It's absorbing to read Cayard's words from a few hours before the keel problem. His tenor is more measured. You can feel the responsibility weighing him down. 'The boat is slamming downwind very violently. No one can sleep when it's this rough. As you go from 25kt to 30kt of boatspeed the keel hums to a higher and higher pitch. Then you feel the boat unweight itself, you also go a bit weightless like in an aeroplane sometimes, and you just cringe in your bunk as you know the bottom of the wave is coming.

'Sometimes it is just a big snowplough – a rapid deceleration – which makes you hold onto your bunk so you don't slide onto the guy in front of you. Those are the ones that produce 2ft of white water rolling down the decks. Other times we find the bottom with a violent belly flop that shudders and sends vibrations throughout the boat. It is hard not to spend time wondering how long these boats can take this type of punishment.'

T MARTINEZ

NO SHARPER END

Russell Bowler, president and engineering partner, Farr Yacht Design

SH: Farr are under the spotlight!

RB: All the issues that have occurred are comprehensible and repairable. There is no mystery about what went wrong. There is still the 'why' question with *Ericsson*'s hydraulic system and conjecture if *MoviStar* hit something on the first night. But we have been working with the shore crews and sailors to understand and overcome the problems and get the boats back racing

SH: Let's go through them individually.

RB: The first thing to understand is that, contrary to some statements, none of the problems are identical. *Pirates* dropped the wedge out of the bomber door. The design was the same for all our boats so this wedge and sliding plate may have been built or installed differently. They also damaged a centreline-strut forward of the mast.

SH: And *MoviStar*?

RB: *MoviStar* fractured the shelf that supported the starboard hydraulic ram for the canting system. This was a sudden failure that occurred when the boat slammed down particularly hard, but an event the boat had seen before and should have survived. However, the shock travelled right around the solid part of the bulkhead and popped the skins off the core halfway up the topsides on the port side opposite.

SH: *Brasil 1*?

RB: The skin lifted off the core of a side deck panel. There were skin/core bond problems detected in the deck at construction stage and these were diligently surveyed and replaced by the building team. Skin to core bond strengths are very difficult to assess during build and it seems there may have still been a defect. The boat proved its reliability on Leg 1 with less damage than any other in the fleet and was performing well in rough conditions on Leg 2 when the deck problem occurred.

SH: *Ericsson*'s ram issues?

RB: Some components in the hydraulic ram failed. We are not experts in hydraulic systems although we have learnt a lot about them in the past weeks... We hosted a meeting at our offices with the designer of the ram components and Magnus Olsson from Ericsson Racing, who managed the construction, to learn about the rams and what may have caused the problems. The design and manufacture of these hydraulic systems were performed by outside suppliers and unfortunately we are not fully informed about the details they finally put into the boat... Some titanium parts broke and are being replaced with new designs and materials as specified by the hydraulics designer.

SH: Looking at *MoviStar*'s bulkhead tear in more detail, was this in any way due to the builders choosing whether to wrap a skin around the open core end of the sandwich before applying a heavier capping?

RB: That's a theory I haven't heard. The edge detail looked OK to me – what I saw of it. The crew did report a crease across the aft-faced skin right where the bulkhead broke, so there may have been some skin-wrinkle there that propagated to the edge detail. Or it could have been the more typical situation where lots of small things contribute to a bigger failure.

SH: The shelves to which the keel rams anchor are attached to the hull and to a frame at either end. Bouwe Bekking wasn't sure if these shelves were solid?

RB: They are part Nomex-cored and part solid carbon. Where the trunion supports for the ram are bolted they are solid carbon. Plus there are very thick layers top and bottom running back to the bulkhead.

SH: And what went wrong with *MoviStar*'s shelf?

RB: There was a 45-degree shear failure towards the outboard ends. When we were able to take the pieces apart in Portemão it was clear that the bond between the bulkhead and the shelf had been decaying over time from the centre out, which meant that less and less material in the shelf was doing the job until it got to the stage where there was not enough to manage the load. If the bond of the shelf to the bulkheads had been better, I think it might have survived.

Generally we do design things knowing that construction will sometimes be less than perfect but it was not enough in this case. As far as *Brasil 1* is concerned I think this points out that these boats are working very hard. If you don't get things dead right, they will catch up with you. Remember that *Brasil 1* got through Leg 1 without a problem.

