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ShipArrestor Project 222575

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SYNOPSIS

What do you do when a disabled tanker or other large vessel starts to drift against a lee shore, or possibly worse, an offshore oil installation? This dilemma has been faced many times by emergency services around the world and to this day no good answer has been available. To address this problem, an international consortium led by Miko Marine has begun a two-year EU-sponsored research project to develop the ShipArrestor.

In addition to Miko Marine, the consortium consists of the commercial enterprises Norlense, Norway; Haberkorn, Austria; Opus Marine, Germany and Le Floch Depollution, France. The research institutions involved are the Ship Stability and Research Centre, UK; Dr Vernikov Magnetics, Holland and the National Institute of Technology, Norway. In addition, several technical experts and advisers have been involved.

This paper will explain the background of the project and the development of the lightweight connector before the merits of a large-scale sea anchor is investigated.

BASIC PRINCIPLE

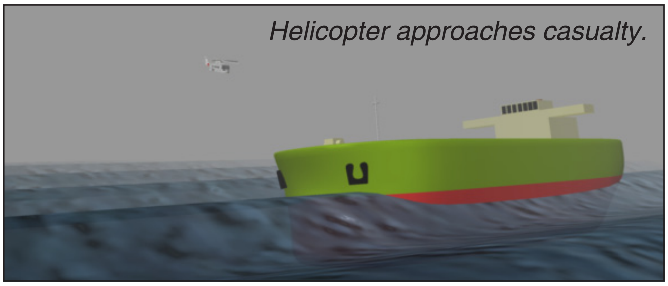
The basic principle behind the ShipArrestor is illustrated in the diagram below.

The ShipArrestor principle

The basic concept is to use a helicopter to secure a towline to a casualty. In order to buy time before the arrival of the Emergency Towing Vessel (ETV) this towline will be fitted with a large scale sea anchor at the end. This will slow the vessel's drift rate but, equally importantly, it will rotate the casualty's bow up against the weather. This reduces the roll motions, making it more comfortable and safer to work on-board.

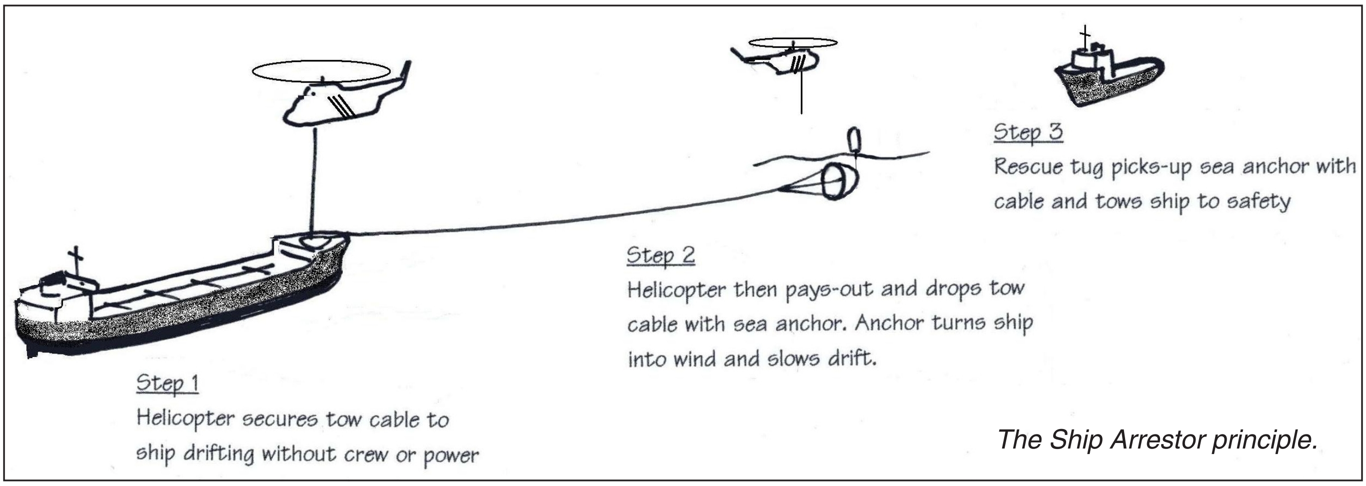
BACKGROUND

The ShipArrestor system is partly based on an earlier system called the NepCon (illustrated in four images on page 2). This system was a helicopter-applied connector developed in the 1990s by a consortium led by Norway's biggest tug operator, Buksèr og Berging.

