Safety At Sea Studies - 1995 Anchor Study

THE SAILING FOUNDATION ANCHOR TESTS
PUGET SOUND, 1995

By Doug Fryer

On June 17 and 18, 1995 the Safety at Sea Committee of the Sailing Foundation conducted anchor tests on five selected sites on Puget Sound. The tests were co-sponsored by West Marine Products and attended by their representative, Chuck Hawley. Also in attendance were Portland naval architect Robert Smith who has written and tested anchor behavior extensively[1], and Andy Peabody of Creative Marine who markets the MAX anchor. Diving services and underwater video were donated by Dwayne Montgomery of Emerald City Diving.

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OBJECTIVE to METHODOLOGY

Objective

The test objective was to evaluate the relative performance of anchors commonly used on sailing craft of the 40'-45' class in bottom conditions typical of the northwest. Performance characteristics included holding capacity, setting, stability and veering[2]. A visual underwater site investigation with divers was conducted prior to the tests but no detailed soil analysis was performed. The areas selected were chosen by the author based on extensive anchoring in Puget Sound and on the diver's opinion that the areas were typical of Puget Sound bottom conditions. It is also recognized that conditions will (and did) vary to some extent within each site. To make up for this, each anchor was tested at different locations within each site and different anchors were tested at approximately the same sites.

Synopsis

A cautionary note should be mentioned at the outset. That is, this is not to be understood as the definitive anchor study but rather as one series of tests which we have compared with other tests. The tests did not focus on any special handling requirements of each anchor but effort was made to simulate an ordinary, careful setting procedure. The test collectively lead to only very general conclusions and do not account for anecdotal evidence. While there were controls applied to minimize variables, each attempted set was not on the exact location of other sets but rather in the same general area a short distance away. The boats used each had different horsepower which prevented some tests from recording the maximum resistance of the CQR, Delta and Performance 35 until they were placed on tugs the second day. Approximately 280 sets were accomplished in five areas in the two-day period of tests.

The tests were conducted on a variety of bottom which ranged from good holding to foul. In general, than anchors with the largest surface or fluke area performed the best in good holding bottom and all anchors had trouble setting in rocky, kelp infested areas. The Davis and Luke anchors did not perform well in any area. The Bruce, which set virtually every time, had the least holding power of the remaining anchors.

In the vast majority of anchoring situations in Puget Sound, resistance of 300-400 lbs. is probably more than adequate for summer cruising. Any anchor's best performance is probably optimized after some hours of soaking. Nevertheless, when the higher holding power is needed (storm conditions, lee shore, etc.), it is probably needed immediately and there may not be time to "soak." Getting underway can be difficult or dangerous. Two of the anchors that sustained the highest loads suffered damage, but the loads imposed were probably higher than would ever be imposed by weather except for shock loads caused by "bar tight" all chain rode. It also should be noted that the tests only recorded the static resistance in pounds given by the anchors, and dynamic shock loads, such as those caused by wave action or wind gusts, were not duplicated. Static holding power is nevertheless an important measure for anchor capability. Of the anchors tested, only five passed the threshold of 1,000 lbs. and only four could arguably pass as storm anchors. The holding power of those four - the MAX, CQR, Fortress and Performance 35 - exceeded storm anchor requirements, but failed to do so on a consistent basis.

ANCHORS AND EQUIPMENT SELECTED AND PROCEDURES EMPLOYED

Anchors and Gear

The anchors selected[3] were the Davis DXL 45, Luke 50, Delta 35, CQR 45, Fortress FX 37, MAX 17, West Marine Performance 35 and Bruce 44. Four identical rodes of 3/4" New England Ropes 3 Strand nylon line with 30' of 3/8" high test ACCO chain were supplied. The rodes were marked at 15' intervals and the distance from water line to where the rode led over the (bow/stern) of each boat was also measured to

make sure a consistent 5:1 scope was selected. The 5:1 scope was chosen as a constant factor for all tests because it was the standard for the San Francisco 1990 tests and the most common standard used by Bob Smith in his Columbia River Tests. At 5:1 about 80% of each anchor's holding power should be achieved compared to 10:1 scope. Each boat had a strain gauge made fast to the rode. Three strain gauges had capacity up to 4,000 lbs. or more; the fourth gauge had a 2,000 lb. capacity. Two of the boats had insufficient horsepower to maximize the strain gauges but the anchors they worked with did not approach those limits. In theory a boat should be able to pull 30 lbs. per rated horsepower. However, two boats could only pull about 1/3 of this backing down.

