CRANK AND SCREW SHAFTING

IN THE

MERCANTILE MARINE.

Being asked to read a Paper before your Institute, I have chosen this subject, as I think no part of the Marine Engine has given so much trouble and anxiety to the seagoing engineer, and from the list of shipping casualties in the daily papers, a large proportion seem due to the shafting, causing loss to the shipowner, and, in some instances, danger to the crew.

My endeavour is to put some of the causes of these casualties before you, also some of the remedies that have tended to reduce their number.

Several papers have been read on this subject, chiefly of a theoretical description, dealing with the calculations relating to the twisting and bending moments, effects of the angles of the cranks, and length of stroke—notably that read by Mr. Milton before the Institute of Naval Architects in 1881. The only *practical* part of this paper dealt with the possibility of the shafts getting out of *line*, and, regarding this contingency, Dr. Kirk said that "If Superintendent Engineers would only see that the Bearings were kept in line, broken crank and other shafts would not be so much heard of."

Of course, this is one of those statements made in discussions of this kind, for what purpose I fail to see, and, as far as my own experience goes, is *misleading*; for, having taken charge of steamers new from the builders' hands, when it is at least expected that these shafts would *be in line*, the crank shaft bearings heated very considerably and *continued* to do so, rendering the duration of life of the crank shaft a short one, and though they were never what is termed "out of line," the bearings could *not* be kept cool without the use of sea water, and occasionally the engines had to be stopped to cool and smooth up the bearing surfaces, causing delays, worry and anxiety, for which the Engineer in charge was in no way responsible.

Happily this state of what I might call *uncertainties* is being gradually remedied, thanks being largely due to those Engineers who have the skill to suggest improvements, and the patience to carry them out against much opposition.

These improvements, in many instances, pertain to the Engine Builders' duties, and are questions which I think have been treated lightly, notably that of insufficient bearing surface, and one of the principal causes of hot bearings, whereby the oil intended for lubrication was squeezed out, and the metal surfaces brought too close in contact, and when bearings had a pressure of 200 lbs. per square inch, it has been found that not more than 120 lbs. per square inch should be exerted to keep them cool (this varies according to the material of which the bearing is composed) without having to use sea water, and prevent them being ground down and thus getting out of line.

I have known a bearing in a new steamer, in spite of many gallons of oil wasted on it, wear down one-eighth of an inch in a voyage of only 6,000 miles, from insufficiency of bearing surface.

Several good rules are in use governing the strength of shafts which treat of the diameter of the bearings only, and angles of the crank, and the Engine Builder along with the Shipowner has been chary of increasing the surfaces by lengthening the bearings, for to do this means increase of space taken up fore and aft the vessel, besides additional weight of engine.

Engine Builders all aim in competing to put their engines in less space than their rivals, giving same power and sometimes more. I think, however, this inducement is now more carefully considered, as it has been found more economical to give larger bearing surfaces than to have steamers lying in port refitting a crank shaft along with the consequences of heavy bills for salvage and repairs, also the risk of losing the steamer altogether.

Proportioning the bearings to the weights and strains they have to carry has also been an improvement, the different bearings of marine engines were usually made alike in surface, irrespective of the work each had to do with a view to economy in construction; in modern practice the after bearings have more surface than the forward, except in cases where heavy slide valve gear has to be supported, so that the wear down in the whole length of the shaft is equal, thus avoiding those alternate bending strains at top and bottom of the stroke every revolution.

Another improvement that has been successfully introduced, adding to the duration of life of crank shafts, is the use of white bearing metal, such as Parson's White Brass, on which the shafts run smoothly with less friction and tendency to heat, so that along with well proportioned surfaces a number of crank shafts in the Peninsular and Oriental Company's service have not required lining up for eight years, and I hope with care may last till new boilers are required.

Large and powerful steamers can be driven full speed from London to Australia and back without having any water on the bearings, using oil of only what is considered a moderate price, allowing the engineer in charge to attend to the economical working of both engines and boilers (as well as many other engines of all kinds now placed on board a large mail and passenger steamer), instead of getting many a drenching with sea water, and worried by close attention to one or two hot bearings all the watch. Compare these results with the following:—"In the same service in 1864, and with no blame to the engineers in charge, the crank shaft bearings of a screw steamer had to be lined up every five days at intermediate Ports; through insufficient bearing surfaces, sea water had continually to be used, resulting in frequent renewal of crank shaft."

Steamers can now run 25,000 miles without having to lift a bearing, except for examination at the end of the voyage. I would note here that the form of the bearings on which the shafts work has also been much improved, they are made more of a *solid character*, the metal being more equally disposed *round* the shaft, and the use of gun metal for the main bearings is now fast disappearing; in large engines the only metals used are cast iron and white brass, an advantage also in reducing the amount of wear on the recess by corrosion and grinding of the cast-iron under brass, where sea water was used, often to a considerable extent.

Figures No. 1 and No. 2 show the design of the old and new main bearings, and I think require but little explanation. Most of you present will remember your feelings when, after a hot bearing, the brasses were found to be cracked at top and bottom, and the trouble you had afterwards to keep these brasses in position. Where a smoking hot bearing occurred, say in the heating of a crank pin, it had the effect of damaging the material of the shaft more or less according to its original soundness, generally at the fillets in the angles of the cranks; for when the outer surface of the iron got hot, cold water, often of a low temperature, was suddenly poured on, and the hot iron, previously expanded, was suddenly contracted, setting up strains which, in my opinion, made a small tear transversely where the metal was *solid*, and where, what is termed lamination flaws due to construction, existed; these were extended in their natural direction, and by a repetition of this treatment these flaws became of such a serious character that the shafts had to be condemned or actually gave way at sea. Figures 3, 4, 5, and 6, show these flaws.

The introduction of the Triple Expansion Engine with the three Cranks gave better balance to the shaft, and the forces acting in the path of the crank pin being better divided, caused more regular motion on the shaft, and so to the propeller.

This is specially noticeable in Screw Steamers, and is taken advantage of by placing the cabins further aft, nearer the propeller, the stern having but little vibration; the dull and heavy surging sound due to unequal motion of the shaft in the two crank engines is exchanged for a more regular sound of less extent, and the power formerly wasted in vibrating the stern is utilised in propelling the vessel.

In spite of all these improvements I have mentioned, there remain the serious questions of the defects in the material—due to variety of quality—and the extreme care that has to be exercised in all the stages during construction of crank or other shafts built of iron.

Many shafts have given out at sea and been condemned through no other cause than *original defects* in their construction and material.

The process of welding and forging a crank shaft of large diameter now is to make it up of so many small *pieces*, the *best shafts* being made of what is termed scrap, representing thousands of small pieces of selected iron, such as cuttings of old iron boiler plates, cuttings off forgings, old bolts, horse shoes, angle iron, &c., all welded together, forged into billets, re-heated and rolled into bars; it is then cut into lengths, piled, and formed into slabs of suitable size for welding up into the shaft; no doubt this method is preferable to the old method of "faggoting"—so-called—as the iron bars were placed side by side resembling a bundle of fagots of about 18in. or 20in. square; the result was that while the outside bars would be welded, the inside would be improperly welded, or the hammer being weak, the blow would be insufficient to secure the proper weld, and it was no uncommon thing for a shaft to break and expose the internal bars, shewing them to be quite separate or only partially united, as in Figure 4.

This danger has been much lessened in late years by careful selection of the materials, improved methods of cleaning the scrap, better furnaces, the use of the most suitable fuel, and more powerful steam hammers. Still, with all this care, I think I may say there is not a shaft without flaws or defects more or less, and when these flaws are situated in line of the greatest strains, and though you may not have a hot bearing, they often extend until the shaft becomes unseaworthy.

Figure 4 illustrates section of a shaft that gave way, and found not to be welded about the centre; this shaft was made in 1869. Figure 5 illustrates the section of a shaft made in 1880. You will see this shaft gave way from flaws situated near the outside of the section, the opposite of figure 4; these flaws were not observable when the shafts were new, although carefully inspected; they gradually increased under strain, came to the outside and were detected, having assumed the form as per figure 5. Considerable loss fell upon the owners of these vessels who were in no way to blame, nor could they recover any money from the makers of the shafts, who were alone to blame. I am pleased to state, and some of the members here present know that considerable improvement has been effected in the use of a better material than iron for crank shafts by the introduction of a special mild steel by Messrs. Vickers, Sons and Company, of Sheffield, and that instead of having to record the old familiar defects found in iron shafts, I can safely say no flaws have been observed when new, or during eight years' running, and there are now twenty-two shafts of this mild steel in the P. & O. Company's service.

I may here state that steel was used for crank shafts in this service in 1863, as then manufactured in Prussia by Messrs. Krupp, and generally known as Krupp's Steel, the tensile strength of which was about 40 tons per square inch, and though free from flaws, it was unable to stand the fatigue and broke, giving little warning. It was of too brittle a nature, more resembling chisel steel, which you will see by the fracture as shewn in figure 7, it was broken again under a falling weight of 10cwt. with a 10ft. drop=12 tons.

