Capt. Denison R.E.
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R.E.

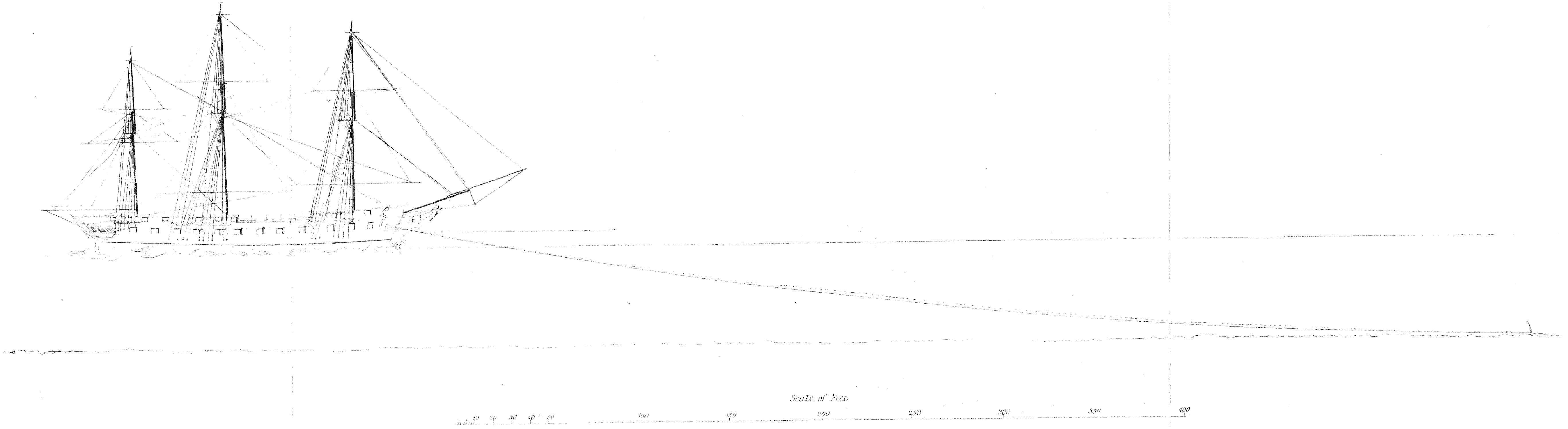
AN INQUIRY

RELATIVE TO

VARIOUS IMPORTANT POINTS

OF

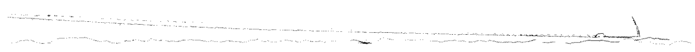
Seamanship.



A 36 Gun Frigate of the "Inconstant" Class at Anchor

This Figure is introduced to show the Catenary curve of a chain Cable 100 Fathoms in length, which has been determined by Actual experiment upon that length, The depth of water being 10 Fathoms and the amount of tension 63¾ Tons, which is the testing strain for 1⅞ inch chain, the proper size for that Ship

The dotted line represents the curve when the chain is in water



400

h, The depth of water being 10 Fathoms

AN INQUIRY

RELATIVE TO

VARIOUS IMPORTANT POINTS

OF

SEAMANSHIP,

CONSIDERED

AS A BRANCH OF PRACTICAL SCIENCE.

BY

NICHOLAS TINMOUTH,

MASTER ATTENDANT OF HER MAJESTY'S DOCK-YARD AT WOOLWICH.

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TO

THE RIGHT HONOURABLE

THE EARL OF HADDINGTON,

ETC., ETC., ETC.,

First Lord Commissioner of the Admiralty,

THIS INQUIRY

UPON SOME IMPORTANT POINTS OF SEAMANSHIP

IS (BY PERMISSION)

RESPECTFULLY INSCRIBED,

BY HIS HUMBLE AND OBLIGED SERVANT,

THE AUTHOR.

PREFACE.

UNDER the impression that no addition has been made to the general stock of information upon seamanship by any recent publication, at least none that has come under my notice, and that my own practical experiments and observations might be useful to others, if properly arranged, I have been induced to submit the results of my experience to the consideration of the public; but I can with truth declare, that neither the prospect of gain nor the vanity of authorship has had the smallest influence in the matter, neither do I presume to offer, as a plea for its introduction to public notice, any claim to superior professional knowledge, or arrogate a competition with numerous able individuals, whose education and attainments entitle them to attention. Nevertheless, I humbly apprehend, that the constant unbroken practice of nearly half-a-century, a close and watchful observance of all that pertains to seamanship, and a long intercourse with intelligent and experienced Naval Officers, have enabled me to form a competent judgment of what I have attempted to describe in the following sheets, viz., Strength of Materials, the best manner of raising heavy weights in ships, the character and properties of a Span, and the Catenary Curve of a Chain Cable.

Local position and a peculiarity of professional employment have afforded me opportunities at various times for investigating and proving by practical experiments all those subjects which other men of perhaps better abilities have never had the means of accomplishing. This remark applies with peculiar force to the numerous opportunities for determining the strength of Rope and Chain, particularly those of a large description, which could not be elsewhere ascertained than in this Dock-yard, where the only testing machine of any magnitude belonging to Government has long been in use.

It fell to my lot, in the course of service, to reside for a period of twelve years in a Shear Hulk, a position of all others the most favourable for daily witnessing the effect of strain upon this

kind of instrument, and so placing the supporting Guys to the various parts, that the greatest degree of strength and security may be insured with the smallest quantity of materials. Local position at a subsequent period imposed upon me the responsibility of raising the great equestrian statue of George the Third in Windsor Park, where it now stands. It was necessary to transfer this enormous weight a distance of twenty-four feet horizontally in a suspended state at the height of sixty-four feet above the level of the ground, with a very imperfect security for shears in such a position, and a wet swampy ground to act upon, all evils bad enough in their way, but upon the whole they were valuable in practice.

Ready expedients in sudden difficulties are of the utmost value to a seaman, as he, of all other men, is the most liable to encounter them. Many men are fully prepared with quick resources for any emergency, but all are not so; some there may be who have not had the benefit of much practice, who would yet, probably, be willing to profit by another man's experience. It is to them these pages are offered, by one who is most anxious to do all the good he can, before the rapidly approaching time arrives, when he shall no longer be able to perform it.

The other subjects which I have ventured to investigate, have each been familiar in practice for a considerable time in this Dock-yard; and in no case have I delivered an opinion upon professional subjects which has not been previously verified by experiment, or confirmed by experience. I am aware that the contents of this little production will be liable to comment, which naturally enough makes a man cautious and look about him, ere he ventures for the first time within point-blank range of the critic's shot; but if the motive shall be found good, even though the subject-matter turn out objectionable, it will surely be but fair play to admit the one to balance the other. Upon this point, however, I must take my chance, but may be allowed to hope, in the language of a talented naval officer, "that those who are mighty in criticism will be merciful in censure, and not visit with asperity that which is humble in pretension."

CONTENTS.

A Brief Exposition of Subjects

IN

CONNECTION WITH SEAMANSHIP.

CHAPTER I.

Observations on the Strength of Materials, more particularly ROPE *and* CHAIN; *with a statement of numerous facts developed by a series of Experiments made in* WOOLWICH DOCK-YARD *to determine the actual strength of* HEMPEN *and* CHAIN CABLES.

IN the observations which I have to offer upon this subject, it is not my intention to enter into any consideration of the strength of materials generally; for that has already been well and ably performed by those who are better qualified; it is rather to state such facts as have come within my own observation in the performance of professional duties, particularly with reference to the strength of Rope and Chain, and the peculiarities of the materials of which they are composed. Any information, however trifling, upon the strength of these two substances, is of the utmost value and importance to the seaman, for there is scarcely an operation in his complicated and arduous duties which can well be performed without their aid. The safety of his ship and likewise of himself being in a great measure dependent on them, it is the more necessary that he should have full acquaintance with their strength and peculiarities. But this important information it is no easy matter to obtain; it is not, I believe, to be found in any recent publication; neither do I think that any experiments have ever been made upon the larger description of rope and chain. There is no difficulty about light and slender substances, which admit of being broken by any temporary contrivance; but an instrument fit to tear asunder those substances which have the strength of one hundred tons or more is of such value, that few individuals would be willing to incur the expense; and if they did so, the cost of the material to experiment upon, would exceed the other to a very great extent, as it must of necessity be superior in quality and considerable in quantity to make it suitable for the purpose required.

About Midsummer, 1842, when the intention of revising the Establishment of Anchors and Cables for the Navy was first intimated, it was found, or rather it was previously known, that no positive information on the strength of hempen cables was in existence. Some experiments on the smaller kinds had been made, and the strength of a good $10\frac{1}{2}$-inch cable or 10-inch hawser laid rope was considered to be about twenty tons; these formed a scale by which the strength of other sizes had been calculated, but there was no satisfactory evidence in

proof of this with regard to any size. It was therefore suggested, and very properly ordered, that a series of experiments should be made in this Dock-yard, to ascertain by positive proof the strength of all cables, both hempen and chain, of various sizes, from the smaller kind up to the largest at present in use.

Table No. I. contains the results of these experiments; and it is highly improbable that any similar undertaking so extensive in its operations, and embracing materials of such magnitude and value, may ever again be attempted. No consideration of time or expense in providing materials has been allowed to interfere with or prevent the fulfilment of the original intention. Many difficulties of a formidable kind have presented themselves, and several accidents have occurred occasioning expense and loss of time; but in no case have they had any influence on the final results of the trials.

It being deemed advisable to have a sufficient number of experiments upon each kind of cable, to give a satisfactory average; a considerable quantity of both kinds was accordingly provided. The sizes selected for experiments of hemp were 25 inches circumference, $22\frac{1}{2}$ inches, 20 inches, $17\frac{1}{2}$ inches, 15 inches, $12\frac{1}{2}$ inches, 10 inches, $7\frac{1}{2}$ inches, and 5 inches. The sizes of the chain cables were those corresponding according to classification, viz., $2\frac{1}{8}$ inches diameter, 2 inches, $1\frac{7}{8}$ inches, $1\frac{3}{4}$ inches, $1\frac{1}{2}$ inches, $1\frac{1}{8}$ inches, 1 inch, $\frac{7}{8}$ of an inch, $\frac{3}{4}$ of an inch, and $\frac{5}{8}$ of an inch. It is necessary to state, that the $2\frac{1}{8}$ inch chain was not tested, on account of the probability that the testing machine would be seriously injured in the event of this chain breaking under a heavy strain. There were six experiments upon each of the other nine different sizes of chain cable, amounting in the whole to fifty-four; and eight upon each of the nine hemp cables, making together seventy-two. These experiments are easily distinguished in the Table by extending through all the columns from side to side, and the strength of all the intermediate sizes both of hemp and chain has been calculated with the greatest care by the following rule:—"Divide the difference of the two strains by the difference of the squares of the diameters (or circumference) for a constant multiplier. This multiplier into the difference of the squares of any two sizes will give the number of tons to be added to the strain upon the smaller." As the actual strength of any instrument can only as a whole be considered equal to its weakest part, the minimum column of strength in the Tables must be considered the safest. The right-hand column has been calculated from the weakest of all the experiments, and may be serviceable where risk is apprehended and great caution necessary. With reference to the strength of the hawser laid rope, and rigging or crane chain, in Table No. II, the experiments have been made at various times for isolated purposes; and although not in the same progressive order as in the case of the cables, yet the strength has been ascertained by the same means, by the same machine, with the same degree of accuracy, and embracing a sufficiently numerous class of sizes to render the calculation of all intermediate kinds equally correct.

TABLE I.

FOR ASCERTAINING THE STRENGTH OF HEMPEN CABLES.

	Size. Inches.	No. of Yarns.	Weight 100 Fath. lbs.	BREAKING WEIGHT IN TONS. Maximum.	Intermediate Strains.						Minimum.	Mean.	Calculated from * weakest.
	26	3528	14112	122.2							105.9	111.6	101.5
	25½	3393	13572	117.5							101.9	107.3	97.6
†	25	3267	13068	113.	107.	106.5	102.	101.5	99.	99.	98.	103.2	93.8
	24½	3122	12488	114.4							94.4	102.5	90.1
	24	3006	12024	115.7							91.	101.9	86.5
	23½	2880	11520	117.							87.6	101.3	82.9
	23	2763	11052	118.3							84.2	100.7	79.4
†	22½	2646	10584	119.5	109.5	101.7	99.5	99.	96.5	94.	81.	100.1	76.
	22	2529	10116	111.4							77.9	95.	72.6
	21½	2412	9648	103.5							74.9	90.1	69.4
	21	2304	9216	95.8							72.	85.3	66.2
	20½	2196	8784	88.3							69.2	80.6	63.1
†	20	2088	8352	81.	78.5	78.2	78.	77.	75.5	74.2	66.5	76.1	60.
	19½	1980	7920	76.7							62.1	71.3	57.1
	19	1881	7524	72.6							57.9	66.6	54.2
	18½	1782	7128	68.6							53.8	62.1	51.4
	18	1692	6768	64.7							49.8	57.7	48.6
†	17½	1597	6388	61.	59.7	54.7	54.5	52.	50.	49.2	46.*	53.4	46.*
	17	1512	6048	57.3							44.9	51.	43.4
	16½	1422	5688	53.9							43.8	48.7	40.8
	16	1332	5328	50.5							42.8	46.5	38.4
	15½	1251	5004	47.3							41.9	44.3	36.
†	15	1179	4716	44.2	43.	42.7	42.5	42.	41.7	41.5	41.	42.3	33.7
	14½	1098	4392	41.6							38.4	39.9	31.5
	14	1026	4104	39.1							36.	37.6	29.4
	13½	954	3816	36.7							33.6	35.4	27.3
	13	882	3528	34.4							31.3	33.3	25.3
†	12½	810	3240	32.2	32.2	32.	32.	31.2	31.2	31.	29.2	31.3	23.4
	12	756	3024	29.8							26.6	28.6	21.6
	11½	693	2772	27.6							24.2	26.1	19.8
	11	630	2520	25.5							21.8	23.7	18.1
	10½	576	2304	23.4							19.6	21.4	16.5
†	10	522	2088	21.5	21.	19.7	17.7	17.7	—	—	17.5	19.2	15.
	9½	468	1872	19.							15.7	17.1	13.5
	9	432	1728	16.7							14.	15.2	12.1
	8½	396	1584	14.6							12.4	13.4	10.8
	8	315	1260	12.6							10.9	11.7	9.6
†	7½	288	1152	10.7	10.5	10.5	10.3	10.3	10.3	10.	9.5	10.2	8.4
	7	252	1008	9.3							8.2	8.8	7.3
	6½	216	864	8.1							7.	7.5	6.3
	6	189	756	7.							5.8	6.3	5.4
	5½	162	648	5.9							4.8	5.3	4.5
†	5	135	540	5.	4.9	4.6	4.2	4.	4.	4.	3.9	4.3	3.7
	4½	108	432	4.							3.1	3.4	3.
	4	90	360	3.2							2.5	2.7	2.4
	3½	69	276	2.4							1.9	2.1	1.8
	3	54	216	1.8							1.4	1.5	1.3

NOTE.—The lines marked thus (†) contain the results of actual experiments, and the intermediate lines those derived from calculations.

TABLE I.

FOR ASCERTAINING THE STRENGTH OF CHAIN CABLE.

	Size.	Testing Strain in Tons.	Weight 100 Fath. lbs.	BREAKING STRAIN IN TONS. Maximum.	Intermediate Strains.				Minimum.	Mean.	Calculated from * weakest.
	2¼	91⅛	27216	130.3					121.8	125.9	107.4
	2⅛	81¼	24276	116.2					108.6	112.3	95.8
†	2	72	21504	103.	102.5	101.	97.5	97.	96.25	99.5	
†	1⅞	63¾	18900	99.	97.75	93.5	90.	89.	88.	92.8	
†	1¾	55⅛	16464	85.25	81.5	80.5	67.	65.5	65.	74.1	65.
	1⅝	47½	14196	75.					59.5	66.5	56.
†	1½	40½	12096	65.5	65.5	59.25	57.75	55.	54.5	59.5	
	1⅜	34	10164	53.6					44.4	48.5	40.1
	1¼	28½	8400	42.8					35.3	38.5	33.1
†	1⅛	22¾	6804	33.	31.75	29.	29.	27.5	27.	29.5	26.
†	1	18	5376	27.25	26.	24.75	23.	22.75	22.	24.3	21.2
†	⅞	13¾	4116	22.5	21.5	21.1	20.7	20.5	20.3	21.1	16.2
†	¾	10⅛	3024	15.	14.25	14.	12.75	12.62	12.5	13.5	11.9
	11/16	8½	2541	12.3					10.8	11.4	10.
†	⅝	7	2100	9.87	9.75	9.5	9.5	9.5	9.37	9.5	8.2
	9/16	5½	1701								
	½	4½	1344	6.3					5.9	6.	5.3

NOTE.—The lines marked thus (†) contain the results of actual experiments, and the intermediate lines those derived from calculations.

TABLE II.

FOR ASCERTAINING THE STRENGTH OF HAWSER LAID ROPE.