Vessels

The boats used in the tests were:
1. Gilcrest - A 53' former tug with a 400 H.P. Allis-Chalmers engine. Owner/operator Bob Coe.

2. Portage Bay - The Seattle Yacht Club race committee boat, a 40' displacement trawler with a 120 H.P. Ford Lehman. Operator Denny Johnson.

3. Comfort - A 34' displacement trawler with a 120 H.P. Ford Lehman. Owner/operator Frank Shriver.

4. Reliable - A 45' commercial tug with a 225 H.P. 671 GMC rated at a bollard pull in excess of 6,000 lbs. Owner/operator Phil Shiveley.

Methodology

A maximum limit of 4,000 lbs. was imposed for all tests. This was well under the published breaking strength of the nylon rodes (16,000 lb.). Sometimes this limit was exceeded because of imprecise throttle setting.

a. Straight Pulls. The procedure was to deploy the anchor, set it as gradually as possible to simulate normal anchoring, and observe the strain gauge and if it steadied at idle speed, gradually increase the rpms until the anchor dragged or until the strain gauge achieved the maximum predetermined limit. Dragging was ascertained to be any movement. It was usually indicated on the strain gauge first as a sudden drop in tension. Holding was determined to be steady tension for several seconds with no movement. Two people were assigned on each boat to take bearings and ascertain movement and one to monitor the strain gauge. When an anchor gave short periods of resistance or spikes, those were not recorded as holds. For instance, in foul ground anchors would apparently catch rocks and sometimes spike at 500-800 lbs., then let go and sometimes reload at equal stains. This was not regarded as holding. Slow consistent drag was not regarded as holding if the anchor did not stop although it might have been sustained for long periods. An exception to this procedure was with the Luke anchor which manifested some slow drag at the first series of tests and no numbers could otherwise be recorded. Sometimes it was difficult to assess dragging because it was very slow, perhaps one foot per minute was reported by the divers.

b. Veering. If an anchor was initially pulled to drag, it was re-set at a minimum 300 lbs. then the boat maneuvered to 90-degrees from the original heading and power increased to drag or maximum strain. If the anchor did not drag initially a 90-degree veer was conducted without a reset. The same procedure was then repeated for a heading of 180-degrees from the 90-degree heading. Because of time constraint and anchor damage at the higher loads, the veering tests were primarily conducted only on the first day.

c. Resetting. If an anchor dragged and did not reset immediately it was pulled to the surface and cleaned before reset. Only attempts with clean anchors were recorded.

RESULTS TABLES 1-3

RESULTS

The results are broken down by area tested. The sites had been initially selected based upon Washington State, Corps of Engineers and NOAA charts for differing soil conditions and were then surveyed on April 22 by diver Montgomery during a reconnaissance. Additional underwater site checks were conducted during testing to confirm bottom characteristics.

Site 1. Off Point Monroe and entrance to Port Madison. Bottom consists of some scattered eel grass, kelp, and mostly sand. This was a good holding area for most anchors. There was some unevenness in the area which caused difficulty in maintaining scope at 5:1 when some anchors were pulled into deeper water.

Table 1
Results Straight Pull - Site #1

Anchor	Maximum Line Tension Before Dragging									
Luke 50 (53 lbs) [1]	Slow drag to 440	Slow drag to 360	Slow drag to 300	Slow drag to 240	Slow drag to 300	Slow drag to 280				
Bruce 44 (45 lbs.)[2]	780	580	680	600	600	530	700	560		
Davis 45 (45 lbs.)[3]	No Set	No Set	No Set	No Set	No Set	No Set	No Set	No Set		
CQR 45 (47 lbs.)[2]	350	500	1400	1100	1800	3200	No Set[4]	No Set[4]	No Set[4]	No Set[4]
Delta 35 (35 lbs.)[2]	900	600	950	800	1100	600	600	1100*		
MAX 17 (43 lbs.)	1016	1334	3110**	500[4]						
Performance 35 (40 lbs.)	1100	2200	3100*	1600	2330*					
Fortress 37 (24 lbs.)		No Set	710	4100*	4100*	2400	4510*	4205*		

*No drag at maximum applied strain.

