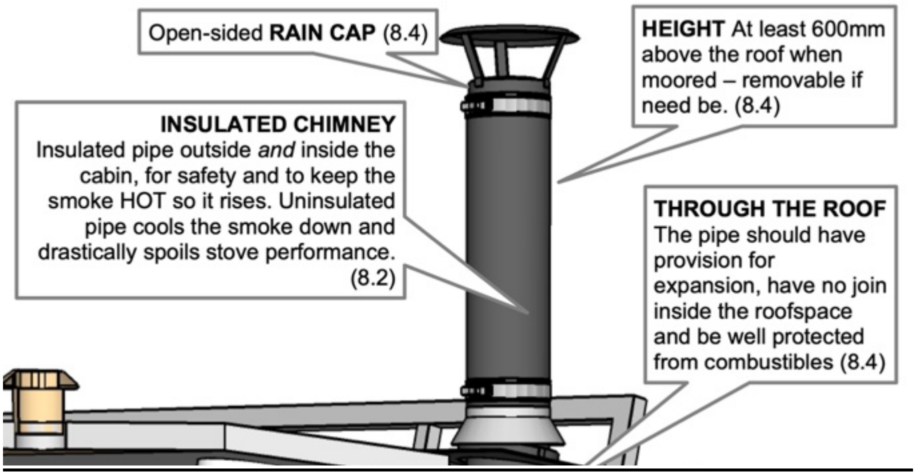


*Figure 21 - Extract from Soliftec BS 8511:2010*

As the drawing shows, the external part is insulated and minimum 600mm high; the external chimney affecting the subject boat in Case Study 3 was 250mm high, single walled. Most are; search for “narrowboat chimney” (Google, 2024) and there are many 250mm examples available, as Figure 22 shows:

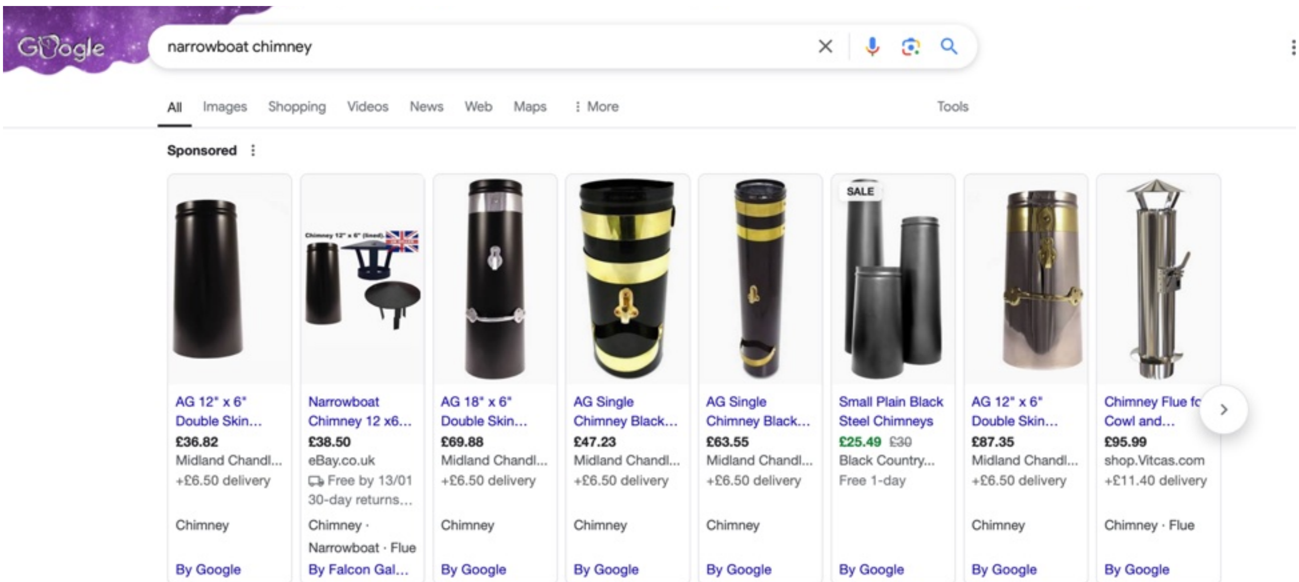


*Figure 22 - Google search for "Narrowboat Chimney"*

Taller chimneys can be bought, but in the main boats have shorter chimneys to avoid damage when out in use, with a taller reserve for marina use not a norm. CRT census (2022) shows 66.6% of respondents have a solid fuel stove, with a further 2.5% of respondents having a solid fuel stove for cooking; anecdotally the vast majority of liveaboards use solid fuel stoves.

As discussed, liveaboard boats are often located in large marinas, and a quick check of the terms and conditions of marina mooring agreements available online often shows such moorings are not to be used for residential purposes, nor can any vessel located in such marinas be let out to a tenant, yet many marinas have a liveaboard population as everyone knows. However, the marina designers are presumably considering the leisure use of such facilities, with occasional overnight stays on a largely seasonal basis, yet the reality is we have lines of closely arranged liveaboards all burning carbon fuels to stay warm. The boater is not to blame for the convergence of all these factors. If a marina designer was told to accommodate numerous boats burning carbon fuels, undoubtably their approach to layout – particularly proximity - would be influenced.