	Size.	No. of Yarns.	Weight 100 Fath. lbs.	STRAIN IN TONS.				Mean.
				Maxi-mum.	Intermediate Strains.		Mini-mum.	
†	12	1173	2940	45.5	40.5	39.	35.	40.
	$11\frac{1}{2}$	1077		41.7			32.	36.7
	11	987		38.2			29.3	33.6
	$10\frac{1}{2}$	900		34.9			26.7	30.7
	10	816	2136	31.7			24.2	27.9
	$9\frac{1}{2}$	738		28.6			21.8	25.2
	9	660	1712	25.7			19.6	22.6
	$8\frac{1}{2}$	591		23.			17.5	20.2
	8	522	1379	20.4			15.5	18.
	$7\frac{1}{2}$	459		18.			13.6	15.8
	7	399		15.8			11.8	13.8
	$6\frac{1}{2}$	345		13.7			10.2	12.
†	6	294	834	$11\frac{3}{4}$	$10\frac{3}{4}$	10.	8.7	10.3
	$5\frac{1}{2}$	249	712	9.8			7.3	8.7
	5	204		8.2		7.	6.1	7.2
	$4\frac{1}{2}$	168	413	6.7		5.	5.	5.9
	4	132		5.3			4.	4.7
	$3\frac{1}{2}$	102		4.1			3.2	3.7
	3	75	203	3.1		2.5	2.4	2.8
	$2\frac{1}{4}$	54		2.2			1.8	2.1
	2	33		1.5		1.7	1.3	1.4
†	$1\frac{3}{4}$	27		1.28	1.28	1.23	1.13	1.23
†	$1\frac{1}{2}$	21		.90	.89	.88	.86	.88
†	$1\frac{1}{4}$	15		.60	.56	.55	.53	.56
†	1	12		.58	.51	.49	.46	.51
†	$\frac{3}{4}$	9		.51	.46	.46	. 2	.46
†	$\frac{1}{2}$	6		.28	.28	.28	.28	.28

NOTE.—The lines marked thus (†) contain the results of actual experiments, and the intermediate lines those derived from calculations.

TABLE II.

FOR ASCERTAINING THE STRENGTH OF ROUND LINKED CRANE CHAIN.

	Size.	Weight 100 Fath. lbs.	STRAIN IN TONS.				Mean.	Testing Strength.
			Maxi-mum.	Intermediate Strains.		Mini-mum.		
†	$1\frac{5}{8}$	15569	75.	74.7	74.5	68.	73.	31.6
	$1\frac{1}{2}$		64.			58.2	62.3	27.
	$1\frac{7}{16}$		59.			53.8	57.4	24.7
	$1\frac{3}{8}$		54.2			49.6	52.8	22.6
	$1\frac{5}{16}$		49.7			45.5	48.4	20.6
	$1\frac{1}{4}$		45.3			41.7	44.1	18.8
	$1\frac{3}{16}$		41.2			38.	40.1	17.
	$1\frac{1}{8}$	7481	37.3			34.5	36.3	15.3
	$1\frac{1}{16}$		33.6			31.2	32.7	13.6
	1	6490	30.1			28.1	29.3	12.
	$\frac{15}{16}$	5600	26.8			25.2	26.1	10.5
	$\frac{7}{8}$	4500	23.7			22.5	23.1	9.1
†	$\frac{13}{16}$	4000	20.9	20.3		20.	20.4	7.9
	$\frac{3}{4}$	3449	17.8			16.6	17.3	6.8
	$\frac{11}{16}$	2900	14.9			13.5	14.6	5.6
	$\frac{5}{8}$	2538	12.3			10.8	12.	4.6
	$\frac{9}{16}$	2001	10.			8.7	9.7	3.8
	$\frac{1}{2}$	1583	7.9			6.9	7.7	3.
	$\frac{7}{16}$	1060	6.			5.2	5.9	2.3
	$\frac{3}{8}$	827	4.4			3.8	4.3	1.6
	$\frac{5}{16}$	581	3.			2.7	3.	1.1
	$\frac{1}{4}$	392	1.9			1.7	1.9	.75
	$\frac{3}{16}$		1.1			.97	1.	.42

NOTE.—The lines marked thus (†) contain the results of actual experiments, and the intermediate lines those derived from calculations.

The execution of these experiments occupied a period of six months, commencing in September, 1842, and by performing a certain number in each week were finally completed in March, 1843. Some facts of importance have been developed in the course of these operations, which will hereafter be described, and others previously uncertain, or imperfectly comprehended, have, to a limited extent, been confirmed, or better understood.

With reference to the comparative strength of various kinds of hempen rope, it has been ascertained that the untarred white three-strand hawser laid is stronger than any other: and it may here be remarked, that all rope made with four strands is weaker than that of three strands in the proportion of about one-fifth. The next in the scale of strength is the common three-strand hawser laid rope, tarred. This kind is in more extensive use and greater annual consumption than any other; it constitutes the running rigging in all ships, and embraces nearly every size and description of rope which is subject to the friction of blocks and thimbles, including many that are exposed to great strain, and to the deteriorating effects of atmospheric changes. The cablet or cable-laid rope of nine strands, so manufactured to render it impervious to water, is decidedly the weakest. It stretches enormously under a heavy strain, which occasions a reduction in the circumference, and no doubt a serious loss of original strength. The first effect of strain appears to operate upon the crooked fibre, drawing it straight; and as the strain is increased, the cohering fibre is doubtless more or less disturbed in proportion to the amount of tension, which in the end causes a total derangement. This touches upon the question whether a hemp cable after

being severely strained is fit to stand, and will actually stand the same strain a second time.

The following facts observed in the course of these experiments are important in this matter:

A portion of $22\frac{1}{2}$-inch cable was attached to the testing machine in the usual way, for the purpose of ascertaining the number of tons necessary to break it, and when the strain had been increased to ninety-seven tons, (the supposed strength of the rope being about ten tons more,) one of the shackles used in the process broke, and it became necessary to remove the rope from the machine to repair the defect. No apparent injury could be discovered in any part of the rope, no rupture of the yarns, or visible difference, except the lengthened angle of twist, and reduced circumference by extension in length. When this piece of rope was placed a second time in the testing machine, it suddenly and unexpectedly broke at a strain of sixty-five tons.

Another piece of the same size and description of rope was taken out of the testing machine under similar circumstances, to repair an accident, the only difference between them being, that the amount of strain in this case when the accident occurred was one hundred and nine and a half tons. This piece on a second application of the strain broke at sixty-nine tons. The first of these two cases bears strongly on the question, and is in some degree strengthened by the second, which gives one hundred and nine and a half tons at least for the strength of the rope; indeed, the maximum strength of this cable, which was made at Chatham, was one hundred and nineteen and a half tons, although one of the same size, made at Deptford, proved much weaker. It appears evident by the result, although not externally visible except by extension, that the strain had been carried so far beyond the limit of perfect elasticity that it could not recover its former dimensions when the strain was removed; it is analagous to taking a set; and as the absolute strength in any part of a body by which it resists being pulled asunder, is proportional to the area of the section perpendicular to the extending force, and as this area measured twenty-two and a half inches in its original state, and is contracted by the strain to twenty-one inches, it certainly seems to prove that the strength is proportionally reduced. Thus far theoretical reasoning would induce us to look at one side of this important question; but it is difficult to reconcile these apparently conclusive facts with the practical experience of many years' duration in ships of war at the time when hempen cables were exclusively in use. It was well known to the majority of Naval Officers then employed, that the identical cable by which the ship rode out a gale of wind on one particular occasion likewise sustained her at a subsequent period under very similar circumstances. It is, however, possible, and extremely probable, that the strain produced upon the cable by the gale of wind was not equal to that produced by the testing machine. Therefore, in turning again to the theory or mechanical law, it may be a matter of doubt with many, though I can have no doubt whatever about it, that a cable, or any other rope, which has been strained to the extent here mentioned, is permanently, and irretrievably weakened; the amount of strength lost, however, it would perhaps be difficult to determine, and with reference to the cable, still more difficult to draw the line, where safety ends, and

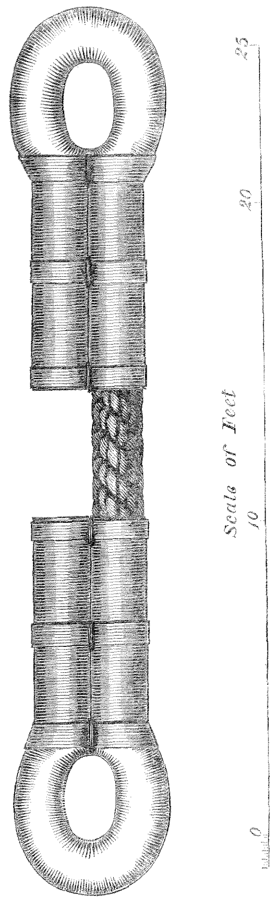
danger begins; but I should at all times use with extreme caution, any rope, which has been subjected to a great strain.

Of all the difficulties which presented themselves in the execution of these experiments, that of holding the hempen cable in the testing machine proved the greatest. It was absolutely necessary so to fix the rope in the machine, that the full strength might be ascertained without injury to the outer yarns by chafe or pressure in the operation. All the various modes of splicing and knotting were found upon trial to be weaker at the neck of the splice or knot, than at the main part of the rope; and it was likewise found, that the method which answered well with a small rope failed entirely with a large one.

Under the supposition that the large cables might be secured, partly by compression and partly by the resistance of a knot at each end, much time was spent in the endeavour to do so; but this method was found to be weaker, and the injury to the rope much greater, than in the case of the common splice.

After many fruitless endeavours to succeed by the various methods just stated, it became evident that no better means could be devised than is here shown in the annexed figure.

FIG. 1.



For which purpose it was found necessary to cut the pieces of large cables about fifty-two feet long, and turn each end back about twelve feet along the main part of the rope, with a strong heavy thimble in each bight well secured with racking lashings, leaving three or four feet

of the middle of the rope entirely clear. By this process, when carefully executed, it was invariably found that the full strength of the rope was in every case clearly ascertained.

The superiority of the hempen cable as compared with the chain in the important and valuable property of elasticity, does not exist to any great extent in the substance of the hemp. Repeated experiments have proved that a fibre of hemp will extend by a moderate strain about $\frac{1}{100}$ of its length, and contract again when the strain is removed. It therefore appears evident that the whole amount of elasticity, or nearly so, which any hempen rope possesses, is derived from the degree of twist imparted to it in the process of manufacture. From the result of long practical experience, and in connection with what has been stated at page 11, I have no doubt whatever of the fact, and an interesting and important one it is, that a strain of one half the full strength of any rope or chain, *constantly or even frequently applied*, will eventually break it. The effect of a great strain has been stated, and the progressive effect will be detailed; but on the present subject it may be mentioned, that a permanent extension in the length of a rope, is the first indication of a permanent reduction of its strength, and as this change is produced at a strain less than one half its full strength, it follows that, although trifling in extent, a constant application of the same strain must in a given time exhaust the whole strength and break the substance. The knowledge of this fact offers a valuable and useful lesson to all who have the care and management of standing rigging, particularly when it is new and liable to serious injury by injudicious haste in over-straining it.

The rope in its original state possesses the valuable properties of strength and elasticity, upon which depends the extent of durability. The perfection of these properties, so valuable in practice, may in a great degree be preserved by economy in management. It must, however, be admitted, that the usual manner of treating new rigging is the reverse of what it should be to attain this end. A system is pursued, with the apparent object of arriving in the shortest possible time at some imaginary point of stretching where it seems to be supposed the extension of the rope will in a great measure terminate; and for this purpose it is set up almost daily during the period of fitting the ship for sea, swifting it in on each occasion to hasten the operation; and it is of course during this time exposed to all the fluctuations of temperature in a variable climate, where cold rain will in a few hours so contract the material, as to produce a breaking strain. The whole intent and purpose of this proceeding is to stretch the rope well before the ship proceeds to sea, and when it is accomplished, no matter to what extent, it is still supposed that the full original strength of new rigging remains undiminished. No greater delusion can be entertained, neither can it be too extensively known, that the expenditure of strength in rope is progressive with the amount of strain applied, and in strict proportion to it, so that even a moderate tension renders a permanent extension in length inevitable, and a consequent permanent reduction of circumference. Hence it follows that the sectional area of substance which is the measure of strength, diminishes by every fresh application of strain, until, as has been already stated, the material is destroyed.

It is to be regretted that no certain, undeviating rule

can be suggested to determine the strain upon rigging when setting it up; the judgment of the officer must decide it in practice; but in order to prove that it is unnecessary to put a severe tension upon shrouds and backstays for the purpose of supporting a mast under a press of sail, some calculations have been made with reference to the mainmast of a 52-gun frigate having the main course, whole topsail, and top-gallant-sail set upon it at the time. To arrive at any thing like truth on a question of this complicated character, a variety of considerations must be entered into to determine the whole amount of pressure by the force of the wind upon the sails, and the leverage of the mast, with all the weight that is on it according to the angle of inclination of the ship; and on the other hand the whole amount of support afforded by shrouds and backstays to resist that pressure.

The vertical angle which the main lower shrouds of a 52-gun frigate make with the mast is 22° 18′, that of the topmast backstays 12° 10′, and that of the top-gallant backstays 9° 15′. The horizontal angles vary from 0 to 43°16′, (the foremost shroud being abreast the mast;) making the necessary resolutions of forces into their proper planes, and multiplying by the respective perpendicular heights of the points at which the shrouds and backstays are applied, we have the effort of the 8 shrouds on the mast = the tension of a shroud × 177.88.

The effort of 4 backstays = tension of a backstay × 80.04, and the effort of 2 top-gallant backstays = tension of a top-gallant backstay × 28.2.

The minimum strength of a 10-inch shroud is 24 tons, of a $6\frac{1}{2}$ backstay 10 tons, and of a 4-inch top-gallant backstay 4 tons. If we take these as the actual tensions of the shrouds and backstays, we have,

		Tons.
Effort of shrouds on the mast	24 × 177.88 =	4269.
backstays	10 × 80.04 =	800.4
top-gallant backstays	4 × 28.2 =	112.8
Whole effort on the mast	=	5182.2

The areas of the main course, whole topsail and main top-gallant-sail of a 52-gun frigate, multiplied by the respective perpendicular heights of their centres of effort above the deck = 666140 ; this multiplied by the effective athwartship force of the wind gives the effort of the sails on the mast.

Let the direction of the wind be supposed to be five points from a fore and aft line, and the yards braced up to an angle of 21° ; then, by the resolution of forces, the effective athwartship force of the wind on the sails will be the absolute force multiplied by 0.503.

Let us take for example 2lbs. to the square foot, which is the force of the wind in a strong breeze, in which this ship could just carry these sails close hauled ; the effective athwartship force = 2lbs. × 0.503 = 1.006lbs. Multiplying 1.006 by 666140, (as above given,) we have, the effort of the sails on the mainmast in an athwartship direction = 299 tons ; to this force must be added the effort of the weights of the mast, topmast, top-gallant-mast, yards, caps, cross-trees, rigging, &c., when the ship is inclined. If the angle of inclination be 20°, the effort of the top weight, from a rough estimate, would be about 500 tons, making with the effort of the wind on the sails 799 tons.

Hence the effort of the sails and top weight on the mast is to the maximum support which the shrouds, &c., would afford, as 799 tons to 5182 tons, or as 1 to 6.48.

In a very strong gale, the force of the wind may be taken as 6lbs. to the square foot, in which case the top-gallant-mast would be struck, and the main-topsail close reefed. Under these circumstances the effort of the sails on the mast would be 354 tons ; to this must be added 450 tons for the effort of the top weight, making together 804 tons.

The effort of the lower shrouds and topmast backstays on the mast would be 5069 tons. Hence the effort of the sails and top weight on the mast is to the maximum support which the shrouds would afford, as 804 to 5069 tons, as 1 to 6.3.

The results of the two calculations upon the small amount of 2lbs. and the greater one of 6lbs. per square foot, being so near, may induce the supposition of some inaccuracy ; but I think it will be found upon investigation, that the effect of the reduction in the area of sail, weight of mast, and height of centre of effort, is nearly equivalent to that of the increase of pressure per square foot.

If 9lbs. be taken as the force of the wind, the strain on the mast will be 982 tons, and the support of the shrouds 5069 tons, giving a ratio of 1 to 5.1.

This calculation is not to be regarded as minutely correct in all the details, but it is sufficiently so to prove that a tension of one-quarter the full strength of the supporting ropes would be ample security to the mast, allowing at the same time for the effect of the momentum caused by the rolling of the ship, and this strain of one quarter, above proposed, might be continued for several years without any serious loss of strength to the rope, thereby insuring the valuable advantage of durability.

Enough, perhaps, has been said to excite attention to the injurious effects of a great strain upon standing rigging; but one case may be mentioned to show the reality of much risk and danger to life and property by pursuing the practice. This case was related to me by a gentleman who purchased the ship at a period subsequent to the transaction.

The "Repulse" East Indiaman of 1400 tons sailed from the Downs on the 14th of March, 1829, for Madras and China, laden with a general cargo. She had been fitted in the Thames with a new set of lower rigging, which was frequently set up; and during the early part of her outward voyage she sprung a leak, and put back to Portsmouth, where she was taken into one of the Government Docks. It was found that the downward pressure of the mainmast had started the garboard streak, which rendered the removal of the mast necessary to fit another step, which is still in the ship.

