ONE HUNDRED AND TWENTY-FIFTH PAPER
(OF TRANSACTIONS).

STEAM PIPE EXPERIENCES.

BY

MR. D. S. LEE, R.N.R. (MEMBER).

READ AT

58 ROMFORD ROAD, STRATFORD,

ON

MONDAY, OCTOBER 23rd, 1905.

CHAIRMAN :
MR. W. C. ROBERTS, R.N.R. (CHAIRMAN OF COUNCIL).

ADJOURNED DISCUSSION,
MONDAY, OCTOBER 30th, 1905.
CHAIRMAN :
MR. FRANK COOPER, R.N.R. (MEMBER OF COUNCIL).

THE subject of the present paper will most probably be in the experience of many sea-going members ; but as it does not fall to the lot of many junior engineers to be sent along with the surveyor to examine the steam pipes, it is hoped that these remarks may be at some time of use, and help the young aspiring engineers to take an intelligent interest in the appearance and sound of any steam pipes they may be called upon to examine.

It is a well-known fact that all copper pipes get corroded by sea water, if it is allowed to come in contact with the surface, owing to chemical action being set up.

First, the oxygen of the air attacks all copper in a slight degree, forming that blackened surface we all know as "tarnishing," which requires a continual amount of polishing off to keep the copper clean and bright.

Secondly, all copper, when strongly heated, gets covered with black scales, due to oxygen having a great affinity for copper, and forming copper oxide, thereby rendering brazed joints difficult to make tight, except the surfaces are kept perfectly clean during the process of brazing.

Thirdly, sea water being a solution of sodium chloride, contains chlorine, which has the power of decomposing water with the liberation of oxygen, and when sea water falls on a copper pipe this chlorine is set free and salts are deposited; but chlorine being in the presence of water is rendered moist, and, combining with carbon dioxide and the salts present, forms carbonate and oxychloride, both of which are practically insoluble; these combining with the copper, form a greenish blue deposit, often erroneously called "verdigris," which can be scraped off copper pipes any time when they have been exposed to sea water, thereby reducing the thickness, and consequently their strength.

Fourthly, when the pipes are covered with lagging, which on occasions becomes unavoidably saturated with sea water, the action is still of a more active nature—not due to the composition of the lagging, if it is of recognised make and quality, but to the fact that, water being in contact with a hot pipe, steam is generated in the lagging, which would accelerate the chemical action I have just described, besides forming a small amount of hydrochloric acid from the combination of hydrogen and chlorine gas. As all metals, with the exception of gold and platinum, are acted upon by hydrochloric acid, this would attack the copper in the well-known form of "pitting." Besides, metals at a high temperature are more electro-positive to the colder parts even of the same pipe or plate; thus the wasting action is intensified, as shown in a case which has come under my personal observation, where the copper pipes were reduced in thickness from ·252 in. to ·09 in. at the side next the boiler, the outside or cold side being nearly its original thickness. From this it is obvious that sea water has a very destructive action upon copper pipes, and we, as marine engineers, ought to be on the "look-out" for these detrimental effects, and not wait till a failure occurs, attended with disastrous results, before a remedy can be applied.

My experience is that it is not enough to have the pipes tested to twice the working pressure, but that the whole of the lagging should be stripped off, thus exposing the whole of the pipe to view, and then by carefully examining and sounding with the hammer for any irregularity of thickness, the difference in the sound produced cannot fail to be an indication of reduced thickness if the process of testing is in the hands of an observant man. If still not satisfied, and it is known that corrosion has been going on, take the pipe down and have it gauged—not in the usual way, with a pair of outside and inside callipers, which would only give the mean thickness, but with a gauge that will reach to the suspected part of the pipe, and enable the different thicknesses to be accurately ascertained at every part of the circumference. Then if by calculation the thickness is found sufficient to satisfy the Board of Trade regulations—

$$t = \frac{p\,d}{6{,}000} + \tfrac{1}{16} \quad \text{or} \quad p = \frac{6{,}000\,(t - \tfrac{1}{16})}{d}$$

—the water-pressure test can then be applied to double the working pressure of the boilers for old pipes, and two and a half times for new pipes.

While the pressure is on, in the case of a brazed pipe, examine the seam carefully, at the same time tapping it with the never-erring hammer, which would cause the seam to open up if there is faulty brazing; also examine the brazing at the flanges for any leakages.

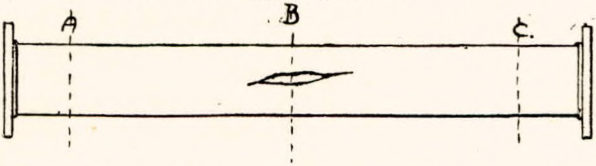
If a pipe stands all the above tests, it would, in my opinion, be again quite ready for use and capable of fulfilling all that is required of it; but we are all aware that exceptional cases do arise when failure takes place even after the greatest care and skill has been used in testing.

One case in particular is in my mind—that of a solid-drawn pipe, which gave out with fatal results while working at the ordinary pressure for which the pipes were designed; yet the same pipe, when the burst part was cut out and flanges again fitted to the remainder, on being tested to destruction stood a little over seven times the working pressure, while two other pipes of the same diameter, and from the same range, gave out at $3\frac{1}{2}$ times the working pressure, when the apparent thickness led us to expect about eleven times the working pressure before bursting. On further investigation, having the flanges removed and the pipes cut along one side, then turned inside out, flaws were discovered in the copper—a most unusual thing in solid-drawn pipes; in fact, I believe the only case on record. One of these flaws was close on 3 ft. long, starting from 0 to a full $\frac{1}{16}$ in. in depth. This would leave very little solid metal, the perceptible thickness being $\frac{3}{16}$ in.—accounting for the very big difference in the bursting pressure, viz., 560 lb.

How the flaws came there it is not my province to say; but as far as I know there was nothing to cause them on board ship.

The following figures and sketches may be of interest, showing the burst made by water pressure and the stretch in circumference at different pressures, also flaws on inside of one pipe. It is interesting to remark that the fractures all occurred longitudinally, owing to the well-known fact that the stress in the longitudinal section in any cylinder subjected to internal pressure is twice that of the circumferential (per unit of section).

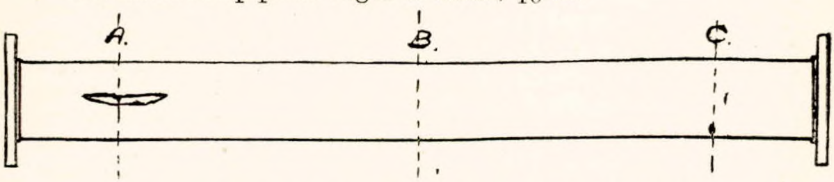
Amount of stretch in the circumference at different pressures in inches on copper pipes as under:



COPPER PIPE $6\frac{1}{2}$ IN. DIAMETER, 4 FT. 11 IN. LONG.

170 to 300 lb.	$\frac{1}{16}$ in. full	0 in.	$\frac{3}{32}$ in.
450 lb. ...	... $\frac{3}{32}$,,	$\frac{3}{64}$,,	$\frac{3}{16}$,, bare
600 ,, ...	... $\frac{5}{16}$,,	$\frac{7}{32}$,,	$\frac{5}{16}$,,
750 ,, ...	... $\frac{1}{2}$,, full	$\frac{7}{16}$,,	$\frac{17}{32}$,,
950 ,, ...	... $\frac{7}{8}$,,	$\frac{27}{32}$,,	$\frac{7}{8}$,,
1,100 ,, ...	... $1\frac{1}{4}$,,	$1\frac{1}{2}$,,	$1\frac{1}{4}$,, full
1,150 ,, ...	... $1\frac{7}{16}$,,	Opened out at B	$1\frac{7}{10}$,, full

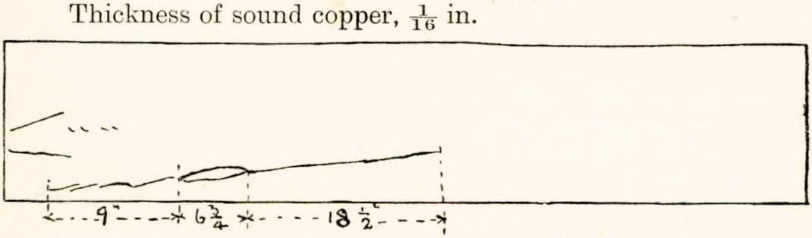
Thickness of pipe at edges of burst, $\frac{1}{10}$ in.



COPPER PIPE $6\frac{1}{2}$ IN. DIAMETER, 9 FT. 3 IN. LONG.

150 lbs.	0 in.	0 in.	0 in.
300 ,, ...	0 ,,	$\frac{1}{16}$,, full	0 ,,
450 ,, ...	$\frac{1}{16}$,,	$\frac{3}{32}$,,	$\frac{1}{32}$,,
590 ,, ...	Opened out at A	$\frac{3}{16}$,,	

Thickness of sound copper, $\frac{1}{16}$ in.



EXPANDED VIEW SHOWING SURFACE OF INTERIOR OF PIPE.

To "water-hammer" can be attributed many failures in steam pipes, caused by accumulation of water in the pipes due to condensation. When this gets cold and steam globules continue to come in contact with it, the lower temperature causes condensation to take place, thus forming a vacuum, which the water immediately fills up, thereby producing motion at a high velocity in the body of water collected. This process continues till the pipe gets full of water, and at the same pressure as the entering steam, thus producing that hammering or cracking noise heard in pipes after the steam is supposed to be entirely shut off. I have known a pipe, with one end open and the other closed by a flat mushroom valve, of which the spindle, $2\frac{1}{4}$ in. in diameter, was squeezed out of position and bent $\frac{1}{2}$ in. to one side through the drain-cock being shut accidentally.

The pressures due to "water-hammer" have, as far as my knowledge goes, not yet been satisfactorily investigated, but from the records of their effects one can name them enormous. This furnishes us with a very good reason for having drain-cocks fitted to all steam pipes and casings where water is likely to lodge. When a steam pipe is shut off it is well for it to be drained, as a slight stoppage in the drain-cock is liable to result in "water-hammer." It has been suggested that a safety-valve be fitted to relieve any extra pressure caused by such circumstances. I think this would only complicate matters without removing the evil. As water collects locally, it would be nearly impossible to put a valve in the right place. Besides, the trouble with it leaking would very soon cause it to be screwed down solid or thrown out altogether. The real, safe remedy is to drain the pipes. One other example might be with advantage cited and noticed specially by young engineers—that is, the effect of opening a steam valve suddenly on to an empty pipe.

