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President: JAMES DENNY, ESQ.

VOL. XX.

LECTURE ON THE TREATMENT OF COPPER FOR STEAM PIPES

BY

MR. J. T. MILTON (MEMBER OF COUNCIL),

DELIVERED AT

THE LONDON INSTITUTION

ON

Monday, February 3rd, 1908; *and Monday, February 10th,* 1908.

ADJOURNED DISCUSSIONS

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President: JAMES DENNY, ESQ.

Lecture on the Treatment of Copper for Steam Pipes.

BY MR. J. T. MILTON (MEMBER OF COUNCIL).

DELIVERED AT THE LONDON INSTITUTION

on Monday, February 3, 1908.

CHAIRMAN: MR. ALEXANDER BOYLE (VICE-PRESIDENT).

CHAIRMAN: We are very fortunate to-night in having a paper to be read by Mr. Milton on a very interesting subject to all engineers, "The Treatment of Copper for Steam Pipes." I am sure no words of mine are needed to introduce Mr. Milton to a gathering of marine engineers, neither is it necessary to say a word to ask your attention to the paper he will read, because anything which Mr. Milton takes in hand, any paper which he proposes to read, is sure to be worthy of the most careful consideration of engineers.

Mr. MILTON: After these words from Mr. Boyle the first thing I shall have to do is to apologize and to say that I have not a paper to read, and not having prepared a paper, the subject has not had that great amount of preparation that he implies. As a matter of fact what I propose to give has been expressly described on the syllabus as a lecture. To prepare a paper means a very great deal of time taken out of a busy man's leisure, whereas, to give a lecture, containing as much, if not more, information, does not involve so much labour, and is in many respects a better way of imparting information than a paper. To-night I hope to find that some of those present will discover that I do not know so much as I ought to know about copper pipes, and they will be able to supplement what I have to say. After all, we ought to learn as much as we can with regard to copper and copper pipes. Marine engineers are, necessarily, not always conversant with branches of work not directly connected with their machinery details. They must necessarily be brought up in marine engineering workshops, and in the majority of those shops the copper pipes are not made, but are brought in ready made, and I should like to supplement, to-night, the general knowledge that marine engineers have of how to fit up a copper pipe, by dealing with the subject of copper, not only for steam pipes, but for all other pipes. I shall begin by saying something about copper, how it is obtained, some of its qualities, how it should be treated, how pipes are made and how they ought to be used. Copper is used by marine engineers for pipes only. It is used, of course, as a constituent or alloy for many other purposes—brass, bronze, white metal, etc.—but copper by itself is only used for pipes. During our lecture we shall have to deal with one alloy—that is, the brazing solder or spelter—but chiefly we will confine our attention to copper. Copper is a metal which is very expensive. It is produced from the copper ores by smelting. There are a few places in the world where native copper is found, but nearly all the copper used is made by smelting. It is a very difficult process to separate the copper from the ore by the smelting process, and unfortunately, or perhaps fortunately, while reducing the copper, other elements present in the ore are also reduced, and so the copper thus produced nearly always contains a large proportion of impurities, and those impurities each and all have their effect in influencing the properties of the copper. During recent years, however, progress in electrical and chemical science has enabled copper-makers to obtain copper from ores which our forefathers could not use, as there was not enough copper in them to make it profitable; also from the slag and dross then thrown away, which are acted upon by chemical means and the copper deposited by electricity, giving us electrolytic copper, an exceedingly pure metal. The exceedingly pure copper is not so good for many purposes as the slightly impure, but it is very much better for some other purposes; for electrical constructions, for instance, the purer the metal the better. In former days, the very purest copper made had a certain conductivity for electricity, and that was taken as the standard of perfection, the standard being reckoned as 100. Nowadays, the very pure copper made by the electrolytic methods has enabled us to get still better results, and it is not uncommon to get as high as 102 per cent. of conductivity. Any impurity in the copper has the effect of decreasing the conductivity to an extent greater in proportion than the amount of the impurity. For instance, in a very useful paper given before the Institution of Mechanical Engineers a number of years ago on the Alloys Research Committee's Report, statements were made by Mr. Wm. Dean of the conductivity of certain coppers, and taking 100 as the standard, in some coppers the conductivity fell as low as 22; that is to say, nearly five times as much copper would have to be used in making a wire as in the pure copper to give the same amount of conductivity. Now that copper had a total purity of 98·9 per cent., just over 1 per cent. of impurity, and yet the conductivity dropped from 100 to 22. There are other coppers mentioned in the paper which are not quite so bad, but there is one, with a total purity of 99·828 per cent. where the conductivity is only 69. It will therefore be seen that pure copper is exceedingly useful for electricians, but impure copper is better for ordinary work. When I say "impure," I do not mean containing *any* impurities, each of the impurities, arsenic, antimony, bismuth, lead, silver and other elements, has its own effect upon the copper. Of these the most useful is arsenic, and some of the best copper used for locomotive fireboxes and other purposes have contained at least as much as ½ per cent. of arsenic. Mr. Dean, the locomotive superintendent of the Great Western Railway, gives in the paper I alluded to, remarkable results of tests showing the durability of the copper in eighteen cases that he investigated, and he found that the ordinary copper was always best. In every one of the locomotives where the copper for the fireboxes stood well, it was not classed as pure copper, and the conclusion to be derived from this is that the presence of arsenic, at any rate, is not a disadvantage. Arsenic is a great disadvantage for some other purposes, which we shall see presently. Bismuth, however, although chemically somewhat similar to arsenic, is exceedingly deleterious in copper. If there is 1 part of bismuth in 1,000, the copper is rendered absolutely useless for mechanical work. Although the total strength might not be much reduced when cold, when at the temperature of boiling water it is enormously reduced, while with high pressure steam it has not one-tenth of its value, and not only is the strength gone but it is exceedingly brittle. The reason why bismuth makes it so brittle was for some time a mystery. Professor Roberts-Austen thought he had solved the problem by some experiments he made on the cooling of copper containing bismuth, but he did not thoroughly explain as much as was afterwards discovered with the microscope by, I think, Professor Arnold. Bismuth has a similar effect on copper to that on silver, and one of the marvellous things about the action of bismuth is that if a piece of silver is melted up with bismuth in the proportions of 1 part of the latter to 1,000 of silver, the result is that the silver becomes extremely brittle, and if it is tapped with a hammer it will break into small crystals. Each of these crystals, however, is very ductile and can be drawn out into a long, very fine wire. The bismuth has a similar effect upon copper. The copper when liquid dissolves up the bismuth as salt is dissolved in water. As the copper cools part of it solidifies or freezes. If you take salt and water and begin to freeze out, the resulting ice, although it is not absolutely pure, is much purer than the water was originally, and as the freezing continues, there is more and more salt left in the water not yet frozen. This takes place until the little water left comes to a certain degree of saturation. The same thing happens with bismuth. The copper, while fluid, contains bismuth in solution, but when solid it will not contain bismuth in solution, and so when the melted copper solidifies, the little parts first frozen out are pure copper, leaving the remaining molten copper richer in bismuth. The copper thus crystallizes out piece by piece, until at last the crystals begin to touch one another, and in the end the little liquid left between the various crystals is pure or nearly pure bismuth, and when the copper is struck the bismuth cracks up, and the copper separates out into the crystals. Many of the other impurities in copper are not so deleterious as bismuth. The old Cornish copper, from the nature of the ores from which it was made, contained arsenic, and it was long an article of faith among coppersmiths that the old copper was good and the new bad. The fact is that the old copper was impure, but it contained impurities which had a good effect; there is no doubt that the new is purer than the old. For brass-making it is very desirable to have pure copper and electrolytic copper is useful for this purpose. Copper containing arsenic does not make good brass; I am unable to say why. Brass-makers, makers of alloys, have a very good workshop test for copper, and can tell by this means if there is the slightest trace of arsenic or antimony in it. The method adopted is to take of the copper that they wish to test 60 parts by weight and of pure zinc 40 parts by weight. These are melted together and a Muntz metal formed—"60, 40" is the term used. This Muntz metal is cast into a cake about 1 inch thick in a cast-iron ingot mould, and cooled, the usual size being about 4 inches square. When cold it is taken out, nicked, and broken with a hammer, when an examination of the fracture tells at once whether it contains arsenic or antimony. If it is good it has a very even silky fracture, while in the bad metal the fracture is of a very different crystalline character. The curious thing about it is that when they are both polished up one could not tell the difference between the good and the bad from the appearance of the metal. The metal used to make alloys is tested in that way, and is called "best selected copper." But best selected copper in ingots is not necessarily best for good sheets, and copper good for sheet copper is not necessarily good for alloys.

The next point in connexion with the manufacture of copper is a very interesting one. It is a chemical process, but one not generally known because as I have already said, engineers either get the sheets and tubes finished by the copper-makers or else buy the pipes from the coppersmith ready made, and the methods of manufacture do not appeal to them. In the manufacture of the copper there is a very important process called "poling," and that process is one I want to refer to specifically, because the principle involved ought to be known more generally. The copper when smelted lies in a molten condition in a bath at the bottom of the furnace. The air going over the furnace contains an excess of oxygen. Copper at a high temperature has an exceedingly great affinity for oxygen and the top of the molten copper becomes oxidized.

There are two copper oxides, the cuprous and the cupric, but this we are speaking of is cuprous oxide, which forms very rapidly, but as soon as it forms it is dissolved into the copper. Molten copper dissolves copper oxide just as water dissolves salt. In time the copper becomes saturated with the oxide, and when it reaches the saturation point it can dissolve no more. Well, if you had the most excellent copper that could be made in a molten condition saturated with the oxide dissolved up in it, and then cast it, it would be a very brittle product. The oxide of copper, therefore, when in excess takes away the ductility of the copper. It is got out by the method of pushing into the molten copper a pole of wood—I am told by some that any kind of wood will do, but copper-makers prefer a birch or beech-pole. When this pole is pushed into the molten copper the heat of the copper causes the pole to distil off gases and steam, which bubble up through the copper. The red-hot charcoal of the pole has a greater affinity for oxygen than the copper has, and the hot gases also have a greater affinity for it, so between the two they speedily reduce the copper oxide, and in this way the whole of the oxide may be got out of the copper. But it appears that, although the copper oxide in excess is a very objectionable constituent of copper, when it is present in a slight degree it is very beneficial. Every different impurity has its own effect on copper. Some have the effect of making the copper less ductile than it should be, but the more impure the copper the more oxide is required to correct the want of ductility, caused by the impurities, and thus the copper has to have a little oxide left in it to make up the maximum ductility. If the copper is absolutely pure, no oxide at all is required, as it is very ductile and copper oxide would take away this ductility, but for ordinary copper some oxide has to be left in. When it is sufficiently "poled" the workmen take out a small ladle-full and cast a small portion of it, nick it and break it off, and are able to tell from the fracture whether it is ductile or not, and to tell what degree of oxidation is required. This is the case where the skill of the workman is of more value than the skill of the chemist. If it is not sufficiently poled the pole is pushed in again, if it has been overpoled and there is not sufficient oxide the process is delayed until a little more oxygen is absorbed. When the copper is cast into ingots, in what is termed "tough pitch" copper, the top of the ingot is left smooth ; if it is "overpoled" or underpoled the surface is no longer smooth. The workman can always tell at sight from the surface whether it is "tough pitch" or "overpoled" or "underpoled." "Tough pitch" copper for pipes and sheets used by engineers is made in this way and may contain arsenic and other impurities. In the paper by Mr. Dean, he gives the amount of oxygen recorded in the different kinds of copper used in the locomotive fireboxes. In some there is ·076 per cent., and in one instance it is actually up to ·248 per cent. One sees, therefore, that the amount of oxygen is very varied—it varies with the ingredients in the copper—but only the practical man can tell what this proportion should be. I want you to thoroughly understand the poling of copper because I wish to refer to it in my next lecture, as the effect of oxygen and of reducing flames upon copper is not so generally known as it should be. In making sheet copper, the copper is first cast into slabs and then rolled out while hot, in a similar manner to that in which boiler plates are rolled, to a certain thickness, but all subsequent reductions in thickness are made by cold rolling. When this is done a great deal of work is put upon the material, and I do not think I need say that the amount of rolling which a metal undergoes has a great effect upon its strength and properties. In the question of determining tests for different qualities of copper, there is one point nearly always forgotten, which I think an exceedingly important one. One of the questions which should be asked in every case is, how much work has been put on the copper? In the case of the locomotive fireboxes which I have mentioned this question was never asked, and when we see that in some cases the copper stood for some 500,000 miles and in others it failed at less than one-tenth of that distance, it is very evident that there must be something seriously wrong in the quality of the copper, and it is quite possible that it is not so much the difference in the composition of the metal as some other cause that would account for such an immense difference in the running. I think it is very likely that some of the copper was better worked whilst being made into plates than some of the other plates. Of course there is also the question of the flanging and the other work in the boilershop and the defect might have happened in the smithing.

It may be interesting to know how pipes are made. Nearly all the pipes of small diameter used by engineers are the "seamless" or "solid drawn" kind, as it is called; "seamless" is the proper term. Seamless pipes are made in two or three different ways, but I will first mention the way I have seen them made in a works which, if they are not the best works in the country, are certainly in the first rank. The copper is melted in a furnace, and in melting it picks up the copper oxide. It has to be "poled" over again, and when it is exactly right, it is cast in a suitable mould, the molten copper is subjected to fluid compression and afterwards hydraulically forged from a solid to a hollow shell. The hollow shell thus produced is machined and then subjected to a series of cold drawing operations. The shells are then put on a mandrel and drawn through a hole smaller than their outside diameter to give them a good squeeze. This thins them down and makes them longer, but it has also made the copper harder. The tube is then pulled off the mandrel, put into a furnace and re-heated to redness, again cooled and again drawn to a smaller size. This process is repeated several times and its sectional area is reduced very many times by repeated drawings before the pipe is finished. I impress this upon you because I think work is a very important matter in the treatment of copper, and has the effect of reducing the size of the crystalline structure very much. Pipes are sometimes made in a very different way. One method is by first casting the pipe. The cast pipe, I believe, is bored and turned, although I am not quite sure. It is then made hot and put on a mandrel and passed several times between rollers with various-sized grooves cut in them. After it has been rolled down hot to certain sizes it goes through the same cold drawing process as in the other case. There is a very great difference in the way copper is annealed at different works. It is a singular thing that although copper has been used from time immemorial—it was one of the first metals used—yet at the present day we do not find unanimity as to the right temperature to which to raise it in order to anneal it. At one works it is raised to a very high temperature, at another it is made only just visibly red.

Brazed copper tubes are made in a rather different way to the seamless tubes; they are made from copper sheets. The sheets are rolled into long narrow strips, the edges are thinned by machine and the sheets are then bent up and folded into tubular form. They are then loaded with brazing solder and borax all along the seam. Each tube is then passed through a furnace, the speed of passing it through and the heat of the furnace being regulated so that the brazing solder just melts and forms the joint. After this the tube is generally given one draw on the draw bench. Very good tubes are made in this way and a brazed tube very often stands as high a test as a seamless one, but there is just the possibility of the brazing not being good in some places, and it is for want of reliability rather than for want of strength that brazed tubes are not so much used. For large pipes brazed tubes seem to be preferred to seamless, because in seamless tubes there is not, necessarily, the same amount of work put on the metal of large pipes as is the case with small ones, but particularly from the fact that in the large pipes made from large ingots, there is more possibility of having blow-holes in the ingots, which in the drawing process are drawn out lengthways into longitudinal defects.

One other way of making pipes, used in days gone by and afterwards discarded, but which has come into vogue again and probably will be discarded again, is the electrically deposited pipe made by the Elmore Company. A few years ago it was very much used because it was as easy to make the largest possible pipe as the small pipes, perhaps even cheaper, and when it was impossible to obtain large seamless pipes by any other process, the Elmore Company did it and at a very reasonable price. They were used to a large extent in the North of England, but unfortunately they did not seem to last very long. They gave very much trouble when in use, and at last two important firms that had used them took out every Elmore pipe they had used, or at least as many as they could get out, and replaced them with ordinary pipes rather than run the risk of a disaster. Recently some improvements have been made in the manufacture of the pipes, and it is claimed for them that these pipes are now satisfactory. I will mention how they are made. The copper from which they are made is cast into long strips, and three or four or more of the strips are placed in the bottom of a bath, which is the length of the pipe required to be made. The bath is filled with a solution of sulphate of copper. The copper strips are connected to one pole of a dynamo and the other pole is connected to a mandrel immersed in the bath. The mandrel is made of metal covered over with a surface polishing of blacklead, polished with a great degree of skill and perfection so as not to show the least scratch or flaw. The blacklead is a conductor of electricity. The mandrel is made to revolve, the electric current is turned on and electrolytic action begins, the copper from the sulphate is deposited all over the blacklead, an equal quantity of copper taking its place from the bars put in the bath so that the sulphate solution remains of the same strength. Along the mandrel, while it is rotating, a burnisher slowly traverses from end to end, backwards and forwards, so that every particle of deposited copper is burnished. The little crystals become flattened out of shape, others are flattened on top of them, and after many hours, in some cases hundreds of hours, a tube of copper is obtained of the desired thickness, of a beautiful colour, beautiful surface and very smooth—it does not feel a bit like the ordinary copper to the touch—and that copper will stand any mechanical test to which it may be subjected ; it will stand a good hydraulic pressure, it stands good tension and extension tests, it can be doubled up close like soft lead, it can be doubled three or four times over, but when made into steam pipes it does not appear to have the necessary ductility. The copper originally used is not pure, but the impurities are left at the bottom of the bath. They get the pure copper out and leave the impurities in the sludge which accumulates in the bottom of the bath. They prefer to use copper containing small quantities of silver and gold as impurities which are left behind in the form of sludge. A great deal of commercial copper contains gold and silver in small quantities. The improvement they have made is that they put some work upon the pipes, and instead of using the electrolytic pipes as they are made, they are finished by being drawn down upon a mandrel. The amount of work put upon them in this way, however, is not anything like the quantity when made in the ordinary way, and the pipes made by the improved process are not altogether satisfactory—in fact, in some cases they are the reverse of satisfactory—and the people most concerned are beginning to realize that purity of copper is not a good thing for steam pipes, however useful it may be for other purposes.

I mentioned that copper has to be annealed. It has to be annealed after any considerable amount of work has been put upon it. The mechanical properties of copper are such that when it is annealed it is an exceedingly soft metal, but when it is worked in any way it becomes harder and loses some of its ductility, but still it ought to retain a good deal of ductility, even after considerable work has been put upon it. But the chief thing engineers want in copper pipes is that they shall be able to withstand a considerable number of repetitions of small changes of form. If one wishes to break a piece of wire one cannot pull it apart, but it can be broken by successively bending it backwards and forwards many times. This holds good with most metals, but with copper we want a metal that will stand a number of these wrigglings without giving way. Another reason why it is used for steam pipes is because it does not rust with the action of the water. When I say it does not rust, I mean generally speaking; sometimes it does waste rapidly, but we shall treat of that in our next lecture. With regard to mechanical tests, I may say that the Admiralty, during the last fifteen to twenty years, have been going through a series of changes in their ideas on copper. At one time they were very much alarmed at the frequency with which failures of copper pipes occurred, and as a way out of the difficulty they specified stringent tests in order to get pure copper. But this was found to be quite as bad as the impure, and now in the specifications they allow a certain amount for impurities, not very much, they ask for 99·3 per cent. of pure copper, allowing ·7 per cent. for impurities; that is, they allow this for impurities, but the copper-maker may put in pure copper if he likes. The mechanical test is a tensile test of 13 tons per square inch, with an extension of 35 per cent. in a length of 2 inches. A good deal of copper will stand over 14 tons and 45 per cent. extension, so there is no doubt a good copper will have no difficulty in standing these tests. The bending test they ask for, and this is a thing they should not ask for, is that the unannealed copper should stand bending until the space between the two arms of the bend is twice the thickness of the copper, without the sign of a crack on the outer edge. I say

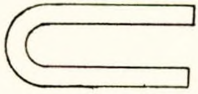

FIG. 1.

BEND TEST OF UNANNEALED COPPER.

a test of that kind should not be asked for, as there is no definite standard of unannealed copper; it may be much worked or it may be only a little worked so as to be in a nearly annealed condition. The annealed copper has to be bent absolutely close without the sign of a crack on the edge, then afterwards

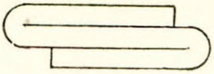

FIG. 2.

BEND TEST OF ANNEALED COPPER.

it has to be hammered down to a feather edge at the bend without sign of a fracture. That is the Admiralty test, and

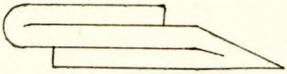

FIG. 3.

