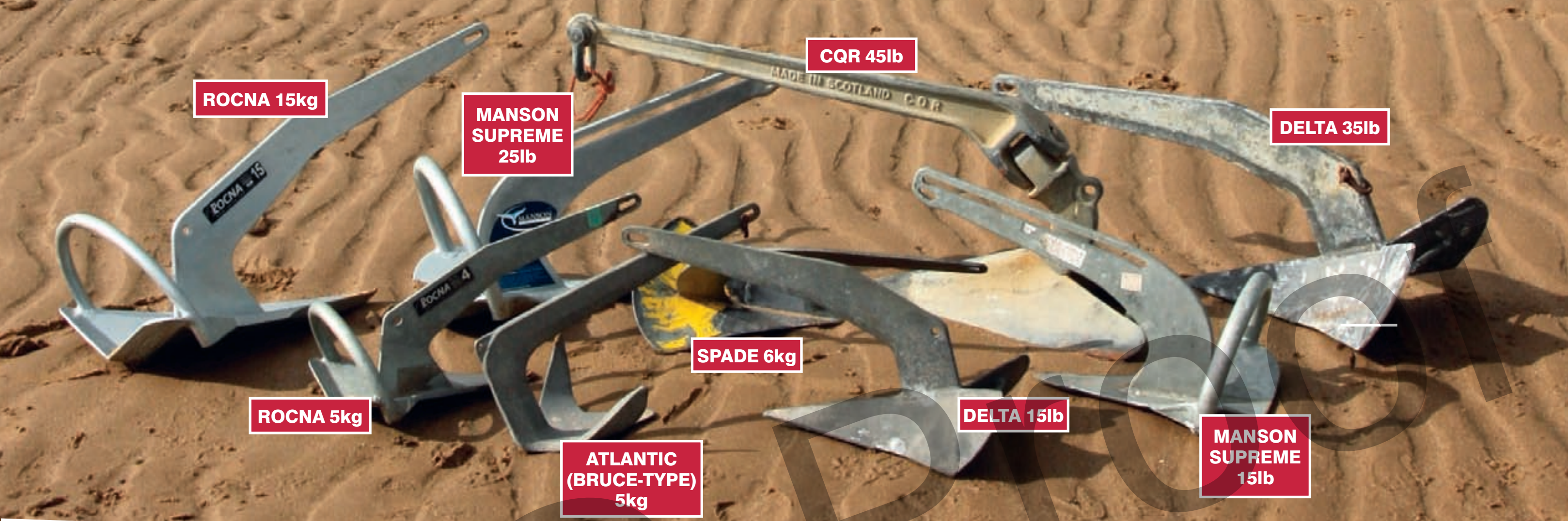
Anchors on test

What is the maximum force an anchor will hold without moving in the seabed? Professor John Knox reveals the results of over 20 years' research into the holding capacity of different anchor types



Many modern anchors are designed to set by the fluke rotating into the seabed

The storm came out of the blue on Saturday 24 July 1988. At the end of a beautiful sail in *Myfanwy*, our Hustler 35, we anchored for the night under blue skies in the bay on the west side of Gometra, an island in the Inner Hebrides.

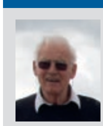
With the wind rising, we set a second anchor, ending up with a 15kg (33lb) Bruce and a 16kg (35lb) CQR.

As the wind rose further to SW Force 8, we switched on the engine. There was a treacherous reef on our starboard side, easily visible in daylight but invisible in the dark. We kept an anxious watch all night, peering into the darkness and watching the barometer fall rapidly. Were we dragging? It was impossible to tell.

We were relieved when dawn broke to find we had not moved. The wind had moderated to Force 5, but soon returned from the opposite direction with even more ferocity, gusting to Force 10.

On the VHF we heard that a Dutch vessel had been driven aground in Loch Scridain a few miles to the south. We were chastened, and thankful to have survived winds stronger than we had experienced before, or endured since.

ABOUT THE AUTHOR



■ Professor John Knox, now retired, held a Personal Chair in Physical Chemistry at the University of Edinburgh. His lifelong interest in boats has included kayaking and dinghy sailing. He now cruises on Scotland's west coast.

A learning experience

This episode convinced me that I needed to know more about anchoring. Had we just been lucky? We had dragged on other occasions. What made the difference? What sort of winds could we have expected our anchors to withstand? Do all anchors of a particular weight perform in the same way? Are some better than others? How could you test anchors to compare them?

What we needed first of all was an instrument to monitor the tension on the anchor cable. In 1993, with the help of an old friend Dr Kevin Scott, an expert in electronics, we designed Anchorwatch. This measures anchor cable tension, remembers the maximum load since resetting, and sounds an alarm when the load exceeds a preset value.

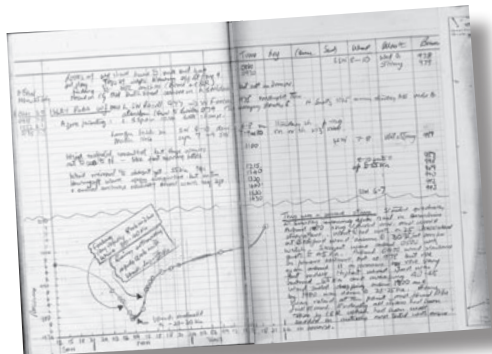
We made up a batch of 50 and eventually sold most of them, but surprisingly the yachting community was not very interested.

Using Anchorwatch on my own boat has allowed us to collect a substantial amount of data showing how the tension in an anchor cable varies with wind strength. For example, a 12m (40ft) yacht can be expected to experience peak cable tensions of around 250kgf (1kgf = 1 kilogram force = 9.8 Newtons) in a 30-knot wind and 600kgf in a 45-knot wind! The average cable load is usually around half the peak load.

How can we measure an anchor's hold?

What a yachtsman needs to know is the maximum force his anchor will hold without moving in the seabed. This is the Ultimate Holding Capacity or UHC, and is the metric used for massive oil rig anchors. ➔

The UHC is not the force at which an anchor finally breaks out from the seabed, as measured in most magazine anchor tests. Normally, when forces greater than the UHC are applied, a good anchor will slowly plough through the seabed while remaining buried. The resistance which it offers is known as the Dynamic Holding Force or DHF – this can be many times greater than the UHC, depending upon the speed of ploughing.