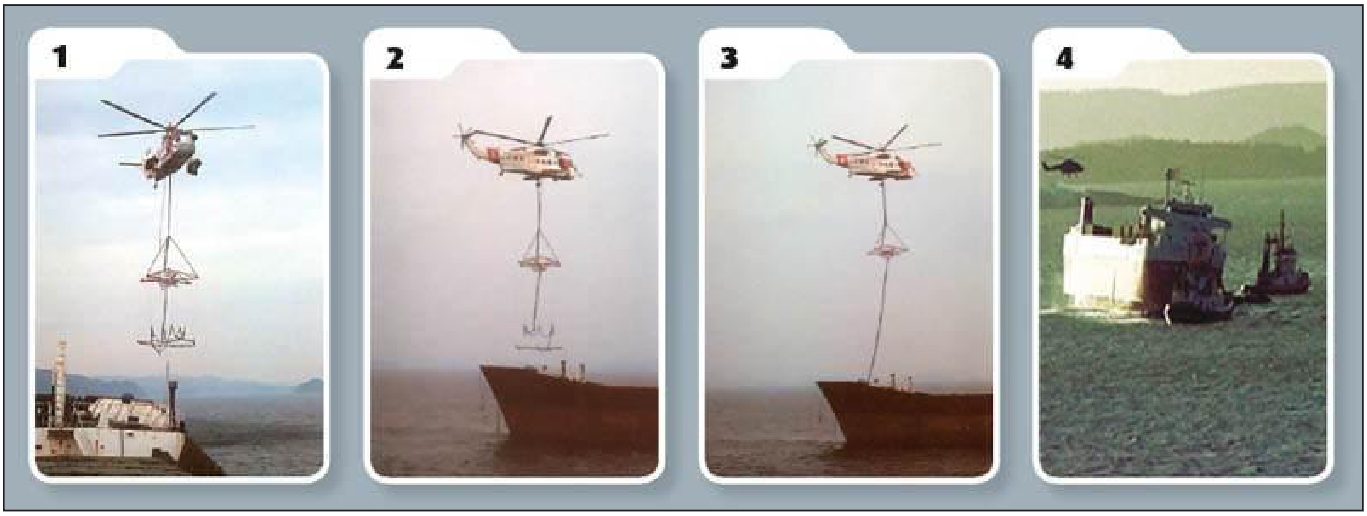


Helicopter approaches casualty.

The original NepCon system was based on a steel chain lasso being dropped around the anchor windlass or similar strong point on the casualty. To maintain the circular shape of the lasso during flight and deployment, a steel frame and some wooden planks were used. The lasso was dropped over the windlass by a hydraulic



The Ship Arrestor principle.



The original NepCon System.

release mechanism before a towline was spooled out to the tug. In total the NepCon weighed around 1,500kg and, although it was successfully deployed during a full-scale exercise, some deficiencies were identified. The system was too heavy, not accurate enough, not aerodynamic enough and required too much storage space when not in use.

THE CONNECTOR

The material

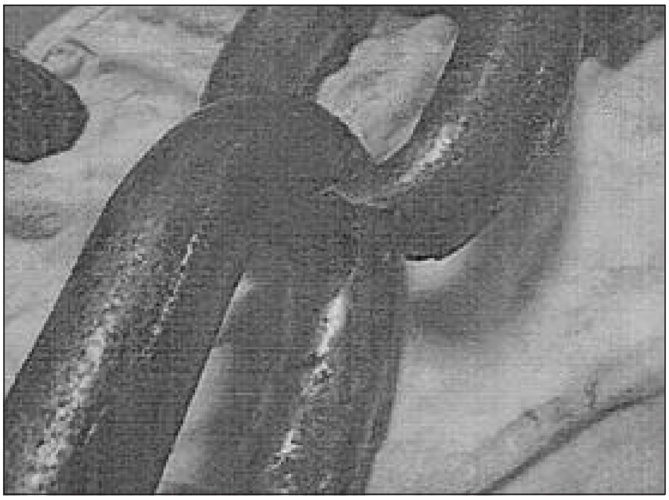
The work on the NepCon system showed that the total weight on the system was critical and it was therefore proposed to replace the original steel chain with a synthetic fibre rope. Given the recent advances in this field and the immense weight savings normally associated with replacing steel chain with rope, this was indeed an attractive option. And although several manufacturers of both rope and chafing protection were approached, no one could supply a product that would withstand the enormous cutting forces.

Gusset plates and other sharp edges pose a challenge.

Although several elaborate solutions were investigated, it became evident that the only material that could sensibly be put around the windlass and over the gunwale was a chain. It was therefore proposed to make one in titanium to make the necessary weight savings.

Titanium is, however, a difficult material to weld if the maximum strength is to be maintained. As a consequence, the whole chain had to be cast in one piece and the outer contaminated layers had to be ground off. Making a titanium chain was, therefore, both costly and complicated.