BEND TEST OF ANNEALED COPPER, ONE EDGE AFTERWARDS HAMMERED COLD TO FEATHER EDGE.

it is a test for copper that should be used in every workshop. With annealed copper, when a stress is put upon it, it is found that it has very little, if any, elastic limit, if a little more stress is put upon it it stretches more, and so on. If you take an ordinary stress diagram of copper, starting with a piece of annealed copper and stressing it in the ordinary way, you will find it will come out something like this :—

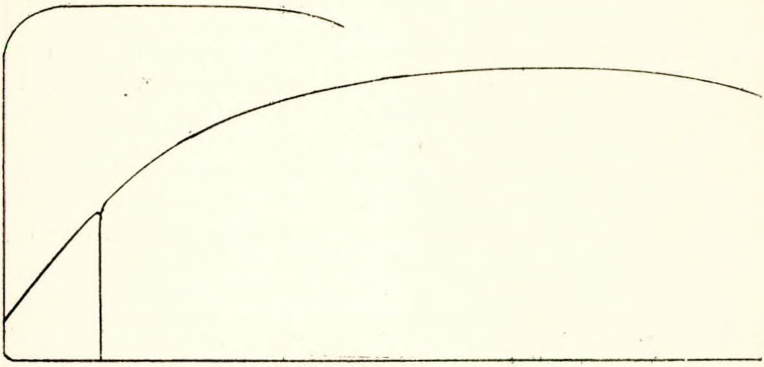

FIG. 4.

Now if that were a piece of steel or iron you would find the curve representing the extension proportionate to the stress put on up to what is called the elastic limit, which is generally more than half of the ultimate stress, but this curves away almost immediately from the beginning, so that in copper a permanent set is got almost immediately. Go on stretching it up to say 4 tons per square inch, and after having put this stress on it let the strain off and you will find that you have produced a permanent elongation. After it has once been stretched by a particular load you can put a strain on it up to that amount without giving it any more permanent set What you have been doing is that you have been hardening it. When it is again annealed you take away that hardness and the stress and strain diagram comes back to the original. When a bell-hanger uses copper wire he wants it to be of invariable length; he obtains annealed wire, fastens one end of the wire up and pulls at the other with all his might, stretching it a very perceptible amount, and after that he finds that the wire is perfectly elastic up to the stress he had put upon it. The same thing happens with copper generally. When dealing with copper the only way to get a fixed definite degree of hardness or softness is to get it annealed. Any test, to be anything of a standard, should be of annealed copper. With regard to steam pipes, these should be flexible and the copper should be annealed when delivered. You do not want a hard pipe. Years ago the coppersmiths used to make all pipes quite hard; they had a great pride in the appearance of their work and used to planish the pipes all over. A planished pipe, although it may be good for an exhaust pipe, is not good for a steam pipe. The next question which occurs is, what is annealing? Well, as I said, in the manufacture of copper tubes we do not find even among copper-makers unanimity as to the right and proper way of annealing copper. At one works they are exceedingly careful to raise it to a very high temperature, at another works they do not raise them quite as high, at another they are raised to only a very dull red. If copper is raised to a very dull red it is softened, but is not quite so soft as it should be. A bright red heat is probably best. The brazing on the flanges of a copper pipe requires to be heated to a bright red, and the temperature necessary for brazing is, at any rate, not too high for copper when it requires to be annealed. Another point that might be mentioned with regard to annealing copper and most other metals is that it does not matter whether they are quenched out from the annealing temperature or allowed to cool down gradually. Steel and iron are exceptions to this rule, but with copper the same annealing effect is produced either way. From some experiments that a friend of mine has been making, it appears that the results are somewhat in favour of quenching, but I should not like to say that that is always the case without having more proof than I have now.

Up to the present I have said nothing whatever about the design of steam pipes. I propose to keep that for my next lecture. We shall then go into the making of pipes as we use them, and I shall refer to one or two things which it is important to know. I shall also show a few samples of some curious experiences with copper. To-night I have dealt with copper as copper only, but I shall be glad if anyone will ask any questions they may wish to put or tell us something about the subject which they think would be interesting.

CHAIRMAN: It appears that I used the word "paper" instead of the more accurate word "lecture" in referring to what Mr. Milton was going to give us to-night, but I think you will all agree with me, after listening to Mr. Milton's most interesting and valuable remarks on the subject which he has spoken about, that it does not matter to us as engineers whether we call it a paper or a lecture. The lecture has been so full of information that I do not think there are many gentlemen in this room, even if they are experts in copper, but will carry away something that they did not know quite so well when they came in. Many points that were familiar to us in a perhaps somewhat hazy way have been made clearer by the very plain and definite manner in which Mr. Milton has explained them. I am sure there are gentlemen present who would like to say something in reference to the subject before us, and as Mr. Milton has invited questions, I think the remainder of our time this evening could not be better spent than in having the opinions of others who can give us their experiences and perhaps throw some more light upon one or two of those points on which opinions may differ. Perhaps Mr. Brown would say a few words to open the discussion.

MR. AITKEN BROWN (Companion): I am not prepared to speak on the subject to-night, but I must certainly thank Mr. Milton for what he has put before us. I only wish that it had been a paper printed beforehand instead of a lecture, so that we could have prepared ourselves for a discussion upon it. As you know, it is rather difficult to take notes and listen to the lecture at the same time. Several things Mr. Milton said have been very interesting to me, and I should have liked to hear a good deal more upon them than he has mentioned. As far as deposited copper is concerned, I was not aware until to-night that they intended continuing with that process. Deposited copper never stood the test it should have stood, and the very impurities left in the bath, referred to by Mr. Milton, were the very elements required to make good copper pipes. We all know that pure copper is not good for copper pipes; in fact, I think it would be better to have a higher percentage of impurities than the ·7 per cent. which Mr. Milton spoke of, and if we put it at 1 per cent. or a trifle more, the copper would stand a good deal better. With regard to the test of bending the copper and hammering it out at the bend to a feather edge, no doubt that is a good plan, but could one be certain that there was no dirt in the bend? It is not quite a fair test, as the least dirt getting into the copper might do a lot of injury. With reference to the different processes of making solid drawn tubes, there is no doubt the works referred to is one of the best in the country, but there is very little difference all over in the process of making solid drawn copper tubes. The important point is in having the dies true in the first place. We that use copper pipes continually will very often see a ridge right down the pipe, and when it is annealed or bent, it sometimes splits or cracks across.

Mr. Milton: I trust you will excuse me for interrupting, but when you say it "cracks across," do you mean that it cracks down the pipe or across the pipe?

Mr. Brown: We have seen them crack both ways, but generally it cracks across. We have seen them cracked down to 2 inches where there was a reed in the pipe due to a fault in the die. As to the annealing, I am not prepared to agree with Mr. Milton about the heat to which the copper should be subjected. It is very well for him to say that when brazing a flange it undergoes a certain amount of heat, and if the flange in the copper will stand that heat, the pipe itself will stand it, but there are different processes of brazing copper pipes. The process used at one time we would not think of using to-day. We do a good deal of our brazing to-day not only with the ordinary fire, but with oxygen gas. We put the flange over the fire, get it to a good heat and put the oxygen gas on the top of the flange so that there is no chance of burning either the flange or the pipe. I think it would be better if more of that kind of brazing were done. Of course it is more expensive, but it is more effective and makes a far better job. I am sorry I have not more to say: had I a copy of the lecture beforehand I should have been able to speak more fully, but I must again say that we are all very much indebted to Mr. Milton for the very valuable lecture he has given us to-night.

Mr. D. Hulme (Member of Council): I came here this evening with a thirst for knowledge, and, as Mr. Brown has stated, not expecting to make any comment at all, so that I will reserve any remarks or questions until I have heard the further part of the lecture.

Chairman: I am sure that Mr. Milton has travelled over so much ground that without anticipating what he may say at the second part of the lecture there is ample material for remarks to be made by any of the gentlemen present.

Mr. Geo. Adams (Member of Council): I must add my quota of thanks to Mr. Milton for the admirable lecture he has given us, but I would prefer to hear more remarks from the lecturer before entering into the discussion. Mr. Milton has described in a most comprehensive manner the manufacture and qualities of copper itself, and the three ways in which copper pipes are made: the seamless, the brazed, and the electrically deposited processes. Reference has been made to coppersmith's work done by hand. Recently I had the privilege of seeing some of the copperwork made by hand for one of the large Cunarders, and it was quite a pleasure to stand by and see the coppersmith at work, moulding and shaping the graceful bends and curves, particularly for the expansion bends, all of which exceed in dimension anything of ordinary practice; so large, in fact, that they had to be made by hand for that reason. In reference to copper pipes, from what I have been able to gather from Mr. Milton to-night, I think he and most of the gentlemen who have to deal with copper steam pipes in steam-ships will agree with me in the advisability and necessity of periodically annealing all steam pipes in steamers, as well as the necessity of testing them from time to time; that is to say, of course, a test beyond their ordinary working pressure, as a dislocation of the molecules of copper must take place in time, due to strain and stresses caused by the vibration constantly going on in steamers. With regard to the way in which seamless pipes are made, I had the pleasure once of visiting one of the bronze works, and I saw there that the manganese bronze tubes for ordnance purposes, were made in a similar manner, by first casting the ingot, then casting the tube which was afterwards bored inside and turned externally to get the perfect regularity of section, and also to discover any flaws that might be present before rolling out. As to the purity of copper sheet itself, that is somewhat of a complex question. I do not know whether there is much in the suggestion, but perhaps the money market may have something to do with the quality of copper pipes. Now and again I have seen copper pipes which, when subjected to analysis, were reported upon as good commercial copper. There was a very strong action of pitting or corrosion going on internally, and when they were examined inside it was found that this was forming small cup-shaped depressions or honeycombs in the material. That result we did not find say twenty years ago, so that one is inclined to think that the quality of the copper then used was better than it is now.

CHAIRMAN: Were those salt-water pipes?

Mr. ADAMS: Salt water only, these were not steam pipes. Mr. Milton's lecture has kept our attention all through, but I think we would rather hear lecture number two before asking questions. I should like to thank Mr. Milton very much.

Mr. D. MCNAUGHT (Visitor): I have listened with very great interest to Mr. Milton's lecture. At one part he mentioned about the electro deposited copper pipes, and I think one of the previous speakers said that he did not know they were still being made. I might say that the Elmore Company is still in existence, although they have not works in this country. The works are in Germany, and I do not know why there is not a place here, as there are some cases where the deposited copper is better than the solid drawn or brazed. For instance, in the place where I am engaged we have a hydraulic press. At first we had a brazed copper liner which gave us a great deal of trouble, and we had no means of covering the ram with copper. In the present press the liner is of deposited copper, and we have the ram also covered with copper deposited by the Elmore Company and these have not given any trouble. We have also had some trouble lately with the ordinary ball float. We fitted several of these, made in halves and brazed together, and found that three-quarters of them have failed during the last year through the brazing. We had to go to Elmore's —I am sorry to say that we had to send the work out of this country—and get a ball with deposited copper on the outside. These are instances where we find the Elmore deposited copper of great practical use. Some friends of mine also use it for the rollers of calico-printing machines. In the old plant the expense of providing these rollers was enormous, the copper being 1 inch in thickness, but now they use deposited copper to a thickness of $\frac{1}{8}$ or $\frac{1}{16}$ of an inch on cast-iron rollers, and when it is remembered that in a fair-sized works there are about twenty calico-printing machines, it will be seen how great an amount of money is saved. That is another use for deposited copper from a commercial standpoint. Mr. Milton and the last speaker spoke of the necessity for annealing copper steam pipes. We have several copper steam pipes, and we always make a point of annealing them every two years and test them also. However, I do not know how it will appeal to the coppersmiths present, but wherever we can possibly do without them we do not use copper pipes, we always use steel ones.

Mr. W. McLaren (Member): Mr. Milton has treated us to a very interesting lecture on "Copper" to-night, but as some of the others have said, most of us would like to reserve our remarks until we hear the lecture on "Steam Pipes." There is one simple matter I would like to touch upon. As marine engineers we rather pride ourselves on doing a little bit of tin work now and again, and I would like to ask if Mr. Milton could explain the reason of the trouble the junior very often experiences in using the ordinary copper soldering bolt. He makes it red hot and burns it, and has great difficulty in getting the metal to hold. No doubt the filing away of the surface to tin it has something to do with it, but he can never get the tin to take after the bolt has been heated.

Mr. Milton: I am very much obliged for your kind words, and I hope the next lecture will produce a longer discussion, because it will deal with the questions of the design of pipes, which will appeal to some, the methods of making pipes, which will appeal to others, and the taking care of pipes, which should appeal to all. Mr. Brown will find, I hope, that I shall discuss the matter which he has referred to with respect to brazing on flanges. I am very pleased, indeed, to know that there is an enterprising coppersmith who has gone out of the beaten track, and I think you will find that I shall commend the way in which he says he puts on his flanges, and perhaps in my lecture he might see a way to still further improve his method and induce other people to look upon it as the right way, so that it will become the common way. Mr. Adams spoke, and very much to the point, on the question of annealing steam pipes. I have had the matter in my mind very many years, and I agree that pipes ought to be annealed frequently or periodically, and yet I have never recommended that it should be made a rule that pipes should be annealed. I shall mention the reason in the next lecture, but I will say now that while agreeing that annealing when done properly is right and proper with careless workmen and improper appliances crooked pipes may be more damaged than by not having the pipe annealed at all. However, that is a point for discussion, and one of those points upon which practical men like Mr. Adams and others will be able to throw some light. To my mind there is not so much difficulty in annealing a straight pipe, besides straight pipes as a rule do not want annealing so much as bent pipes; it is the crooked pipes that require it most, and at present there is a great deal of difficulty owing to the absence of proper appliances; but we will go into that question next Monday evening. Mr. Adams was speaking about some of the wonderful copperwork used on the Cunarders. Well, I think you will find that the majority of main steam pipes on those vessels are of that metal which, as Mr. McNaught suggested, is better than copper for this purpose—namely, steel. But although it may be the rule for steel steam pipes to be used wherever possible, coppersmiths need not be in fear of going workless. There are a great many copper pipes in a ship now besides steam pipes. All kinds of pipes are now made of copper, so the coppersmith's trade is not in danger of dying out, even if steel steam pipes come into use. Mr. Adams, again, touched upon the point of copper pipes corroding. I freely admit that I do not know, and I do not think any one knows, the real reason for the corrosion, but it is certain that some copper pipes do corrode when submitted to water action, and other pipes again do not give that trouble. I will deal with that also next time. When dealing with the question of the corrosion of copper pipes, I think the pipes which give most trouble are the condenser tubes. I have studied the subject for many years and cannot find out the reason. Only lately I was told by a superintendent engineer that he was exceedingly particular in getting condenser tubes of pure metal, and made in the right and proper manner, turned outside and bored inside before going on to the mandrel, yet one voyage proved so disastrous that they had to take out all the condenser tubes and replace them with tubes from an old ship which were supposed to be worn out, and these are still in use, giving no trouble whatever. Chemists cannot tell the reason, and it is not due to the electric current in that particular ship at any rate. Mr. Adams suggests that it is due to the high price of copper. I do not think the price of copper has anything to do with it. Modern copper is made much purer than the old, simply because our forefathers could not make pure copper and the new method does make pure copper. But of course impure copper can be made if once it is recognized that it is the best for the purpose, and if an alloy of copper and arsenic is better than pure copper for ordinary work, those who now use pure ingots can add to them the necessary amount of arsenic without much extra cost, as a matter of fact they do that in some places. Mr. McNaught is altogether wrong and yet absolutely right in saying that the Elmore pipes are not made in England. Pipes are made in this country, only they do not call them Elmore pipes. The place in Leeds where the Elmore pipes were made is now the Leeds Copper Company, and they are making hundreds of tons of pipes, but they have recognized that the pure copper which they make is not altogether suitable for all purposes. They do make a lot of things which their process enables them to make and which could not be made by the ordinary processes—beautiful work. I saw some exceedingly thin copper tubes as thin as ordinary writing-paper and about $\frac{3}{8}$ to $\frac{1}{2}$ inch diameter. I should think there would be miles and miles of them; they were for some industrial purpose, I think for radiators of motor-cars, but at any rate they were exceedingly thin and beautifully made pipes and could not be made by the ordinary processes. As Mr. McNaught said it is a very useful process for calico-printers' rollers. I was once in a copperworks where these rollers were made, and after these are turned, I was told, on looking over them with a lens, if there was a minute speck in them, not $\frac{1}{32}$ of an inch, it condemned them. The electrically deposited copper is flawless and spotless and does not require so much copper, so for that purpose again the electrically deposited copper is a good thing. For such purposes as covering rams the deposited copper is very good also, either by the Elmore system or plain deposited copper without being burnished. What I maintain is that they are not fit for steam pipes nor for feed pipes. I know of more than one ship where the pipes have had to be taken out recently when they were suspected of being made by that process, and the annoyance was so great in one case that a marine engineering firm rather than get the pipes from outside makers have started a copper shop of their own so as to make sure of the origin of their pipes. Mr. McLaren has asked a question, which has nothing to do with steam pipes, about the soldering iron. I have been using it off and on for a good many years—I am not exactly a tinker, but a tinker's job never comes amiss—and I have often burnt it, but have never had any trouble in getting the tin on again. There is one curious thing, however, about the soldering bolt—we call it a soldering "iron," probably because it is made of copper, others call it a soldering "bit"—and that is, if you put on the soldering bolt a piece of the "tin,"—which is not tin but solder, an alloy of tin and lead—and afterwards put the soldering bolt in the fire the tin disappears. It dissolves into the copper and forms a tin-lead-copper alloy, an exceedingly hard alloy which will almost take the edge off a file. Something similar happens in the case of brazing metal, which I will speak upon at the next lecture.

Mr. W. Britton (Assoc. Member): I should like to ask the lecturer one question respecting the planishing of pipes. He stated that planished pipes were not good for steam, but he had no objection to them being used for exhaust. Would he give us the reason for this ?

Mr. Milton : "Planished" is a technical word, and I do not know that it comes into the engineer's vocabulary. The pipes are placed on an iron mandrel and hammered all over. The result is that the copper is hardened, and being hardened it is stronger and stiffer but not so ductile and cannot take up alterations of shape so easily as pipes which are soft. Copper pipes for steam pipes need to be able to stand changes of form due to changes of temperature and to vibration in the ship, but in the exhaust pipes these vibrations are not so dangerous in character. If a pipe is a little out of the circular shape, and no pipes are perfectly circular, while subjected to internal pressure the internal pressure tends to keep them round, but exhaust pipes are in a state of compression, and when they are not perfectly round they are liable to be distorted and flattened, especially when they are made thin from a question of economy, and I have seen an exhaust pipe flattened right in. The planished pipe keeps its shape better, being harder, and the exhaust pipe never gets very hot, so there is not so much expansion in it.

Mr. McLaren : Might I be allowed to ask Mr. Milton another question in the process of annealing steam pipes. Would he recommend quenching or allowing them to cool down ?

Mr. T. S. Tidman (Visitor) : While on the question of annealing the main steam pipes of steamships, I might say that there have recently come before my notice one or two cases where certain gentlemen in fairly high positions in the engineering profession are strongly against having the steam pipes in their ships annealed. As you gentlemen here know, when going through a survey, as a general rule, it takes a very long time to take down the main steam pipes, anneal and test them, and some have protested against it, stating they did not believe in annealing pipes, as copper steam pipes could not be annealed, or that in annealing they were raised to such a heat it destroyed the brazing. Where I am engaged we have taken down some hundreds of these steam pipes ; our practice is to anneal and test them, but I should like to know what gentlemen present think on that subject. As far as my experience goes we always get the best effects by passing them through the fire. In one particular case the pipes were not allowed to be annealed. They were examined inside as well as possible, and then finally, after patching them, a test was applied using tapping hammers, and as the pipes appeared to be in good order they were put back again. That was four months ago. A short while ago that same vessel came under my notice again, and we found there was a complaint that one of the principal pipes had a leaky place in it. I claim that if it had been passed through the fire, annealed and then tested in the ordinary way we should have found out that defect ; the pipe is now being repaired. I should like to know whether the lecturer thinks it is advisable or right that a pipe can be properly annealed without interfering with the brazing; personally I am in favour of annealing the pipes.