John's log from the storm that prompted his anchor research

The test I have developed uses a winch to pull the anchor at a constant speed. Pulling is periodically stopped without releasing the tension; the anchor then stops moving. The residual tension if the anchor is fully buried is the UHC.

Anchor efficiency

While the UHC is the crucial measure of hold, it is specific to each anchor – heavier anchors have higher UHCs. To compare anchor designs we need a metric that is independent of weight.

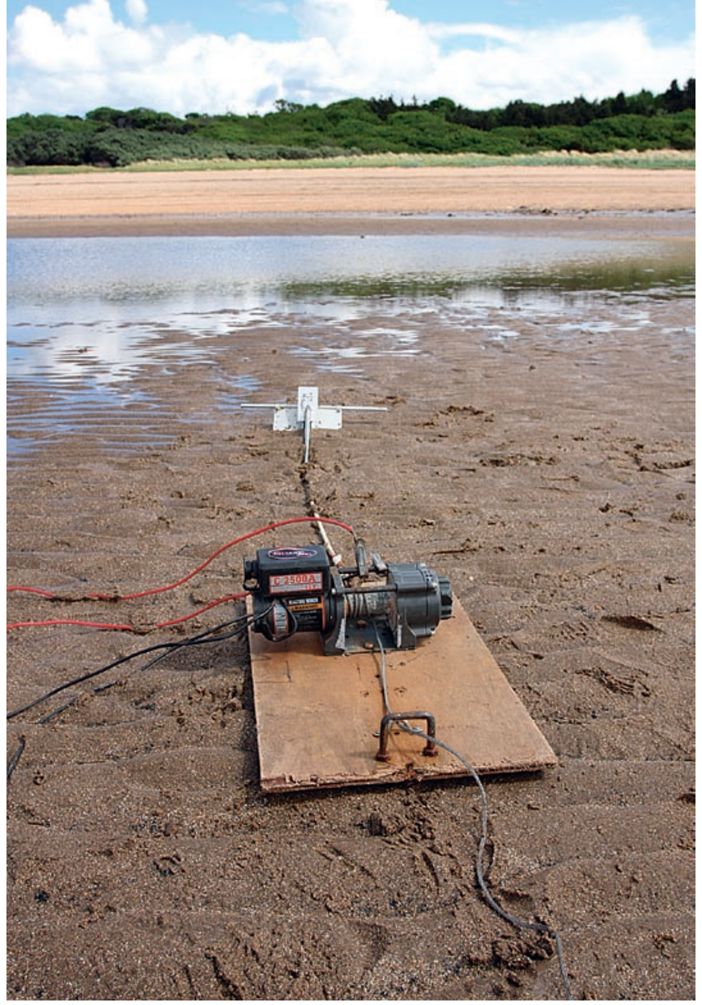
Vryhof, who manufacture and test large anchors for oil rigs, claim that for anchors in the weight range 1 to 50 tonnes, UHC is proportional to $(\text{weight})^{0.92}$. For a moderate range of anchor weights, this is close enough for practical purposes to the UHC being directly proportional to weight. Both my results and manufacturers' recommendations for anchor weights for different yachts confirm that there is indeed a reasonable linear relationship between UHC and anchor weight. Efficiency may therefore be defined as UHC (in kgf) divided by anchor weight (in kg). The efficiencies shown in the table on page 87 amazingly range from about 3½ to over 30.

The test strategy

One of the results I hoped to obtain from the test was how recent types of anchor fared against more traditional designs. An interesting feature of many modern anchors is their single, concave fluke, unlike the plough or multiple-fluke designs found on most boats. With this in mind, I have tested three modern, single-fluke anchor designs, together with a selection of the most common bower anchors.

My experiments were carried out in shallow tidal pools at Gosford Bay on the south side of the Firth of Forth near Longniddry. Here the seabed consists of medium-hard sand including coal granules. Tidal pools are convenient for anchor testing as there are no problems with tide or waves, and the anchors are easily seen in the shallow water.

Initial engagement and embedment was tested independently in hard sand/mud at the nearby Kilspindie Beach in Aberlady Bay. These tests were conducted when the tide was out but the seabed still moist. While all anchors engaged immediately at Longniddry, this was not the case at Kilspindie. However, comprehensive testing across a range of seabeds is extremely time-consuming, so I have concentrated on the popular holding of medium-hard sand, as seen at Longniddry.



The load is shared between three anchors firmly embedded in the sand at the end of the purchase and the winch assembly (above)

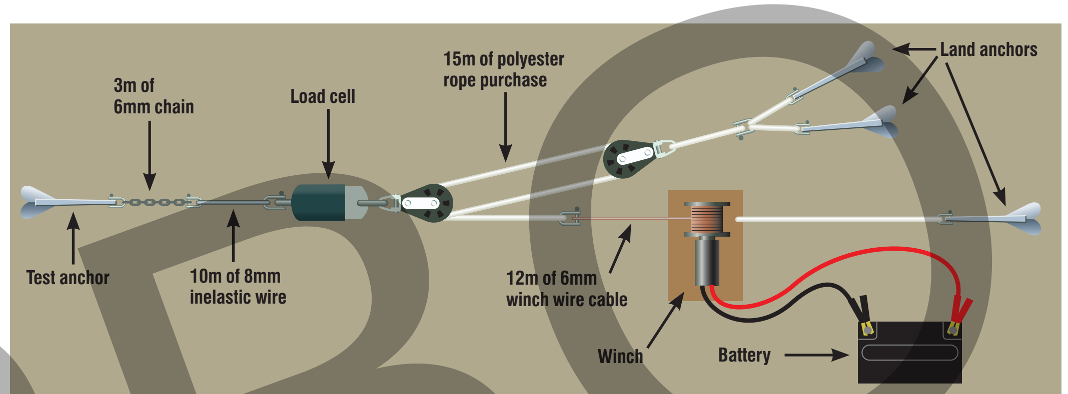


Diagram of pulling system used to determine SHF and DHF values

Anchor loads are measured using the Anchorwatch system

The method

The test anchor is first laid gently on the seabed under water as if lowered from a yacht. It is then pulled in stages by a winch and purchase system. This system provides a horizontal pull on the anchor corresponding to infinite scope (height of cable above the surface divided by length of the cable to the anchor).

The force applied is measured by the Anchorwatch load cell, fitted directly in line with the anchor. The speed of the anchor through the sand is calculated by noting the distance it drags in a fixed time, and can be varied by altering the purchase.