The mild steel now used was first tried in 1880; it had a tensile strength of 24 to 25 tons per square inch, it was then considered advisable not to exceed this, and err rather on the safe side; this shaft has been in use eight years and no sign of any flaw has been observed. Since then the tensile strength of mild steel has gradually been increased by Messrs. Vickers, the steel still retaining the necessary ductility and toughness to endure fatigue; this has only been arrived at by improvements in the manufacture, and more powerful and better adapted hammers to forge it down from the large ingots to the size required; the amount of work to which they can now subject the steel renders it more fit to sustain the fatigue such as that to be endured by a crank shaft. These ingots of steel can be cast up to 100 tons weight and require powerful machines to deal with them. For shafts, say of 20 inches diameter, the diameter of the ingot would be about 52 inches; this allows sufficient work to be put on the couplings as well as the shaft; to make solid crank shafts of this material, say of 19 inches diameter, the ingot would weight 42 tons, the forging when completed 17 tons, and the finished shaft $11\frac{3}{4}$ tons, so that you see there is 25 tons wasted before any machining is done, and $5\frac{1}{4}$ tons between the forging and finished shaft. This makes it very expensive for solid shafts of large size, and it is found better to make what is termed a *built shaft*—the cranks are a little heaver and engine framings necessarily a little wider, a matter comparatively of small moment.

I give you a rough drawing of the hydraulic hammer, or strictly speaking, *press*, used by Messrs. Vickers in forging down the ingots in shafts, guns, or other large work; this hammer can give a squeeze of 3,000 tons. The steel seems to yield under it like tough putty, and unlike the steam hammer, there is no *jarring* on the material, and it is manipulated with the same ease as a small hammer by hydraulics.

The tensile strength of steel used for shafts having increased from 24 to 30 tons, and in some cases 31 tons—considering that this was two tons above that specified, and that we were approaching what may be termed *hard steel*—I proposed to the makers to test this material beyond the usual tests, viz.:—Tensile, extension and cold bending tests; the latter I considered was much too easy for this fine material, as a piece of fair iron will bend cold to a radius of $1\frac{1}{2}$ times its diameter or thickness without fracture, and I proposed a test more resembling the fatigue that a crank shaft has sometimes to stand, and more worthy of this material, and in the event of its standing this successfully, I would pass the material of 30 or 31 tons tensile strength. Messrs. Vickers readily agreed, and I give you a sketch of the apparatus used, viz.:—Figure 9. Specimens of steel used in the shafts were cut off different parts—crank pins and main bearings—(the shafts being built shafts) and roughly planed to $1\frac{1}{4}$in. square, and about 12 inches long; they were laid on the block as shown, and a cast iron block, fitted with a hammer head half-ton weight, let suddenly fall 12in, the block striking the bar with a blow of about four tons; the steel bar was then turned upside down and the blow repeated, reversing the piece every time until fracture was observed, and the bar ultimately broken. The results were that this steel stood 58 blows before shewing signs of fracture, and was only broken (as shown in fig. 9*a*) after 77 blows; it is noticeable how many blows it stood after fracture.

A bar of good wrought iron undressed, of same dimensions, was tried, and broke the first blow.

A bar cut from a piece of iron to form a large chain, afterwards forged down, and only filed to same dimensions, broke at 25 blows. I was well satisfied with the results, and considered this material, though possessing a high tensile strength, was in every way suitable for the construction and endurance required in crank shafts.

Sheet No. 1 shows you some particulars of these tests. A.

	Tensile Tons	Elong. in 5in.	Bend.	Fractured blows	Broke blows	Fall
A. =	30·5	28°/。	Good	61	78	12in.

In order to test the comparative value of steel of $24\frac{3}{4}$ up to 35 tons tensile strength, I had several specimens taken from shafts tested in the manner described, which may be called a *fatigue* test; the results are shown on same sheet. B, C, D, E, F, G, H, I.

B. =	$24\frac{1}{2}$	..	Good	64	72	7in.
Ditto =	..	..	..	48	54	12in.
C. =	27	25·9°/。	Good	76	81	12in.
D. =	29·6	28·4°/。	Good	71	78	12in.
E. =	30·5	28·9°/。	Good	58	77	12in.
F. =	35·5	20°/。	Good	80	91	12in.

The latter was very tough to break. Specimen marked A shews you one of these pieces of steel.

I show you also fresh broken specimens which will give you a good idea of the beautiful quality of this material. These specimens were cut out of shafts made of Steel Company of Scotland's steel. I also show you specimens of cold bending.

G.	30 9	27½°/o	Good	59	66	12in.
H.	29·3	30°/o	Good	66	90	12in.
I.	28·9	28·9°/o	Good	53	68	12in.

I think all of the above tests show that this material, when carefully made and treated with sufficient mechanical work on forging down from the ingot, is suitable up to 34 tons for crank shafts; how much higher it would be desirable to go is a question of superior excellence in material and manufacture resting with the makers. I would, however, remark that no allowance has been made by the Board of Trade or Lloyd's for the excellence of this material above that of iron.

I was interested to know how the material in the best iron shafts would stand this fatigue test compared with steel, and had some specimens of same dimensions cut out of iron shafts. The following are the results:—

J.	18·6	24·3°/o	Good	17	18	12in.

Made of best double rolled scrap 4½ cwt. blooms.

K.	22·	32½°/o	Good	21	32	12in.

Best iron, three good qualities, rolled into flat bars, cut and made into 4½ cwt. blooms.

You will see from these results that steel stood this fatigue test 73°/o (Vickers) 68°/o (Steel Company) better than iron of the best quality for crank shafts, and I am of opinion that so long as we use such material as these for crank shafts, along with the present rules, and give ample *bearing surface*, there will be few broken shafts to record.

I omitted to mention that built shafts both of steel and iron of large diameter, are now in general use, and with the excellent machines and special mechanics, are built up of five separate pieces in such a rigid manner that they possess all the solidity necessary for a crank shaft. The forgings of iron and steel being much smaller, are capable of more careful treatment in the process of manufacture. These shafts, for large Mail Steamers, when coupled up are 35 feet long, and weigh 45 tons. They require to be carefully coupled, some makers finishing the bearings in the lathe, others, depending on the excellence of their work in each piece, finish each complete.

To ensure the correct centring of these large shafts I have had 6in. dia. recesses, ¾in. deep, turned out of each coupling to one guage, and made to fit one disc. Duplicate discs are then fitted in each coupling, and the centring is preserved, and should a spare piece be ever required, there is no trouble to couple correctly on board the steamer. Photograph shows a built shaft in the lathe. Figure 10 shows the recesses and disc.

PROPELLER SHAFTS.

The Propeller Shaft is generally made of iron, as per figure 11, and if made *not less* than the Board of Trade Rules as regards diameter, of the best iron, and the gun metal liners carefully fitted, they have given little trouble; the principal trouble has arisen from defective fitting of the propeller boss.

This shaft, working in sea water, though running in lignum vitæ bearings, has a considerable wear down at the outer bearings in four or five years, and the shaft gets out of line. This wear has been lessened considerably by fitting the wood so that the grain is end way to the shaft, and, with sufficient bearing surface, these bearings have not required lining up for nine years; it is, however, a shaft that cannot be inspected, except when in dry dock, and has to be disconnected from the propeller and drawn inside for examination at periods suggested by experience. Serious accidents have occurred through want of attention to the examination of this shaft, working in salt water with liners of gunmetal, galvanic action ensues, and extensive corrosion takes place at the ends of the brass liners, more especially if they are faced up at right angles to the shaft—Some engineers have the uncovered part of the shaft between the liners inside the tube protected against the sea water by winding over it tarred line; as this may give out and cause some trouble by stopping the water space, I have not adopted it, and shall be pleased to have the experience of any seagoing engineer on this important matter—A groove round the shaft is formed due to this action, and, in some cases, the shaft has broken inside the stern tube, breaking not only it, but tearing open the hull, resulting in the foundering of the vessel.

Steel has been used for screw shafts, but has not been found so suitable, as it corrodes more rapidly in the presence of salt water and gun metal than iron, and unless protected by a solid liner for the most part of its length—a mechanical feat which has not yet been achieved in ordinary construction, as this liner would require to be 20 ft. long. I find it exceedingly difficult to get a liner of only 7 feet long, in one piece, and the majority of 6 ft. liners are fitted *in two pieces;* the joint of the two liners is rarely *water-tight*, and many shafts have been destroyed by this method of fitting these liners. I trust that Engine Builders will make a step further in the fitting of the liners on these shafts, as it is against the interest of the *Shipowner* to keep ships in dry dock from such causes as defective liners, and I think it will be only a matter of time when the screw shaft will be completely protected from sea-water, at least inside the stern tube; when this is done, I would have no hesitation in using steel for screw shafts.

Though an easier forging than a crank shaft, these shafts are often liable to flaws of a very serious character, owing to the contraction of the mass of metal forming the coupling; the outside cooling first, tears the centre open, as per sketch, figure 14, and when there is not much metal to turn off the face of the coupling, it is sometimes undiscovered; having observed several of these cavities, some only when the *last cut* was being taken off, I have considered it advisable to have holes bored in the end and centre of each coupling, as far through as the thickness of the flange; when the shafts are of large size this is sure to find these flaws out. Another flaw, which has, in many cases, proved serious when allowed to extend, is situated immediately abaft the gun-metal liner in front of the propeller, as per figure 12.

This may be induced by corrosion caused by the presence of sea-water, gun-metal, and iron, assisted by the rotation of the shaft. It may also be caused under heavy strain, owing to the over finishing of the shaft at this part under the steam hammer.