Fortunately, one of the consortium members had access to ex-Soviet Union space and defence metallurgical technology and was therefore able to develop a steel chain that was lighter per ton breaking load than the proposed titanium one. A prototype of this 24mm stud-less chain was built and tested to a breaking load of 1,250kN.



The special chain after destructive test.

The special chain developed can be compared to a standard R4 stud link chain:

Quality	R4 stud link 32 mm chain	Special 24 mm chain
Weight / m	23.9 kg	11.1 kg
Load cycles	150.000	50.000
Breaking load	1163 kN	1250 kN

Comparison of new chain with similar anchor chain.

Part of the reason why the special chain has a better breaking load per weight ratio is that it has been optimised for fewer load cycles. Given that this is emergency equipment meant to function only for a limited time, this should not pose a problem.

The design

In general there are two hooks from which a load can be hung on a helicopter – the cargo hook underneath the helicopter and the personnel hoist in the door. Normally the personnel hoist is rated to approximately 300kg. As it turned out this was not enough for our needs and as it is against air safety regulations to use the personnel hoist whilst there is a load attached to the cargo hook, the entire load of the ShipArrestor system had to be attached to the cargo hook.

As previously mentioned, the original NepCon system had a steel frame to give the lasso the correct shape during transport and deployment. In addition it had a hydraulic release system to enable the helicopter crew to drop it over the windlass. This constituted a considerable amount of the total load of the system and although dropping it from above meant less risk to the helicopter, it also reduced the accuracy of the system.

For these reasons it was evident that the steel framework had to be replaced by an inflatable ring, and in order to make the total system more aerodynamic, it was decided to position the chain within the ring itself.

Test flying the inflatable ring.

As with the original NepCon system, the lasso was 6m in diameter. During testing at Bergen Airport the pilots found this ring to be surprisingly stable and with an Augusta Westland AW139 helicopter fitted with a downward-looking mirror, they had no problem positioning the ring gently on to a stationary object. The pilots engaged in this trial were normally transport pilots flying to and from cargo vessels in bad weather and they were highly experienced both in flying underslung loads and in offshore work.

One of the challenges faced in the ShipArrestor project is that none of the consortium partners had helicopter expertise. An external expert was therefore hired as a consultant. Several other pilots were also consulted. Based on this, it seems that the envisaged system, whereby a ring is gently lowered on to a windlass or similar is within the capability of helicopter pilots experienced both in cargo flying (which is generally done over land) and flying to and from ships.

THE SEA ANCHOR

Sea anchors are in widespread use both for recreational craft and fishing vessels and are also standard equipment on every SOLAS certified liferaft. Large scale sea anchors are also used in the squid fishing industry in the South Pacific. Knowing how a large, drifting vessel would behave when subjected to a sea anchor was, however, a task for the Ship Stability and Research Centre at the University of Glasgow. This comprehensive study was aimed at deciding the shape and size of the anchor and to calculate the design loads on the connector.

The free-drifting scenario is computationally complicated and, for obvious reasons, often a neglected part of sea keeping. Numerical models were therefore developed both in the time domain, to compute instantaneous loads, as well as in the frequency domain, to analyse statistical parameters. In order to increase our confidence in these models, tank tests were performed in the Acre Road towing tank in Glasgow.

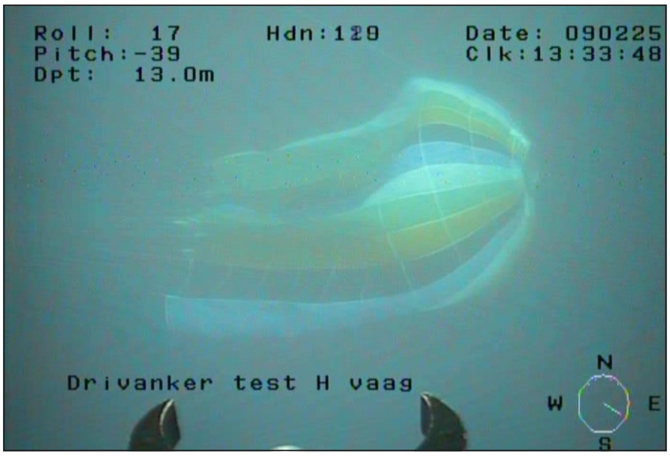
As it turned out, it was particularly difficult to carry out scale model tests of the sea anchor. This could be because it is hard to know how to scale it, since the viscous effects will scale with Reynolds number, the vortex shedding will scale with Strouhal number and the wave-making near the surface will be dominated by the Froude number. It is also difficult to make a scale parachute sea anchor in which the cloth is light enough and stretchy enough to behave like its full-scale equivalent. The same is true for the towing line and other lines of the system – it is simply not possible to make them thin enough and stretchy enough to give a good representation of the real system at model scale. It was therefore decided to perform a full-scale test with a 30m diameter sea anchor and an ETV.