On *Pirates* a wedge came loose. It's

***Clockwise from top left*: ABN AMRO 1 continues on her mother of all charges; during the second In-port the Pirates struggle to get to grips with a mix of tight corners, big sails and a large canting keel; it's a tonne lighter than mum and dad's (see *Snapshots*, page 11) but we're still the fastest kids in town – the nippers of *ABN 2* set another 24-hour record on Leg 2; and the return of hanked sails continues, here onboard *ABN 1* – far from easy for the bowman, but then with a regular foil such large sails are in any case near-impossible to slide against each other when wet**

difficult to say precisely what the problem was because it was gone! But the same detail is on several other boats and they have not had a problem.

The failure of the link-strut forward was due to an almighty big landing. Talking to the crew I know they came down pretty darned hard both when they were racing and when they were heading back to port. The big panel underneath the strut must have got an extreme localised load and the post got crushed. All the boats have this feature; no one else had this problem.

SH: This is one area where FYD advised modifications during the Cape Town stop?

RB: Yes, we asked that a little more material be put on the frame at the base of the strut. For the cost of a couple of hundred grams you can get a lot more strength and perhaps stop a similar occurrence on the other boats. The teams have been very good about co-operating on the exchange of this sort of information. We have taken the path of being very conservative and adding additional strength wherever there is the slightest doubt.

SH: How much reinforcement are we talking about for the base of this strut and the frame outboard of this, the ram shelf and the main keel bulkhead?

RB: 1.3kg, 1kg and 7.6kg respectively.

SH: That's it? For cloth and resin?

RB: Yes.

SH: Against the total weight it's tiny…

RB: The hull weight varies from 7.4kg/m^2 to 11kg/m^2 and the deck is 5.7kg/m^2. So in terms of overall weight the extra material is negligible. In terms of what it does to the areas concerned, it lifts the margin of strength significantly.

SH: *Ericsson* has had no hull problems but has twice been afflicted by her keel; yet these systems are nothing to do with FYD?

RB: Actually none of our boats has had hull problems. Each group engaged their own hydraulics engineers to design the rams and associated pumps and controls. We provided the loading specifications and general geometry of the arrangement. Most groups kept secret the details of their hydraulic activating systems so it is difficult for us to offer any opinion on those parts of the boat. We believe there needs to be far more co-ordination between designers, teams, suppliers and project managers so that there is a better understanding of what's required of these specialised parts.

SH: It is not just the weight of these hydraulic systems but their operating speed that's made them so wickedly complex and expensive?

RB: Yes. Speed of cant is important, particularly for the inshore races. The VOR 70 rule encourages lightweight canting systems and all teams went searching for the lightest systems.

SH: *Ericsson* and *Pirates* have the same Marine & Hydraulics system, don't they?

RB: I don't actually know 100 per cent for sure if they are the same or if the parts are different. The teams have been so secretive about what they went with. Cayard's programme were very late and their system is probably similar to *Ericsson*, but the manufacturer says some parts are different. I think Horacio Carabelli put a Cariboni system into *Brasil 1*, but again I don't know for certain!

SH: Are carbon cylinders and ceramic-coated titanium pistons desirable…

RB: If they are reliable and light they will always be desirable. There was a suggestion that the canting mechanism should have a minimum weight and I agreed with that. It was considered by the rulemakers but their answer was that the Whitbread 60s had no limit on the weight of the water ballast transfer system and contestants had worked very hard to get the weight out of that and it was quite a neat side of the process. Shouldn't it be the same for the canting keel, they reasoned?

SH: Did you foresee the vast effort and expense that would be applied to these hydraulic systems?

RB: Frankly, yes. It was immediately evident that you had to go into new fields with the canting system because it was the single heaviest element you could work on. The hull shell was subject to limits. So too the rig, but the keel-activating system was fair game.

SH: Why did you leave a gap either side of your keel fin which necessitated a complex system of sliding doors?

RB: There is no gap either side of our fins; but a fairing system is required to make the underbody of the boat fair with the cant axis of the keel inside the boat. The system we developed uses a sliding plate driven by a sliding barrel on the keel. This gives the fairest lines for the water to flow over either side of the keel and the least volume changes for the water flow around the keel. And it complies with the rule.

SH: Are the structural requirements sound?