The forgemen in these days of competition and low prices are instructed to so finish that there will not be much weight to turn off when completing the shaft in the lathe; this is effected by the use of half-round blocks under the hammer at a lower temperature than the rest of the forging is done, along with the use of a little water flung on from time to time, and it is remarkable how near a forging is in truth when centred in the lathe and how little there is to come off; the effect of this manipulation is to form a hard ring of close grain about one inch thick from the circumference of the shaft inwards. The metal in this ring is much harder than that in the rest of the shaft, and takes all the strain the inner section gives; consequently when strain is brought on either in heavy weather, or should the propeller strike any object at sea or in the Suez Canal, a fracture is caused at the circumference; this, assisted by slight corrosion, has, in my experience, led in the course of four months to a screw shaft being seriously crippled. Fig. 13 shows a section of a screw shaft found to be flawed, and which I had broken under the falling weight of a steam hammer, when its appearance conveyed to me that it was weakened by the treatment I have referred to. I think more material should be left on the forging, and the high finish with a little cold water should be discontinued.

Doing away with the outer bearing in the rudder post is an improvement, provided the bearing in the outer end of screw shaft in the stern tube is sufficiently large; it allows the rudder post to have its own work to do without bringing any strain on the screw shaft, and in the event of the vessel's grounding and striking under the rudder post, the direct effect does not bear on the screw shaft—it also tends to reduce weight at this part, where all the weight is overhung from the stern of the vessel.

Having placed these experiences and remarks before you, I shall be pleased if some of the members will give the Meeting some information on these important shafts that will tend to their duration and efficiency.

MR. A. BELDAM'S REMARKS—*27th May.*

I agree with Mr. Manuel, that for crank shafting, at least, steel is much more reliable than iron; one reason, probably, that scrap iron shafting is not so reliable as it used to be, is that a great deal of steel is used now for ship-building and other purposes, and the scrap steel getting mixed with the iron scrap, makes the welding of these many thousand pieces more uncertain, as it is well-known the welding together of steel is not so reliable as wrought iron, and that, with the greater number of pieces, a great deal of dirt is collected, and which also prevents amalgamation or solidity.

In the case of steel this is quite different, as the steel is run into pigs, and then a sufficient quantity of the pigs is melted, and the whole run into an ingot; the size of the ingot of course is regulated by the weight of shaft required to be forged from the said ingot (allowing for waste). This process, with care, ensures a clean block of steel, on which the forgeman operates and draws down his shaft. It is essential that the greatest care should be taken in securing a sound ingot, for instance, with reliable firms, such as Vickers', of Sheffield, and other good makers. The ingots are watched most carefully by reliable men, and should a report be given out whilst the ingot is cooling down, it is a sure sign that a fracture has taken place by contraction in the ingot ; this being so the ingot is condemned, as it is certain a contraction crack cannot be hammered together to ensure thorough amalgamation, and a sound forging.

The risk in the manufacture of crank shafts has been considerably reduced by the introduction of built shafts (thus dispensing with the very heavy ingot and forging). The built shaft, in my opinion, has great advantages over the solid forged shaft, as the parts are forged separately, thus making the forging perfectly reliable. Therefore, having reliable forgings, the building of the shafts depends entirely on nicety of workmanship, the right amount of shrinkage to be allowed, and the parts being bored and turned truly ; much has been said about keys in the webs and journals, but in my opinion the whole depends upon the shrinkage, and that, if this is not right, keys are utterly useless. My experience also teaches me that for marine purposes all crank shafts which exceed twelve inches in diameter should be built ; and that, if this course were adopted, we should seldom hear of broken crank shafts.

With regard to Mr. Manuel's remarks as to steel being used for propeller shafts, I quite agree that steel would deteriorate more rapidly by the churning action in the tube, and also by the action of the brass liners, unless the shaft was entirely cased over with brass, which is now in first-class work becoming general.

The paper, put before us by the author, reflects the greatest credit upon him, as the many diagrams and specimens of tests put before us shew us the great amount of trouble he has taken in the matter.

MR. A. J. MAGINNIS' REMARKS—*27th May.*

Before making any remarks, I must express the pleasure I have experienced in being present to hear such an interesting and instructive paper, and being, perhaps, amongst one of the first who had to do with the question of the adoption, or rather re-introduction of the built design of crank shaft for large mail steamers, about fifteen years ago, it is interesting to re-call the very considerable doubts and troubles experienced, not only as to the design, but also as to the mere question of whether they ought to be adopted or not, the almost universal design then existing being the well known solid forged type. Messrs. Vickers made out a design, and I think you will agree with me that it reflects great credit on the gentleman (Mr. Horsburgh, Superintending Engineer of the White Star Line) who adopted a design which has since become almost universal for large steamers.

As regards the propeller shafts, my own experience is almost identical with that so clearly put forward by Mr. Manuel, and the difficulty of casing propeller shafts is certainly very great indeed. I may mention two cases which some time ago were fitted under my superintendence in twin screw steamers, of about 2,000 I.H.P., the shafts were not cased with brass but simply left larger in the stern-tube-bearings, which were of white metal (Fenton's); on each end of the bearings were packing glands, and a pipe led from the interior of the bearing to above the water line, so that thick lubricating liquid could be permanently kept pressing into the bearing and thus prevent the water or corrosive action from getting at the bearing proper. and this, I may add, has turned out a complete success, after some years' trial.

MR. BARRINGER'S REMARKS—*27th May.*

With regard to fitting keys into the webs of built cranks, I think that it is very necessary to do so; for, although the webs might never move whilst the shaft is cold, I have known a case where no keys were fitted and where the web did shift on account of a hot journal, but, on cooling down again, firmly gripped the shaft although slightly out of position. As to tail end shafts, I am of opinion that it is bad practice to lap the space between liners, as I have known the lapping to get loose and cause trouble by jambing when drawing in the shaft to line up the bushes. I may also mention I have seen a shaft when the brass liner was fitted in two pieces, where the water had cut into the iron for a distance of $1\frac{1}{2}$ inches all round at the point where the liners butted, although the joint seemed quite close, and it was only discovered when the liner was taken off in order to straighten the shaft which had been bent by a hawser getting foul of the propeller.

MR. A. GIBBS' REMARKS—*27th May.*

I am pleased that Mr. Manuel has come forward and given us such an able Paper; there are only one or two things I should like to say. Mr. Manuel asks us to express our opinion on outer bearings; I, for one, am of opinion that in most cases where they are fitted the vessels would be better without them. Mr. Manuel also referred to forging wrought iron shafts, and hammering them when they were almost cold. I should think there was nothing worse than that; but often a shaft looks a little black when being finished under the hammer, although no doubt the centre of the shaft is very hot. I am rather surprised that Mr. Manuel has not described to us what he considered the best possible way of preventing corrosion taking place on the propeller shafts, just at the forward side of the boss or the large part of the cone. The White Star steamers have a gland arrangement, and when the propeller is taken off, the shaft is as bright as a new shilling. In my opinion propeller shafts covered from end to end with liners and having two or three joints in the stern tube are not a thorough job; and, unless the joints are perfect, the liners between the bearings would be better off, having only the usual amount of liners with the centre of the shaft bare.

When shrinking on liners they are hot, and when put on to the cold shaft they gradually contract, and the contraction takes place from the end of the liner (lengthways) towards the centre of the liners, and this leaves a small space at each end; this space is usually soldered up. I have often found this soldering bad, and pressed as it were a little full of the brass, if liners on a shaft were getting warm this is what would take place, and if the sea-water once gets in between the ends of the liners there is no telling what is taking place, and you cannot inspect it unless you take off the liners which is rather costly.

Steel shafts are worse than iron shafts; on the steel shafts the water acts more like a knife. I approve of the plan Mr. Manuel suggests, viz.—chamferring off the ends of the brass liners as much as possible when the shaft is left bare in the centre.

Some years ago I saw two ($12\frac{1}{4}$ inch diameter) steel propeller shafts fitted, and they were not long in when they broke—one just abaft the after liner and one just forward of the after liner—they looked as if they had been cut through. These shafts were taken to the works and I broke one up to pieces with a ball, after cutting all round the shaft with a cold set, the shaft being placed on two strong supports, having the cut in the centre. When the ball fell for the second time the shaft broke in two, not where the cut was, nor between the supports, but outside the supports. Some of the pieces of this shaft I had drawn out under the hammer to about a quarter-of-an-inch square, and you could bend it about any way. The shafts that had been taken out of the ship and had done good work were only $11\frac{1}{4}$ in. diameter and made of iron. I would only add there is nothing I would like better than a good steel-built crank shaft, and, when working, to be kept free from sea-water.

MR. D. GREER'S REMARKS—*27th May.*

My remarks will be but brief, and not, I am afraid, of much importance. I have had considerable experience in dealing with tail end shafts and have found that with regard to putting on the brass liners, that it is much the better way to shrink them on; for, although this is probably the more costly method, I always found a better casting and that the liner had a better grip on the shaft.

MR. JAS. ADAMSON'S REMARKS—*27th May.*

I did not wish to rise and speak on this subject to-night, as I have observed several members, whom we cannot expect to be with us very often, taking notes, and whose experience it would be well to hear.