If there was no water in it, on opening the valve, the condensation that takes place owing to difference of temperature will very soon form a body of water, and this being rushed along a pipe with a quantity of high-pressure steam behind it would cause a severe stress when the rush was in any way stopped, due, clearly, to the KE of the moving mass.

Now KE being $\frac{MV^2}{2}$, and the velocity of escaping steam, say at a pressure of 150 lb., being roughly taken at 1,600 ft. per second, or, as calculated by the formula given by Molesworth, V *in vacuo* $= 60\sqrt{T+459}$, the velocity would be 1,722 ft. per second. If one gallon of water is put in motion at that speed the energy would be about 5,000 tons. It is therefore easily understood how covers get split and valve seats shaken in their places, besides the danger arising from unequal expansion in thick iron stop-valves.

The suspension or fastening of steam pipes next calls for attention, as the easiest drilled place is generally looked for from which to make the fastening, without any consideration as to movement in the pipe longitudinally, or whether there will be any rise in it due to expansion when engines and boilers get heated up. Very often pipes connected to boilers rise ½ in., entirely due to difference of temperature, each time the steam is raised. This bending action must come on part of the pipe, if clipped with a hanger, and the hanger, as is often the case, bolted on to one of the beams or 'thwartship girders, with the result the metal becomes fatigued, and later a crack appears. All pipes should be suspended, not "clipped," at the flanges. This will prevent any abrasion on the body of the pipe, or any action, either electrical or chemical, from affecting the strength of same. In a range of piping fitted with expansion joints and bends it is well to have the pipe anchored in different places, so that the expansion may be equally divided, and not all take place at the weakest bend, or possibly the shortest stuffing-box.

During last winter session a paper was read on insulation and steam-pipe coverings, and mentioned again during the summer at one of our "outings."

All coverings have special merits, according to the makers, but it depends greatly on what has been the custom in any particular firm to use just what suits them either in price or quality.

Good covering contains no acids and no chlorides, and to be effectual should be put on properly to the required thickness, afterwards covered with a waterproof material, if there is any moisture or sea-water about, the whole secured to the pipe by bands, though to make a more lasting job a portable sheet-iron casing may be put outside of all, as nearly watertight as possible. Under such circumstances it can be safely said that all has been done that can be done to stop condensation in, as well as corrosion on, copper pipes.

Iron pipes are coming into general use now, and although they are liable to the same chemical action, yet iron being of a higher tensile strength, not affected by heat to the same degree as copper, and of more uniform quality in the finished pipe, it is most probable that before long copper for steam pipes of large size will be ancient history.

DISCUSSION.

MONDAY, OCTOBER 23rd, 1905.

A SAMPLE taken from a steam pipe which had become thin was handed to the members for inspection.

Mr. W. LAWRIE (Member of Council) said he thought Mr. Lee was to be complimented for bringing that subject before the notice of the Institute. Referring to the following paragraph—"From this it is obvious that sea-water has a very destructive action upon copper pipes, and we, as marine engineers, ought to be on the look-out for these detrimental effects, and not wait till a failure occurs, attended with disastrous results, before a remedy can be applied"—it struck him as being very proper, and at the same time it had set him thinking that it was rather a peculiar thing at this time of day that such a warning should be necessary for marine engineers. He supposed that the marine engineer when on board ship got into such close contact with high-pressure steam that he began to dull a little as to the powerful effect which might result from the steam-pressure he had to control suddenly let loose; otherwise, he thought the warning should scarcely be necessary. It seemed rather astonishing, also, that at this time of day sea-water should be allowed to get on to steam pipes. He could remember when vessels had 10-in. coamings on deck, and then it was difficult to keep the sea-water out of the stokehold. But now, with the high fiddley casings and ordinary care, they need scarcely have sea-water getting on their steam pipes. However, it did occur, and if the warning given by Mr. Lee had the effect of wakening up engineers generally to the danger around them he thought it would be very useful. Mr. Lee had referred to some copper pipes which were reduced in thickness from ·252 in. to ·09 in. at the side next the boiler, the cooler side being nearly of the original thickness. He would like to ask if it was only the question of heat on the one side of the pipe which caused all that wasting. He had seen a good many pipes alongside boilers, but it had never yet come to his knowledge that they went so badly as quoted, providing that they were properly covered and kept in proper order. A little further on Mr. Lee said: "It is not enough to have the pipes tested to twice the working pressure, but that the whole of the lagging should be stripped off, thus exposing the whole of the pipe to view." How often was it suggested that should be carried out? He did not think it would be necessary to do so at every survey. With regard to the following paragraph in the paper—"While the pressure is on, in the case of a brazed pipe, examine the seam carefully, at the same time tapping it with the never-erring hammer, which would cause the seam to open up if there is faulty brazing; also examine the brazing at the flanges for any leakages"—he might be wrong, but he doubted the wisdom of hammering a steam pipe when it had two and a half times the working pressure on. His ideas had been that when they wanted to dispose of the material they did so by using the hammer or drill, but when they came to testing with water-pressure they were testing for the workmanship. If the workmanship stood two and a half times the ordinary pressure he thought that was sufficient without hammering, because if they began to touch and hammer they might start the brazing somewhere, and although it might not leak at the moment, when they got up steam and had expansion and contraction they might find that the brazing had started. He had always objected to the hammer being used when there was high water-pressure on, inside a pipe or boiler. He thought the most interesting part of the paper was that relating to the question of internal flaws in steam pipes. It seemed rather difficult to account for those flaws which Mr. Lee described, and which he had told them were 3 ft. long, starting from 0 to $\frac{1}{16}$ in. in depth. Mr. Lee had not told them the width of the crack, and it seemed to him that to arrive at a proper conclusion they ought to know something about that. He understood that those pipes were examined very carefully internally, but the cracks were not discovered until high water-pressure had been put on. It had been suggested that they might have been caused probably by flaws or blowholes in the billets. Well, those particular pipes were fitted in 1899, and the accident happened in 1904. If there was a flaw in that pipe originally when it was first fitted on board the ship, it seemed almost impossible that steam could have been got up again and again, with the continual opening and expansion of the pipe, without showing any indication internally of a crack. He thought if those pipes had been examined carefully inside some indication would have been found before they were burst by the hydraulic pressure. He did not know whether it was possible that the cracks had been aggravated by the water-pressure, but they had also some cracks inside where the pipes did not burst, so the pressure could not have aggravated them, although it might have been so in the places where the pipes did burst. Then there was the question of clipping steam pipes. He had thought that the practice had been done away with many years ago of making steam pipes rigid. It seemed to him that to clip up a steam pipe absolutely and fasten it to a beam along the ship in anything like a rigid manner was hardly looking very far ahead. Where that was done there was sure to be trouble. Then there was the question as to how far the covering or lagging affected the steam pipe. For his part, he had had no trouble when the pipe had been properly covered, and that covering taken off and put into a thoroughly good state at certain intervals. But it had recently been suggested that steam-pipe coverings wasted the pipe at the end of the covering. He did not know whether that had been the experience of any of the members. He had seen it so stated, but he had never personally had that experience. In the last paragraph of the paper iron pipes were referred to as coming into general use. He did not know why iron pipes seemed to make such slow progress, as those he had had to deal with were excellent pipes. Mr. Lee had said that iron pipes were liable to the same chemical action as copper pipes. He had frequently examined the iron pipes under his charge, and it was almost a difficult thing to find a pipe at all different from what it was when originally made ten years ago. The Board of Trade had made a special point of looking at some of the steam pipes which he had under his charge. They had a considerable experience of pipes which were in use year in and year out, but they thought they would like to see those pipes which had four months' service each year and were doing nothing the remaining eight months. Those iron pipes were taken down and specially examined, and passed as being in the very best possible condition. Then there was the question as to the best method for examining a pipe internally. He used to get the pipe into the best light possible on deck and look inside, but he had found that by taking the pipe into the engine-room altogether, and then passing an electric lamp through it, that they could make a much better examination of the interior surface of the pipe than on deck, where they could not get the light bearing all round the pipe with the same force. On deck some parts would be in the shade. With an electric light he found they could examine the pipe very carefully, and he did not think there were many cracks which would not be discovered.

Mr. J. G. HAWTHORN (Member of Council) said he had hardly had time properly to digest the figures in Mr. Lee's paper. Was the pipe shown in the first sketch a solid-drawn or a brazed pipe?

Mr. LEE: Solid-drawn.

Mr. HAWTHORN said they could not expect copper to stand anything like such an enormous stress per square inch as indicated. He presumed the pipe was originally $\frac{3}{16}$ in. in thickness when the pressure was put upon it, so there was nothing extraordinary to be inferred from the pipe opening out at 1,100 lb. pressure. Presuming that it had lost $\frac{1}{16}$ in. by stretching, it gave a stress of 28,000 lb., and it was only to be expected that the pipe would burst at that pressure. It was, however, interesting to see the pressure, given a little lower down, which the pipe had withstood. He thought their thanks were due to Mr. Lee for bringing those interesting examples before them. In regard to the internal corrosion of copper steam pipes, they were, he said, to a certain extent conversant with nearly all the effects of sea-water on the outside of the pipes, and the effects of the chemical action of lagging, etc. Was it not a fact that the internal corrosion in those pipes was largely the effect of certain ingredients which were now put inside their boilers in order to prevent the formation of scale? They were apt to put carbonate of soda into the feed-water when they were using any sea-water at all in the boilers. With 10 per cent. of wetness in the steam generated they got a certain amount of deposit in all the small bends of the pipes. If water impregnated with carbonate of soda were allowed to rest in the steam pipe, did it not affect the copper? Had not Professor Arnold gone into that very question? It would also be interesting if anyone could supply any information as to what effect oils had on the internal surfaces of the pipes. They saw the corrosion that went on on the outside, and to a certain extent could keep themselves up to date; but the internal corrosion was going on like a thief in the night. In the accident on the *Prodano* he thought the pipe opened out 3 ft. 6 in. along the brazing to the extent of 4 in. That was the greatest width, and in reading the Board of Trade report he thought the conclusion arrived at was that the copper itself had been underpoled in its manufacture. Perhaps he ought to explain the meaning of the term "underpoled." In the preparation of copper the process was to run it into pits, and sometimes women were employed to stir it about with a pole so that it should get the proper amount of oxygen. If the copper used had not its proper amount of oxygen it was underpoled, and if it was brazed in a coke fire it would probably take what little oxygen there was in the copper out of it, and so render the copper brittle. If the copper was over-poled it would give up its oxygen to the fire. Underpoled copper had been known to take oxygen. If they could get any information relative to the effect of ingredients entering into the boiler after lubricating purposes in the cylinders, and the effects, also, of carbonate of soda to prevent scaling, it would be very valuable, and they would then be able to know why in some cases the pipes had thinned themselves down so much on the inside. The idea of Mr. Lawrie that they should use an electric lamp for examining the inside of pipes was, he thought, an excellent one. They would be able to throw light on the affected or suspected part of the pipe. Sounding, even in the hands of an expert, would not always indicate the affected part of a pipe. Sounding was rather a difficult matter if they happened to strike a weak place.