RB: I think it's important to note that they were put together by consultation between the rule writers and designers. The Wolfson Unit were also consulted. The panel weights for the deck, hull and watertight bulkheads are fairly conservative. This is a very positive aspect of the rule. The grounding load requirements and the material limits for the keel produce a pretty solid keel arrangement. Mast rule weights are also conservative – no mast failures so far. Overall you would have to say they did a good job on the structural requirements. However, we have to get to the end of the race and listen to the crews to see if it makes sense to revise these requirements.

SH: If the rule is conservative how do safety factors compare with other classes?

RB: We realised early on that these boats were going to achieve speeds we have not seen before. We used the DNV high speed and light craft rule (a rule used for powerboat design) to arrive at the panel pressure loads. We used the ABS Guide also and had lengthy discussions with SP; ultimately we researched the problem many ways because we wanted a better feel for sailing boats ▷

that would be behaving like powerboats. Rudders and canards were designed for high speed. The rule itself dictated grounding loads, which are very high. The margins all around the boat were very solid.

SH: Crashing down upright at 20-40kt downwind was anticipated and understood?

RB: We learnt from the Volvo 60s what upright, high-speed downwind sailing was like and what it meant for impact down the centreline. So we considered slamming down the centreline, around the bilge and into the topsides as well. That was anticipated when the rule was put together too, with the shell weight graduated according to its location and load. We used resilient foam in the bottom forward panels which performed well compared to *ABN*'s Nomex cores which had problems in Leg 1. [In Cape Town some of *ABN ONE*'s Nomex was replaced in the slamming area]

SH: Does the rule specify how these panel weights are to be achieved?

RB: No, designers are free to specify the laminate; but there are also maximum panel dimensions

SH: What difference has the switch from Kevlar in the old Whitbread 60 to carbon in the VO70 rule made? The old boats wobbled whereas the new ones seem rigid?

RB: Kevlar was selected in the old rule because there was a concern about damage from impact. The boats were seen to be at risk from ice, other flotsam and jetsam, and containers. It was seen as a good safety move to have a substantially Kevlar skin so that the hulls wouldn't rip open if they hit something. Of course the boats were a bit bendy relative to IMS boats of similar size. Carbon, if handled correctly and sandwiched with the right material, will do anything you want it to do. In terms of delivering on its promise, it is the material of choice.

SH: The Goodwood Conference for designers which helped create the Whitbread 60 rule followed the 1989/90 race. That's a long time ago in terms of composites development?

RB: A lot has moved on since then. And Kevlar is not an easy material to work with. It is difficult to cut, difficult to wet out and more difficult to fair afterwards. It was not a popular material with boatbuilders. But you can't point at carbon fibre and say it is too stiff and rigid a material for this application. It is a matter of organising it so that it performs to its specification and can handle shock loads.

SH: Are there any useful comparisons to be made with America's Cup boats?

RB: They are a completely different set of challenges. There are some similarities in the sense that there is a minimum shell weight and so the goal is to strip weight out of the interior to put in the bulb. The America's Cup boats have been through five cycles now and many, many millions of dollars have been spent on their structural design, testing and construction. So the level of structural refinement in the boats now under build is extremely high.

SH: And the ACC issue you're dealing with is slamming upwind at slow speed on one, two or three waves simultaneously?

RB: That's right. And in sheltered waters. A Cup boat may exceed 20kt but that will be a rare event, whereas a Volvo boat will do twice that – and in parts of the ocean that very few of us have been to.

SH: Do you wish your boats had sailed more miles before the start?

RB: Absolutely. All the programmes were severely rushed, especially given there were many new aspects of this rule to explore, particularly with sail shapes, materials and restrictions. Building time was fast-tracked on very high-tech builds. Other than for ABN, there was little time for pre-race trialling and almost no two-boat testing.

SH: How do you balance the objective calculation of a structure and the more subjective allowance for safety factors or unforeseen conditions?

RB: We try to go through events that occur to boats at sea and duplicate the accelerations and forces at play and combine those to see if any parts are overstressed. You go through a number of events and load case situations, then stand back and wonder if you have got them all. After that you estimate how many times these events may occur and what sort of safety margin you might need for them for the strength of the material. You also have to put into the calculation that the boat may be damaged through normal wear and tear, that the strength may not be there in some elements that was there originally. There is a lot to account for.

SH: So what sort of life are these boats designed for?

