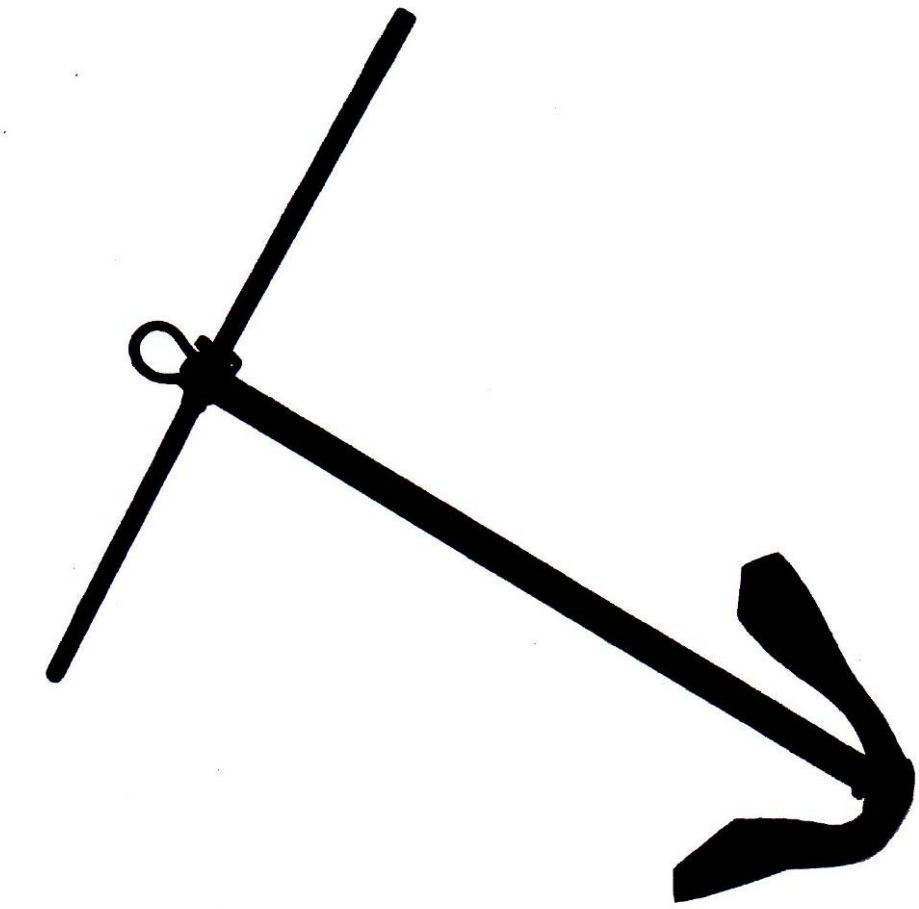
THE HERRESHOFF MANUFACTURING COMPANY
THREE PIECE STOCK ANCHOR



AN EXAMINATION OF THE ANCHOR AND ITS DESIGN

October, 2020

Introduction

This study of the Herreshoff three piece anchor has expanded well beyond the initial objective of satisfying my curiosity regarding the anchors history. The large quantity of material available and the detail it contained dictated a more thorough investigation. The design records and correspondence that survive provide the opportunity to examine, in detail, the design and development of these anchors. Perspective is required; anchors were a very small portion of the production of the Herreshoff Manufacturing Co. and this makes the attention Capt. Nat devoted to perfecting this one piece of hardware all the more remarkable.

Capt. Nat's command and application of mathematics was extraordinary and I hope this paper provides some insight and appreciation of that ability. I am certain it was both NGH's experience and mathematical skills that afforded him the ability to carefully analyze and have confidence in the application of new materials and in the many design innovations he introduced. Anchors are an important part of any ship's or boat's outfit, none the less, the considerable time and attention to detail that NGH devoted the design, testing and improvement of these anchors is terribly impressive and certainly explains why they were so highly regarded by those who used them.

The great number of superb yachts large and small, particularly the magnificent yachts built for the America's Cup races, tend to eclipse the exceptional, vertically integrated and efficient organization that was the Herreshoff Manufacturing Co. Think about it, two brothers working together in their home town of Bristol, Rhode Island built and operated a world renowned company whose innovation, productivity, quality, and engineering was unmatched. I have difficulty comprehending the level of dedication, intelligence, management skill and self-confidence these two brothers brought to this extraordinary enterprise.

The Herreshoff Manufacturing Company; good management at all levels, combined with engineering excellence and with intimate knowledge of their work created exceptional products that commanded a premium price.

Jim Giblin
April 21, 2017

Acknowledgements

The drawings and materials available from the Haffenreffer-Herreshoff Collection Hart Nautical Collections at the MIT Museum, The G.W. Blunt Library at Mystic Seaport Museum and the The Herreshoff Marine Museum were essential to this endeavor. I am grateful to the curators, librarians and staff of these institutions for providing access to their collections.

The information from Nathanael G. Herreshoff's Design Notebooks provided by Halsey C. Herreshoff contributed significantly to the content and accuracy of this document.

In addition to the museums and libraries, Paul Bates, Maynard Bray and Claas Van der Linde have been very generous sharing material from their collections.

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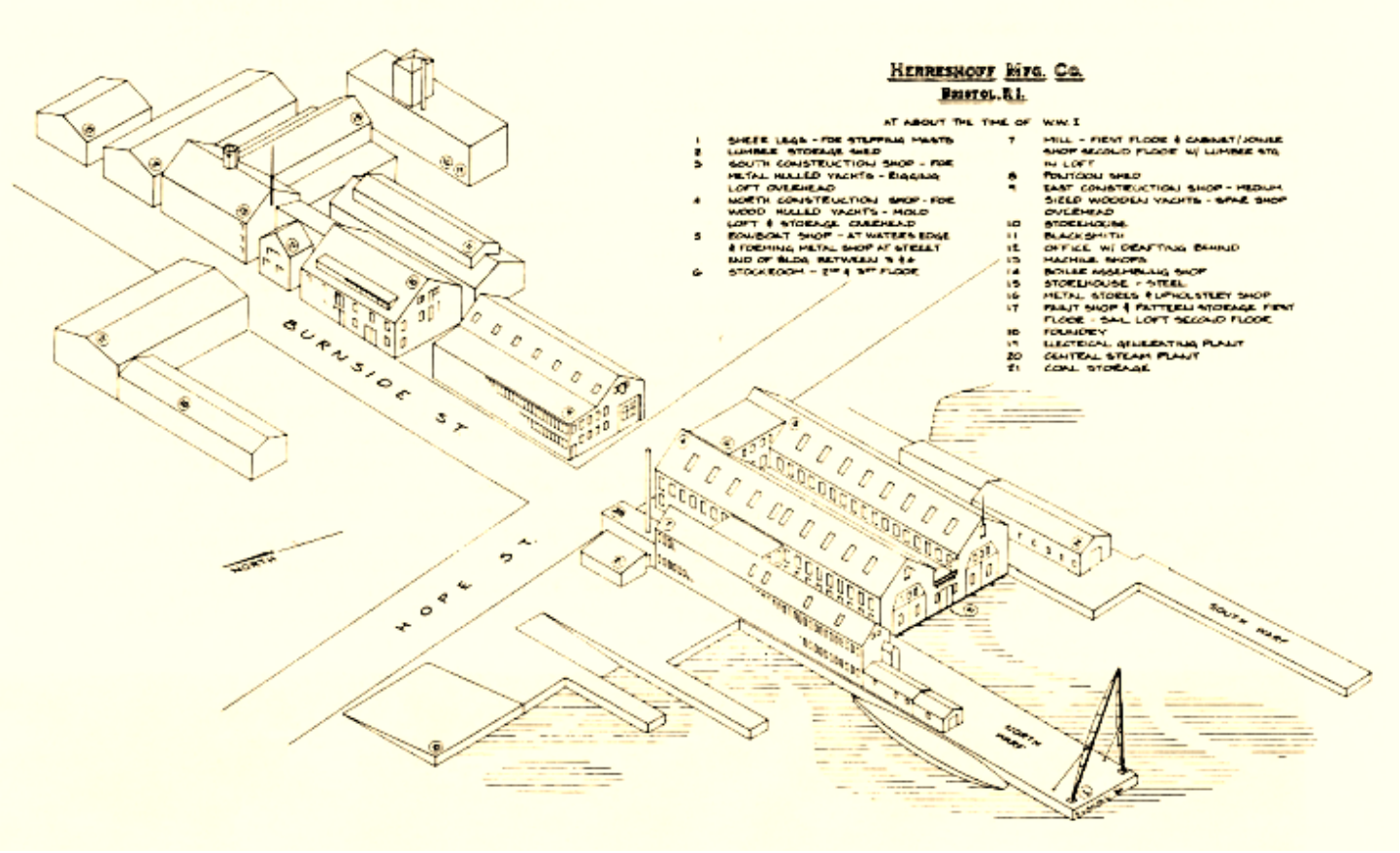
Herreshoff Manufacturing Company, Bristol, Rhode Island

1878 - 1945



Circa 1915

(Courtesy Herreshoff Marine Museum/Americas Cup Hall of Fame)

History of the Herreshoff Three Piece Stock Anchor.

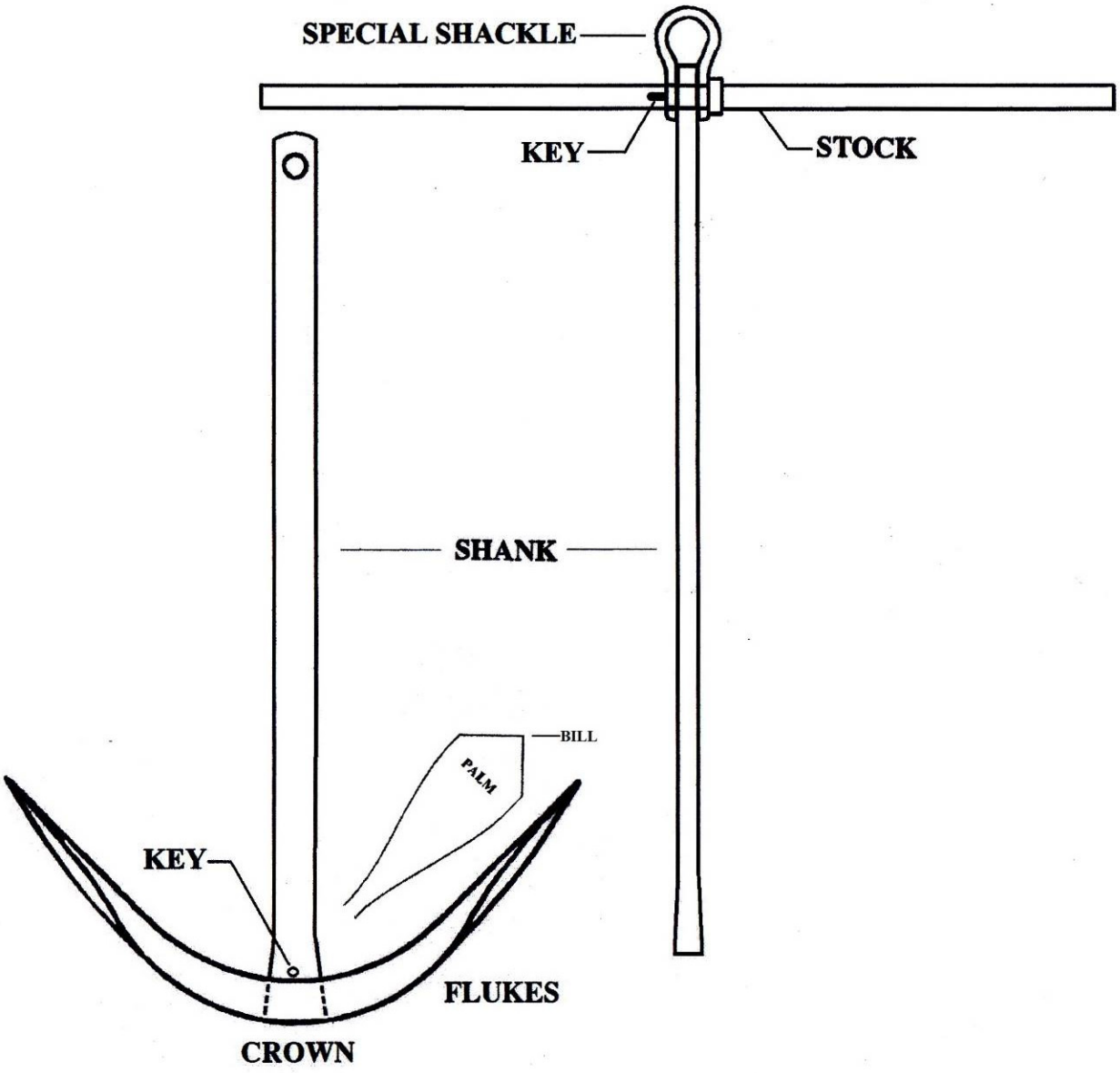
L. Francis Herreshoff wrote that his grandfather, Charles Frederick Herreshoff, conceived the idea of the three piece stock anchor about 1860-1870 and had the first such anchor made for him by a Bristol Rhode Island blacksmith.[(1)]. In a 1935 letter to L. Francis Herreshoff discussing his various accomplishments NGH stated he considered the Herreshoff anchor in its final form one of his most important achievements and credited the original design of the anchors to his father in about 1854.*

Existing documentation and the writings of L. Francis Herreshoff indicate the Herreshoff Manufacturing Company began to produce the three piece stock anchors early in the early 1880s for the yachts and naval vessels they were building. In "The Common Sense of Yacht Design Vol 2" L. Francis Herreshoff states the three piece anchors were made in three styles, those with a straight stock, those with a folding stock and a third style which had a longer shank that his father sometimes called sand anchors.[(1)] I have been unable to locate any information regarding the sand anchors. Based upon both testing and experience the design of the Herreshoff anchor was continually refined over a period of more than thirty years. The design evolution is well documented by a series of drawings in the Hart Nautical Collections at the MIT Museum; the earliest drawing describing these anchors is dated March 29, 1882 and provides dimensions for twenty-two anchors ranging in size from 10 pounds to 640 pounds. Later drawings reflecting design refinements to all anchors were issued in 1905, 1907 and 1911. The final 1911 drawings provide the dimensions for 27 anchors weighing 10 to 1260 pounds.
The Herreshoff Manufacturing Company continued to produce and sell anchors until it ceased operations in 1945. Merriman Brothers, who had for many years sold near copies of the Herreshoff anchors acquired the rights to the Herreshoff anchor patterns and continued to sell anchors cast from these patterns[(3)] until they too went out of business. Some cast steel Herreshoff anchors remain in private hands and now and then one appears on Ebay or in a second hand store, but it is most uncommon to locate one of the earlier forged anchors. The Herreshoff Marine Museum and Mystic Seaport Museum both have examples of Herreshoff anchors in their collections.