The contraction of rope by the effect of cold rain has been mentioned at page 16, and I think it extremely probable that the immense downward pressure in the present case may have originated in that way immediately after the rigging had been set up.

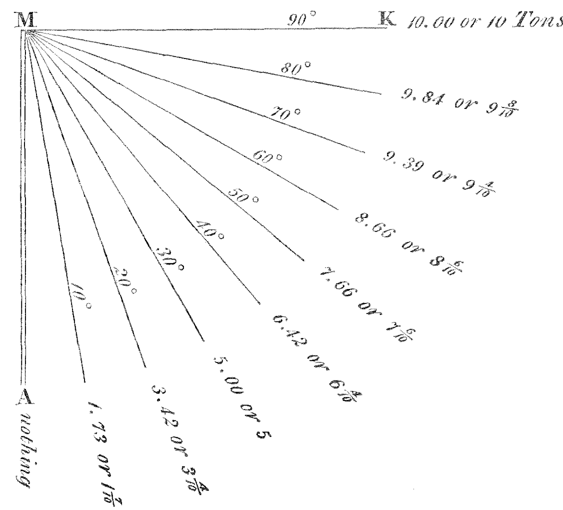
The effect of downward pressure by the masts has been noticed in many ships, and was conspicuously evident in all the ships of war at Antwerp in 1814. Within a certain radius of the wedges round the mainmast, a depression of the deck was in every ship visible, occasioned no doubt by the weight of the mast, and a great tension on the shrouds.

It appears to me of more value to have an equal strain upon each, rather than a great strain upon all the shrouds; because a ship sitting upright in harbour or anywhere in a quiescent state, presents a favourable opportunity to economize the strength of rope by an easy tension upon the shrouds, such as they can well sustain without loss of original strength.

A short rule might be useful to calculate the comparative effect as a support with reference to the strength of a rope when applied at various angles.

In the following figure, let a rope be applied from K to M for the purpose of resisting a force acting in that direction; the strength of the rope being 10 tons, what effect would it have if applied at any of the angles 10°, 20°, 30°, &c.

Rule.—Sine of angle × tension = effective force.



It will be perceived that, if the rope be applied from M to A at a right angle with the force, it can have no effect as a support, and that at every 10° it will increase as marked against each division up to K, the maximum strength of 10 tons.

The stretching of the rope is an evil which cannot well be altered, and will always require considerable attention; but there is another cause operating in the same direction, and nearly to the same extent, which with common care might be in part, if not altogether prevented. The cause here alluded to, is in the mode of placing the shrouds over the mast-head, the permanent position of the eye being entirely lost sight of in the endeavour to perform the whole operation in the shortest possible time. The consequence is, that the eyes of the rigging keep shifting their position down upon the mast-head for many months afterwards, producing as much slack rope, if it could be fairly measured, as the whole amount of stretching on each pair of shrouds.

I am fully aware of the unpopularity of any attempt to break in upon a practice so long and so firmly established, more particularly as the whole work of rigging a ship in a certain number of hours with very few hands has been very justly the boast of many naval officers; but notwithstanding the acknowledged value of competition as a spur to alacrity and emulation in the majority of naval operations, such as reefing topsails, weighing anchor, topgallant-yard exercise, shifting topmasts, and many other duties, I certainly would not include the operation of rigging a lower mast in the number, if the allotted time to fit the ship for sea would admit it to be so. The gain of a few hours under such circumstances is a poor compensation for the risk and days of labour which it must cost afterwards, particularly in the winter season, with a

cold wet atmosphere, and hard rigid rope to deal with, which requires not only force but careful management to bend it into shape round the mast-head.

It may be briefly stated, that what is here recommended to be done is no new discovery; it is merely to deal with each pair of shrouds separately at the time they are placed over the mast-head; and it may be observed that percussion, by far the most valuable means of accomplishing the object in view, cannot be made available after the eyes of the shrouds are all piled up one above the other upon the mast, it must be applied to each of the eyes successively in connection with downward pressure, in order to ensure a permanent and solid bearing, and prevent the possibility of any alteration afterwards.

Another branch of the subject necessary to notice, is the manner of turning dead-eyes into standing rigging for the purpose of setting up.

The old plan of securing the dead-eye by a throat and two end seizings, is nearly abolished by the prevalent custom of attaching dead-eyes similar to a cutter's stay.

This plan is considered by the majority of naval officers to have a snug, neat appearance; but it is found to be inferior in strength to the old plan. For instance, let three shrouds or three pieces be cut from the same rope, each piece having the dead-eye secured in its own peculiar way, viz. one to have the dead-eye spliced in, another similar to a cutter's stay, and the third to have the dead-eye secured by a throat and two end seizings. In order to ascertain the actual strength of these three different methods, repeated experiments have proved that, under the pressure of a breaking strain, the rope would first give way at the neck of the splice. The next weak point will be found in the cutter's stay plan, at the nip in the main part of the rope, where it is compressed by the bight which passes round it. The third or old plan, if the throat and end seizings are well and properly secured, will break the main part of the rope at the maximum strength. As each of these methods has some merit and corresponding disadvantages, it may be well to consider each of them impartially and decide accordingly.

The splice is never used for this purpose except where the rope is short, and it is well known that any splice is weaker than the rope itself by about one-eighth.

The cutter's stay plan has the advantage of holding well, and it admits a sail when set upon the rope to be hauled close down; but on the other hand, it is weaker than the main part of the rope, about one-tenth, principally caused by the compression of its own running eye, which reduces the sectional area of the substance at that spot, and renders the rope less durable.

With respect to the old plan, it was found upon some occasions, particularly when warm register rope was in use, that where the shrouds were long exposed to a hot sun, and heated atmosphere, the throat and end seizings did not hold the rope firmly. Having witnessed this evil to some extent, I am fully aware of the risk it involves, and the necessity for extreme caution; but there are five different methods of applying the throat and end seizings, all, or each of which, have been found by experiment to be stronger than the main part of the rope at the cutter's stay nip; therefore the old plan has strength and durability to recommend it.

It has been ascertained that a good salvagee, carefully made with the same number and description of yarns as

the common three-strand hawser laid rope, possesses about the same degree of strength. Theory would claim for it a superior character in this respect, which no doubt it would have, if all the yarns could be so arranged as to pull together; but the inference is, that they have an unequal bearing, and are broken in detail as the strain is multiplied.

It appears that the strength of hawser laid rope exceeds the strength of cablet in the proportion of 8.7 to 6.0. The average strength of each yarn in hawser laid rope is found to be greatest in the smaller sizes; thus, for 12-inch rope, the mean average strength is 76 lbs. per yarn; for 6-inch, 78.4 lbs.; for $1\frac{1}{2}$-inch, 93.8 lbs.; for 1-inch, 95.2 lbs.; for $\frac{1}{2}$-inch, 104.5 lbs.

A hempen cable of one hundred fathoms supports about twenty times its own weight; a chain cable about ten times its weight. This is not to be considered as a positive rule, but as an approximation.

The difficulties which have been experienced as stated at page 13, of holding the hemp cables in the testing machine without injury to the outer yarns, apply with equal force to the manner of joining a chain and hempen cable together. Hitherto there have been two modes in use in the Navy for accomplishing this object:—one by an artificial eye formed in the end of the hemp cable, which admitted a shackle to which the chain was joined; —the other by three chain tails formed into a splice with the three strands of the hemp cable. It has been deemed of sufficient importance to make several experiments in order to determine which of these two methods is the stronger; and as it is not necessary to give a detailed account of all the operations, it will be sufficient for the purpose to state that in ten experiments with the eye, the rope was broken once, and in nine experiments with the splice, the rope or the eye was broken eight times. The splice has therefore an advantage in point of strength, and is superior in other respects, inasmuch as the greatest degree of care and attentive management will not insure a smooth easy passage round the bits for the eye when veering under the pressure of a heavy strain. The great width of the shackle and bulk of the eye, with its abrupt termination, renders a sudden check almost inevitable, which of all other evils is most to be dreaded. The splice, on the contrary, having a smaller diameter in the proportion of 7 to 9 nearly, at the same time being compressible, which the eye is not, and having tapered *ends, is free from all these objections.* Considerable caution is necessary in using the splice, to fortify the chain tails well with soft strands and parcelling, to insure the safety of the hempen strands in contact with them.

There does not appear to be a probability of devising any better means of accomplishing this object, except that it may be possible for a rope maker to manufacture an eye in the end of each hempen cable, which shall possess equal strength with the main part of the rope.

It is necessary to notice and explain briefly such peculiarities in the different kinds of chain as have been ascertained in the course of these experiments.

There is very little difference in the actual strength of cable chain which has a stay-pin to each link, and that without any stay-pin, which is called rigging or crane chain; but there is a very considerable difference in their

efficiency, arising out of the peculiar shape of the link, which in the crane chain admits of an alteration of form at a moderate strain; in the cable chain, which has a stay-pin, this evil is in a great degree prevented, although it stretches nearly in the same proportion as the other.

It may be well to state the result of several experiments made upon the larger kinds of crane chain, measuring $1\frac{5}{8}$ inches diameter, as affording some important facts in strong contrast with the cable chain. The maximum strength of this chain was ascertained to be seventy-five tons, and the minimum strength sixty-six tons. It was manufactured in lengths of thirty feet each, and at a strain of twenty-five tons, it was found that each length stretched $4\frac{1}{2}$ inches, but contracted again, when the strain was removed, $3\frac{3}{8}$ inches, leaving the chain permanently stretched, $1\frac{1}{8}$ inches on each length of thirty feet.

At a strain of thirty-five tons, it was found that the links collapsed one-sixteenth of an inch, but returned again when the strain was removed.

With a strain of forty tons, the links collapsed three-sixteenths of an inch, and many became permanently set.

With a strain of fifty tons, the links in general collapsed five-sixteenths of an inch, and most of them became firmly set, and as rigid as a bar of iron, retaining still the appearance of chain, but deprived of flexibility, and no longer fit for chain purposes.

Another set of experiments was made with chain of the same size and description, the result of which was, that the maximum strength as ascertained, was $75\frac{1}{2}$ tons, and the minimum strength $71\frac{3}{4}$ tons. With this chain it was ascertained that a strain of forty-five tons caused the links to collapse three-sixteenths of an inch, and many to become firmly set and fixed.

These facts are all confirmative of what has been stated at page 15, " that a strain of one-half the full strength of any rope or chain constantly or even frequently applied, will eventually break it." It is, however, necessary to state, that it applies with greater force to crane chain, than to cable chain, and with still greater force to rope of any kind, particularly cablet rope.

CHAPTER II.

Observations on the Theory and Practice of RIGGING SHEARS, *and on the manner of supporting the Lower Yards of Ships of War, for the purpose of sustaining heavy weights, with plain Directions for ascertaining in the most simple and easy way, the effect which a given weight will produce upon the* GUYS, *upon the* FALL, *and upon the* YARD *or* DERRICK, *according to their relative positions.*

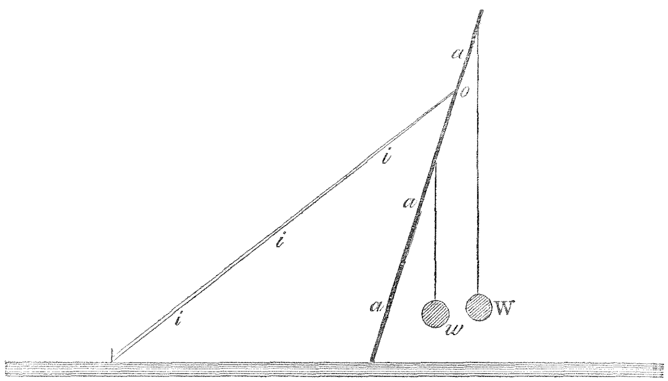
IN the complicated duties of the naval officer, he has in numerous instances the responsibility of lifting heavy weights, such as boats, anchors, heavy guns, and many other things of similar character, which are generally raised by a tackle, or purchase, on the lower yard ; but as this method involves the safety of the spars, it appears desirable to examine and consider the subject in all its bearings, in order to determine upon mechanical principles, which is the best and safest mode of lifting any weight.

It is well known that the strain upon a lower yard by the suspension of a weight, varies according to the angle at which the yard may be placed, and the manner of supporting it, either by topping-lift guys, or by a shore, or prop, from the deck ; and as a very extensive difference is known to exist in the various methods generally adopted, although the materials employed may in all cases be the same, I purpose to show, by a variety of examples, a sure and certain means of ascertaining, first, the actual strain which any given weight will produce upon the supporting guys, according to their position; and, secondly, the whole amount of downward, or crushing pressure, which the yard or spar used for the purpose will have to sustain.

It is necessary to observe, as a general rule, that in supporting a yard, or derrick, or shears, the supporting guys should be attached to the yard or spar, at the spot from which the weight is to be suspended.

The annexed figure will explain the character of the leverage here described.

FIG. 2.

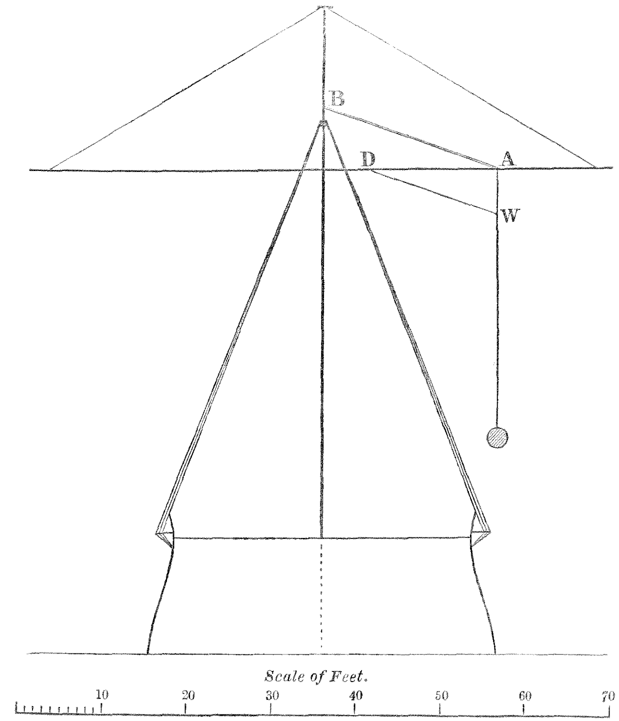


The weight W, attached to a derrick *a a a*, above the guys *i i i*, constitutes a lever of the first kind, with the fulcrum between the power and the weight. The weight *w*, attached to a derrick below the guys, constitutes a lever of the second kind, with the weight between the fulcrum

and the power, and in either case the instrument is weakened, in proportion to the distance between the back support (which in this instance is the fulcrum) and the weight. On the contrary, let the weight be attached to the derrick at *o*, and the whole strength of the material employed will be obtained.

This rule holds good in all cases, whether it be a lower yard, or derrick, or shears, to be supported.

FIG. 3.



Note.—The scale of feet attached to this Figure, applies also to Figs. 3, 4, 5, 6, 7, and 8.

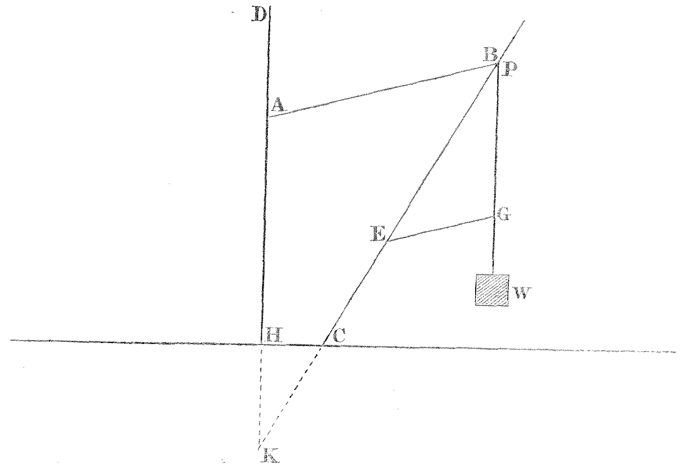
Fig. 3 represents a weight of five tons suspended from the lower yard of a frigate, and is intended to illustrate the effect it would produce upon the guys, and upon the yard; but as it is highly improbable that a weight of five tons would actually be suspended from a yard in such a glaringly weak position, it is merely drawn for the purpose of illustrating an extreme case. It is necessary to observe, that the guy A B would be in a decidedly better position, and afford greater security to the yard, if it was carried up to the lower cap; but as the lower mast-head is not supported by either shrouds or stay, and depends entirely upon the diameter and strength of the wood, it is deemed unsafe to attach much additional weight to the cap, particularly as instances have been known, (one of which occurred at Woolwich not long ago,) when the fore-mast head was broken short above the eyes of the lower rigging, solely by the weight of the bower anchor being suspended to the quarter of the fore-yard, and the strain carried up to the cap by a guy. I mention this occurrence in order to guard others against a repetition of that which may prove a serious evil, and recommend the guy A B to be attached to the mast-head immediately above the lower shrouds; or if it should be secured to the cap, then it is absolutely necessary that the mast-head be well supported to bear the additional strain.