While the anchor is being pulled, the DHF is recorded at 2-5 second intervals. At the end of each stage, when the winch is locked, the anchor continues to move or plough for a short distance as the elasticity of the polyester part of the pulling system relaxes. At the same time the tension on the pulling cable falls, rapidly at first then more slowly until, after a minute or two, it reaches a steady value which can be maintained more or less indefinitely. This steady value is the Static Holding Force (SHF), the maximum force which the anchor can withstand without moving at that stage in the experiment.

The experiment continues until plateau values, or near plateau values, are reached for both the dynamic load (DHF) and the static load (SHF). The final plateau value of the SHF is the UHC of the anchor. It is the highest hold which the anchor can provide without moving once fully buried.

Generally, the UHC is reached after an anchor has ploughed 10 to 20 fluke-lengths – typically 4-8m for a 5-7kg anchor and more for heavier anchors.

The distance dragged is measured at the shackle of the load cell

What is required of a safe anchor?

■ HOLDING CAPACITY To be safe, any anchor must provide adequate holding for the conditions anticipated, be it for an oil rig or a yacht.

■ RAPID EMBEDMENT Whereas an oil rig anchor is placed on the seabed in a specific orientation so that it immediately engages the surface, a yacht anchor must engage the seabed from any position it can adopt when lowered from the yacht. Once on the seabed, an anchor's fluke-tip should engage the seabed as soon as the anchor is pulled. If the anchor has to drag any distance before it engages, it may pick up weed, fail to engage, or give a poor hold when it does.

■ ROLL STABILITY A safe anchor must be stable and not roll out when forced to plough by excessive force. When an anchor is pulled with a force large enough to make it drag, it should plough slowly through the seabed without rolling out.

■ MECHANICAL STRENGTH An anchor must be robustly enough constructed that it does not deform under extreme loads. Inevitably, a compromise must be struck between robustness and efficiency.

Crunching the numbers

How does cable tension relate to wind speed?

Well-established theory of the wind resistance of large objects, coupled with many Anchorwatch measurements, has led me to develop the following approximation for the peak force due to wind on a yacht, not subject to snubbing:

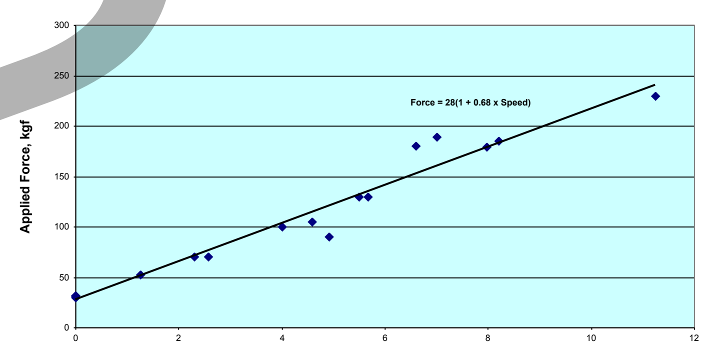
$$\text{Wind force in kgf} = \frac{(\text{LOA in metres})^2 \times (\text{wind speed in knots})^2}{500}$$

Understanding UHC and DHF

The chart on the right shows the force required to pull a fully-buried 2kg claw anchor at different speeds through medium-hard sand. The force is the DHF, and can be seen to increase more or less linearly with speed.

After each pull the tension was released and the borderline force required just to start the anchor moving recorded, giving the UHC. All these values were closely centred around 28kgf.

The UHC is the value of the DHF when the ploughing speed is (just) zero, and is represented by the intercept on the vertical axis. The chart shows that an anchor experiencing a force around four times its UHC will plough at around 5cm/sec (0.1 knot). Only with extreme force will a good anchor pull out completely.

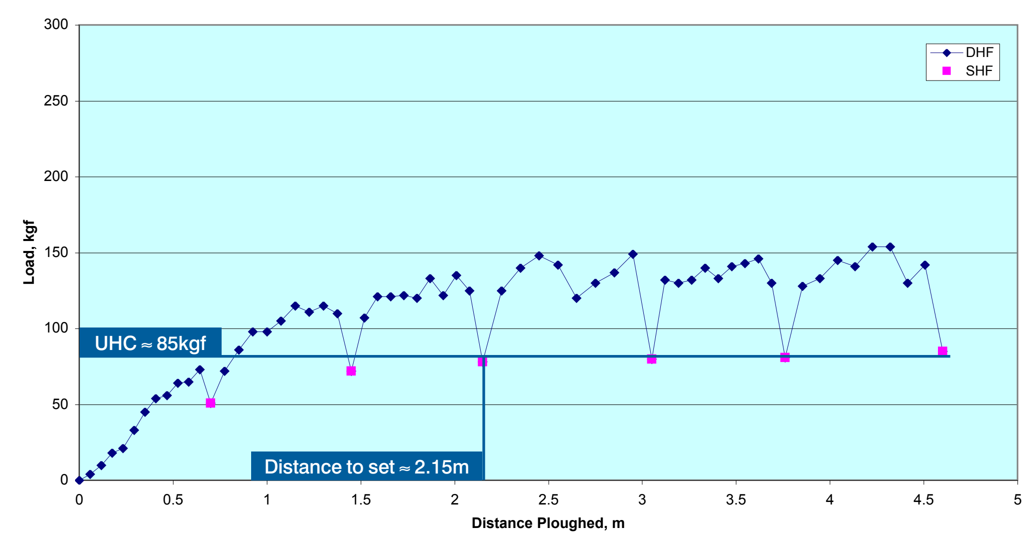


From my experiments, the relationship between DHF and UHC can be expressed as DHF/UHC = $1 + \alpha \times$ (speed of ploughing in cm/sec), where α is a constant for the particular anchor and seabed being used for the test. In the case shown in the chart the seabed was medium-hard sand, with an α value of 0.68. For a wide range of anchors in this seabed, α-values consistently fall between 0.5. and 0.7.

Reading the results

Each test was carried out in a series of stages. The load was measured at 2-5 second intervals, giving the DHF as the anchor was pulled at a constant speed for a fixed time period, usually a minute. At this point the winch was locked. The elasticity in the polyester line would then drag the anchor a short distance further until the tension in the system and the hold of the anchor reached equilibrium.

This tension, when the anchor is static but just about to drag, is called the Static Holding Force (SHF). When the SHF values reach a plateau, as shown on the chart (right), the UHC of the anchor has been reached. The point at which this plateau begins is the point at which the anchor is set.