Mr. George Shearer (Member) said he would like to ask Mr. Lee, in the first place, whether three of the fractures had appeared to come from those flaws that he had spoken of, and which were discovered after the pipe had been opened out. Were those flaws a continuation of the fracture?

Mr. Lee: Yes.

Mr. Shearer, continuing, said he thought the explanation of those fissures was that they had been caused by a blowhole in the ingot. That blowhole might, perhaps, have been a speck not larger than the point of a pin, but the continual drawing of the metal from the ingot state until the finishing of the pipe might cause it to extend to some feet in length. He had noticed the same thing in piston-rods, etc., where, in the rolling, a small speck of that kind would sometimes draw out for half the length of the rod, and to his mind there was no doubt the same action had taken place in the drawing of the copper. He thought there was no doubt that when the hydraulic pressure was on that pipe it was one of those fissures that gave way. Of course, in that place they would not have much more than half the thickness of the pipe; consequently destruction would take place. In regard to drawing metal, he had noticed in sporting-gun barrels there had been several cases where the barrel had split up, and that, he thought, had been due simply to a speck in the ingot which had been elongated by the drawing process. He was speaking, of course, of ordinary modern sporting guns—not the highest class of sporting guns, which, up till recently, had the Damascus barrel. He supposed many of them had an idea of the manufacture of the Damascus barrel. It was by twisting and turning, thus making coils of the metal. He remembered, a long time ago, reading up a lot of experiments made by Greening, the great sporting-gun maker, upon gun barrels. He took a gun barrel and cut a slit in it, so that a sixpence could be inserted in the slit longitudinally. When the gun was fired, with the excessive pressure on it, that barrel almost gave way, but when the slit was cut across the barrel to the same size it had no effect when fired. No action took place which was apparent by the calliper or micrometer. He thought the blowhole was the cause of those fissures in the steam pipe, and no doubt the cause of the bursting of the drawn copper pipes when such did take place. Touching upon the corrosion of copper pipes, he must say that so far as his experience went he had never noticed what he would consider to be corrosion on the outside of a copper pipe that would do any damage to it. But on the inside he had noticed such corrosion. In many cases, especially when they had a sharp bend in a pipe and a high velocity of steam passing through this, they would find that the interior surface of the outer side of the elbow was worn thin. That, he thought, arose from washing by the steam passing over the surface. The bend was directing the steam out of its straight line of action. The steam came in contact with that bend, and in sweeping round tended to wash away the surface. Possibly the action was mechanical by reason of the particles of one description or another that might arise from the surface of the water in the boiler. They all knew that they found floating matter in the boilers, and he thought that the dust or material that was drawn from the surface of the water was really the cause of the washing away of the inner surface of the bend in the steam pipe. Of course, he was also of opinion that a chemical as well as a mechanical action took place, for they did not know of what that dust consisted. As Mr. Hawthorn had remarked, the different materials which were put into some boilers at the present day, causing the dust, possessed no doubt a certain acidity, which would set up chemical action when the steam carried them over the bends in the pipes. He would give them his experience of a copper pipe, but he might say that that special pipe was a bilge pipe, and it was the greatest curio he had ever seen of the sort. It was in a ship the builders of which were in the habit of putting in a large drain extending the whole length of the engines, under the cranks and eccentrics. Consequently there was no surface water which was used from the engines that flowed into the bilges. It was pumped away by bilge pumps directly over the side. The pumps were continually giving trouble, and when the pipes were taken out and examined—well, instead of being suction pipes, he thought they would have been better suited for a common rose injection-pipe. They were simply a mass of holes, not only in one place, but all over. There was no doubt that was caused by the acid which was in the oil mixing with the sea-water and generally forming into a lather. That mixture had acted on the surface of the copper, and had eaten it into the condition described. Further, in regard to the washing action, he had seen it on many occasions in cast-iron stop valves, and also in iron pipes. Where they had a short bend and steam at high velocity they would always find that the outer portion of the elbow was washed thin. He had also seen the same thing in the old diagonal superheater, where the washing of steam between the connecting pipes occurred—S-shaped pipes they generally were at that time—and in the way of the superheater opposite where the steam passed through, those pipes were washed away, in one case he remembered, to $\frac{1}{16}$ of an inch. The plates were originally either $\frac{3}{8}$ or $\frac{7}{16}$ of an inch thick. He thought that the velocity of the steam, when it was directed out of its course, would act in the same way in steam pipes. That, at any rate, had been his experience with copper, iron, or any other metal that might be used. In regard to water-hammering and the heating up of pipes, he had on one occasion a very narrow escape of his life from a main steam pipe when steam had been suddenly let in. He gave orders to one of the engineers to ease off the stop valves for heating up the engines. That engineer was a careless man. He took a fireman with him, and the fireman did the job. He happened to be standing alongside the stop valve on the top platform. All at once there was a crash and a cloud of dust. He sprang to the door and got clear. The pipe, which was covered with some sort of cement, did not burst, but not a bit of the cement was left on the pipe, and every hanger that supported the pipe was torn and thrown on to the platform. He saw the pipe opening out as he sprang out of the door. That was a case of carelessness. The best way, he thought, in all steam pipes, especially in large steam pipes, was to have a small by-pass between the boiler and the engines. One a quarter of an inch would be big enough. By the employment of such a by-pass between the stop valve and the pipe they would do away with danger of the kind he had just described. Of course, there was a drain pipe on the main steam pipe, but if a $\frac{1}{4}$-in. bore pipe was opened full, or partially, that would heat the engines up gradually, without endangering the steam pipe in any possible way. The drain would carry away the water as it was condensed. Consequently, they would always have a dry steam pipe, and a pipe of equal temperature. With reference to the change from copper to iron pipes, there was, he thought, no doubt that was going on gradually. It could hardly be otherwise, now that they had such high steam-pressures, such as 200 lb. He had been with iron steam pipes for a couple of years, but that was the extent of his experience with steam pipes of that description.

Mr. JOHN MCLAREN (Member of Council) said there were one or two questions he would like to ask Mr. Lee. One was in regard to the flaw inside the pipe. Was it a groove, or did it widen?

Mr. LEE: It was simply $\frac{1}{16}$ in. in depth—only a hair-line, so far as we could see.

Mr. W. MCLAREN (Vice-President) said he had not the slightest doubt that was caused by some acid from the boiler. In his experience the wear and tear of steam pipes was internal. Pipes were generally pretty well covered, or lagged, and were not subjected to so much corrosion on the outside. He thought it was a good idea to examine pipes internally by the aid of an electric lamp. Did the Board of Trade reports always state whether the weakness was caused by the internal or external corrosion? He thought they did not say what caused the corrosion, but only stated that the pipe had burst at a certain pressure.

Mr. HAWTHORN said that could be found from reading the evidence. The finding of the inquiry was always put in the reports. About twenty-five or thirty years ago it used to be the common practice to get the impression of any suspiciously thin place by using a long stick and some soft material at the end of it. That was passed up the pipe, and they got the impression off the inside surface. That was before the days of the electric light.

Mr. BERTRAM (Hon. Min. Secretary) said he was quite at one with Mr. Shearer that an action was caused by high-velocity steam and the particles of dust taken from the surface of the water. It was an action like that of a sand-blast. He had seen bends quite worn away in a torpedo-boat destroyer by that action. He agreed with Mr. Lee that the action of sea-water was very great. The Admiralty had ordered that all skin fittings should be tinned inside to a depth of $\frac{1}{16}$ of an inch.

Mr. D. HULME (Member of Council) said he was sorry he was not in time to hear the paper read. His experience of copper pipes had been somewhat varied, both as regards built and solid-drawn pipes. In built pipes, main steam pipes, and suchlike, they found that if they were well built and thoroughly well brazed with proper and suitable spelter the brazing would stand longer than the pipes themselves, but where there were bends they knew they had to be handled, and were thinner than any other part of the pipe, and owing to the neck of the pipe being thickened up the straight pieces which were attached to the bend took up the strains. They all knew that if metal was worked backwards and forwards it would ultimately break. Another thing to which he was very much opposed was putting double the working pressure on any pipe which was to be tested. He failed to see the necessity for it. They got pipes sometimes into the works to be tested to double the working pressures after annealing them. If they were bends they frequently had to chain them together, as the double pressure tended to straighten them out. Frequently when such pipes were returned after the double-pressure test they were asked by the pipe owners what they had been doing to their pipes. Unless they were chained in position they could not, after testing them to double pressure, get them back to their proper places. That was due to putting on double pressure. Solid-drawn pipes sometimes had sears in them, due to old or badly-worn dies being used for drawing the pipes out from the ingot. They had tried a testing pressure of 1 ton on a $1\frac{1}{2}$-in. pipe and 2 tons on a $2\frac{1}{2}$-in. pipe. Up to 2 in. they found no show of distortion in the metal, but when they came to $2\frac{1}{2}$ in., with $2\frac{1}{2}$ tons pressure on, the pipe would expand. Consequently it would thin. If they watched a coppersmith they would frequently see him with his spelter on the fire. It burned and flaked. When the engineer got his machine to sea he found a pipe choked up, with the result that there was trouble. He had had to cut pipes 2 in. in diameter because of the flakes which had closed them up. There would be no pressure at the one end, and nothing but vapour, as the flakes had perfectly closed it up. That was caused by allowing the temperature of the pipe to fall below the melting point during the operation, and it was very frequently the last end of the pipe. Solid-drawn pipes burst as shown in some of the sketches in the paper, due to the sear which was in the pipe. They had had others bursting during the coiling-up, due to the bend being rigid at the neck and thin on the back, and that was why he thought the same action took place in the bursting of a pipe in the straight length where there had been a sear, and that had given way in the action on the straight length.