I have proposed to the Chairman that another evening should be set apart for a further discussion on the subject, which has been so well brought before us to-night by Mr. Manuel.

I have no doubt that there are those present who could give an interesting experience in Crank and Propeller, and probably also Intermediate Shafts, not only for the profit of those who are present, but of those of our members who are now tossing on the mighty deep.

Having been called upon by the Chairman, I may remark on one or two cases of Propeller Shafts which have come under my notice, owing to trouble with the brass liners. In one steamer on the homeward run, the whole of the *lignum vitæ* bearing strips were torn out, the shaft was thus running for several days at reduced speed without any bearing in the after end of the stern tube. When the shaft was drawn in dry dock, grooves were found to be cut into the shaft, at the junction of the liners, nearly

1 in. deep. In this case the liners were shrunk on in two lengths, the water had entered at the junction of the two pieces and had gradually eaten away the shaft, causing the brass to become slack and leading to the shaft itself being condemned. Soon after this, in another steamer fitted in the same style and about the same age when examined in dry dock, the shaft was found to be gone almost to the same extent and was also condemned, being reduced below the margin of safety.

There is considerable difference of opinion as to the best plan of dealing with the brass liners. I am inclined to think that the method of casting the brass on the shaft is preferable to shrinking the liners on. Great care, of course, must be exercised in the casting, that nothing may enter between the brass and the shaft to prevent the whole being a solid job.

In reference to the proposal of a continued discussion, I would suggest Thursday or Friday next week, as may be convenient.

MR. MANUEL'S REPLY.—*27th May.*

Mr. Beldam has referred to the great care required in the manufacture of Steel Shafts, and to the watchfulness required when cooling, as the steel might give way in the centre with a crack that could be heard. I think, however, that the same thing applies to iron forgings, for the two metals are much alike in this respect. A mass of iron or steel unless gradually and equally cooled down, is likely to give way in the centre, and I do not think that in any way goes against the use of steel; it shows how carefully Mr. Beldam has given his attention to this detail. We are much indebted to Mr. Maginnis for the interesting remarks he has made, and also to the other gentlemen who have spoken.

In regard to water getting between the cast iron of the boss and the propeller shaft, very little trouble would be experienced if the Superintending Engineer, when inspecting these shafts, sees that the boss is a thorough fit on the shaft cone. A plan which I have found very successful, and which I should be inclined to repeat, is:—After the boss had been fitted to the shaft to bore two holes in the boss to the space round the shaft, and fill the space up with tallow; this, if done carefully, prevents the water—even if the shaft was not a very good fit—from getting to the shaft and so prevents corrosion.

In regard to Mr. Adamson's proposal that the discussion be continued at the next meeting, I can only repeat what has already been said— the proposal is a good one, as I consider this question a most important one, and one upon which as many as possible should give their experience as well as any suggestions which might tend to the efficiency and endurance of these shafts. We must bear in mind also, that while we are exercising our minds in this direction it is not labour that will be lost, it may be the means of saving life and property. We do not think of this sometimes as we ought; and I am sure if we were to go about our work with these views before us, the skill of Engineers in this and other countries would be the means of saving not only property, but life, and what can we do better? I shall, if possible, endeavour to be present at the next meeting. I have to thank you for the manner in which you have received the Paper, and for the honour you have conferred upon me in electing me a Vice-President of the Institute. Let me add that it shall be my endeavour to do my utmost to promote the best interests of this Institute. Our thanks are due to those gentlemen who have brought us together, and who have succeeded so well in forming this Society of Marine Engineers, following the lines of the Institute of Naval Architects. Here we can discuss many important subjects, the effect of which will not only elevate our minds, but fit us all the better for the discharge of those duties we are called to perform.

CHAIRMAN'S REMARKS—*27th May.*

(Mr. J. McFarlane Gray.)

In rising to propose a vote of thanks to Mr. Manuel for his very interesting paper, I would just like to point out that it is of the utmost importance that we should pay attention to the details of every accident which occurs on board a steamer. The breaking of a shaft is providential in the way of your education as Engineers. Great improvements have been made in shafts. By whom? Not by you; not by seagoing Engineers, so you ought to be grateful to those who have worked out these improvements for you and not be too proud to acknowledge how little you have done towards them. Marine engineers, however, have to do with so much complication of machinery on board the steamship of to-day, that it surprises me that more of them do not lose their heads or become incapable from heart disease while on duty.

We are now, I believe, within measurable distance of getting a steel twice as strong as that now used, and of great utility and cheapness, if there was only the demand for it. I have not been so much amongst the practical part of the work of late years, and therefore, my information is somewhat second-hand, as compared with Mr. Manuel's; but I hope ere long to be able to visit steamers more than I have, and to get out of Engineers all the information they will give me, perhaps more than they think they know themselves.

We will continue the Discussion, as proposed, next week, and no doubt members will receive due notice when the evening is fixed.

I have also to thank you for electing me a Vice-President of the Institute; I take a deep interest in it, and wish it all success.

CRANK AND SCREW SHAFTING

IN THE

MERCANTILE MARINE.

CHAIRMAN'S OPENING REMARKS—

(Mr. JAS. ADAMSON).

Continued discussion on 6th June.

In his absence I have been called to occupy the place which, much to his, and I may also say our, regret, our President is unable to take, on account of being called out of town. In order to refresh our memories as to the most noteworthy points in the paper read by Mr. Manuel, who at some personal inconvenience, has kindly come to-night to hear the discussion and reply to what may be enquired—I will give a few of the leading heads, some of which may serve as starting places for discussion and remarks.

Mr. Manuel referred to the difficulty which has frequently been experienced with steamers from the time of leaving the builders' hands, such being indicative of insufficient bearing surface, disproportion of metal in the blocks, or inaccuracy in originally lining off the shafting. As to the original lining off I would briefly refer to a good practice adopted by Mr. Manuel himself, and others, of marking each bearing block and having gauges made, so that at any time it can be seen at glance, how much the shaft has fallen from its original bearing.

I know one steamer of over 1,100 H.P. which has given considerable trouble, both with the main and thrust bearings; the latter especially having very little surface—only one ring =2·1 sq. ft. —required constant attention and a liberal supply of water to keep it working cool; since cutting certain oil grooves in the ring, it has been working better.

The introduction of white metal has certainly been an improvement (for bearings) both in respect to the general working and overhauling.

I may instance one case where a serious flaw was developed in the after crank shaft—No. 4 bearing—the time at command being short, in place of fitting the spare or a new shaft, the forward shaft was reversed with the after one so as to bring the flawed bearing forward, thus making it No. 1—fortunately the shafts were reversible. This shaft is still working in this position, and illustrates Mr. Manuel's remark as to the strains on the respective shafts and bearings.

I may mention the case of another steamer which has now been constantly running for over eight years, the main bearings of which have not been touched during that time, and have given no trouble.

The reference made to the very great increase of work and responsibility which have been added to the duties of the Chief Engineer and his juniors, will meet with hearty response from many of those present, as with electric light, refrigerators, hydraulic and other engines, and the modern appliances fitted with the high pressure steam, the engine room of to-day is very different from what it was a few years ago.

The diagrams and samples, which by the kindness of Mr. Manuel, will be allowed to remain for closer inspection in the reading room for a few weeks, indicate the great interest taken by the author of the paper in the Institute and its members. The extra tests to which the steel was subjected are very interesting.

Reference was made to the paper, read by Mr. Milton before the Institute of Naval Architects, in 1881, in the discussion on which a remark made was repeated, and its value questioned by Mr. Manuel, much to the effect that all credit is due to the engine builders, when all goes well with the shafting, and discredit to those who have charge of the working of the shafting when anything goes wrong.

There is a later paper by Mr. Hector McColl, read before the Institution of Engineers and Shipbuilders, in Scotland, session 1886-7, which is very interesting, and full of information, and will amply repay perusal. The questions arising out of built shafts are dealt with, as the shrinking in of the pins, and keying of same.

In connection with this, I have seen, recently, one or two small shafts, in which the crank pins were turned up with two different sets of centres, *i.e.*, the centres used for the crank pin proper, being different from the centres used for turning the ends of the pin, which are shrunk into the webs; the object is to save pins or keys, and ensure the crank pins against shifting. The names of the patentees I believe are H. and G. E. Fownes; the London Representative is J. H. Taylor, Fenchurch Avenue.

Regarding the propeller shaft, there was one point, which was hardly touched upon in the discussion last evening, viz., the fitting on of the boss. I know one steamer which has given a great deal of trouble on account of the boss being slack, and having to be fitted further on the shaft and refitted nearly every voyage at considerable expense; in this case my impression is that the boss was never a proper fit on the shaft originally, and the sea water getting in to the badly fitted part, gradually destroyed the cast iron, and rendered a good fit impossible. A new boss was fitted to the spare shaft in the workshop by Messrs Stewart, Blackwall, and since then no trouble has been experienced. I may add the taper of the cone in this case was ⅔rds in. to the foot, the metal of the boss had not been destroyed by over-heating in trying to get it off; it usually came off too easily.

MR. SHOREY'S REMARKS—*6th June.*

I should like to ask Mr. Manuel a few questions with regard to fig. 13, which represents section of a broken shaft; and which, he informs us, was broken owing to extra finishing under the steam-hammer, also the use of water during the process.