Mr. Hulme : Mr. Tidman has just said that he considers main steam pipes ought to be annealed, and Mr. Milton has stated that it was necessary only in the case of bent pipes, not straight ones. One of the difficulties that have come under my notice has been in reference to another statement made by Mr. Milton, the possibility of the pipe not being through the hands of good workmen, resulting in the necessity of a test. After having annealed a pipe with one or two or more bends in it, at the high pressures put on pipes I have invariably found that, due to the annealing, when high pressure is put on, in many cases it has altered the position of the pipe, and when the pipe is again put in its place it is found to be deformed; that is to say, it has tended to elongate or straighten itself. In some cases, where as much as 300 lb. pressure is put upon them, they have to be buckled up to columns, or some other means have to be found of securing them so that they will be kept in the same position as they were originally. That is one of the great difficulties in sending main steam pipes to be annealed.

Mr. J. Grisdale (Companion) : I had not intended to say anything to-night but reserve my remarks until the second part of Mr. Milton's lecture, but as the subject has developed more into the question of annealing, and the opinion on annealing varying to some extent, I can say that in all the pipes that have come under my notice—and I am speaking as a coppersmith of long standing—annealing has been the only safe way of detecting faults which would not have been detected if the pipes were not annealed. I do not quite agree with Mr. Milton that the straight pipe ought not to be annealed, in my opinion the straight pipe ought to be annealed. I am glad Mr. Tidman asked the question because it is a point around which a controversy is going on at the present time. I maintain that pipes cannot be tested to satisfaction when in position, and the only safe plan is to take them out and have them thoroughly examined. Mr. Milton's lecture so far, treating of copper and its qualities, has been very interesting, but I think he might have said that in the manufacture of pipes the more the copper is compressed by rolling or in the manufacture, the better it is for the working strength. It is surprising how seamless or solid drawn copper pipes can be worked and what can be done with them. We have made large air vessels and compressed them until there is just a $\frac{1}{8}$-inch hole at the top, and it seems to me that we have not yet got at the bottom of the question of the working of copper to get its proper strength. By compressing the grain together greater strength is got out of the material. That is the only point, to my mind, that Mr. Milton did not bring out clearly, the compressing of the grain.

Mr. Milton: I think no less than three gentlemen have misunderstood my words, so I am very pleased that they have spoken. The last speaker says he believes copper is made better by compressing it. I distinctly said that I thought the most important thing in the manufacture of copper was the amount of work put upon it and to "put work on" means exactly the same thing as the last speaker means by "compressing the grain." On the other point, both the last speakers thought I said straight pipes did not require annealing at all. If I have given that impression I am sorry; what I said was that bent pipes required annealing more than the straight pipes. It is well to anneal all pipes, but what I wished to point out was that there was no anxiety whatever about annealing a straight pipe, it can be annealed over a coppersmith's fire very well; but it is bent pipes that are difficult to anneal and the bent pipes most require it. I am pleased to see that so many are taking an interest in the annealing. I am going to refer to it particularly in my next lecture. I shall state the reasons for my opinion that coppersmiths do not anneal pipes in the proper way, and you coppersmith gentlemen ought to come up and show that you do. Mr. McLaren asked whether it is better to quench the pipe or allow it to cool down. There is not much difference in the ultimate result, but certainly there is no harm in quenching. One of my friends in a works in the North of England where they have a large coppershop, tested this by having a thin pipe fitted with flanges, and to make sure he fitted gauge plates to the flanges. He then annealed the pipe in the way in which I consider that all pipes should be annealed, by putting it into a furnace and raising it to an equal temperature all over. He then drew it out and quenched it with watering cans and had no trouble in finding that it preserved its shape. Mr. Hulme spoke about the alteration in the shape of the pipe when annealed and tested. The alteration was due to the pipe not being circular originally. If the pipes are well made, so that the cross section is perfectly circular, they do not undergo any alteration, but if made in the ordinary way somewhat flattened at the bends the pressure tends to open them out. Of course if the pipe is badly made it is time it was made right. However, next lecture I shall deal with the question of annealing, and I see it is going to be a point of considerable interest, but I shall also have something to say about coppersmiths' work in general. One thing I will say, I never recommend people to anneal pipes because they send them to the coppersmith's shop. There is something I have to say about the coppersmith's shop, and what I have to say I hope will bear fruit in the future.

Mr. John Clark (Member of Council) : I have been asked to call upon you for a vote of thanks to our lecturer. I am sure, as one who has followed him from the beginning to the end, I have been extremely enlightened. The points he has brought out about the different kinds of copper have been most interesting. Many of us marine engineers who are only dealing with the actual pipes fitted and have just sufficient knowledge to be able to state whether it is a good or bad pipe, as the case may be, may not have given the subject that amount of attention which it deserves. I was quite interested in hearing about the properties of bismuth and its effects upon copper. I had some knowledge of the properties of arsenic, but the effects of the introduction of bismuth into the copper is something I have never heard of before. The fact of so small a proportion of bismuth when found in copper altering and entirely changing the value of it is a point which probably we shall hear more of when we begin to discuss further on the methods of treatment of the copper for steam pipes. Seeing that this lecture is on the subject of the treatment of copper for steam pipes, we do not appear to have touched upon the main question; but the lecture we have heard, as a primary one, has given many of us an opportunity of seeing some of the difficulties that exist in the selection of copper for the purposes to which we apply it as marine engineers. The lecturer has told us how different varieties of copper may hold different impurities, valuable in some cases and disadvantageous in others. These matters will, of course, be quite familiar to the coppersmiths, one or two of whom I see are present, and judging from the remarks these gentlemen have made as to the working of copper pipes, they will no doubt enlighten us engineers further on what their experiences have been when the second lecture is delivered. One gentleman made reference to the vibration in pipes. That is a point to which we have probably not given the attention it demands. We have ships now running at high speeds, and in some cases very light draught ships experiencing considerable vibration, and no doubt in contending with these different kinds of vibrations as compared with that of the old days when vessels carried 20, 30 or 40 lb. of steam instead of 200 to 215 as is now sometimes the case, we have probably something further to learn as to these greater vibrations and the different conditions brought to bear on the pipes. I know of cases where the old-fashioned method of securing pipes to beams by hangers, keeping them close and rigid, proved destructive to the pipes, but that is entirely changed now, allowance being made for expansion. In some ships of large dimensions there may be about 40 to 50 feet between the boilers and the engines, and in such cases there must be a great deal of trouble experienced with the expansion in pipes of this length, and many means have to be resorted to in order to avoid overstraining. I ask you to render to the lecturer a very hearty vote of thanks for the trouble he has taken in preparing such a lecture which has proved so eminently interesting and educating to us all.

Mr. J. E. ELMSLIE (Member of Council): I have great pleasure in seconding this vote of thanks. It has been a very interesting and instructive lecture, and very few of us can go away without having learned something more about copper and its treatment. We have also had the advantage of hearing the experience of some of the gentlemen who have spoken, and I hope the next discussion will be an extremely good one.

The vote of thanks was carried with acclamation.

A vote of thanks was accorded to the Chairman on the proposal of Mr. Robt. Balfour, seconded by Mr. T. F. Aukland, and the proceedings terminated.

Lecture.

PART II.

Monday, February 10, 1908.

CHAIRMAN: ALEXANDER BOYLE, ESQ. (VICE-PRESIDENT).

CHAIRMAN: We had the privilege last Monday evening of hearing a most instructive lecture by our friend Mr. Milton on "The Treatment of Copper for Steam Pipes." Mr. Milton then dealt more particularly with the copper from the ore to the ingot, when it is rolled into sheets, or drawn into seamless tubes. He also explained the methods adopted to ensure obtaining the quality of metal desired; and pointed out the very great and very serious effect on the quality of copper which was caused by the presence of extremely small percentages of foreign ingredients. Mr. Milton also touched on the Elmore or depositing process of making seamless copper pipes; described the Admiralty tests for copper, and gave a most interesting account, illustrated by diagrams, of the behaviour of copper when subjected to tensile and other tests. Mr. Milton proposes to-night to give us the second part of his lecture, and that is, I understand, more immediately connected with the copper pipes when made. The first lecture, as I have said, was interesting and instructive, and I have no doubt this lecture will be even more so, because as engineers we are more particularly called upon to deal with copper in the form of pipes, either for steam or water. I will not occupy your time with any more remarks, but will call upon Mr. Milton.

Mr. Milton: To-night the subject that will first interest us is the design of steam pipes, after the question of the design of steam pipes, I shall discuss the corrosion of copper pipes, and afterwards pass on to give a few remarks upon coppersmiths' work. My remarks about the design of steam pipes are equally applicable to steel or iron pipes as they are to copper. All steam pipes must be, first of all, strong enough to withstand the pressure. A very important point is that their design shall be such that it will not be possible for water to accumulate in them when in use; if there are dips where water may accumulate disaster is sure to occur when changing the speed of the engines and at other times. Where there is only one boiler in a ship or in an installation the matter is not so difficult to deal with as where there are more, because where there is only one boiler, if you always get up steam with the stop valves open and if the pipes are made so that the highest point is only in one place between the boiler and the engine, any water that condenses in the pipe runs down either into the boiler or into the engine and can be drained away, but if there is more than one boiler, when there is steam in one boiler and not in another the steam pipes are filled with steam, and during the time when one boiler is not being used, there is sure to be an accumulation of water in the pipe running to the boiler out of use, and when coupling up the boiler again it is exceedingly difficult to avoid the trouble caused by that water being set in motion. I think it is a blemish in many designs if, in each case where there is more than one boiler, there is not a drain cock and pipe fitted above the stop valves, so that the pipes can be drained. Of course I am perfectly well aware that there are ships where such drain pipes are fitted and not used. Well, if a disaster occurs in such instances it is no fault of the design. I cannot emphasize too much the importance of not having a dip, and where there is a possibility of an accumulation of water to have a properly fitted drain pipe.

The next point, another very important one, in the design of steam pipes, is that provision should be made for the expansion of the pipes. The pipes are fitted when cold, but when in use they are hot, and very hot in cases where high pressure steam is used. The expansion of the pipes is, then, a thing to be very carefully considered, because it means that if they are made to fit properly when cold, when hot they are squeezed up and that causes a great strain not only on the pipes but also on the parts from which they are squeezed. These fixed points are the stop valves of the boiler and engine, and when we realize how much strain comes on them, one is not surprised that the pipes very often fail at the flanges where they are fastened on to the stop valves. What expansion, then, is to be allowed for? First of all the expansion of the boiler itself. The boiler is made of steel, and we may take 180 lb. pressure as a very reasonable and usual pressure; there are some which work to 215 lb. and a few even higher than that, but 180 lb., at which the temperature of the steam is 380° F., is a reasonable figure for modern steam pipes to withstand. They may be fitted in the winter, when the temperature is only about 40° or 50°, so that provision has to be made for a rise of temperature of about 340° F. Between 40° and 380° F. the steel boiler itself expands $\frac{1}{8}$ of an inch for every $4\frac{1}{2}$ feet, so that if the boiler from the cradle to the top of the stop valve is 18 feet in height, the top of the stop valve where the pipes are connected is lifted $\frac{1}{2}''$. The engine does not lift $\frac{1}{2}''$, so provision has to be made for one end to lift $\frac{1}{2}''$ higher than the other when in use. The steam pipes themselves, if of iron or steel, have the same ratio of expansion, they have to expand $\frac{1}{8}''$ for every $4\frac{1}{2}$ ft. in length, but copper expands $\frac{1}{8}''$ for every 3 ft. in its length. Of course copper is much more pliable, and for the same deformation does not undergo the same stress as steel, but it will be seen that there is always a great deal to provide for. One method of dealing with the matter is by making the pipes nearly straight and having packed expansion joints. That, indeed, would be a very good way, if it were not so troublesome to keep such expansion joints in good order and to prevent leakage. But when expansion joints are fitted there is something more to be provided for, and that is to make the design of the pipes so that they will expand into the expansion joints. I have seen them where they will not, and one of the difficulties when dealing with the expansion of pipes is to see that the ends or other parts are properly fixed where it is not intended for them to move, so that the pipes will move where provision is made for movement. When you have a steam pipe, in any case, whether there is an expansion joint or not, there is always a longitudinal tension due to the pressure upon the area of the pipe and that has to be taken up so that it is necessary to see that the pipe is properly "anchored." Another plan is to provide for expansion by means of bends, which certainly saves the trouble with the stuffing-boxes, but creates the difficulty of keeping the pipes soft. Many engineers think that if there is a bend in a pipe it must be very flexible, but I think they forget, or often forget, that a hollow cylindrical form is an exceedingly strong one and not a flexible one. A hollow shaft or column is stronger, weight for weight, than a solid shaft or column, and it is generally recognized that the hollow form gives the greater amount of stiffness in proportion to the material used. Now, it is a matter easily calculated how stiff a pipe is, just as it can always be determined how strong a hollow shaft is, compared with a solid one of the same material. A 6″ pipe, $\frac{3}{8}$″ thick, is quite as stiff as a $4\frac{1}{2}$″ solid bar of the same material, and a 6″ copper pipe, $\frac{1}{4}$″ thick is quite as stiff as a 4″ solid copper bar. If we remember this we can see the importance of having flexible bends and plenty of them. Another point that is very often forgotten in putting up pipes is the way they are fixed in the ship. I suppose that pipes are as often injured by unsuitable fixing as by anything else. A very common plan is to hang the pipe by hangers fixed to the beams or other parts of the ship, forgetting that the expansion of the boiler lifts the pipe up fully $\frac{1}{2}$″ in the first place, and that the expansion of the pipe itself, in all probability, wants the pipe to move, and no provision is made for the alteration in bending that it is necessary to provide for on the expansion of the pipes. Perhaps I might illustrate that (Fig. 5).

Suppose the points marked *A A* are the stop valve flanges. These are the fixed points of a pipe which has to expand in length. What happens is that when expanded the pipe bends up in the direction shown by the dotted lines. If the pipe is prevented from rising by the hanger then practically the pipe has been made rigid and you have not the freedom for expansion that you think, or that you ought to have on your pipe. It is seen that it is a very important thing to properly design the pipe hangers, it is quite as important to fix the details of the hangers of the pipes in the drawing office as it is to fix the design of the pipe itself. There is one other point about the design of pipes in the drawing office. It is my lot occasionally to see drawings of steam pipes, and I find that on some of them proper directions are given to those who are to fit the pipes up in the ship as to how the different parts are to be fixed. Where necessary, directions are given for the holes to be made oval in order to allow for the horizontal or lateral movement of the pipe,

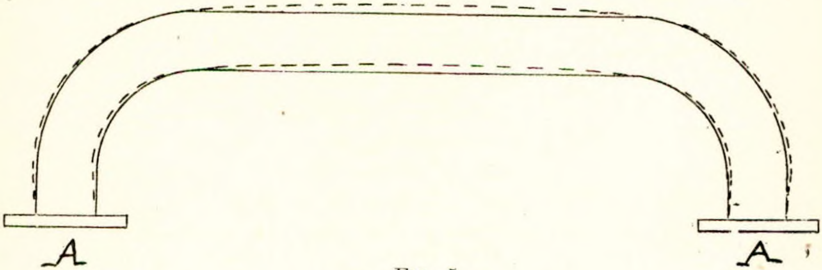

Fig. 5.

but one of the directions some engineers put on their drawings, and it is a very important point, is to specify that the full length of the pipe as made shall *not* be the distance between the stop valves, that the pipes shall be made short by a definite amount and drawn up to their places cold, so that when the pipes are cold they are being stretched and have a strain put upon them in the opposite direction to the strain which comes upon them when hot. By that means the strain when put on hot is about halved. This is a very simple precaution and should be put on every drawing, but it is not often done. There is another thing, too, that I think engineers do not realize sufficiently. They count up the number of bends in a pipe, and because they are sufficient in number, therefore they think the pipe is good enough, but if there is any part of the pipe lying in a straight line joining the fixing flanges, that pipe cannot be so flexible as if the pipe was throughout its length at a distance away from the line joining those flanges. For instance, take the case of two pipes with an equal number of bends in them. One is constructed in the form shown in Fig. 5.

The pipe is fixed at the ends *A A* and the expansion is resisted by pressures tending to push these flanges *A A* together so that the straight portion has then a tendency to bend upwards, the bending moment at any point being equal to the force exerted by the flanges multiplied by the distance of the point from the line joining the flanges. But it often happens in the design of pipes that one is shaped like this—

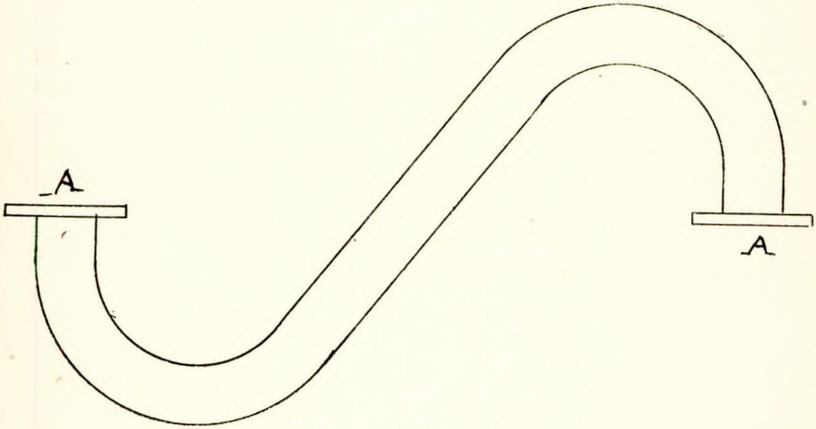

FIG. 6.

This pipe is not nearly so flexible as the other, because with the same forces acting on the flanges an appreciable bending movement only comes on the bends and very little on the part practically straight. Roughly, the flexibility is proportional to the area contained between the pipe and the line joining the points of fixture. The rectangular form gives a much larger area than the two triangular spaces and the latter pipe is not so flexible as the former, although there are the same number of the same size of bends in it. So much for the design of pipes. I have not by any means exhausted the subject, but I have given you something to think about. Drain them properly, make them shorter when cold by half the amount of the expansion which they will undergo when heated, and take particular care that they are flexible in the design and that the hangers are so arranged as to anchor the parts intended to be anchored and leave the parts free that are intended to be free to move or you will have the hangers preventing the arrangements for expansion being effective.

In the last lecture I mentioned some of the properties of copper. To-night I have brought a diagram showing two of the properties of copper, the first of which I have taken from a paper I read about twelve years ago before the Institution of Naval Architects. I may say that some of the ideas put forward in that paper were those of Dr. Watson, of the Broughton Copper Company, and I am pleased to see that that Company has a representative here to-night, but what was true twelve years ago is equally true to-day in connexion with the treatment of copper. In that paper I passed some remarks about the Elmore copper, and this happens to be a diagram of a tension experiment with Elmore copper, but in principle it is perfectly true for ordinary copper. When a piece of copper is properly annealed, it is very soft, and on a tensile strain being put on it, when about two tons per square inch is reached, it begins to perceptibly stretch, and as more stress is put on so the copper stretches more and more.

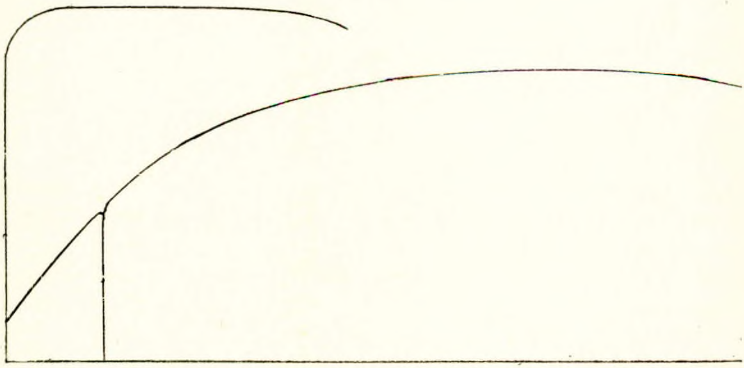

FIG. 7.

In this particular sketch the distance horizontally represents the extension caused by strains proportional to the ordinate of the curve, of which the total height represents 13·13 tons. At the point representing about 2½ tons there is a perceptible stretch, at 5 tons it is much greater, and so on till the total curve is obtained. The total amount of extension in 8 inches was 48 per cent., so that it will be seen that the metal is exceedingly ductile. The tests were conducted by Professor Unwin, and when the strain had got to the point shown by the break in the curve, viz. about 6 or 7 tons per square inch, he let it off. The strain fell to nothing, but there was found to be a permanent set, and after putting the strain on again there was no further stretch until it reached 6 or 7 tons, or where he had left off stretching it before. That is to say, when copper is stretched to a certain amount, it is afterwards practically elastic up to the limit to which it has been stressed. Another piece of hard, unannealed copper was tested, and the strain put on ran up to about 14 tons before it began to stretch, and then it stretched rapidly to about 21 per cent. in 8 inches. Although it was Elmore copper that was used in these tests the recorded behaviour is characteristic of all good copper under similar conditions. When copper is properly annealed it is very soft, when it is not annealed it has still a good deal of ductility, but not nearly so much as when soft. The French have a term for the opposite of annealing, to denote the condition of the metal, which we cannot describe in English with one word. They say it is *écroui*. We find this word translated in technical dictionaries as "hammer-hardening," but the same word is used whether the hardness is put on by hammering, wire-drawing, tube-drawing, bending, cold rolling, or in any way in which an amount of mechanical work is put upon it and makes the metal hard. In copper-making, when drawing the tubes, as we saw in our last lecture, at every draw the copper is very much elongated and left *écroui*, then it is annealed and again drawn, and so on until it gets its final dimensions.