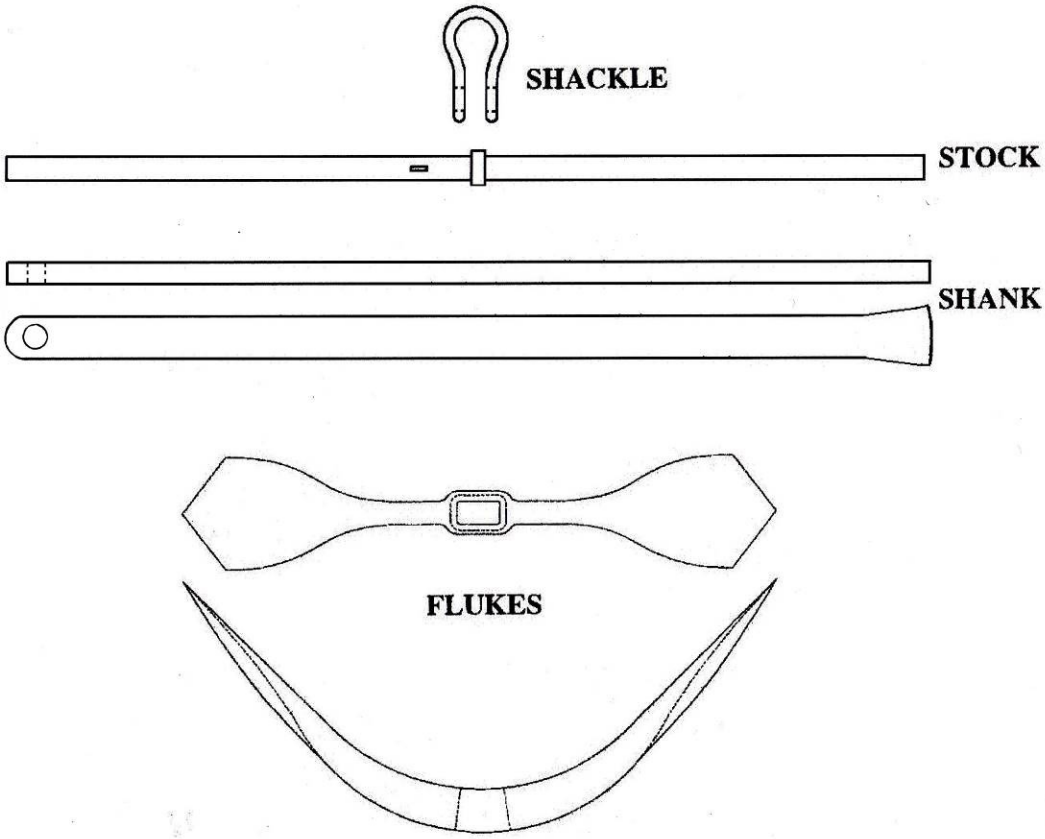
FOLDING STOCK ANCHOR

STRAIGHT STOCK ANCHOR

Terms Used to Describe the Herreshoff Straight Stock Three Piece Anchor



Innovative Design Elements of the Herreshoff Manufacturing Co.
Three Piece Stock Anchors

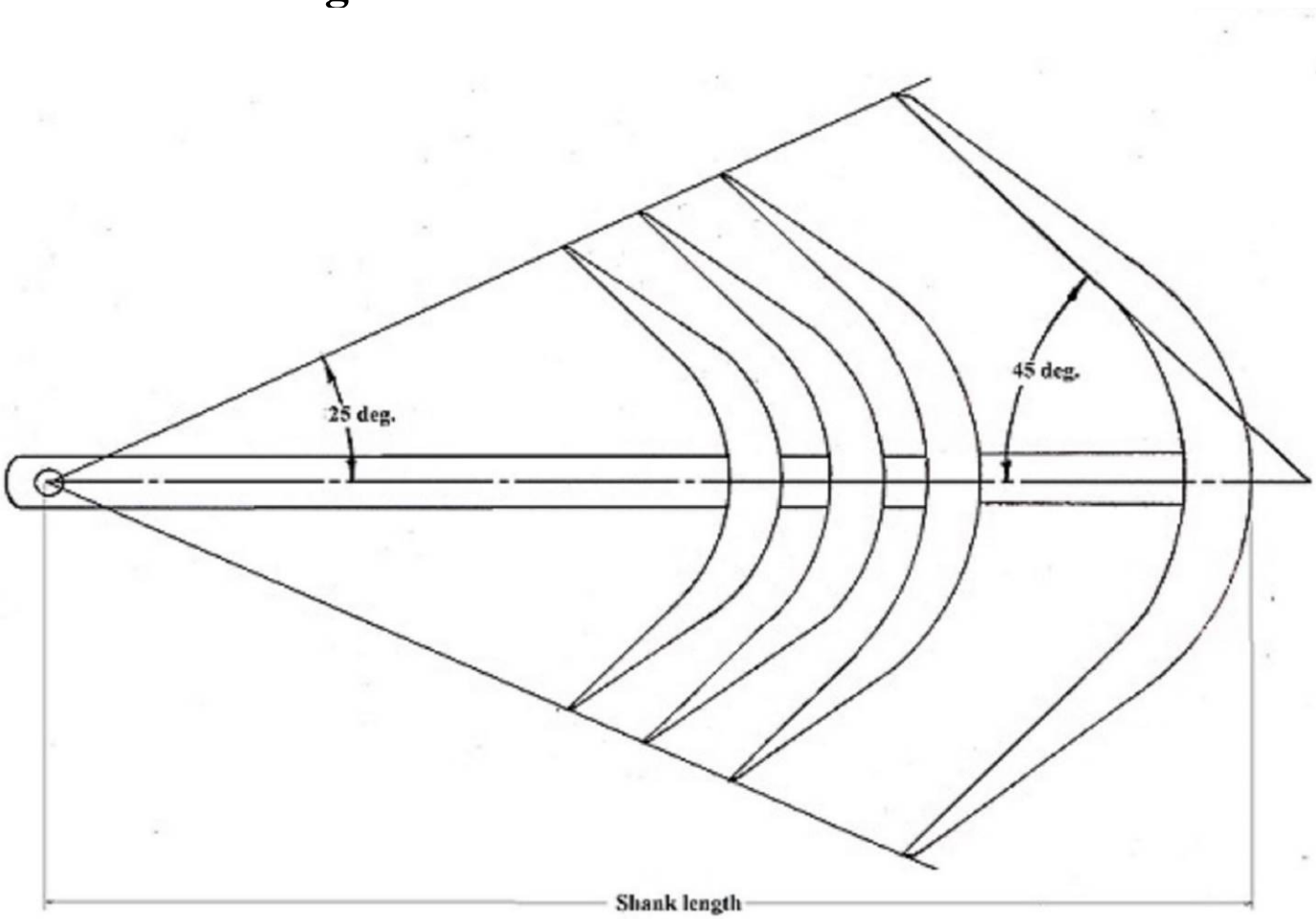


- The Herreshoff anchor is composed of three separate pieces: Shank, stock and flukes, all mechanically assembled with only two keys.
- The smoothly curved shape of the palm and the triangular shape at the end of the palm were significant improvements over the heart shaped palm of the traditional stock anchor.
- The smoothly curved palm significantly reduced the potential for the anchor rode to foul the unburied portion of the fluke and the triangular bill increased the area of the palm, thereby increasing the holding power of the anchor.
- The edges of the flukes were sharp to improve the anchors ability to cut and penetrate the bottom soil permitting it to set quickly and reliably.
- A tapered socket was used to join the shank and flukes. This eliminated the forge weld commonly used for the purpose and permitted the anchors to be easily disassembled, and stowed on or below deck.

The rectangular cross section of the shank is easily fabricated and presents less resistance to penetration of the bottom soil than an equivalent weight round cross section. The rectangular cross section is also stiffer in the critical direction than a round cross section of equivalent weight. The design of these anchors is based upon engineering calculations and testing which places material only where it is required to meet the design loads and improve holding power.

Collectively, these innovations produced an anchor that, <u>in its day</u> had considerably greater holding power per pound than any other.

Design of the Herreshoff Anchors



The basic geometry of the Herreshoff anchors is the only design parameter that was not in some way revised during the more than 30 year design development of these anchors.

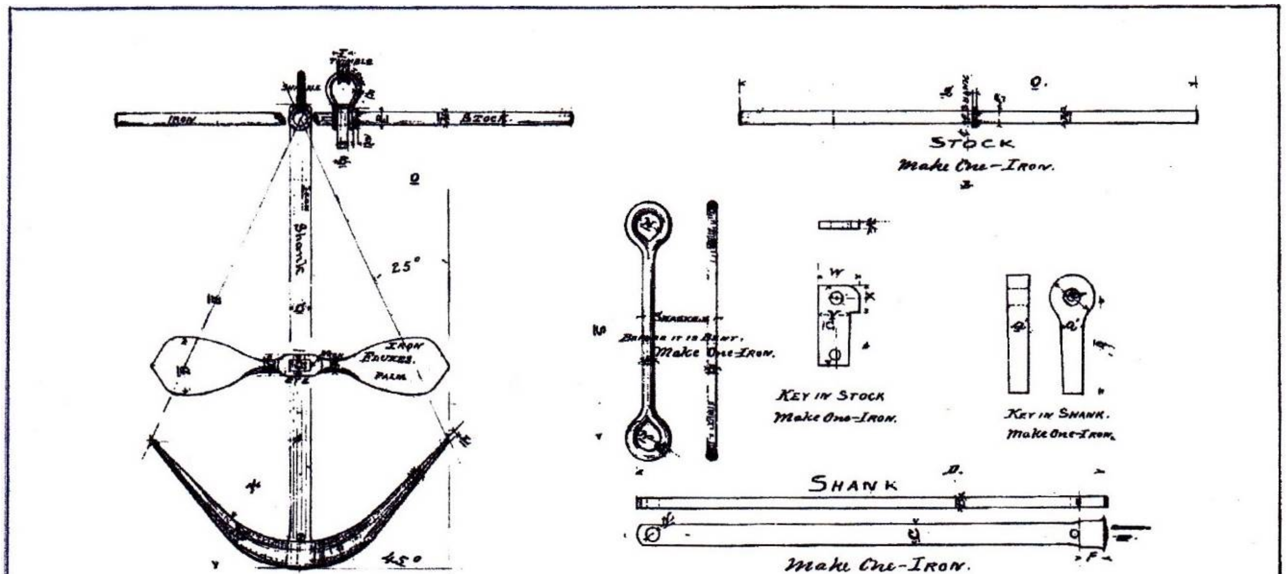
- The flukes of all anchors are at a 45 degree angle to the shank centerline.
- The angle formed by the shank and a line from the stock to tip of the flukes is always 25 degrees.
- The angle at which the palm initially penetrates the bottom is 70 degrees.

There are seven tabular drawings in the MIT Museum Heffenreffer-Herreshoff Collection which document the design development of these anchors.

- 1882 Drawing 74-1 describes 21 Straight Stock Anchors from 10# to 640#
- 1905 Drawings 74-44, Straight Stock Anchors & 74-45, Folding Stock Anchors, describe 25 anchors from 11# to 1130#
- 1907 Drawings 74-51, Straight Stock Anchors & 74-52, Folding Stock Anchors, describe 28 anchors from 9.6# to 1250#
- 1911 Drawings 74-54, Straight Stock Anchors & 74-55, Folding Stock Anchors, describe 27 anchors from 8.6# to 1260#

The Earliest Available Documentation of Herreshoff Anchors

1882 TABULATION of ANCHORS



Tabulated Sizes of Anchors ~ Herreshoff Manf'g Co. Bristol R.I.
March 29 1882

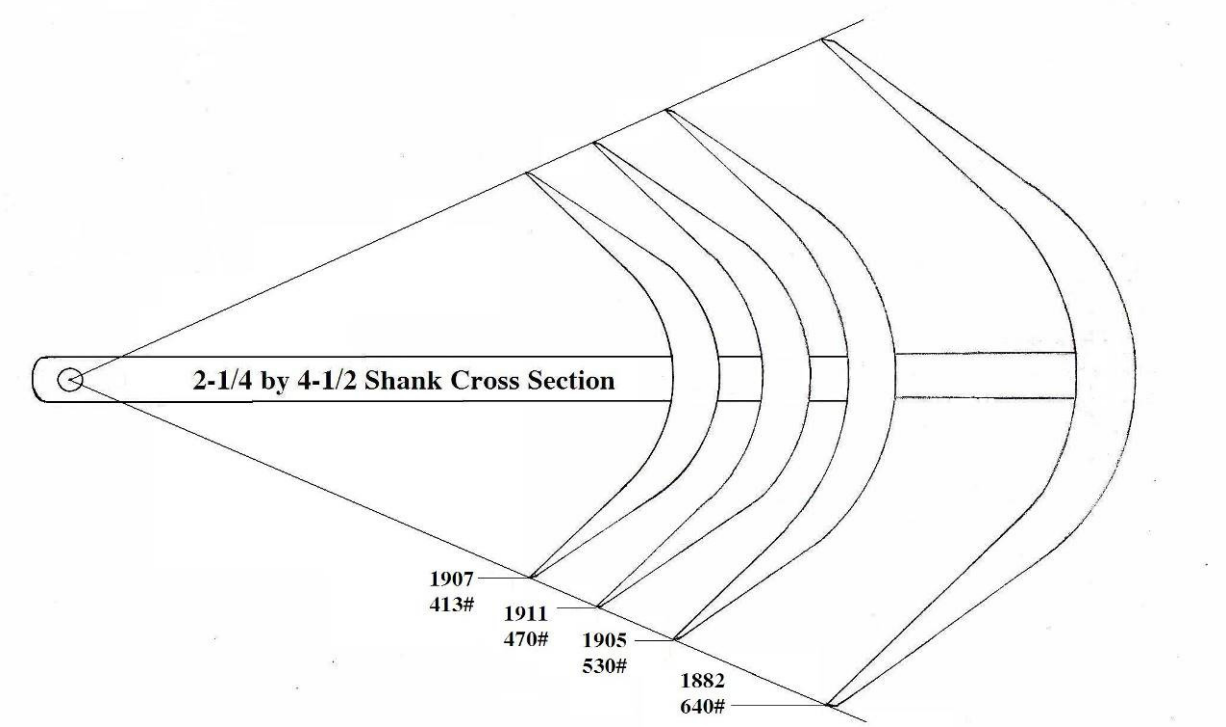
WEIGHT	SIZE OF SHANK: THICK	WIDTH	LENGTH	SIZES OF FLUKES: AT NECK WIDTH	THICK	PALM WIDTH	THICK	WIDTH		THICK	TOTAL LENGTH	SIZES OF STOCK: DIAM.	LENGTH	COLLAR DIAM	WIDTH	SHACKLE: DIAM		THIMBLE WIDTH	KEY IN STOCK: LENGTH	THICK	SCREW LENGTH	DIAM		KEY IN SHANK: DIA	LENGTH			REMARKS
A	B	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	a	b	c	d	----
10	5/8"	1"	25	5/8	1 1/4	3 1/4	1/2	1 1/4	5 5/8	1/8	20	9/16	24	1 1/8	1/4	1/4	6	1/2	1 5/16	1/8	5/8	3/16	3/8	1/4	1 1/4	1/2		
14	5/8"	1 1/4	27 1/2	3/4	1 1/2	3 1/2	1/2	1 1/4	6 1/4	1/8	22 1/2	3/4	26 1/2	1 1/4	1/4	5/16	6 1/2	1/2	1 11/16	1/8	11/16	7/32	7/16	1/4	1 1/4	1/2	8832	1 1/2 in
18	3/4"	1 1/4	30	3/4	1 3/4	3 3/4	5/8	1 1/2	6 3/4	1/8	24 1/2	3/4	29	1 1/4	1/4	5/16	7	5/8	1 11/16	1/8	11/16	7/32	7/16	1/4	1 1/2	1/2	•	
24	3/4"	1 1/2	33	7/8	1 3/4	4	5/8	1 1/2	7 1/2	3/16	26	7/8	32	1 3/8	1/4	3/8	7 1/2	5/8	1 3/4	5/32	3/4	1/4	1/2	5/16	1 1/2	5/8	8831	1 3/4.
30	7/8"	1 1/2	36	1	2	4 1/4	3/4	1 3/4	8 5/8	3/16	28 1/2	7/8	35	1 3/8	1/4	3/8	8	3/4	1 3/4	5/32	3/4	1/4	1/2	5/16	1 3/4	5/8	•	
38	7/8"	1 3/4	38 1/2	1	2 1/4	4 3/4	3/4	1 3/4	8 3/4	3/16	31 1/2	1	37 1/2	1 1/2	1/4	7/16	8 3/4	5/8	1 13/16	5/32	7/8	5/16	5/8	5/16	1 3/4	5/8	8830	2".
47	1"	1 3/4	41	1 1/8	2 1/4	5	7/8	2	9 3/8	1/4	33 1/2	1	40	1 1/2	1/4	7/16	9	1	1 13/16	3/16	7/8	5/16	5/8	3/8	2	3/4	•	
57	1"	2"	44"	1 1/8	2 1/2	5 1/2	7/8	2	10	1/4	36	1 1/8	43	1 5/8	1/4	1/2	10	1 1/8	2	3/16	1	3/8	3/4	3/8	2	3/4	8829	2 1/2".
68	1 1/8"	2"	46 1/2	1 1/4	2 1/2	6	1	2 1/4	10 5/8	1/4	38	1 1/8	45 1/2	1 5/8	1/4	1/2	10 1/2	1 1/8	2	3/16	1	3/8	3/4	3/8	2 1/4	3/4	•	
80	1 1/8"	2 1/4	49 1/2	1 1/4	2 3/4	6 1/4	1	2 1/4	11 1/4	5/16	40	1 1/4	48	1 3/4	1/4	1/2	11	1 1/4	2 3/8	7/32	1 1/8	7/16	7/8	7/16	2 1/4	7/8	8828	2 1/4.
94	1 1/4"	2 1/4	51 1/2	1 1/2	2 3/4	6 3/4	1 1/8	2 1/2	11 5/8	5/16	42	1 1/4	50 1/2	1 3/4	1/4	9/16	11 1/2	1 1/4	2 3/8	7/32	1 1/8	7/16	7/8	7/16	2 1/2	7/8	•	
112	1 1/4"	2 1/2	55"	1 1/2	3	7	1 1/8	2 1/2	12 1/2	5/16	45	1 3/8	53 1/2	1 7/8	1/4	5/8	12	1 1/4	2 3/8	7/32	1 1/4	1/2	1	7/16	2 1/2	7/8	8827	2 1/2.
135	1 1/2"	2 1/2	58 1/2	1 1/2	3 1/4	7 1/4	1 3/8	3	13 1/4	3/8	48	1 1/2	57	2	3/8	5/8	12 1/2		2 1/4	1/4	1 1/4	1/2	1	1/2	3	1	8826	2 3/4.
163	1 1/2	2 3/4	62"	1 3/4	3 1/2	7 3/4	1 3/8	3	14 3/8	3/8	51	1 1/2	60	2	3/8	3/4	13		2 1/4	1/4	1 1/4	1/2	1	1/2	3	1	•	
195	1 1/2	3	66"	1 3/4	3 3/4	8 1/4	1 3/8	3	15	3/8	54	1 5/8	64	2 1/4	3/8	3/4	14		2 1/16	1/4	1 3/8	9/16	1 1/8	1/2	3	1	8825	3".
225	1 3/4	3 1/4	69 1/2	2	3 3/4	8 3/4	1 5/8	3 1/2	15 3/4	7/16	57	1 5/8	67	2 1/8	3/8	3/4	15		2 1/16	9/32	1 3/8	9/16	1 1/8	9/16	3 1/2	1 1/8	•	
260	1 3/4	3 1/2	73"	2	4	9	1 5/8	3 1/2	16 1/2	7/16	60	1 3/4	71	2 1/4	1/2	7/8	16		2 3/8	9/32	1 1/2	5/8	1 1/4	9/16	3 1/2	1 1/8	8824	3 1/4.
295	1 7/8	3 1/2	77"	2	4 1/4	9 1/2	1 5/8	3 1/2	17 3/8	7/16	63	1 7/8	75	2 3/8	1/2	7/8	17		3	9/32	1 1/2	5/8	1 1/4	9/16	3 1/2	1 1/8	8823	3 1/2.
370	2"	3 1/2	82"	2 1/4	4 1/2	10	1 7/8	4	18 3/4	1/2	66	1 7/8	80	2 3/8	1/2	1	17 1/2		3	5/16	1 1/2	5/8	1 1/4	5/8	4	1 1/4	•	
460	2"	4"	88"	2 1/4	5	11	1 7/8	4	20	1/2	72	2	86	2 1/2	1/2	1	18		3 3/16	5/16	1 5/8	11/16	1 3/8	5/8	4	1 1/4	8822	3 3/4.
550	2 1/4	4	93"	2 1/2	5 1/4	11 3/4	2 1/8	4 1/2	21 1/8	1/2	78	2	91	2 1/2	5/8	1 1/8	19		3 3/8	5/16	1 5/8	11/16	1 3/8	5/8	4 1/2	1 1/4	•	
640	2 1/4	4 1/2	99"	2 1/2	5 1/2	12 1/2	2 1/8	4 1/2	22 1/2	1/2	84	2 1/4	97	2 3/4	5/8	1 1/8	20		3 3/8	5/16	1 5/8	11/16	1 3/8	5/8	4 1/2	1 1/4	8821	4"

[illegible] (signature)

74-1

L = Length overall, B = Breadth overall, D = Depth Hull + mean height [illegible], M = [illegible] — d = (L × B × D) + (1/2 M)² = wgt of anchor [illegible]
Measurements all in feet. [illegible]

The strength of the shank and holding power were the principle focus of the development and refinement of the Herreshoff anchor design. The first list of anchors dated March 1882 contains faint pencil changes, presumably entered sometime following the initial issue of the drawing. These changes increased the shank cross section of the eleven largest anchors and also increased the diameter of the stocks of the larger anchors. The 1882 shank cross sections were rectangular but were not all of the same proportion. These early changes began the process of establishing what was to become a uniform 2:1 ratio of the shanks rectangular cross section. The drawings issued in 1905 shortened the shank length of all anchors in an effort to increase the stiffness of the shank and the drawings issued in 1907 continued this process.