Having witnessed the forging of several large shafts, also having had the job of turning some of them up, I cannot say that in my experience I have found that the outside of such became contracted and closer grained, through the small quantity of water used in finishing off the forging.

I was always, and still am, under the impression, that the little water thrown on the forging, when finishing, was to cause the scale to become loose and flake, so that it could be swept off with a broom and thus prevent such scale from flying off into the workmen's faces.

It also appears to me that the outside could not become so cooled as stated by Mr. Manuel in his paper; as on such a mass of heated metal, the outside would almost immediately become the same temperature as the other heated part.

When turning these shafts in the lathe, one has not found any perceptible difference in the grain, after the first roughing cut has been taken off, although in some instances a good bit has had to come off; yet, apparently, no difference in the grain could be seen between the first and last cut.

MR. D. GREER'S REMARKS.—*6th June.*

I cannot quite agree with Mr. Manuel's theory that the water thrown upon the shaft in process of forging had anything to do with the crystallization and corrosion near the surface of the shaft—section of which is represented on the diagram. It is my opinion that the deterioration so frequently found between the propeller boss and after end of the liner, is due solely to galvanic action, combined with the continuous vibration and consequent strain on this part of the shaft. I would ask Mr. Manuel, one or two questions in reference to this part of his paper:—

Are we to consider that the failure of the shaft in question was due to the extra finish put on it by the forgeman?

Is there not another cause to which the failure of this shaft may be attributed?

Why should the process of extra finish put on the shaft by the forgeman in order to make a smooth job, be looked upon as hurtful to the shaft?

I may say I have seen one shaft lately which had been broken right off at this part by a barge striking the propeller, and that the broken part looked just like cast iron, and in this particular case the surface was corroded slightly, probably less than $\frac{1}{8}$ in. all round. In speaking of built crank shafts, I agree that if they are properly proportioned, webs strong enough, and properly fitted, there is not much danger of their ever getting slack, but at the same time it is a fact that some crank pins have become slack in the crank, as referred to at the discussion on the previous evening.

MR. RUTHVEN'S REMARKS—*6th June.*

With regard to iron shafts and the process of finishing the surface known as "smithed," to show that it had some merits, I knew of a case where in a line of 7 in. shafting of ordinary make, a new length was supplied, turned out of a larger old shaft,so that nothing but the central portion was retained; it was left about 8 in. dia., on a short voyage the new 8 in. part broke. I conclude from this that the "smithed" portion of the old 7 in. shaft was of some use.

Again, referring to the faulty parts within a coupling, the inference is that the hammer which was heavy enough for the main portions of the shaft, was too light for the extra diam. at couplings. I would suggest that as built crank shafts are so successful, built couplings would give a good result. Regarding the breaking of shafts, that must be expected after a number of reversals of the engine has taken place, especially when done suddenly. I would suggest that a record be kept of the number of times the engine has been reversed, so that with a shaft of known material it might be condemned when its life was up, as is done with heavy ordnance.

If this were done and understood by Navigating Officers, they would know that when many and sudden reversals were made necessary, the life of the shaft was being quickly used up.

MR. W. W. WILSON'S REMARKS—*6th June.*

With regard to the opening remarks by the Chairman in which mention was made of a slack propeller, might I ask if in taking it off at first it had to be fired, as that probably might be the cause of it getting slack? For I am of opinion that if it is necessary to fire a propeller and get it off, the tendency is to alter the shape, and consequently the boss would, in a manner of speaking, require to be refitted on the shaft to make a good sound job. Of course I understand that it is only in extreme cases that firing is resorted to, and as I may infer from the chairman's remark, the fault in the case cited, does not seem to be attributable to this cause; it may have arisen from defective fitting originally, or a bad taper on the cone.

MR. J. H. THOMSON'S REMARKS.—*6th June.*

It is very many years ago since Built Crank Shafts were introduced. I remember the trouble there used to be in the paddle ships with the crank pins getting loose, and I would like to ask if any of the members present have had any similar experience with the modern style of built shafts in screw steamers, or whether the present system and superior workmanship have reduced the liability to get loose; the only instance I noted was that given and referred to by Mr. Barringer at the previous meeting, of a crank having moved three quarters of an inch on the circumference of the shaft.

In reference to the advisability of keying on the webs, or depending entirely on shrinkage, regarding which there seems considerable diversity of opinion, I observe in the paper by Mr. McColl, copy of which has been handed to me by Mr. Adamson, there are several paragraphs dealing with this part of the subject, and as they are *a propos* of what has been touched upon, with your permission I cannot do better than read them.

"The allowance for shrinking should be about one-thousandth of the diameter in steel cranks, but possibly more might be required in those made of iron; this amount of shrinkage will hold well without over straining either the eye or the shaft.

"Some prefer not to key the crank on the shaft, but as it is quite possible for the heat from a warm pin to pass through the webs and slacken them on the shaft it is necessary that they be keyed, and a good plan of doing so is to bore one or two holes longitudinally along the junction of shaft and crank, and to drive in well-fitted steel pins."

Before sitting down I would like to say that when I see so many present whose experience I know to be considerable, and who have not so many opportunities of letting their voices be heard at our meetings together on account of their absence on the sea, I hope some, at least, will give the benefit of their opinions, in addition to the pleasure they have already given in showing their appreciation of the Institute and its objects by their presence to-night.

MR. J. STEWART'S REMARKS—*6th June.*

I was unfortunate in not being present at the last meeting to hear the paper read by Mr. Manuel, and therefore any observations I may have to make are suggested to me by the remarks of the other speakers this evening.

Referring to a case mentioned by the Chairman, in which trouble had been caused by the repeated loosening and necessary refitting of a propeller boss on the shaft, it would be interesting to know what amount of taper there was on this shaft, for this is a matter of some importance. Cases have come under my notice in which continued trouble was caused by the boss working slightly forward on to the shaft, and consequently getting slack, necessitating repeated tightening up of the nut. The taper in these instances was about half-an-inch to the foot, and that it was insufficient, is proved by the fact that since the taper was increased no such trouble has been experienced, and as far as I am aware, the taper about an inch to the foot has always proved satisfactory.

One of the wall diagrams of a propeller shaft, Fig. 11, with linings at the bearings only—suggests to me the question of lining the whole of the shaft inside the stern tube, as is now customary with some builders. The two systems have each their advantages and disadvantages, and I should like if Mr. Manuel would give us the benefit of his opinion aad experience in the matter.

MR. J. SIMPSON'S REMARKS—*6th June.*

Referring to the question of the propeller boss being a good or a bad fit on the cone of the shaft, I know one Firm which has an excellent method of dealing with all their propellers. There is a mandril to which each boss is fitted and the shafts are accurately made to suit this mandril—where the steamers are all about the same dimensions or power—so that when a new shaft or boss is required, the mandril is always available for obtaining the dimensions as nearly as may be, and very much more accurately than by templets, the work of fitting the boss on the shaft cone itself, which is frequently a too hurried job in order to save time in Dry Dock, is thus minimised and more likely to be a good fit.

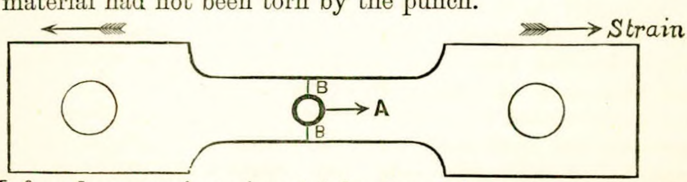
MR. MANUEL'S REPLY, *6th June,* 1889.

Mr. Adamson—after bringing before you some of the leading points in my Paper, read at the former Meeting—refers in concluding his remarks, to the necessity of carefully fitting the cone of the boss and shaft, in order to prevent damage and vexatious delays in dry docks—refitting where this kind of work cannot be so well done as in a factory—and this is getting daily more important, for steamers to pay now, have to be kept constantly at work.

With regard to the taper of the core being ⅔rd of an inch to the foot, ⅝ths of an inch is the general practice; less taper may do, but the propeller having to be disconnected periodically, the taper should have both holding and disconnecting properties.

In reply to Mr. Shorey's remarks as to the damage done to the material of iron shafts by over finishing at the forge under the steam hammer and the use of water, to give a clean and true forging for the purpose of keeping down the weight, and reduce the time occupied in machining; I may again state, that this finishing being done at a lower heat than when forging the shaft, and the blows given affecting only the material next circumference, as shewn by a ring of fine grained metal in fig. No. 13, about an inch-and-half thick round the circumference; whereas the larger and central part has the grain or crystals so large, extending from that ring to the centre, the result of such a marked inequality of the material must affect the strength of the shaft when under strain, the harder parts getting—through their unyeilding nature—more strain than they can bear on the small area of ring, thus causing fracture at the circumference, and when this is begun it is only a question of time before the shaft gives way.

I would illustrate this by a small sketch which represents what I witnessed while testing steel under strain, to discover the cause why a punched hole damaged steel plates, reducing their strength as compared with drilled holes 30°/₀, at the same time its strength was restored by annealing the plate after punching, shewing that the material had not been torn by the punch.



A I found was a ring of metal hardened by compression of the punch, varying in its depth according to the thickness of the plate. When the testing strain was put on the specimen in the machine, the softer and more ductile metal marked B outside of the hard ring A stretched; ring A held on, got the strain, and was fractured, the specimen therefore failed 30 per cent. below what it would have stood if the hole was drilled and no hard ring. The remedy was found in annealing, but it would be difficult to anneal a long shaft and I have never heard of such being done.