Let us see how annealing affects a steam pipe made of good copper. We will imagine that the steam pipe is properly annealed and soft throughout, then fitted into place and put into use during which it has to be repeatedly deformed. When the first change of shape takes place in the part where the greatest strain comes it begins to yield, when the stress on the part comes to two or three tons per square inch. Then another part begins to take up some of the strain, and so it goes on until some yielding has taken place nearly all over the pipe. Then the pipe is cooled down and some further slight yielding takes place. Steam is then raised the second time. The copper becomes strained at the same parts as before, but it has been hardened and strengthened by the previous yielding. Further yielding, therefore, must take place in some other part of the pipe and the repetition of many expansions gradually hardens and strengthens the pipe in different places ; if the straining has not all been concentrated on one spot. That is the condition which explains the failures of some pipes to which I will refer later, and gives the explanation of how pipes when subjected to repeated alteration of shape may last a long time, until they gradually get hard throughout, and then they should be annealed again.

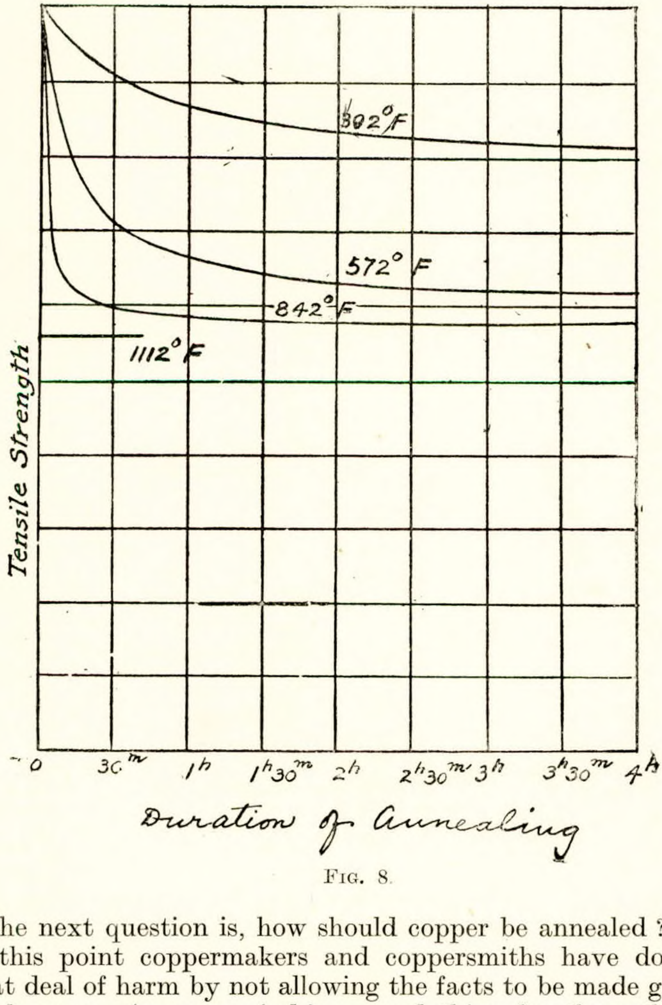

FIG. 8.

The next question is, how should copper be annealed? and on this point coppermakers and coppersmiths have done a great deal of harm by not allowing the facts to be made generally known. An open mind is a good thing for these things, as for everything else, and although we must believe that coppermakers know all about the treatment of copper, I have never been able to find out, until I came upon it by accident in a French book when looking for some particulars about the fragility of steel, how much the annealing is affected by the purity of the metal. M. André le Chatelier, a French engineer, has written many papers on steel, amongst them is one on the influence of time and temperature on the mechanical properties of all kinds of metals. This paper is to be found in a collection of papers by the French Institution for the Encouragement of National Industries. In treating of the question of annealing metals generally, he speaks of the influence of the chemical composition of the metal and states that the impurities contained in a metal modify, often very appreciably, the effects of annealing, and their tendency is always, whatever be their nature, to retard the annealing. The metal most pure is that for which the annealing for a given temperature is the most rapid, and the purer the metal, the more complete are the effects produced.

The curves in the sketch are relative to impure copper. He does not say how impure the copper is, but I presume he means the ordinary commercial copper. A piece of impure copper which was made *écroui*, or hardened (he does not say how hard), was then submitted to a temperature of 392° Fahr., which is very nearly that of 180 lbs. pressure of steam. After being annealed for 30 minutes at this temperature its strength or hardness has considerably fallen, in one hour it has fallen still further, and even after the four hours it will be seen that the curve is still falling. At a higher temperature, 572° F., shown by the second curve, which is below red heat, the same copper had its strength brought down very considerably in half an hour and after the four hours it was pretty low down. At 842° F., which is incipient or faintly visible red, the curve takes the form as shown on the diagram, while at 1,100° F., which is, I think, somewhat below the temperature used for brazing, the annealing instantly brings it down to its lowest tensile strength. So that one sees that with ordinary copper some annealing takes place at 400° F., but not very much, and one can see that at that temperature the copper can never be properly annealed. Even at the very dull red the copper is not thoroughly annealed, whereas at a full red it is annealed immediately. Now comes the important point which I wish to mention.

Electrolytic copper it is said in the paper anneals itself at 200° C., that is what I want to point out, the very low temperature at which electrolytic or pure copper is annealed. I had been told this by some of my friends as a fact not generally known, but this French engineer records as an experimental fact that at 200° C., the copper is absolutely annealed. Now, I think that accounts for the fact which has been proved by unfortunate experience, that electrolytic copper, although it will stand severe mechanical tests, is not suitable for copper pipes that are exposed to great changes of form and temperature. It certainly fails very much more quickly than ordinary commercial copper. The reason is that every time the pipes are in use they get softened, and the little deformation that takes place always takes place in the same spot; the effect is concentrated on the one spot generally at or near the flange and ultimately the pipe breaks there, whereas the impure copper does not anneal at the 400° and the hardness created at the first yielding helps to spread the subsequent deformations over the remainder of the pipe; at any rate, they are not concentrated on one spot.

Now a word with reference to our friends the coppersmiths. How are we to properly and thoroughly anneal pipes that have been hardened or made *écroui* in use? The coppersmiths say they do it, but it is impossible for any human being to properly anneal a large crooked pipe over the ordinary coppersmith's fire. They may think they can, but they cannot. They take the pipe, put it on the fire, blow the blast and make one part red hot and that spot is annealed. Then they shift the pipe and anneal another spot. They cannot make the pipe uniformly hot throughout; the man has to carry in his mind all the spots where he has made it hot, and he tries to get over the whole of the pipe in that way, but there is sure to be some spot that has never been red at all. I think when you consider the bends in the pipe, you will see that some of the parts cannot be got near enough to the fire to get the proper treatment. It is very essential, if annealing is done at all, that it should be done thoroughly and throughout the pipe. A straight pipe may be annealed over a fire, but a crooked pipe cannot be annealed in this way. What is the cure? The cure is for superintendent engineers to insist that the people who undertake the work shall have a proper furnace, so that they can raise the pipe to a proper temperature throughout its whole length. The proper furnace can be made—not without difficulty, perhaps, but it can be made—and pipes can be put into it in such a way that the weight of the pipes will not sag them. My friend, Mr. Allan, of Messrs. Hawthorn, Leslie & Co., is going to read a paper on "Copper Pipes" at the North-East Coast Institute of Engineers and Shipbuilders shortly, and he has been making a number of experiments. One of his experiments was to take a crooked pipe and put it into a furnace, where it was made red hot; it was then taken out and quenched with water from a watering-can, and it was found on this being done that its shape was not appreciably altered. The bugbear as to change of shape by annealing does not exist in practice, a furnace can quite well be made to do the work properly

There is another thing about annealing that I want to mention. When a coppersmith has to make a bent pipe out of a tube, the first thing he does is to get a good tube from a good maker and then he anneals it, fills it up with resin—there is another material that they sometimes use, but resin is generally used—and then, after it is cold, he bends it as near to the required shape as he can, or, if much bending is required, he bends it as far as he dares. He then runs out the resin and anneals the tube again, re-charges it with resin and completes the bend. For a severe bend he may have to reload two or three times. Each time the pipe has to be annealed and each time, as it becomes more bent, it is more and more difficult to get it properly annealed, and it is not to be wondered at if some of these pipes crack across the back during bending, as one of our friends mentioned last week, not because the copper is bad, but, in my opinion, because there happens to be a spot there where it has not been properly annealed. After the pipe is bent to shape the flanges have to be put on, and again in brazing on the flanges the pipe near the flanges has to be raised to a high temperature. I mentioned in the last lecture that in all ordinary copper there has to be a certain amount of an element called oxygen. What that amount is I do not know, but the more impure the copper is the more oxygen has to be contained in it. In the paper to which I then referred, read by Mr. Dean in connexion with the Alloys Research Committee's Report, he gives the analysis of the copper in eighteen locomotive fireboxes, some of which gave good service and some bad service, and the analyses show the oxygen to vary from ·019 to ·248 per cent., a very large amount, so that some copper appears to require a good deal of oxide of copper dissolved in it to make it the proper pitch. When the copper is raised to a red heat for annealing or brazing, if by some mistake the workman has the copper in a reducing flame, a flame greedy of oxygen, it takes some of the oxygen from the copper near the surface and produces an effect which many coppersmiths call "burning," but which copper-makers call "gassing." I will show you some pieces of "gassed" copper, but before doing so I will pass around this piece of annealed copper showing the Admiralty test. The copper, as you see, is bent over at both ends absolutely close, and one of the closed ends is afterwards hammered down to a feather edge. A piece of good copper ought to stand this, and if there is the least sign of a fracture it should be condemned. Here is another piece which has been raised to a much hotter temperature than is ordinarily used for annealing, but it has stood the double bend very satisfactorily. Here are two pieces which have not been quite closed down. These two pieces were obtained from the shop of an eminent coppersmith, and the copper in both cases is gassed on one side and not on the other. This shows that it has been gassed at the coppersmith's shop and not at the coppermaker's works. You will see that in each case one of the bends shows the copper to be perfect on one side, while on the other side, in each case, it is full of little cracks due to the "gassing." Here is a piece of a failed copper pipe flattened out after condemnation. I am not sure of the reason for which the pipe was condemned, but it has been gassed, most probably during the brazing. If you look at the one side it will be found to be full of minute cracks which do not go far into the copper. In this piece of a condemned steam pipe the gassing has led to the pipe beginning to crack right through. One of the things that occurs with many materials is that if a crack is started and the material is afterwards worked or stressed the crack will go right through although the material may be fairly good. So that with a pipe it is necessary to keep the highest quality of the copper right out to the surface, for if the copper is cracked, even to the extent of $\frac{1}{100}$ part of an inch in depth, those little cracks will gradually work through until they go right through the copper. In the case of the pipe shown the crack had got half-way through. I have had a piece of this pipe annealed and bent over, and you will find the back is full of little cracks, showing that the copper has been gassed or de-oxidized on the surface, and showing also that annealing will not restore a piece of gassed copper. I tried to de-oxidize a piece of copper last Saturday. I had it for ten minutes in a flame which I thought was a reducing flame, but it was not gassed. I expect the reason was that it was very nearly pure copper and had not much oxygen in it. I mentioned that the best workshop test was to bend the copper both ways. Here is a piece which bends one way admirably, but when bent the other way it breaks. Here are two pieces of electrolytic copper. One piece, perfectly hard from the drawbench, has been bent over until it just began to show very small cracks. This other piece, also hard, stood the bend test exceedingly well.

You now see, if there is anything in this gassing of the copper, how very important it is that the coppersmith, who has to heat a pipe several times, does not gas it while brazing on the flanges, and also when a pipe has become hardened in use, how very important it is that it should not be gassed while it is being annealed. It was mentioned last week that there are some engineers who do not like their pipes annealed. I then gave it as my opinion that if a pipe could be properly annealed it would be better to do so, but said that it was quite possible to damage a pipe by improperly annealing it. The reason, first of all, is that it may be made soft in some places and have other parts of it left hard, because of the difficulty in attempting to uniformly heat it over a coppersmith's fire, and, secondly, every time it is put on the fire there is a risk of gassing the copper. If enterprising coppersmiths would make furnaces where it would be impossible to gas the copper, and where pipes could be uniformly annealed throughout, then I think every steam pipe ought to be periodically annealed. One other thing about brazing pipes. Brazing flanges on, or brazing seams, are matters that depend very largely indeed on the skill of the workman. The skilled workman thinks he knows, and no doubt in many cases he does know, when he has made a good job, but it is quite possible to make a bad job of brazing while thinking it is a good one. One of the effects of brazing is that if one is too long about it the copper is damaged in another way. There are right ways and wrong ways of designing pipes and designing flanges, and I have known people make very bad flanges when they thought they were making very good ones. One flange which used to be thought to be an excellent one had a very high collar. I think that a very bad flange. The best way to put a flange on a pipe is as follows :—

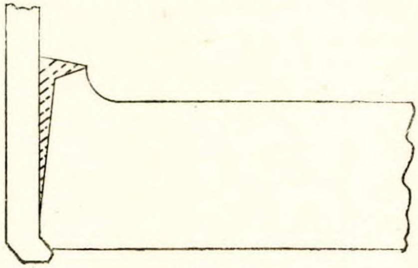

Fig. 9.

Have only a small collar on the flange, bore out the flange for a short distance nearest the face to a diameter equal to that of the pipe and taper the rest of the bore to about $\frac{1}{16}''$ all round larger than the pipe. The pipe end will then be a good fit at the face of the flange. Make the top of the collar to slope down towards the pipe so that when the brazing material melts it will run right down into the space made by the taper boring of the flange, there will then be a good union between the brazing metal and the pipe, and between the brazing metal and the flange. If there is not taper enough in the bore of the flange the metal will not run down, and the union will be something like this—

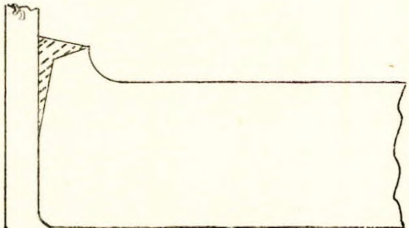

Fig. 10.

which is not at all satisfactory. When the brazing is completed, the question arises, How can the joint be tested? Our worthy Chairman knows of a case very well where a poor fellow lost his life through a pipe drawing out of an inefficiently brazed flange. The flange appeared to be all right, but when it was examined after the accident it was found that the brazing was defective in this way. Now as to the best way of testing the brazing of the flange. File off the protruding part of the copper pipe absolutely flush with the face of the flange, take a very light hammer and give the pipe a few blows inside at about the middle of the thickness of the flange, where the brazing metal ought to have come to, and if it is not

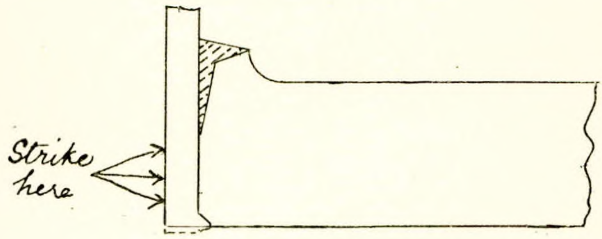

FIG. 11

brazed properly the copper will stretch and will be felt to protrude at the flange face. I believe that many flanges tested that way, would be condemned and re-brazed. Another word in connexion with brazing. Brazing metal consists, when made, of about 53 parts by weight of copper to 47 of zinc. These two metals are melted together, and the resulting alloy is cast into ingots. These are then raised to a high temperature, causing the metal to become very brittle, and it is then pounded up and it breaks into the beautiful little crystals of which brazing metal is composed. The temperature at which the metal is brittle is not very much beyond that of steam, so that I am quite sure that brazed steam pipes, or pipes with brazed flanges are not suitable for superheated steam, although they may be all right for ordinary steam. The metal is not a stable chemical compound. When hot, some of the zinc evaporates from it in the form of vapour and may be seen burning into zinc oxide. The brazing metal thus tends to get richer in copper and poorer in zinc, and when so much zinc has been evaporated that the proportions of copper and zinc have changed to 60 to 40. Muntz metal is formed, which is stronger and less brittle than the original metal. But the molten metal has also a tendency to dissolve up some of the copper of the pipe, and if the brazing is too long on the fire it dissolves up some of the copper, thinning the copper of the pipe, and you will find that the brass has eaten, as it were, into the copper. Here is a sample where some brazing metal has been kept over the fire too long. It will be seen that the brazing has eaten its way into the copper for a considerable depth. Any one with a critical eye can always tell after the pipe has been cut up whether the coppersmith has had the brazing too long over the fire or not.

I will now say a few words on the corrosion of copper. I am no further on than I was at the time of the last lecture, I know no more on the point, but I will show you some examples. As a rule we do not find copper steam pipes corroded, but occasionally we do; here is a sample of a piece cut out of an auxiliary steam pipe, full of pitted holes. The pipes which give most trouble in this respect are those which convey sea-water, and I do not think we should be much surprised when these water pipes go. In the old days of wooden sailing ships, they used to put copper on the bottom to keep off barnacles and weeds. Through the action of the water the copper was slowly exfoliated and copper good for the purpose exfoliated very slowly but very uniformly, so that although the copper wasted it lasted a long time and when it was done it was done all over. But occasionally there were cases where the copper did not waste uniformly, but wasted in holes very quickly, and I do not think these cases have ever been satisfactorily explained. These peculiar cases often occurred with copper sheathing, and that is the kind of thing happening with our sea-water pipes. The uniform waste of the copper sheathing in sea-water is said to be due to a chemical compound called oxychloride—the oxygen of the air being a very important factor in it. If we could sail the ships in water where there was no air at all in solution there would probably be no corrosion, but unfortunately all sea-water has oxygen dissolved in it, and I suppose all our sea-water pipes must be expected to waste. But it is when the waste is not uniform, when it forms holes in the copper, that trouble is given, and that is what is occasionally met with. Here is a piece of a bilge pipe very much corroded. I do not know why a bilge pipe was made so very thick, most probably to replace one that had failed before. Here is another piece I have got from a discharge pipe used with a surface condenser. It took eight years to get into this condition. The top half is wasted almost through, while the lower half is almost perfect. There is, however, a little bit at the top where there is still the same thickness of copper as originally, but I think there is no doubt whatever that in the case of this pipe the corrosion was in some way due to the air separating from the water in coming through the pumps. This piece of pipe fastened on to the card is a very marvellous case of a copper bilge pump discharge pipe, which was found holed. It was carefully lapped round with canvas and sheet iron put on the outside as a temporary repair, and at the end of the voyage it was taken out, and part of it was found to have been made into the lace-work pattern that you see. In some parts there is still the full thickness of metal left, while in others there is nothing left. It is this very erratic nature of the corrosion that causes the trouble, and if we knew the reason for it we might possibly devise a cure. The fact that some coppers do not corrode, while others corrode very rapidly, is a very disquieting thing, and I think it must be due mainly to the composition of the copper. As we have seen, ordinary commercial copper contains a great many different kinds of ingredients in small quantities. Each of these has its influence, but why some of them should act in the direction of forming these pit holes I cannot tell. One of the causes generally given is that it is due in some way to stray electric currents in connexion with the electric light, but there was no electric light in the old wooden ships, and the fact remains that in some steam ships that have the electric light, a replaced copper pipe does not give way like the old one. The whole thing is obscure. There must be a reason, probably more than one reason.

To-night we are very favoured in having with us a gentleman representing a very eminent firm of copper-makers, and if our Chairman would ask Mr. Tomlinson to open the discussion I think we would all be very pleased.

Chairman: We are all very much indebted to Mr. Milton for the very interesting and instructive lecture we have heard to-night on the subject of "Copper for Steam Pipes," and I shall be pleased if many will now enter into the discussion. It has just occurred to me that as Mr. Milton has divided his lecture into three heads, it would perhaps be more convenient if the discussion on the subject of corrosion be deferred, and the discussion on brazing taken first. I have great pleasure in asking if Mr. Tomlinson will kindly say a few words on the subject.