Mr. W. E. FARENDEN (Associate) said that Mr. Lee had referred to a pipe being reduced in thickness from ·252 in. to ·09 in. If they took the Board of Trade rules for a solid-drawn pipe of the size given, and substituted $\frac{1}{32}$ in. for $\frac{1}{16}$ in. in the formula, at the point where the pipe gave out it was good only for about 60 lb. pressure. Mr. Lee had said: "If still not satisfied, and if it is known that corrosion has been going on, take the pipe down and have it gauged—not in the usual way, with a pair of outside and inside callipers, which would only give the mean thickness, but with a gauge that will reach to the suspected part of the pipe, and enable the different thicknesses to be accurately ascertained at every part of the circumference." Would Mr. Lee kindly explain how he gauged that suspected part of the pipe to enable him to arrive at the difference in thickness accurately? Again, referring to the kinetic energy in the case of water-hammer action, it was stated that if one gallon of water was put into motion at a speed of 1,722 ft. per second the energy would be about 5,000 tons. That seemed to be a tremendous pressure to put on the internal parts of machinery. If they got 5,000 tons he should think it would carry everything away—even the engines themselves. He had been looking into those figures, and he would like Mr. Lee to kindly explain how he arrived at that 5,000 tons. Then there was a question as to whether it was desirable to use iron hangers for supporting copper pipes in the presence of sea-water, in view of the galvanic action which resulted between the copper and the iron. He thought, to summarise the points in question, it was necessary to keep the sea-water from contact with the pipes, using a good non-conducting material, free from acid, and paying special attention to the method of supporting the large copper pipes, and well protecting the ends of the covering, so as to prevent sea-water gaining admission into the air cells. As Mr. Lee had said, there should be a good waterproof material over the covering. The point the author had referred to about the solid-drawn copper pipe with the internal flaw was a very serious matter, and, being inside, he did not know how they could get at it to see what it was like. Even with an electric light, as mentioned by Mr. Lawrie, he did not see how they would be able to find a flaw like that in pipes 10 to 12 ft. long. He had always understood that solid-drawn copper pipes were much better than the brazed longitudinal joint.

Mr. JAMES HOWIE (Member) said one or two points had been raised as to brazing. It had always been considered a good thing to put a lip on the back of the flange to get as much depth as possible to hold the pipe ; yet that was not always a good thing. If the lip were not opened up well, so that the brazing material got through all round, it was not good. Some coppersmiths said that, from their experience, it was better to do away with the lip, and they insisted on having only the thickness of the flange itself. Again, he might cite a case where there was a bend in a pipe which had been working, and the brazing not being good the pipe had been gradually working out. When disconnected for repairs and the brazing made good, that pipe had afterwards nipped at the neck, showing there was something weak in the design. Mr. Shearer had remarked upon the thinness on the outside of the bend, but he would not share the opinion that there would be much wear inside due to scouring action, as he thought the thinning was more likely due to hammering the pipe in the bending. The outer part always was thinner. The contraction was in the inner half, and its tendency was to be thicker than the original thickness of the copper plate, whereas the other got thinner. Of course this referred to large pipes and other pipes made years ago.

Mr. SHEARER: All large pipes are made in two parts.

Mr. HOARE: What is the diameter of the largest solid-drawn pipe procurable?

Mr. HAWTHORN said the Board of Trade allowed for 8-in. solid-drawn pipes.

Mr. HULME: You can get 9-in. solid-drawn pipes.

Mr. HOWIE, continuing, said the subject of water-hammering in pipes was a rather hazy one. He had not had much experience in regard to that particular trouble; he thought it had not yet been brought into the exact formula of science. He had heard various opinions on that matter, but there had not been an opportunity of taking it up with exactness. Then, in regard to the endurance of pipes, there were members present who had had more to do with pipes than he had, but he had seen some old pipes taken out of steamships, tested, annealed, and passed, and then replaced in the vessels, after, say, twenty years of service. That may be something exceptional, and he thought the material was quite as good in the present period as when those pipes were made. But there must be an exception which proved the rule that copper pipes were quite efficient for the work they had to do, the material being generally good, unless they went to very high pressures. They could not have the pipes perfect, and if they found faulty design it was no use condemning the system. The exceptions proved that copper was still an efficient factor. In conclusion, he must congratulate Mr. Lee on his paper. It was concise, of a nice length, and very practical.

Mr. W. McLAREN, in referring to the corrosion caused by sea-water, said in his experience he had not found it so bad as evidenced by the sample shown by Mr. Lee. Even in the business which he was then following, where there was so much acid used, he had not found it so bad as that sample. In fruit-boiling, with some classes of fruit they found more corrosion than in others. In his belief the corrosion was due to the material itself, and those vessels to which he referred were jacketed, the steam for boiling being in the jacket. They used a pressure of about 70 lb., and he believed that the trouble arose chiefly from the increased temperature at which copper pipes were now used, compared with, say, twenty or thirty years ago. Possibly the excessive vibration, added to the higher temperature, which they had with shallow-draught vessels had a bearing on the subject. Mr. Lee was closely connected with a ship which had a flat bottom, so the vibration theory might attach to that particular vessel. It would seem to be a difficult matter to gauge those pipes. Even from 3 ft. to 4 ft.

from the end it would be difficult to gauge them; but he might mention from his experiences of testing pipes of various kinds, and also water-tube boilers, that the use of an electric lamp was an advantage. When looking for scale the electric lamp had a magnifying effect, and he thought that method would be applicable to steam pipes for showing any chances of flaws. He thought Mr. Lawrie had brought forward a good hint in regard to getting an illumination right round the inner surface of the pipe. He was pleased to coincide with Mr. Lee in regard to water-hammering. If they did not have a cock of fair area to drain the pipe, they might have the system mentioned by Mr. Shearer, but he thought there was no system which would meet all emergencies. On the question of the use of iron, he thought the steel pipes had the advantage. He knew one firm who would set a pipe to any length in reason, say from 12 ft., with flanges screwed or, preferably, welded on, and he thought they made a first-class job. He was only able to speak in that respect of pipes up to 4 in. in diameter, but he could cite one particular instance where a cast-iron pipe had to carry a pressure of 80 lb., and that pipe ran some 350 ft altogether. He was forced to hang it up from girders in the factory. There was no wall that could be used to support it, and to see that arrangement of piping it was like a forest of trees, yet that pipe had worked admirably. Three steel expansion bends had been put in, but he was doubtful of their utility, owing to their stiffness. At the time that the steam had been put on, there was not sufficient time to make the anchorage, but it so happened that the first time the steam was put on, the travel of the pipe run was 4 in., and it went in a sort of diagonal fashion. The hangers were 15 ft. in length, and the pipes were not clipped. Each hanger had a roller, and the travel of the pipes was 4 in. from cold to hot. Those were cast-iron pipes.

Mr. HAWTHORN said he considered the paper was an important one, and they, by virtue of their calling as marine engineers, and by the vicissitudes of that calling, required at the present moment all the information they could get from their members on the steam pipe. Therefore, from the importance of the subject, and from the able manner in which the points had been brought forward at that discussion, he thought it absolutely essential that the discussion should be adjourned. They would then have an opportunity not only of getting the opinions of other members and their experiences on that subject, but it would also give many of them a little time for reflection. When the paper went into the press, with the remarks of the members, it was then, and then only, that the outside members of the engineering world—not necessarily members of the Institute—would look upon the matter and take it up, and give it a certain amount of thought, coming probably to the adjourned meeting and giving them the benefit of their experiences. He would suggest that the discussion be not closed that night, and that every opportunity be given to discuss it more fully on some future evening.

Mr. J. R. RUTHVEN (Member of Council) seconded the proposition, and it was decided that the discussion should be continued on October 30.

Mr. LEE, in reply, said that one of the first questions raised by Mr. Lawrie was whether the heat on one side of the pipe caused all the wasting action. He did not know, he said, that the heat had caused the whole of it, but it happened to be at the bottom side, or bottom centre, which got saturated with salt water, and the intense heat, due to steam at 160 lb. pressure, had the effect of accelerating the action, causing the pitting and other wasting action to go on. From the small sample they would see the result of that action. The sample was originally ¼ in. thick, some ten years ago. The inside of the pipe appeared to be perfectly good, and none of the pipes taken down showed any sign of a scouring action. As regards the flaws in small copper pipes, it was impossible to see them unless they turned the pipe inside out. In the first place, they cut it right round. When the bursting took place it ought to have stood 1,150 lb. pressure, but that pipe carried away at 590 lb. pressure. They could see there was some other reason beyond the weakness of metal to cause it to go. It was impossible to find those causes by any light showing on the internal surface of the pipe. Mr. Lawrie had also asked how often it would be necessary to have the lagging stripped off. He thought the Board of Trade made them remove the lagging every four years. That was the latest requirement. Mr. Lawrie had also asked about sounding the pipes with a hammer when the water-pressure test was being carried out. Sounding with a hammer with twice the pressure did not, in those conditions, affect the pipe much. If it burst it did not give a violent shock. It did not affect anything. He had had one case where a pipe gave out at 600 lb. pressure. It struck him on the foot; he simply felt a slight blow, and there was no severe explosion.

They would find that the Board of Trade surveyor, when he was examining any brazed pipe, went along and gently hit the pipe to simply sound it and see if there was any opening going on. A coppersmith's hammer could be employed, if used lightly. Mr. Farenden had asked about the method of gauging the thickness of those pipes. He could best explain that method by a diagram. [Mr. LEE here explained the point on the blackboard.]

Mr. HULME said he would like to describe a special pair of callipers which he used practically daily for the same purpose. [The formation and method of using the callipers were described by Mr. HULME by means of a sketch on the blackboard.] That special pair of callipers, he said, they were very careful of. They were in daily use, and had very fine points. They had other rough callipers for general use.

Mr. LEE, continuing his reply, said he thought Mr. Farenden had raised a question in regard to the 5,000 tons of energy. That did not mean there was 5,000 tons pressure on the pipe. It was a big calculation to go into, because they had all the condensing in the pipes which took place, so even when the steam was admitted into the pipe they might have that energy given out, but when condensation of the steam ensued they were bound to get very much less. That was only put in as showing what enormous pressure they could get when the steam and water were rushing along the pipe—the time when the damage was usually found to be done. Not that it had happened to himself, but he had known it to take place. If they were to go into a calculation and take all the condensation according to the temperature that was taking place they would find a big result, but they would not get anything like 5,000 tons pressure, not when they allowed for condensing and friction in the steam. He thought Mr. Shearer was right in his opinion as to the flaw getting into the inside of the pipe. So far as he had read and heard, it was due to a bubble of air in the rolling of the copper. That was the first example they had had of a flaw of that description in solid-drawn pipes, and although the Board of Trade did not say so in their remarks and in their examination—it was not quite settled, so far as he could gather in the way of conversation—yet the likeliest thing to cause it was either a bubble of air or a particle of dirt. So far as could be seen, there was nothing else that could have caused the flaws, and the pipe to burst. It was a thing which took place in rolling sheet copper, and not only in solid-drawn pipes. In regard to the scouring action which Mr. Shearer had referred to, he had seen that action in a low-pressure valve casing, and anywhere where there was cast iron. Subjected to the scour of steam he had never noticed it in copper pipes. In cast iron, where the metal appeared to get soft, some of the hard particles would remain intact and cause a roughened surface, due to the action of the steam. Mr. Bertram had mentioned about inlet pipes which were fitted to the ship's skin being tinned on the inside. He did not think the Board of Trade would pass steel pipes, especially if they had been welded. What they might do with solid-drawn steel pipes he could not say, but they would not pass welded pipes. He did not think they would get anything near 16-in. solid-drawn steel pipes. He had known $4\frac{1}{2}$-in., and that was the biggest steel pipe that had come under his notice solid drawn.