As regards the use of the water it seems to reduce the temperature during the operation of finishing more than removing scale, for the latter has been mostly removed beforehand when forging, the close grained ring was caused by the hammer when finishing, the hardening was increased by the water temperature.

The remedy for this: make the forgings rough, but straight and fair, leave $\frac{3}{4}$ in. to turn off at this part, avoid finishing to within $\frac{1}{8}$ of an inch; a shaft to stand fatigue well should be homogeneous throughout. I have to state that the water alone would not cause the ring of close grained iron as shewn in fig. 13, and replying further to Mr. Greer's queries 1, 2 and 3, I have to state:—

Query 1. I do think that the fracture in this shaft was caused by this thin hard ring giving way at sea when under strain.

Query 2. I do not know of any other cause to alter the material as shewn; the shaft was large for the work, considerably above the Board of Trade Rules, and on examination was solid and free from dirt or lamination flaws. The fracture commenced at right angles to the shaft line on the circumference.

Query 3. I think my previous explanation answers this along with the sketch fig. 13, the ring of hard iron, insufficient for the whole strain, first fractures, the result is the whole shaft goes in time.

The remarks of Mr. Ruthven bear out my opinion as to the existence of inequality of material in shafts, the extent of which varies with the diameter and treatment the shaft receives; with regard to the cavity in the forging as shewn in a coupling fig. 14; this was not caused by want of power in the steam hammer but by contraction while cooling, similar to that referred to in Mr. Beldam's remarks on steel ingots.

In regard to the alternate strains brought on crank and other shafts by stopping and starting the engines suddenly, they no doubt in the end weaken the shafts, more especially iron shafts, where flaws and laminations exist; but I do not think it would do to lay down a hard and fast rule for the navigating officer, who on many occasions must act quickly and prevent collisions, &c. The engineer in charge must handle the engines with discretion, and with the powerful appliances he now has, he has time to do this quickly, at the same time cautiously.

Mr Wilson calls our attention to the risk of alteration of the bore in a propeller boss by heating it in order to disconnect it from the shaft. When this is carefully done, I may say I have found no perceptible difference in the bore, the small movement that is required to break contact of the surfaces is but little; the danger in this operation arises mostly from the sudden cooling of the boss, causing its fracture.

Mr. Thompson reminds us of the trouble in earlier times through the crank pins getting loose, but the appliances then existing and the want of special care in the fitting and in the choice of material in some measure accounted for this.

Very great care is taken in procuring machines to turn the shafts perfectly true, and to bore out the eye of the crank, which is more difficult to do truly, but after boring, the bore is scraped up perfectly true to a gauge, so that when heated and shrunk on to the shaft, it bears equally all over.

In eight years' experience with built steel shafts, I am pleased to say I have not found one slack or any signs of it.

Mr. Stewart raises the question of propeller bosses getting slack on the screw shaft owing to insufficient taper. I cannot say this has been my experience, the usual taper of screw shaft cone is $\frac{5}{8}$ths of an in. to the foot and if a good fit and plenty of bearing surface in the boss there is little chance of the screw getting slack, want of bearing surface, especially in the forward end of the boss, where the greatest strain comes, has in my experience led to the boss getting slack on the shaft when there has been too much of the metal cored out in order to give ease in fitting.

Lining the screw shaft all over with a solid liner would be an advantage, providing the engine makers would do this satisfactorily. I have seen much trouble caused and unnecessary expense by the careless fitting of the short liners we now have—the effects of hurried work, one of the greatest troubles sea-going Engineers have to contend with in these days of competition.

I heartily agree with Mr. Simpson's remarks as to the use of a mandril or duplicate of the cone of screw shaft in trueing up the bore of a propeller boss; if this is done and the boss carefully fitted to the shaft afterwards, there is no fear of it getting slack.

In conclusion I have to thank the different gentlemen who have taken part in the discussion of my paper, and for the practical and complete manner they have done so. I trust many such papers will be read and discussed here, for they will tend to advance the art of the Marine Engineer and the proficiency of the Merchant Service.

Figure 1.

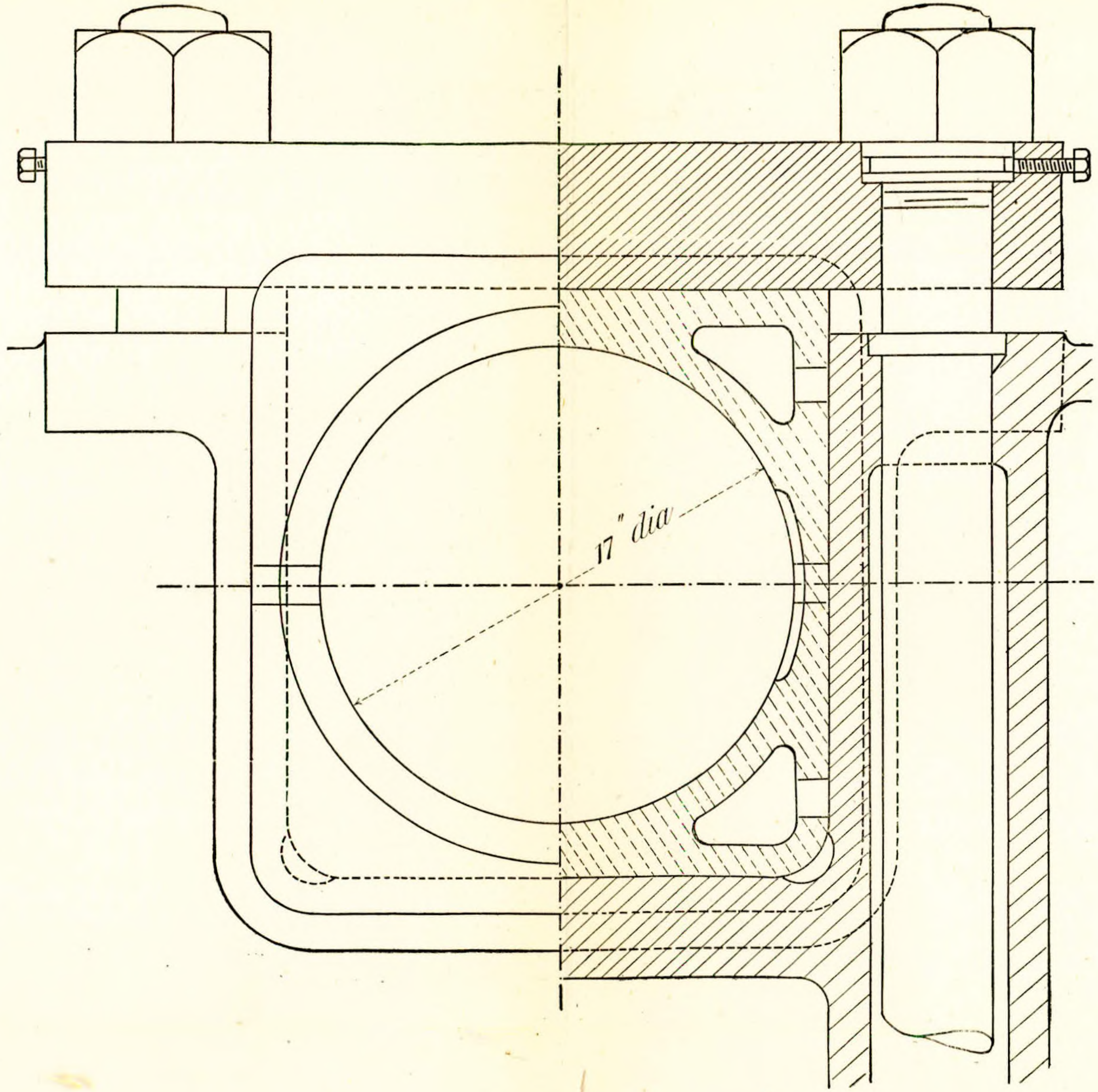


Figure 2.