Mr. F. Tomlinson (Visitor): I am very pleased to have this opportunity of expressing my appreciation to Mr. Milton for the very able lecture he has given. All the information he has given has been of a very practical nature, and I specially appreciate it as a manufacturer, interested in the manufacture of copper in its various forms, especially in the form of tubes. I think all engineers will agree that copper has been a very good friend to them, but like many good friends it has often been imposed upon, and in many cases where it has been used in form of pipes, sheets, etc., it has been condemned when in reality no blame rested with the metal itself or to the mode of manufacture. In instances where failure has occurred it is generally due to harsh treatment received at the coppersmith's hands or in use, therefore I am very pleased that Mr. Milton laid such great stress upon this point, and I feel sure that coppersmiths or others interested in the use of copper will profit by his remarks. One point I would like to remark on is in reference to the experiments on copper made by M. le Chatelier quoted by Mr. Milton. He said that ordinary commercial copper at a temperature of 380° to 392° F. underwent a change similar to annealing, or was practically annealed. Experiments I have made are not in accord with that result, and I think the copper used by M. le Chatelier must have been different to the good cômmercial "tough" copper manufactured in this country. I have made experiments with the ordinary "tough" commercial copper (hardened by rolling), heated the samples up to 350° to 400°, and kept them at that temperature for three or four weeks; no change could be detected after submitting them to tensile tests. However, on the other hand, I found that samples of pure copper submitted to the same conditions were practically annealed, as stated by M. le Chatelier. On the same diagram Mr. Milton referred to a temperature of 1,100° F. as a brazing temperature. This must be a clerical error as the brazing temperature is some 400° or 500° over the figure mentioned. Another interesting point I might take the opportunity of mentioning is the result of a prolonged heating test on copper. The tests I made were to compare the properties of arsenical, or "tough," with those of pure copper. The copper in both cases was heated to 1,600° F. (a good red heat almost approaching bright red), for four hours. With the "tough" copper, containing 99·32 per cent. copper and ·36 per cent. arsenic, the loss in a tensile strength was only 6 per cent., whilst with the pure copper, with a purity of 99·9 per cent., the loss was 44·0 per cent.; this bears out Mr. Milton's remarks in one portion of his lecture.

Mr. Milton: May I ask, Mr. Tomlinson, in regard to that loss of 6 per cent., what it was that you started with, whether it was compared with copper annealed or *écroui*?

Mr. Tomlinson: The samples were, of course, in the annealed state. I think the exact figures for the *pure* copper were 14·4 tons per square inch tensile strength before and 8·10 tons per square inch after being heated, and for the "tough" copper 14·9 and 14·0 tons per square inch respectively.

Mr. Milton: As we shall not have the pleasure of seeing Mr. Tomlinson with us next week, I think we might ask him to give his opinion about the corrosion of copper. He has had so much experience that anything from him would be of great value.

Mr. Tomlinson: There is a great amount of mystery about the corrosion of copper, and especially in the peculiarity which shows itself in the formation of holes at local spots. As Mr. Milton says, there is a reason for it, but I cannot give a general explanation as to the cause of corrosion. Mr. Milton really gives you the key to the situation, "there are many causes," and I think each case has to be examined and investigated, and conclusions deducted on its own merits and on the particular conditions under which the corrosion takes place. In many cases of corrosion which have been investigated no definite explanation can be found. In carrying out such investigations one is often at a great disadvantage, owing to the lack of reliable information relating to the history and conditions of use which the copper has undergone since leaving the maker's hands.

Mr. Milton: Is the question of purity one explanation?

Mr. Tomlinson: I do not think so, I have seen examples where absolutely pure copper pipes have corroded in a similar manner to this specimen, which is very unevenly and deeply pitted.

Mr. J. Grisdale (Companion): We are much indebted to Mr. Milton for all the trouble he has gone to in the preparation of this lecture, which must have been considerable, before he could have worked out the matter placed before us to-night. I might say that I have served my time as a coppersmith, and for the last thirty years have been supervising that class of work; and I think I can claim to speak with some authority on the matters Mr. Milton has referred to, and can speak of what I know has happened during that time. My experience has been principally on copper main steam pipes on the three-boiler system, and in that system the long lengths of pipe on the wing boilers have worked all right. It is on the centre boiler where there is a shortness of pipe that unequal strains have taken place, and unequal expansion has caused many pipes to give way. I know of pipe arrangements in a whole fleet of five steamers which have been altered by making long expansion bends, and when they were altered there was not a sixpence spent on the pipes for years afterwards. Where does this difficulty arise? Is it with the coppersmith or in the metal, or does it arise in the drawing office? The coppersmith can only do as he is told; he gets his instructions and has the plans laid down for him to work from, and yet he is blamed for faults which really occur in the design. These five steamers are not the only cases. In many ships where failures have occurred, and where allowance has afterwards been made for expansion and plenty of room provided for it, there has not been any expense attached to the pipes for years. Mr. Milton has spoken about brazing. When I was a boy serving my apprenticeship, the tubes were not so perfect as they are to-day. We had to make our own tubes, principally used for feed pipes, and they were a little superior to the ordinary Birmingham tubes. We drew them ourselves, and perhaps they were not always as straight as they might have been, but we have got over those difficulties to-day by the advancement in tube-making and the splendid character of the tubes supplied. I may say that during that time we have found bad tubes and bad sheets too, but I think it is sometimes the fault of the smelter, and we have to blame him as well as the coppersmith. Very often we have been supplied with tubes that have been hard, and it did not matter how careful one was in the annealing, they would break. In my opinion it is a good thing pipes have to be bent, it shows the quality directly; but that difficulty seldom arises with the class of tubes used to-day. It is surprising the amount of work done with copper pipes; they are so elastic and work so easily, and, considering the amount of repairs done to steamers to-day, the repair list as far as copper is concerned is very small in comparison with other parts of the ship. I do not quite agree with Mr. Milton regarding the flanging; I think sometimes a high collar is better. It all depends on the shape of the pipe it is used for. If I think there is a lot of strain going on the head, I taper the collar gradually down to where it is not likely to break so easily. I am sure we have all been very much interested in Mr. Milton's lecture, and I shall leave others to continue the discussion.

Mr. R. Balfour (Member): The lecturer, in connexion with this most interesting subject, made special reference to the corrosion of copper pipes. I would like to make use of the blackboard to illustrate and help to give you one or two instances of my experience with corrosion of copper circulating water pipes.

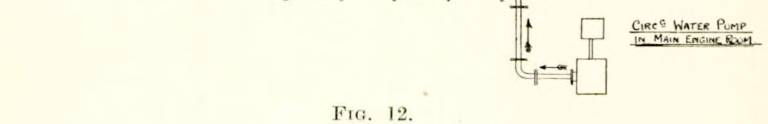

Fig. 12.

A B represents the horizontal line of a range of pipes which gave trouble from time to time from corrosion along the inside at the top, a scale having formed, breaking off in irregular patches and eventually holding at those parts. The vertical *B C*, and other lengths leading from the pump in main engine room, showed no signs of corrosion. This being experienced in other two instances, I attributed the cause to the free air in the pipes. As these pipes are designed large enough to meet high temperatures or tropical conditions of cooling or sea-water, it follows that under normal conditions, say 50° F., the quantity of water circulated is proportionately less and along the uppermost horizontal range the pipes will only be partially filled, thus allowing the air to attack the upper portion of the pipe, and the vibration may account for the scale breaking off in the irregular forms referred to. I may say that the trouble was in two cases overcome by fitting a stand pipe at *B*, leading to the sanitary water tank, so as to ensure the pipes being kept full. In the case of main engine copper circulating water, inlet and discharge pipes, similar trouble with corrosion has been experienced.

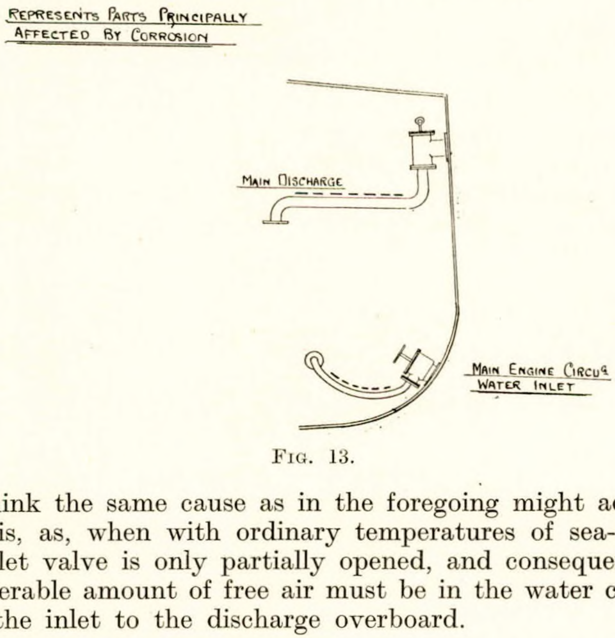

FIG. 13.

I think the same cause as in the foregoing might account for this, as, when with ordinary temperatures of sea-water, the inlet valve is only partially opened, and consequently a considerable amount of free air must be in the water courses from the inlet to the discharge overboard.

Mr. GEO. ADAMS (Member of Council) : Mr. Milton this evening has carried us on very rapidly from the point at which he stopped last lecture. At the commencement of his lecture he dealt with design of pipes, manner in which they should be fastened, draining arrangements ; he has given us some new ideas as to proper system of annealing, which is a most important item, and he has gone into the question of annealing.

Referring to the fixing of pipes Mr. Milton pointed out the precaution of proper lengths of pipes when expansion glands are fitted, and the necessity of making elongated holes in pipe-hangers or brackets to allow for lateral and vertical movements, but there was one point which of course is well known to him, but which he omitted to mention. I refer to the practice of fitting pipe-hangers having a spring underneath or on top of the pipes so as to yield freely to expansion, and thus relieve the strain in a great measure. The question of draining is most important; it is well known to most of us present that when steam is carelessly put on to a range of pipes and drains neglected, a great deal of water hammering takes place, and it must be apparent that this action is detrimental to the pipe, creating a liability to fracture which might result in serious accident.

There was a reference made to electro-depositing, and I should have made mention at the last lecture of an instance where, some time ago, it was found desirable to consider the question of the internal corrosion that goes on in the covering shell of centrifugal pumps. The corrosion takes place on the inside of the cast-iron shell in vicinity of the impeller, and if this is not attended to it soon becomes eaten through and requires to be renewed. In order to overcome this it is the practice of some engineers to introduce brass plates to shield the inside of the shell. If the system of electro-depositing of copper could be successfully and cheaply introduced for such purposes it would be a distinct advantage, as I understand the process is being used for other engineering problems of a like nature.

An important improvement in brazing by local treating has been touched upon, and the system of brazing flanges well-described and illustrated. A point which may be of interest here, however, occurs to me, that in testing a pipe after repair to a flange or a new one brazed on, care should always be exercised to see that the jointing of the flange is kept clear of the line of brazing, as there have been instances in which pipes apparently sound at testing have afterwards proved to be defective when the jointing has been removed from vicinity of the seam.

We have seen this evening some very interesting samples of internally corroded pipes, showing results of the action which is frequently found to be going on in the inside of main condenser, circulating inlet and discharge pipes, including condenser tube ferrules and at times the tubes themselves; it is found also in bilge discharge pipes; in some cases the action is found very active in the water ends of brass-fitted pumps and attacks the bucket rods, valve seats and valves and studs, and which are being constantly renewed, athough metal of different mixture is tried in order to overcome the difficulty. One very noticeable feature met with is that in two sister vessels trading in the same waters, and under exactly similar conditions, we find in the one this corrosion taking place very rapidly, whilst in the other it is scarcely perceptible.

Considerable trouble has been experienced in some steamers with water circulating pipes for refrigerating plants, and which at the time occupied the attention of experts and others a great deal, and various experiments were made to get at the solution, and after taking into consideration the pipe arrangement, conditions of working, the conclusion arrived at was, that it was due to air in the pipes, the presence of which in one instance was proved by fitting a small cock at the highest point in the pipe range, and while the circulating pump was working under ordinary conditions the cock was opened, and it was found that an appreciable time, some seconds, elapsed during which air only was passing, and then came the water.

It has been suggested by some engineers that electric light installation on steamers was responsible for the corrosive action; this idea, however, I cannot altogether agree with, as I have found the action going on in steamers in which there was no electric light, and afterwards when a plant was fitted on the vessel it made no difference in this respect at all.

Mr. F. M. Timpson (Member): Mr. Adams has referred to the advisability of having spring hangers, and I do not think these are as generally adopted as they might be. I know of two ships, where in the one instance these spring hangers were fitted on the main steam pipes and no trouble was experienced, but in the other vessel the pipes were made fast to the beams, with the result that continuous annoyance was caused. Recently an engineer with whom I am acquainted, and who is employed in a large factory in London, had a lot of trouble in the pipe lines, but since he has adopted spring hangers his troubles have ceased. There is no doubt the coppersmiths are often blamed where it is the engineer's fault. In connexion with the jointing of pipes over the brazing line, which Mr. Adams mentioned, I think that difficulty might be met by providing an ordinary service spigot joint. With regard to corrosion in the pipe lines, air, no doubt, is a great factor. Some few years ago I had an experience of corrosion in a condenser, the condition of the upper part of which caused much alarm. We treated it with cement wash and red lead paint, and had a stand-pipe arrangement so as to keep it thoroughly filled up, and had little trouble with it afterwards.

Mr. W. McLaren (Member): In regard to the expansion and anchoring of the pipe, I think that is a vital point, the question of where to anchor it. I hear friends on the right and left speaking about spring hangers and spigot joints, but I hear no mention of a flexible gland, a roller traveller, that is away from the anchorage. The use of stuffing-boxes with an anchorage is adopted to some extent, but it is liable to leakages and to be squeezed so up that it is often useless. With the expansion joint, if it is properly anchored and the conditions for the movement are in good order, it is no doubt an admirable method; but when steam has been up for about thirty days or so there is no play on it, and it becomes so stopped up that it is practically useless. With regard to bends, I do not know to what extent circular bends have been made use of, and I think a bend like that ought to be effective in taking up the expansion of the pipes, provided it is anchored well at the proper end. That is the difficulty, the question of where to anchor the pipes, and when we consider Mr. Milton's figures, the boilers rising $\frac{1}{8}''$ for every $4\frac{1}{2}$ ft., and the copper pipe $\frac{1}{8}''$ for every 3 ft., it will be seen that it is necessary for allowance to be made for a good deal of expansion. I think when Mr. Timpson drew attention to spigot joints he suggested a way of meeting the case, as the last spigot could not be got in without the pipe being short. I would like to corroborate Mr. Balfour's statements with regard to the action of the air. I can speak of a similar thing occurring in wrought-iron pipes for hydraulic pressure return. We have the pressure set full bore, but in the working of machines where we are working irregularly we do not get the full amount of water into the return. Therefore we find that all these pipes begin pitting on the top, and this goes on until the pipe has to be renewed, but I have never known of a vertical pipe where the corrosion occurred. Mr. Adams drew attention to the corrosion in centrifugal pumps. In two cases that came under my notice we were not able to keep the shell going for more than six or nine months, working with artesian well water. We tried a phosphor bronze wheel or disc, and that is not so bad, but the pump shells still suffer. I was much interested in hearing Mr. Balfour's remarks, and also must thank Mr. Milton for his very valuable lecture.

CHAIRMAN: The subject is so interesting and covers so much ground that it is proposed to adjourn the discussion until Monday next. The meeting will take place at the rooms of the Institute in Stratford, as we have not engaged this building for next Monday. I hope it will be convenient for a great many of the members to be present, and I am sure those who are able to attend will hear something which will be both valuable and interesting.

Mr. J. FELL REDMAN (Member of Council) proposed a vote of thanks to Mr. Milton, which was seconded by Mr. J. THOM.

A vote of thanks was also accorded to the Chairman on the proposal of Mr. Geo. Adams, seconded by Mr. W. McLaren.

ADJOURNED DISCUSSION.

Monday, February 17, 1908.

CHAIRMAN: MR. ALEXANDER BOYLE (VICE-PRESIDENT).

CHAIRMAN: As you are aware, the discussion on Mr. Milton's lectures on "The Treatment of Copper for Steam Pipes" was adjourned until this evening, and I am pleased to see so many present. At the London Institution Mr. Milton, in his able and interesting lectures, travelled over a great deal of ground. Starting with the treatment of the copper from its rough state in the ore, he described the effect which the presence of an extremely small percentage of foreign matter had on the quality of copper, and gave an account of the rolling of the copper ingot into sheets and drawing it into pipes. The Admiralty tests were touched upon, and he also explained a good many other points with regard to the construction of pipes, and also in connexion with the Elmore electrically deposited process for the formation of tubes. Several other matters which we as engineers are very much interested in were ably dealt with by Mr. Milton : the question of annealing, the causes of failures in pipes, and the causes of the corrosion which takes place, not only in copper steam pipes, but copper pipes when used for conveying salt water. There are several gentlemen present who, no doubt, will be able to say something either from their own experience or about what they may have heard or read regarding copper pipes, and I am sure Mr. Milton would be very pleased to deal with any points which are not clear, or to give any further information which any one may desire. I trust, therefore, no one will hesitate if they have anything to say on the subject. If any gentleman did not see the specimens which were handed round at the London Institution, showing the effects of corrosion on copper pipes, there are a good many examples here that might be of interest.

Mr. McNaught (Visitor) : It may be out of place for me to ask questions, not being a member of the Institute and not a marine engineer, but there is one point I should like Mr. Milton to give an explanation of in connexion with coppersmiths', or rather copper-founders', work. When the copper is obtained from the ore it is cast into billets or ingots—I do not know the technical term—and in drawing tubes or other articles I would like to know how they do it to be certain of getting a sound casting. I have only had experience of founders' results, and when Mr. Milton was giving his lecture I could not understand, seeing that the tubes are drawn so many times, how they can tell what is inside the casting. I know from my experience the casting is often honeycombed all the way through, and when drawn out it is still honeycombed. That may be an explanation of what Mr. Milton referred to in connexion with condenser tubes being faulty, for which he was unable to give a reason.

Mr. W. E. Farenden (Assoc.) : I should like to ask Mr. Milton a question as to the temperature in annealing, as I am not quite clear as to what the temperature should really be.

I think he referred to a dull red heat, and then a blood red heat and also a bright red heat, and I do not quite know which he considered would be the best temperature. Then again, he stated in his first lecture that copper, in annealing, could be either quenched by water or allowed to cool down gradually, and I would like to know which he considers the better of these two methods.

Mr. McNaught: With regard to brazing pipe flanges on to copper pipes I would also like to ask Mr. Milton if there is not a way of effecting the result by putting strong flanges on to the pipes without brazing. I have seen it either on the "Belle" boats or on the "Palace" steamers, where the flanges are not brazed, and where steel flanges are used.