**Bent fluke.

[1] Observers felt that the Luke moved more or less slowly and consistently at all times up to the time it broke free. In general they felt they were never confident the anchor had actually set.

[2] The Bruce, Delta, MAX and Performance 35 set every time.

[3] The Davis did not set in ten attempts.

[4] These sets were on deep slope areas which presented more difficulty in setting. This was poor technique and not the fault of the anchors.

Table 2
Results on 90-degree Veer Pull - Site #1

Anchor	Maximum Line Tension Before Dragging							
Luke 50 (53 lbs)		Slow drag to 220	Slow drag to 440	Slow drag to 310				
Bruce 44 (45 lbs.)		800	600	860				
Davis 45 (45 lbs.)[3]								
CQR 45 (47 lbs.)[2]		No Set	550	900	1700	1400	1900	2250
Delta 35 (35 lbs.)	950	900	No Set	750	450	400	1000	1050
MAX 17 (43 lbs.)		360	3105	No Set	No Set	1300	Several Attempts	2300
Performance 35 (40 lbs.)[3]								
Fortress 37 (24 lbs.)		4248 [1]						

[1] Bent anchor shank and did not repeat veer test. (Previous straight line set at 4100.) Anchor did not break out. *See* Table 3.

[2] No attempts were made on the Davis for the 90-degree veer as it had failed to set in ten consecutive attempts at straight pull. *See* Table 1, above.

[3] No attempts at 90-degree veer conducted. The Gilcrest was having some difficulty maneuvering at this point.

Table 3
Results on 180-degree Veer Pull - Site #1

Anchor	Maximum Line Tension Before Dragging							
Luke 50 (53 lbs) [1]	140	320	350	280				
Bruce 44 (45 lbs.)	700	680	600	600				
Davis 45 (45 lbs.)[2]								
CQR 45 (47 lbs.)	No Set	No Set	1100	700	1300	800	1100	850
Delta 35 (35 lbs.)	900	1150	No Set	950	No Set	No Set	550	
MAX 17 (43 lbs.)	400	900	No Set	No Set	2200			
Performance 35 (40 lbs.)	1500		830 [3]					
Fortress 37 (24 lbs.)		4001 [4]						

[1] Slow drag in all sets but resistance noted.

[2] No 180-degree tests were done with Davis as the anchor had not set in ten consecutive attempts on straight pull test. *See* Table 1.

[3] Pull into deeper water so scope changed dramatically.

[4] Anchor initially set at 4100, then 90-degree at 4248 then 4001 at 180-degree. Shank bent during process so veer tests with this anchor not repeated. Underwater view of anchor shows it completely buried in sand initially, with about 4" of fluke out during veering tests.

Site 2. Off Wing Point in an area of kelp (none detected from surface but indicated on chart)[4] small rock and more rocky as it deepened. A poor holding area for all anchors. Rocks about fist size and hard glacial clay bottom. Anchors generally observed by divers as skipping over rocks without being able to penetrate clay. The larger surface anchors picked up a lot of kelp.

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SUMMARY OBSERVATIONS PUGET SOUND TESTS, SITES 1, 3 AND 5[6]

AVERAGE HOLDING POWER

FX 37	3,263 lbs.
Performance 35	1,724 lbs.
CQR 45	1,304 lbs.
MAX 17	1,268 lbs.[7]
Delta 35	801 lbs.
Bruce 44	496 lbs.

The results are slightly skewed in favor of the anchors tested with the higher horsepower boats. In a few tests the CQR, Delta and Performance 35 were not dragged because of limits on the horsepower of the boats setting those anchors. Nevertheless, the averages give a reasonable picture of relative holding power.

Wing Point and Jefferson Head are not included as being generally foul ground.

COMPARISON WITH OTHER ANCHOR TESTS

A summary of the West Marine San Francisco mud tests of 1990 and the 1990 Biscayne Bay sand tests reflects the following.[8]

Type	Weight	San Francisco Mud Results -- Average	Slack Line	Florida Sand Test Averages [9]
Bruce 44	46	280	0	1883
CQR 45	47	440	4	3350
Delta 35	33	502	4	N/A
H-1800	33	725	4	3700
FX 37	20	825	2	7580
MAX 38 [10]	38	800	0	N/A

Comparison with Columbia River tests[11] in sand bottom.