Pretty much every marina has lines of boats with chimneys in close proximity to neighbours.


*Figure 23 - A not uncommon marina scene*

## 7. Considering dynamic ventilation

One simple answer seems to be to make some ventilators closeable so that an occupier can choose to manage their own air space and exposure. There is nothing that prevents that happening now on a private boat, because even if the vessel had zero ventilation it can still be issued with a BSS certificate, gain a licence and be lived on (it would also receive an Advisory fail, warning notice and CO info leaflet). However it is impossible to advocate for a position where no or low ventilation is the default OK. It is also hard to understand why the industry can't work with a background minimum and a warning label on a cooker that states "open ventilators when in use" or similar, like the LAV world does (Figure 12).

Meeting the minimum recommended ventilation is strongly recommended by so many sources any deviation seems to go against the flow. A simple google search for "BSS ventilation requirements" returns a large amount of web sources all stating that ventilation aboard a boat is essential to prevent carbon monoxide buildup, yet in the case studies all boats were affected by carbon monoxide from external sources, leading to a poisoning event. It's worth noting these are just three 'to hand' examples, there will be many more out there. There will be even more where alarm activation has never occurred but low-level CO exposure does.

The case study boats are lived on, with neighbouring boats also lived on, all these boats are being used in a way and in an intensity that the ventilation requirements for boats did not have to consider in the same way as now. In 1979, liveaboard boats were an exception, large marinas with 100s of boats lined up in rows did not exist. Usage was largely light, leisure and seasonal. Culturally people were different, taking much more responsibility for their own fate as compared to now. CRT (2022) found 16.3% of respondents to their Boater Census have lived aboard for less than 1 year, 25.3% stating 1-2 years, corroborating anecdotal evidence that post-COVID there was an influx of new liveaboards; many of these will have no boat experience and rely on the safety frameworks available, perhaps assuming their safety is in part managed for them. Combined, the above numbers indicate 41% of respondents have lived aboard less than 2 years.

The Advisory nature of the ventilation check (8.9.1) completed on private boats during BSS examination relates to a core risk focus of the BSS, this being to protect third parties from each other, the idea being that poor ventilation on a boat affects the occupiers not the 3rd party waterways user (fisherman, boater, cyclist). It seems an impossible place to be for the BSS, they can only assess what is there against a criteria as is the present process; assessing the design or effectiveness of dynamic ventilation cannot be effective on an object that moves and can encounter different situations every day. In case study 1, blocking the galley high level ventilator would have prevented the ingress of CO, on that night. The next day it might not, and if it had been blocked it might not be unblocked by the user, resulting in inadequate ventilation when the cooker was used to cook breakfast.

The advisory nature of the ventilation check for private boats does however challenge the efficacy of this check. In conversation, boaters often struggle to understand what is an advisory check, because to them something is either dangerous or it is not. Many BSS examiners, registered gas engineers and marine surveyors are uneasy with the advisory nature of the check (Paris, 2022), and it is hard to explain to a customer. Often they do not hear the part about it being "advisory" just the bit about "inadequate ventilation" and the next question they ask is how to resolve it, placing the BSS examiner in an uncomfortable and often unqualified and uninsured position of giving advice. At best they can do is say "add more ventilators", which can result in the boater cutting holes in doors at will to deal with the danger. Some reach for the multi-tool and hack out a square in the door there and then; whereas careful placement of a scooped or ducted ventilator might be more suitable. In adding random holes to doors there is no design or thought about external factors this could introduce. For our novice liveaboards, this is all new and a problem to be dealt with ASAP; many bought boats post-Covid with no survey and often without sight of the BSS paperwork, so are unaware of an advisory fail issued at the last examination and detailed to a previous owner.

It's clear that the current method of calculating ventilation requirements aboard small craft does not consider the effects of neighbouring stationery boats bunched together, but focusses on the requirements for the people and appliances aboard a boat used for navigation. The design of ventilation does not consider CO from other vessels nor is there any indication that any consideration has been given – and perhaps has not been previously needed - to how boats are often stacked in lines, in close proximity to each other, in sheltered environments, all lived on throughout the year and all burning carbon fuels to stay warm.

If all ventilators aboard a boat were closeable, there could be easily be a situation where these remain closed by accident or intent and cause other problems. There is some sense then in providing over-ventilation and enabling occupants to close off some of them. For example providing four low-level ventilators where only two would be necessary, and providing stoppers for just two of them along with a design statement, and possible a warning notice at the cooker.

Take our example boat discussed in Figure 2. To recap, this was the ventilation requirement for Christmas day:

$$V = (2200 \times U) + (650 \times P) + (440 \times F) + (550 \times H)$$

| | | |
|---|---|---|
| Cooker, unflued,10kw | (10 x 2200) | = 22000mm2 |
| 6 persons | (6 x 650) | = 3900mm2 |
| Diesel central heater, flued, cabin, 5kw | (5 x 440) | = 2200mm2 |
| Solid fuel stove | (5 x 550) | = 2750mm2 |
| | V | = 30850mm2 |

30850mm2 divided equally between high and low levels = 15425mm2 each.