Mr. Milton: The flange Mr. McNaught speaks of is called Pope's flange. It was introduced by Mr. Pope, one of the partners of Messrs. Denny & Co., of Dumbarton. They are made of wrought iron, very thick, with a round lip at the inner circumference. When dealing with a seamless pipe the pipe is softened at the ends and flanged out, making a little collar on the outside all round. The flanges must be put on the pipe before this small collar is made, or they could not afterwards be put on. Then the two collars are nicely faced—then drawn up metal to metal between the two heavy flanges, the lips of which sink somewhat into the copper. These flanges have been used largely in some of the ships built by Messrs. Denny. In the cases of brazed pipes, where the brazed seam presents an irregularity of thickness of the copper, Mr. Pope preferred to make separate collars of the same shape, and braze them on to the brazed pipe, so that there is really a brazed joint round the pipe. There was a slight difference between the Pope flange and a similar kind of flange made by the Central Marine Company about fifteen years ago for use with Elmore seamless pipes, the difference being that the flange had no lip, and the whole width of the collars was squeezed into contact. It was, however, found that the Elmore pipes did not stand well for marine work and had to be given up, and then this method of flanging was also given up, and the firm went back to brazed tubes and flanges. Mr. Farenden has asked what is the proper annealing temperature. Let me say again, as I read out of the French book at my last lecture, that the purer the copper, and also the higher the temperature at which annealing takes place, the quicker is the total annealing performed. You will see in the diagram on page 37, at the low temperature of 392° F., which is only the temperature of high-pressure steam, it takes thirty minutes to lower the tensile strength, and even after four hours the annealing is not complete. At a higher temperature, dull red, the annealing is quicker, and at a very high temperature, bright red, the annealing is perfect almost at once. But when one speaks about annealing it must be remembered that one has to consider the material from which the start is made, that is to say, if one starts with copper not very hard it is not such an important matter to anneal it, nor does the operation take so long. Copper when perfectly annealed is in its softest condition. When very hard it takes time to change the crystalline structure. When dealing with large pipes, if you wish to anneal them, that is to say raise them up to a uniform temperature throughout at one operation, you have to take into consideration the necessary time for heating up; first of all it is raised to a low temperature, then to bright red, until by the time it is nicely heated throughout most of it has already been heated for a considerable time, and, I daresay, properly annealed. With regard to the question of which is better, quenching or cooling out, Mr. Tomlinson, who favoured us with some remarks at the last lecture and who is one of the most skilled copper-makers in the country, maintains that there is absolutely no difference whether the copper is cooled slowly or quenched out. This may be so when the heating has been prolonged, but there must be a difference if the heating has been hurried, because if it is cooled down slowly it is really hot a little longer than if it is quenched, and the annealing is therefore prolonged a little more. Mr. Allan, manager of Messrs. Hawthorn, Leslie & Co.'s engine works, where they do their own coppersmiths' work, has been making a series of experiments on the annealing of copper, and he intends to publish the results in a paper which he is to give at the North-East Coast Institution of Engineers and Shipbuilders. He communicated the results to me, and he has found that if there is any difference it is in favour of quenching out. He took tests in pairs, and where there was the least doubt as to the results he submitted an extra pair to the same conditions, and came to the conclusion that the quenching was a little the better, but that there was not much in it. He was quite surprised, however, to find how serious were the effects of "gassing." He did not realize that it caused so much harm as he found to be the case. He gassed some specimens for quarter of an hour—of course that is too long a period, as copper would hardly be gassed to that extent, but to show the effects of gassing perhaps it is useful to go to the extreme. He took all the strips from the same sheet, and these strips were then annealed, some of them, and others gassed. Speaking from memory, the hard copper—which was not very hard, but as usually bought from the copper-makers—stood about forty bends backwards and forwards through a definite angle and over a definite radius, so that every strip could be submitted to the same conditions. When properly annealed and quenched it stood seventy bends, but when gassed for quarter of an hour one stood seven and the other eight. The difference is enormous. Now, the gassing is the taking away of the quality of the copper from the extreme outside surface. Quarter of an hour's gassing seemed to go right through, and I do not think there is any doubt that gassing, even for a minute or two, will go in some little distance. It therefore causes the metal at the outer surface to be less ductile than it ought to be, and we all know that where there is work put on backwards and forwards it is the initial crack that counts, and if it is gassed at all, if the surface is cracked, it is only a question of time before the crack will run right through the copper. You have seen some of these test pieces, double bends with one side gassed and the other sound, and you will have noticed the little cracks I am speaking of. They are an important element, and it would be a good thing for engineers, who have to get copper pipes elsewhere, perhaps in foreign ports, to keep an eye on the copper to see if it is gassed, and if there is any cracking of the surface do not pass it—better delay your ship. What is meant by "gassing"? It is the effect of heating the copper to a red heat in a reducing flame. You gentlemen who go to sea in ships and have charge of boilers know something about combustion, and you know, when burning carbon, if you have a good supply of air you burn the whole of the carbon to CO_2, but if there is a deficient supply part of the carbon is burnt to CO, which is greedy of oxygen. It is the CO in the flame, the imperfectly burnt carbon, which gives the reducing flame. Now I fancy

—I am not a coppersmith and probably Mr. Brown knows more of this matter than I do—but I fancy that at the most critical time in getting the brazing metal "just right," not overburnt, when the smith turns off the blast, that is the time when the harm is likely to be done, when there is not a full blast through the fire. Another point is the annealing temperature. I should like to see annealing done with the whole of the copper at nearly as high a temperature as is necessary for brazing, but not with an old pipe, because you must not run the risk of damaging the brazing in any way. That is one reason why it would be wise to say that a rather dull red is best for an old pipe. But with regard to new pipes, if seamless, it is best to anneal them before brazing the flanges on. Mr. McNaught asks how sound castings are made. I do not know how sound castings of copper are made, but I know that at the Broughton Copper Co.'s works the ingots are cast, and while fluid are put under hydraulic pressure, and that closes up every blowhole. But I believe there is a difficulty in casting copper sound, as there is in casting some other metals. This is due to the occlusion of gases in the liquid metal, the gas being given off just as it is settling into solid form. One gentleman mentioned at the last lecture about calico printers' rollers. In shrinking on the copper linings to the iron rollers for calico printing they sometimes run across a little blowhole which is fatal to the lining. This is one of the points in which deposited copper has a great advantage over the other method. The electrically deposited copper has the absolutely coherent and uniform surface necessary for articles of that kind. With regard to brass castings, there is no difficulty in making a copper-zinc casting perfectly sound. Condenser tubes are of copper-zinc and are made from perfectly sound castings. I have had the experience of examining many hundreds of copper-zinc alloys under the microscope, and it is the rarest thing to find a blowhole in them, but with gun metal-copper-tin alloys it is the rarest thing, when examined under the microscope, to find them sound. As I mentioned in the first lecture, molten copper oxidizes and then dissolves the oxide of copper formed. Just as the copper is about to solidify, it gives up some of its oxygen. With copper-tin alloys something similar occurs, and the minute defects in these alloys are the very minute particles of copper oxide thrown out of solution. But with copper-zinc alloys, the zinc vaporizes at the high temperature, and the oxide of zinc which is formed remains in the air and is not dissolved into the metal at all. So that the castings for making brass condenser tubes are practically sound castings, except for the slight defects which really are surface defects. To get rid of these surface defects it should be general to do what the Admiralty do, that is, to specify that the cast brass tubes should be turned outside and bored inside before being drawn. The ordinary condenser tubes are not made in that way. There was a point that Mr. Tomlinson remarked upon—and if I mention this now it is only to produce some further discussion. Mr. Tomlinson spoke about the corrosion of copper pipes. He could not account for it altogether, but suggested that it might be due to very slight differences of surface conditions of the copper. Well, to some extent that may be right, but the question is, I freely admit, an exceedingly difficult one. The fact that corrosion takes place is very serious, and it is the more difficult to get at the reasons for it as the action itself is really extremely slow. An engineer thinks it is a serious matter if the copper in a pipe corrodes away in six months. So it is, because we expect it not to corrode at all, but when it is remembered that this action only bores through say one-eighth of an inch in six months, it will be seen that it is really a very slow action, and although it is undoubtedly due to chemical or electrical causes, it cannot be expected that the effects of that action can be seen in an hour or two's testing in a laboratory. The difficulty is not so much to account for the corrosion as for the erratic nature of the corrosion. Another trouble is, what is the corrosive agent? Mr. Balfour and another gentleman spoke about some hydraulic pipes. They said that the delivery pipes into hydraulic machines were practically free from corrosion, while the exhaust pipes, where there was not so much pressure, were corroded very badly. Mr. Balfour gave an account, which Mr. Adams confirmed, of a long run of copper pipes subjected to sea water, and he explained that the pipes were sometimes full and sometimes partly full. Both of these gentlemen hit upon a very possible cause of the corrosion, but neither of them have explained why the corrosion is erratic, or sporadic, as I think our Chairman called it. Many of you gentlemen must have seen corroded propeller blades. In general they corrode very badly near the tips, always on the back of the blade and mostly on the leading edge—the other side does not corrode. All sorts of schemes have been arranged to try to overcome this. One scheme was to polish the back of the blade and sweat tin on it. Another way was to pin on brass sheets. I think probably this difficulty is not experienced so much nowadays, as manganese bronze propellers are very much used, which I suppose do not corrode, but why do those blades corrode on the back and not on the face ? It was the same iron. Every engineer is familiar with Weir's pumps. The patentee of those pumps, Mr. Weir, made a lot of experiments on the corrosion of iron by water. In one of these you could see a piece of bright iron, which under certain conditions began to blacken within an hour, and under other conditions it could be kept bright for many hours. The blackening was due to heating the water in which the iron was placed. He undoubtedly showed that ordinary water—either pure water or sea-water—when exposed to the atmosphere dissolves up in it a quantity of atmospheric air. If the pressure is relieved from the water containing air a lot of air bubbles will arise from it. Under a great pressure much air is dissolved up into the water, and if the pressure is then taken away rapidly some of the air is released, and the more the pressure is reduced the less air will remain in solution, and of course the warmer the water the less air it will retain in solution. In Mr. Weir's experiments, as he warmed the water, the oxygen of the air just coming out of solution in the water attacked the bright iron. At the back of the propeller blade there is a reduction in the hydraulic pressure, the air comes out of the water in minute globules and this comes up against the backs of the propeller blades and so tends to rust them. In the pipes Mr. Balfour spoke of, at the bottom of the pipes, where there was great pressure, the air was kept in solution in the water. In the vertical pipe the pressure was reduced, but by the time the water came to the top some of the air came out of solution, and so the water became over-charged with air, and this is the condition in which its oxygen has the most rapid effect upon metals. Mr. Balfour said this was overcome by putting a head on the water so as to keep the pipes full. In all probability this put more pressure on the pipe and this pressure prevented the air from disengaging itself. But all this does not account for the local spots of corrosion. I think Mr. Tomlinson's suggestion may be near the mark, and that I will go into further when I give the lecture on "The Decay of Metals" some time during the summer.[1] I mentioned in my lecture that the purer the copper the greater, in a marked degree, is its conductivity of electricity. I mentioned, from a table I had, that ordinary commercial copper with a reasonable amount of impurity—about 99 per cent. of copper to 1 of impurities—had the conductivity brought down to 22 per cent. of that of the very pure copper. Well now, when copper is in a molten condition, when it contains impurities while in the liquid state, I believe the impurities are mixed up through the liquid absolutely uniformly, as we know salt is dissolved in water. If you take any quantity of sea-water, if you take the minutest particle of it, a very clever chemist will find that there is absolutely the same percentage of salt in that tiny drop of water as in a ton of it. The diffusion of substances in solution appears to be absolutely uniform down to anything that can be seen by the microscope. But of course we cannot determine with certainty what goes on when we come down to what the mind can think of in the way of molecules. Our late friend Mr. Macfarlane Gray told us that Lord Kelvin had stated that if we could magnify a drop of water so that the drop would appear to be as big as the earth, the individual molecules of the water would be represented by particles about the size of cricket balls. If the proportion of the solution is one part in a thousand, there must be large collections of water molecules without a particle of the dissolved material in them. But in the main, for anything that the human mind can grasp, there is a uniformity of composition in liquids, and this must be the case with the liquid copper, but when solidifying the first piece that freezes out is not quite of the same composition as the remainder, it is more nearly pure copper, so that the part remaining is less pure. The freezing out goes on until there is a stage reached in which we have crystals of pure copper surrounded by molten impure copper, which solidifies afterwards and thus pieces of impure copper when laid under the microscope and suitably acted upon by acids are seen not to be homogeneous. That may be one reason why these little local differences occur, the differences in the starting

[1] Arranged to be given at the Franco-British Exhibition on Saturday, September 5.

points of corrosion. The purer the copper the more easily is electricity carried by it, so that if there is a surface of copper exposed to electrical action, the current goes through at a greater intensity on the pure spots than on the impure, therefore it is to be expected that there will be greater corrosion on those pure spots. Mr. Tomlinson seemed to imply that it may be due to particles scaling off, but even absolutely pure copper would have spots where the corrosion would start first, and if there are parts which show quite a clean spot, it is through the clean surface you would expect more of the current to pass. That may be one reason why this action should be erratic.

Mr. Aitken Brown (Companion): Mr. Milton has given us two splendid lectures at the London Institution, and not only has he been most willing to come down to the Institute here to answer any questions, but he has even volunteered one more elaborate lecture to-night, and I am quite sure we are all pleased that Mr. Milton has given us such a great deal of information. With regard to the position of coppersmiths, I am afraid they have to suffer very often for the sins of omission and the sins of commission of others. I remember the case of a new ship in the early days of high pressure steam. It was built by a fairly eminent firm of shipbuilders and engineers, and the main steam pipes were 13 inches to a specified gauge. The gauge was all right, but they put on flanges $\frac{3}{4}$-inch thick. Would you blame the coppersmiths for that? The result was that after making one trip the flanges were all torn to pieces. They put on flanges double the thickness and increased the number of bolts by half as many again, with the result that the flanges never got out of order afterwards. But still the coppersmith is blamed for things of that kind. The greatest difficulty as far as Pope's flanges are concerned is that they are not strong enough. The collar is not strong enough for the work it has to do, and consequently it cracks across almost invariably. I would always have these Pope's flanges if the collars were strong enough. I daresay Mr. Milton knows something of a construction one sometimes sees, where a copper pipe is fixed between two cylinders, and probably the coppersmith will be blamed for work of this kind. A pipe, say $\frac{1}{4}$-inch thick, is fixed between two cylinders and made a stay of, with the certain prospect of failure.

The poor coppersmith is blamed for that, and many other things which could be avoided if only the matters were thought out in the drawing office and other places. I know of a case in point where there were three facsimile pipes, one of which burst, resulting in the death of several men. The other two pipes were handed over to the Board of Trade and the Home Office and experimented upon. They were burst in our works, and the first of the two burst in exactly the same place and at a pressure of, I think, 1,550 lb. Well, if that one burst at 1,550 lb. the other must have burst at 1,550 lb. as the pipe gave way in exactly the same place and in the same way. The next pipe went at 1,590, but instead of going in the same place it did not burst, the brazing was opened up. These were experimented on and tried before officials of the Home Office and the Board of Trade. I have not the statistics in connexion with the tests; I tried to get them, but was told they were the property of the Government—probably Mr. Milton might have more information than I have; no doubt Mr. Boyle has some slight recollection of it, and probably Mr. Adamson knows of the same case. Mr. Milton referred to expansion joints, and I have no doubt our firm has had quite as much experience of these as any coppersmiths in London—the result of that experience seems to indicate that expansion glands are not of much use. Certainly they do a little good, but I could take you to where there are a number fitted for the London County Council to a long range of pipes with very bad results. With a proper expansion bend these difficulties would not happen. I do not quite agree with Mr. Milton in the blackboard sketch which he gave at the last meeting night, but I have no doubt we can agree to differ. I remember a paper read by him at the Institution of Naval Architects, and he then used drawings of some splendid expansion bends. I know of a ship where they had main steam pipes which used to cost in London something like £30 every voyage, and in the colonies about £55. The chief engineer wanted an expansion gland; this led to a controversy, as we advocated an expansion bend. It was then decided to have the bend. We made a corkscrew bend, like a spiral stair, but the chief engineer was not convinced that this was better than the gland; however, two years after he volunteered the admission that he was glad to own the bend had cured the trouble. That same pipe never cost a single penny for eight and a half years, as a gentleman present can confirm. Another thing with regard to coppersmiths is the way pipes are fitted. Large pipes are connected as close to the boiler as possible—I am speaking of the three-boiler system—a large pipe is taken away to the throttle valve instead of putting a dividing piece on the throttle valve chest, whence smaller pipes are so led that if any accident happens they shut off there instead of having all the work on the large pipe. The smaller the pipe the more expansions it will stand, and if you have good expansion bends it is better than having a bigger pipe. I have one or two drawings that might be of interest, and if a good black board demonstrater were here we would have shown some expansion bends. That is what in my opinion we ought to go into more than we do to-day. With regard to corrosion I might mention a word or two in connexion with the corrosion of winch exhaust pipes. In the case of iron pipes, corrosion goes on on the outside, and about every four years at the least they have to be renewed. This is one of the cases where I would advocate copper pipes being used instead of iron. Not only because of the corrosion, but there is not the same expansion in the iron winch exhaust pipes as with copper, and they do not stand so well. You see them drawn out at the sockets and flanges. If copper were used the pipes would last the life of the ship, while iron pipes require renewal every four years. The salt water gets on the outside and corrodes the iron, and I think if shipbuilders and superintendents looked at it carefully and went into the price with regard to renewals, they would certainly have copper pipes in preference.

Mr. J. THOM (Member): We have heard the point of view of the coppersmith. I am an engineer and of course the engineer has his own way of looking at things. Mr. Brown mentioned a case of flanges $\frac{3}{4}$-inch thick being put on a 13-inch pipe. The man who proposed that evidently had a good knowledge of coppersmiths, and he knew that copper was sold by weight. It was a commercial question when he fitted $\frac{3}{4}$-inch flanges. Speaking of the expansion of pipes, the case was mentioned of a pipe being fitted between cylinders, where it was stayed up and there was not sufficient room to allow it to "humour" itself. Any engineer would know that. A coppersmith would know it too, and might have recommended that it be altered. As regards anchoring of pipes and these giving way for want of sufficient expansion, fault was found with expansion joints, but in my opinion the average expansion joint is all right if the anchorage is all right, but when pipes are put in anyhow most likely they will give trouble. Sometimes the expansion joint is put in so that the pipe will not go any further in, and although it is the right length when cold, when heated up it lengthens and consequently it goes all ways. Success depends upon the way in which the various details are put together. The fitter is often to blame, possibly he has never been to sea, he has never seen a pipe expand, and he has no idea of how much a length of 30 to 40 ft. will expand. The most important thing is in the anchoring, and when done properly there must be a certain amount of motion possible at the free end, and if it is not fixed properly at the end where it should be fixed there is no use putting on an expansion joint at all. Mr. Brown also mentioned about a pipe that gave way at 1,590 lb. I think that pipe must have been a very good one when it could stand that pressure, but what about the temperature ? This test was no test with regard to the strength of the pipe when hot. It is put under pressure and the result is noted, but how do the conditions correspond with the arrangements on board ship ? What are these to the pressure of steam ? that is a vital point in connexion with the test. The reason of the bursting in this case was possibly on account of the way the pipe was put in the ship, and the conclusion to be drawn is that pipes should be put in properly. The workman may forget about the temperature—he tests it in the shop, puts it on board the ship and thinks it is all right. With regard to deposited copper, Mr. Milton told us that the whole secret of the copper business lies in the purity of the copper. The depositing is done by electrolytic action; the copper is put into a bath and a pipe is created for any size job you like and of the very best material. With regard to corrosion, in my opinion a good deal of it is due to electrical action. I do not think there is a ship where electricity is used in which everything is perfect on board. There is always something wrong, leakage of current takes place in one part to-day and cures itself to-morrow because the weather changes, and so on. Supposing you are supplying current to a certain part and one of these defects occurs, the current goes home again by the easiest road to the dynamo, very often choosing the copper pipes as the means of conduction. The purer they are the easier they are attacked, the less pure they are the less liable to be attacked, and, as far as copper goes, the more suitable they are for the work on board ship. The electrical action goes on, and goes on periodically, varying according to the weather conditions. I think that is one thing that causes the erratic corrosion. I do not think there are any ships that have proper testing sets or sufficiently good instruments to try if everything is in good condition. There is a very simple way, however, of finding out the lead of the copper pipes and the probable cause of those little spots and holes. The parts near lamps in exposed conditions are particularly affected, and it will be found that near the lamp electrolytic action is going on between the lamp and the wires. That is the beginning of the trouble. At another place water gets in and makes a connexion, and as soon as it does that the current takes the nearest road it can get. I do not think there is any question but that a great deal of the decomposition is simply due to the electrical arrangements on board ship. I know an instance in one of His Majesty's ships which, until seven years old, had no electric light. Then the light was put on board, and two years afterwards the condenser tubes had to be taken out and others put in. Those tubes gave out in two and half years, and another set in three years. In the case of another ship, an ordinary commercial trader, there were no electrical arrangements on board until it was four or five years old; eighteen months afterwards quite a number of the pipes were taken out in an extraordinary state of corrosion, so much so that some were quite flattened out. All those pipes that gave trouble were near circuits that gave trouble in connexion with the electric light, that is to say they lay in the easiest path for the current to get back to the dynamo.

Mr. G. W. NEWALL (Member): I should like to ask the lecturer whether the pitting he describes is as common to pipes carrying steam and hot water as in pipes where there is a very low temperature. The cause of corrosion seems to be an unknown quantity, and I was just thinking of the trouble that was caused in the Atlantic cable through the boring effects of the Toredo beetle. This insect seemed to like the copper and bored through it, with the result that the cable of copper wire, say one-eighth of an inch diameter, was destroyed. May not something similar be taking place in the pipes where there is no heat ? Of course living creatures could not stand the steam.