Average Observations

Anchor	Cable Tension to Drag
CQR 45	437
Bruce 45	305
Luke 50	186
Dan Hi Tensile 25	849
Lightweight 25	809

Three other anchor tests are summarized in Appendix 2. They provide an interesting comparison. They confirm that the Bruce style generally does not perform as well as the CQR or Danforth types. The MAX anchor tests at Pensacola indicate that at least on those tests which were commissioned by Creative Marine, the MAX out-performed the FX 37, CQR 45 and Bruce 44 consistently.

CALCULATED RODE TENSION IN WIND AND WAVES[12]

The following is Bob Smith's analysis of the force applied to sailboats of different sizes in wind and waves based on observations in the Columbia River. *See* "Anchors Selection and Use" 2d ed. (1983).

		WIND VELOCITY - KNOTS														
		21	**24**	**27**	**30**	**33**	**36**	**39**	**42**	**45**	**48**	**51**	**54**	**57**	**60**	**63**
LENGTH OF BOAT IN FEET	**21**	46	60	76	94	114	135	158	184	211	240	271	304	339	375	414
	24	60	78	100	123	149	176	207	240	275	313	354	397	442	490	540
	27	76	99	126	155	188	223	262	304	349	397	448	502	560	620	684
	30	94	112	156	192	232	275	323	375	430	490	553	620	691	765	844
	33	113	148	188	232	281	333	391	454	521	592	669	750	836	926	1021
	36	135	176	224	276	334	397	465	540	619	705	796	893	995	1002	1216
	39	158	207	263	324	392	465	546	634	727	827	934	1048	1168	1293	1427
	42	183	240	305	376	455	540	633	736	843	960	1083	1215	1355	1499	1655
	45	211	275	350	431	522	620	727	844	968	1102	1243	1395	1555	1721	1899
	48	240	313	399	491	594	705	827	961	1101	1253	1415	1587	1769	1958	2161
	51	271	354	450	554	671	796	934	1085	1243	1415	1597	1792	1998	2211	2440
	54	303	397	504	621	752	892	1047	1216	1394	1586	1790	2009	2239	2479	2735
	57	338	442	532	692	838	994	1166	1355	1553	1767	1995	2239	2495	2762	3048
	60	374	490	623	767	929	1102	1292	1501	1721	1958	2210	2480	2765	3060	3377
	63	413	540	687	845	1024	1215	1425	1655	1897	2159	2437	2735	3048	3374	3723
	66	453	592	754	928	1124	1333	1564	1816	2082	2370	2675	3001	3345	3703	4086
	69	495	647	824	1014	1228	1475	1709	1985	2276	2590	2923	3280	3656	4047	4466
	72	539	705	897	1104	1337	1586	1861	2162	2478	2820	3183	3572	3981	4406	4863
Factor		0.104	0.136	0.173	0.213	0.258	0.306	0.359	0.417	0.478	0.544	0.614	0.689	0.768	0.85	0.938

ANCHOR CABLE TENSION = $(\text{LENGTH})^2$ X FACTOR. SCOPE OF FIVE BOAT. VEERED 30-DEGREE TO WIND. TABLE VALUES ARE FOR SLOOPS OR CUTTERS, ADD 15% FOR YAWLS, 25% FOR KETCHES AND SCHOONERS.

CONCLUSIONS

Selection of Anchorage

The tests indicate that because no anchor performed well in rocky, kelp-infested areas, a selection of suitability of bottom for anchoring, may be more important than selection of an anchor. Indications on nautical charts of bottom characteristics are very general. Cook and Vancouver took the time to investigate potential anchorages but in these days of electronic gadgets it is probably unrealistic to expect yachtsman to use tallow on a lead line. Investigation of holding ground is possible through experience and, if all else fails, experimentation. Since it is generally difficult to verify the quality of the set, the best insurance is personal experience with a given anchor design and its suitability for specific bottom conditions.

Selection of Anchors

There would appear to be at least four important criteria for anchor selection: (1) reliability to set, (2) holding power, (3) ability to withstand veering, and (4) susceptibility to damage.

The Luke and Davis anchors failed to either set or hold so consistently that they can be considered unacceptable.