All the information which can be derived from the consideration of this example as illustrated by Fig. 3, and indeed the foundation of the rule to the whole question, is to be found in the triangle D A W. The perpendicular A W represents the weight five tons; W D, drawn parallel to the supporting guy A B, (and which in every case is necessary to be observed,) represents the strain upon the

guy to be fifteen tons; and D A, the remaining side of the triangle, is the measure of the crushing pressure upon the yard, amounting to $14\frac{1}{2}$ tons.

As the known weight to be lifted determines in all cases one side of the triangle, and the direction of the guys and the position of the yard or derrick gives the angles, the solution of the other parts of the figure may be determined, by arithmetical calculation, as a plain question in trigonometry; thus:—

FIG. 4.



Let a weight W be suspended from any point P in a derrick C B, which is supported by the guy A B, fixed to the mast H D.

In the vertical line through P, take any length P G to represent the weight W; through G draw G E, parallel to the guy A B. Produce A H, B C to meet in K.

Then P E will represent the pressure on the derrick in the direction of its length; and G E the force at P, in the direction of the guy A B.

Then P E, or pressure on derrick in the direction of its length $\left.\right\} = W \times \frac{KB}{AK}$

$$\text{or } W \times \frac{\text{sine } KAB}{\text{sine } ABK}$$

$$\text{Tension on the guy } AB = W \times \frac{AB}{AK} \times \frac{CP}{CB}$$

$$\text{or} = W \times \frac{\text{sine } AKB}{\text{sine } ABK} \times \frac{CP}{CB}$$

Force perpendicular to the mast head at A

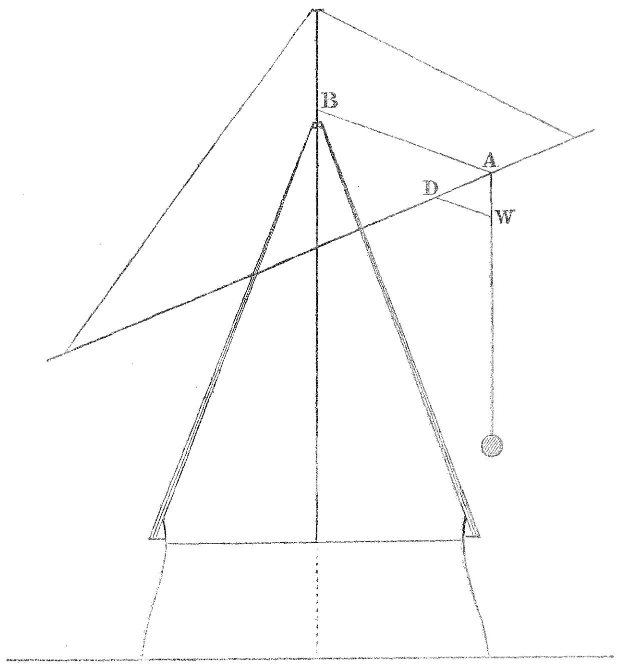
$$= W \times \frac{AB}{AK} \times \frac{CP}{CB} \times HA \times \text{sine } BAD$$

But it may also be accomplished in a very simple way, with equal accuracy, by constructing a figure upon paper, which will answer the same purpose, and allow all the various parts to be measured upon a scale.

By this example it appears, (as it was anticipated,) that the strain upon the guy, and likewise on the yard, amounts to nearly three times that of the weight lifted, evidently caused by the very large angle of ninety degrees' difference between the vertical direction of the strain and the horizontal position of the yard; therefore the nearer these two lines can be made to approach each other, the less excess of weight will the guy and the yard have in all cases to sustain.

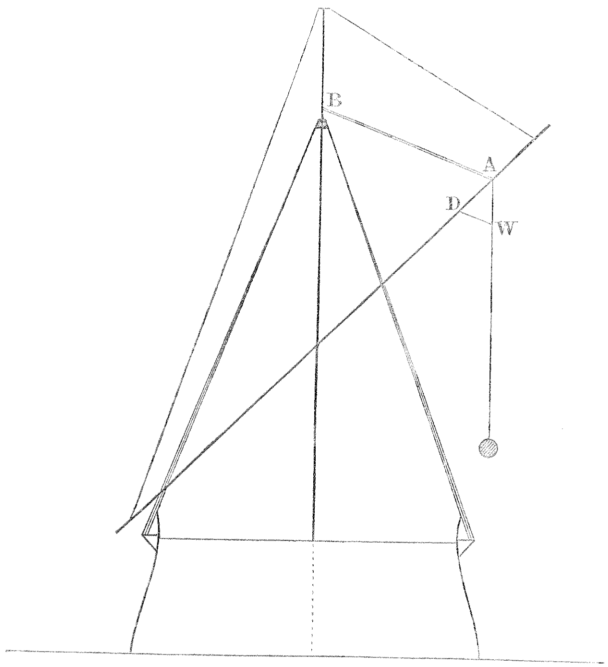
In proceeding with the consideration of this subject, and in order to render it comprehensively clear and intelligible to any person of ordinary understanding, I shall next refer to a lower yard in the position in which it is generally placed in ships of war, for the purpose of lifting a heavy weight.

Fig. 5.



In Fig. 5 the yard is placed at an angle of $22\frac{1}{2}$ degrees from the horizontal line, the weight suspended is five tons, the same as in the former case; the strain upon the guy A B is now seven tons; and the crushing pressure on the yard is $6\frac{3}{4}$ tons.

FIG. 6.



In this example the yard is placed at an angle of 45 degrees, the utmost limit of elevation that can be obtained. The weight suspended is five tons as before, and the strain upon the guy is now reduced to $4\frac{1}{4}$ tons, and the downward or crushing pressure to $5\frac{1}{2}$ tons.

It is scarcely necessary to observe, that a strictly perpendicular position is superior to any other that a pillar or spar can be placed in, for the purpose of sustaining a heavy weight. The downward pressure in such a case, is in the direction of the grain of the wood, all lateral strain is

avoided, the supporting guys are relieved, and the actual weight of the substance lifted, together with the amount of friction produced by the operation, is the only calculation necessary.

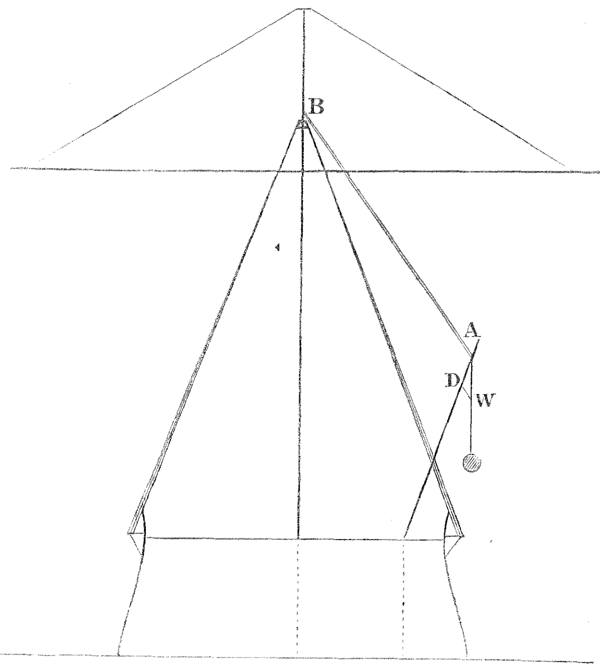
The result of the preceding examples on the various modifications of the position of the lower yard, not only confirms this fact, but strikingly illustrates the advantage gained in strength by every step from the weak horizontal position towards the perpendicular; but as the angle of forty-five degrees shown by the last example terminates the beneficial range of the lower yard, it becomes necessary to investigate such other available means for the service in question, as the resources of a ship can supply.

By examining the merits and character of a derrick, I have no doubt it will be found to possess advantages so numerous and valuable, as to render it superior in every respect to a lower yard for the purpose of lifting a heavy weight. The main and principal advantages are, that it transfers the whole weight to the deck, which can be well supported by props below, it relieves all anxiety about the safety of the mast and yard, and it can be placed vertically, or at any angle most suitable to a particular case. It can be supported without any difficulty either with or without the aid of a mast, it is very soon rigged and ready for use, and as quickly dismantled. These advantages are sufficiently numerous to recommend it for general use in all cases where strength is required.

And on the subject of providing the means;—few ships go to sea without a spare topmast or a spar to make one, and this latter, the hand-mast as it is called in the navy, is generally a Riga spar, the diameter of which is larger than the lower yard-arm; it is very strong, being nearly as large at one end as the other, and is in every respect well calculated for a derrick.

The rigging, that is, the various guys and ropes necessary to sustain it in its position, and the purchase block for lifting the weight, may be secured to the spar at any height above the deck to suit the particular purpose in hand, without either cutting the spar, or nailing on cleats, as by a well managed arrangement of lashings, all slipping or shifting of position may certainly be prevented.

Fig. 7.

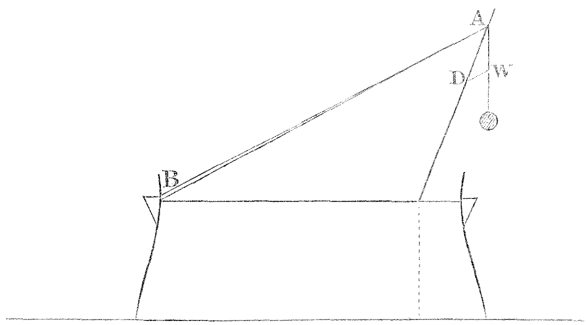


In this example, the derrick is 26 feet long, and is rigged at 24 feet above the level of the deck; it stands at an inclination of 20 degrees, but has the same projection as the examples with the lower yard. The weight is five

tons, the same as in all the former cases, the strain upon the guy is $2\frac{1}{2}$ tons, and the downward pressure is 4 tons, in addition to whatever amount of friction may be produced by raising the weight.

With reference to what has been stated at page 36, that in the event of a derrick being placed in a strictly perpendicular position, the downward pressure in such a case would amount to the actual weight of the substance lifted, with the amount of friction, whatever it might be, added to it;—in the last example the downward pressure is found to be less than the actual weight of the substance lifted, and may appear inconsistent if not explained. The cause is to be found in the great elevation of the derrick—about seventy degrees, and the near approach of the supporting guys to the perpendicular position; the weight being partly sustained by guy and the derrick combined; the more the derrick approaches the perpendicular, the less will be the strain upon the guy, and this strain will not be felt at all, when the derrick is strictly vertical, as has been already stated.

Fig. 8.



Example of a derrick on a ship's deck supported without a mast.

In this case the derrick is 25 feet long, the rigging 22 feet above the level of the deck, and the inclination $21\frac{1}{2}$ degrees; the weight is five tons as before, the strain on the guy is 3 tons, and the crushing pressure is $7\frac{1}{4}$ tons. The main and principal difference to be noticed in this case is the direction of the guy, which, being below the horizontal line, adds considerably to the crushing pressure; in all the former cases, except the first, the guy was above the level, and relieved the downward pressure.

All the preceding examples have reference to a vertical strain in raising a weight, but there are many cases where the derrick or shears are necessarily placed some distance from the weight, and consequently, the direction of the strain is at a considerable angle with the perpendicular. A formidable weight of the kind has recently been raised in this Dock-yard, which I shall endeavour to describe, and which will afford an opportunity in the necessary illustration, of explaining some important facts connected with this particular kind of strain, not included in the preceding examples.

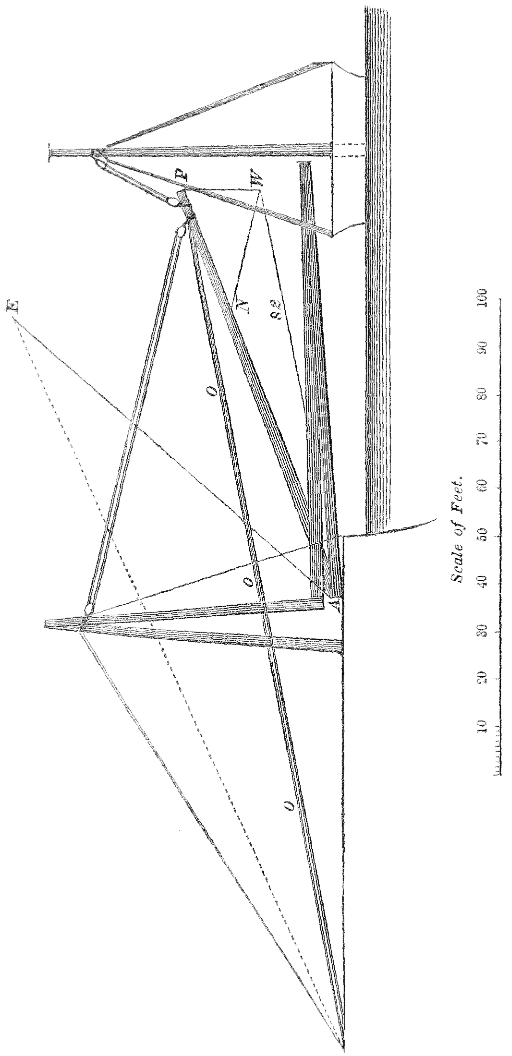
The weight here alluded to, consisted of two masting spars of the largest dimensions converted into a pair of shears, intended when erected and complete, for the purpose of lifting heavy boilers into or out of steam vessels; each spar being upwards of ninety-one feet long and twenty-nine inches in diameter, connected together at the top by a cross beam through cast iron sockets, and separated thirty feet at the bottom. The weight to be lifted, by raising the upper end of these shears, including the necessary iron-work to connect them to each other, was estimated at fifteen tons, that is, fifteen tons perpendicular weight, independent of that which might be produced by leverage. But as these spars projected eighty-two feet beyond the coping of the wall over the surface of the water in the basin, no means could be devised to insure the lifting strain in the perpendicular direction, except in the first part of the operation to a very limited extent, by the aid of a vessel's mast; they were therefore raised to the point P, in Fig. 9, by that means; and the usual mode of proceeding towards the vertical position would be by the guys *o o o*. This, however, on account of the immense leverage, is nearly impracticable, as will be seen by the triangle A P W. P W represents the weight, 15 tons; A W the lifting strain, 82 tons; and A P the crushing pressure, 85 tons.

To prevent the risk of accident, it was not deemed prudent to attempt this enormous weight, and therefore a temporary pair of shears was set up immediately behind the heel of the large spars, and a purchase applied fifty-five feet above the level of the ground; the lifting strain by the aid of these shears, as shown in the triangle N P W, is reduced to twenty-five tons, and the crushing pressure to twenty-six tons.

This strain being little more than one quarter the amount of that which the usual mode of proceeding would have produced upon the guys *o o o*, all difficulty and danger is avoided. The spars are raised to the position E, by the purchase on the temporary shears, and as every degree of elevation reduces the lifting strain and the horizontal or crushing pressure in proportion, the guys *o o o* become more efficient in bearing, being in the right position to finish the operation.

It has been mentioned before, that the dimensions of the triangle do in all cases determine the amount of strain

FIG. 9.



Note.—The scale of feet attached to this Figure, applies also to Figs. 10, 11, 12, 13.

which a given weight produces upon the guys, and upon the derrick, or shears, whether the lifting strain be perpendicular or not; and if the materials which are in use can, by any contrivance consistent with safety, be so arranged as to reduce the length of each side of the triangle, the strain upon the guy, and upon the spars, will be reduced in proportion.

CHAPTER III.

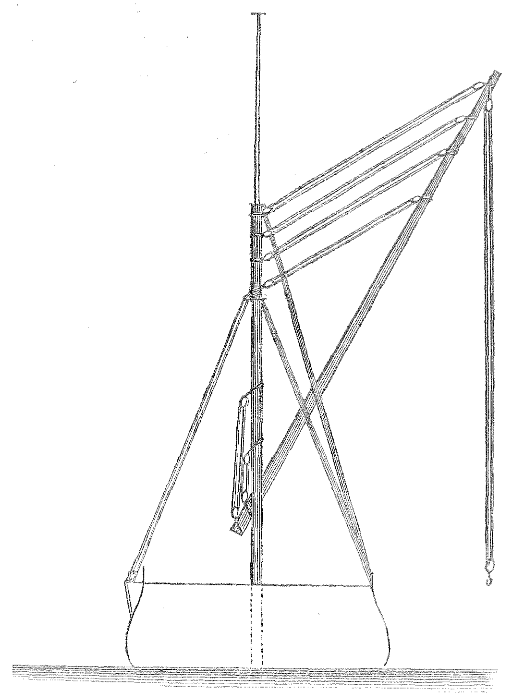
Remarks and Observations on the old method of Rigging Shears *in hulks, for the purpose of masting ships of war.*

In the absence of any written authority or documentary evidence of any kind, calculated to afford information on this subject, it is very difficult to trace with any approach to certainty the original mode of fitting hulks for the above purpose.