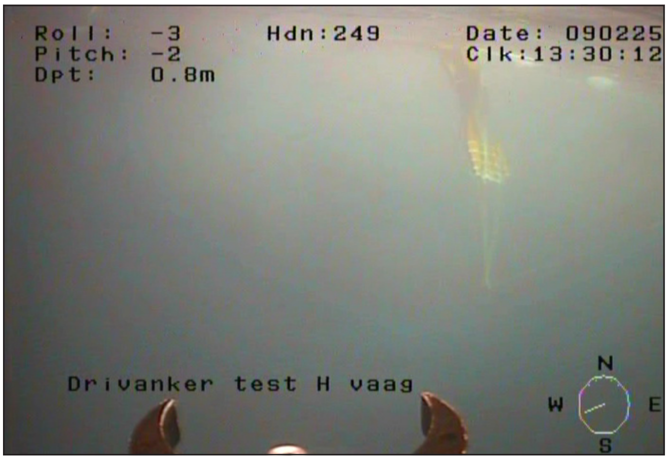
The ETV **Beta**.

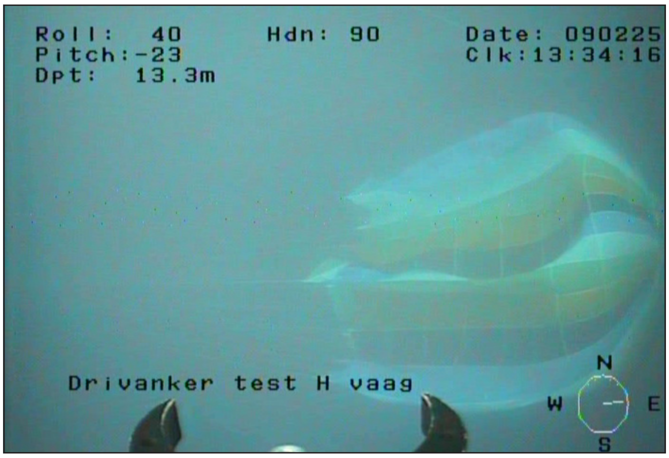
The ETV has a shape that, in many respects, resembles a tanker turned back to front. The superstructure of a tanker will act as a sail and thus help rotate the bow into the wind, whilst the lateral projected area of the underwater body of a tanker has its centroid quite far forward due to the large bulbous bow. For this reason attaching the sea anchor to the main towing line of the tug through the towing pins gave us both a large working deck and a relevant hydro- and aero-dynamic shape.

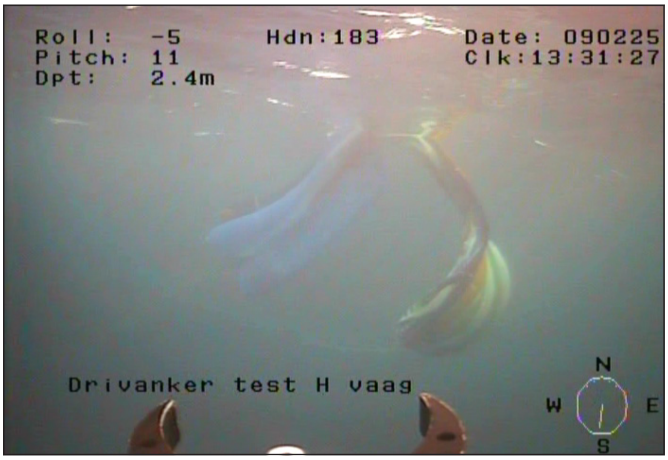
The full-scale tests were performed in the Barents Sea in February 2009. At that time of year, the water is still exceptionally clear and the daylight hours long enough to permit underwater photography and filming.

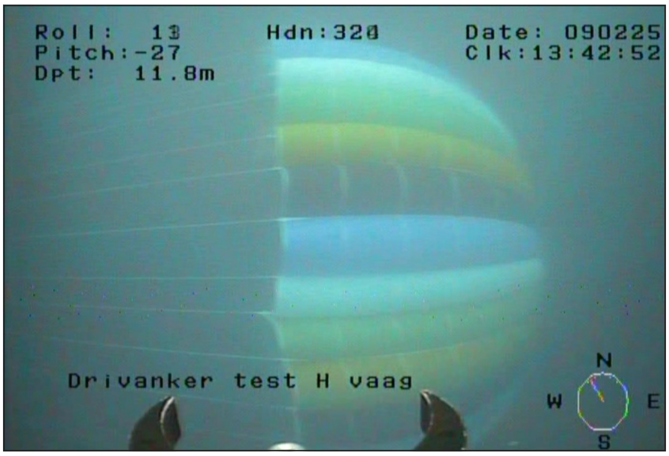
These pictures are taken from an ROV operated from the ETV during the exercise. It can be seen that although the sea anchor landed in the water in a somewhat untidy fashion, it had no trouble untangling itself. The lines did not get entangled in any of the full-scale trials, nor has this happened during scale trials.