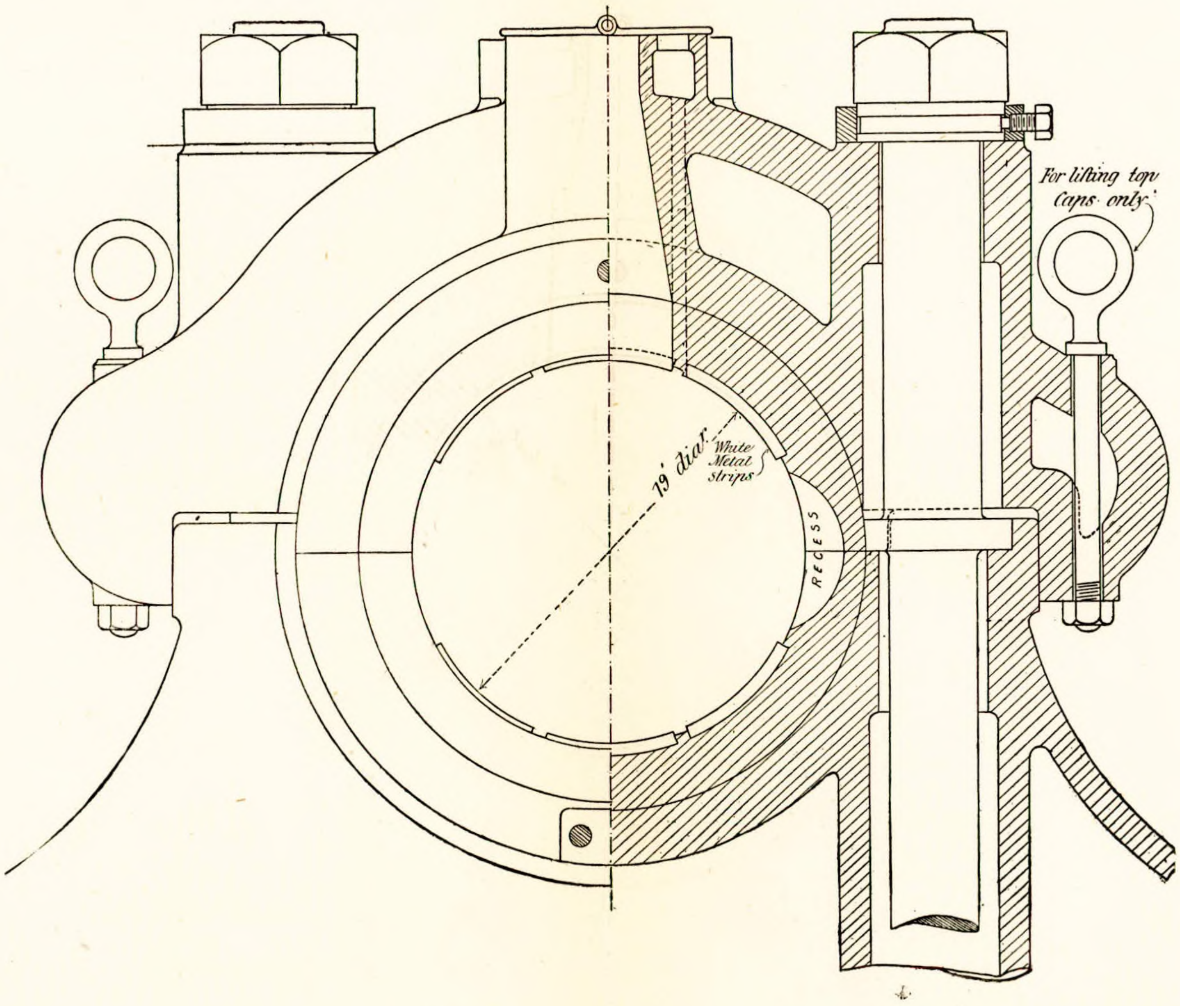
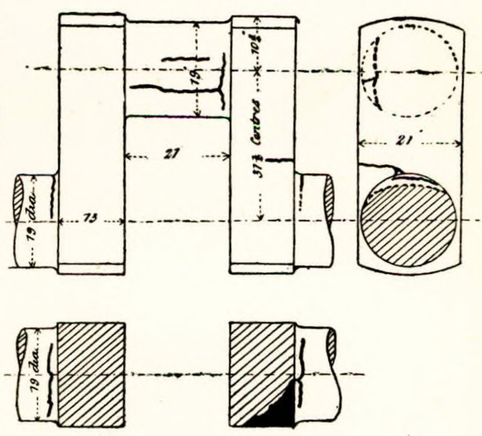
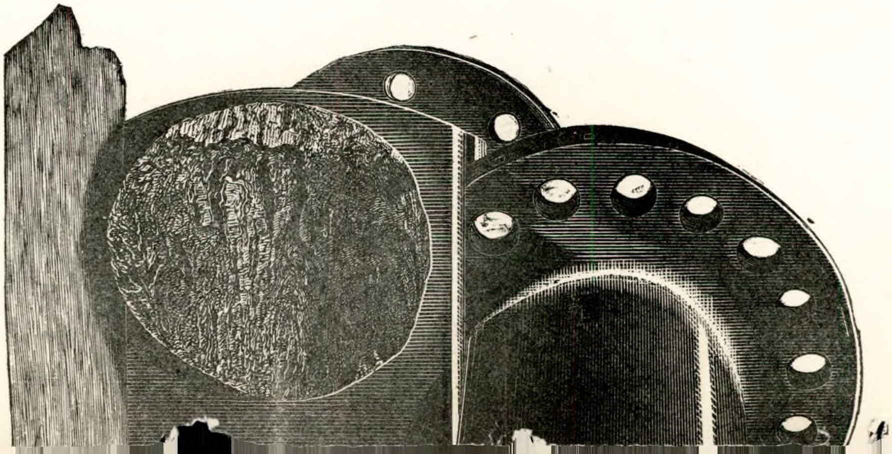


Fig. 6.

Figure 3.





GURE 4.

Figure 5.

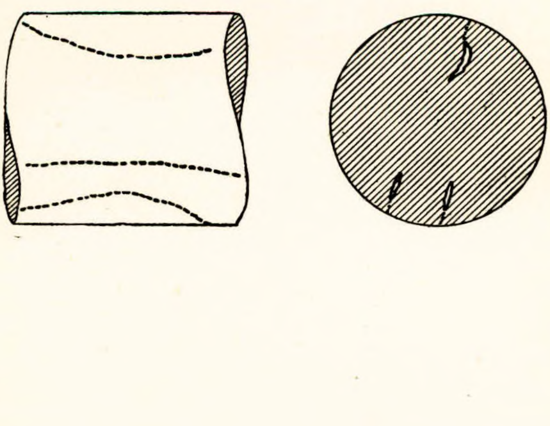


FIGURE 7.

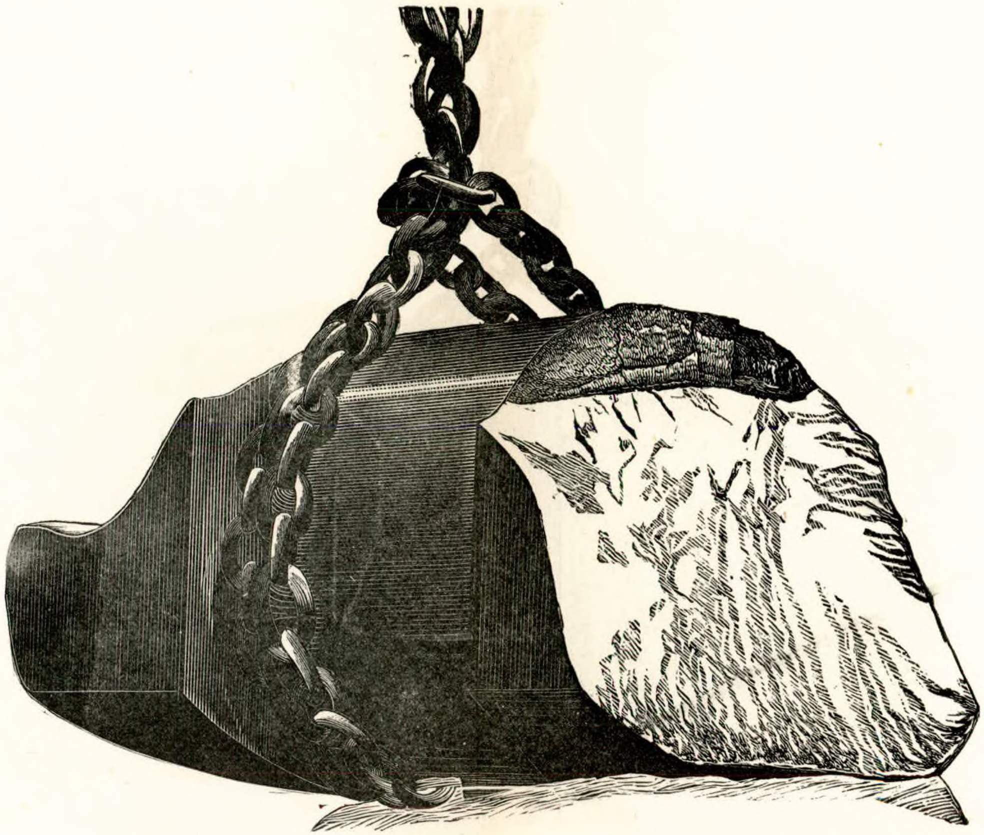


Figure 8.