Importance of High Percentage of Setting. This is a very important factor in all but windy conditions and in this regard the Bruce would rank the highest. This is probably why many Bruce anchor owners express satisfaction with its properties. The setting percentage in our tests were.

Summary of Holding Per Attempt

Rank	Anchor	Total Attempts	Set	Did Not Set	Percent of Attempts
1	Bruce 44	33	32	1	97%
2	MAX	31	20	11	64.5%
3	Perf 35	28	18	10	64.2%
4	CQR 45	48	30	18	62.5%
5	FX 37	27	16	11	59%
6	Delta 35	58	33	25	56.8%
7	Luke 50	28	4	24	14%
8	Davis 45	27	0	27	0%

The results are skewed in favor of the anchors which set in foul ground. However, those areas should not be selected for anchoring in all but the lightest weather, e.g., day anchorages and calm.

Impact of Veering Tests

The veering tests were 56 in number and primarily conducted at one site, which was good holding ground. In general, the unstable anchors were unstable on veering and the good holding anchors held well on veering.[14]

Holding Power

The worst time for an anchor to drag is in extreme conditions. Those situations often occur at night, on lee shores or when a vessel may be surrounded by coral heads, reefs or other boats. Most cruising boats in Puget Sound may anchor thousands of times in summer weather yet never experience a storm anchorage. However, the probabilities of foul weather increase if a boat cruises to the West Coast of Vancouver Island, further north, or in the winter months. For argument, two thresholds could be

established for a 45' sloop (1) 42 knots (rare indeed in an anchorage), (2) 63 knots (the edge of the hurricane and perhaps a once in a lifetime event).

42 knots

Strain of 844 lbs. according to Smith tables; for safety factor, deck houses and or ketch rigs raise this to 1,000 lbs. Assessment is made on the minimum capability of the anchors to achieve 1,000 lbs. holding power, in the Puget Sound tests the anchors.

Pass	Fail
Delta 35	Davis 45
CQR 45	Luke 50
MAX 17	Bruce 44
Performance 35	
FX 37	

63 knots

Strain of 1899 lbs.; for safety factor, deck houses and/or ketch rigs raise to 2300 lbs. The ABYC tables state that a 45' boat with 13' of beam should have a storm anchor capability of 3,200 lbs. For our purposes four anchors demonstrated the capability of more than 2,300 lbs. holding power one or more times during our testing sequence.

Pass	Fail
FX 37	Davis 45
CQR 45	Luke 50
MAX 17	Bruce 44
Performance 35	Delta 35

Damage

The MAX and Fortress anchors both sustained significant damage. The MAX bent its flukes twice and shank once (seriously). The Fortress bent both flukes on one test and the shank twice. However, most damage was sustained at strains in excess of 3,000 lbs. which was probably more tension than would be generated by a sailboat of less than 56 feet in winds of 63 knots. Boats that size should have bigger anchors. The Performance 35 sustained no damage although it sustained loads of 4,100 lbs. The Fortress did bend flukes at 2,100 lbs. on primarily sand bottom at Blake Island.

The first thing the tests indicate is that the Puget Sound areas tested do not compare exactly with the Columbia River, San Francisco or Florida tests. Just as the holding power of mud varies, so does the holding power of sand. In the end it is an analysis in soil cohesion; just as a civil engineer would analyze soils for construction of a pier and vary the piling length, so must power of the anchor depend on the particular soil. Nevertheless, there are similarities in how the holding power of the anchors ranked.

A comparison of the San Francisco mud tests, the Smith observations and Puget Sound tests would rank the similar anchors as follows for holding power:

	Puget Sound	San Francisco	Columbia River[15]
Rank 1	FX 37	FX 37	FX 37
Rank 2	Performance 35	Dan H 33 Dan T 39	Dan H 33 Dan T 39
Rank 3	CQR 45	Dan Plow 38	Dan Plow 38
Rank 4	MAX 17	Delta 36	Delta 36
Rank 5	Delta 35	CQR 47	CQR 47
Rank 6[16]	Bruce 44	Bruce 46	Bruce 46

In the Puget Sound tests the Performance 35 had only slightly less holding than the FX 37. It was not tested in San Francisco but would be more comparable to the Danforth Hi Tensile 33. The Bruce demonstrated the least holding power and the CQR about mid to low range in all three areas. The Delta was marginally better than the CQR in San Francisco and Columbia River, but the reverse was true in Puget Sound.