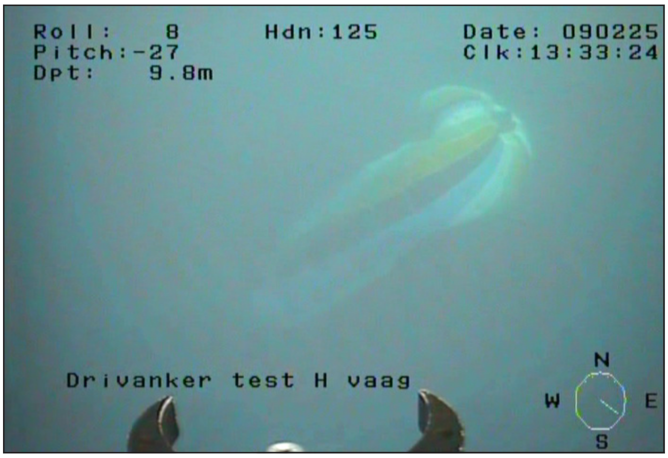


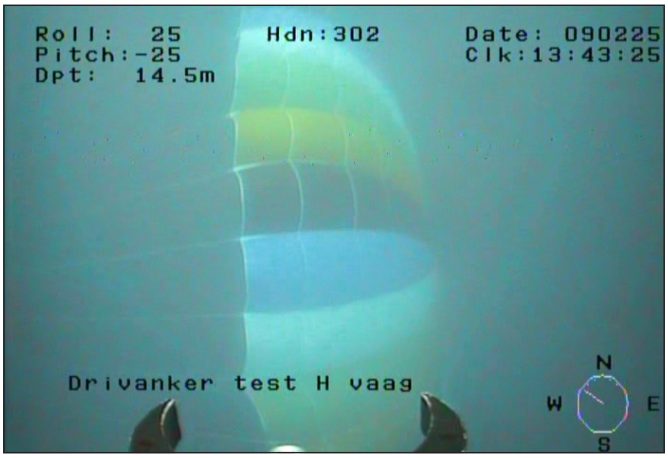












In the trial depicted, it took more than five minutes from when the sea anchor first landed in the water until the air had escaped, the anchor had sunk into the water, fully opened itself and started to exert force on the tug.

Ideally, we had hoped for gentle conditions during the first trials with increasing wind and sea conditions to allow for more realistic trials as our experience with the system grew. Unfortunately the weather is uncontrollable and nowhere more so than in the Barents Sea. Consequently, we had a fresh breeze during the very first trial, rapidly dying to flat calm waters for the rest of the week. The free drifting tests were therefore of no use, but we gained good experience with the sea anchor and our measurements underpinned the numerical simulations.

How big an anchor? How big a load?

One of the most crucial questions the numerical simulations where meant to answer was how big the sea anchor needs to be in order to turn the bow up against the weather and give a sensible reduction in drift speed. Unfortunately, this question is directly linked to how big a load the connector can withstand as a bigger anchor will lead to less slippage and, therefore, generate a bigger extreme load.

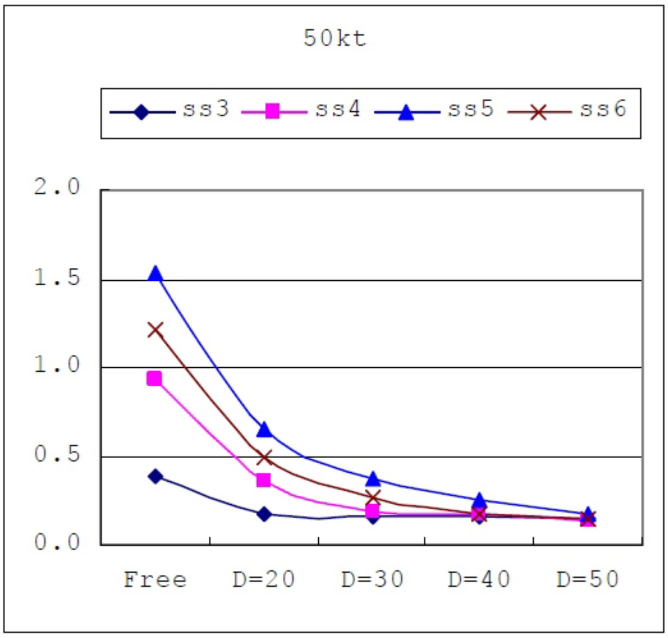
The fact that the entire system has to be transportable by helicopter therefore limits the size of the sea anchor, not so much because of the weight increase of the sea anchor itself, but because of the weight increase of the connector. The size of the sea anchor must, therefore, be sufficiently small not to generate more than the 1250kN or approximately 125-ton breaking load of the connector.