Mr. Milton : With regard to Mr. Newall's remarks about the Toredo beetle, I do not know exactly what it is, but I have heard of an insect with a similar name, the *Teredo Navalis*, which, however, does not eat the copper. I had a friend who was an expert in submarine cable work and I understand from him that the Teredo is very fond of the insulation, gutta-percha especially. It makes a hole through the gutta percha and the sea water gets through and does the rest. As a matter of fact, in general cold water pipes corrode very much more than the steam pipes, but occasionally the reverse happens. I have just had a case submitted to me where a water gauge pipe on the boiler—I do not know whether it was the steam or the water end—was corroded very badly in a few months, and that corrosion was exceedingly unique. The surface was corroded more on the side nearer the boiler than the other. The inside of the pipe was covered with a coating of black oxide—cupric oxide—and immediately underneath it a coating of red oxide. It is therefore a case of oxidation pure and simple, but in most cases of corrosion the substance formed is washed away and you cannot get at what is really the cause.

Mr. Aitken Brown : Would that boiler be in the habit of priming ? I know of two similar cases where it was due to that cause.

Mr. Milton : This case is not a coppersmiths' fault, Mr. Brown. I must say that Mr. Brown has been very fair in giving us his remarks. If Mr. Brown were actuated by motives of £ *s*. *d*. I do not think he would advocate what he has done if it is true that "the decay of the article is the strength of the trade." He is advocating pipes which will give no expense when once made. I think all that Mr. Brown has said has emphasized what I said in my lecture, that pipes ought to be designed in the drawing office, and it should there be determined how much shorter they are to be when cold than when hot, and how they should be fastened in the ship. It should be a matter of more than merely drawing lines and leaving the foreman or anybody to suggest how the hangers are to be put on, and how much clearance there should be for the expansion of the pipe. I have heard, and no doubt Mr. Boyle has heard also, of an important case where a man was killed by a pipe drawing out. The pipe was too short, and the packing was squeezed out into the bottom of the bottom stuffing-box. This was a point which was not properly considered in the drawing office. With regard to the cork-screw pipes, no doubt this is a flexible form, but there is one serious disadvantage. Unless it is nearly vertical it forms a water trap, and of all things there must be no traps in steam pipes. This morning my attention was called to a Board of Trade report on the failure of a long range of iron pipes due to water hammer. The final recommendation of Mr. Samson was to the effect that drains connected to pipes ought not to be opened when the stop valves were open. In this particular case they opened the drain while the steam stop valve was full open, and the water hammer action started breaking the flanges to pieces. He made a recommendation that when you open drains and start the water you must be sure there is not much steam in the pipe, and when you do start it don't let it get on straight away. I do not know that the fact of the two pipes mentioned by Mr. Brown standing the high pressure proved that the other pipe was very strong. It may be that one was defective and the others not defective. We do not know the conditions, but certainly the effect may have been due to water hammer, defective workmanship or faulty design. The test was not made under the same conditions of heat or expansion, and you cannot draw conclusions from what another pipe will stand under hydraulic pressure. It may be that the copper was at fault. There are some impurities which make copper unreliable when hot and not when cold; bismuth is one. At the temperature of steam, the copper will stand only about 2 tons per square inch, whereas it will stand 14 tons when cold. When hot it is absolutely brittle. Mr. Adamson has brought down this specimen of Pope's flange. That is a specimen of a lapped pipe made by Messrs. Denny after the scare produced by the *Elbe* explosions fifteen or twenty years ago. That was a serious explosion of a brazed pipe, and it was stated that it was burnt during brazing. My impression now is that it was gassed and not burnt. But to overcome the possibility of ruptures in brazed pipes, Messrs. Denny introduced that system of lapping it round with iron bars put on red hot and twisted. Some engineers at that time lapped the pipes up with steel wire ropes. I think you will find, if you look through statistics of pipe failures, that at least 95 per cent. of the pipes have failed in a way that neither that style of lapping nor the steel wire ropes would have prevented. Nearly all fail through cracking around the brazing of the flange, through defective design in not having sufficient room for expansion allowed. As Mr. Brown has said, having a separate pipe from each boiler is an easy way of obtaining more flexibility, but the multiplicity of flange joints means a multiplicity of leakages. In a warship there is a large range of boilers and a large number of auxiliaries, and the question of tightness or otherwise of the steam pipes is a serious matter. In some ships it is a question whether the evaporators can keep up the supply of fresh water even with double the ordinary evaporative power, simply because of leakages from the multiplicity of small pipes. In other ships with very carefully designed steel pipes with as few expansion joints as possible, but good provision for expansion at the bends, there is no difficulty whatever. With a bad design the best workmanship is of no use, with a good design and good workmanship everything is right.

Mr. J. Grisdale (Companion): Mr. Milton described two kinds of bends as shown in Figs. 5 and 6. My experience is that it is better not to have sharp bends even of the description given in Fig. 5, for this reason, that a greater part of the work would come at the bends and the pipe would give at the inside corners. The best way, in my opinion, would be to take the bend gradually round and make a regular circle of it, and by that means the whole of the pipe has the work on it instead of the two bends only.

Mr. Milton: Suppose you have not got the head room.

Mr. Grisdale: Of course it depends upon whether there is room for it, but the more circular you get a pipe the more expansion you get, because the radius is easy all the way round and the work is equally distributed. I maintain with Mr. Milton that the design is a very important matter, and care should be taken with reference to drainage at a bend where there is any appearance of a well. For my part, I think people should be compelled to put escape valves on every pipe as a drain, or to prevent steam hammer going on. We have had pipes bulged right out all the way round just next to the flange with water hammer. It is surprising what the copper pipe will stand before it will burst. These are all points that the engineer has to deal with in regard to the work, and sometimes the engineer, if he has an interest in the work, will follow all these points and will be able to get better results from the pipes. With regard to the use of iron flanges, there are some firms which put on iron flanges instead of copper, but while I do not say anything about the cheapness I do know there is nothing like the same durability in the work.

Mr. N. K. MacLean (Member) : I have not had the pleasure of hearing Mr. Milton's papers read, but in reference to the question of the corrosion of copper pipes an instance came under my notice three years ago of a main circulating pipe with the inlet and outlet always under water from condenser to outlet valve. The pipe was corroded so much that large patches of it were more like sieves than anything else. On taking the pipe apart the right angle bend was so far gone that it had to be taken off and a cast-iron bend was made and put in to save the other lengths. They were washed internally with caustic soda and coated with asphaltum, and from that time till the present there does not seem to be the slightest difference in the pipes, the corrosion having ceased. A piece of the bend was cut out and sent to a chemist to be analysed. The report was that the corrosion was caused by a gas that attacked the copper where it was not homogeneous and when the temperature was above 108°. Mr. Milton also spoke of the corrosion going on on the backs of steel or cast-iron propeller blades. Many attempts have been made and various devices applied to stop this, but I have never heard that any of these devices have had great success. I noticed the other day in bronze blades a slight corrosion on the face of the blades, while the backs were quite smooth. I cannot explain the reason. I have also had condenser tubes corroding on the top division of the condenser, while the lower section remained good. Almost all of the tubes were holed about an inch from the end where the water first enters the tube.

Some of the members seem to differ very much as to the shape and sweep of a bend for expansion. Well, little things often show us what should be done with great. In small copper heating pipes I had trouble with an expansion pipe bent to the coppersmith's idea. Every voyage this pipe had to be repaired, as it always gave way close to the flange. At last I got tired of the thing and had the pipe made straight with one circle coil in the centre, and have had no trouble since. I am sorry I did not hear Mr. Milton's lectures, but I would like to propose a hearty vote of thanks to him for his presence with us to-night and for the great amount of information he has given us.

Mr. E. W. Ross (Hon. Fin. Sec.): I have very much pleasure in seconding the vote of thanks proposed by Mr. MacLean. Several things came up in the course of the evening in connexion with brazing, but nothing was said particularly on that subject. I would like to have heard more on the subject either of brazing over the coke fire or by means of oxygen, and if the hour were not so late I would have been pleased to hear Mr. Milton's opinion on these two methods. There have been many remarks made with regard to pitting of copper, but there does not seem to be any satisfactory explanation of it. May it not be in connexion with the homogeneity of the copper. Copper containing some impurities apparently stands better for pipes, and it seems to be the case that the parts affected are the parts composed of pure copper, and the part not corroded that composed of the more impure copper. Mr. MacLean has referred to the pitting of propeller blades. Even in our newer blades of phosphor bronze and other somewhat similar alloys, we have signs of pitting, not to the same depth as formerly with iron, but a roughness of the blade which is a minute pitting. We are very much indebted to Mr. Milton for giving us these lectures; he has given us a lot of his time and deserves our heartiest thanks.

The motion was carried with acclamation.

CHAIRMAN: We are all of one opinion—that Mr. Milton deserves our heartiest vote of thanks. The lectures have been exceedingly interesting, important and valuable, and will prove a great acquisition to our Transactions.

Mr. McNAUGHT: I am not a member of the Institute, but I received a very cordial invitation to hear Mr. Milton's lectures, and have listened with great interest on the three occasions. I would like to propose a very hearty vote of thanks to our chairman for the very able way in which he has fulfilled the duties of chairman on those occasions, and I hope you will show your appreciation.

Mr. W. BRITTON (Assoc. Member): I have great pleasure in seconding this vote of thanks. At the same time I would like to express the opinion that there is a lot more matter regarding copper that we have not gone into, and I wondered whether it would be advisable to have a further evening to discuss the subject again.

The vote was carried with acclamation.

CHAIRMAN: I am glad to do anything I can for the Institute, and if what I have done has met with your approval I am very pleased. There is an evening vacant on March 16, which would give plenty of time for the members to prepare their remarks. I am of the opinion of the gentleman who said that there are certain points which could be more fully dealt with; the subject is not at all exhausted. Perhaps Mr. Adamson would communicate with Mr. Milton to arrange for a further discussion if it is thought desirable.

Mr. MILTON: If it is going to be a bona-fide discussion I will be very pleased to come.

ADJOURNED DISCUSSION

March 16, 1908.

CHAIRMAN.—MR. ALEX. BOYLE, VICE-PRESIDENT.

CHAIRMAN: It was suggested at the last meeting that the discussion on Mr. Milton's lectures on "The Treatment of Copper for Steam Pipes" was not quite complete, and that perhaps some gentlemen might wish to add something before the discussion closed. Mr. Milton very kindly promised to come down to the meeting to-night, although at some inconvenience, and I am sure he will be pleased to answer any questions or give information on any point which may not be quite clear. You have copies of the lectures in your possession this evening which will be a great advantage. Perhaps it would have been a greater advantage if you had had these some time previous to the meeting, but as it is, a hasty glance through them may provide ground for some remarks, or any gentleman may give his experience of copper pipes, which I have no doubt would be very interesting, The lecture, as you will observe, divides itself somewhat naturally into three parts, first, the treatment of the copper from the ore, the various impurities contained in it and its treatment until it reaches the stage of the ingot, secondly, how it is rolled into sheets and drawn into seamless and other kinds of pipes ultimately to be used on board ship, and the various failures now and again met with, and thirdly the question of annealing, brazing and the quality of copper generally.

Mr. E. W. Ross (Hon. Finan. Sec.): I think we ought to thank Mr. Milton very heartily for favouring us as he has done so often with his presence on the occasion of these discussions. One of the speakers at the last discussion spoke as if coppersmiths were on their defence. I do not think it was Mr. Milton's object to disparage the coppersmith's mode of working at all, it has been merely a lecture on copper from the ore to its finished state. A point that has been very much emphasized is the pitting that takes place in the copper pipes. I had hoped that we might have had some explanation from an expert of Mr. Tomlinson's experience on that subject, but we seemed as far off a solution as before. Mr. Milton has dealt with the matter in a very interesting way, but we still want some explanations to account for it. We are told that copper in a pure state is much more liable to pitting than when impure. If that is so, could an explanation not be found in stating that the copper might not be homogeneous right through, that it may be due to the pure leaving the impure copper to stand the test of use. Mr. Balfour showed us very plainly by diagrams the well known effect of air in the pipes and he showed us a way of getting over the difficulty which I believe is a very good one. We have seen in discharge pipes which are only partially filled, that the pitting has gone on at the top, and by keeping the pipes filled that defect has been cured. Then again, the action of acids in the bilges undoubtedly deteriorates the metal. We have seen cases of telegraph and telephone wires which have either fallen down without apparent cause or when there has been a slight wind, or through the effects of a heavy fall of snow. In some of these cases the real cause is not far to seek. I know of several districts where pitting has been caused by the acid fumes from chemical works and factories and the wires have been destroyed. Mr. Milton gave a description in his first lecture of the process of pipe drawing. We would have been greatly indebted to him if he had gone into that part more fully to show how the drawing is done, how the copper is not turned or buckled by the great pressure required in the process, also how the drawing out of wire is done. With regard to the brazing, we have of course the old-fashioned coke fire brazing, but of recent years there has been a departure in the way of brazing by means of oxygen gas, and I should be pleased to have Mr. Milton's opinion on the two ways. The question of annealing has also, I think, been very forcibly put forward as being an absolute necessity. One speaker expressed a doubt as to the advisability of annealing brazed pipes. I think all pipes ought to be annealed, brazed pipes included. There is no use hiding it and thinking it is a good pipe when it is not. They should be all effectively annealed to find out the weak and uncertain parts. In years. past we went in for large pipes, and as has been already noted, the smaller pipes, one from each boiler to the main stop valve chest, are more in favour now. The larger pipes were more uncertain than the pipes of smaller diameter and consequently the multiple system was more largely used than the one pipe system, as when one gives out, that boiler is knocked off and the others continued. The question of pipe bends has been very fully gone into, and this is a matter which has not had the consideration it deserves. The anchoring of pipes is all very well for expansion joints and glands, but there are certain places where one cannot always anchor a pipe and expansion bends are found necessary. The chief matter is to get a proper expansion bend which will stand the test of its work and not fail after a short period of use.

Mr. A. Robertson (Member) : At the commencement of his lecture Mr. Milton says that copper is nearly all obtained by smelting. I believe at the Rio Tinto mines a large proportion of the copper is obtained from the ore by means, first of all, of roasting it and then stacking the roasted ore in mounds and allowing it to remain open to the atmosphere, saturating these mounds with water at stated periods. This water is then run off into drains, into which pigs of iron are thrown and the copper becomes deposited upon these pigs. The natives are then employed in chipping off this coating of copper and the pigs are used over and over again until they are wasted away. I believe there is a very considerable amount of copper obtained in that way.

Mr. F. M. Timpson (Member) : In relation to the expansion of pipes, there is a system of expansion joints or bends which I have not heard mentioned. I cannot name it but I have seen it on board one of the Trinity House steamers, the *Irene*. It appears to form a case, one pipe inside of the other. In that vessel they had a lot of trouble previous to putting this pipe in and they have had no trouble now for a number of years. Perhaps Mr. Milton has some knowledge of the system. It is a double shell with corrugations in the outer shell and I believe one slides inside the other. It is a patented article but I do not know the name of it. At any rate it has evidently proved very effective in this case.

Mr. Milton : I have not heard of it and have never seen an expansion joint like that, but I remember many years ago seeing one proposed in which there was one of these concertina joints put in a pipe. I do not think it was patented and do not think they made many of them. There was an inner sleeve put in, fitting fairly easily inside the pipe and fastened only at the flange at one end. Probably this one that Mr. Timpson refers to is a modification, but I have not seen it. With many of these corrugations the pipe would be necessarily more flexible. In the case I remember the straight inner sleeve was not intended as a safeguard for expansion, but solely to prevent a great outrush of steam in case of the fracture of the outer pipe. Mr. Robertson spoke about the smelting of copper as mentioned in the first lecture. Of course we do not know much about the copper trade in all its branches.

The copper trade is the most secretive there has ever been in connexion with metals, but in this lecture you will see I said : "During recent years, however, progress in electrical and chemical science has enabled coppermakers to obtain copper from ores which our forefathers could not use as there was not enough copper in them to make it profitable." The method Mr. Robertson spoke of is one of those methods. In that method I do not think it is the running in of water that extracts the copper, I think they must use acids of some kind to dissolve the copper. When a copper solution is in contact with a piece of iron, the copper becomes deposited on the iron, that is one way they have of coppering iron wire. Atoms of copper take the place of an equal number of atoms of iron, and in time the iron disappears because it is replaced by copper, every atom of copper using up one atom of iron. Some system of that kind is used by the coppermakers of this country for dealing with the waste of copper from the scaling of pipes and wires. The run from the baths is passed over iron and the iron corrodes away, leaving very fine particles of copper which are gathered up and used. Another gentleman spoke about flanges. I had a letter, only within the last two or three days, from one of our eminent engineers settled in Italy. He said he had seen in a paper some notice of the lectures in connexion with this Institute, and that the question of flanges was one he was interested in. He sent a sketch which is precisely the same as Fig. 9, which he spoke of as being the right way to put flanges on. Mr. Ross asked for a little more information about the drawing of pipes on the mandrel. I thought I had made it perfectly clear, but if he would say in what way it was not clear I should be very glad to give information. I mentioned first of all that it was very essential, before beginning to draw the copper pipe on a mandrel, that the pipe at starting should be perfectly true. If one begins to draw a pipe which is eccentric instead of being concentric, all the drawing will never make it true afterwards. It is important to see that the pipe is turned outside and bored inside from one setting of the machine so as to get it perfectly true.

Mr. Ross also asked how they prevent the pipes from crumpling up in the drawing process. There is no danger of this in drawing the pipes, but there is a danger when drawing the mandrel out of them afterwards. The mandrel is a long rod with a very slight taper on it, and one end of it is slightly reduced in size. The pipe to be drawn has one end reduced in size. It is then put on the mandrel, the smaller end is put through the die and then the pipe is secured to the mandrel at the small end by a ring driven on it, forcing it into the reduced part of the mandrel. It is then drawn through the die, which is of steel, turned smooth and bright inside. The reduction in area each time is about 20 per cent.—I think it can be reduced about 25 per cent., but 20 per cent. is the average. They generally draw it as hard as they can without risk of breaking, and the more they reduce the area the greater the risk of breaking it. The drawing hardens the copper very much and it has to be annealed before being subjected to another drawing. The mandrel is greased and the outside of the pipe also, to lessen the friction. After the pipe is thinned down, the mandrel is turned end for end, a stop is put on against the die and the mandrel is drawn out. The moment the mandrel starts it comes away altogether because of the slight taper. If there is any difficulty in drawing the mandrel they put it back again and draw the pipe the second time through the same die piece. But there is a great difficulty with very thin pipes. Many of them crumple up in drawing the mandrel out. There is a good deal of waste of labour but the material is merely cut up and melted over again.

Mr. Britton: Do the dies revolve?

Mr. Milton: No, they are fixtures.

Mr. Britton: Both the pipe and the die stocks?

Mr. Milton: There is no revolution in it. There is a long endless chain with plate-links. The grippers on the mandrel slip in that chain, which works with a continuous forward motion.

Mr. G. W. Newall (Member): About what size of pipe is drawn in that way?

Mr. Milton: The largest I have seen is 8 ins., but I think they run up to about 12 ins. in seamless pipes. Some years ago when I was at one of the works 8 in. pipes were drawn down to successive stages to ¾ in. pipes. They stopped the drawing process when they got to the particular size wanted, and all the rest went on further till the smallest size was reached. I believe that now smaller ingots are used for the smaller pipes. With regard to drawing tubes, I can tell of an interesting incident which happened not long ago in connexion with a small vessel on the shaft of which it was necessary to put a long continuous brass liner. It was $\frac{1}{4}$ in. thick and there was a difficulty in getting the liner on in one piece, and at last a seamless tube was put on. The shaft took the place of the mandrel and it was sent to one of the tube drawing works to have the tube drawn through a die. It was secured on in the way I have described and was found to be perfectly tight. I have been told by one of my friends in a large engineering works that many rods are covered in that way, with brass tubes put on.

Mr. Newall : Is there not a wave action going on at that nosing at the top of the die ? Is there not a tendency for copper to break up into wave action ?

Mr. Milton : No, there is no wave action. The die simply squeezes the metal down. They do the same sort of thing in wire drawing, making the wire smaller and smaller gradually.

Mr. G. F. Robson (Visitor) : What is the average length of these mandrels ?

Mr. Milton : I should say about 25 feet would be a good length for a mandrel, but for the smaller pipes they are longer than the others. They have every appliance for handling them. As they are drawn out they are placed on a turn-table and slewed round very very quickly. A very similar process is used for drawing steel seamless boiler tubes.

Mr. Ross : If the mandrels are only 25 ft. long, how do they draw the long pipes perhaps 50 to 60 ft. long ?

Mr. Milton : Very likely those are made in two lengths and brazed together. I do not know of any pipes being made that length.

Mr. Britton : I have used copper pipes 28 ft. long, $2\frac{1}{4}$ ins. solid drawn pipes.

Mr. MILTON: They may make them that length. There is no reason why they should not if only the mandrels are kept straight.