Mr. LAWRIE said it was his fortune some time ago to be in some works where copper was very much worked. Some copper came into the works, but the foreman said it would be no use working it, because there was a slight speck in it which would develop into a crack. The owner took off his coat and worked at it a couple of days, and it cracked but slightly. At the same time, it was a crack which would be observable, and when he commenced to draw it off it was no bigger than a pin's point. The 3-ft. defect mentioned by Mr. Lee was $\frac{1}{16}$ in. deep at one end. He did not think it was anything like that depth when it occurred in the copper. It seemed to him that it must have been the action of the steam that deepened it, and he did not see how the steam could deepen without widening the crack. It needed to be explained how it had got down $\frac{1}{16}$ in. and had not widened. He expected it would be said that it was not to be seen by ordinary means, but it appeared to him that it was astonishing that the crack could get that depth without widening through the action of the steam.

Mr. SHEARER said there was no doubt that the bending of the pipe in the reverse opened up the crack. It would still retain its blackened surface to a certain extent.

Mr. LAWRIE : The opening of the pipe did not deepen the crack at one end.

Mr. SHEARER, referring to a remark made by Mr. Hulme, said he would like to know the objection to putting a double pressure on to a pipe, boiler, or anything else for testing purposes. And there was also his reference to the bends straightening out under that pressure. They all knew that if they put a pressure on to a bend that bend would incline to straighten itself out. There was no getting away from that fact—it was the nature of things. It was very annoying to a foreman, if he left all his pipes in splendid order, and his joints well fitted, and when he returned from putting the pressure on found they had all opened up on the one side. But what was Mr. Hulme's objection to putting on the double pressure? Was it only that straightening tendency? If so, what other method would they have for safety? Were they going to take boilers or steam pipes of any kind to the danger of all who were to be connected with them? If it stood, good and well—all right; but if it burst they knew the result. He did not know how they could get along without double, or an increased pressure to a much greater extent than the ordinary working pressure.

Mr. HULME said it was not the practice in high-pressure pipes to test with double the pressure. He thought they would find that all high-pressure pipes were tested to 90 lb. over the working pressure. That was due to the severe strains which were put on. He had had some feed pipes to be tested. and the Board of Trade had compelled a test of double the pressure. They required enormous flanges to carry that out, and it cut the flanges and disturbed everything. It also hardened the copper.

Mr. SHEARER: You will not harden the copper on a single pressure; that happens when vibration takes place.

Mr. HAWTHORN said that double the pressure of 180 lb. on a 6-in. pipe almost brought them up to the limit of the elasticity of the material. They would be setting up permanent strains on their pipe. It strained the material when they had reached the limit of elasticity, and the distortion would be permanent.

Mr. HULME said he had some steel pipes in the works they were testing to 600 lb. pressure.

The CHAIRMAN said he was extremely pleased that Mr. Lee's paper had given rise to such an interesting discussion. It dealt with a most important subject—the question of steam pipes, whether made of copper or any other material. They would have an opportunity of further discussing the paper on that day week. He hoped they would accord Mr. Lee a hearty vote of thanks for his trouble in preparing the paper.

The vote of thanks to Mr. Lee was at once carried.

Mr. LEE said he was obliged for the kind attention which had been given the paper, which had evoked a good discussion, from which he hoped all would gain something. The evening had been a very pleasant experience for him—far more pleasant than his experiences with steam pipes.

Mr. SHEARER moved, and Mr. HULME seconded, a vote of thanks to the Chairman.

ADJOURNED DISCUSSION

AT

58 ROMFORD ROAD, STRATFORD,

ON

MONDAY, OCTOBER 30th, 1905.

CHAIRMAN:

MR. FRANK COOPER, R.N.R. (MEMBER OF COUNCIL).

THE CHAIRMAN: Mr. Lee will now reply to the questions put at the last meeting.

Mr. LEE said that since coming into the room that evening he had been looking over the *Shipping Gazette*, and therein he saw a case in point which well illustrated what his paper pointed out—viz., the necessity for drain pipes and drain cocks on steam pipes. The case referred to was that of the steamer *Lakonia*, in which the third engineer and a trimmer were killed through the opening of the stop-valve when water was in the pipe. That was the Board of Trade judgment. There was one gentleman whose evidence at the inquiry seemed rather conflicting. He said he urged that "steam could be turned on while water was still in the auxiliary pipes without any risk of injury if sufficient time were taken to do so." "Sufficient time" might be two or three hours. The judgment said that no accident should have happened, for the pipe was quite sufficient for the work it had to do. The Board of Trade said no blame was attributable, and it was quite clear that the pipe which gave way was of excellent material, and that the workmanship was open to no criticism. The pipe which he had mentioned in his paper and illustrated at the previous meeting was thought to be quite sound, yet it burst with fatal results owing to the cracks inside. That was very unusual in a solid-drawn copper pipe, and until it was opened out no one could tell what was wrong with it. Mr. Lawrie had said that he thought it possible to discover the cracks by passing an electric lamp through, but he could assure them it was impossible to see anything. In regard to the speed of steam through a steam pipe, he had with him some interesting figures taken from experiments carried out with the De Laval steam turbine. With an initial steam pressure of 60 lb. the velocity per second was 2,421 ft. A pressure of 160 lb. per square inch gave a velocity of 2,992 ft. per second. That was against atmospheric pressure. With a vacuum of 25 in. it went up much higher—by 1,000 ft. per second. It was with a vacuum in the pipe that he had referred to the energy developed as 5,000 tons. That also illustrated the benefit of high vacuum in a turbine engine on the condenser. The velocity went up in some cases more than 1,000 ft. per second. Mr. Shearer had mentioned some experiences he had had in connection with bilge pipes. He had come across a paper which went into that question very fully, and the destructive action had not been altogether due to sea-water. He should say that, as Mr. Shearer had remarked, it was due to the action of oils. Here was a quotation from a technical paper showing the chemical analysis of some of the bilge-water taken from the engine-room well of a steamer :

"(*a*) Hydrochloric acid (trace) (HCl).
(*b*) Sulphuric acid (trace) (H_2SO_4).
(*c*) Carbonic acid (trace) (H_2CO_2).
(*d*) Sulphuretted hydrogen (H_2S).
(*e*) Oxide of iron (Fe_2O_3).
(*f*) Grease and fatty acids.
(*g*) Oxide of silicon (SiO_2).
(*h*) Ashes.

"Now, although the above acids were known to attack copper individually or collectively in a greater or less degree, it is my opinion that another active agent in connection with the corrosion of the copper pipes was free oxygen. The bilge-water, being pretty well emulsified with air in its passage through the pumps, will be quite in a condition for forming cuprous oxide (CuO_2), and, as sulphuric acid readily decomposes this oxide, it would form a cupric salt, and separate metallic copper." That quotation was from a paper read before the Institution of Naval Architects, and it showed what went on in the outside of copper pipes when covered with lagging and sea-water getting at them. The grease and fatty acids would be absent in some water. Mr. LEE then read the following further extract from the paper referred to above: "In this connection it may be mentioned that the results of some experiments carried out by Mr. James Weir on the corrosion of iron and steel exposed to water showed that it was not the water which oxidised iron or steel, but that it was the corrosive agents contained in and brought by the water into contact with the metal. The corrosive agents were found to be atmospheric air and carbonic acid. When the water contained only the constituents of atmospheric air (oxygen and nitrogen) a coating of ferrous oxide was formed, and if this was allowed to remain there was no further action, but when the water contained in addition carbonic acid in solution the iron oxide scale was at once attacked by the carbonic acid and changed into ferrous carbonate. The ferrous carbonate in its turn was immediately acted upon by the oxygen, forming ferric oxide, and setting free carbonic acid, which in turn was free to attack more ferrous oxide, and so on. Mr. Weir very aptly describes the process of corrosion as an oxygen pick and a carbonic acid shovel. It will be seen from this that, given a plentiful supply of oxygen, the amount of carbonic acid need not be increased in order to have extensive corrosion." Mr. Lee said he thought that was well illustrated in the paper which he had read last week, showing it was not altogether the lagging or the sea-water. It was the turning of the steam to vapour and chlorine being given off the hot pipe, causing chlorine and hydrogen to mix, forming hydrochloric acid.

The CHAIRMAN: The paper is now open for further discussion.

Mr. W. McLAREN (Vice-President) said he presumed cold water was used in testing with the water-pressure. Would it not have been an advantage to have used hot water, heated to nearly boiling point, for carrying out the test?

Mr. W. E. FARENDEN asked whether the material taken away from the burst steam pipe spoken of by Mr. Lee had been tested in regard to its quality. Were any strips cut from the pipe to test what its tensile strength was? With regard to the velocity of steam through the steam pipe, Mr. Lee had referred to the "De Laval" steam turbine as having a very high velocity of steam. In an ordinary marine engine, he thought if they took 6,000 ft. per minute (100 ft. per second) as the velocity of the steam they would have a much lower figure than Mr. Lee had mentioned.

Mr. J. R. RUTHVEN (Member of Council) said that at their last meeting a member raised a question about the 5,000 tons of energy said to be a possible result from water-hammer action. Was it that the energy of one gallon of water at that velocity would be 5,000 tons? What pressure would that have upon the pipe? He would like to see that point made a little more clear, as to how the 5,000 tons was arrived at. He could quite see that there was an enormous energy with high velocity. How did Mr. Lee work out the 5,000 tons?

Mr. J. CLARK (Companion) said: Mr. Lee's paper may be described as one dear to the heart of every engineer, whether connected with engineering afloat or ashore, as it deals with practical experiences and suggestions to avoid failures in this very important detail connected with all power plant. Everyone, I am sure, will be at one with him where he advises the exposing of the whole pipe to examination, but I somewhat doubt if everyone will agree with him when he suggests that the hammer test is infallible. This requires a very acute sense of hearing, as well as very great experience, and I am by no means certain that everyone who has to test steam pipes in this manner can do so accurately. Bad cases, no doubt, are easy to locate, but probably they will locate themselves long before the opportunity presents itself to anyone for carrying out this kind of test, especially if the pipe is subject to trying conditions in actual use.

