The Unsinkable Dragon.
A report by Ron James on behalf of a Subcommittee of the Technical Committee. March 2020

1. **Remit**

The remit of the Subcommittee set by Klaus Diederichs was
"to review the recent incidents of Dragons sinking and near sinking and to consider the safety of Dragons and evaluate what can be done to make the boats safer once filled with water and suggest measurers to make the Dragon truly unsinkable (if possible)."

2. **Subcommittee Membership**

The members of the Subcommittee were
Ron James, Chair
Tim Tavinor
Joop Doomernik
Peter Liebner
with contributions from members of the Technical Committee.
However, no responses were received from emails sent to Peter Liebner perhaps partly because, somewhere along the way late in the process, his email address was corrupted then this copied using the "reply all" button.

3. **The Technical Bit (for non-technical readers).**

A stationary object (i.e. no lift from foils) floats when placed in a fluid if the weight of the object is less than the weight of fluid it displaces. If it floats, the depth at which it floats is that depth where the weight of the displaced fluid equals the weight of the object. In our case the object is a Dragon and the fluid is water. If we consider a dry (inside) Dragon with no positive buoyancy, floating in sea water, for each litre of sea water that is then poured into the Dragon it will float slightly lower displacing exactly one additional litre of sea water. If water is continually added, because the materials from which the Dragon is constructed are mostly heavier than water, there will come a point where the weight of the Dragon plus the weight of the water it contains, together weigh the same as the water a fully submerged hull displaces. If any more water is added the Dragon will sink.
The weight of a given volume of a substance is called its density, which is usually measured in kilograms per litre (Kg/l). The density of some substances is listed below in Kg/l:
Pure water at 4 degrees centigrade 1.000
Pure water at 25 degrees centigrade 0.997
Sea water at 25 degrees centigrade 1.025
Ice at 0 degrees centigrade 0.917 (this is why icebergs float 90% submerged and ice floats in your G&T!)
Human bodies (average build and lung capacity) 0.985
Dry Air at 0 degrees centigrade at sea level 0.00125 (humid air weighs less than dry air, air weighs less at higher altitude and hot air weighs less than cold air, hence clouds float in the sky, and hot air balloons work).
For our purposes it is sufficiently accurate to assume that water and humans have a weight of 1 Kg/l and air weighs 0 Kg/l. It follows that positive buoyancy is provided by air space within the Dragon **that cannot be replaced by water**. This means that, if there is enough positive buoyancy, the weight of water displaced by a hull will always be greater than the weight of the hull with water filling all the space it can occupy, and the Dragon cannot sink. Note that it does not matter where the air-filled space is, so long as it takes up space the water would otherwise occupy. Although the position of the buoyancy can affect the stability of a submerged object, the heavy keel of a Dragon means it will always float the "right way up".
The minimum all up sailing weight of a Dragon is 1700 Kg. Adding the weight of things not included in this weight (anchors, batteries, sails etc) and 285 Kg for the crew plus items they take onboard

gives a weight of approximately 2100 Kg. The latest Class Rules [CR's] require 2500 Kg of positive buoyancy i.e. 2500 litres of sealed air, so why do these boats still sink? The reason is that much of this so-called positive buoyancy is air in the front and rear tanks and these tanks are **not** watertight. In calm conditions a Dragon that comes upright after a knockdown will float with the holes in these tanks above the level of the water in the boat, however, in waves the continued ingress of water and the consequential pitch of the boat from the waves lead to these tanks slowly filling with water thereby reducing the buoyancy they provide. Leakage through the "sealed" inspection hatches will exacerbate this effect.

4. "Y RED" Sinking and "Louise" near sinking.