Adequate holding power should be the most important criteria rather than the ease of setting. An average sailboat auxiliary engine of 30-40 H.P. can exert perhaps 300-400 lbs. backing down while setting an anchor. Many anchors would hold at that tension, giving the illusion that the vessel is secure, only to fail when the wind builds. In our tests the Bruce had a tendency to reset after a drag then it would drag again only to reset. If a person had been below during dragging, the dragging might not be observed. It would seem preferable for an anchor to not set than to set and hold at only moderate conditions.

For Puget Sound conditions we would therefore rank the anchors as follows:

1. Performance 35 or similar pivoting fluke steel Danforth style. Ample holding power, construction resistant to damage. Adequate setting characteristics.

2. CQR 45 - Although significantly less holding power than the Danforth types, it is resistant to damage, has enough holding power for most conditions, and is relatively easy to set.

3. Fortress 37 - When set has more holding power than any of other anchors tested. Harder to set than most anchors and subject to damage.

4. MAX 17 - Very good holding power in most areas but subject to damage at higher loads.[17] This anchor did not hold well at Blake Island.

5. Delta 35 - Not easy to set and not a storm anchor for Puget Sound.

6. Bruce 44 - Easy to set and strong but must be ranked as a moderate weather anchor for Puget Sound.

7. Luke 50 - Consistently failed to show even minimum requirements for holding.

8. Davis 45 - Consistently failed to set at all.[18]

The foregoing recommendations are made on the basis of the tests observed and review of other tests. It is recognized that there is anecdotal evidence that some of the lower ranked anchors will occasionally perform better than indicated. For example, *see Practical Sailor* August 15, 1994, describing an incident where a CQR failed and a MAX held in severe conditions.[19] Or, *see* the report of Bloodhound anchoring on a rocky lee shore in a storm with a fisherman style anchor. Heavy Weather Sailing, Coles (1956). However, the anecdotal reports are subject to imprecision and soils differing from those observed during our tests.

We acknowledge the help of Bob Smith in preparing this report and the comments of Andy Peabody of Creative Marine and Chuck Hawley of West Marine. Wilbur Andrews and Bob Taylor provided comments on the test procedure when the test plan was designed

August 1, 1995

FOOTNOTES:

1. "Anchors Selection and Use" 2nd ed. (1983).

2. It is recognized that anchor size may vary the result, *e.g.*, a 750 lb. Navy anchor will have substantially better penetration characteristics than a 75 lb. Navy anchor, although data does not support the conclusion that there is constant efficiency with size. "Interaction of Anchors With Soil and Anchor Design" R.J. Taylor (1983).

3. Prior to the tests, each anchor was individually weighed. The actual weights are as follows: West Marine Performance 35-40 lbs.; Luke 50-53 lbs.; CQR 45-47 lbs.; Davis 45-45 lbs.; MAX 17-43 lbs.; Fortress FX 37-24 lbs.; Delta 35-35 lbs.; Bruce 44-45 lbs.

4. Kelp grows in the Spring and Summer. By late summer the kelp here is visible on the surface.

5. "Mud is obviously a generic term when used on charts. Mud strength varies considerably. "Interaction of Anchors With Soil and Anchor Design" R.J. Taylor (1983).

6. These are:

Point Monroe: uneven bottom, sand, eel grass, kelp;
Port Madison: sticky mud, shells, weed, eel grass;
Blake Island: sand, clay, eel grass.

7. If holding power as a factor of weight was considered, the CQR and MAX would change positions.

8. Data supplied by West Marine Products. Note the anchor weights are somewhat different than those recorded in the Puget Sound tests.

9. This study in Biscayne, Florida, was reported in Sail June 1990 and in a report by Nav-X Corporation dated February 28, 1990. Nav-X manufactures the Fortress. The tests were conducted in coarse grain coral sand.

10. A prototype MAX anchor tested only two times at San Francisco held to 800 lbs. on both occasions. Its promise in those tests led to its selection for the Puget Sound tests.

11. Source "Anchors Selection and Use" R. A. Smith, 2d ed. (1983).

12. Ibid Table 15.

13 The ABYC (American Boat and Yacht Council) values are higher and are discussed *infra*. Some observers, Wilber Andrews included, do not agree that veering will affect load.