As a result of the anchors geometry a change in shank length dramatically changes the size and weight of an anchor of the same shank cross section, therefore, the only constant to follow when tracing the development of these anchors is a specific shank cross section. The sketch above illustrates how one anchor, with the same 2¼ inch by 4½ inch shank cross section, changed in both size and weight as the shank length was modified from 1882-1905-1907-1911.

Two tabular drawings were issued in 1905 describing both straight stock and folding stock anchors. These drawings introduced significant changes and established the baseline design for the Herreshoff anchor that was only slightly refined in the years to follow. Three anchors were added to the list increasing the number of anchors available to 25 with a range of 10# to 850#.

Significant 1905 design developments;

- The ratio of the rectangular cross section of all shanks was standardized at 2:1.
- The straight socket connection previously used to join the shank and flukes was replaced with a tapered socket connection.

- The crown of the flukes was more rigorously dimensioned by using a pair of equal radii in place of the previous single radius
- The palm width was dimensioned as 2.66 x the shank width dimension **C**.
- The stiffness of all shanks, particularly those over 200#, was increased both by reducing the shank length as well as increasing the shank width of 13 anchors.
- The diameter of almost all stocks was changed, the stock diameter of most small anchors was reduced slightly and those of the largest anchors were increased significantly.
- **All critical dimensions of the anchors became a mathematical function of the shank width, dimension "C" on the tabular drawings.**

In 1907 NGH established three rules governing the design of the Herreshoff anchors.[8]

"1st. A vessels drag on cable is proportional to the exposed surface both above and below water, omitting projecting keels."

"2nd An anchors holding power is proportional to the area of the palm multiplied by the square of the distance they are buried in the mud and should be equal or proportional to its strength or proof test."

"3rd Anchors conforming to law 2nd. and of similar design would have strength and holding power proportional to their weight. Also (shank) lengths would be proportional to the square root of (shank) thickness. And the diameter of chain proportional to square root of weight of anchor."

In May 1907 two new anchor drawings were issued superseding the 1905 drawings. Notes on the bottom of these drawings provide definitive evidence of the engineering devoted to these anchors. These notes provide the arithmetic proportions that determine the size of all critical dimensions of the anchors design and describe how they are all mathematical functions of the longer dimension of the shank cross section (C). These notes also provide the formulas used to calculate the proof test and anchor weight. There are no conceptual changes depicted on the 1907 drawings but clearly some additional engineering had been applied to the anchors.

- The 1907 drawings are the first to list a proof test for each anchor.
- Once again, to increase stiffness, the shanks of the medium and large anchors were shortened.
- The length of all straight stocks was made to equal the length of the shank.

Arithmetic proportions described on drawing 74-51 May 8-1907

C = the longer side of the anchor shank rectangular cross section

Shank Length- D = sq. root of 800 x C	Stock diameter- O = .54C nearly	Width of palm- H = 2.66C
Short side of shank cross section- B = ½C	Width at neck- F = .54C nearly	Weight = .34(C squared) x D
Depth at neck- G = C	Stock length- P = D	Proof test = 49(weight of anchor)

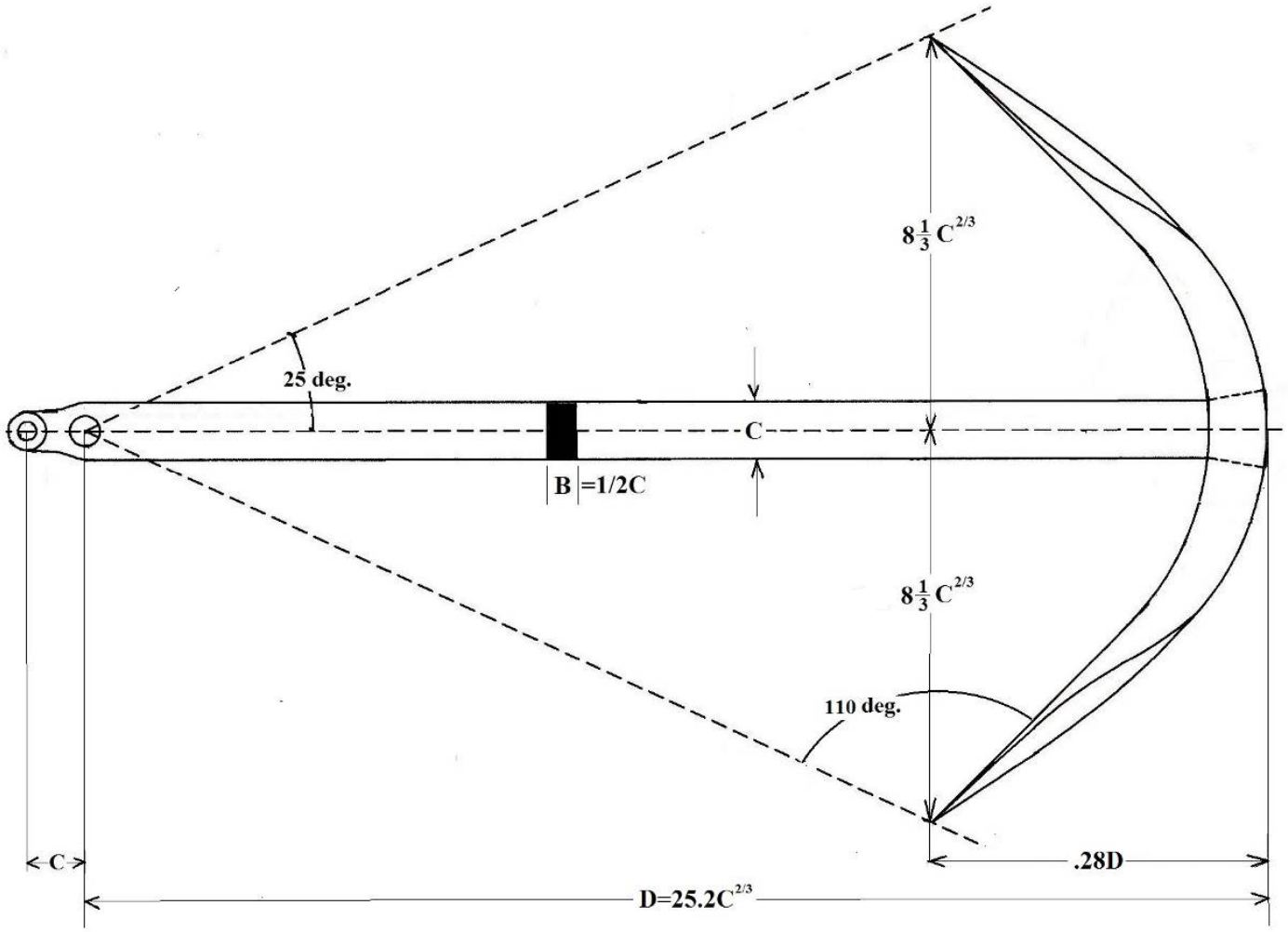
The final tabular drawings describing 27 anchors from 8.6 pounds to 1260 pounds were issued on January 12, 1911. These two drawings lengthened the shanks of those anchors greater than 50 pounds and slightly shortened the shanks of the smaller anchors. On December 26, 1910 NGH wrote "It is quite certain the anchors made to the list of May 1907 are too "chunky" in the larger sizes and have not the holding power in proportion to their strength. The fallacy is probably in the supposing that the holding power increases as the square of the length of the fluke multiplied by its area or in other words the resistance or holding power of a bottom does not appear to be as the square of the distance below the surface". [6]

This understanding changed the mathematical function which determined the length of the shank from $\sqrt{800C}$ to $25C^{2/3}$ [6]. All other dimensional functions developed in 1907 remained the same. Capt. Nat's 1910 Design Notebook provides mathematical functions for determining the proof test, weight of the anchor and length of the flukes before bending (dimension N on the table of anchors). The length of the flukes before bending was a critical dimension when the flukes were produced as forgings.

$$\text{Weight of Anchor} = .34C^2D \qquad \text{Proof Test} = \frac{13333C^3}{D}$$

$$\text{Length of flukes before bending} = .88D = N$$

The 1910 design notes[6] pertaining to anchor design also include this sketch which provides dimensional



information not shown on the issued drawings.

There are two later faint mark ups on these design notes in NGHs hand that slightly modify the previous mathematical functions. One, dated 1924, refines the function that calculates the anchor weight.

The other mark up alters the function for the shank length from $25C^{2/3}$ to $25.2C^{2/3}$

The final 1911 tabular drawings document four important features:

- The double tapered socket connection joining the shanks and flukes is shown as a mark-up on the drawings although anchors corresponding to the 1907 dimensions had double tapered socket connections.

- The drawings provide, as mark ups, pattern numbers for casting (26) flukes and (12) shanks.
- The eventual transition to cast steel as the material for all flukes and most shanks.
- The shanks of the largest 18 of the 27 anchors were increased in length.

Pattern numbers for castings were added to the 1911 drawings at various times following their initial issue which indicates the steel castings were phased in over a period of time following 1911. The earliest cast steel HMCo. anchor I can presently document is April 1914.[7] Pattern numbers for the flukes of the 710#, 805# and 907# anchors were added to the drawing as late as April 1923.

The holding power of these anchors was determined by four principal design elements, the design geometry, the area of useful holding surface (palm), the weight of the anchor and the vertical penetration of the bottom soil (fluke length). It is very clear from Capt. Nat's design notes[8] that he considered the holding power of the anchor to be equal to the proof test. When you think about it, if the bill of the anchor was hooked in the crevice of a granite ledge it might indeed see such loading. Capt. Nat's involvement with the anchors design did not end in 1911. The 1924 note added to the December 26, 1910 anchor calculations indicates he continued to devote attention to the anchor's design.

The following table illustrates the mathematical relationships of the most important dimensions of the HMCo. three piece anchors and how they developed throughout the years. As all critical dimensions of the Herreshoff anchors are a mathematical function of the larger side of the shank cross section "C" they were initially calculated as decimals[8] then rounded to fractions for use on the drawings and in the shops. It is instructive to observe the increased precision used to round these dimensions to fractions as the anchor's development progressed between 1882 and 1911.

	1882	1905	1907	1911
SHANK LENGTH	31.2 (shank cross section)	**Undetermined**	$\sqrt{800C^*}$	$25.2\,C^{*\,2/3}$
PALM WIDTH	.125 shank length	2.66 C *	2.66C *	2.66C *
CROWN RADIUS	.23 shank length	.22-.3 shank length	.25 shank length	.25 shank length
STOCK LENGTH	.975 shank length	.96 shank length	equals shank length	equals Shank length
Rounding to fractions	shank length 1/2 inch	shank length 1/4 inch	shank length 1/8 inch	shank length 1/8 inch
	palm width 1/4 inch	palm width 1/8 inch	palm width 1/16 inch	palm width 1/16 inch
	crown radius 1/8 inch	crown radius 1/8 inch	crown radius 1/16 inch	crown radius 1/16 inch
	stock length 1/2 inch	stock length 1/4 inch	stock length 1/8 inch	stock length 1/8 inch

*** C is the longer side of the shank cross section**

The 1882 and 1905 mathematical relationships above have been derived from drawing dimensions, expressed as fractions. The 1907 and 1911 functions are from NGH notebooks and drawings.

Design information derived from drawings issued after 1911

All the following drawings (1915-1918) document cast steel and cast bronze folding stock and straight stock anchors and provide greater design detail than is available on the tabular drawings. As an example, the upper end of some cast shanks are shown to have a slight taper whereas the tabular drawings that describe the earlier anchors indicate the shank as being straight. The folding stocks are greatly simplified, the previous elegant tapers have been eliminated, and the folding stock is fitted with a ball on only the bent end. These drawings clearly describe, with dimensions, a double tapered socket in the crown of the anchors. The 1911 tabular drawings contain only a mark-up depicting this double taper without dimensional information.

Three of these more detailed drawings provide sufficient palm dimensions to permit a calculation of the palm area and the center of palm area for each of the anchors. Plotting these centers on full size copies of the original drawings indicates the center of palm area is located at the point where a line drawn from the center of the stock at an angle of 16 degrees to the shank centerline intersects the face of the palm.

74-60 March 1915 7 ½ # Cast Bronze Anchor

This drawing describes the 7 ½ # anchor designed in 1915 for the #744 Class (Herreshoff 12 ½) and therefore is not listed on the 1911 tabular anchor drawing. The 1911 design functions were used to develop this anchor, the geometry is identical but the arithmetic proportions were slightly modified. The 7½ # anchors have the same ½ inch by 1 inch shank cross section as the 8.6# anchor design on the 1911 tabular drawings but the upper portion of the cast shank is tapered. The palm design was also slightly modified as the palm width is 2.5 inches rather than the 2.66 inches that would result if the standard proportion of 2.66 times the longer side of the shank cross section (C) had been applied. The 78 degree bill angle, is 4 degrees sharper than the standard proportions would have produced. I believe these refinements were made to permit the very light weight of this anchor to better penetrate the bottom soil. Drawing 74-60 depicts the standard HMCo. three piece construction with pattern numbers for both shank and flukes, the casting cards **(9)** indicate a total of 353 of these three piece anchors were cast between April 1915 and September 1936. Although the drawing specifies M bronze the casting cards indicate a small number of anchors were cast from other suitable bronze alloys. Also on this drawing, together with an additional pattern number 12589,(4)is a view depicting this anchor with the shank and flukes cast as a single piece thus eliminating the standard HMCo. tapered socket connection. The casting card**(4)** for this integrated shank and fluke pattern contains a single entry dated June 1, 1939. The casting order was for a quantity of 50 pieces, for stock, and was completed over a period of eight months. The reverse side of the casting card indicates the pattern was sent to Quincy Adams Yacht Yard in December 1945. (*In October 2011 a coffee table created from pattern #12589 and incorporating a 7½# anchor cast from this pattern was auctioned in Hartford Connecticut.)*

The 8.6# anchor on the 1911 list of anchors is a bit of a puzzle. It may have been produced as a wrought iron forging prior to the introduction of the small cast bronze anchors. However, since no patterns were ever made for this anchor it seems reasonable that development of the 7 ½ # anchor eliminated the need for the 8.6# anchor. Interesting to note is the Beverly Yacht Club Racing Rules for the Herreshoff 12-1/2 Class required an anchor of

10 # or greater.[10]

Drawing 74-61 January 29, 1916 127# & 64# Cast Steel Anchors

This is one of the series of individual anchor drawings which identify pattern numbers for cast steel shanks and flukes and provide the detail dimensions required to produce casting patterns. My judgment is the dates of these drawings provide good evidence of the time span during which steel castings replaced forging as the production method for these anchors. A later note on this drawing also specifies .3-.4 carbon steel (medium carbon steel) as the material for these stocks. The crown socket tapers are fully dimensioned as 1 in 6 on the narrow face and 1 in 12 for the wider face. The casting card[11] for the fluke of the 127# anchor on this drawing, is titled "Anchor Fluke for 40 foot Class" (#773-NY 40 Class). The issue date of the drawing was January 29, 1916 and the first order for castings was placed only 16 days later.