RB: Generally we keep the stress down below the micro-crack level so that the life of the laminates exceeds what we'd deem to be the serviceable life of the boat. Where laminates do become a little decayed is through events we don't design for, such as repair from collisions or the dropping of spinnaker poles through decks. Those defects accumulate and can catch up with a boat through hard usage. So we don't say this boat has got to last 20 years but we do design laminates to deal with stress for a long and reasonable life.

SH: But how do you estimate the number of 'episodes', heavy landings for instance?

FEELIN' UGLY

'Yesterday we and *Ericsson* witnessed a pretty impressive display of boatspeed by *ABN 1*. Around 11:00 local time they were one mile dead astern of us and we were the same one mile astern of *Ericsson*, all lined up on starboard tack. As the wind built from 8kt to 20-25kt, *ABN* simply sailed through our lee and that of *Ericsson* and back up in front of both of us; they'd put another two miles on us by sunset. The *ABN* design is very good in conditions where stability is required. Unfortunately, I think that will be most of the time in these boats...'

Paul Cayard, two days out of Cape Town on the *Black Pearl*

M MUINA

Adding to *MoviStar*'s woes when they suffered damage at the start of Leg 1, it is almost certain the boat had also hit a large fish or other object – though the hull and frame problems were not believed to be related to whatever took these 'bites' out of the appendages

RB: We can look at our race model for the Volvo 70, for example, and we can calculate the number of hours that the boats will be reaching, will be on the wind, will be downwind. So we can say for heavy running conditions you are going to plug the nose in every two minutes, you're going to have water on the deck for this length of time. There is a way of anticipating episodes and events and arriving at a calculation. Generally speaking, though, fatigue calculations are very small numbers in terms of working out the total that the structure should be capable of enduring.

SH: Engineering these boats is a huge effort?

RB: The projects become larger and larger as time goes on but the tools get better too. We FEA-modelled the Volvo 70 quite extensively and it's useful now to go back to the model to see if we can duplicate conditions where problems occurred.

SH: Are the structures of the Don Jones and Juan Kouyoumdjian much different?

RB: I don't know but I doubt it. The hull shell and deck shell and watertight bulkheads are all rule-controlled, and then there is a big grounding load to get out into the structure. I think we are all dealing with things in a similar way.

SH: Are there any changes you would make for the next race?

RB: You've really got to listen to the guys sailing the boats at the end of the race for the lead on this. We want to know if the boats are just too brutal for the good of our sport. If they are not, we will just get on with it. I saw Moose's [Mike Sanderson, *ABN 1*] comments and I thought they were very sound: 'It's tough, but we know what we're doing and it's fun.'

If that's the message we get from everybody, then go for it. It seems to me, however, that they could do with more shelter on these boats. Perhaps a mandatory deckhouse or something that reduces the risk of being swept out of the cockpit. The Open 60 sailors have learnt that keeping relatively dry and protected makes them more efficient. One of our recommendations during rule formation was to have additional freeboard forward. That will be an interesting question to put to the crews...

SH: In not just the Volvo 70s but the 100ft supermaxis, too, are we reaching a limit in terms of sailors being able to deal with the speeds, the motion and the gear. It used to be that size and speed were limited by the gear but modern materials for rigging, spars and sails have changed all that. Is the limit now the crew?

RB: I think that's the case. But then that was probably said when fin keels and spade rudders were put on boats 50 years ago. It's evolution. This was a big step forward and it will take a while for people to learn how to manage the boats. I think, once the sails are sorted out and there's more protection from the water, they will soon say, 'OK, how do we go a bit faster?'

SH: A race boat often had the ability to look after its crew; now it's imperative the crew preserve the boat?

RB: That's valid. But they've always had to look after the boat in some sense. In conditions where these boats race hard, the older boats would be hove-to.

SH: More entries would be welcome in the VOR. Would a one-design hull, appendage and machinery package work, leaving just rigs and sails open?

RB: I know your editor is pushing this debate! The concept was kicked around at the end of the last race; certainly a strong contingent wanted standard hulls and it would probably have got the numbers up. But there are problems with such a programme. The boats become available only over a couple of years if they come from one builder. That creates a disparity between early and late boats. Another flaw was that it needed someone putting in a bucket-load of dollars at the front end. And that's tough!

Tim Jeffery ❑