THE TESTS – the experimental data

Test parameters

■ **DIFFERENT SEABEDS** The UHC depends critically on the nature of the seabed in which tests are carried out. I would like to emphasise that it would have been desirable to carry out tests in other seabeds, especially mud. Unfortunately, with a two-man research team, this was not possible. While different results would undoubtedly have been obtained in other seabeds, the order of performance of different anchors would probably not have changed significantly. What would have been different in different seabeds would have been the ability of the anchors to penetrate. All the anchors tested engaged immediately in the medium-hard sand at Longniddry, but not when tested in the harder sand/mud of Kilspindie.

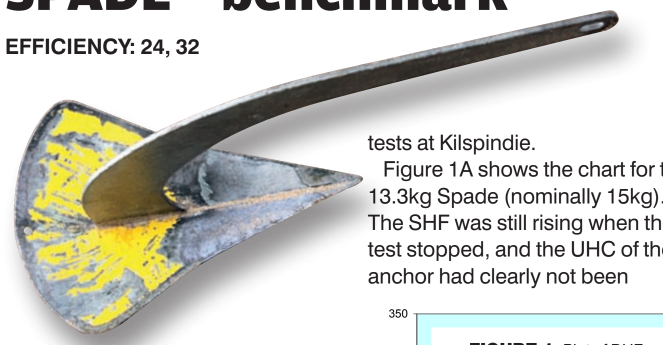
■ **NORMALISATION** Even in the same location, results can differ from day to day. Standardisation from one experimental session to the next is therefore necessary. I used the 5kg Spade anchor as my standard. In any session, the 5kg Spade was tested first followed by the anchor or anchors for which new data were required. The pulling tracks of the anchors were separated by about 1m so that they could not overlap.

Over the years of testing, the UHC of the standard Spade anchor varied randomly from 100 to 150kgf, so to compensate the UHCs quoted in the summary table have been normalised to a standard value of 120kgf for the Spade. For example, if on a particular test day the 5kg Spade gave a UHC of 130kgf while the test anchor gave 80kgf, the normalised value for the test anchor would be 80 x (120/130) = 74kgf. The charts, however, show the actual values as measured on the day, together with the UHC of the Spade.

■ **WINCH EFFECTS** As the cable is taken up by the winch, the diameter of the coil on the winch drum increases, so the rate of intake of the cable increases as it winds in. But the cable does not always wind in uniformly so the diameter of the coil can suddenly change. Also, the winch cable will be rewound several times in any one test, so there are considerable variations in the rate at which the anchor ploughs. This affects the immediate DHF, but not the SHF and UHC values.

SPADE – benchmark

EFFICIENCY: 24, 32



Over nine independent measurements on different occasions, the mean UHC of the 5.1kg (nominally 6kg) Spade was 120kgf. The results of one of these experiments is shown in Figure 1, where the SHF plateaus at a UHC of about 105kgf. The DHF over the whole run is just under twice the SHF when the ploughing rate was 1.5cm/second.

The heel of the anchor was buried to a depth of 30-32cm while the top of the shank was 5-7cm below the surface. When fully buried, there was only a very slight sand mound ahead of this anchor. In contrast, the sand behind, although not visibly disturbed, had the consistency of quicksand. It can take more than a week before the disturbed sand recovers its long-term consistency. The Spade always showed immediate engagement in the hard sand/mud tests at Kilspindie.

Figure 1A shows the chart for the 13.3kg Spade (nominally 15kg). The SHF was still rising when the test stopped, and the UHC of the anchor had clearly not been reached after ploughing 4m. I estimate that the UHC is around 350kgf which, when normalised to 120kgf for the standard anchor, becomes 420kgf. The corresponding efficiencies of the 5kg and 13kg Spades are therefore 24 and 32 respectively. The heavier anchor is 30% more efficient than the lighter one.

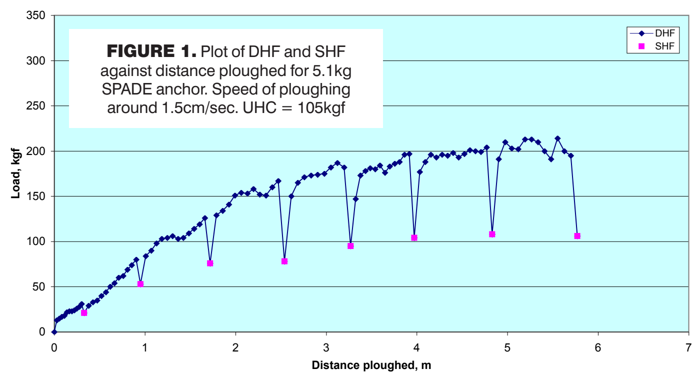


FIGURE 1. Plot of DHF and SHF against distance ploughed for 5.1kg SPADE anchor. Speed of ploughing around 1.5cm/sec. UHC = 105kgf

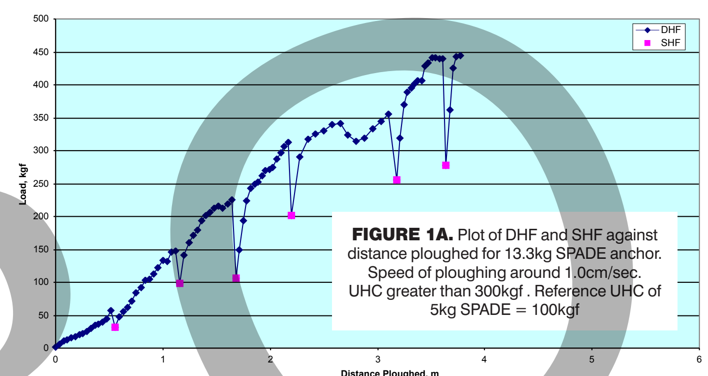
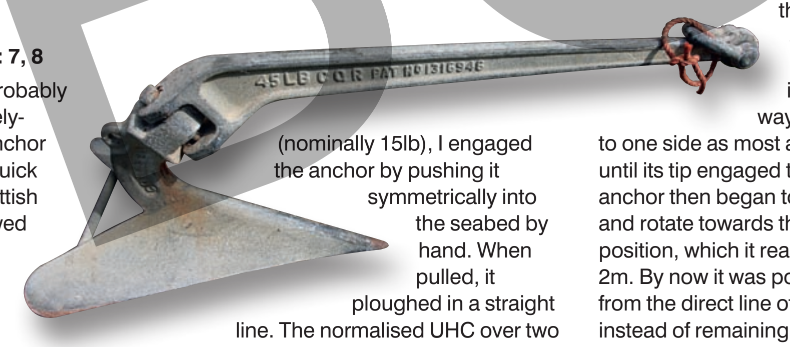