Drawing 74-62, March 4 1916 12# and 16# Anchors

This drawing specifies cast manganese bronze as the material for the flukes and shank and Tobin Bronze rod for the stock of the 12# anchor. Cast steel is specified for the 16# anchor shank and flukes. This drawing also dimensions the socket tapers in the crown of both these anchors as 1 in 8 and 1 in 16. The upper portion of the shank of the 12# cast bronze anchor also had a slight taper.

Drawing 74-64 May 26, 1917 288# and 199# Cast Steel Anchors

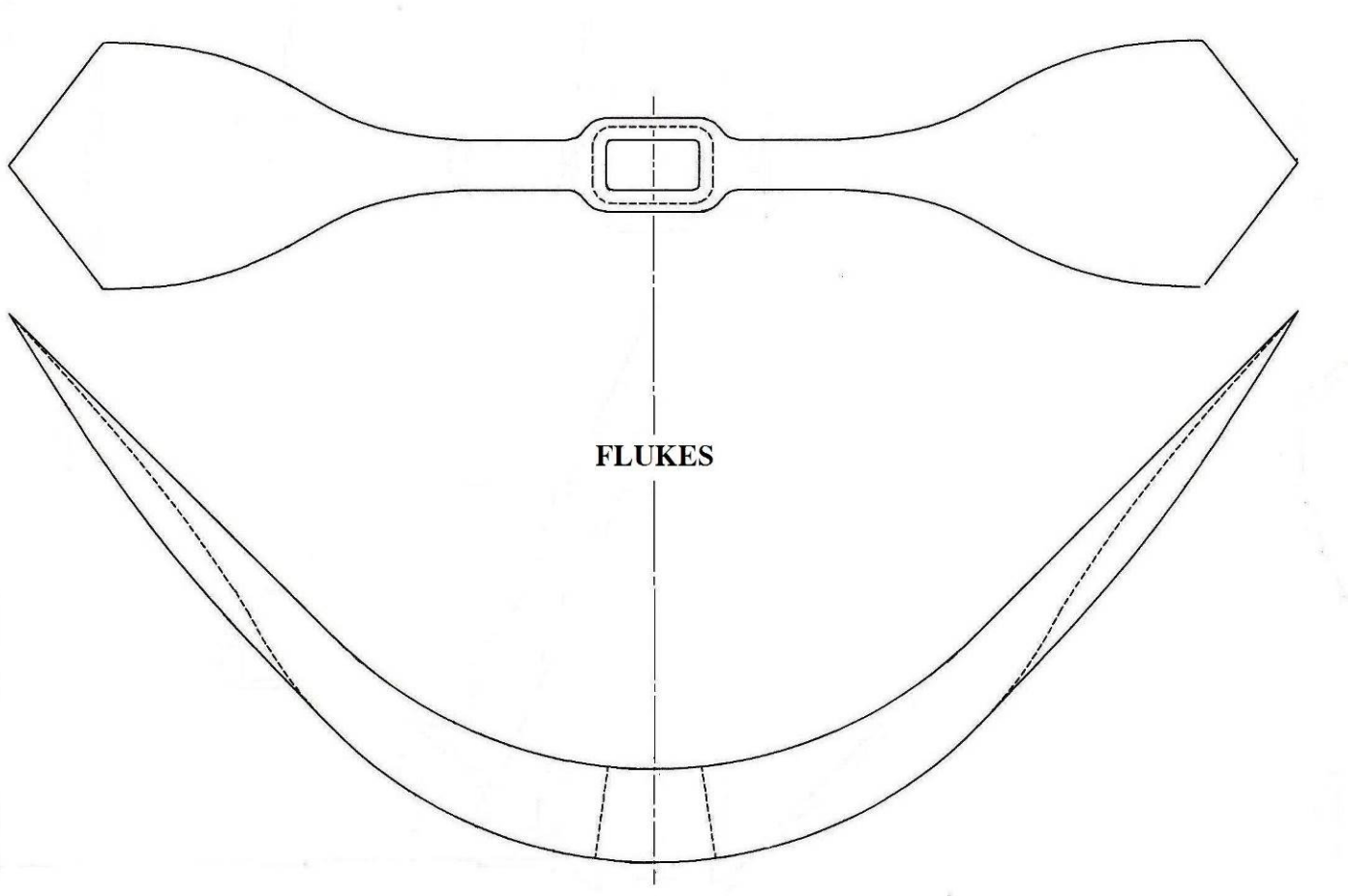
The 288# anchor had crown socket tapers of 1 in 5 and 1 in 10; the socket tapers for the 199# anchor were 1 in 6 and 1 in 12. Thus confirming the shank tapers became steeper as the size of anchor increased. This drawing provides true palm dimensions for both anchors.

Drawing 74-69, (64# & 74.7#) Drawing 74-72, (545#), Drawing 74-81, (470#)

When pattern numbers were added to the 1911 tabular anchor drawing the same shank pattern number was specified for straight stock and folding stock anchors of equal weight. These four drawings clearly depict the cast shank to be used for both the straight and folding stock versions of a particular size anchor. This made perfect sense as it eliminated the need for an additional shank pattern as well as eliminating the special shackle previously used on straight stock anchors and created a commonality of parts.

An Examination of the Important Elements of the Herreshoff Manufacturing Company Anchors

Flukes

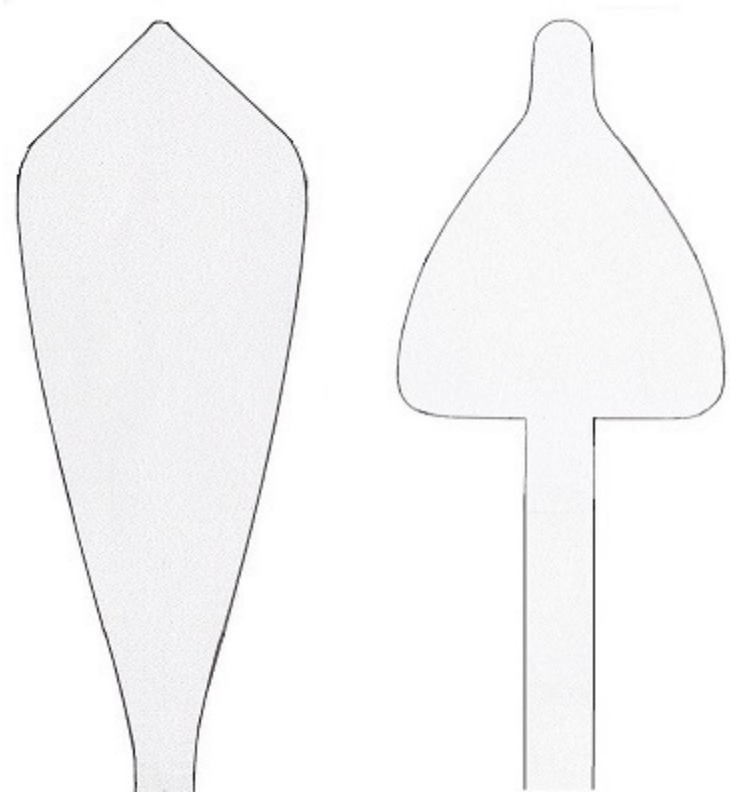


The flukes are the product of five important design parameters:

- The length of the flukes is determined by the anchors shank length and the basic 25 degree and 45 degree geometry of the anchor.
- The crown, is defined by its radii, which are a mathematical function of the shank length
- The palm width is a mathematical function of the longer side of the shank's cross section "C"
- The tapered socket, is also a function of the shank's cross section
- The bill angle is a function of shank length.

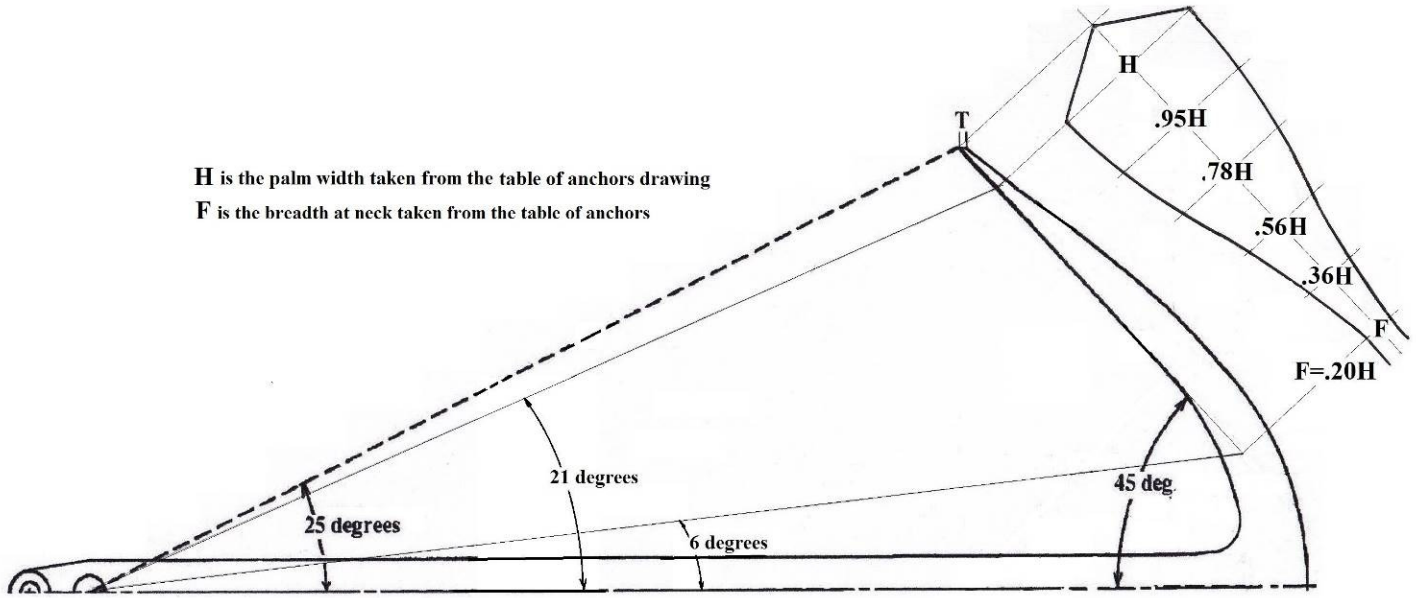
Palm

The most distinctive feature of the Herreshoff anchor is the smooth curved shape of the palm, this design greatly reduces, but does not eliminate, the potential of the anchor rode to foul the exposed fluke when the anchor is set. Importantly, it also serves to increase the area of the palm. The edges of the palm on Herreshoff anchors are significantly sharper than was common practice at the time; the edge thickness for each anchor is dimensioned on the 1882 tabular drawing 74-1 but not on later drawings. This palm design represented a considerable innovation and improvement over the heart shaped palm design that had been used for centuries and which is now sometimes referred to as the fisherman or Admiralty style anchor.



Herreshoff Palm Design Admiralty or Fisherman Style Palm

I have not been able to locate any documentation regarding how the area of the anchors palm and the curved shape of the palm were developed. Based upon a study of the available anchor drawings I have determined the curved shape of the palm can be reproduced for any of the HMCo. anchors by the method described on the following sketch. I am very certain this was not the method NGH used to create the shape of the palm but rather a consequence thereof.



On this sketch the maximum palm width, dimension H from the table of anchors drawing, is located where a line drawn from the stock at an angle of 21 deg. to the centerline of the shank intersects the face of the palm. Dimension F from the table of anchors drawing is located where a line drawn from the stock at 6 deg. to the shank centerline intersects the palm face. These two points and the bill are projected to depict a true view of the palm face. The distance between dimensions H and F is divided into five equal segments and the resulting lines dimensioned as shown.

Bill Angle

The bill of an anchor is the tip of the palm which must penetrate the bottom soil if the anchor is to set. An examination of the Admiralty/fisherman-style heart shaped palm will easily explain the origin of the term "bill". The triangular shaped bill of the Herreshoff anchor was another dramatic departure from the anchors of the time. The angle at the bill of the Herreshoff style anchors (which I refer to as the "bill angle") increases as the size of the anchors increase, many other anchor manufactures later adopted features of the Herreshoff anchors but I have not yet found one that made the effort to adopt this sophisticated detail. Smaller anchors require a sharper bill angle to permit their lesser weight to penetrate the bottom soil, larger anchors with their greater weight can penetrate the same soil with a less sharp bill. The purpose of increasing the bill angle is to increase the area of the palm at the location of the fluke's greatest penetration where the bottom soil is more dense. Together, the sharper edges of the palm, the increasing bill angle and the increased area of the palm provided by its long curved edges create an anchor that sets quickly, buries easily and provides greater holding power than other anchors of its type.

The tabular anchor drawings issued in 1882, 1905, 1907 & 1911 make no reference to, or provide a value for the bill angle. The eight later, more detailed, drawings describing the cast steel and bronze anchors together with measurements of surviving anchors provide the only definitive information I have been able to acquire regarding bill angles. The smallest bill angle I have measured is 78 degrees on the 7-1/2 pound anchors for the #744 class.

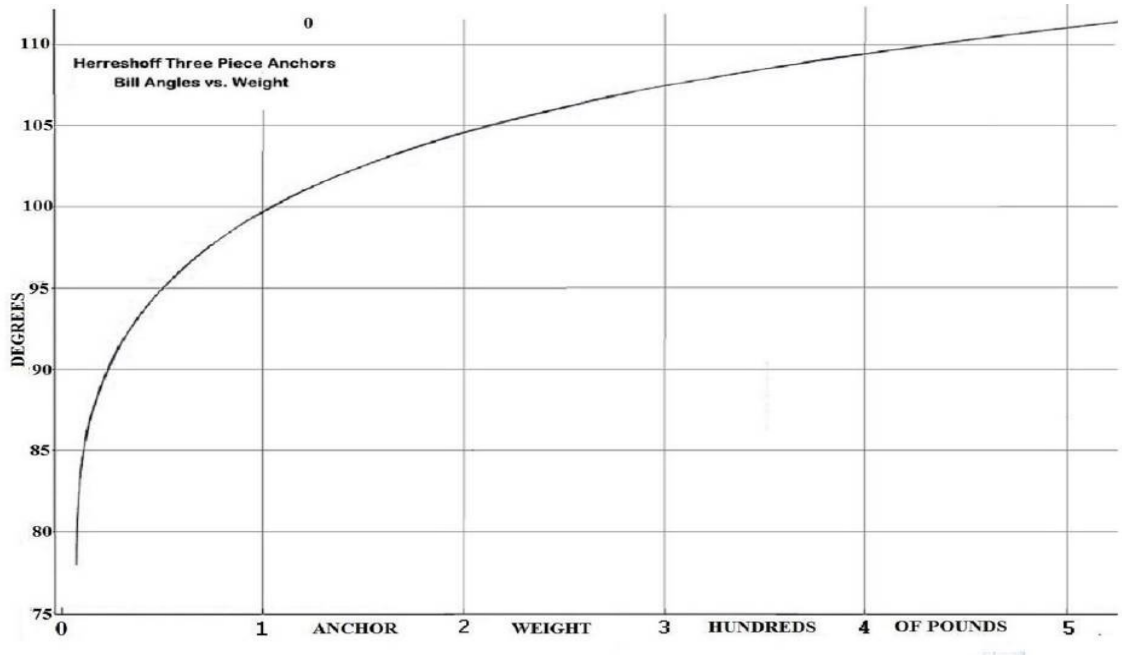
The bill angle is a function of the palm width and its location relative to the bill. The palm width of each Herreshoff anchor is listed as dimension "H" in the tables of anchor dimensions but neither the bill angle nor

the location of the palm width are dimensioned. The location of the maximum palm width and size of the bill angle are critical design dimensions as they directly influence the palm area and therefore the anchors holding power. Several of the later drawings describing the individual cast steel anchors dimension the bill angle for those specific anchors but contain no information indicating how those angles were established. Using full size copies of those drawings which provide dimensioned bill angles it was possible to derive a method to generate the altitude of the bill angle and thus provide the ability to calculate the bill angles for the complete range HMCo. anchors. The following table and curve provide bill angles for a range of anchors based upon measurements of existing anchors, drawings and calculations.