Mr. TIMPSON: A few years ago, when there was great trouble with the small size watertube boilers, a large firm of builders had a brass liner drawn right through the tube. I have not seen it described to-night and I should like to know if it is still in use. It was used for the high pressure boilers, at 120 lbs., where the pitting action was very strong. They were Express type boilers, an adaptation of Thorneycroft's tubes, and twenty to thirty boilers of that type were made with the brass liner right through the inside of the steel tube. The idea was to stop the pitting by lining the tube with brass.

Mr. MILTON: As a matter of fact some of those tubes were used but were afterwards cut up and I do not think they were ever repeated. I did not know that there were as many as thirty boilers fitted, I thought there were only one or two. The tubes were brought before the notice of the Admiralty Boiler Committee with which I happened to be connected. They had a thin brass tube drawn in, the brass could not get any metallic union with the iron at all, it was simply stuck inside. It was not as though it were brazed on, and what was feared was that small holes in the brass would allow water to get in between the surfaces and crumple the inner tube and so stop up the circulation of the tube in the boiler. The fear of that more than anything else killed that kind of tube. There was another tube that was proposed at least twenty years ago by the late Sir William Allan. It was an iron pipe lined in the same way with copper, for steam pipes. That never came into general use. At the time when the iron tube with the copper liner was first proposed, Mr. Alexander Taylor of Newcastle had been using plain pipes for steam pipes without the copper liner. He found they gave no trouble in the way of corrosion, he took out one of the pipes and had it cut up to show that the inside of the pipe was as good as when it was put in, and from that time plain iron steam pipes began to be used. That is, I suppose, the reason why the copper lined pipe was not continued.

Mr. J. F. REDMAN (Member of Council): That would be wrought iron pipes for steam pipes, I suppose, not cast iron?

Mr. MILTON: Yes, wrought iron.

Mr. BALFOUR (Member): I would like to take this opportunity of amplifying what I said at the London Institution in connexion with the corrosion of copper pipes, which is one of the most important points brought to our notice. From Fig. 12, page 50, in the discussion you will observe I affirm that the corrosion takes place at the highest point of circulation, and in the horizontal range. Now supposing we remove the circulating pump from the engine-room as shown and place it near to the machine itself at the highest point of water supply, thus converting the pipe into a suction or inlet. I do not think any of you have observed corrosion in pipes under such conditions, because the pump is inoperative unless it is fully charged with water. I offer these remarks in support of my theory of corrosion as being the result of free air. There are numerous refrigerating machines working with the circulating pumps driven off the crankshaft, and I have never found in my experience any corrosive effect in pipes under those so-called suction conditions. With regard to Fig 11. It is admitted that trouble has been experienced with the main inlet. It is a very important pipe in a ship and I think that trouble from corrosion may be cured by having a regulating valve fixed on the pump itself, thus insuring the full pressure of water in the inlet pipe. We have been told about trouble with condenser tubes corroding, and that we cannot get at a solution of the difficulty. I suggest that this might be overcome by adopting a by-pass which I think would tend to prevent corrosion, resulting from the freeing of the air, as it insures a solid body of water in the pipes under various conditions of temperature. I have just learnt to-day, with much satisfaction, that an Institution similar to the Iron and Steel Institute is about to be, if not actually established, to consider the question of copper and its alloys and all non-ferrous metals. And the fact of Mr. Milton bringing this subject so prominently forward in his lectures before this Institute, is to my mind a remarkable coincidence that such an Institution is being formed to investigate and deal with matters in connexion with this very important metal.

Mr. W. BRITTON (Assoc. Mem.): I should like to ask Mr. Milton what is his opinion of hangers for copper pipes. Several gentlemen spoke on the matter at the previous meetings, but Mr. Milton did not state which type he approved of. I think it is quite within the scope of his lecture and should value his opinion. Mr. Milton said the largest pipes drawn were about 12 ins. and he had seen them drawn from 8 ins. I may say that Messrs. Thomson's have worked solid drawn pipes of 9 ins. diameter in this district. I deal largely in my work with pipes considerably under 6 ins. diameter and we have invariably used expansions for the flanges of copper coils. I wondered whether it could not be adopted to a greater extent for the larger diameters. For 2½ ins. pipes we used brazed flanges for a time, but went back to the expansion joints as they were more secure, and, so far as I know, they last better. With regard to corrosion I might say that during the war in South Africa, a battleship was fitted with two sets of distilling machinery in duplicate—I am now speaking of the parts made of gun metal and alloys. The machinery for each set was made at the same time and the two worked side by side in the same waters. When they came back from the war one of the machines was wasted away whilst the other was in perfect condition. I should have liked Mr. Milton to explain that, but it seems to be beyond explanation. In connexion with this matter of the expansion bends in the two pipes shown in the sketches, I am inclined to favour Mr. Grisdale's view that the first figure, if made circular in shape, would have been preferable to the one shown, and I cannot see why the latter should be preferable to Fig 6. I asked a question at the first meeting with regard to planished pipes. I was thinking of planished pipes for use on a smaller scale than Mr. Milton had in view. I was using them in connexion with pumps, and since then I have noted that the vibration on the exhaust pipe is considerably in excess of the vibration on the steam pipe. Whether the same thing applies on board ship I cannot say. I thought it remarkable, as in some of the exhaust pipes the vibration is not so apparent.

Mr. Milton: I will speak about that matter of the planished pipe first of all. In dealing with the question of the suitability of the planished or annealed pipe, there is not only the vibration to be considered, there is also the alteration in the length when getting up steam; the small vibration does not much alter the length of the pipe or the shape, and exhaust pipes are not so hot as steam pipes. There is another point. If there is a failure in a steam pipe it is serious, but it is not so serious if the failure happens in the exhaust, and so one can afford to take more risk with the exhaust and so take advantage of the stiffness of the planished pipe. A question was asked with reference to the suitability of expanding or brazing flanges. If you expand copper into a flange it must be hard, where you expand it you make it hard. It is a matter of impossibility to have it annealed at the joint and it is just at the flange that it needs annealing most, there are such great changes of form. I hope what I have said has not led to the thought that 12 in. pipes were not to be obtained. As far back as 1889 12 in. copper pipes were made in this country, but unfortunately some of those pipes were spoiled in the coppersmith's shop and when cut open were found to have longitudinal seams in them. Sir John Durston, who examined them, said " Replace them with brazed pipes " and that was done. The multiple system certainly has been more favoured than these large pipes, but you cannot use the multiple system in high power steamers. Where there is a multiplicity of boilers you cannot have a multiplicity of pipes, so where there are large vessels like the *Mauretania* or *Carmania* they have, perhaps, two lengths only to the engines, but they are made of iron or steel instead of copper. If there were separate pipes from each boiler to the engine room, the multiplicity of pipes would be a constant source of trouble. With regard to pipe hangers, generally speaking, I should be very sorry to think that anybody could design a hanger that would be a universal pipe hanger. In putting in a pipe each case has its own separate conditions and has to be considered separately—how the pipe will move under expansion and how to avoid any undue strain on it, and the hanger should be designed so as to take the weight of the pipe and at the same time allow it to be free to move in some definite direction. One gentleman spoke about spring hangers. Spring hangers are the only solution in some cases where it is necessary to provide for the motion up and down, that is the direction in which the weight is to be supported. When it is hot the pipe will move upwards and when cold it will assume a lower position, and I think circumstances of that kind can be provided for by the spring hanger. But the hangers are details that ought to be considered and thought out in the drawing office, and not left to the erectors on board the ship. It is a very important point in connexion with the supporting of the pipes. With regard to the pipes themselves, of course the more bends in general will mean a more flexible pipe. What I wanted to draw attention to is the fact that the amount of bend is not everything. A pipe came before my notice not long ago which the engineer thought an excellent arrangement.

There were several bends in it but a large part of the pipe was in a straight line joining the flanges and this part of the pipe therefore was subject to a direct compressive stress when hot and gave no flexibility to the pipe. With regard to the corrosion in pipes it is a very difficult problem, and I think if the very unique experience which Mr. Britton described of the two similar machines apparently used under similar conditions had been investigated, some difference of treatment would have been found which might have thrown a great deal of light upon the subject. I should say they could not have been under similar conditions. In all probability the one was affected by the electric light and the other was not, but these things are difficult to find out. Some time ago I saw a lot of boiler tubes that had been taken out of one of the Express type boilers, and they were all thinner on one side than on the other, all eccentric instead of being concentric, and the conclusion was jumped to immediately that the thin side was that exposed to the fire, but when we came to ask the engineer how they had been placed in the boiler it was found that he had omitted to mark them in any way and we could only guess at the cause. It may have been that those tubes had never been concentric, because a good many eccentric tubes are made and the use of the boiler might have been blamed instead of the makers. Some of my friends in His Majesty's navy hold absolutely diverse views as to the cause of corrosion and the frequency of corrosion. One of them told me that there was proportionately just as much corrosion of copper pipes twenty years ago as there is now, only it was not so much spoken of. If pipes gave out they were replaced and nothing more was said about the matter. But now, with our warships, all these things are gone into, and the number of bad pipes and other matters are recorded against the ship. This gentleman said the electric light had nothing to do with it, as there was just as much trouble before the electric light was installed. Another engineer officer whom I was talking to on the subject was in one of the large ships just before the war. He said the electric leads were always giving trouble and the pipes were also going wrong, and on repairing the electric leads they found that they had no further trouble with the pipes. When I was on the Boiler Committee, we got an invitation to look over some of the cruisers in the Dutch navy, and we learned that they had the same trouble as ourselves with condenser tubes. A careful experiment was being made. One of the condensers was being insulated with vulcanite, every bit of it insulated. I should have been very pleased to have known the result, but it shows that troubles with corrosion are not confined to the English ships. Another thing we saw there. They were using a nickel-copper alloy instead of zinc-copper alloy for the condenser tubes, and they said they expected the extra cost would be repaid in the saving in condenser tubes. What Mr. Balfour said about the Copper Institute is a matter of great interest to marine engineers generally. I was present at a meeting in Manchester last week in which this proposed Institution was very strongly advocated by metallurgists in the copper trade and others, but there seems to be some little difficulty in overcoming the prejudices of coppermakers against the imparting of knowledge from one to another. They seem to like to keep all their experience to themselves. But some are getting more enlightened, and now realize that with a large body of men, each of whom has one little bit of knowledge of his own, when they freely communicate their ideas to one another each gains the experience of many men and only gives up the experience of one, the result is to benefit the whole trade. This is one of the great advantages in Institutes like the proposed Institute of Copper or like this Institute. It is not only the reading of papers; the conversations that we have with our friends at these meetings, the giving of knowledge, the recital of experience from one to another, all tend to the advancement of the profession generally, and I feel sure that the members of this Institute, who are continually receiving these benefits will be very pleased to see an Institute formed in connection with the copper industry, so that things at present obscure and unknown will become investigated and deprived of the mystery now surrounding them.

Mr. W. C. Roberts (Vice-President): I have very little to say on this subject, not being a coppersmith by profession, nor having the knowledge Mr. Milton has acquired through his visits to the different works where the manipulation of the copper is carried on. My experience of copper pipes is in the use of them. Only on one occasion, I think, have we had a main steam pipe burst; it was a 6 in. brazed pipe, and the cause of giving way we never discovered. Two of the firemen were scalded to death and had the engineers on watch not taken shelter in the tunnel, they would likewise have been scalded. It occurred on a voyage between Hong-Kong and Shanghai, and that is the only accident I remember having where a steam pipe burst at sea. Mr. Ross elucidated the subject a good deal with regard to the bilge discharge pipes corroding away, and the bends leading out from the straight length from the pump up to the valve chest getting pitted, due to acids, oils and so forth getting into the bilge water. With other pipes there is not much trouble, except with condenser tubes, which, of course, are partially copper. With regard to the matter mentioned by Mr. Milton of insulating the condenser to prevent the action of electricity, this has been done in the Navy. I have had some trouble from time to time with some classes of condenser tubes. Of course in the composition of condenser tubes there is more or less a proportion of zinc, and where the proportion of zinc is large, there you get corrosion in the tubes, in my opinion due to the composition of the metal itself. I have proved that by replacing the tubes that gave way in the condenser with tubes of the Admiralty quality. This is the most reliable quality; no doubt they have found out the proper composition for condenser tubes. I replaced those tubes that gave way after the vessel had made two or three voyages, and the new tubes gave no further trouble. I am very sorry I have not had the pleasure of reading Mr. Milton's lectures, but we are all much indebted to him for the lucid way in which he has treated all the questions. I might say that copper main steam pipes are almost becoming a thing of the past, the solid drawn steel pipes, and even solid pipes, are being substituted instead, that is for straight lengths. I was on the Continent some time ago, and in going through one of the engineering works I saw pipes made out of a solid bar of steel, a bar 6 ins. diameter, bored out of the solid and turned down from the flange to the area of the pipe outside. The bar was, of course, the full diameter of the flange to begin with. These were for straight lengths of steam pipes for warships of the German Navy.

Mr. MILTON: I can confirm what Mr. Roberts says, not for the particular ship but for another continental warship. They were not only made for the straight lengths, but the bends were made in the same way and bored slightly eccentric so that after bending the outside of the bend was left of uniform thickness with the other parts.

Mr. J. FELL REDMAN (Member of Council): Many years ago when I was in Liverpool we used to have the old-fashioned engines with the main steam pipes coming down into the slide valve casings between the two cylinders. In process of time

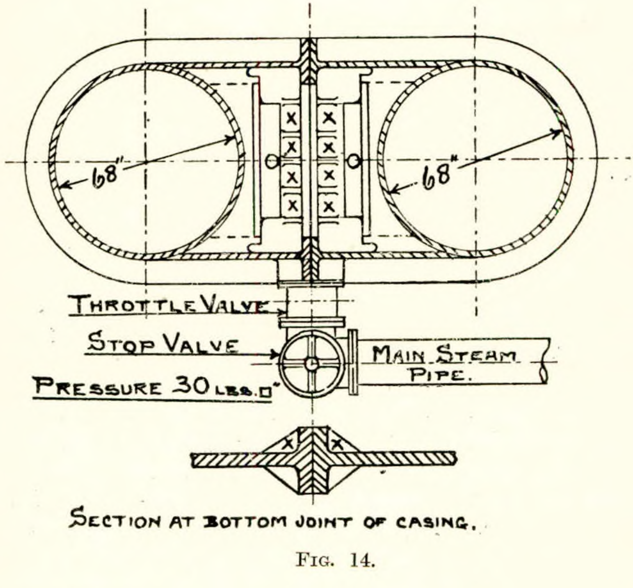

FIG. 14.

those engines were destroyed and when they came to break them up all in between these flanges was solid copper, simply abraded by the action of the steam. The flanges were filled up solid and samples were sent to the Admiralty of that copper as pure as one could get it. That is a thing we have to fear, the abrasion of the pipes. Another thing in connexion with the pipes I may as well mention. This was a job which I undertook about ten years ago. These pipes were solid drawn 6

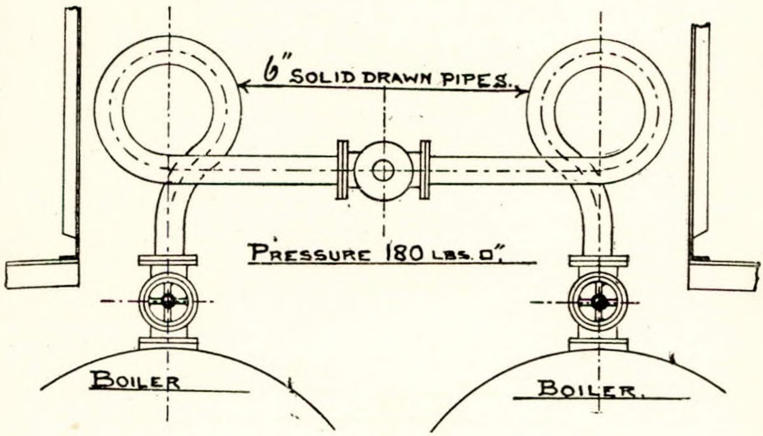

FIG. 15.

in. pipes, and at the suggestion of Mr. Milton's colleague, in order to overcome trouble which was being experienced with these pipes, I made a complete curve like the coils of a trumpet; it was rather expensive, but it answered perfectly.

CHAIRMAN: I do not propose to say anything on the subject matter of Mr. Milton's lectures, but I cannot help repeating that we are all indebted to him, not only for the lectures themselves, but for the great pains he has taken, and for his readiness and willingness to come to our meetings here. This is our fourth meeting, and I feel sure I am speaking for you all when I say that Mr. Milton's readiness to freely answer the questions of any one who wished for information on the subject has increased our indebtedness to him. Mr. Balfour made some remarks in reference to the proposed formation of an Institute of Copper and Mr. Milton supplemented those remarks and spoke very much to the point indeed. As he said, it is much better for a number of men engaged in any particular profession to unite together rather than to attempt to keep any secret or benefit for themselves alone. As Mr. Milton pointed out they have only their own knowledge to retain, where they might gather in the united knowledge of the whole industry. I do not think that holds good anywhere more than in this Institute. The members have an opportunity of communicating with one another, and many of our members have unique experiences as marine engineers which are very valuable to others. The value of this Institute is that every member has got an opportunity of communicating his experiences to his fellow-members, and those who are unable to be present at the meetings receive the Transactions and gain the benefit in that way. It is the accumulation of this experience that works for the benefit of the profession at large. In reference to this proposed Institute I think that, seeing we are so thoroughly convinced of the advantages of such an Institution, we might send the following message to those who are undertaking the formation of the Institute.

"That this Institute learns with satisfaction that it is contemplated to found an Institution on the lines of the Iron and Steel Institute, to deal with copper, brass and other non-ferrous metals and alloys, and it cordially wishes success to the undertaking."

I might say that the proposed Secretary is Dr. Carpenter, Professor of Metallurgy in the Manchester University. Mr. Adamson will doubtless bring this matter before the Council of the Institute.

Mr. E. W. Ross (Hon. Finan. Sec.): I have much pleasure in seconding the proposal that this matter be put before the Council as a recommendation to send the resolution that Mr. Boyle has read.

The motion was carried.

Mr. Jas. Robertson (Member): I think we are all very much indebted to Mr. Milton for the very able way he has delivered these lectures. He has given us two splendid lectures and in the discussion he has given a dissertation on the whole thing from beginning to end. I was pleased to be at the first lecture, but I have not been able to come to the two intervening meetings. To-night, however, we have again heard the various questions and Mr. Milton's replies, and I think this Institute owes a very great debt of gratitude to him. He has given us of his time, and not of his time only, but of his mind and experience. He has rendered a great service to this Institute, and what he has said and done will bring the Institute further forward in the public notice than it has been previously. I have much pleasure in proposing that we accord him a vote expressing our very heartiest thanks.

Mr. W. C. ROBERTS (Vice-President): I have very great pleasure in seconding the vote of thanks so ably proposed by Mr. Robertson and I fully endorse everything he has said. No doubt Mr. Milton has come here at great inconvenience to himself and I think we ought to give him our very heartiest thanks.

The motion was carried with acclamation.

Mr. MILTON: I feel rather ashamed to have had all these things said about me. It is not a great inconvenience, it is one of my greatest pleasures to "talk shop" with you.

Mr. BRITTON: I do not think we should go away without giving a vote of thanks to Mr. Boyle for occupying the chair so ably to-night. I do not think we could have had a better Chairman and I think he should have a cordial vote of thanks.

The motion was carried with acclamation.

Mr. BOYLE: Thank you very much. I am very pleased to do anything I can for the Institute and if my efforts are appreciated I shall feel deeply rewarded.

INSTITUTE OF MARINE ENGINEERS

INCORPORATED

SESSION 1908–1909

President: JAMES DENNY, ESQ.

VOL. XX.

PAPER NO. CXLVII. OF TRANSACTIONS.

THE ORGANIZATION OF THE PERSONNEL OF AN ENGINEERING WORKS

BY MR. MATTHEW LANG (ASSOC. MEMBER).

READ AT

58, ROMFORD ROAD, STRATFORD,

Monday, March 2nd, 1908.

CHAIRMAN: MR. J. LANG, R.N.R. (MEMBER OF COUNCIL).

LECTURE ON "ARTIFICIAL ILLUMINATION, HISTORICAL AND PRACTICAL,"

BY MR. A. E. BATTLE (MEMBER OF COUNCIL),

With Electrical Demonstration by Mr. Holmes (West Ham Corporation Electricity Dept.),

Monday, March 9th, 1908.

LECTURE, "HISTORY OF LLOYDS,"

BY MR. T. F. AUKLAND (COMPANION),

Monday, March 23rd, 1908.

CHAIRMAN: MR. J. T. MILTON (MEMBER OF COUNCIL).

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