Y-Red sunk returning to harbour after racing in Cascais in high winds with large waves when Helm, Peter Gilmore slipped and the boat unintentionally tacked with the main cleated and genoa backed resulting in a knockdown which lasted long enough for the boat to come upright but full of water. The boat stayed afloat for some 3 to 4 minutes but with waves coming over the cockpit coaming faster than the water could be bailed out. Peter's crew told me that the front hatch then imploded and the boat sunk stern first. Sinking stern first seems to be the common feature of all recent sinking events.
In similar wind and wave conditions, Louse had a knockdown while racing in Sanremo but on this occasion helm Grant Gordon and his crew of 3 managed to get the swamped boat into harbour in spite of waves entering the cockpit as fast as they could be pumped and bucketed out. The CR's were changed following the latter incident to allow more than one electric pump.
Both these Dragons were relatively new and helmed by very top-class helms with very good, experienced crews, showing that sinking can happen to anyone. These incidents also show that modern Dragons have almost enough buoyancy to prevent sinking ***provided that*** hatches are strong enough and properly secured and that pumps are well maintained and batteries charged. Never the less, it is clear that if swamped for a few minutes in waves, because there are control lines passing through the bow and stern buoyancy tanks, these gradually fill with water. There is then insufficient buoyancy and because the position of the cockpit fore and aft governs the relative volume of the bow and stern tanks meaning that the stern tank is smaller, the boat sinks stern first. Both these Dragons happen to have been made by Petticrows and before either incident occurred, the bulkhead and hatches strength had been increased, new firmer closures fitted to the hatches and two pumps with two batteries included in the latest models. Even so, it is believed that these improvements alone would not have completely prevented these boats sinking.

5. The Ideal Solution.

The Subcommittee believes that the ideal solution

A. Should not alter the appearance of the Dragon;
B. Should be applicable to both new boats and the installed base of existing Dragons;
C. Should be easy and not too expensive to retro fit;
D. Should not alter the sailing characteristics of the Dragon, in order not to split the Class

6. Solutions Considered and Rejected

Of the 10 suggested solutions considered 9 were rejected. Briefly, these were
(i)Fitting Self-Bailers. While self-bailers may supplement pumps in removing water when the boat is moving, it is considered that the Dragon is too slow for self-bailers to work well especially in a swamped boat following a knockdown. In this condition self-bailers would do nothing to prevent sinking.
(ii)Self-Draining Cockpits. To be self-draining, the floor in the cockpit and under the cuddy would have to be at least 250mm higher than the current floors in new Dragons. While the additional under floor buoyancy would help, such an increase in floor height is considered impractical and it would be difficult and expensive to retro fit to existing Dragons.

(iii)Narrower cockpits. Narrow cockpits/wider side decks, as found in many P&T Dragons, undoubtedly make it make it more difficult for water to enter the boat when it is heeled, however they would not prevent swamping in the event of a complete knockdown and would not be easy to retrofit to existing Dragons. Conversely, allowing outward sloping cockpit coaming exacerbates the problem making it easier for water to enter the boat when heeled.
(iv)Higher Cockpit Coaming. Higher cockpit coaming would also both make it more difficult to swamp a boat in a partial knockdown and make it more difficult for waves to enter the boat when it became upright, however in increase of at least 5 mm would be needed to have any meaningful effect. This would make moving to a hiking position more difficult and it would be a difficult and expensive retrofit to existing boats.
(v)Reduce Bilge Volume. A smaller bilge volume would mean more buoyancy low down in the hull but having inspected the bilge of the latest Petticrows V6i any further reduction in volume would make maintenance of the, now standard, two electric pumps difficult. This suggestion was rejected because the marginal increase in buoyancy is outweighed by the disadvantage of poorly maintained pumps that would probably result. This potential solution would only really be applicable to new boats.
(vi)Side Buoyancy Tanks. Both the latest Petticrows and Doomernik Dragons incorporate sealed tanks along the insides of their boats. It might be possible to fit inflatable buoyancy bags beneath the side decks and forward into the cuddy in older boats. Such additional buoyancy would be expected to help keep Dragons afloat longer but the reduced water accessible volume inside the boat will mean a given amount of water entering the boat from waves will fill the boat to a higher level, reaching the control lines holes more quickly. Side buoyancy tanks on their own would probably not have sufficient buoyancy to prevent sinking if water fills the bow and stern tanks and having inflatable bags along the sides of existing Dragons would do nothing for the modern appearance and they could be difficult to site without compromising the various control line that run beneath the side decks.
(vii) Make One or More Electric Pumps Mandatory. The current CR's allow, but do not compel, the fitting of one or more electric pumps. It is beyond question that a working electric pump, or better two pumps each with its own battery, will help to expel water from a swamped boat. If of sufficient pumping capacity they might even expel water faster than it comes in due to waves and thus prevent sinking. Moreover, having an electric pump in each of the bow and stern tanks, especially if pumping water outside the boat rather than into the cabin or cockpit, would at least increase the time before sinking and might prevent it. A majority of the Subcommittee were, however, against making pumps mandatory for two reasons; first it was said to be common sense to fit pumps without the need for compulsion in the CR's; and secondly it was stressed that many pumps, both manual and electric are not well maintained, and this is potentially a greater contributor to sinking than most things that are controlled by the CR's.
(viii)Use the Volume under the Helm's Seat. One space that could be used to provide additional buoyancy is the space under the helm's seat. This could be a sealed space and the top surface could be moulded to form the seat. In existing Dragons, a buoyance bag could be fitted under the existing seat fairly easily and without compromising control lines. While the extra buoyancy would be at the stern of the boat where it is most needed, it would not be enough on its own to have a significant effect. If it was a built-in sealed unit it would make it very difficult to fit a rear inspection hatch large enough to be useful and having a hatch is essential for maintenance. A buoyancy bag beneath the helm's seat would overcome this, but would not enhance the appearance of the boat.
(ix)Make the Bow and Stern Tanks Completely Sealed. Making the bow and stern tanks truly waterproof (as required by CR 2.192 first line, but contradicted in the final paragraph of this rule which permits holes for control lines) is not impossible and, indeed, it has been done in the past. It involved covered recessed channels within the deck to carry all the control lines and furler as permitted by CR 2.511. It was significantly more expensive to build, added weight at the ends and made the layout of the control lines more complex but it worked. The main disadvantage of such a