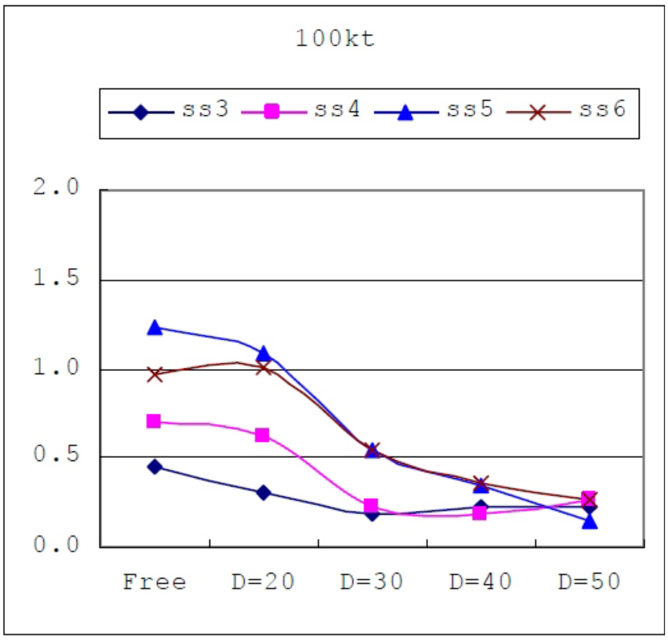
The load in the towline of a ShipArrestor system is dependent on several variables of which ship size, wind and wave conditions and sea anchor size are the most important. In order to assess the behaviour of the system a set of environmental data were chosen based on the two parameter JONSWAP spectrum.

Sea state	Significant wave height	Wave period	Wind speed
3	0.88 m	7.5 s	6.9 m/s
4	1.88 m	8.8 s	9.8 m/s
5	3.25 m	9.7 s	12.6 m/s
6	5.00 m	12.4 s	19.3 m/s

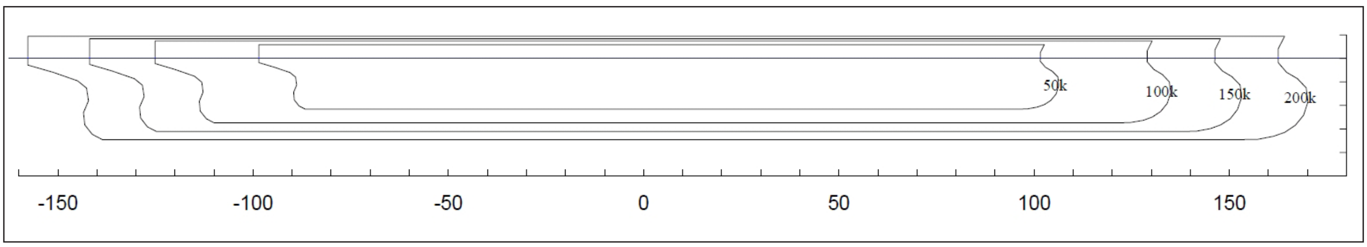
Sea state codes for the North Atlantic.

Once the environmental criteria had been established, the potential casualties could be set. Traditionally, the largest environmental disasters have involved tankers and for this reason a generic tanker in four different sizes was investigated (see graph at bottom of page). These different tankers displaced around 50kT, 100kT, 150kT and 200kT respectively. Once the environmental data and the casualties had been selected, the effect of sea anchor size could be investigated, illustrated by the following four charts.