FIGURE 1A. Plot of DHF and SHF against distance ploughed for 13.3kg SPADE anchor. Speed of ploughing around 1.0cm/sec. UHC greater than 300kgf . Reference UHC of 5kg SPADE = 100kgf

CQR

EFFICIENCY: 7, 8



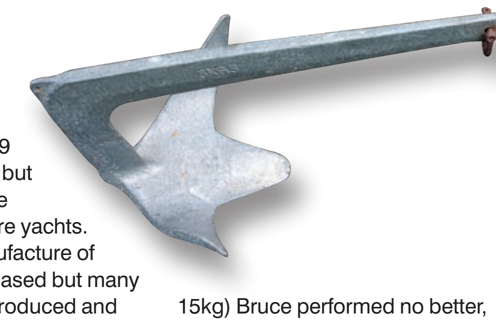
The CQR is probably the most widely-used yacht anchor in the UK. A quick survey of Scottish marinas showed that around 50% of yachtsmen use a CQR or CQR-type anchor, about 20% use Deltas and about 20% Bruce or Bruce-type anchors. This leaves only about 10% of Scottish yachtsmen using other types of anchor.

When dropped from a yacht, the CQR ends up lying on its side with its fluke almost upside-down. However, in the first of my experiments with the 6.7kg CQR (nominally 15lb), I engaged the anchor by pushing it symmetrically into the seabed by hand. When pulled, it ploughed in a straight line. The normalised UHC over two runs was just under 70kgf, corresponding to an efficiency of 10. This is very similar to the result with the 6.7kg Delta, closely modelled upon the CQR, but without the hinge.

However, when the CQR was initially laid on its side, its natural position, it behaved very differently, as shown in Figures 3 and 3A. Starting from this position, the anchor started burying itself in the normal way, veering off to one side as most anchors do until its tip engaged the sand. The anchor then began to embed itself and rotate towards the vertical position, which it reached in about 2m. By now it was pointing away from the direct line of pull. Then, instead of remaining vertical, it continued to rotate further towards a horizontal position, now the opposite of its starting position. Eventually, it lay with one half of its fluke proud of the surface and the anchor horizontal. By this time, it had ploughed about 4m. The anchor then started to re-engage, repeating the cycle. Subsequent tests confirm that the CQR ploughs a serpentine track.

Bruce

EFFICIENCY: 5, 6



The Bruce anchor was invented in 1979 primarily for oil rigs, but smaller models were widely sold for leisure yachts. Subsequently, manufacture of the yacht version ceased but many copies have been produced and marketed, including the Lewmar (Simpson Lawrence) claw, the Atlantic and the Marathon. We bought a 15kg Bruce when we acquired *Myfanwy* in 1983.

Figure 2 shows the performance of a 5.8kg genuine Bruce anchor (nominally 5kg). When pulled in sand, the anchor fully embedded after a short pull of only 1.5m. The normalised UHC was surprisingly low at 35kgf, giving an efficiency of only 6. Even when fully buried, the Bruce showed the back of its shank clear of the surface.

Our treasured 16.1kg (nominally 15kg) Bruce performed no better, as shown in Figure 2A. The UHC of 80kgf corresponds to an efficiency of only 5. Again, the top of the shank was proud of the surface. The chart shows unusual peaking of the DHF immediately after the anchor started ploughing after resting for measurement of the SHF. This peak in the DHF is immediately followed by a fall. This seems to indicate that the anchor initially dips forward when pulling starts, but then flattens out once ploughing gets under way. In other seabeds it may perform differently and provide better eventual hold.

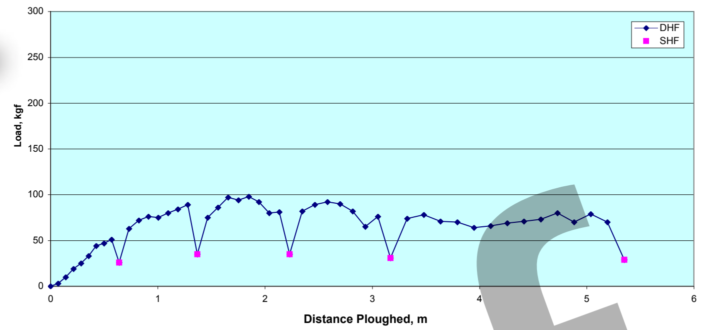


FIGURE 2. Plot of DHF and SHF against distance ploughed for 5.8kg Bruce anchor. Speed of ploughing about 2-3cm/sec. Reference UHC of SPADE = 113kgf

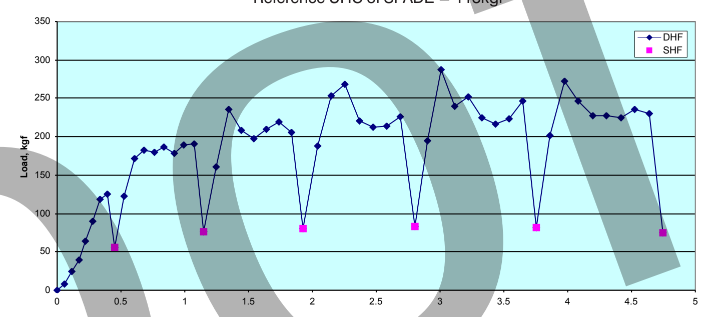


FIGURE 2A. Plot of DHF and SHF against distance ploughed for 16.1kg Bruce anchor. Speed of ploughing 3cm/sec. Reference UHC of SPADE = 120kgf

Bruce copies

EFFICIENCY: 3.5, 9

Many copies of the Bruce have been marketed since the original patent expired. The Atlantic is a good copy. Its performance is shown in Figure 2B. The anchor gave a normalised UHC averaged over two runs of 43kgf, corresponding to a normalised efficiency of 9. My results show that the Atlantic is considerably more efficient than the original Bruce.

Another Bruce copy is the crudely constructed Marathon. A 14.2kg model (nominally 15kg) gave a poor performance, with a UHC of only 50kgf corresponding to an efficiency of 3.5, roughly the efficiency of a fisherman's anchor. This anchor, when it had ploughed 4m, showed the whole of the top part of its shank above the surface of the sand.