It has been suggested that external corrosion is sometimes caused by the action of damp and heat in conjunction with asbestos composition when used for covering. I cannot say I have ever seen this effect, but have heard of it, the remedy suggested being to give the pipe a good coat of graphite paint before applying the composition. Regarding the subject of internal corrosion, a great deal of future trouble can be prevented in riveted steel pipes by arranging that the longitudinal rivets all come to the top side; this avoids the wasting action caused by condensed steam lying about projections. As evidence of the importance with which the Admiralty consider the inspection internally of tubes for Belleville boilers, it is a well-known fact that they insist upon galvanising them chiefly for the purpose of facilitating examination, as, of course, galvanising will not last long under the conditions the tubes meet with in raising steam. Mr. Lawrie gave us some interesting details regarding the internal examination of pipes by means of an electric lamp. The first time I saw this method used was about fifteen years ago, in connection with the tubes of an evaporator; these were straight tubes. I have, however, at times something to do with copper pipes in the form of spirals or coils, and I think it would add greatly to our knowledge if Mr. Lawrie could suggest a means for ascertaining the inside of pipes in this form. It is a curious fact that the steam travels like a screw through pipes of this shape, and I have known quite an appreciable corkscrew groove being cut in the pipes due to this. Vibration and want of alignment have, next to water-hammer, been the chief causes of steam pipe failures, and I am sure Mr. Lee could have added much to our knowledge by giving these two causes a little more prominence; in fact, I hardly think he touches on them. The subject of water-hammer, however, is dealt with in a most practical manner. At the same time, no harm would have been done by pointing out that quite a number of the failures caused by this action have been primarily due to choked drains as well as the bad arrangement of valves or pipes permitting the lodgment of water. At the present day it seems superfluous to call attention to this, but the fact remains, and, from the Board of Trade reports, this has been a common source of failures. One would almost think that the present-day engineers make a practice of starting where their fathers commenced instead of where they left off. This is a case in point where the good old adage can be legitimately reversed to the advantage of all concerned. Curiously it is not always at the weakest point where pipes subject to water-hammer action give way, but very often where the direction of the steam is changed or at the point of impact. Mr. Lee warns the young engineer as to the effect of suddenly opening a steam valve on to an empty pipe. He might have also added that, if the pipe managed to survive the ordeal, probably the boiler would not, as it is likely to draw the water out of it, or at least sufficiently to bare the furnace crowns. The example of KE given by Mr. Lee is, I think, most unhappily chosen, and, as stated, somewhat misleading. The velocity of escaping steam stated at 1,722 ft. per second into a vacuum is not actually correct. This velocity is undoubtedly correct if it is desired to know the quantity of steam passing per minute, when the area of the aperture is known; but in addition to the velocity through the opening there is the enormous velocity due to the expansion of the steam. Under these conditions this may be over 4,000 ft. per second; in fact, the De Laval turbine is one of the best examples of utilising this principle of which I am aware. I cannot quite follow the 5,000 tons of energy mentioned, unless it be that Mr. Lee has assumed the accumulated work of 206 foot-tons brought to rest in the space of half an inch. This figure, however, cannot be considered simply as a pressure, as one would readily assume was intended from the way in which it is put. In any such example, to be of practical use, the modulus of elasticity of the material under shock must be considered to give approximately the pressure developed by the moving mass. I think Mr. Lee could have illustrated his meaning much better by taking the case of shutting down a cock on the blow-off pipe of a boiler under pressure—not necessarily the cock next the boiler. Taking the same pressure, namely 150 lb., the length of the pipe to the second cock, say 5 ft. 6 in., the pipe 3 in. bore, and the area of metal in the cross section equal to 2·25 sq. in., if the cock could be shut instantaneously, then the pressure that pipe would require to stand would amount to 75 tons per square inch or more than double the tensile strength of steel.

There is little doubt but that the last paragraph in Mr. Lee's excellent paper will not be long before it is actually fulfilled, and copper for steam pipes abolished. Superheated steam is coming more into use every day, and the unsuitability of copper for this purpose is well known and recognised. Some of the gentlemen present may have seen at the recent Electrical Exhibition, at one of the stands there, some steel superheater tubes which had been in use for nine years at Maiden Lane Generating Station, and, as far as one could see, they appeared to be practically as good to-day as when they had been put in. If pipes can be made, and, from what we have seen, they are made to do good duty under the stringent conditions to be found in the working of superheaters, then I think it is only a matter of time before the copper pipe, which has seen its day and generation, is done away with.

Mr. FARENDEN: Perhaps our Chairman will give us some of his experiences of steam pipes.

The CHAIRMAN said he had enjoyed the paper very much. In the first place, Mr. Lee had told them to look out for sound pipes, and then to see that they caused no flaws in them. He had given several ways of looking out for that, but the most important point was the reference to the care which was necessary in letting steam into the pipes. He should think that more steam pipes had been burst, if not at once, at least eventually, by steam being allowed to enter too suddenly than from any other cause. He had seen a pipe ripped up ten feet, and there was apparently no very great pressure going into the pipe. It was due simply to the other end of the pipe being full of water, probably cold water. Then, in regard to the covering of steam pipes, he supposed it was agreed that the pipe covering had rarely anything to do with the failure of the pipe. He did not imagine that it mattered much what the pipe was covered with, so long as they had no leakage. Some coverings might be more liable to chemical action than others, but that meant they might have water getting to the pipe and causing that action. That, however, was due to the leakage, and not the covering itself. He would like to hear some further remarks on the use of iron pipes instead of copper pipes for steam. He thought there was no doubt they would very soon come to the use of steel in place of copper pipes.

Mr. J. RENDALL (Member) asked whether, when steam-pipes were on deck, and were subject to salt water spray always passing over them, it would be advisable to keep such pipes covered or uncovered. He meant, of course, when the steam was always on them.

Mr. J. G. ROBERTSON asked what temperature or steam pressure was most detrimental to copper pipes.

Mr. RUTHVEN said that query brought to his mind a point in the Board of Trade regulations. The Board of Trade made no allowance for extra heat. "P" = pressure, but suppose it might be 300 lb. per square inch, and the corresponding heat due to such a pressure, where would the factor of safety be? It was all right when steam pressures were low, but high pressures had a detrimental effect upon copper.

Mr. JAMES ADAMSON (Hon. Secretary) said Mr. Lee had done them a great favour by bringing a subject before them which had caused a good deal of speculation in connection with the special pipe to which he referred, and, as he had remarked in his opening sentences, they had all had some experience with steam pipes, some more, some less. The importance of the subject had grown upon them since the pressures, and consequently the temperatures, which copper pipes had now to stand had become so great. One pipe that he saw recently which gave way was due to faulty design. The pipe was led from the boiler stop-valve with a bend up towards the throttle-valve chest on the engine. As the boiler rose when heated up, that end of the steam pipe also rose; then when the movement and vibration of the engines came into play the tendency was to tear the pipe away at the flange, as illustrated by the sketch on the blackboard. There was no expansion gland on the pipe, and there did not appear to be much room for an addition to the right-angled bend in order to give play to the pipe when the movements came upon it. He might state a case which occurred in a ship over twenty-one years old. Her steam pipes, at 80 lb. pressure, had never given any trouble, but in the course of attaining her majority the ship had sagged, and although there was plenty of clearance below the beams when the ship was in port with the boilers cooled down, when at sea, and the stokehold heated up, those beams were gradually cutting into the pipes, the non-conducting covering hiding it from view. Fortunately it was noticed that a beam had been touching one of the pipes in the stokehold, and that had the effect of bringing the whole of the pipes under observation, and it was then found that three or four pipes were being abrased by the ship's beams. Alterations were made in the contour of the pipes to give ample clearance. Between cold and hot there was a difference in the clearance of about $\frac{7}{8}$ in.; so that although the pipes were clear of the beams when cold they were touching when they were hot. With the introduction of higher pressures they were now avoiding pipes of large diameter. The pipes were now generally small, and led up to a 3 or 4 branch piece on the throttle-valve chest at the engines—a practice generally obtaining favour nowadays. In another case he had seen the pipe from the centre boiler stop-valve chest led to a cross-piece by a right-angled bend, the pipes from the wing boilers being also led to the cross-piece, but with ample and easy bends for expansion. There was an expansion gland—of the stuffing-box style—at the stokehold end, adjoining the cross-piece. The main pipe was a brazed one, led through a tunnel into the engine-room, with a bend up to the throttle-valve chest. In this case the pipe from the centre boiler gave a good deal of trouble, and the main pipe followed suit. These results were probably due to faulty design—ultimately corrected by an alteration in the arrangement, the pipe from each boiler being led right up to the throttle-valve chest and connected by a breeches piece. The expansion by heat on the boilers and the pipes raising the ends at the stop-valves while the other ends were held more or less rigid no doubt caused the trouble with the centre boiler pipe, and also the main pipe to a less extent, but aggravated by the vibration of the engines. They knew the trouble there was at times with the expansion gland stuffing-box when leakage became persistent. The temptation to use the spanner too much, when yielded to, sometimes rendered the gland inoperative. He had seen a large main steam pipe scored very badly inside at the bend, apparently caused by either a mechanical or chemical action from *débris* carried through by the steam striking on the outer circle of the bend. He did not know the history of the pipe or the steamer from which it came, hence he was unable to form any opinion of the cause or causes which had been at work to waste away the material of the pipe, as the wasting was not confined to the brazing metal. The action was confined to the outer circle of the bend. Within the last few years he had seen cases of brazed pipes, after fifteen or sixteen years' service with steam-pressure of over 150 lb., where the brazing seemed to be perished on the inside, while there was nothing apparent on the outside. In one such case, where the pipes outwardly seemed perfect, and stood the double pressure, yet on examining them inside, after the pressure was removed, it was found that the brazing was perished inside as far as visible from the ends. He did not think the sound of a hammer would have indicated what was going wrong, as the pipe to all outward appearance was sound and good; it also stood the pressure and the tapping of the hammer while so pressed. As those pipes had bends, it would have been not only a long and tedious, but an expensive job to rebraze them, so they were replaced by solid-drawn pipes. Mr. Lee had referred to a safety valve, and doubtless they would all agree with his remarks on the subject. He might mention that one of their members, whose name he regretted to place in the obituary list of last year, had obtained a patent for a safety valve, the object of which was to give warning if the pressure in the pipe went to an abnormal extent. A model of it was made and tried experimentally, but he was not aware of the device being adopted, and he did not know whether the patent rights had expired. The safety valve was not to be compared with the systematic draining of the pipes. With regard to the water-hammer action, no doubt they all had had curious experiences of it. He had seen a steam pipe which burst while being covered with non-conducting material, with only from 15 lb. to 20 lb. pressure on the boiler at the time; yet that pipe had stood a pressure of 160 lb. not long before; and no doubt failure was entirely due to water-hammer action. He thought it would be very interesting to discuss what value was due to the annealing of pipes. The consensus of opinion was that by annealing a pipe or any material, after undergoing a certain amount of fatigue, they did it good, and not only preserved the pipe or material, as the case might be, but they lessened the risk of disaster. The recently issued rules and regulations which were designed by the Board of Trade to keep them all safe and sound in life and limb recommended the annealing and testing of all steam winch and cargo gear. No doubt the Board of Trade were convinced that the annealing process was a good one, and likely to minimise risk. One method that a coppersmith used for examining the inside of a pipe was a red-hot poker—a first-rate thing to use as far as it went; but, as Mr. Clark had said. there were pipes which they could not get into far enough with such an instrument, and it would be very good if they could adopt some means of seeing a pipe inside, whether by an adaptation of the Röntgen rays or otherwise. If they could see the inside of a pipe it might reveal to them defects that they could not otherwise see. He remembered a good many years ago, when they were talking about putting the Röntgen rays on to tunnel shafting, Mr. Macfarlane Gray suggested that it would be a very bad thing indeed, because engineers might see more than they ought to see. If they saw the inside of a shaft, and it was bad at the core, they might think it was bad all through. *A propos* of that, he did not know if the members had been up to the museum lately, but the next time they were on the premises, if they went up to the museum they would see a small propeller shaft, the like of which, he dared say, had seldom been seen. It was sent home by one of their members from China, and he thought it was a specimen that every engineer ought to have a look at, as it was a curio worth examining.* The question of covering for