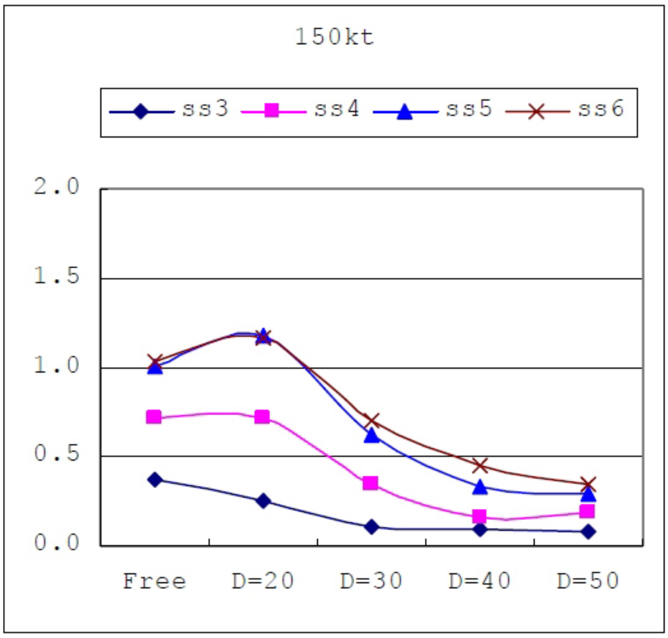


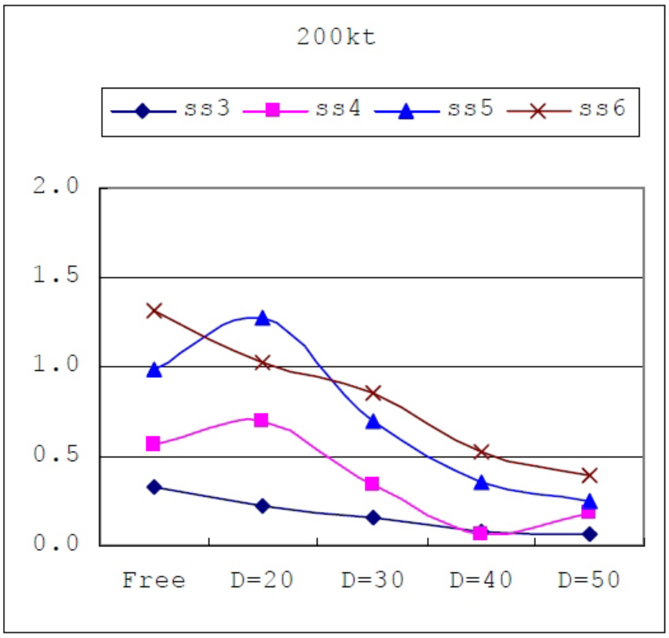


Mean drift rate, in knots, of various tankers (continued on next page).



The generic tanker in four different sizes.





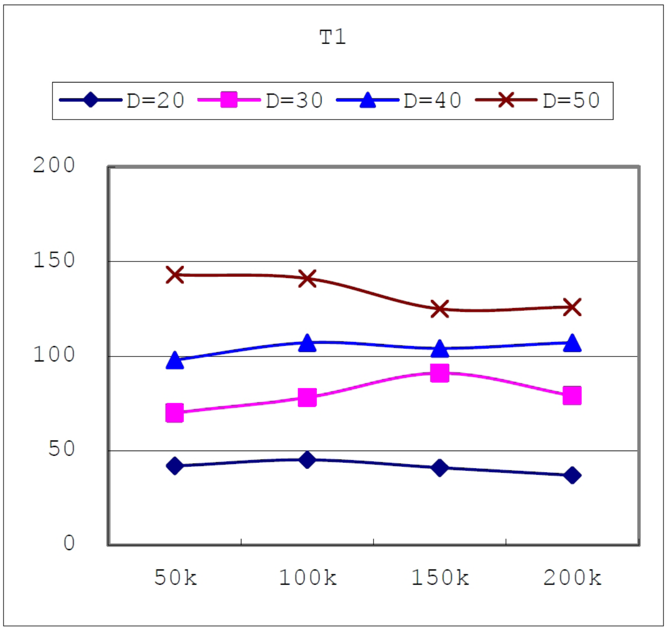
Mean drift rate, in knots, of various tankers.

In these graphs, the mean drift rates are compared when free drifting and when attached to a sea anchor of 20m, 30m, 40m and 50m diameter respectively.

It can be seen from the graphs that, for all but the smallest tanker, the 20m diameter sea anchor will actually lead to an increase in drift rate for at least some sea states. This may be counter intuitive and has been the subject of several debates within the consortium. The reason for it though, is that when a large tanker drifts beam to the seas, the submerged part of its hull represents a huge sea anchor in itself. When a small sea anchor is used to turn the tanker's bow up against the weather, the projected area of its submerged part greatly reduces and becomes more hydrodynamic in shape. If the added drag of the sea anchor is insufficient to counter act this reduction, the tanker will actually drift faster with a sea anchor attached than what it would if left on its own.