From the recollection of those ships that were fitted for sheer hulks and in use as such previously to the commencement of the present century, I am inclined to think that at an early period of our naval history, ships of war, although mounting a great number of guns, were nevertheless small in tonnage, and the mast and other spars in all probability of a light description, not requiring either a powerful instrument or one of great height. It appears

likely enough that a single derrick was then used, similar, it may be supposed, to what is here represented in

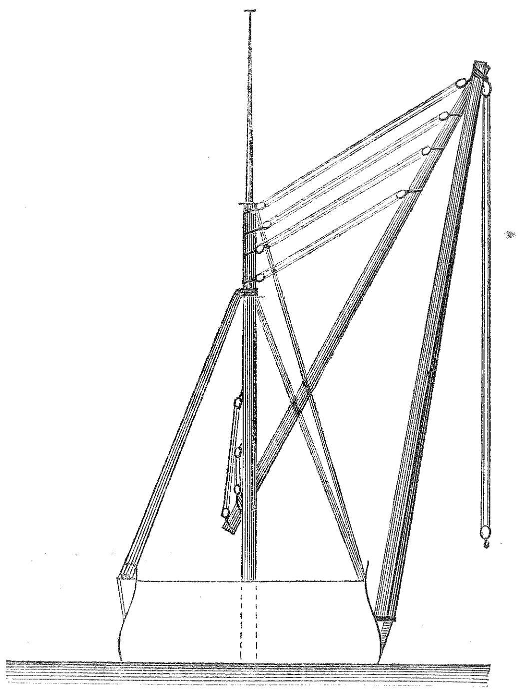
Fig. 10.



This idea seems to derive additional weight, in the well-known fact that the derrick or spreet was wholly suspended from the mast, not unlike the spreet of a boat's sail, the lower end being about fifteen feet above the level of the deck, supported by hanging tackles and roundabout lashing, the upper part attached by blocks and falls to the mast head, indicating that the angle of projection was occasionally changed, to give it more or less inclination suitable to particular purposes.

This is, in my opinion, a reasonable conjecture; and in the course of time, when larger ships became necessary and the masts heavier, it was probably deemed advisable to add the two shears, in order to give greater strength and security to the derrick, as represented by

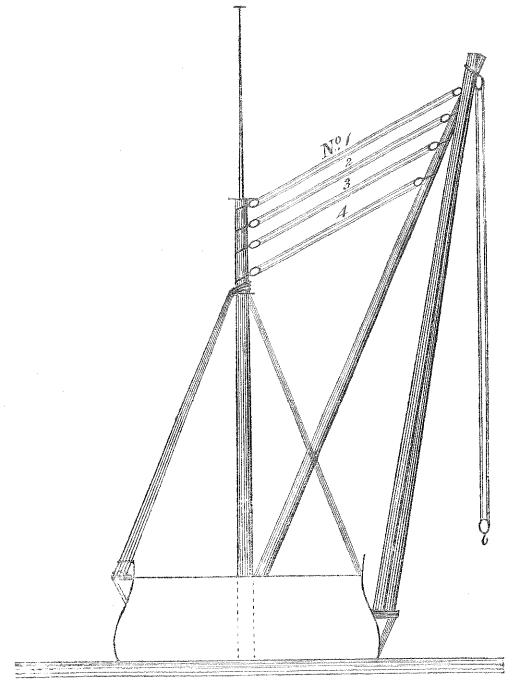
Fig. 11.



The shears in this form continued in use during the whole of the French War, until the year 1815, about which

time, on refitting some of the hulks, it was deemed advisable to lengthen the derrick, and fix the lower end on the deck, as shown in

Fig. 12.



This highly important change relieved the mast from an immense weight which it had long and unnecessarily sustained, and transferred it to the deck, its proper resting-place.

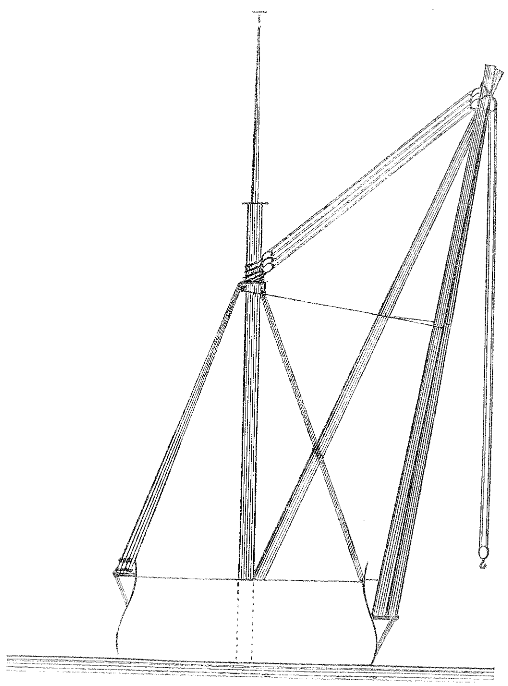
After this change was accomplished, the shears and derrick became fixtures, and no longer required any blocks aloft to alter their position; it is therefore a matter of surprise that the rigging was not at the same time arranged upon a better principle, more suited to the improved condition of the shears, and better calculated to sustain a heavy weight. The main and principal objection to shears rigged as these are, has been explained at page 30, as constituting a lever of the first kind, with the fulcrum below the weight, which renders the whole instrument weak in proportion to the distance between the fulcrum and the weight.

To a casual observer it has all the appearance of strength and security, but extensive practice has repeatedly proved the fallacy of such an opinion. There is no want of material to insure strength if it were properly applied, as the derrick is supported by twelve parts of chain, $\frac{11}{16}$ of an inch in diameter, the combined strength of which, at a moderate computation, exceeds one hundred and twenty tons. These twelve parts of chain compose four guys, which extend from the mast-head to the derrick, and are placed at nearly equal distances above each other; they are numbered one to four in the figure. Each of these four guys has a radius and bearing peculiar to its own position, and when the shears are at rest they have of course an equal tension; but the first effect of a weight suspended, is to bend the head of the shears outward in the direction of the weight, and in the middle inwards, or back towards the mast; therefore Guy No. 1 has in that case nearly all the strain, Guy No. 2 much less, and Guys No. 3 and 4 no strain whatever. The greater the weight suspended the more extensive will be the effect, and it is evident that no degree of care and attention on the part of those who may have the management can ever make these guys efficient when so placed, or even render them safe; the principle being wrong, the whole machine is so

much at variance with all mechanical rules, that it has generally been treated with derision by men of practical knowledge, and not unfrequently pronounced an absurdity. Another serious objection proper to notice, is, that as the whole of the mast-head guys are attached to the derrick, and not to the shears, which sustain all the weight, each spar suffers by a twisting process on all occasions when one purchase block is used and not the other. Whether the origin of this plan may exactly coincide with what has been stated at page 45 or not, is of little consequence; the character of it is evident in various ways, particularly by the blocks and falls to change the angle of inclination; the derrick being then the only branch of the instrument in use, requires all the guys to give it proper strength, and it is not improbable that, at a subsequent period, when the shears were added, it was still regarded in the same light as the principal spar, requiring the whole support as before, although the addition of the shears had rendered it a simple auxiliary, forming the longer side of an oblique triangle and a determined fixture.

The maximum weight to be raised at that time, (the first rate's mainmast,) seldom exceeded 20 tons; and as the machine had answered every purpose, and little probability existed of any additional weight being required beyond that of masting ships, any consideration of the efficiency of the shears or an alteration of principle appeared unnecessary. Time has, however, totally changed the aspect of affairs; the boilers for steam vessels are enormous both in dimensions and weight; in some cases the iron alone is estimated at 35 tons, and with the accumulation of salt and dirt frequently exceed 40 tons. No doubtful instrument is therefore safe under such a pressure; the strongest and best in principle that can be set up are absolutely necessary for the purpose. It is far from my wish and foreign to my intention to claim exclusive knowledge on this subject; but it must be obvious that no important alteration can be proposed or accomplished but by the detection and exposure of defects. I have, therefore, full confidence in the arrangement of the various guys and all the parts of shears fitted as

Fig. 13.



It may be advisable to give some explanation of this plan of rigging shears, which shall be confined to the smallest possible limit, as I have no doubt it will be found upon trial, whenever it may be adopted, superior in every respect to that now in use, and its merits for strength and efficiency become apparent to every person. Experiments have been made upon a well constructed model of good proportions, which have proved that these shears will sustain double the weight, with less distress to the spars than on the old plan; and it is to be observed, that one quarter less chain is used, and that each spar is supported by its own guy. The back support and the weight being attached to the same spot upon the spars, the leverage is thereby prevented, and there is no tendency in them to bend either one way or the other under a strain. The twisting process before noticed has by this arrangement been prevented, the strain in every part has been equalised, and the whole instrument rendered as effective and strong as the quantity of materials employed will admit. The blocks and chain for guys are used in this plan as a matter of economy; single chains of sufficient strength would answer the same purpose without blocks.

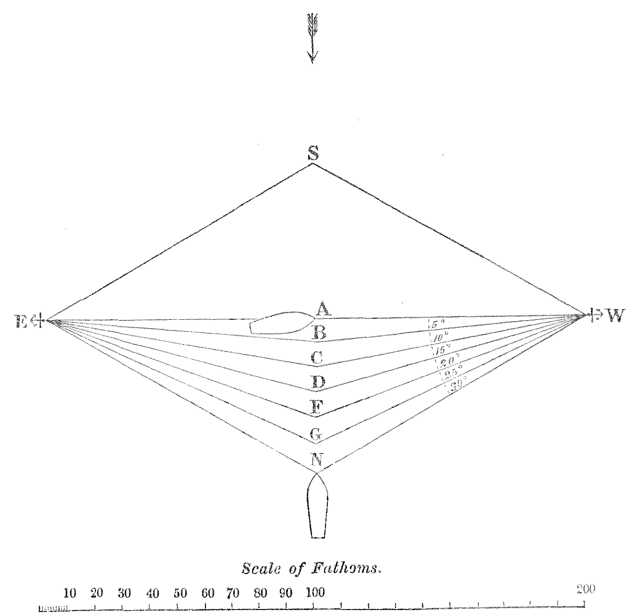
CHAPTER IV.

Remarks and Observations on the Nature and Properties of a SPAN, *that is, both the ends of a Rope or Chain secured to a fixture, and subsequently strained in the middle, at a right angle or oblique angle to the line of its length. With an account of some experiments to prove its strength at various angles and in different positions.*

SUPPOSE a Ship to be moored with one hundred fathoms of cable to each bower anchor in an east and west direction, as in Fig. 14. And that in calms or light winds she would ride in the direct line between the two anchors as at A. With the wind at east or west, she would of course be sustained in position by the strength of one cable; but the seaman who does not consider the subject theoretically might be led into the supposition, that, with a south wind blowing in the direction of the arrow, the ship then, as she rides between the two anchors, would be sustained by the strength of two cables. This is an extremely deceptive and fallacious idea, calculated to favour the notion of security at a time when the position is the weakest and most unsafe in which a ship can be placed. I shall endeavour as briefly as possible to describe why it is so. In mooring a ship,

there are generally a few fathoms of slack cable, sufficient to admit of her falling to leeward of the direct line

FIG. 14.



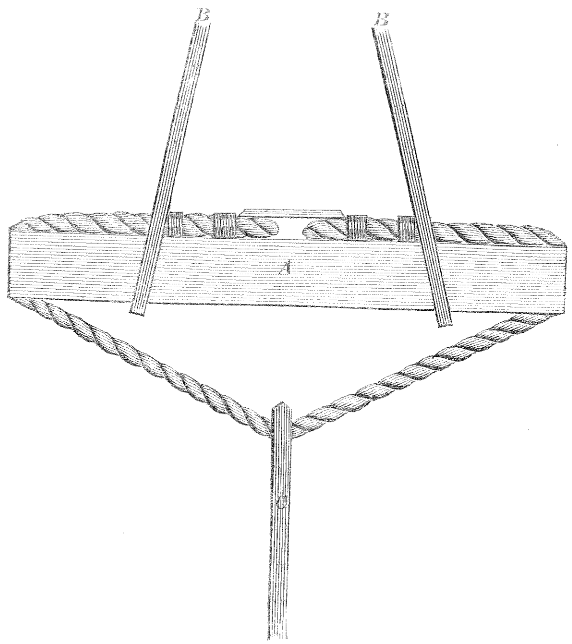
between the two anchors, when the wind blows at a right angle with that line, as in the case here alluded to; and in order to illustrate the subject properly, I have calculated the amount of support which the two cables would afford to the ship in each of the positions B C D F G N in the Fig., and as these results are geometrically obtained, they may be depended on. It is improbable that a ship could be maintained in the position B, at the small angle of five degrees, even under the force of a moderate breeze, and with the unyielding character of chain to ride by; but supposing it to be possible, then the whole amount of support which the two cables would give to the ship is $\frac{17\cdot4}{100}$ parts, or about one-sixth of the strength of one cable and no more. At the angle of ten degrees in the position C, it would amount to $\frac{34\cdot7}{100}$ parts; at the angle of fifteen degrees in the position D, it would amount to $\frac{51\cdot7}{100}$ parts; at the angle of twenty degrees in the position F, it would amount to $\frac{68\cdot4}{100}$ parts; at the angle of twenty-five degrees in the position G, it would amount to $\frac{84\cdot5}{100}$ parts; and in the position N, at an angle of thirty degrees, it would amount to the strength of one cable, that is, one cable laid out in the direction of the wind at south, would yield the same support to the ship as both the bower cables do in the position N; for as N W, N E, represent the two cables, so N S likewise represents the amount of support in that position. It is evident that, by veering a long scope of these cables, a greater angle, and a consequent nearer approach to the strength of two cables will be obtained; but it is necessary to observe that, by a peculiar law of mechanics, two parts of a rope which are not parallel, or two ropes connected together as the cables are by the ship, and equally strained in the same direction as the ship strains the cables, do not possess the full strength of two parts; therefore, as the wide-spread position of the anchors renders it impossible that these cables can become parallel even with a long scope, so the full strength of two cables under such circumstances is not attainable. In explanation of this part it is necessary to refer again to Fig. 13, where it will be perceived that as N S represents the amount of support to the ship, with the cables at a certain angle, so N S would always represent the strength

of a similar span at any other angle, it being the key to the question,—the measure of the force employed as well as of the strength of the resisting material,—and as N E, N W, represent the two parts of the span, N S must be less than those two parts combined, under any circumstances, however great the angle; and consequently, two parts of a rope or chain forming a span which cannot become parallel, although they may only differ from the parallel by a very few degrees, must be weaker than the full strength by the amount of that difference. This theory, which I have thus endeavoured to describe, is capable of practical proof, and has been proved by many experiments in the testing machine. These experiments have been made at different angles, and with rope of various sizes, but a description of one or two may be sufficient for the present purpose.

Fig. 15 illustrates the method of experimentally proving the strength of a span.

The beam A is attached to the lever of the testing machine by the clamps B B, and the middle of the rope is drawn from the beam by the power attached to the clamp C; the distance which the rope is drawn from the beam before it breaks is shown in inches on a scale fixed to the beam, and this determines the angle.

Fig. 15.



Experiment.

It was ascertained in April, 1843, by three experiments, that the mean average strength of a piece of 4-inch hawser laid rope was $6\frac{3}{4}$ tons. The same rope when strained as a span in the testing machine, similar to Fig. 15, broke in the first experiment when at an angle of $31\frac{1}{2}$ degrees, at a strain of seven tons.

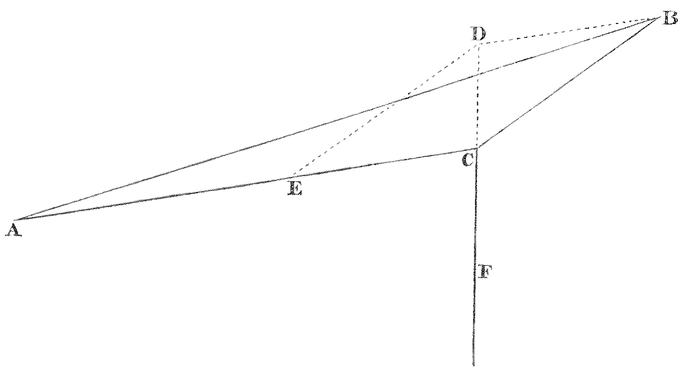
In the second experiment, a piece of the same rope, when at an angle of $29\frac{1}{4}$ degrees, broke at a strain of $6\frac{1}{4}$ tons.