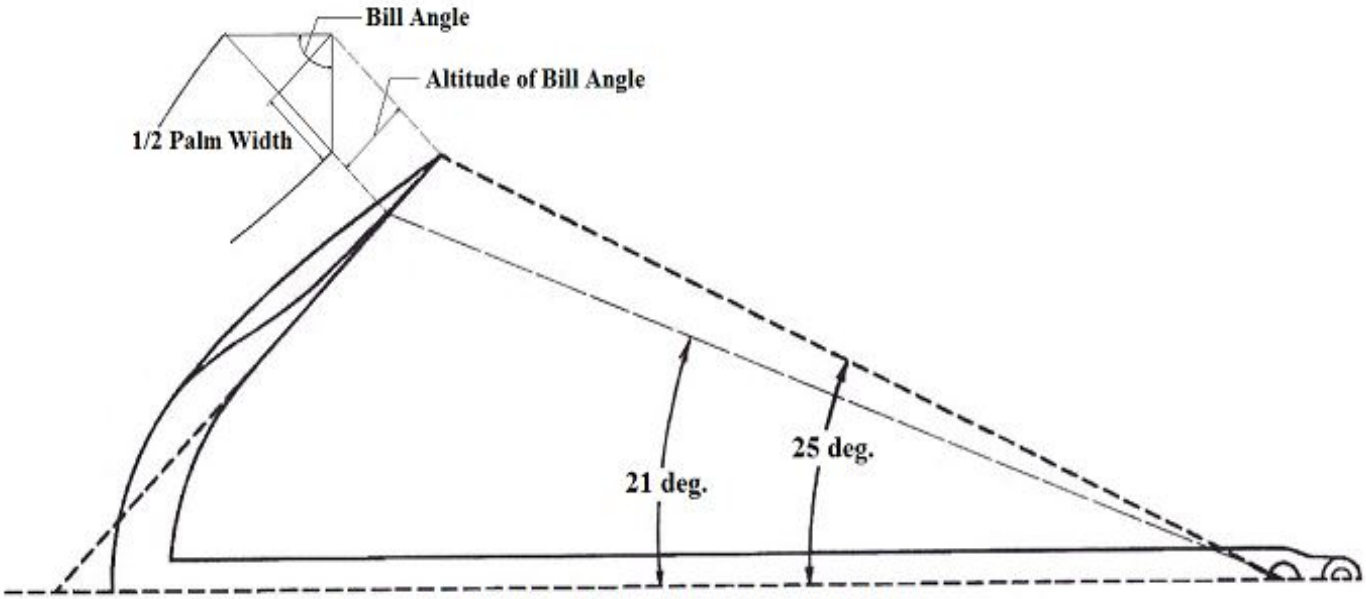
Anchor Weight	**7.5**	**12**	**16**	**20**	**25**	**31**	**38**	**46**	**64**	**75**	**99**	**127**
Bill Angle- deg.	78	86	87	89	90	91	93	94	97	98	99	101
(Rounded to nearest Degree)	M	C	C	D	M	D	C	D	D	D	C	C

Anchor Weight	**159**	**199**	**242**	**288**	**345**	**405**	**470**	**542**	**622**	**805**	**1260**
Bill Angle- deg.	103	104	105	107	108	109	109	111	112	114	117
(Rounded to nearest Degree)	M	C	C	C	C	C	D	C	C	C	C

M- Measured, C- Calculated, D- Drawing



Curve of Bill Angles vs Anchor Weight



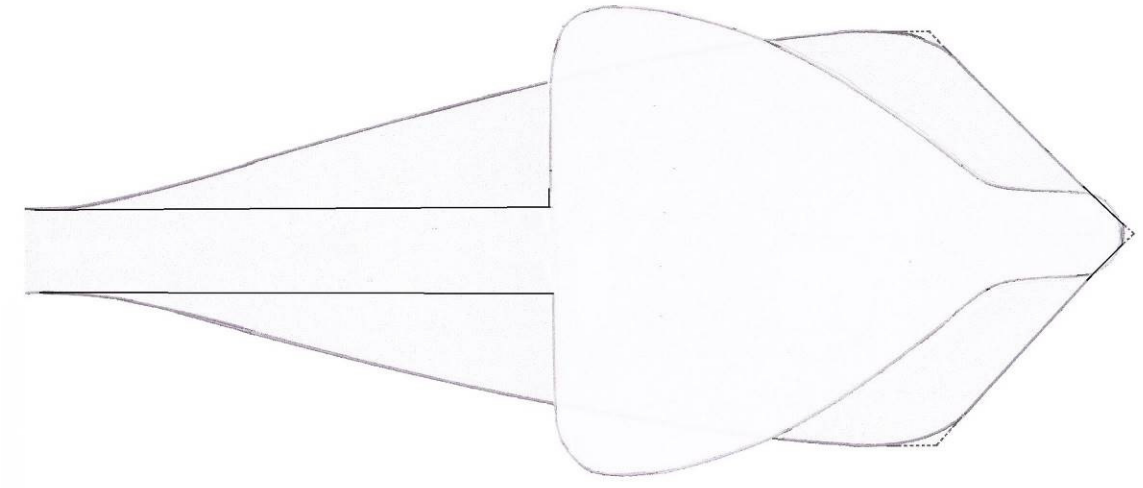
Determination of Bill Angle Altitude & Bill Angle

As shown on the sketch above, the location of maximum palm width is determined by the intersection of a line drawn from the stock at an angle of 21 degrees to the shanks centerline with the 45 degree face of the palm. The length of a line from this point of intersection to the anchors bill is the altitude of the bill angle. As all Herreshoff anchors are geometrically similar it is possible to express this dimension for all anchors as a function of the shank length. The relationship is: Bill Angle Altitude equals .061 times the anchor's shank length. Once the angle's altitude is determined the bill angle may be calculated as follows:

Bill angle = 2{ angle whose tangent is ½ the palm width divided by the altitude}

This would indicate the bill angle for the largest anchor, 1270#, was 117 degrees.

It is unlikely this is the method NGH used to determine the bill angle but rather a consequence of his method.



This overlay of existing anchors of equal size depicts the greater palm area of the HMCo. anchor over that of an equal weight admiralty/fisherman style anchor of the time. A considerable portion of this greater area is at the point of the fluke's deepest penetration of the bottom soil.. Although the design drawings for the Herreshoff anchors depict the corners of the triangular bill as sharp points those points are slightly rounded on the finished product. The smoothed corners are much less likely to severely mare a surface the anchor would contact.

Shank

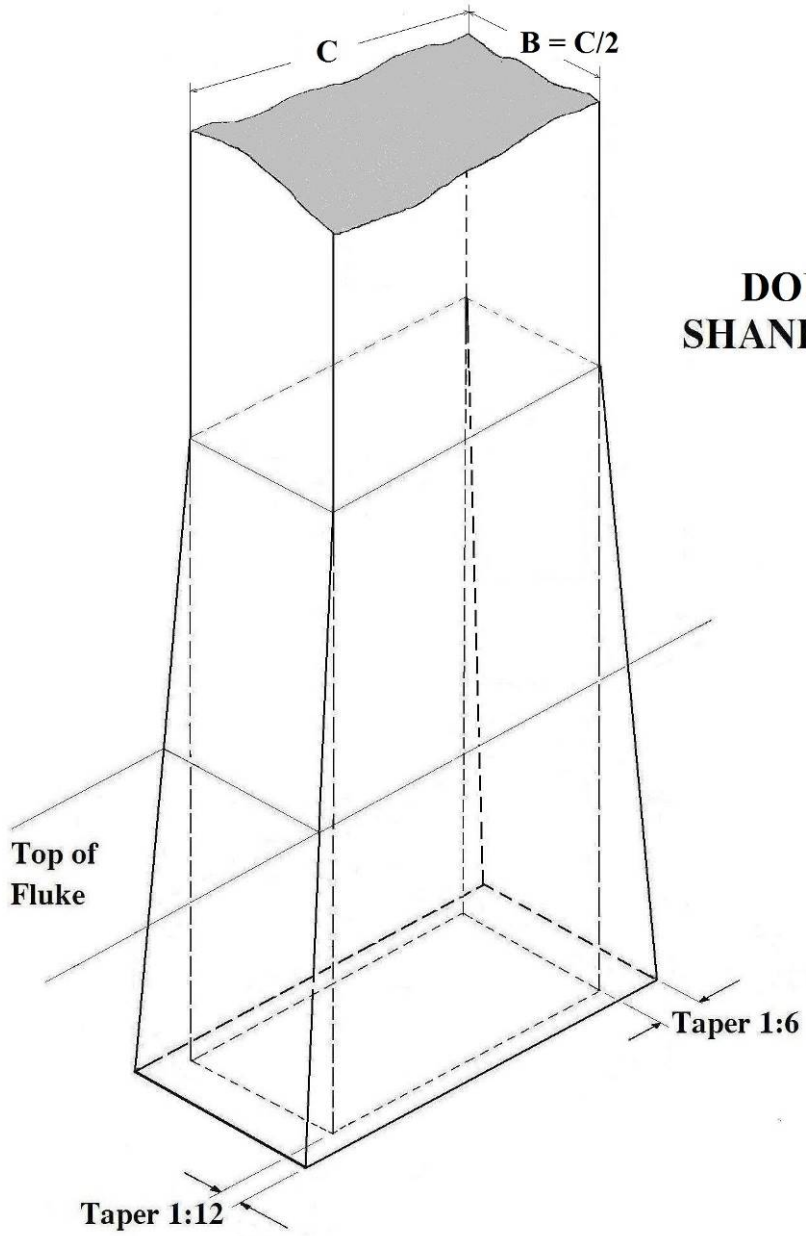
The rectangular shank cross section of the Herreshoff anchor was a revolutionary departure from centuries of anchor design and is another of the design elements which define the Herreshoff anchors. The shank of each anchor has a different rectangular cross section, and all critical dimensions of the anchor are a mathematical function of the larger dimension (C) of this cross section. The sides of all shank cross sections are in the proportion of 2:1. This provides a shank that is 60 percent stiffer, in the critical direction, than a solid round shank of equal weight while at the same time significantly reducing the frontal area of the shank which must cut through the bottom soil to permit the anchor to bury.

The other unique feature of the shank is the lower end which is swelled out to fit and lock within a corresponding socket in the crown of the flukes. The original 1882 drawing clearly indicates this socket connection as a straight, parallel sided, socket. The 1905 Table of Anchors Drawing depicts the change to a tapered socket connection, measurements of a forged HMCo. 26.5# anchor built to the 1907 drawing dimensions provide evidence the double taper was in use at that time. Based upon the available information my judgement is the double taper was introduced with the other major design changes of 1905. The double tapered socket and locking key produce a very firm and superior mechanical connection between the shank and flukes. It may not be entirely coincidental that a double tapered socket connection is also used to join the handle to the head of a shipbuilder's adze.

As stated earlier the detailed drawings for the cast steel anchors issued in 1915 and later provide detailed dimensions of the shank tapers. The smallest anchors have locking tapers[(12)] of 1:8 on the narrow faces and 1:16 on the wide faces. The larger anchors utilize a 1:6 non locking taper on the narrow faces and 1:12 locking tapers on the wide faces. Several of these later detailed drawings depict the shank tapers beginning well above the fluke socket connection. This is an important detail as it serves to increase the shank cross section at the point of greatest stress.

Instructions on the bottom of the 1911 table of anchors, drawing 74-54 , describe exactly how the proper fit of the stock, stock key, shank and flukes is to be achieved, , both before and after galvanizing

"*The shank is to be fitted into the crown eye with #18 iron shim extending around two sides. The stock to slip through eye in end of shank with a #22 iron sheet wrapped around it."*
"The stock key to be fitted with a #22 iron shim in two sides of it"
"After galvanizing have the anchor go together freely with a #22 iron shim in 2 sides of crown eye
#28 brass shim at stock into eye and shackle"
"#28 brass shim 2 sides of stock key."

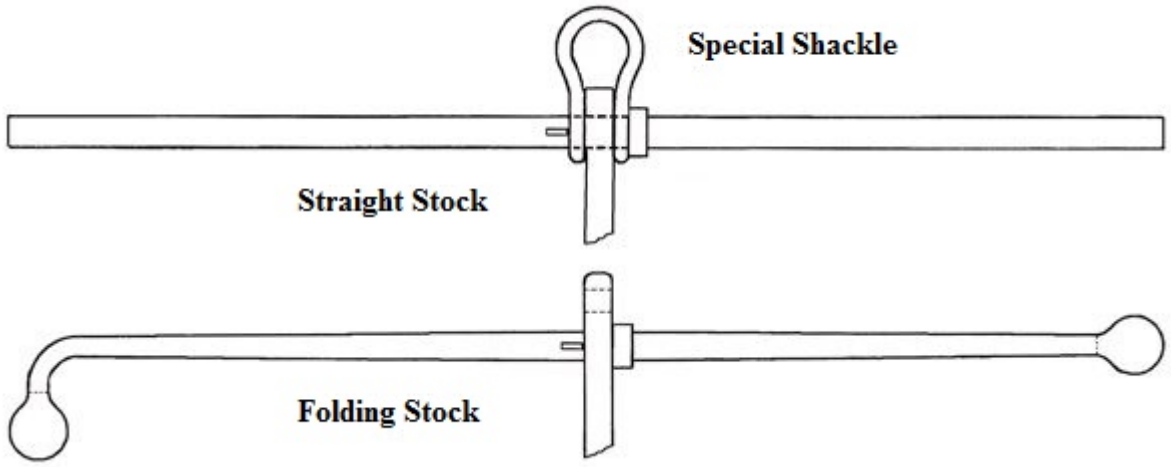


Although patterns were eventually produced to cast the flukes of 26 anchors, patterns were made to cast only 16 shanks[13]. The remaining shanks continued to be forged. I can only speculate there was less demand for those anchors whose shanks did not have patterns and as shanks were far easier to forge than flukes it was determined not to be worth making a shank pattern for those particular anchors.

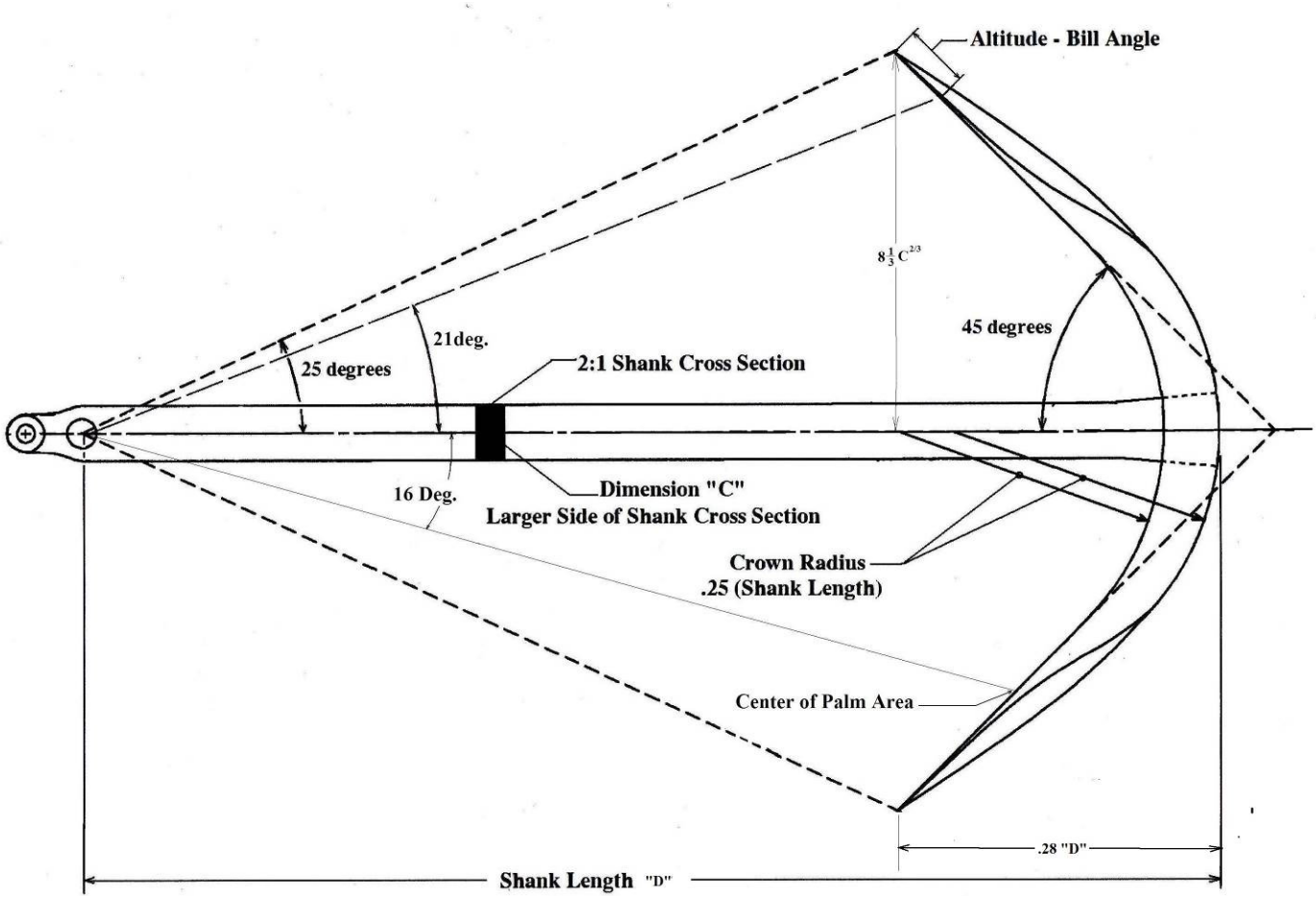
Prior to the introduction of cast shanks the shanks of folding stock anchors and straight stock anchors were distinctly different. Shanks for the straight stock anchor used a special shackle to secure the stock in place and provide an attachment point for the rode. Shanks for folding stock anchors were slightly longer as an additional eye at the top of the shank was required to provide an attachment point for the anchor rode. Several surviving drawings which detail the later cast steel anchors indicate that shanks cast for the folding stock anchors were also intended to be used as shanks for the same size straight stock anchors. This eliminated both the cost of making an additional shank pattern for each size anchor and the cost of the special shackle previously required for the straight stock anchor.

Stock

The purpose of the stock is to position the anchor on the bottom in a manner that permits the flukes to penetrate the bottom soil.