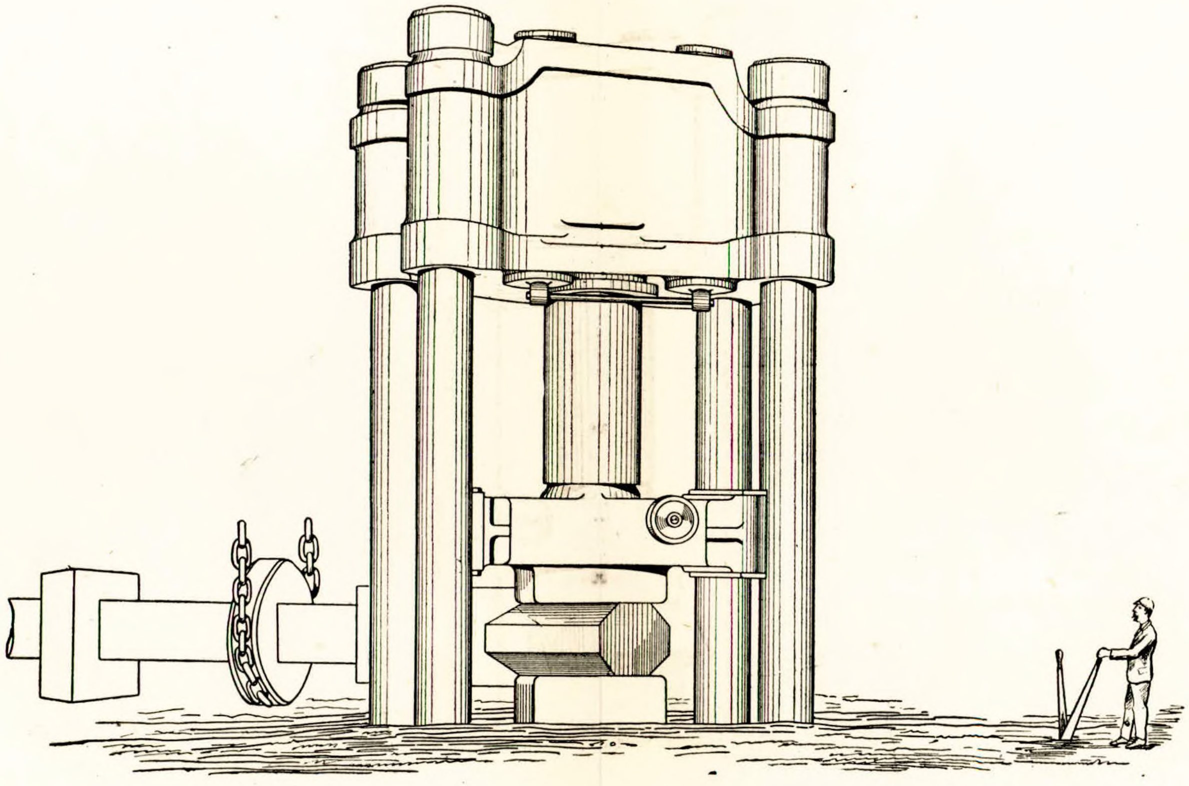


Figure 9.

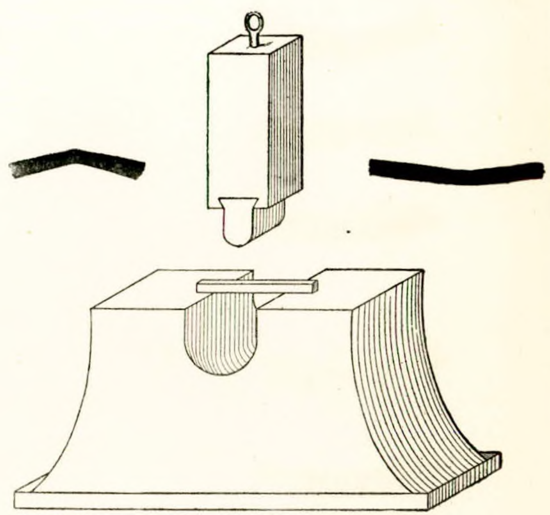


Figure 9a.

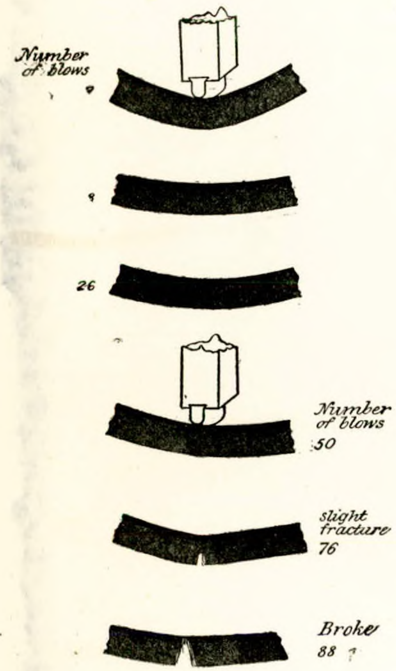


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FIGURE 10.

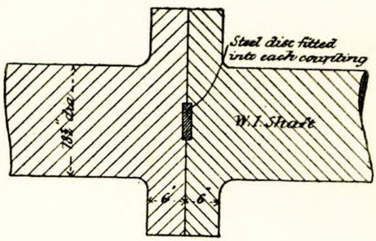
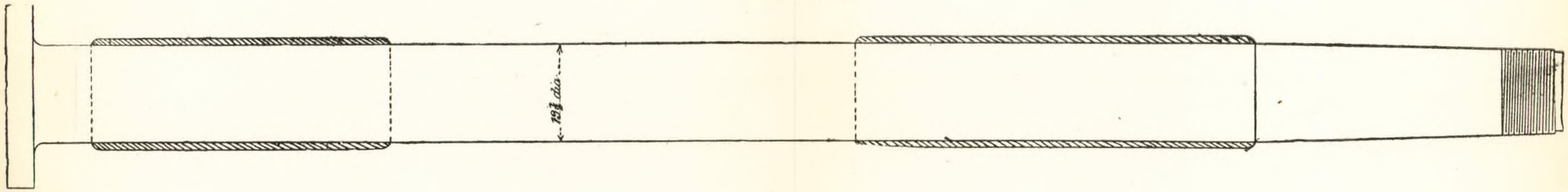


FIGURE 11.



B

FIGURE 12.

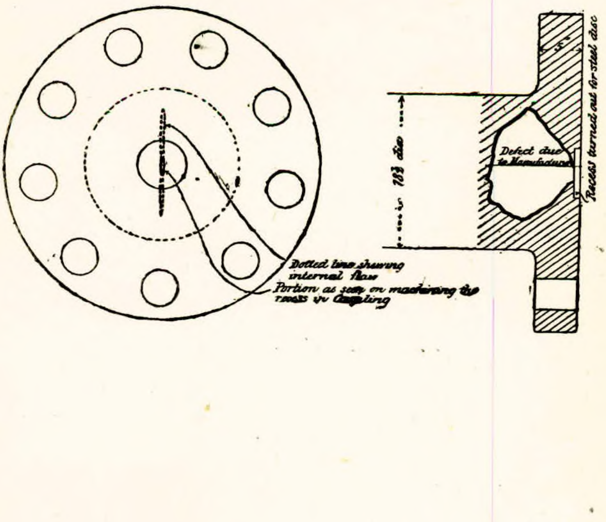

Dotted line shewing internal flaw
Portion as seen on machining the recess in Coupling
Defect due to Manufacture
Recess turned out for steel disc

FIGURE 13.

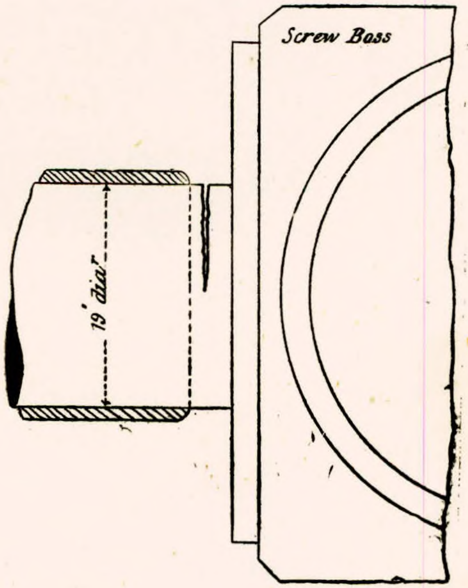
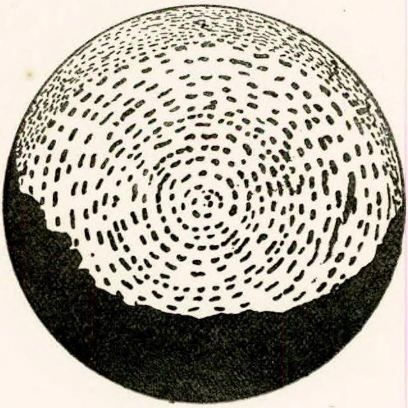


FIGURE 14.



THE LANGTHORNE ROOMS,

15 & 17, BROADWAY,

STRATFORD,

September 2nd, 1889.

A Meeting of the INSTITUTE OF MARINE ENGINEERS was held here this evening at 8 o'clock, presided over by Mr. F. W. WYMER.

Mr. W. J. CRAIG read a paper entitled "*Scientific Tri-Unities*," specially for Junior Members, to whom the following pages are commended as illustrating the interest taken in their welfare, and at the same time affording mental food, which, if well digested, will result in much increase of intellectual power.

It is well to have a recreation study, apart from the study of Mechanical and Engineering Science, and one chosen from amongst those which have been referred to by Mr. Craig, will amply repay any time and attention devoted to it.

The advantages afforded by the Institute to its members are many, and these we hope to see extended and added to month by month. Any volume not in the library, considered to be a desirable addition, will be added on a request being made in writing by two members, if not at once, as soon as the funds admit.

The reading-room and library are open every evening from 5—10 for the use of members and friends introduced.

Each member should enter his home address in the roll book as soon as convenient, if not already entered.

Several experiments have been made with samples of coal on occasional evenings with the testing machine presented to the Institute by Mr. McFarlane Gray.

The General Business Meeting will be held on Friday, Nov. 1st, at 7 p.m.

JAS. ADAMSON,

Hon. Secretary.