* This shaft was forwarded from Hong Kong, as the following letter explains:

"DEAR SIR,—I forwarded per ss. *Glaucus* yesterday the small fractured propeller shaft which I wrote about some time ago. The small piece of brass liner left on it is the forward end of the after liner. The Chinaman in Canton who made the shaft says it was made from a bar about one inch larger than the finished shaft, which bar was purchased from a dealer in the city. This I doubt very much. I think the members will admit that it is unique as far as fractured shafts go.—Yours very truly, "JAMES MACDONALD.

"The HON. SECRETARY,
"Institute of Marine Engineers."

deck pipes was a very mixed one. The point had been raised that night as to which was the best kind of covering to use. They had all tried various kinds, but he thought if our cork-cutters would only take a leaf out of the book of the Continental cutters we might have a good specimen of cork covering for deck pipes, and that covering not running into so much money as it did at present. He understood that that cork covering was almost entirely in the hands of Continental firms. He had been trying to stir up some of our own firms in the direction of a good cork pipe covering. Personally he had not seen any corrosion either on boilers or pipes due to the covering. It was only in the presence of moisture that they found corrosion going on, and it was not due to anything deleterious in the lagging but to the moisture being held in contact so long. He thought in most cases it would be found to be due to the moisture, and not to the lagging itself.

The CHAIRMAN said that he remembered on one occasion using a bilge pipe for discharging overboard, and that pipe was very much corroded indeed. The superintendent of the company he was then with, considered the corrosion was due to the use of disinfectants in the bilges, such as chloride of lime, and the other disinfectants which were used in bilges—also from acids in the boilers. Some of the pitted parts in the pipe were $\frac{1}{4}$ in. in diameter and about $\frac{1}{16}$ in. deep.

Mr. E. W. Ross (Hon. Fin. Secretary) said Mr. Lee's paper seemed to treat of experiences that were general in the use of steam pipes. It was a pity they could not go a little further back in regard to the manufacture of copper—to the general conduct from the beginning of the manufacture of the copper. It was a vexed question how the flaws occurred in the pipes. It was supposed that globules of air were in the copper ingot, and those globules would be aggravated by the drawing. He was sure there were more of those laminations in the copper than they knew of. He did not say that a lamination would weaken a pipe—in fact, he was of opinion that it did not, unless the flaw caused by the globule of air cut into the thickness of the pipe. If it occurred in the circular way of the pipe, and concentric, it would not cause any weakness. He had known pipes with laminations, and they had been tested to two and a half times the pressure without any bad result showing. With regard to testing pipes to two and a half times their pressure, he thought that the Board of Trade had some idea that that extra half which was put on to the pipe was a guard against bad workmanship. Copper would also lose some of its tensile strength through being heated, and that would reduce the pressure down to the double pressure. Then there was the question about covering the pipes. He had seen those pipes in the way of sea-water exposure, and if the non-conducting material were covered with lead, so that no sea-water or moisture could get through from the outside, it would prevent the corrosion which Mr. Lee had spoken of. It was said in the paper that the copper pipes which gave way were reduced in thickness from ·252 in. to ·09 in. He understood that the corrosion shown on that pipe was all from the out-side. He would say, on the subject of staying for the benefit of the pipe, they should be suspended so that no undue strain would come on them. There were several ways of supporting steam pipes. There was the old-fashioned way of clipping the pipes where they could get at them, but no allowance was then made for expansion or movement. There was a good way which he had seen lately in long runs of steam piping. The supports were at convenient positions, but with springs interposed between the fixed part and the pipe itself so as to allow for a certain amount of give-and-take, whether the pipe wished to come to the ship or the ship to the pipe. He thought it went without saying that nobody would ever dream of fitting a steam pipe without a drain. That was an axiom —a self-evident truth. They must have a drain. He had seen a discharge pipe very much pitted, almost to a finish, within three voyages in about eighteen months. That pipe had to be condemned. He was not prepared to go into the chemical causes which had caused pitting, but it was evident that pipes had been done to death in a year or eighteen months, whilst other pipes had run for a number of years without any action at all. Steel steam pipes were coming much into evidence now, and the old-fashioned stuffing-boxes were coming into fashion again, fitted to allow for expansion and the motion of the pipes.

Mr. W. MacLaren (Vice-President) said he had been with a coppersmith that day, and had been discussing with him the subject Mr. Adamson had remarked upon in regard to annealing pipes. Mr MacLaren remarked that his firm had a long range of copper pipes, on which there was about twelve coils, each of 6 in. in diameter from centre to centre, of $\frac{1}{2}$-in. pipe. These were used as expansion pieces for a continuous lead of steam to hydraulic presses. They had had serious trouble for some time through those small pipes giving out at the flanges. The coppersmith had recommended them to anneal those pipes once a month. The pitch of the coil when hot and when it came back to its cool state varied about 1 in. That would give one an idea how much the range of pipe was twisted or stretched. That went on about twenty times per day—they might say once an hour. The coppersmith's idea was that all copper pipes should be annealed after a certain amount of work. Then, in regard to testing the pipes to double, or two and a half times the working pressure, he thought it was not reasonable to subject to that test any material such as steam pipes were made of, where they might be working under a varying pressure and temperature. He thought that one and a half times the working pressure was quite sufficient. It was as a test of workmanship that the pressure was put on. If they tested to such an extent it was likely that some parts of the pipe might be overstrained, yet show no defect for a long time; and after all these years of experience they knew that copper was not to be relied upon at pressures of 150 lb. and upwards. It was unreasonable to overstrain the material. Mr. Ross had referred to the manufacture of copper, and it had struck him as a forcible remark that they ought to know how the copper was put to work in the first instance. He had noticed in cast copper, or ingot copper, that it was a hard job to get the ingots free from blowholes or something of that nature. So, after copper had been taken and put through a process and had been drawn into pipes, then they would get those defects still in the pipes. Possibly those defects would not exist as laminations, but in a series of cracks, which no doubt might have been the cause of the bursting of the particular pipe of which Mr. Lee had had some experience. Then they had had under discussion the sighting or examining of the inside of pipes. As he had said at the previous meeting, he recommended the incandescent electric lamp. It was surprising the magnifying power they had when examining the interior of a pipe by that means. They had only to try it to find the result from it. He was speaking mostly of the water-tube boiler, and the examination of the tubes in regard to scale; and to see the thickness of the scale, when the scale was in contact with the pipe and everything in place, they had only to drop an electric lamp down, and shift it along, whatever the angle might be, and then get a piece of the scale off. One of the speakers at the previous meeting had raised a question in regard to the hanging of pipes, and about sheet lead. In his experience he thought the object of the lead was to ease the pipe from hammering by the vibration when hung up. He had seen a steel pipe that had just been fitted, and instead of going back to the old stuffing-boxes they had put a copper pipe with a circular bend to take up the action. That, he should think, would be the more advisable style. He had three or four such bends in his care, and they served well for their purpose. In his opinion the circular bend was the best thing to take up the movement.

Mr. LEE then replied to the points which had been raised. Mr. McLaren, he said, had asked a question as to whether hot water would be an advantage in testing. He did not think it would. In the first place, they would have to get the water hot, which would be rather inconvenient, and then they could not keep it to a very high temperature, not over 200°, for any length of time, except they had a furnace underneath the pipe. He did not know that it would be an advantage for testing even with all those appliances. Mr. Farenden had asked a question as to whether tests had been made in regard to the tensile strength of the pipe which he had referred to in his paper. He might say that they tested that copper in sixteen instances, both circumferentially and longitudinally, and all stood 14 tons, which was 31,060 lb. So, if copper would stand anything like 14 tons, it was looked upon as very good copper, both from the commercial and engineering points of view. Reference had been made to the De Laval turbine. The figures he had given were the result of actual experiments carried on by Mr. De Laval. He could not then go into the method Mr. De Laval had employed for testing the results, but he had quoted the figures as they appeared in *Engineering*, and he would say that they were pretty reliable. A question had also been asked in regard to the energy developed. Well, that was a very big question to go into to explain the whole thing fully. The expression in his paper, "5,000 tons of energy," was really a figurative statement. It was the energy that would be developed if they allowed a quantity of steam to pass into a pipe by opening a 4-in. stop-valve, and that pipe under a vacuum. According to a formula of Molesworth, the rush of steam into a vacuum at 150 lb. pressure would be about 1,722 ft. per second. If they took that and supposed that they put one gallon of water in motion at that speed, it would develop the energy to which he had referred—that was to say, all that energy would not be fixed on one spot or on one square inch. When they tried to stop that water they would get an enormous force at either end of the pipe. That was the reaction due to stopping the gallon of water put into motion. If they went into a calculation of the losses due to condensation and radiation that took place in the pipe, they would, no doubt, get a different result, and he dared say they would all differ in the result when they found it. As a figurative statement, his remark as to the 5,000 tons of energy would convey something of the enormous energy which would be developed if they opened a stop-valve suddenly. One gentleman had remarked that the pipe would give out long before anything else did; but it was where the water was first stopped that took all the stress, and took the power out of the water. Mr. Adamson made a remark about hammering tests, when he referred to the defective brazing not being distinguishable by the hammer. If the brazing was all gone on the inside and only a very thin layer of brazing was left on the outside, the seam would give out if they went along with a hammer when the pressure was on. The pressure would tend to open up that seam, and if it stood the test without hammering the result of going along the seam with a hammer would be to open it still further out, and cause a leakage. He had seen attention called to defective brazing by a slight leakage of water. They could not distinguish the weakness until they had gone along with a light hammer and tapped it all over. Mr. Rendall had asked whether deck steam pipes would be better covered or uncovered. Well, so far as economy of steam was concerned they would be better covered, but for stopping corrosion they would be better uncovered. That was, of course, unless they got a good material, and it was properly lapped over after being put on, and cased with sheet iron or lead, as a speaker had instanced. Another question which had been put was, What was the most detrimental temperature for copper pipes ? Copper lost much of its tenacity at 600° F. He did not know what that temperature of steam would correspond to in pressure.