Engagement of all these Bruce and Bruce-type anchors was immediate in sand, but at Kilspindie, both the 5kg Bruce and Atlantic simply skimmed along the surface and gave no hold. I have yet to test the Marathon and 15kg Bruce in these conditions.

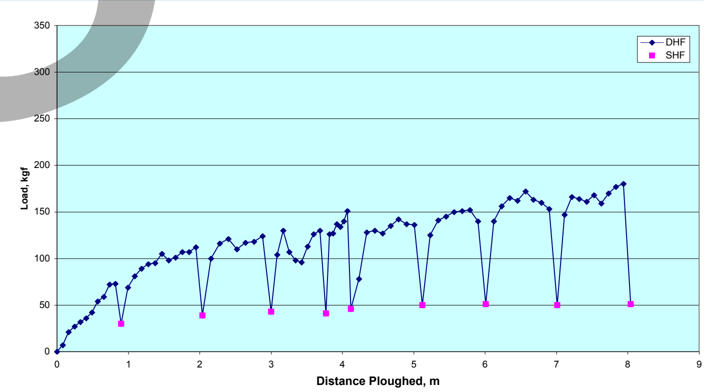


FIGURE 2B. Plot of DHF and SHF against distance ploughed for 4.9kg Atlantic (Bruce-type) anchor. Speed of ploughing about 2-3cm/sec. Reference UHC of SPADE = 135kgf

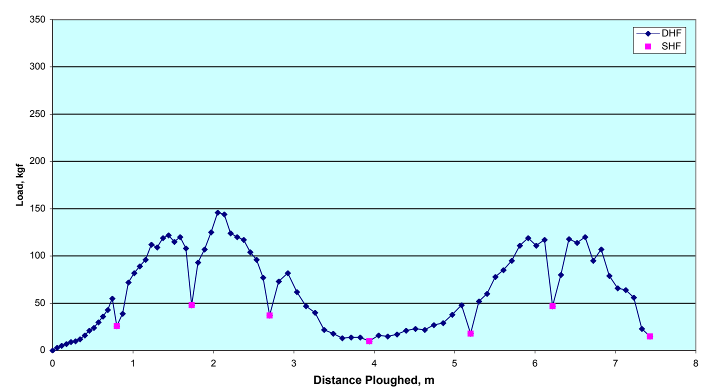


FIGURE 3. Plot of DHF and SHF against distance ploughed for 6.7kg CQR anchor. The anchor was initially laid on its side on the sand surface. Speed of ploughing about 2cm/sec. Reference UHC of SPADE = 135kgf

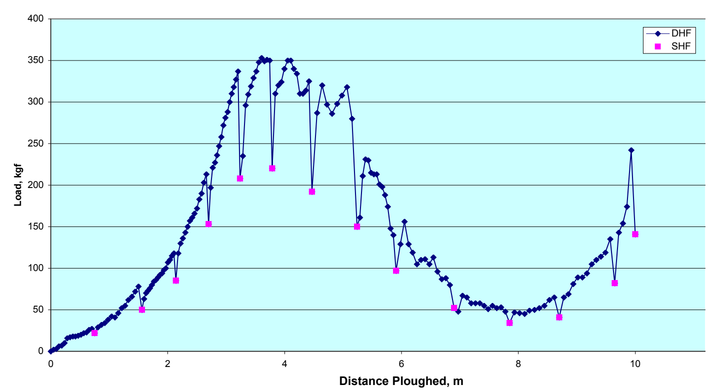


FIGURE 3A. Plot of DHF and SHF against distance ploughed for 21.5kg CQR anchor. The anchor was initially laid on its side on the sand surface. Speed of ploughing about 1 cm/sec. Reference UHC of SPADE = 150kgf

As the values never plateau it is impossible to calculate the UHC for the CQR, but the maximum (normalised) SHF as the 6.7kg anchor passed the axis of the serpentine was only 44kgf, giving a low efficiency of 7. The 21kg (45lb) CQR (Figure 3A) behaved similarly to the 6.7kg version, with the engagement cycle taking around 8m rather than 4m. The maximum normalised SHF was 175kgf and the efficiency was about 8.

In the hard sand/mud tests the 6.7kg CQR did not embed, but simply skimmed along the surface. The 21kg version behaved better, skimming the surface for about 2m before engaging. In sand, both anchors engaged immediately.

The widespread popularity of the CQR suggests that the behaviour exhibited in my tests may not be characteristic of all seabeds. However, the results show that in medium-hard sand it can break out at high loads, offering no hold at all until it re-sets.

THE TESTS continued

DELTA EFFICIENCY: 8, 11

The charts for the 6.7kg and 16.3kg Delta anchors (nominally 15 and 35lb), are shown in Figure 4 and 4A. They are similar to those for the Spade, except that the plateau value for the SHF has been reached for the heavier Delta, giving a clear value for its normalised UHC of around 186kgf.

As it ploughs, the Delta behaves differently from the Spade. It forms a distinct trench with banks of sand on either side. This anchor does not bury itself completely. Rather, it ploughs or surfs with the top of the shank only just below the surface, while a sand mound forms ahead of the anchor. The mean normalised UHC over three runs for the 15lb (6.7kg) anchor was 76kgf, and the efficiency about 11, less than half that of the Spade at 24. The normalised efficiency for the 35lb (16.3kg) Delta was again 11. A 4.1kg (nominally 9lb) Delta gave a normalised UHC value of 34kgf corresponding to an efficiency of 8. The efficiency thus rises from 8 to 11 as the weight increases from 4kg to 7kg, but is independent of weight from 7kg to 16kg.

Testing of the 6.7kg Delta in the hard sand/mud at Kilspindie showed that it had to be pulled about twice as far as the Spade before engaging the surface. In sand, engagement was also slower, as seen from the relatively slow build-up of DHF over the first metre or so of ploughing.