A more satisfactory proof of the theory than that afforded by these experiments can never be expected, as they strictly coincide. It is not an unusual thing to find upon some important occasions, that practice will not confirm the theory—whichever way it is tried there will still be a wide difference between the two; but in this case the excess of strength by experiment at the angle of $31\frac{1}{2}$ degrees over that at $29\frac{1}{4}$ degrees is in exact accordance with the theory. Many other experiments have been made with pieces of rope of various sizes to determine this question, and in every case it has been clearly proved that, where a span is so placed as to have a less angle than thirty degrees, the strength of the two parts of rope or chain of which it is composed, is less than the strength which one such part would have, if placed in a direct line with the strain. I am fully aware that the manner of mooring ships of war here described, is not practised now to any thing like the same extent, as when hempen cables were exclusively used; but the facts which have been experimentally proved in confirmation of the theory, are of sufficient importance to excite attention to the subject whenever it may be necessary. The same argument is equally applicable to the use of a span in many other positions, such as that from the mainmast to the head of the foremast of a ship, for the purpose of attaching tackles to hoist in boats, instead of the old method of fixing them to the mainstay. Should this span form a direct line from one mast to the other, the strength of it when strained downwards in the middle will be very trifling, notwithstanding the rope may be large and of the best quality. It is therefore quite certain, that the greater the dip or downward deflection, a rope in this position may have in the middle, the stronger it will be, although, when curved down to the deck, it cannot much exceed the strength that one part of it would have, if placed in a vertical direction. A mooring chain stretched across a river, similar to those in use at Deptford, is liable to the same objection. It is strained at all times, in a greater or less degree, in the direction of the tide, at a right angle with itself, which is not only the weakest position in which it can be placed, but it frequently happens, where the ships are formed into tiers, and several bridles are used, that the sides of the ground chain links, instead of the ends, have to sustain the whole weight. It must not be supposed that it is the intention of the author, in making these observations, to cast censure on any person in that neighbourhood, for he himself had the charge of these chains during a period of twelve years, and is therefore fully aware of the difficulty of providing in any shape, an adequate extent of moorings, consistent with the free navigation of a river so crowded as this part of the Thames generally is. The locality of Deptford has been mentioned more on account of old acquaintance, and being strictly a case in point, than from any other motive, as the same thing exists at some of the other ports, although not perhaps to the same extent. There is no position in which a span can be applied that does not require great care and attention; but it is particularly the case when they are used round such substances as are of a square form with projecting corners, a steam-boiler for instance, to which they are very commonly attached, either for the purpose of vertical suspension, or horizontal removal along the ground. As chain is more frequently used on these occasions than rope, it requires still more care on account of non-elasticity, and the unfair strain by lateral pressure, to which some of

the links are liable at the corners of the substance, and in the middle of the span, where the power is applied. As these boilers are of large dimensions, it is more probable that the span will be used at a small angle, an additional reason for precaution, and one which renders it more advisable to refer again to Fig. 14, where it will be found, that the single part of a rope, or chain round a substance of this shape, and used as a span, at an angle of thirty degrees, is stronger than the same rope or chain would be if passed twice round, and the double part used as a span at fifteen degrees.

It is to be understood in discussing this subject, that although spans in general are so objectionable, on account of extreme weakness, which renders them dangerous in practice, yet in numerous instances they cannot be dispensed with, as no other means can be applied to meet the difficulty; their use in various positions is unavoidable, but in order to prevent the numerous and in some cases fatal accidents which occur, it is necessary to investigate the peculiar character of a rope in the position alluded to, that by the evidence of established mechanical laws the reader may be able to understand why the small force of a few pounds, applied to a rope or chain when in use at a flat obtuse angle, shall produce the astonishing strain of eighteen hundred per cent. upon it. This may in a great measure be explained by Fig. 16.

FIG. 16.



Let a rope be extended from A to B with any degree of tension; if a force, however small, be applied at any part of the rope, in any direction out of the line A B, it will cause a deflection, and increase the tension on the rope.

Let the force F be applied at C in the direction D C F, and let the rope take the position A C B. Let any length C D represent the force F, draw D B parallel to A C, and D E parallel to C B. Then C B will represent the tension produced by F on the part C B of the rope, and C E that produced on the other part of the rope A C.

$$\text{E C} = \text{F} \times \frac{\text{sine D C B}}{\text{sine A C B}}$$

$$\text{and C B} = \text{F} \times \frac{\text{sine D C A}}{\text{sine A C B}}$$

Suppose F be taken = 10lbs.; the angle A C B = 175°; and D C B = 50°; then the angle D C A will = 125°, and E C, or the tension on the part A C of the rope =

$$10\text{lbs.} \times \frac{\text{sine } 50^\circ}{\text{sine } 175^\circ} = 10\text{lbs.} \times \frac{0.7660444}{0.0871557} = 10\text{lbs.} \times 8.78 =$$

87.8lbs.

C B, or the tension on the part B C of the rope =

$$10\text{lbs.} \times \frac{\text{sine } 125^\circ}{\text{sine } 175^\circ} \left(\text{or } 10\text{lbs.} \times \frac{\text{sine } 55^\circ}{\text{sine } 5^\circ}\right)$$

$$= 10\text{lbs.} \times \frac{0.8191520}{0.071557} = 10\text{lbs.} \times 9.39 = 93.9\text{lbs.}$$

Hence, the greater the obtuse angle A C B, the greater the tension on the part A C, or C B, or on both parts, according to the direction of the force applied.

If the force F, and the angle A C B, be supposed to be constant, the effect of varying the direction of the force may be seen.

Thus if D C F, the direction of the force, bisects the angle A C B, the tension of A C is equal to that of C B; and the tension on the whole rope A C B is a maximum.

Again, if D C F be perpendicular to the part A C of the rope, the maximum tension is produced on the other part C B; and if D C F be perpendicular to C B, the maximum tension is produced on the part A C of the rope.

It will be seen by this example that the small force of 10lbs. applied to this span produces an effect of 87.8lbs. upon one part of the rope, and 93.9lbs. upon the other part, the whole effect being 181.7lbs., that is, upwards of eighteen times the force applied. A still greater effect might be produced by a more obtuse angle; but sufficient has been done to show that by the information to be obtained in the Tables which this work contains of the strength of materials, any person of ordinary understanding, having previously ascertained the weight of the substance to be lifted, may easily calculate beforehand all that is requisite to ensure safety; and if the weight of the substance to be lifted is not certain, there can be little difficulty in estimating it sufficiently near for the purpose. It is probable, that, in a confined situation, want of space may compel the use of a span at a very small angle in lifting a weight, but this only proves that, as weakness is incurred by the smallness of the angle, safety may be insured by an additional number of turns with the lashing which forms the span; so that by the length of the span, or by adding more parts, accidents may always be prevented. A sad and fatal accident which happened in this Dock-yard a few months since by the breaking of a span, and by which a valuable officer lost his life, deserves some notice here. In the progress of various duties, it became necessary to move a heavy steam-boiler horizontally along the ground for some distance, for which purpose it was placed upon rollers, to facilitate the operation. A chain was put round it as a span, to which the tackle or power was applied for dragging it forward. This chain was composed of $\frac{5}{8}$ iron, equal in strength to about eight or nine tons. It happened that Mr. Ewart, the chief Engineer, stopped for a moment in front of the boiler a few yards in advance, and it is remarkable that he should have taken his stand in that position, for he was eminently skilled in mechanics and no man was better qualified to judge of the risk and danger of mechanical operations. The onward movement of the boiler was impeded, probably by a projecting stone on the surface of the ground in front of the roller, which rendered an additional effort necessary with the power. This effort unfortunately broke the span chain, part of which flew with the velocity of a shot and struck Mr. Ewart to the ground, who unhappily appeared to be deprived of the power to use his hands, and fell heavily with his forehead upon a heap of granite stone, recently broken, to repair the road; the injuries he received by the blow and the fall caused his death a few

days afterwards. In this melancholy transaction no blame could attach to any person; it was purely accidental, and it is probable that the single part of this chain would have borne the strain, if it could have been applied, which the double part, as a span, failed to do. In several other cases of spans used in ships, all such shrouds and backstays as have the two parts much separated at the lower end may be mentioned. It is very true that the downward strain put upon a shroud or backstay in setting it up, is in a direct line with the rope itself; but then again the upward pull which the leverage of the mast brings upon each pair of shrouds afterwards, is exactly similar in character to the strain which the ship exerts upon the cables as a span in Fig. 14; only that, in the case of the shroud, it is at a very long angle.

It frequently happens that a pair of shrouds are so placed, that one part is set up to a dead-eye before the port-hole of a gun, and the other part abaft the port, the horizontal distance between them being sometimes six or eight feet. This in itself does not weaken the shrouds much, but taken in connection with the angle caused by the eye above, it is seriously objectionable, as it produces a severe strain upon the seizing, and an equally severe and injurious pressure upon the rope.

If we take as an example the mainmast of a small frigate, the "Dædalus," now fitting at this port, the length of shroud from the eye-seizing down to the channel will be about fifty-nine feet; the horizontal distance from one dead-eye to the other, where a gun-port intervenes, as is the case in this ship, will be six feet, giving an angle of eighty-seven degrees to each leg of the shroud; but above the upper seizing each part of the eye leading round the corners of the mast-head has an angle of forty-five degrees, the effect of which is much greater than may generally be imagined.

The circumference of the shroud rope is $9\frac{1}{2}$ inches (cablet), the strength by experiment 15 tons; and when the two parts are strained parallel, the strength will be 30 tons; but by the deviation from the parallel line above, and likewise below the seizing, the strength by calculation is only 21.2 tons. Unfortunately, no remedy can be offered for this evil, except that, in most cases, the spreading of the parts of shrouds and backstays so far from each other at the lower end, may be prevented.

The eye of the shroud, which causes the greater angle, and which gives all shrouds and backstays the character of spans, must remain as it is, because no other method so appropriate in every respect can be devised for attaching shrouds and backstays to masts.

Many other cases of spans used in ships might be mentioned, but my chief desire is to excite attention to the subject, which I hope these few remarks may have accomplished.

In reference to the angle which the eyes of shrouds form, it is necessary to state that, in this particular instance, the rigging was previously fitted and subsequently applied to a ship with the mast-head of large diameter, which rendered the angle less and the span weaker than it generally would be, where the shrouds are fitted to suit the proper mast.

CHAPTER V.

Observations on the various properties of CHAIN CABLES, *with numerous experiments to determine the curvature which they assume under the force of a certain strain, in a given depth of water.*

THERE is scarcely any modern invention which has so rapidly advanced into general use as the Chain Cable, and certainly none is better calculated to confer lasting benefit and advantage on that particular branch of the sea service to which it belongs. A few years ago, comparatively speaking, it was unknown, and when fairly tried about the year 1811, like many other new things, it was viewed with suspicion and distrust, while its real value being neither understood nor appreciated, its use for a time was retarded; but as the various properties of the cable began to develope themselves, its superior strength, matchless durability, and easy management, it was eagerly and universally adopted, not only in this country, but in every maritime nation in Europe. To the coasting vessel it proved a source of economy in every sense of the word, beyond expectation; to the ship of war and foreign trader, in distant voyages and long absence from sources of supply, a security of paramount importance.

Friction upon rocks, or contact with hard substances, which destroys the Hemp Cable in a few hours, has but little effect upon the invulnerable surface of iron, and the deteriorating causes of decay to the fibre of hemp, by the effect of moisture and evaporation, are entirely harmless to the chain. To these immense advantages may be added the small space required for stowage, and the absence of nearly all labour in performing it, as the cable coils itself in the locker with a degree of exactness amounting to a near certainty of being clear for running out again, at a moment's notice.

The original cost of the two kinds of cable being a matter of some importance, I have ascertained the price of one hundred fathoms of hemp cable eighteen inches in circumference to be, at £39. 12*s.* per ton, if machine made, £116, if common made, £122. 9*s.*—and of one hundred fathoms of chain cable $1\frac{3}{4}$ inches diameter, the corresponding size, at the rate of £15 per ton, the cost is £115. 5*s.*, therefore in first cost there is very little difference.

Great as these advantages undoubtedly are in favour of the chain, others of an opposite character require to be noticed. First, for equal strength, the chain will be found by referring to the table heavier in the proportion of 16.4 to 6.7. This additional weight renders more labour necessary to heave it up in deep water with the weight of the anchor added, and it likewise requires great caution to restrain the velocity with which it and the anchor together descend to the bottom, endangering the anchor when the ground is hard, and likewise rendering it probable, that the chain will entangle itself with the anchor, as the momentum drags out much more of it than is required for the perpendicular depth of the water.

Another disadvantage is to be found in the non-elasticity of the chain. This is a very serious feature in its character, and requires a peculiar and attentive management, which, if disregarded, may involve the safety of the ship. Although several mechanical contrivances have been proposed, I am not aware that any have been adopted to compensate this evil, which, however, may in a considerable degree be obviated, and the danger removed, by a determination never to ride a ship by a short scope of chain cable. This precaution it is to be feared is little regarded, for, in addition to the numerous disasters daily occurring by ships parting their cables, it is notorious that many masters of vessels make a merit of riding out a gale of wind with no more than thirty or forty fathoms of chain. Several cases of the kind are described in a small pamphlet recently published on the merits of "*Porter's Anchor*;" but whatever merit may be due to this or any other anchor in riding out a gale of wind, none can be awarded to such management of a cable; for it may be inferred, that the majority of masters of ships consider fifty fathoms of chain sufficient to constitute a long scope.

It must be in the recollection of many old seamen who served in the Navy before the introduction of chain cables, that we were not in the habit of using a short scope at any time, either when anchoring for a tide or a shorter period. Half a cable, fifty fathoms, was the common quantity, and this too with the advantge of an elastic material. It is the more remarkable now, when the valuable substance of iron is universally adopted, which, in its peculiar non-elastic character, requires a greater length of chain to insure safety, that we should adopt the contrary system of using less.

I have no doubt that by far the most numerous cases of parting a chain cable or breaking the anchor, are caused by a sudden jerk; but a long scope will in a great measure render a sudden jerk harmless, as it is only to be dreaded when riding short, or veering chain under the pressure of a heavy strain.

With those who consider a long scope unnecessary, the idea is founded upon the great weight of the chain, which favours the very prevalent opinion, that the curvature or deflection of it is considerable, even when used in deep water and with a severe strain, that all the chain near the anchor rests upon the ground undisturbed by either the pitching motion of the ship or the tension which she causes, and therefore it is useless to veer more. This is indisputably a fallacious notion, and the point I particularly wish to consider—indeed, the principal reason for introducing the subject; the question therefore seems to resolve itself into this: "What is the curvature of a chain cable when under the pressure of that kind of strain so nearly approaching the breaking point, that it appears doubtful whether it will do so or not? Does the curvature of it at any time, or under any circumstances when so strained, make a near approach to a straight line?" That is the question, and it is much easier proposed than decided, for although the curve may be calculated by the law of catenary, yet it appears very desirable to have experimental proof.

The daily practice of testing chain cables at this Yard has afforded repeated opportunity for measuring the deflection of all the various kinds of chain at the testing strain, a few of which are here inserted.

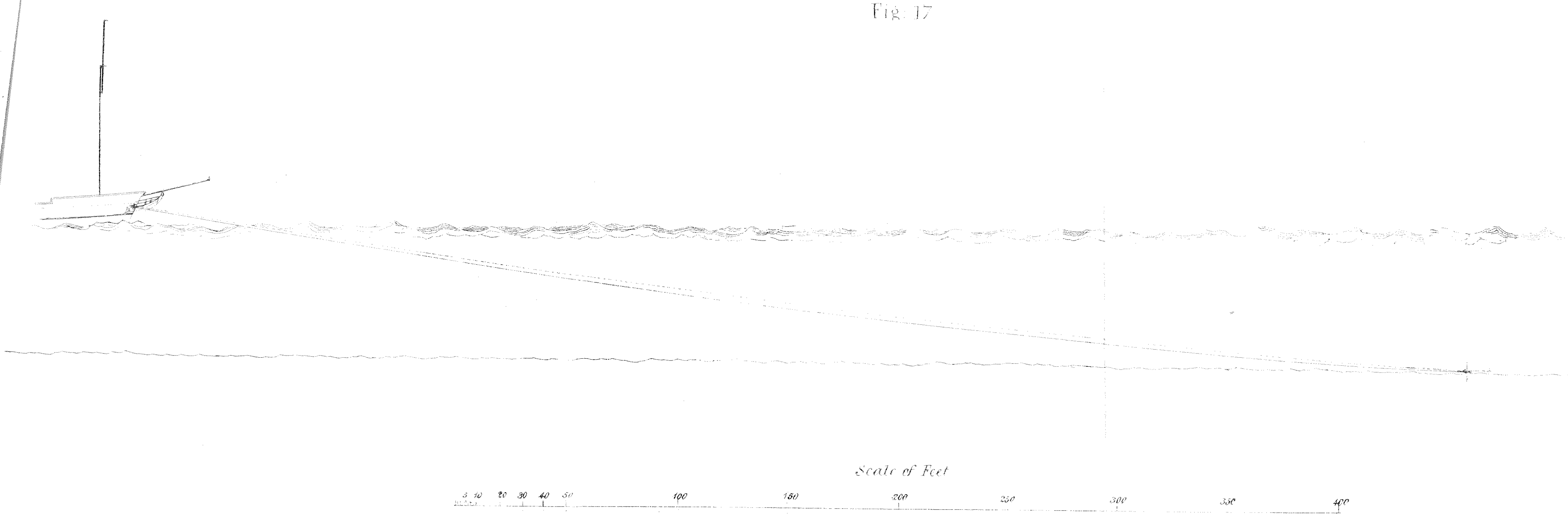
Size of the Chain.	Length.	Testing strain.	Curvature.	
$1\frac{3}{4}$ in. diameter.	$12\frac{1}{2}$ fathoms.	$55\frac{1}{8}$ tons.	$1\frac{3}{8}$ inch.	
Ditto	Ditto	Ditto	$1\frac{1}{2}$ do.	
Ditto	Ditto	Ditto	$1\frac{7}{16}$ do.	
			$1\frac{1}{2}$ mean.	
$1\frac{1}{2}$ in. diameter.	Ditto	$40\frac{1}{2}$ tons.	$1\frac{3}{4}$ inch.	
Ditto	Ditto	Ditto	$1\frac{5}{8}$ do.	
Ditto	Ditto	Ditto	$1\frac{3}{4}$ do.	
			$1\frac{5}{8}\frac{1}{16}$ mean.	
$1\frac{3}{8}$ in. diameter.	Ditto	34 tons.	$1\frac{3}{8}$ inch.	
Ditto	Ditto	Ditto	$1\frac{5}{16}$ do.	
Ditto	Ditto	Ditto	$1\frac{3}{8}$ do.	
Ditto	Ditto	Ditto	$1\frac{1}{4}$ do.	
			$1\frac{1}{4}\frac{1}{16}$ mean.	
$1\frac{1}{4}$ in. diameter.	Ditto	28 tons.	$1\frac{1}{4}$ inch.	
Ditto	Ditto	Ditto	$1\frac{5}{16}$ do.	
Ditto	Ditto	Ditto	$1\frac{3}{8}$ do.	
Ditto	Ditto	Ditto	$1\frac{5}{16}$ do.	Whole average $1\frac{3}{8}$.
			$1\frac{1}{4}\frac{1}{16}$ mean.	
$\frac{7}{8}$ in. diameter.	Ditto	$13\frac{3}{4}$ tons.	$1\frac{1}{4}$ inch.	
Ditto	Ditto	Ditto	$1\frac{3}{16}$ do.	
Ditto	Ditto	Ditto	$1\frac{1}{8}$ do.	
Ditto	Ditto	Ditto	$1\frac{1}{4}$ do.	
Ditto	Ditto	Ditto	$1\frac{3}{8}$ do.	
			$1\frac{1}{4}$ nearly mean.	
$\frac{3}{4}$ in. diameter.	Ditto	$10\frac{1}{8}$ tons.	$1\frac{1}{8}$ inch.	
Ditto	Ditto	Ditto	$1\frac{1}{8}$ do.	
Ditto	Ditto	Ditto	$1\frac{3}{16}$ do.	
Ditto	Ditto	Ditto	$1\frac{1}{8}$ do.	
Ditto	Ditto	Ditto	$1\frac{1}{8}$ do.	
Ditto	Ditto	Ditto	$1\frac{1}{4}$ do.	
Ditto	Ditto	Ditto	$1\frac{1}{4}$ do.	
			$1\frac{3}{16}$ nearly mean.	
$\frac{1}{2}$ in. diameter.	Ditto	$4\frac{1}{2}$ tons.	$1\frac{1}{2}$ inch.	
Ditto	Ditto	Ditto	$1\frac{3}{8}$ do.	
Ditto	Ditto	Ditto	$1\frac{5}{8}$ do.	
Ditto	Ditto	Ditto	$1\frac{5}{8}$ do.	
			$1\frac{1}{2}\frac{1}{16}$ mean.	