Two separate stocks were designed for the Herreshoff three piece anchors, a straight stock and a folding stock. Those anchors fitted with the folding stock are known as folding stock anchors and those with a straight stock referred to as straight stock anchors. The straight stock was removable and permitted the anchor to be disassembled into three separate pieces for handling and more compact stowage. The folding stock was a more complex forging than the straight stock; it was originally nicely tapered with a 90 degree bend at one end which permitted it to be folded against the shank when stowed. Cast balls and a collar permanently fitted to the folding stock prevent its removal. At some point the stock design was simplified, the tapers were eliminated and just one ball was provided on the end of the stock with the 90 degree bend. Although the original 1882 drawing describing the Herreshoff anchors depicts only straight stock anchors later markups on the drawing added pattern numbers for the cast balls used on the ends of the folding stocks. These same patterns were used, without change, throughout the anchors design development. An 1890 photograph of the torpedo boat CUSHING[(14)] with a folding stock anchor on her foredeck indicates folding stock anchors were produced very early in the anchor's history. Although many shanks and all flukes became steel castings, all stocks remained forgings.



Drawing of the final 1911 design of the Herreshoff Anchor incorporating both documented and derived information

The above sketch depicts the significant geometric design elements and dimensions that define the 1911 Herreshoff three piece anchor as I have been able to derive or document them from the available information.

If you start with the shank cross section and use dimension (C) to calculate the shank length, then apply the basic 25 degree and 45 degree envelope you can develop all other dimensions of the anchor using the Table of Anchors drawing. The simplicity is elegant.

Weight distribution of the three elements of the straight stock anchors is approximately:[(3)]

Flukes –34%

Shank – 42%

Stock –- 21%

Special Shackle --- 3%

Materials of Construction

Wrought iron was the material of construction specified on the 1882 drawing. In the 1800's and early 1900's wrought iron was the structural metal of the day,[16] it was strong, ductile, corrosion resistant and easily worked by blacksmiths. The stock and shank of the Herreshoff anchors were reasonably simple to forge; the flukes however were somewhat complicated and would have required highly skilled blacksmiths. The Herreschoff Manufacturing Company had a large and very well fitted blacksmith shop equipped with two steam powered drop hammers[17] which were likely equipped with dies designed to forge these anchors as well as the other considerable iron and steel work required by the large HMCo. yachts and steam engines.

By 1914[7] the flukes of a small number anchors began to be produced as steel castings rather than forged in the blacksmith shop. I have not been able, as yet, to determine exactly when the change to steel castings first took place but it is clear from the drawings it did not happen abruptly but was phased in over a period of several years. For design purposes involving tensile and yield properties rolled, cast and welded steel may be interchanged with confidence.[18]It is not clear from the information I have located exactly when the change from wrought iron to steel occurred. There is documentation that indicates the anchors were forged from open hearth steel prior to 1907.[8] Based upon the design evolution of these anchors I am convinced the change from wrought iron to steel took place with the significant design change of 1905.

For those anchors 12# and smaller the drawings specify cast bronze for the shanks and flukes with the stock to be made from Tobin bronze rod. Surviving casting cards[9] indicate the 7½ pound anchors were cast from "M" bronze (believed to be Navy M bronze). The drawing for the 12 pound anchor specifies manganese bronze.

Existing drawings do not specify the class of cast steel or the specific post casting heat treatment the castings would have required. Penciled notes on drawings and in NGH design notes[6] indicate the steel used to forge the anchors was a .3%-.4% carbon steel produced by the open hearth process. The present .3% carbon cast steel specification would be Grade 65-35[19] (65,000 psi. tensile, 35,000 psi. yield). Castings to this specification require heat treatment after initial cooling."Yachts by Herreshoff" states the castings were heat treated and annealed, these are somewhat generic terms and NGH would certainly have been more specific on purchase orders and shop work orders. Once patterns had been made for the cast steel flukes and shanks, fewer man hours were required to produce an anchor than by forging. Steel shanks and flukes were cast both by the HMCo. and purchased from several foundries. It is not clear which of the several manganese bronze alloys was used for the cast bronze anchors.

A study of the surviving anchor casting cards indicates, that in many cases, the HMCo. cast a few pieces of each pattern before the pattern was shipped to an outside foundry for use. On the basis of the surviving casting cards the earliest purchased steel anchor casting I can document is Feburary, 1916[11] when 24 flukes for the 127# anchors were ordered from The Malleable Iron and Fittings Company in Branford Connecticut. The transition to castings for anchor flukes and to a lesser extent shanks may have well have been driven by business considerations. 1914-1915 was a very busy period for the HMCo. and purchasing these castings from others would have reduced the demands placed on both the blacksmith shop and foundry. Casting the flukes and shanks would also have reduced the cost of manufacture of these items and perhaps provided a greater profit margin. This was after all a business.

In addition to the Malleable Iron And Fittings Co. other foundries identified as supplying anchor castings were New England Steel Castings in East Long Meadow Massachusetts, Millbury Steel foundry near Worcester Massachusetts and Lebanon Steel Foundry in Lebanon Pennsylvania. The few surviving casting cards pertaining to anchors also indicate that by the fall of 1926 Lebanon Steel Foundry was the sole source for purchased anchor castings.[21] Eventually patterns were made to permit casting all the flukes, however the absence of pattern numbers for (15) shanks indicates they remained as forgings.[13]

Testing

Both testing and experience indicated a need to increase the stiffness of the shanks.

Griswold Herreshoff recalled:

"The first anchors were set on shore at a time of low tide and the rode was attached to a team of oxen. Pa (NGH) watched the tipping of the anchor, its initial digging in, and its setting under strain. He then redesigned the proportions with particular emphasis on the flukes. Then there were further tests to revise or confirm the design. In practice, it was found the large anchors bent while the small ones did not. Consequently the sizes were recalculated increasing the scantlings to the 2/3 power of the size"[22]

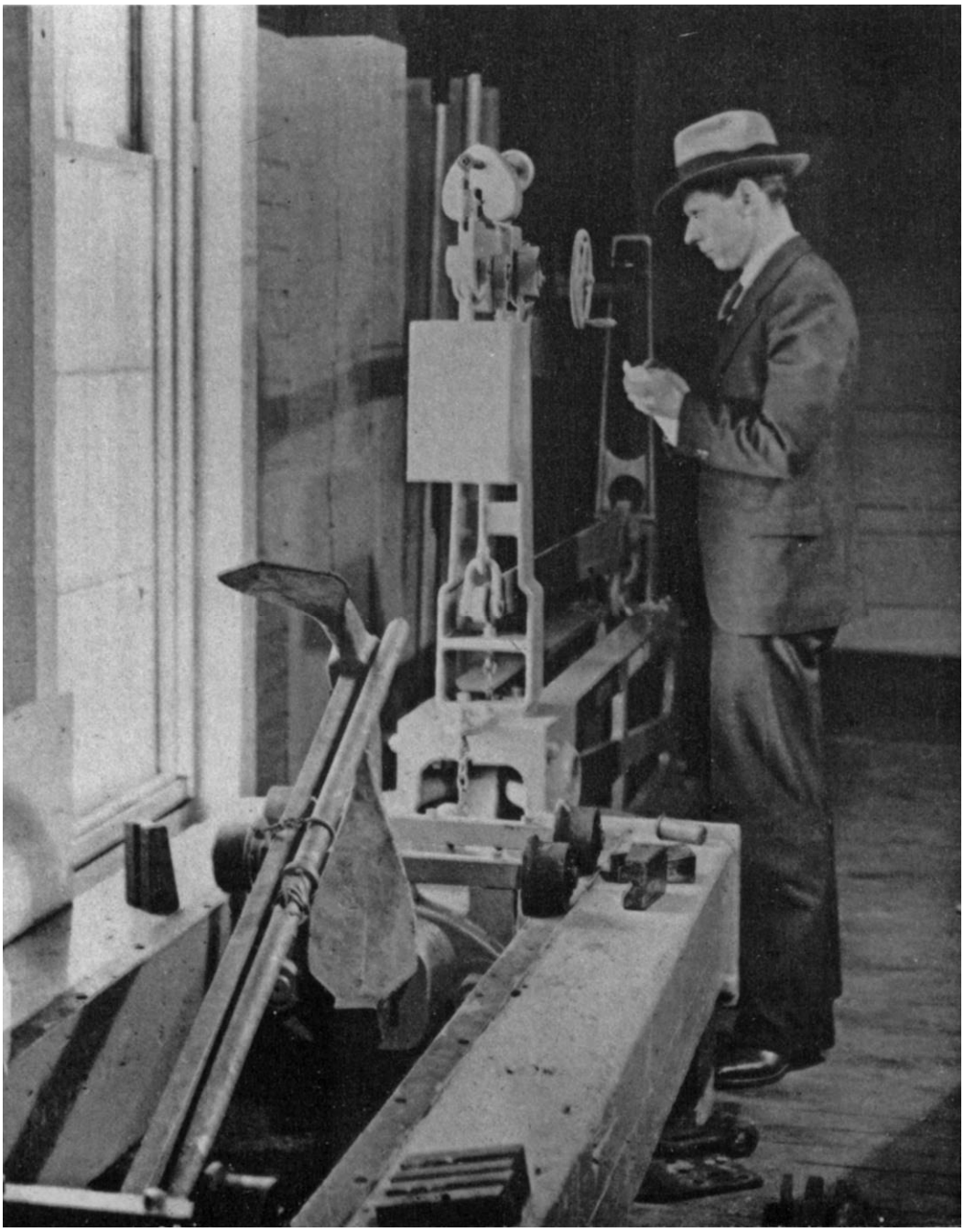
Capt. Nat's design notes state the proof test values were developed from strength tests performed on several anchors with the load applied to the point of the bill.[6]

Proof test values for all anchors first appeared in 1907[23] and were modified slightly in 1911.[13] Every anchor was proof tested and a Lloyds witnessed Test Certificate was available for an additional fee.

In April 1914 NGH tested three steel fluke castings[7]for (#725) KATOURA's 1260# and 470# anchors, these are the earliest cast steel anchor flukes I have been able to document. Two of the three castings failed the proof test due to casting flaws and large grain structure. Casting steel is more difficult than casting iron or non-ferrous metals and if these were some of the first cast steel flukes the flaws and grain structure problems noted might indicate they were early on the learning curve of how to best cast and heat treat these particular castings. The shank used for this test was forged as no pattern was ever made to cast this specific size shank.[13]

Entries on the surviving casting cards indicate fluke castings were tested by HMCo. upon or shortly after receipt and before any fitting or galvanizing was performed. Test failures of several fluke castings produced by the Millbury Steel Foundry in 1925 and 1926 are noted on casting cards and resulted in withdrawal of all work from Millbury by the fall of 1926.[15]

NGH personally performed strength tests of various materials prior to their use, an entry in his materials test record book dated July 29, 1904 records the test of a sample of cast steel which proved to have a elastic limit of 30,000 psi and a breaking strength of 54,000 psi[28] these are typical results for a .3-.4% medium carbon steel.



Anchor Testing Machine

The photograph above appears on page 12 of "Yachts by Herreshoff" and shows a completely assembled folding stock anchor undergoing proof test. The August 1924 Herreshoff Manufacturing Company auction catalog[17] lists two testing machines. This machine may be the 60,000 pound Riehle testing machine in the south store house listed as item 549 on page 34 of the auction catalog.

Selecting the Correct Herreshoff Anchor

Throughout the design evolution of the Herreshoff anchors NGH developed three formulas for the purposes of selecting the proper size Herreshoff anchor for a specific vessel. All were based upon the dimensions of the vessels hull, superstructure and rig.

The earliest formula appears on the bottom of the 1882 table of anchors, drawing (74-1).

$$\text{Thus} \quad \frac{(L \times B \times D)^{\frac{2}{3}} + \left[\frac{1}{4}M\right]^2}{4} = \text{wgt. of anchor in lbs.}$$

"L=length overall, B=breadth, D=depth of hull *(as used in gross tonnage measurement)* plus mean height of deck houses, M=Sum of length of masts above deck plus length of square rigged yards. All dimensions in feet.

An additional note provides guidance when more than one anchor is used:

"If two anchors are used total weight to be 60% greater than by formula "

"If three anchors are used then the total wgt. is to be double weight by formula."

NGH's design notes dated December 1st. 1899 contain a revised anchor sizing formula. and information for establishing the proper weight of multiple HMCo. anchors.

$$\frac{2\left[L \times B \times (D+H)\right]^{\frac{2}{3}} + \frac{1}{5}\left(M^2 + M_1^2 \text{ etc.} + Y^2 + Y_1^2 \text{ etc.}\right)}{12} = \text{Weight of Anchor}$$

"For two anchors the sum of the squares of the two anchors to equal the square of one anchor by formula."

Also provided is a formula to determine the link diameter of the proper chain to be used with a given anchor.

$$\text{Chain link Dia.} \quad \frac{\sqrt{1.6 \text{ wgt. anchor}}}{32}$$

NGH design notes of 1907 relating to anchors contain the following;

"Having been asked by the Racing Rules Committee of the NYYC for information relating to proper size anchors, chains and warps for yachts, also number, I have made the subject a study for a week. Having made 6 tests of anchors of various sizes and applied rules in consideration to many vessels of which I have records. Compared with rules in page 89 Dec.1, 1899 previous book, also with Lloyds Rules for yachts have settled on the following basic formula and have submitted same (in part) to the above committee." [8]

"Formula (A) can be applied to any size steam or sailing yacht equipped for use in yachting weather on our coast." [8]

(A)

$$\text{Drag Force} = 9\left[L \times B \times (D+H)\right]^{\frac{2}{3}} + \frac{(M^2+M_{1\,\text{etc.}}^2+Y^2+Y_{1\,\text{etc.}}^2)}{1.1} = \text{Proof Test of anchor or chain}$$

$$\text{Proof Test} = 49 \text{ Weight of Anchor}$$

Terms used in the formulas:

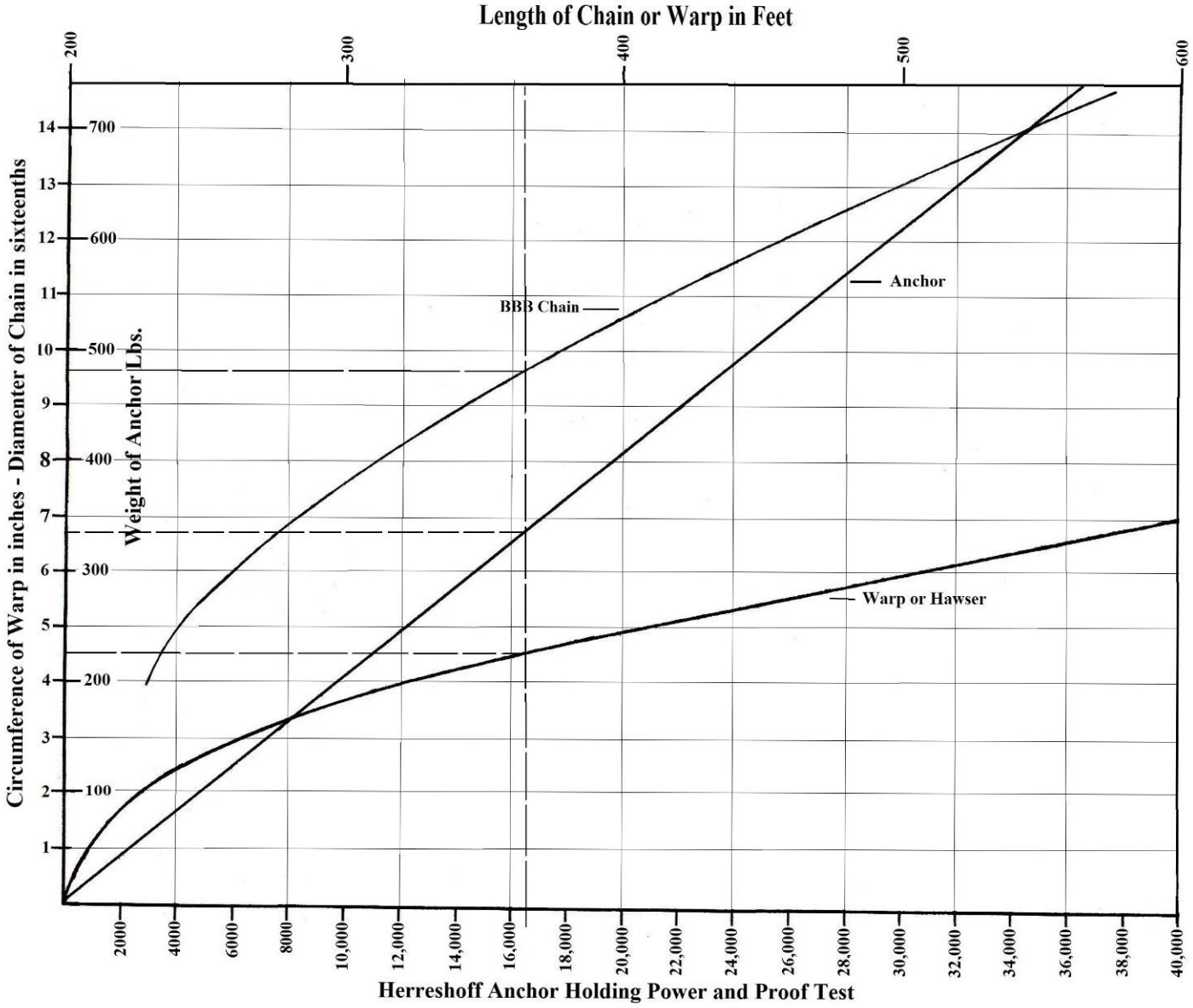
L=length on deck, B=beam, D=depth of hull (*as used in tonnage measurement*) H=Average height of deck erections, M=Length of masts, Y=length of yards. All dimensions in feet. Weight in pounds."