14. However, the Delta did exhibit a tendency to drag and pick up weed on the veering tests. The Luke which was generally unsatisfactory also tended to foul the chain on the stock during the veering.

15. Source - Robert A. Smith. Based upon observation, Smith would also rate the holding power of the Performance 35 second to the FX 37.

16. The Luke 50 and Davis 45 are not listed as they failed to have minimum holding capacity.

17 Andy Peabody who manufactures the MAX suggests that the anchor was at a disadvantage during the tests because the Reliable of 83,000 lbs. displacement was substantially heavier than Comfort and Portage

Bay.

18. Jim Davis, manufacturer of the Davis 45, reported that the anchor had been furnished to the Sailing Foundation with the wrong stock and that this was the reason for its failure.

19. The author has also recently interviewed two ocean cruisers, one returning from the South Pacific, another who has just returned from Patagonia, the Falklands and South Georgia, who both report the Bruce was reliable as a storm anchor in the areas encountered.

APPENDIX 1

Diver Debrief and Video Review

Diver Montgomery reported as follows:
1. Point Monroe Area. Mostly sand, some scattered kelp and eel grass. Bottom uneven in places and when anchors pulled downhill they become unstable. When set on even bottom the Fortress was completely buried. When strain applied the chain lifted off the floor with very slight camber. In one section of bay with compact sand Montgomery couldn't set Davis anchor manually in the sea bed.

2. Wing Point. Small fist-size rock, lots of kelp on top of hard glacial clay. Anchors skipped over rocks and rocks prevented flukes from digging into surface on most occasions. Large fluke anchors became clogged with leafy kelp and other weed.

3. Port Madison. Large areas of sticky mud, some debris on bottom. At entrance some weed and eel grass.

4. Jefferson Head. More and larger rocks than at Wing Point but bottom sand. Again most anchors had flukes deflected by rocks and could not get to the sand. The large fluke anchors became clogged with kelp.

5. Blake Island. More sand, less eel grass than noted on the April 22 reconnaissance. Tests done in 15' of water at minus tide. The hard clay eel grass noted on reconnaissance was inshore at 7' depths. Chart indicates sand at deeper water (1946 survey). More flat than Pt. Monroe and easier setting. Both CQR and Delta pulled furrows with their shanks lying above floor. A longer scope (8 or 10:1) might have helped. The Fortress and Performance 35 buried completely in the sand.

APPENDIX 2

Other Anchor Tests Reviewed and Summarized as Follows:

French Anchor Test

A report issued in 1987 summarized tests conducted at Quiberon Bay, France, examined the holding power of 12 kg. (30 lbs.) anchors on bottoms reported to be mud, sand and hard. The results include the following:

Mud Tests
(Medium Density Mud)

Anchor	Weight	Holding Power
CQR	27.8	1250 lbs.
Bruce	23.5	660 lbs.

Sand and Gravel

CQR	27.8	2530 lbs.
Bruce	23.5	440 skids

Compact
(Madrepores and Pieces of Rocks)

CQR	27.8	2530 lbs. (lost anchor)
Bruce	23.5	770 lbs. (drags)

MAX Anchor Tests

On August 1, 1991, Underwriter Capabilities, Inc., issued a report to Creative Marine regarding tests of Creative's MAX anchor near Pensacola, Florida. The bottom is stated to be light mud to medium soft sand.

The results are summarized as the average results of three sets for each anchor in each area.

Anchor	Light Mud-Holding	Medium to Soft Sand - Holding
MAX 15	280 lbs.	200 lbs.
MAX 17	520 lbs.	450 lbs.
MAX 20	925 lbs.	1050 lbs.
Fortress FX 37	No Set (5 Attempts)	600 lbs.
Bruce 44	173 lbs.	600 lbs.
CQR 45	175 lbs.	375 lbs.

Dutch Anchor Test

A Dutch anchor test was reported in the Wk 12, 1990, Watersport Journal. Anchors were tested in boxes 6 meters in length and filled with sand covered with water. The results of holding power measurements:

Type of Anchor	Weight	Holding Power

Bruce 16	17.38 lbs.	407 lbs.
Danforth 225	24.6 lbs.	2970 lbs
Delta 22	23.1 lbs.	946 lbs.
CQR 25	25.3 lbs	715 lbs.
FX 11	6.16 lbs.	2530 lbs.