The testing strain is much less than the full strength of the cable; but as it has been carefully calculated at 630 lbs. per circular $\frac{1}{8}$ inch, in strict proportion to weight and strength of the various sizes, it is considered a better guide to the experiments than any other, for the actual curvature at the breaking strain; that which would decide the question, and which of all other things it is most desirable to ascertain, never can be experimentally determined, on account of the risk of approaching the spot at the moment when the strain is the greatest. It will be perceived that the utmost dip or deflection in all these thirty experiments is $1\frac{3}{4}$ inches, and the mean $1\frac{3}{8}$ inches, on a length of seventy-five feet; therefore, by taking the greatest as most favourable to those who advocate a short scope of cable, it will produce a downward curvature of ten feet upon a length of one hundred fathoms.

This deflection is as nearly as possible the same as the catenary curve in Fig. 17, which has been calculated with the greatest care, and proved by several experiments upon chain of various sizes and in different positions. The depth of water is ten fathoms, and one fathom more for the height of the hawse-hole above the surface; the length of cable from the bow to the anchor is one hundred fathoms; the diameter of the chain $1\frac{1}{2}$ inches; and the strain $40\frac{1}{2}$ tons.

The curve in this figure differs so widely from all the notions of the short scope people, that little hope can be entertained of convincing them of its truth. It is nevertheless founded upon incontrovertible facts. The strains applied to the various chains in the experiments were as strictly proportioned to the weight and length of each, as the $40\frac{1}{2}$ tons is to that of one hundred fathoms of $1\frac{1}{2}$ inch

Fig: 17



The lower continued line from the Ship's Bow, to the Anchor represents the curve of a chain Cable 1½ inches diameter and 100 fathoms in length, when strained by the established test of 40½ Tons

The upper dotted line represents the curve when strained by the minimum strength of the Cable 54½ Tons chain in the figure; and however unwilling they may be to change their opinion, they may rest assured that, in a common gale of wind, which I have no doubt would produce the strain here mentioned, not one link of the one hundred fathoms of chain will quietly rest upon the ground, as they imagine; on the contrary, it will be found by the experiments on a depth of ten fathoms, that 127.98 fathoms of chain are required to form a semi-catenary when suspended in air, and 137.03 fathoms when in water, the buoyancy of which must at all times have its influence. If the strain in riding a ship be less than that mentioned, the curvature will be greater, and no danger need be apprehended; but in a severe gale, the force of which may be supposed equal to, or nearly equal to a breaking strain, it must be evident that a long scope is the only way to prevent a fatal result.

*Various Experiments and Calculations to determine the Curvature.**

Given the length of a chain cable, the vertical distance between its extremities, the tension on the upper end, and its weight per 100 fathoms; to find the angle between the upper part of the cable and a vertical line, and that between the lower part of the cable and a horizontal line.

Suppose the length of chain cable	100 fathoms
Vertical distance between its extremities	11 ,,
Strain on the upper end .	$40\frac{1}{2}$ tons
Size of cable $1\frac{1}{2}$ inches, whose weight per 100 fathoms is .	108 cwt. or 5.4 tons

Since 100 fathoms weigh 5.4 tons, 750 fathoms will weigh $40\frac{1}{2}$ tons; or 750 fathoms of cable, attached to the upper end and hanging freely, will have the same effect as the strain of $40\frac{1}{2}$ tons.

Fig. 18. Take any vertical line A Q, equal to 100 fathoms; from A as a centre, and with a radius equal to 750 fathoms describe the arc ab. From Q as a centre, and

* In making these calculations, I have had the able and valuable assistance of Mr. JOSEPH LARGE, Member of the late School of Naval Architecture, and eminently qualified for the task by mathematical attainments and superior mechanical knowledge.

with a radius equal to 750 minus 11 or 739 fathoms (11 fathoms being the vertical distance between the extremities,) describe an arc cd intersecting the arc ab in some point P. Join P A, P Q. On P A describe a semicircle. The point Q will in this case be found to lie within the semicircle. Produce A Q to cut the semicircle in R. Join P R. From P, as a centre, with the radii P Q, P R, describe the arcs Q x, Q y, intersecting A P in x and y.

Then P A Q is the angle which the upper part of the cable will make with a vertical line (as P A x=79°52′ fig. 19,) and Q P R the angle which the lower part of the cable makes with a horizontal line, (as L Q x fig. 19,)=2°28′.

A x (figures 18 and 19,) is the vertical distance between the extremities of the cable.

As the length A Q (figure 18) of the cable is increased, the point Q approaches the point R, and the angle Q P R, which the lower part makes with a horizontal line, diminishes. When the point Q coincides with R, or A Q is equal to A R, the angle Q P R vanishes, and a horizontal line forms a tangent to the cable at its lowest part.

Thus in fig. 19, A Q R is the cable represented by A R (fig. 18)=131.89 fathoms, and is a semi-catenary, the horizontal line R y (fig. 19) being a tangent to it at its lowest point R; the vertical distance between its extremities being D R or A y=11.68 fathoms, which corresponds with A y (fig. 18), measured on its proper scale. A Q (figures 18 and 19) is a segment of the semi-catenary A R (figures 18 and 19.)

Hence, a diagram being constructed as above, if the point Q (fig. 18) should be found to lie *within* the semicircle, the cable forms a segment of a semi-catenary, and its lower part makes an angle with a horizontal line; if the point A O (fig. 18) lie in the *circumference* of the semicircle, the cable forms a complete semi-catenary, to the lowest point of which, a horizontal line forms a tangent.

If the point Q (fig. 18) be found to lie *without* the semicircle as q, the length A R of the cable will form a semi-catenary; and the remaining length R q, which is beyond the semicircle, will rest on the ground, as R q (fig. 19.)

If it be required to ascertain what length of chain cable will form a complete semi-catenary, at the proposed depth A x (figures 18 and 19) or 11 fathoms; let the arc x Q (fig. 18) be continued till it intersects the semicircle in some point S; join A S, P S, then A S is the length required; which is the greatest length of cable that can be employed with a depth of 11 fathoms, so that no part of it shall rest on the ground (as A n S fig. 19.)

The angle P A Q fig. 18 (or P A x fig. 19), which the upper part of the cable makes with a vertical line, may be found from the following expression:—

$$\text{Cos. PAQ (fig. 18)} = \frac{(\text{PA})^2 + (\text{AQ})^2 - (\text{PQ})^2}{2 \times \text{PA} \times \text{AQ}}$$

Substituting for P A, 750 fathoms—for P Q, 739 fathoms—and for A Q, 100 fathoms.

$$\text{Cos. PAQ} = \frac{(750)^2 + (100)^2 - (739)^2}{2 \times 750 \times 100} = 0.17586 \text{ to rad. } 1$$

And from a table of cosines we have, angle P A Q (or P A x fig. 19) $= 79^\circ\ 52'\ 16''.66$

The angle Q P R (fig. 18), (or L Q x fig. 19), which the lower part of the cable makes with a horizontal line, may be found from the following expression:—

$$\text{Sin. QPR (fig. 18)} = \frac{(\text{PA})^2 - (\text{PQ})^2 - (\text{AQ})^2}{2 \times \text{AQ} \times \text{PQ}}$$

Fig: 18.

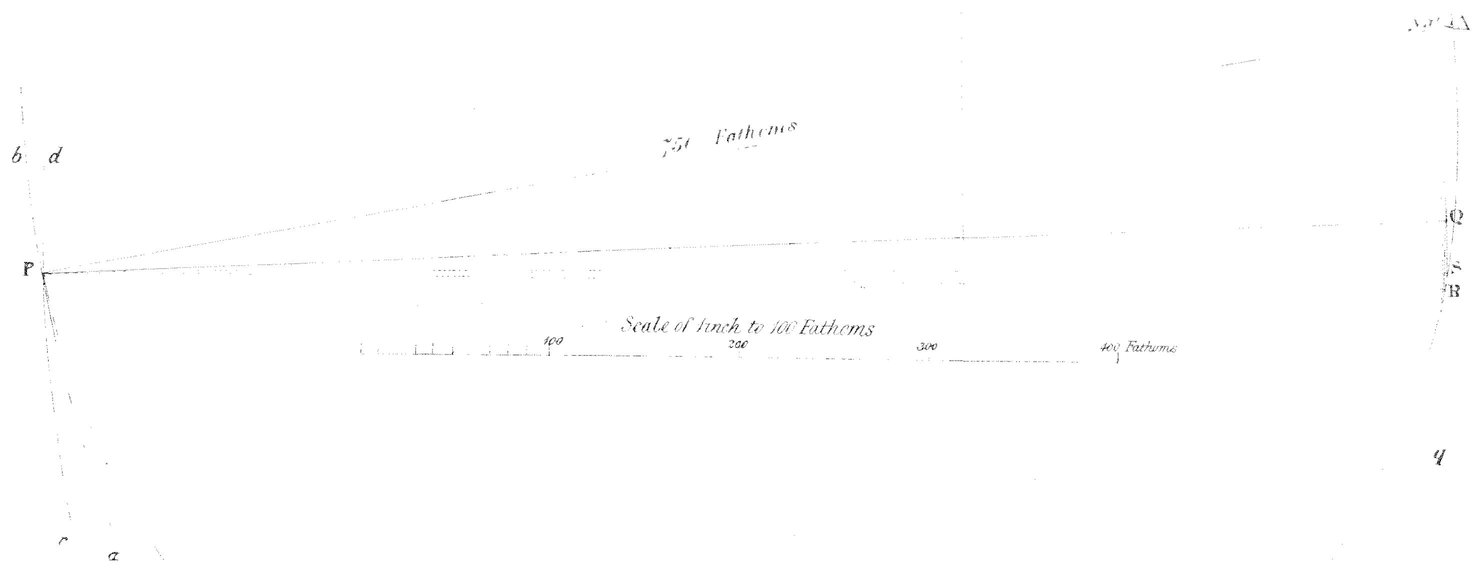
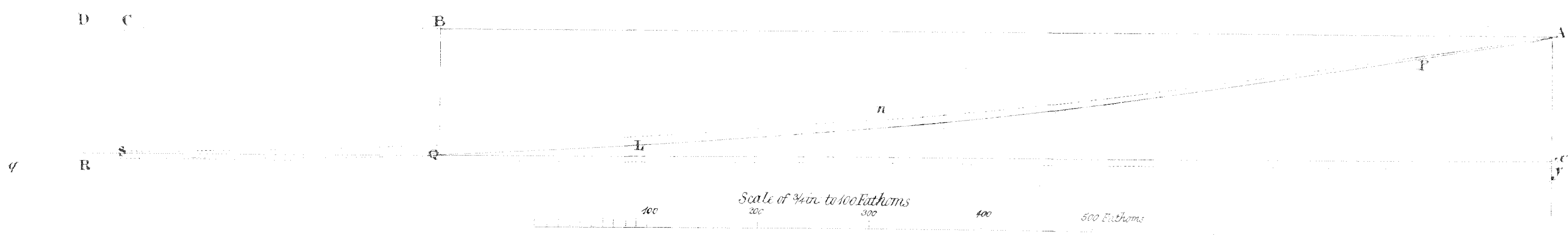

b d
750 Fathoms
P
Q
S
R
Scale of 1 inch to 100 Fathoms
100
200
300
400 Fathoms
q
c a

Fig: 19.


D C
B
A
P
n
L
q R
S
Q
c
y
Scale of ¾ in. to 100 Fathoms
100
200
300
400
500 Fathoms

Substituting the proper values of P A, P Q, and A Q as before,

$$\text{in. Q P R}=\frac{(750)^2-(739)^2-(100)^2}{2\times 100\times 739}=0\cdot 043159 \text{ to rad. } 1$$

And from a table of sines we have

$$\left.\begin{array}{r}\text{Angle Q P R (fig. 18)}\\ \text{or L Q } x \text{ (fig. 19)}\end{array}\right\}=2^\circ\ 28'\ 25''.09$$

The greatest length of cable that can be employed with a depth of 11 fathoms so that no part of it may rest on the ground, is A S (fig. 17), which is equal to $\sqrt{(\text{A P})^2-(\text{P S})^2}$ Substituting for A P and P S their values.

$$\left.\begin{array}{r}\text{A S (fig. 18)}\\ \text{or A } n \text{ S (fig. 19)}\end{array}\right\}=\sqrt{(750)^2-(739)^2}=127.9 \text{ fathoms.}$$

The angle P A S (fig. 18), which this length of cable makes with a vertical line, may be found from the expression :—

$$\text{Sin. P A S}=\frac{\text{P S}}{\text{P A}}$$

Now P S=P Q=739 fathoms,

And P A=750 fathoms.

Hence by substitution :—

$$\text{Sin. P A S (fig. 17)}=\frac{739}{750}=0.9853 \text{ to radius } 1.$$

And from a table of sines we have

$$\left.\begin{array}{r}\text{Angle P A S (fig. 18)}\\ \text{or P A } x \text{ (fig. 19)}\end{array}\right\}=80^\circ\ 10'\ 29''.88$$

The position which a chain cable would assume under any given circumstances, may also be obtained experimentally, by the suspension of a small chain of any convenient length.

Let it be required to find by an experiment on a chain $\frac{9}{16}$ of an inch in diameter, and 25 feet in length, the position which an $1\frac{1}{2}$ chain cable would take, whose length is 100 fathoms, vertical distance between the extremities 11 fathoms, and strain on the upper end $40\frac{1}{2}$ tons :—

The weight of 100 fath. of $1\frac{1}{2}$ chain cable is 108 cwt.
Ditto ditto of $\frac{9}{16}$ ditto 15cwt. 0qr. 21lb.

The proportionate strain to be applied to the $\frac{9}{16}$ chain may be found from the following expression :—

$$\frac{\text{Weight of chain per 100 fath.}}{\text{Weight of cable per 100 fath.}} \times \frac{\text{Length of chain}}{\text{Length of cable}} \times \text{Strain}$$

$$= (\text{by substitution}) \frac{\overset{\text{cwt. qr. lb.}}{15 \;\; 0 \;\; 21}}{108} \times \frac{\overset{\text{ft.}}{25}}{600} \times \overset{\text{tons.}}{40\tfrac{1}{2}} = \overset{\text{cwt. qr. lb.}}{4 \;\; 2 \;\; 27.552}$$

The length of the experimental chain being $\frac{1}{24}$ the length of the cable; the vertical distance between the extremities of the chain should be taken $\frac{1}{24}$ of 11 fathoms or 2ft. 9in.