Since the proof test above is equal to an expected drag force, then as used here, the term "proof test" is the anchors maximum working load rather than a test load based upon a percentage of the design strength as is the common use of the term today.

In his reply to the NYYC Racing Rules Committee[5] NGH also provided a nomogram titled "Yacht Equipment Rules by N.G. Herreshoff April 1907" this nomogram is a plot of anchor weights versus their holding power together with curves of the corresponding BBB chain and anchor warp to be used. Using the value computed from Formula (A) and this nomogram it is possible to select the proper weight Herreshoff anchor and the size and length of the anchor chain or warp for a particular yacht. A blueprint copy of this nomogram mounted on wood, apparently intended to hang on an office wall, is in the Haffenreffer-Herreshoff Collection at the MIT Museum. In his reply NGH also provided three additional curves to indicate the weights of anchors as obtained by this formula for yachts with different rigs and specifically noted that schooners need heavier ground tackle due to the greater amount of rigging aloft. *Copies of these curves and nomogram are included in Appendix II*

Page 132 of the 1924 edition of Skeene's "Elements of Yacht Design" depicts a somewhat different nomogram for selecting the proper Herreshoff anchor, chain and warp and states the nomogram is based upon data compiled by Mr. N. G. Herreshoff. The author goes on to say "The weights given are for the Herreshoff anchor, which is particularly efficient." *A copy of this nomogram is included in Appendix II.*

NGH also provided additional guidance on the selection of anchors, chains and warps. "For yachts over 35 tons we generally supply two bower anchors and chains and make the square of the weights of the two equal to the square of one as by formula. For example in place of one anchor of 100 lbs. there would be 87 and 50 lbs. or 80 and 60 lbs. or equal ones of 71 lbs. each. The chains in each case to be proportional to the anchor attached. Manila hemp cables are convenient in small yachts but are not recommended for yachts over 10 tons. Although every yacht should have a good size hawser for emergency use and towing."[5]



Redrawn 1907 Herreshoff nomogram for selecting ground tackle

The dashed lines on the above redrawn 1907 N. G. Herreshoff nomogram[25] demonstrate how the nomogram is used to determine the proper size anchor, chain and hawser. Using the 1907 equation with a resulting value of 16,500 HP (Holding Power) for this hypothetical yacht the nearest 1907 anchor size is 360#, the specified chain diameter of 9.6/16" is rounded up to 10/16" (5/8"). The indicated warp size is 4-1/2" circumference (1½" diameter) and the length of chain or hawser is 370 feet.

Applying the three anchor selection equations to NEITH (HMCo # 665) produces the following results.

1882 equation – 100.7# anchor

1899 equation - 103.9# anchor

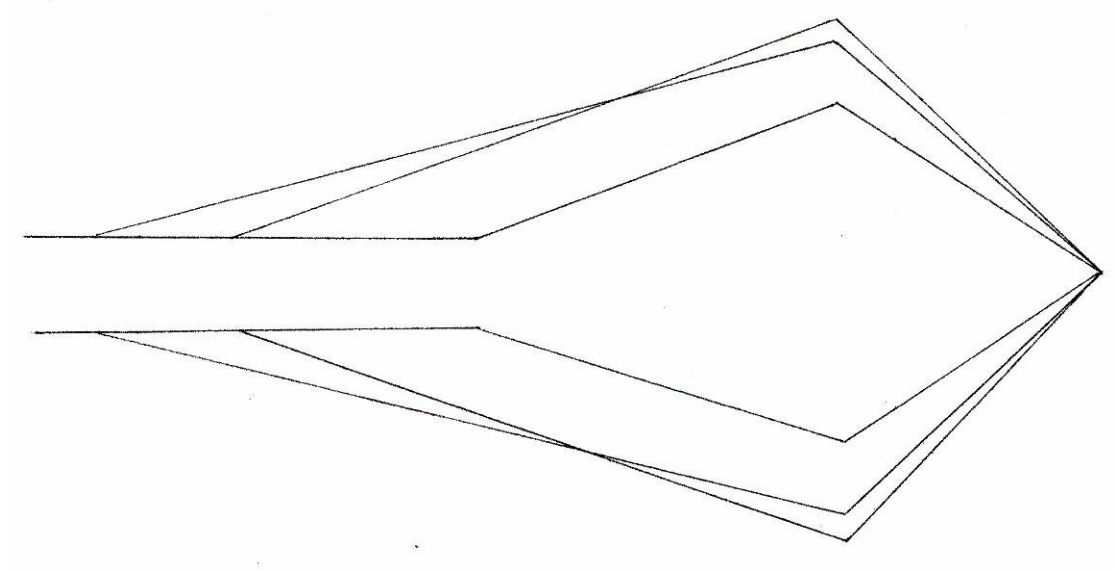
1907 equation - 90 # anchor

The drawings for NEITH, (1907) indicate she was to be fitted with 84# (actual wt.) and 96# (actual wt.) Herreshoff anchors.

Adoption of the Herreshoff Anchor Design Innovations by Others

Imitation is the greatest compliment.

Many anchor manufactures adopted the concept of the triangular shape bill and the extended palm to increase holding power and reduce the probability of fouling the anchor rode. The most common design was a diamond shaped palm with the bill angles held constant throughout the manufactures range of anchor weights. Bill angles varied from one manufacturer to another with 90 degrees being the most common.



This sketch depicts the most common diamond palm shapes taken from a survey of existing anchors.

Only a few adopted the three piece anchor design.

Henry B. Nevins Inc.

Nevins designed and produced a family of geometrically similar three piece, cast steel and cast bronze folding stock anchors for use on many of the yachts they built. These anchors were well made but of a different geometry than the HMCo. anchors. The shank was oval in cross section and therefore would also present less resistance to the bottom soil than an equivalent weight round cross section. The socket connection joining the shank and flukes was oval in cross section and tapered, similar to the socket joining the wooden handle and head of a pick axe. Based upon measurements the Nevins anchors have a sharper bill angle and slightly less palm area than the comparable HMCo. anchor. I have been unable to locate any drawings for the Neins anchors but have been able to examine several of varying sizes.

Consolidated Shipbuilding

Consolidated Shipbuilding designed a family of three piece anchors; the basic geometry differed considerably from the HMCo. anchors. The Consolidated anchors used a socket with a single taper to connect the shank and flukes, the bill angles are sharper and palm area less than comparable HMCo. anchors. The Consolidated shank design is also less stiff than the equivalent HMCo. anchor. The material specified is open hearth steel. The drawings[26] all dated 1930, do not specify if these anchors are to be cast or forged. However, based upon the dimensioning on the drawings and issue date of the drawings my judgment is anchors were castings

George Lawley & Son

Lawley also developed a Herreshoff style three piece anchor design for use on their yachts. A drawing dated September 4, 1917 from the Hart Nautical Collectiion, MIT Museum describes four Lawley anchors of 65#, 85#, 110# and 200#. The drawing is dimensioned but contains no materials of construction or pattern numbers. The anchors on this drawing do not share a common geometry and the socket joining the shank and fluke is less robust and has only a single taper. The bill angles of the 65# and 110# anchors measure 85 deg. while those of the 85# and 200# anchors are 90 deg. The bill angles are smaller and the area of the palm less than equivalent HMCo. anchors.. The shanks of the Lawley anchors on this drawing are rectangular in cross section, tapered slightly from top of the shank to the crown socket and significantly less stiff than comparable HMCo. anchors. The socket connection used to connect the shank and flukes employs a single taper.

Merriman Brothers

Information from Merriman Brothers catalogs:[27]

- 1928 catalog illustrated a three piece anchor and stated “These anchors are designed in accordance with the ideas and experience of the leading naval architects”. The anchors are described as available in both folding stock and straight stock styles from 40#-300#.
- 1933 catalog advertised Herreshoff type anchors with hand forged shank and stock and cast steel head (flukes). The stock of the folding stock anchor illustrated in the catalog has no taper and a ball only on the bent end of the stock. Both folding and straight stock anchors are described as available in thirteen sizes from 65# - 400#.
- 1948 catalog advertised Merriman made Herreshoff straight and folding stock anchors and states “the anchors are made using original Herreshoff patterns employing identical hand forgings, testing methods and materials.” Only fourteen anchor sizes, 30#-400# are listed as available. The folding stock anchor illustrated has no taper and a ball on only the bent end of the stock.
- 1957 catalog advertised Merriman made Herreshoff straight stock and folding stock anchors and stated “the anchors are made using original Herreshoff patterns employing identical hand forgings, testing methods and materials.”, only six anchor sizes, 30#- 260# are listed as available.
- 1962 catalog illustrates a straight stock anchor with the special shackle and the same text as the 1957 catalog, only six straight stock anchors 65#-400# were listed as available.

The 1948 Merriman catalog indicates that Merriman had acquired the rights to the Herreshoff patterns following shutdown of the Herreshoff Manufacturing Company in 1946.

One HMCo. casting card entry, for flukes of the 38# anchor, indicates that on August 28, 1929 two castings were ordered for "Merriman Stk" (stock). Another card indicates that on July 12, 1926 two fluke castings were ordered for Luders. In view of the small number of surviving casting cards for anchor castings it is reasonable to expect there were other anchor parts cast for Merriman and perhaps others. Each of the surviving anchor casting cards has one or two entries for stock. An inventory card for July1903 records (87) straight stock anchors from 10#-460# in stock and in June 1905, an inventory of (59) straight stock anchors[(29)]. A smaller number of folding stock anchors were listed on the same inventory record.

Burgess Swasey and Paine

The Ships Plans Collection at Mystic Seaport Museum contains a very nice Burgess Swasey and Paine drawing dated 1923 (Ships Plans Accession Number 11:19) This drawing contains a table which describes (6) folding stock three piece anchors, the dimensions in the table are identical to the corresponding anchors on the January 1911 HMCo. list of folding stock anchors. Each anchor is assigned a number which corresponds exactly with that anchor's position on the 1911 HMCo. folding stock anchor list, cast steel is specified for the flukes but wrought iron is specified for the shanks and stocks. The drawing depicts a single tapered socket for the shank to fluke connection although all the HMCo cast flukes had double tapered sockets.

This drawing does not contain sufficient detail to produce patterns for the fluke castings, my judgment is the fluke castings and perhaps the complete anchors were to be purchased from the HMCo. The wrought iron specification is perplexing as by 1923 the HMCo. had patterns for casting some of these shanks from steel. If the anchors were to be purchased what was the purpose of this carefully prepared drawing? The drawing does however provide a reference as to the sizing of Herreshoff anchors for these racing yachts in 1923.

Anchors listed on the Burgess, Swasey and Payne drawing;

No. 6 32 pounds designated for an 8 meter yacht
No. 8 45 pounds designated for an 8 meter yacht
No. 11 75 pounds designated as "special" for an 8 meter yacht
No. 12 100 pounds designated for a 12 meter yacht
No. 13 127 pounds designated for an M class yacht
No. 14 159 pounds designated for an M class yacht as well as the schooner NINA

Both L. Francis Herreshoff and A. Loring Swasey who had been employed as chief designer at the HMCo. from 1917-1923, were associated with Burgess Swasey and Paine. It therefore doesn't take much imagination to determine where the dimensional information for this drawing came from.

George Owen

There are two drawings dated May 1921 and November 1925 by George Owen in the Hart Nautical Collections MIT Museum which describe five three piece, folding stock, anchors ranging in weight from 75 pounds to 400 pounds. These anchors share many design elements with the HMCo. anchors. George Owen worked for the Herreshoff Manufacturing Co. for a few years following his graduation from MIT in 1894.

- The drawings are dimensioned in the same manner as the HMCo. drawings
- All the anchors are mathematically similar.
- The basic 25deg / 45deg design geometry is the same as the HMCo. anchors
- The shank is rectangular in cross section but has a ratio of 1.8 : 1 verses the HMCo. anchors 2 : 1 ratio.
- The socket joining the shank and flukes is tapered, but in only one direction.
- The edges of the flukes are sharp and are dimensioned on the drawings. The bill angle is 90deg. on all anchors.

The shanks and stocks were specified to be forged from Class B steel, the flukes were to be cast steel. The stocks were tapered and had balls on each end.

The drawings designate these anchors to four specific boats thus indicating this design was not likely intended for market production.

What Capt. Nat Wrote Regarding Herreshoff Anchors

In a short biography he wrote for The National Cyclopedia of American Biography Capt. Nat mentions as one of his accomplishments " Improvement in form of anchors."[20]

In a letter dated December 2, 1935 to W. P. Stephens Capt. Nat wrote the following. "The character of the bottom when an anchor is cast from small craft is not generally known. If weedy, the conventional stockless anchor is worthless, and only when good clay bottom is struck will it hold. My experiments served to produce good anchors for unreliable holding ground, strength tests on bottom, as well as on testing machines. For best holding power and reliable strength I found larger anchors had to be more robust than smaller ones. I think only a few of the yachtsmen - those having experience realize the better protection they were getting by having our anchors".[30]

In reply to a 1935 letter L. Francis Herreshoff had written discussing NGH's important achievements Capt. Nat wrote "to your list might be added #10 the Herreshoff Anchor in its present form and proportions. The original design & features being by my father in about 1854".[2]

Is It a Herreshoff Anchor ?

The following criteria will help determine if an anchor was fabricated in accordance with Herreshoff Manufacturing Co. drawings.

- The shank must have a rectangular cross section.
- The sides of the rectangular shank cross section must have a ratio of 2:1.
- The palm must have an extended curved shape from its widest point inward toward the crown.
- It must be a three piece anchor (See note 1).
- The tip of the flukes (bill) must be triangular in shape.
- The outer faces of the socket joining the shank and flukes must taper outward slightly at the bottom.
- Is the anchor bronze or galvanized steel. The drawings specify bronze for the 7-1/2 # and 12 # anchors and steel for larger anchors.

If all of the above criteria indicate it is likely a HMCo. anchor, final verification can be made by ordering a copy of the Herreshoff Manufacturing Co. drawing 74-54 or 74-55 List of anchors dated January 1911 from the MIT Museum, Hart Nautical Collection and comparing the detailed dimensions on that drawing with the anchor in question.

Notes:

1. After June of 1939 the HMCo. cast the 7-1/2 # bronze anchors with the shank and flukes as a single piece, it was therefore no longer a three piece anchor
2. JM Reineck and Son produces, under license, three piece cast bronze anchors from the 7-1/2#, 16# and 20# HMCo. anchor drawings.
3. If you find a Ⓛ mark on an a three piece anchor casting it is the casting mark of the Lebanon Steel Foundry and may be a HMCo. designed anchor

Appendix I

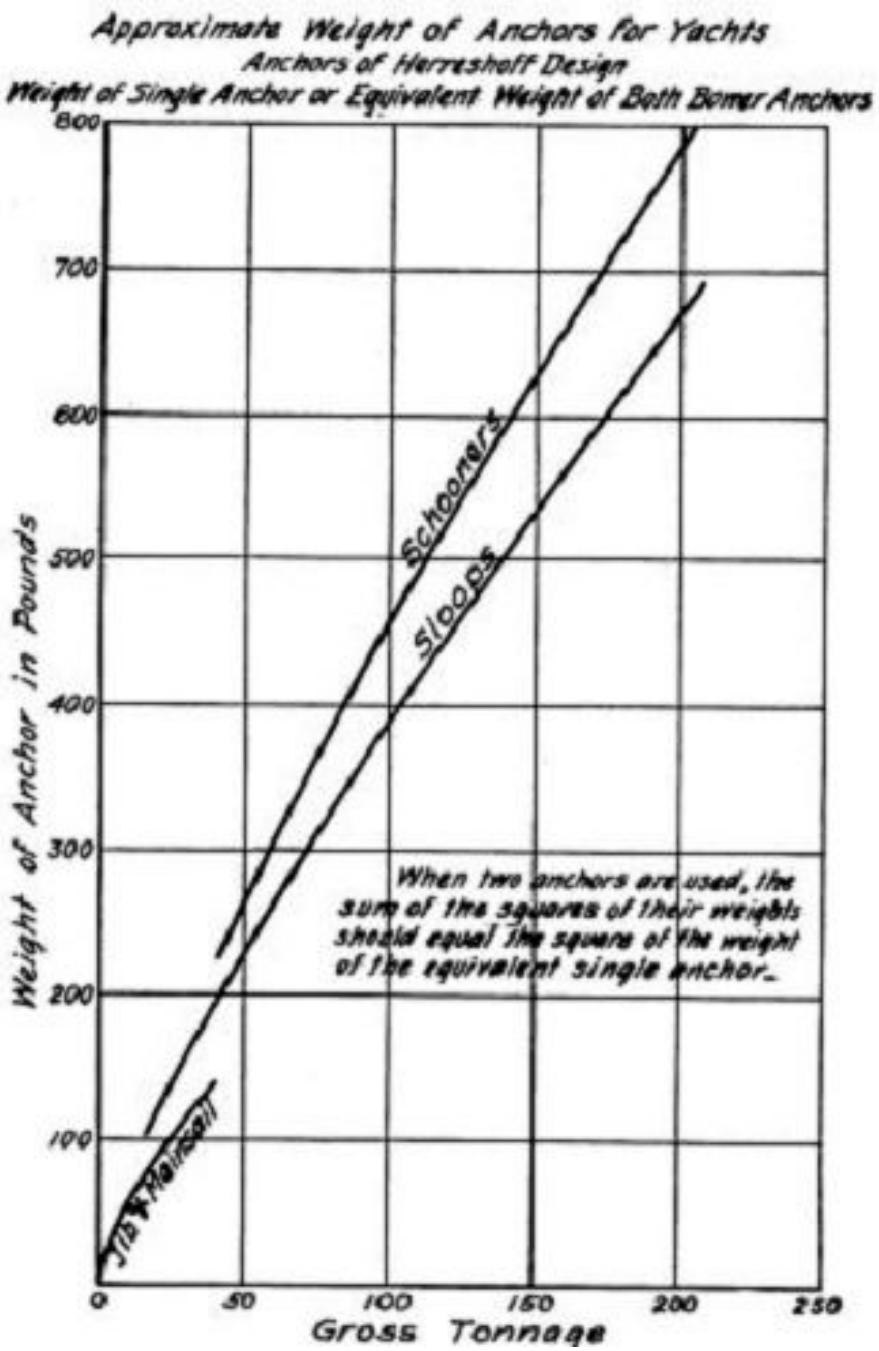
LIST OF HMCo. DRAWINGS DESCRIBING THE STRAIGHT AND FOLDING STOCK ANCHORS AVAILABLE FROM THE MIT MUSEUM HAFFENREFFER-HERRESHOFF COLLECTION