Once the sea anchor has a diameter of at least 30m, this effect is no longer there, even for the 200kT tanker. This means that in order for the system to also be useful for tankers larger than 50kT, the sea anchor has to have a projected area of at least 700m^2. This equates to a flat parachute of about 37.5m in diameter. This difference between the calculated 30m diameter and the required 37.5m diameter is due to the fact that the sea anchor takes up a 'scallop' shape when subjected to a load as indicated in the underwater photos from the tests in the Barents Sea.

Statistical analysis based on a scatter diagram from the JONSWAP project could then be used to determine the extreme tension in the towline in the form of one per cent probability of exceeding (T1).

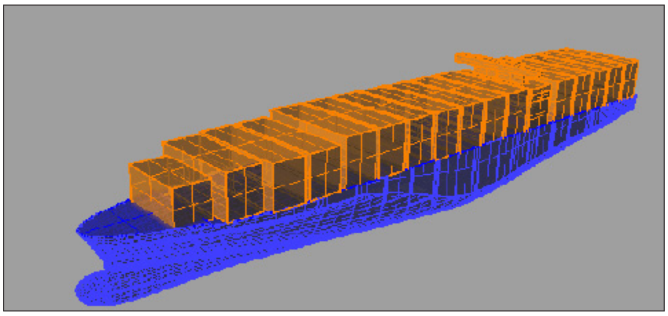


Extreme cable tension based on scatter diagram.

This graph shows one per cent probability of the extreme tension in the towline in tons for the various tanker and sea anchor sizes. This means that there is less than a one per cent chance that a sea anchor with a projected diameter of 30m will generate more than the 100-ton design capacity of the connector even for the worst casualty, which for such an anchor happens to be the 150kT tanker.

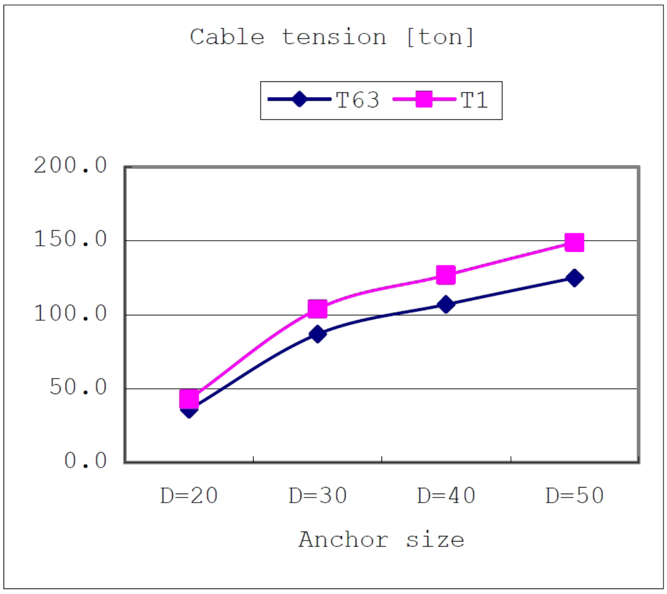
As most people in the industry are aware, there are vessels other than tankers that may pose a threat to our beaches and the offshore oil installations. Consequently, it was decided to see how a container vessel would behave when connected to the ShipArrestor. A typical 5000 TEU post panamax container vessel with the following particulars was chosen:

Length	264.4m
Breadth	40.0m
Draught	14.0m
Block co-efficient	0.6072
KG	18.44m
GM	1.0m



As can be seen, the 5000 TEU container vessel is roughly the same size, though obviously much smaller displacement than the 100 kT tanker. It is, therefore, interesting to compare the behaviour of these two vessels, one displacement dominated and the other volume dominated. Not surprisingly, the container vessel will drift faster, both before and after the ShipArrestor system has been applied. This means that the mean tension in the towline will be much higher. For dimensioning the connector, it is the extreme tension that is of interest.

The final graph shows the extreme statistical tension in the towline between the sea anchor and the container vessel in the form of a one per cent chance of exceeding (T1) and 63 per cent chance of exceeding (T63). It can be seen that the 100-ton design MBL of the connector had just over one per cent probability of being exceeded with a 30m diameter sea anchor. It should be evident from the graph opposite that the achieved 125-ton breaking load of the connector makes it capable of connecting a sea anchor of a projected diameter of 30m to a 5000 TEU container vessel.



Statistical extreme tension in towline.

CONCLUSION

A fully functional ShipArrestor system will be tested in a combined exercise organised by the Norwegian Coastal Administration in the Hjelte Fjord in June 2010. Before this exercise, the sea anchor and the connector have to be integrated into one unit and the helicopter crew have to become familiar with its application. The ShipArrestor is a tool and has its limitation just like any other tool. Its main limitation is that it is a tool that requires an experienced helicopter pilot who is both trained in flying underslung loads, and is familiar with flying to and from vessels in bad weather.