At night the vessel requires much less:

| | | |
|---|---|---|
| 1 person | (1 x 650) | = 650mm2 |
| Diesel central heater, flued, cabin, 5kw | (5 x 440) | = 2200mm2 |
| Solid fuel stove | (5 x 550) | = 2750mm2 |
| | V | = 5600mm2 |

The vessel could have ventilation configured as follows in Figure 24:

| Vent Name | Vent Type | Location | Apertures | Air per vent | `Number | Sub-Totals | Totals |
|---|---|---|---|---|---|---|---|
| **Low Level** | | | | | | | |
| A | Grille | F Bulkhead, port | 100x6x10 | 6000 | 1 | 6000 | 24000 |
| B | Grille | F Bulkhead, s/b | 100x6x10 | 6000 | 1 | 6000 | |
| C | Grille | A Bulkhead, port | 100x6x10 | 6000 | 1 | 6000 | |
| D | Grille | A Bulkhead, s/b | 100x6x10 | 6000 | 1 | 6000 | |
| **High Level** | | | | | | | |
| A | Mushroom | Cabin Top, Saloon | 100mm diameter, open | 7855 | 1 | 7855 | 27492 |
| B | Mushroom | Galley | 100mm | 7855 | 1 | 7855 | |
| C | Mushroom | Bedroom | 100mm | 7855 | 1 | 7855 | |
| D | Mushroom | WC | 100mm diameter, fan | 7855/2 | 1 | 3927 | |

*Figure 24 - Typical ventilation provision, narrowboat*

For Christmas Day the vessel is considerably over-ventilated. At night, there is an option to close off some of the ventilators and still provide adequate for the in-service requirements. If just one each of the high and low levels were left active, the provision would be adequate. The occupant could select which to leave open based on the position of other vessels outputs and required comfort levels aboard.

There would need to be a fully backed information campaign with a useable resource as well as supporting research to credit something like dynamic ventilation, but it doesn't seem too difficult to imagine there being a tiered assessment, with "full use / peak" and "low use / off-peak" options.

## Summary

The time seems right for an appropriate agency such as BRE or other resourced organisation to conduct research into what a boar really needs for the occupants to remain safe from all eventualities.

It is hoped that in the near future PD 54823:2016 can be thoroughly reviewed by experts in the field and finally made in to the document needed to support boaters. As part of the transformation, it is possible that the longstanding ventilation requirements can be reviewed and revised to match the modern world. The “design” based approach advocated in this paper might amend the 46 year old method and help make it suitable for the environment the boater faces in 2025.

There seem to be several converging factors that are influencing boater safety:

A. Ventilation requirements are calculated on a Christmas Day event, on a worst case scenario and while at peak in-service times this level of ventilation is required, at other times it could actually be exposing occupants to CO and other products of combustion from third parties.
B. Design systems for ventilation aboard boats is poorly researched and scantly documented; guidance documents are vague and the industry seems to rely on the BSS for direction, but the BSS remit does not extend to design, instead it is a basic volumetric assessment.
C. The calculations used to decide ventilation on small craft have not been revised for nearly 50 years, and are now arguably outdated in many cases as boat use and population demographic has significantly changed.
D. The demographic change means many more liveaboards and these often found together in marinas. The vast majority burn carbon fuels to cook and heat, meaning localised emissions have increased beyond anything existing guidelines were established to deal with.
E. Design, correct installation and use of appliances can influence pollutant output, but there is no measure of this, for example the design of solid fuel appliances and chimneys on boats is not assessed or enforced.

F. There is growing evidence supporting anecdotal reports that occupants of boats are at risk of both acute and chronic CO poisoning from neighbouring boat emissions, with CO entering through openings including fixed ventilators.

Moving forward, the following points should be further considered:

1. The usefulness of thoughtful ducted low-level ventilation could be considered, as an alternative to blatant door cut-outs. These must be serviceable to ensure it can be maintained and dimensions maintained through any ducting cross-section.
2. The concept of dynamic ventilation should be considered to help boat occupants mitigate the effects of poor air from surrounding vessels. A boat could be provided with much more fixed ventilation than is required, giving an occupant options to close off some vents – to match an environment – while the remaining amount remains adequate for the current in-service requirements.
3. The concept of peak and off peak ventilation could be considered for boats with cookers, with appropriate design and warning labels.
4. Correct appliance use should be encouraged; burning good fuel at the right temperature for solid fuel stoves is essential. Correct installation of appliances should be encouraged and this message should be communicated to boaters.
5. The impact of chimney height in marinas should be considered and previous studies and recommendations revisited; marinas could encourage taller chimneys amongst boaters while moored.
6. CO alarms with ppm read outs should be encouraged, because these can help boat occupants monitor CO levels at pre-activation levels. There is currently no other way for boaters to safeguard against extended exposure to low-level CO exposure from external or internal sources.

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## Notes to Editors

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