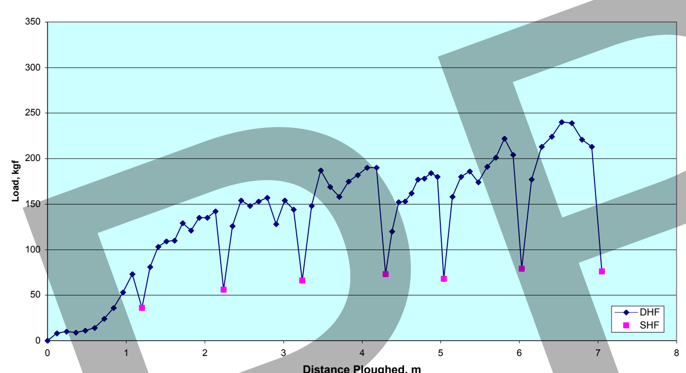


FIGURE 4. Plot of DHF and SHF against distance ploughed for 6.7kg Delta anchor. Anchor initially laid on its side. Speed of ploughing about 2cm/sec. Reference UHC of SPADE = 113kgf

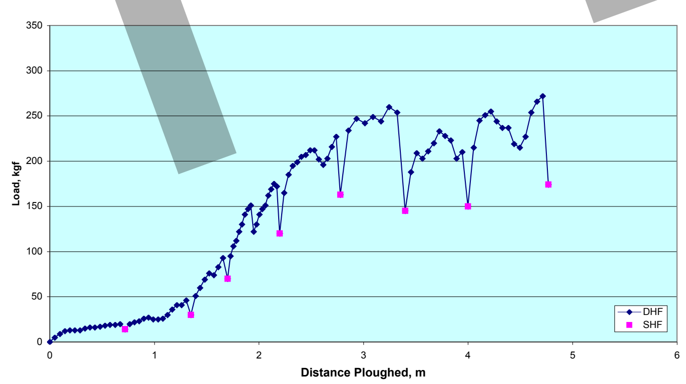


FIGURE 4A. Plot of DHF and SHF against distance ploughed for 16.3kg Delta anchor. Speed of ploughing about 1.1cm/sec. Reference UHC of SPADE = 113kgf

Rocna

EFFICIENCY: 21, 30

The Rocna originates from New Zealand and is designed along similar lines to the Manson Supreme, both having rollbars to encourage initial engagement with the seabed. The plots of DHF and SHF against distance ploughed for 4.1kg (nominally 4kg) and 16.2kg (nominally 15kg) Rocna anchors are shown in Figures 5 and 5A. The normalised UHC of the 4.1kg model is 85kgf and the efficiency is 21. The chart for the 16.2kg model shows that even after ploughing 5m, the SHF has not reached a plateau value. The UHC of this anchor has not been achieved and is probably around 400kgf, normalised to 480kgf. This would provide an efficiency of 30, equivalent to that of the 15kg Spade.

The Rocna showed immediate embedment in the hard sand/mud tests at Kilspindie.

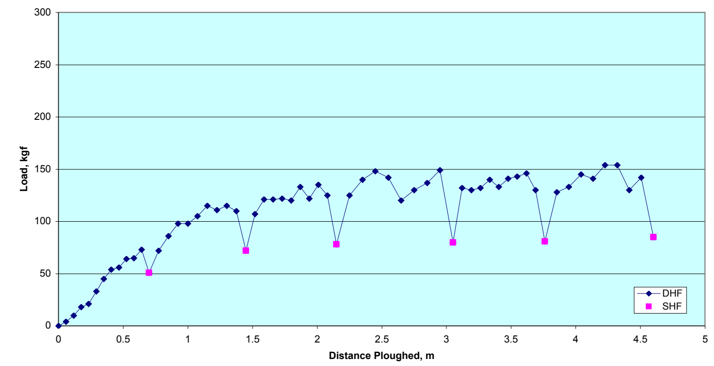


FIGURE 5.
Plot of DHF and SHF against distance ploughed for 4.1kg Rocna anchor.
Speed of ploughing about 1.5cm/sec.
Reference Hold of 5.1kg SPADE = 100kgf

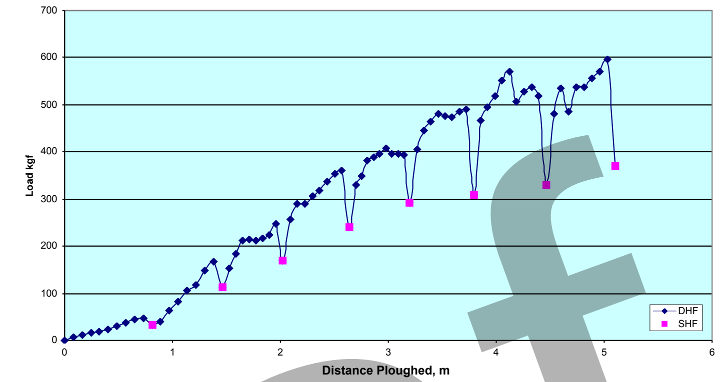
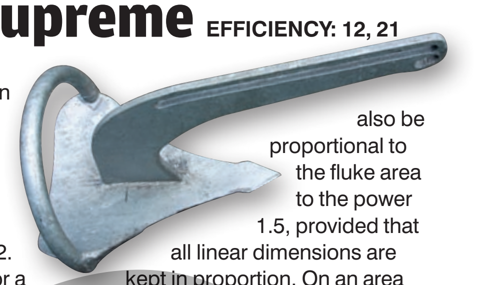


FIGURE 5A.
Plot of DHF and SHF against distance ploughed for 16.2kg Rocna anchor.
Speed of ploughing about 1.0cm/sec.
Reference Hold of 5.1 kg SPADE = 100kgf

Manson Supreme EFFICIENCY: 12, 21



This is a relatively new anchor, again developed in New Zealand. Figure 6 shows the results for the 7.3kg (15lb) model. Over three runs the normalised UHC was 90kgf, giving a normalised efficiency of 12. This is relatively modest for a newer design anchor, and is similar to that of the older Delta. However, Figure 6A shows the 10.7kg model performed much better, giving a normalised UHC of 225kgf and an efficiency of 21.

This wide difference in efficiency for a relatively small increase in weight was unexpected. However, the fluke areas of the anchors are 5.3dm² and 9.5dm² respectively. If the hold of an anchor is indeed proportional to its weight, it should also be proportional to the fluke area to the power 1.5, provided that all linear dimensions are kept in proportion. On an area basis then, efficiencies should be quoted as hold/(area)$^{1.5}$.

The ratio of the efficiencies of the two Manson anchors could therefore be expected to be $(9.5/5.3)^{1.5} = 2.4$, which is exactly the ratio observed. Measurement of the anchors shows that the 7.3kg model is more robustly constructed than the 10.7kg model. The Manson Supreme showed immediate embedment in the hard sand/mud at Kilspindie.

