Some thoughts on the hazards of the sea

With all this talk of failures and safety factors it is easy to drift into the common belief that the marine environment is hostile. When people are asked to list the hazards of the sea the obvious one is the size of the waves. But to complain of the dangerously high waves at a good wave site is like complaining of the high temperatures in the flame of a thermal plant. For low-freeboard devices the stresses in large waves rise at slightly less than the first power of wave height while the available power rises with the square. The analogy in thermodynamics would be of higher temperatures giving higher Carnot efficiency. This means that the economic viability should *rise* in higher waves. This should not be regarded as a hostile feature. Marine currents might also be regarded as a hazard but the same arguments of power rising with the cube of velocity while stresses rise with only the square applies. Marine current designers would dearly love higher velocities. After wave height and current velocity, there is salt. But salt is found at 28 times greater concentration on land and is thrown at high speed, mixed with abrasive gravel, at the underside of every vehicle in an attempt to overcome the serious hazard of icy roads. After salt there are poisonous jellyfish, great white sharks, drifting icebergs, none of these common in European waters. At this point the list usually terminates. I hope that delegates to this conference will help me extend it.

The list of hostile features for land is longer and much more diverse. There is a wider range of temperatures with rapid changes between extremes combined with very poor heat transfer to still air. Air offers very little damping to resonating objects and the wind can induce much higher frequencies of oscillation. There is gravity unopposed by buoyancy with point loading rather than distributed loading. There are cliffs, gullies, crevasses, and steep gradients. There are rockfalls, mudslides, landslides, subsidence, collapsing tunnels and avalanches, volcanic explosions, lava flow and earthquakes, none of which are anywhere nearly as predictable as bad weather at sea. Trees grow very tall but all eventually have to fall. Being under the two hundred year tree when it comes down can be dangerous. When trees are not falling they can be catching fire and spreading it to others. Some have thorns with poisoned spikes. There are snakes, tsetse flies, mosquitoes, river-born bacteria and scorpions. There are corrosive chemicals, asbestos, dioxins, mercury, heavy-metals, NOX, SOX, carbon monoxide and Diesel particulates. There is abrasive gravel and sand driven at high speeds in storms. There are higher water velocities with rocks driven by flash floods. Tornadoes on land move sheets of corrugated iron, bricks and even camper vans at much higher velocities than the spray in typhoons and hurricanes at sea. Tornadoes occur more frequently and with less warning. Tidal waves and rising sea levels are a danger to any coastal structure but of no concern to deep water floating ones. Narrow gaps, traffic congestion, barbed-wire, low bridges, quicksand and marsh make it harder to move large structures on land while there is almost no size limit in the deep sea. Electric cables on the seabed are safe from lightning, vandalism, kites and model aircraft. Properly routed marines cables are more reliable than those on land. Planning objections, which are crippling onshore wind, should be fewer for distant offshore installations. You can dive from greater heights into water than on to earth, and buckets of water hurt less than buckets of stones. It is more comfortable to be under 50 metres of water than 50 metres of rock. Corrosion of steel in clean sea water, which is free from acidic exhaust fumes, occurs at a rate one-fifth of that in the air of a damp industrial city. This can be shown by examination of the steel hulls of 19th century sailing ships abandoned in the Falklands after damage in the passage round Cape Horn and of the remains of riveted hull wreckage (built before World War II) on a beach on Islay.

There can be no doubt that our wave fields are thermally, gravitationally, flammably, structurally, meteorologically, chemically, zoologically, botanically, seismologically, tribologically, logistically and administratively more attractive than many places on land. It was the benign marine environment that allowed life on earth to begin. The creatures that survived species extinctions were those that lived in water. The reason that some made hesitant steps to life on land was that the sea was getting too crowded. They managed to survive on land only by learning all about the dangers. Getting economical power from sea waves will be difficult and will need the very best engineering skills. I accept that conditions at sea are very *different* from those ashore and that every aspect must be carefully considered. However the difficulties arise not so much from hazards at sea as from our practice of applying land-based technology to marine conditions without sufficient thought.

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