system is that it would not be an easy or inexpensive retro fit to existing boats. However, this option should remain available in the CR's.

7. The Solution of Choice.

The only suggestion that meets all the criteria set out in section 5 above is deployable buoyancy bags housed inside the stern tank, and very probably also in the bow tank. These bags would normally be deflated but would be inflated when needed by compressed air contained in a small cylinder. This technology is available and used, for example, in life rafts for cruising yachts. The bags would have to be firmly attached to the hull of the Dragon. Being normally deflated, the bags would not interfere with existing control lines or fittings such as the rudder tube in the stern tank or furler or spinnaker tube in the bow tank. The big advantage of this solution is that it is easy to fit and equally applicable to new build and existing boats, including those older Dragons without any bulkheads. Also, it will not alter the outward appearance of the Dragon.

Tim Tavinor had started researching this solution before this Subcommittee was formed and is in contact with potential suppliers but, unfortunately, it has taken longer to obtain samples for testing than was expected and tests have not yet been done. Tim intends to test the use of these bags by attaching a floating Dragon loosely to a crane to prevent loss if the bags do not prevent sinking, and then to completely fill the boat with water. It is not possible at this stage to give an indication of the weight of the bags and associated compressed air cylinder nor the expected cost.

8. Recommendations for the AGM.

A. In view of the fact that work on the current solution of choice is not yet complete, the AGM is recommended not to take any action on "the Unsinkable Dragon" at this time and that the Subcommittee be left in place until the test results and other information is known. It is expected that the tests etc will be complete within a few months.

B. Despite the majority view of the Subcommittee, I recommend that consideration is given to making the fitting of one, maybe two independently powered, *working* electronic pumps mandatory. While it is accepted that such a rule should be unnecessary and that it cannot ensure that pumps are properly maintained, inclusion of this on the list of things potentially examined at major IDA events should mean the pumps are at least in a working state at the beginning of these events. Testing compliance with this rule would not be difficult if competitors were asked to temporarily seal drain plugs (gaffer tape or bung) and have a bucket of water ready at inspection.

C. For the same reason, the integrity of the inspection hatches in bow and stern tanks should also be on the list of items checked at major regattas.

D. The current "knockdown test" in CR 2.191 does not offer any certainty that a Dragon that passes this test will not sink. The test is not a realistic representation of what can happen in conditions of high wave; exactly the conditions where a knockdown is most likely. Likewise, the "Declaration of Buoyancy" in the same CR offers no comfort on unsinkability. It is therefore recommended that these parts of 2.191 should be either withdrawn or rewritten.

E. In the process of preparing to write this report, I found a couple of, what I believe to be, anomalies in the CR's. In CR 2.192, the closed cell polyurethane used for buoyancy has to have a *minimum* density of 32g/Kg. This should surely be a *maximum* density of 32g/Kg. In CR 2.192 the weight of the inspection hatch must not be *greater* than the bulkhead it replaces. This should perhaps be *less* than the weight of the bulkhead it replaces. If I am right, these CR's should be corrected. The contradictions on holes in watertight bulkheads can be addressed if and when a decision on deployable bags is made.