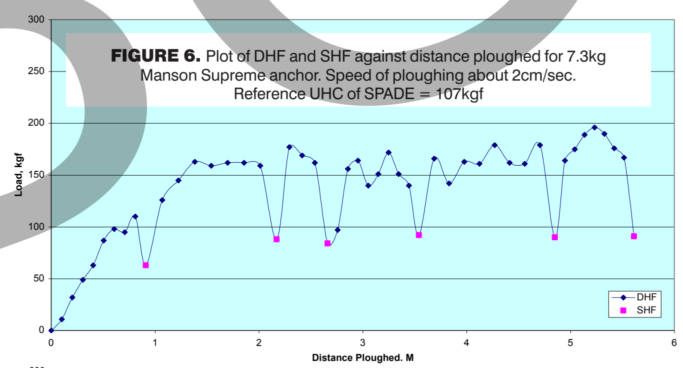


FIGURE 6. Plot of DHF and SHF against distance ploughed for 7.3kg Manson Supreme anchor. Speed of ploughing about 2cm/sec. Reference UHC of SPADE = 107kgf

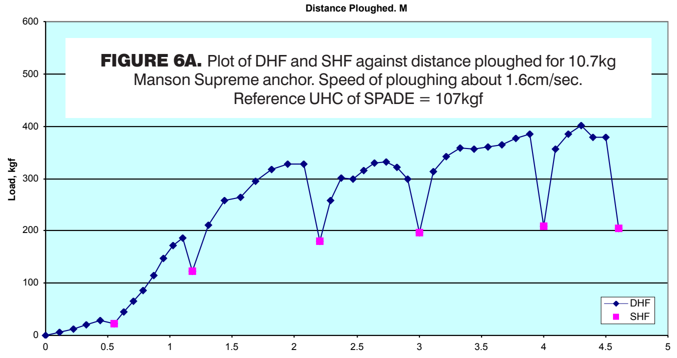


FIGURE 6A. Plot of DHF and SHF against distance ploughed for 10.7kg Manson Supreme anchor. Speed of ploughing about 1.6cm/sec. Reference UHC of SPADE = 107kgf

Summary table of UHC values and efficiencies of anchors

Anchors from 4-22kg weight, tested in medium-hard sand at Gosford Bay, Firth of Forth

Anchor type and nominal weight	Actual weight (kg)	Fluke area, sq dm	UHC normalised to 120kgf for 5.1kg Spade	Efficiency = UHC/weight	Initial engagement with hard sand/mud
6kg Spade	5.1	4.50	120 (mean of 9 tests)	24	Excellent
15kg Spade	13.3	8.4	420	32	Excellent
9lb Delta	4.1	4.6	34	8	Moderate
15lb Delta	6.7	6.3	76 (3 tests)	11	Moderate
35lb Delta	16.3	11.4	186	11	Good
15lb CQR (dug in by hand)	6.7	4.4	68 (2 tests)	10	Dug in by hand
15lb CQR (laid on side)	6.7	4.4	44 (maximum SHF)	7	Dragged on surface
45lb CQR (laid on side)	21.5	9.6	175 (maximum SHF)	8	Poor – eventually after 2m initial drag
5kg Bruce	5.8	3.6	35	6	Dragged on surface
15kg Bruce	16.1	5.9	80	5	Not tested
5kg Atlantic (Bruce-type)	4.9	3.3	43 (2 tests)	9	Dragged on surface
15kg Marathon (Bruce-type)	14.2	6.0	50	3.5	Not tested
15lb Manson Supreme	7.3	5.3	90 (3 tests)	12	Excellent
25lb Manson Supreme	10.7	9.5	225	21	Not tested
5kg Rocna	4.1	4.6	85 (3 tests)	21	Excellent
15kg Rocna	16.2	10.3	480	30	Not tested

PBO VERDICT

EXCELLENT PERFORMANCE

■ **Spade, Rocna, and Manson Supreme.** Holding tests in medium-hard sand show that these anchors give the highest efficiencies. Larger anchors require a longer distance to embed, beyond the limits of the tidal pool in which we were testing, meaning that we were unable to calculate the UHC's for the larger Rocna and Spade anchors. However, the results extrapolate to suggest that the normalised efficiencies for both anchors are around 30. The heavier Manson Supreme gave a lower normalised efficiency of 21, but is the most robustly constructed of the three.

All three anchors engaged immediately in hard sand/mud, and all can be recommended.

GOOD PERFORMANCE

■ **Delta.** This is a reliable anchor with a normalised efficiency of 11 for the heavier models. The Delta is not as efficient as the first group of anchors, and may engage reluctantly in harder seabeds.

POOR PERFORMANCE

■ **The CQR.** My major conclusion is that when the CQR anchor is forced to plough it rolls out sequentially while executing a serpentine track. This could be extremely serious in conditions when the anchor is working at the limit of its holding. In sand it provides a poor hold for its weight, and in hard seabeds is difficult to engage. Even when giving its peak hold, its normalised efficiency is only 7 to 8.

■ **Bruce-type anchors.** Although these do not roll out as the CQR does, they give poor performance with efficiencies in sand of 3.5 to 9. Tests suggest that they do not engage readily in harder seabeds.

The storm revisited

So, with the benefit of hindsight, was *Myfanwy* in real danger on the night of 24 July 1988? We experienced steady winds of 40 to 45 knots with gusts to over 50 knots, so my formula would give peak cable tensions of around 400kgf rising in the strongest gusts to 600kgf. The average cable tension would have been around half this.

If we assume (and it is a big assumption) that the seabed at Gometra had the same holding power as at Longniddry, our 35lb (16kg) CQR anchor would have given a maximum SHF of about 130kgf while our 15kg Bruce would have added another 80kgf. Our engine would have given us an additional 100kgf, so our total holding power without dragging would have been just over 300kgf.

On this basis, our anchors plus engine should have held us without moving most of the time with average cable loads in the region of 200 to 300kgf. However, peak loads would still have substantially exceeded the combined UHCs of the two anchors backed up by the engine. During these surges, we would have ploughed short distances, but would have been safe most of the time. If the wind had been stronger we might well have dragged continually.

As a postscript, we would have been much safer had we had been able to use modern anchors. Two 16kg Delta anchors would have given us enough holding for the conditions and been better then what we had, but by comparison a single 15kg Spade or Rocna, or a 20kg Manson Supreme, would have achived the same result. PBO