The curve formed by the chain suspended under these circumstances, was similar to that derived from calculation for an $1\frac{1}{2}$ chain cable of 100 fathoms (on a $\frac{1}{24}$ scale.)

The deflection at the middle of the length from a straight line joining the extremities of the chain, measured 5 inches. This deflection multiplied by 24, gives the deflection on the full scale 10 feet; agreeing with the result of calculation.

Let one end of a chain cable be made fast, and a given strain act on the other end; both extremities being in the same horizontal line: to find by construction the depth of the lowest part of the chain :—

Let the size of the cable be $1\frac{1}{2}$ inch, length 100 fathoms, strain $40\frac{1}{2}$ tons.

Take a vertical line A R (fig. 18) equal to one half the length of the cable or 50 fathoms : from R draw the line R P at right angles to A R: from A as a centre, with a radius

equal to 750 fathoms (being the number of fathoms of a $1\frac{1}{2}$ inch chain cable due to $40\frac{1}{2}$ tons strain,) describe an arc *a b* cutting R P in P. Join P A from P as a centre with a radius P R, describe the arc R *y* cutting A P in *y*,—A *y* is the required depth of the lowest part of the chain.

The same may also be found from the expression :—

$$\text{Depth of lowest point of cable} = T - \sqrt{T^2 - s^2}$$

Where T is equal to P A, the tension at A in fathoms of chain or 750 fathoms: and *s* is equal to A R the half length of cable or 50 fathoms.

Hence by substitution :—

$$\text{Depth of lowest point of cable} = 750 - \sqrt{(750)^2 - (50)^2}$$
$$= 750 - 748.331 = 1.668 \text{ fath.}$$
$$\underline{\qquad 6}$$
$$10.008 \text{ feet.}$$

The deflection of a cable from a horizontal line, may be found also experimentally, by the suspension of a small chain of any assumed length.

Let the size of the experimental chain be $\frac{9}{16}$, length 25 feet, weight per 100 fathoms, 15cwt. 0qr. 21lb.

The proportionate weight to be attached

$$= \frac{\text{Weight of chain per 100 fath.}}{\text{Weight of cable per 100 fath.}} \times \frac{\text{Length of chain}}{\text{Length of cable}} \times \text{Strain}$$

$$= (\text{by substitution}) \frac{\overset{\text{cwt. qr. lb.}}{15 \;\; 0 \;\; 21}}{108} \times \frac{\overset{\text{ft.}}{25}}{600} \times \overset{\text{tons.}}{40\tfrac{1}{2}} = \overset{\text{cwt. qr. lb.}}{4 \;\; 2 \;\; 27.552}$$

The length of the chain in this experiment, being $\frac{1}{24}$ of the length of the chain cable, the curve observed is the curve on a $\frac{1}{24}$ scale, which the cable will form :—

The deflection was found to be $4\frac{15}{16}$, which being multiplied by 24, gives the deflection, or depth of the lowest point of the cable of 100 fathoms with $40\frac{1}{2}$ tons strain, equal to 9ft. $10\frac{1}{2}$in.

Let the same be tried with $12\frac{1}{2}$ feet of $\frac{3}{8}$ chain, weighing 7.96 cwt. to the 100 fathoms.

Proportionate weight to be attached

$$=\frac{\text{Weight of chain per 100 fath.}}{\text{Weight of cable per 100 fath.}}\times\frac{\text{Length of chain}}{\text{Length of cable}}\times\text{Strain}$$

$$=(\text{by substitution})\frac{7.96}{108}\times\frac{12\frac{1}{2}}{600}\times 40\frac{1}{2}=\overset{\text{cwt.}}{1}\ \overset{\text{qr.}}{0}\ \overset{\text{lb.}}{27}\ \overset{\text{oz.}}{4.7}$$

The length of chain in this experiment being $\frac{1}{48}$ of the length of cable, the curve observed is that (on a $\frac{1}{48}$ scale) which the cable will form :—

The deflection was found to be $2\frac{5}{16}$ of an inch, which multiplied by 48 is 9ft. 3in., the depth of the lowest point of the cable.

Let the size of the chain cable be as before $1\frac{1}{2}$ inch, and the strain $40\frac{1}{2}$ tons, but the length $12\frac{1}{2}$ fathoms. Take a vertical line A R (fig. 17) equal to one half the length of the cable or $6\frac{1}{4}$ fathoms; from R draw the line R P at right angles to A R; from A with the radius 750 fathoms (being the number of fathoms of an $1\frac{1}{2}$ inch chain cable due to $40\frac{1}{2}$ tons strain), describe an arc a b, cutting R P in P: join P A: from P with the radius P R, describe the arc R y, cutting A P in y. A y is the required depth of the lowest point of the chain.

The same may also be found from the expression :—

$$\text{Depth of lowest point of cable}=\text{T}-\sqrt{\text{T}^2-s^2}$$

Where T is equal to P A, the tension at A in fathoms of chain or 750 fathoms; and s = A R, the half length of cable or 6.25 fathoms.

Hence by substitution :—

$$\text{Depth of lowest point of cable}=750-\sqrt{(750)^2-(6.25)^2}$$
$$=750-749.974=0.026\text{ fath.}$$
$$\times 6 = 0.156\text{ feet.}$$
$$\times 12 = 1.872\text{ inch.}$$
$$=1\tfrac{7}{8}\text{ inch nearly.}$$

The deflection may also be found by experiment.

Suppose a length of 25 feet of $\frac{9}{16}$ chain, weighing 15cwt. 0qr. 21lb. to the 100 fathoms, be taken for the experiment.

Then the proportionate weight to be attached, is

$$\frac{\text{Weight of chain per 100 fath.}}{\text{Weight of cable per 100 fath.}}\times\frac{\text{Length of chain}}{\text{Length of cable}}\times\text{Strain}$$

$$=(\text{by substitution})\ \frac{\overset{\text{cwt.}}{15}\ \overset{\text{qr.}}{0}\ \overset{\text{lb.}}{21}}{108}\times\frac{27}{75}\times\overset{\text{tons.}}{40\tfrac{1}{2}}=\overset{\text{ton.}}{1}\ \overset{\text{cwt.}}{17}\ \overset{\text{qr.}}{3}\ \overset{\text{lb.}}{24\tfrac{1}{2}}$$

The length of the chain in this experiment being $\frac{1}{3}$ the length of the chain cable, the curve observed is that which the cable will form (on a scale of $\frac{1}{3}$.)

The deflection was found to be $\frac{13}{16}$ of an inch, which multiplied by 3 is equal to $2\frac{7}{16}$ inches.

On the addition of $\frac{1}{2}$ cwt. to the above weight, the deflection was $\frac{5}{8}$ of an inch, which multiplied by $3=1\frac{7}{8}$, agreeing with the calculation. As the nip on the roller where the weight was attached was considerable, it is probable that the chain was not sufficiently free.

The experiment was also tried with a $\frac{3}{8}$ inch chain, weighing 7.96 cwt. per 100 fathoms, and $12\frac{1}{2}$ feet long.

The proportionate weight to be attached

$$=\frac{\text{Weight of chain per 100 fath.}}{\text{Weight of cable per 100 fath.}}\times\frac{\text{Length of chain}}{\text{Length of cable}}\times\text{Strain}$$

$$=(\text{by substitution})\ \frac{7.96}{108}\times\frac{12\frac{1}{2}}{75}\times\overset{\text{tons.}}{40\tfrac{1}{2}}=\overset{\text{tons.}}{0.49766}=\overset{\text{tons.}}{9}\ \overset{\text{cwt.}}{3}\ \overset{\text{qr.}}{22.32}$$

The length of the chain in this experiment being $\frac{1}{6}$ of the length of the cable, the curve observed is that (on a scale of $\frac{1}{6}$,) which the cable will form.

The deflection was found to be $\frac{5}{16}$, which multiplied by 6 is equal to $\frac{30}{16}=1\frac{7}{8}$ inch, which agrees with the calculation.

The weight attached was $1\frac{1}{2}$lb. more than should have been employed.

Where the result of the experiment does not exactly agree with that of the calculation, it is owing to an imperfection in the experiment.

The difficult experiment of determining and measuring the catenary curve of a chain cable one hundred fathoms in length has been accomplished since the above was written; the difference of level between the hawse-hole and the anchor being 66 feet 8 inches, and the testing strain the amount of tension. The result of this experiment produces a curve (see Frontispiece) so closely resembling that which had been previously determined by calculation, that the one cannot be distinguished from the other. When drawn upon a small scale from the same bow to the same anchor, the two curves cannot be separated, as they merge into each other. The experiment was witnessed by all the men of science in the establishment, and likewise by several naval officers, to all of whom it afforded extreme gratification, both from its novelty, and the most decisive and satisfactory proof of a highly important fact. In applying this to the matter in hand, I consider it necessary to state the facts of a case communicated to me by an officer of the ship in which it occurred, and who was aiding and assisting in the duties during the whole period, and an eye-witness of the events as they happened.

In the summer of 1823, Her Majesty's Ship "Ramilies" was placed in the Downs as a stationary ship. She was anchored on that part of the ground usually occupied by ships of war, rather to the southward, in 10 or 11 fathoms water, and moored with 90 fathoms of chain on the best bower to the S.W., and 75 fathoms on the small bower to the N. E. Nothing connected with the anchorage occurred during the summer months, but on the 17th of October, during a S.W. gale, the ship parted from her best bower anchor; and on the 19th was moored again with 100 fathoms of chain in the same direction and in the same spot as before. On the 21st, in another S.W. gale, the ship parted from her best bower anchor a second time, and in both cases it was found to be the ring of each anchor that had broken; but as they were the large original rings constructed for hempen cables, they were totally unfit to be used with chain, because, with a hempen cable of twenty-two inches, the strain is applied to a large portion of the surface of the ring, but with a two-inch chain cable the strain is confined to a very small section, in proof of which it was found that the fracture of the ring on the 21st had taken place immediately under the shackle, and opened sufficiently for it to be drawn through, when it closed again with the natural strength of the iron, so that the fracture afterwards was hardly perceptible. On the 23rd the ship was moored a third time, with 160 fathoms of chain on the best bower to the S.W., and 150 fathoms on the small bower to the N.E. With this scope of cable, the ship maintained her position through all the gales of wind which afterwards occurred, although many of them were much more severe than either of those previously mentioned.

The character of this anchorage, and the particular part of it alluded to, is so universally known, it need not be described here, but as the depth of water round the ship is the same as that assumed in the calculations, the whole transaction may be almost considered an additional experiment upon a large scale, in proof of what had been previously stated on the subject. In both the gales of wind on the 17th and 21st it is evident the amount of pressure on the ship exceeded the means and strength of security; what result might have followed in this case, if the anchor rings had been of the proper shape and dimensions, can only be conjecture; and, therefore, part of the weakness is undoubtedly due to their imperfect form, but by far the greater portion of it is attributable to the insufficient scope of cable to compensate its non-elastic character; the strain which produced the accident in all probability was equal to or exceeded the testing strain of the cable. The length of a semi-catenary with that strain and the same depth of water, is given in Table III. as 137 fathoms, which greatly exceeds the length of cable used at the time alluded to, and clearly points to the cause of the accident, which is subsequently proved by the simple fact, that the same ship, with 160 fathoms of chain, maintained her

position on the same ground, free from all accident, in gales of wind more severe than either of those which forced her from her anchor when trusting to 100 fathoms. This evidence appears to be decisively conclusive upon the value of a long scope of chain. The hemp cable is well known to possess the valuable quality of elasticity sufficient to accommodate itself to any variety of strain when used as a cable, but the chain is, on the contrary, so stubborn and unyielding, that nothing but a long scope can render it safe; it is equivalent to additional strength, it admits the ship to rise over each successive wave under the constant pressure of a great strain, preventing entirely the danger of sudden jerks, which, of all other trials, is the greatest and the worst to a chain.

It has been remarked, with reference to the experiments upon the full length of 100 fathoms of chain cable, that, although the curvature of it (see Frontispiece) is no doubt perfectly correct in proportion to the strain and the depth of water, yet in a gale of wind the full strain would not be constant, the violence of it is frequently relieved by long intervals of lull, during which time there would be no risk whatever. This may all be very true, but the argument does not apply to the scope of cable; the greater danger is to be watched and avoided, not the less; for, however long the intervals of lull may continue, let the breaking strain be applied but for a moment, and the result must be fatal.

It is to be hoped that enough has been stated to satisfy the sceptic and doubtful; if not, it is useless to say more. Any man in charge of a ship at anchor, with the necessary quantity of chain cable on board and space astern to allow him to make use of it, but who neglects to do so, must be considered the author of his own misfortune, whether it may amount to the loss of his anchor or the loss of his ship. No excuse can be offered for such neglect, which must originate either in indolence or in a mistaken notion of the necessity.

TABLE III.

Results of Calculations on the Catenary Curve of a Chain Cable, 100 Fathoms in length, and 1½ Inch in diameter, under given strains and depths of water.

LENGTH OF CABLE, 100 FATHOMS.	TESTING STRAIN. 40½ TONS ON THE CABLE.				MINIMUM BREAKING STRAIN. 54½ TONS ON THE CABLE.				MEAN BREAKING STRAIN. 59½ TONS ON THE CABLE.			
	DEPTH.				DEPTH.				DEPTH.			
	11 Fathoms.		7 Fathoms.		11 Fathoms.		7 Fathoms.		11 Fathoms.		7 Fathoms.	
	Suspended in Air.	Correction for the Buoyancy of Water.	Suspended in Air.	Correction for the Buoyancy of Water.	Suspended in Air.	Correction for the Buoyancy of Water.	Suspended in Air.	Correction for the Buoyancy of Water.	Suspended in Air.	Correction for the Buoyancy of Water.	Suspended in Air.	Correction for the Buoyancy of Water.
Angle between the upper end of the cable and a vertical line....	79° 52′ 16″.66	80° 21′ 26″.55	82° 9′ 50″	82° 38′ 28″.3	80° 51′ 16″.28	81° 12′ 45″.12	83° 8′ 54″.17	83° 29′ 9″.55	81° 5′ 35″.25	81° 25′ 13″.31	83° 23′ 14″.61	83° 42′ 25″.46
Horizontal pull on the ship and anchor....................		39.927 Tons.		40.166 Tons.		53.86 Tons.		54.148 Tons.		58.834 Tons.		59.14 Tons.
Vertical force to depress the bow		6.78 Tons.		5.187 Tons.		8.326 Tons.		6.17 Tons.		8.876 Tons.		6.52 Tons.
Angle between the lower end of cable and a horizontal line	2° 28′ 25″.09	2° 57′ 59″.37	0° 10′ 26″.15	0° 39′ 19″.07	3° 28′ 10″.54	3° 49′ 52″.29	1° 9′ 59″.26	1° 31′ 54″.18	3° 42′ 38″.55	4° 2′ 27″.78	1° 24′ 25″.45	1° 43′ 43″.19
Vertical force to lift the anchor		2.067 Tons.		0.459 Tons.		3.6 Tons.		1.448 Tons.		4.156 Tons.		1.784 Tons.
Length of semi-catenary, of which the 100 fathoms is a segment	131.895 Faths.	143.88 Faths.	102.16 Faths.	109.71 Faths.	160.41 Faths.	176.43 Faths.	120.403 Faths.	130.32 Faths.	170.598 Faths.	188.06 Faths.	126.88 Faths.	137.67 Faths.
The forces on the bow, and horizontal force on anchor		As above.		As above.		As above.		As above.		As above.		As above.
Depth of the semi-catenary, of which length 100 fathoms is a segment	11.68 Faths.	12.136 Faths.	7.0034 Faths.	7.055 Faths.	12.83 Faths.	13.55 Faths.	7.207 Faths.	7.43 Faths.	13.286 Faths.	14.106 Faths.	7.33 Faths.	7.568 Faths.
Lower part hangs horizontally, hence force to lift the anchor....		0		0		0		0		0		0
Length of semi-catenary at the depth specified in the respective columns, or the greatest length of cable that can be employed, so that no part of it shall lie on the ground (as A *n* s in Fig. 19)	127.98 Faths.	137.03 Faths.	102.23 Faths.	109.29 Tons.	148.6 Faths.	159.018 Faths.	118.66 Faths.	126.74 Faths.	155.35 Faths.	166.16 Faths.	124.00 Faths.	132.42 Faths.
Angle between the upper end of this semi-catenary and a vertical line..	80° 10′ 29″.88	80° 49′ 15″.3	82° 9′ 56″.94	82° 40′ 12″.38	81° 32′ 0″	82° 5′ 9″.08	83° 14′ 52″.96	83° 40′ 41″.5	81° 53′ 41″.5	82° 25′ 32″.74	83° 32′ 18″.14	83° 56′ 2″.35
Horizontal pull on ship and anchor		39.98 Tons.		40.1688 Tons.		53.981 Tons.		54.168 Tons.		58.98 Tons.		59.166 Tons.
Vertical force to depress the bow		6.46 Tons.		5.167 Tons.		7.5 Tons.		6.00 Tons.		7.842 Tons.		6.27 Tons.
Lower part hangs horizontally, hence force to lift the anchor....		0		0		0		0		0		0

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