Drawing #	Date	Title
74-01	March 29,1882	Fabricated Sizes of Anchors
74-44	June 12, 1905	List of Straight Stock Anchors
74-45	June 16, 1905	List of Folding Stock Anchors
74-51	May 8, 1907	Straight Stock Anchor List
74-52	May 11, 1907	Folding Stock Anchor List
74-54	January 12, 1911	Folding Stock Anchor List
74-55	January 14, 1911	Straight Stock Anchor List
74-60	March 30, 1915	Anchor for # 744 Class (7.5#)
74-61	January 29, 1916	127 & 64 lbs. Cast Steel Anchors
74-62	March 4, 1916	12 and 16 lbs. Anchors
74-64	May 26, 1916	288 and 199 LB Cast Steel Anchors
74-69	December 18, 1918	20 LB Anchor
74-70	January 4, 1919	64.2 & 74.7 LB Anchors
74-71	July 1, 1919	405 LB Anchor
74-72	December 24, 1918	31.3 & 45.7 LB Anchors
74-72	No Date on drawing	542 LB Anchor
74-81	March 8, 1927	470 LB Cast Steel Anchor

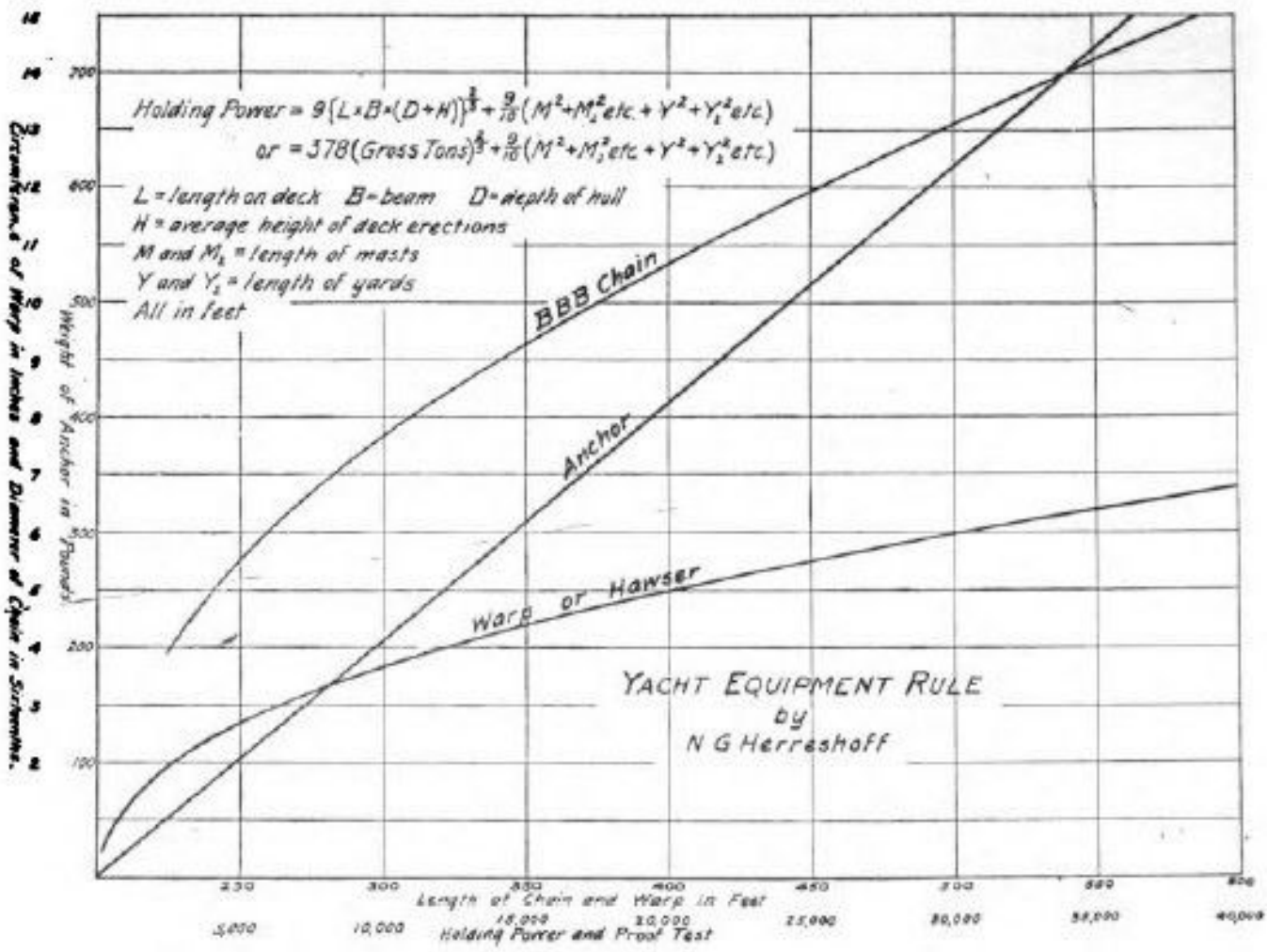
See: http://www.herreshoff.info/Tables/drawings.htm?hdn=074-001,%20074-044,%20074-045,%20074-051,%20074-052,%20074-054,%20074-055,%20074-060,%20074-061,%20074-062,%20074-064,%20074-069,%20074-070,%20074-071,%20074-072,%20074-072,%20074-081

Appendix II

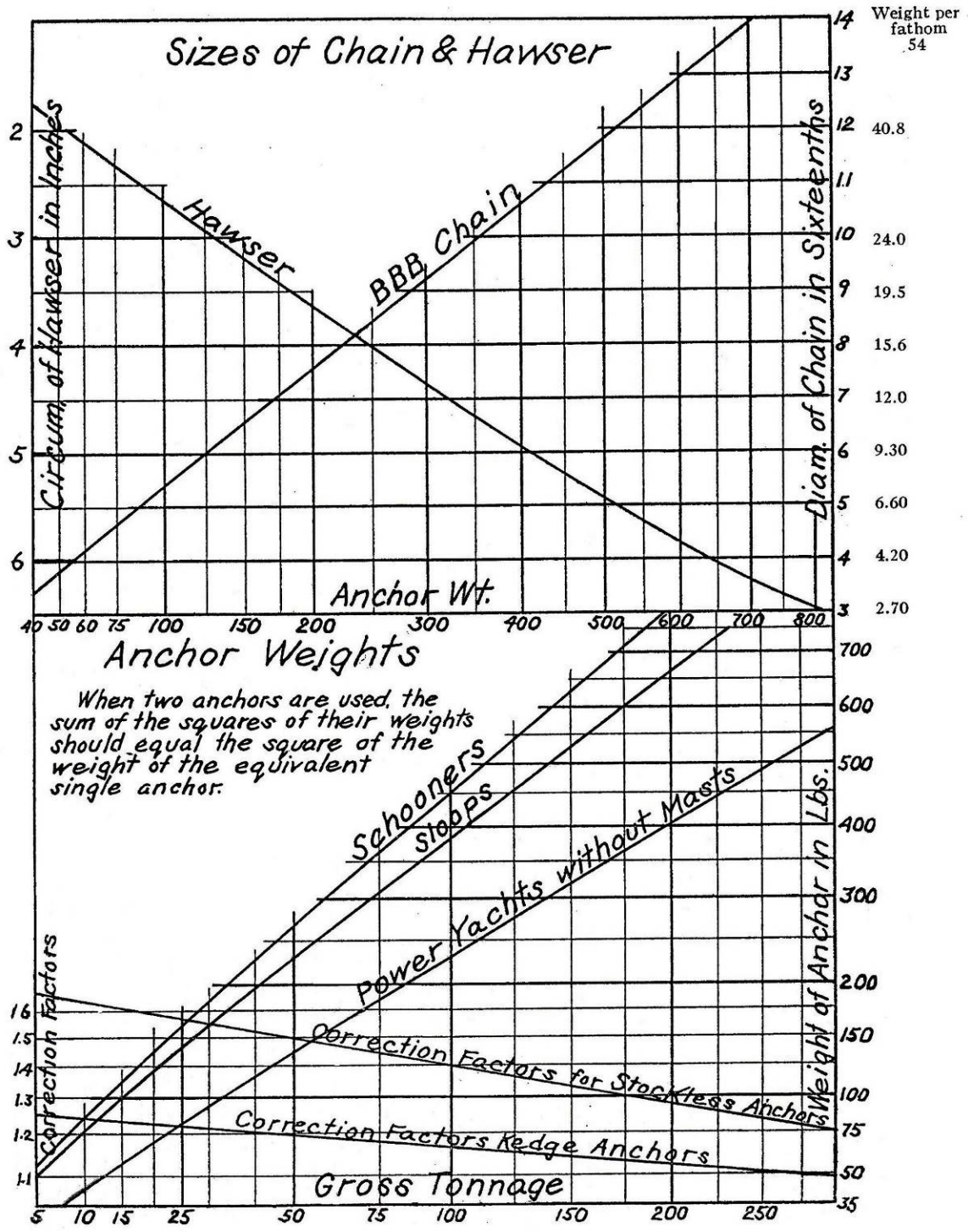
ADDITIONAL NOMOGRAMS FOR SELECTING HERRESHOFF ANCHORS



Curves above, one for the jib and mainsail with simple rig (smaller boats). One for the full rigged sloops (mainsail, main topsail, staysail, jib & jib topsail) and one for schooners. The greater amount of rigging aloft in schooners calls for heavier ground tackle.[25]



This is Capt. Nat's 1907 ground tackle nomogram, together with the 1907 anchor sizing equation as they appear in the 1915 Handbook on American Yacht Racing Rules. [25]



1924 edition of Skeene's "Elements of Yacht Design

This nomogram,[31] based on information attributed to Nathanael Herreshoff, has a curve of correction factors which express the effectiveness of HMCo. anchors relative to the common anchors of the day. The correction factors for stock anchors range from 1.25 for the smaller anchors to 1.1 for large anchors and 1.65 to 1.2 for stockless anchors. Once the proper weight HMCo. anchor is determined from the nomogram it is multiplied by the indicated correction factor to determine the necessary weight of an equivalent Admiralty, fisherman (kedge) or stockless anchor.

Appendix III

CURRENT (2013) MANUFACTURES OF THREE PIECE STOCK ANCHORS

J M Reineck & Son

J M Reineck & Son produce reproductions of 7½ and 16 # Herreshoff folding stock anchors, cast from manganese bronze.

P.E. Luke

Luke advertises a series of (8) galvanized steel three piece straight stock anchors weighing 40#- 200#.

Kingston Anchors

Kingston advertises a series of (7) galvanized steel three piece Herreshoff style straight stock anchors weighing 15#-199#.

Historical Arts and Casting

Historical Arts and Casting has tooling for 40# and 20# bronze reproductions of Herreshoff three piece anchors.

Appendix IV

Herreshoff Anchor Pattern Numbers

Anchor Wt.	Fluke Pat.	Shank Pat.
7.5	10665	10664
127	10779	10778
64.2	11061	11062
12	11528	11527
15.6	698	669
199	11104	11103
288	11106	11105
20	776	11529
31.3	11531	11530
45.7	11534	11533
74.7	11536	
470	10322	8460
405	11853	11854
542	11633	11632
38	11532	
54.3	11535	
99	11537	
159	11538	
25.2	916	
242	11539	
345	11540	
622	10720	
710	11502	
805	11503	
907	11504	
1020	9124	
1260	10314	

See:
http://www.herreshoff.info/Tables/patterns.htm?hpn=669,%20698,%20776,%20916,%208460,%209124,%2010314,%2010322,%2010664,%2010665,%2010720,%2010778,%2010779,%2011061,%2011062,%2011103,%2011104,%2011105,%2011106,%2011502,%2011503,%2011504,%2011527,%2011528,%2011529,%2011530,%2011531,%2011532,%2011533,%2011534,%2011535,%2011536,%2011537,%2011538,%2011539,%2011540,%2011632,%2011633,%2011853,%2011854

Notes and References

1 - Common Sense of Yacht Design, Vol. 2, pages 105-110, *G.W. Blunt White Library, Mystic Seaport Museum*

2- Letter from NGH to LFH dated October 29, 1935. Box 17, folder 11. L. Francis Herreshoff Collection #138 *G.W. Blunt White Library, Mystic Seaport Museum*

3 - Page 94 Merriman Brothers Catalog 1948, *G.W. Blunt White Library, Mystic Seaport Museum*

4- Casting Card 12589 - *Haffenreffer-Herreshoff Collection, Hart Nautical Collections, MIT* Museum

5- NGH Letter to Henry de Parsons, April 24, 1907 - *Herreshoff Marine Museum*

6 - Pages 43 & 44, 1910 NGH Design Notebook, *Halsey C. Herreshoff*

7 - Pages 95-96, NHG Test Record Book, *Haffenreffer-Herreshoff Collection, Hart Nautical Collections, MIT Museum*

8 - Pages 89 & 90 NGH 1907 Design Notebook, *Halsey C. Herreshoff*

9 - Casting Cards 10664 & 10665, *Haffenreffer-Herreshoff Collection, Hart Nautical Collections, MIT Museum*

10 - Beverly Yacht Yearbook 1920, *G.W. Blunt White Library, Mystic Seaport Museum*

11 - Casting card 10779, *Haffenreffer-Herreshoff Collection, Hart Nautical Collections, MIT Museum*

12 - A locking taper is a taper of 1 inch in 8 inches and greater (i.e. 1 inch in 10 inches, etc.)

13 - Table of Anchors Drawing 74-54, *Haffenreffer-Herreshoff Collection, Hart Nautical Collections, MIT Museum*

14 - Page 45 Herreshoff of Bristol, *Carlton Pinheiro and Maynard Bray*

15 – Casting cards # 10779, 11104, 11530, 11531, 11535, 11536 *Haffenreffer-Herreshoff Collection Hart Nautical Collections,*

16 - Wrought Iron, its Manufacture, Characteristics and Applications, *G.W. Blunt White Library, Mystic Seaport Museum*

17 Page 28, Voluntary Liquidation Sale by Absolute Auction The Plant of the Herreshoff Manufacturing Company Inc., August 21-22, 1924, *G.W. Blunt White Library, Mystic Seaport Museum*

18 - Marks Standard Handbook for Mechanical Engineers, Eighth Edition, Chapter 6-53, *Authors Collection*.

19 - Tables 1 & 2 Standard Specification ASTM A27 /A27-A Cast Steel, *Internet*

20 - Mystic Seaport Museum, *L. Francis Herreshoff Collection Box 138, Folder 16, items 11, 12 & 13.*

21- Anchor casting cards, *Haffenreffer-Herreshoff Collection, Hart Nautical Collections, MIT Museum*

22 - Herreshoff Marine Museum Chronicle Spring 1985, *Herreshoff Marine Museum* Chronicle

23 - Drawing 74-51, *Haffenreffer-Herreshoff Collection, Hart Nautical Collections, MIT Museum*

24 - Pages 95-96, NHG Test Record Book *Haffenreffer-Herreshoff Collection, Hart Nautical Collections MIT Museum*

25 - Pages 37-42 Handbook on American Yacht Racing Rules, 1915 *G.W. Blunt White Library*, *Mystic Seaport Museum* Call Number VM 861 M4, *G.W. Blunt White Library, Mystic Seaport Museum*

26- Roll 9, Sheet 10683 Consolidated Shipbuilding Collection, 1930, *Ships Planes Collection, Mystic Seaport Museum*

28 - Page 64, NGH Materials Test Record Book - *Haffenreffer-Herreshoff Collection, Hart Nautical Collections, MIT Museum*

29 -1903&1905 Inventory, straight stock and folding stock anchors HH.6.140, *Haffenreffer-Herreshoff Collections Hart Nautical Collections, MIT museum*

30 -This letter was published as 'Letter Seventeen' in Nathanael Greene Herreshoff, William Picard Stephens their last letters 1930-1938, annotated by John Streeter.

31 - Page 132 of the 1924 edition of Skeene's "Elements of Yacht Design"