The CHAIRMAN: It would be superheated steam.

Mr. LEE said that 300 lb. pressure gave a temperature of about 450°, and the temperature for 600 lb. pressure would be much higher than for 300 lb. Mr. Ruthven had referred to the formula used by the Board of Trade. They used that for the pressures of the present time. They did not go into anything over 200 lb. with that formula. With 300 lb. pressure they went in for steel or iron pipes. He had never known them to use copper pipes for anything over 200 lb. pressure.

At the previous meeting the corrosion of bilge pipes had been referred to, and he thought one gentleman, although he did not actually give an example, had said that such corrosion might also take place with steam pipes, due possibly to some agents put into boilers nowadays to stop scale forming, oil depositing, and other things. But, so far as his experience went, he had never come across a steam pipe that was corroded on the inside. He had heard of them, but had never seen them. Then, in respect to the pipe which he had referred to in his paper, and which had become thin on the side next the boiler, the outer part of that pipe—that was to say, the part away from the boiler—remained about $\frac{1}{4}$ in. thick, whilst the other part, next to the boiler, and therefore subjected to the heat of the boiler, was corroded to the extent of about $\frac{3}{16}$ in. That corrosion only took place in about one-third the circumference of the pipe. It was the whole length, right between the flanges. Mr. Ross had mentioned springs that would be advisable for hangers. He had not come across them, but he thought it would be advisable to know more about the matter. The hanger that was used nowadays, instead of clipping the body of the pipe, simply suspended the flange, so that it was free to move fore and aft or in any way that it liked so long as it did not go sideways. They took the weight of the pipe, but allowed it to go fore and aft with the working of the ship. Reference had also been made to the subject of drains for steam pipes. As recently as the 20th of that month it was apparent that engineers did not all know about the matter. They had a case in point, the *Lakonia*, where two men were killed. There was one cause of pitting in pipes which he had not heard mentioned during the discussion, although he had heard that cause spoken of outside. He referred to electrical action. In many single-wired ships, where they used the body of the ship as the return, the electrical current going back to the machine caused a certain amount of electrical action to take place in copper pipes, and that pitted them very much. It was not only in bilge pipes, for he had heard of condenser tubes being affected in that way. Another affected pipe which he had seen was an overboard discharge pipe ; but only one such instance. In eighteen months there were pit-holes $\frac{3}{16}$ in. deep, but he could not say whether they were caused by electrical or chemical action. He had simply seen the pipe. Many engineers said that the cause of pitting in bilge and ballast pipes internally, and on plates, where they were exposed to moisture, was due to electrical action, and when the ships had been fitted on the return system of wiring they had found that action to cease. Mr. W. McLaren had referred to the blowholes in the copper ingot. If the copper ingot, in the course of manufacture, was well poled when smelted, and well stirred with elm sticks so as to get rid of all the oxygen, then taken out and rolled, they got rid of the air. He had always understood that the sheet lead was put in between the iron hanger and the pipe to prevent the chemical action between the copper and iron. In many cases it had been employed to keep the iron off the copper, so that when the pipe "worked" it would have a softer substance to rub up against. The lead itself was simply reduced in thickness; thus the copper did not suffer.

Mr. W. BRITTON (Member) said there was one experience he had had with a copper pipe, similar to that referred to by Mr. Adamson. It was in regard to testing with the water-test, and tapping with a hammer at the brazed joint of the pipe, the joint being pitted to a depth of $\frac{1}{4}$ in. He tried the test with a small hammer and a pressure of 60 lb., but found no leak. After taking the joint apart he found it was pitted to the depth of $\frac{1}{4}$ in. in the brazing. All the gun-metal was pitted, but the copper had remained intact. In the same ship the copper pipes which led into the ballast tanks were all pitted. He would like to corroborate the statement regarding drain pipes, as five years previously he had been badly scalded by a pipe giving way for want of the drain being open. He would like an expression of opinion as to what was the best pressure to put on to copper pipes for testing, over and above the working steam pressure. In many instances the Admiralty compelled them to put two to two and a half times the working pressure on to copper pipes, which he thought was too high.

Mr. LEE, referring to the copper pipe mentioned by Mr. Britton, where the brazing had not given out when it was tapped, said that the pressure of 60 lb. was certainly a low pressure. If they had had twice the working pressure on he dared say they would have got some result out of it. In regard to the chemical action which went on in the bilges, he did not know of any builders that fitted copper pipes in the bilges. The chemical action which had been referred to was entirely due to exposure—that was to say, the pipe was underneath the boiler. It would be heated at one time, it would be wet, then dry, and thereby getting a coating of salt on it, start generating hydrochloric acid. Another frequent cause of pitting in copper pipes in the bilges was the lubricating oil. Some cheap oils had a certain amount of acid, and when that got into the bilge it immediately attacked the copper and rendered it full of pit-holes. The question of two and a half times the working pressure was a very debatable point with many engineers. If they had a high pressure, say 200 lb., and put two and a half times that pressure on the pipe, it would only be stressing the copper to 500 lb. per square inch. Copper, if it stood a tensile strain of 30,000 lb. per square inch, ought to stand something like 1,000 lb. per square inch before it had reached its elastic point, or before it retained a permanent strain. Even if they tested a pipe to two or two and a half times its working pressure, so long as they did not go in for 300 lb. boiler pressure, or over that, they were going to do the pipe no harm at all.

Mr. BRITTON said he had often put over 600 lb. pressure on to a pipe, and had never had one give out.

Mr. LEE said he was of opinion that it was the quality of the copper and the working it had had before being made into a pipe that would certify whether they could put on double or two and a half times the working pressure with safety. If they had much arsenic in the copper it would make it hard and brittle. If it contained no arsenic, and had been well worked so as to get rid of all the oxygen and other deleterious substances in the copper, he thought they need have very little hesitation about putting two and a half times the working pressure on it.

The CHAIRMAN said he was sure they would all agree with him that they were much indebted to Mr. Lee, not only for his paper, but for coming there that night to answer all their questions. He would conclude by proposing that a very hearty vote of thanks be accorded Mr. Lee for his paper and answers.

Mr. E. W. Ross seconded the proposition. He wished that there were more such short practical papers brought before the Institute. It was an advantage for a man to air his experiences, and it was also a benefit to all who heard him do so.

The vote of thanks to Mr. Lee was unanimously agreed to.

Mr. JAMES ADAMSON: It is a very good rule that the proposer of a motion should carry into effect his own suggestion. I hope we shall soon have a paper from Mr. Ross.

A vote of thanks to the Chairman for presiding concluded the business of the meeting.

ANNUAL DINNER.

HELD IN

THE KING'S HALL, HOLBORN RESTAURANT,

WEDNESDAY, OCTOBER 25th, 1905.

THERE was a large attendance at the annual dinner, presided over by Sir Marcus Samuel. The guests included the Hon. Justices Bigham and Walton, Admiral Sir E. Fremantle, General Sir Alfred Turner, Sir John D. Pender, Sir Wm. Arbuckle (Agent-General, Natal), Captain Makoto Kaburaki (Japanese Naval Attaché), Professor Cormack (Professor of Engineering, University College), J. T. Milton (Engineer-in-Chief, Lloyd's Register), Captain Seuter, R.N., H. J. Cornish (Chief Ship Surveyor, Lloyd's Register), William Milburn, Douglas Owen, Dr. Paul Doorkovitz, Henry Neville Benjamin, T. A. Cook, J. Patten Barber, and others.

The toast of "His Majesty the King" was submitted by the PRESIDENT, who said: I have the honour to submit to you the toast of "His Majesty the King," the greatest statesman and the most successful peacemaker that the world has ever seen. I give you the toast of "The King." God bless him!

The toast of "Her Majesty the Queen, their Royal Highnesses the Prince and Princess of Wales, and other Members of the Royal Family," was also submitted by the PRESIDENT, who said: I now have the pleasure to submit to you the toast of "Her Majesty the Queen, their Royal Highnesses the Prince and Princess of Wales, and the other Members of the Royal Family." I am sure we all wish their Royal Highnesses the Prince and Princess of Wales a successful and pleasant voyage, and a happy return to these shores. They will have the opportunity which they have had before of seeing the work of marine engineers, and I trust that those in charge of their arrangements will ensure them every comfort in every possible way, and I am sure that they will. I give you the health of "The Queen, the Prince and Princess of Wales, and the other Members of the Royal Family."

The toast of "Our Imperial Forces" was proposed by the Hon. Mr. Justice BIGHAM. He said: The toast list to-night, I observe, is short, but that, in my opinion, is no reason why my speech on this occasion should be long, and I promise you it shall not be. I have been asked to propose the toast of "Our

Imperial Forces." Now as to the first of the three great branches of these forces there is no occasion or need to say much. In the last few days we have all been celebrating the centenary of that great hero who assured to us for a whole century the dominion of the seas, and whose great achievement one hundred years ago, I believe, has secured to us the dominion of the seas for the next century to come. As to the second branch, the Army, it is the fashion nowadays to criticise everything connected with that branch of the service severely and adversely. I am not in a position to do either the one or the other, nor do I desire to do it. I know only that the soldiers of the King know how to do their duty when they are called upon to do it. (Hear, hear.) Three years ago we terminated a war which none of us, I expect, look back upon with any great feelings of pride, but we can thank all our men, and we can say of them, "Upon that memorable scene they nothing common did nor mean." There is a third branch—not an unimportant branch—a branch, indeed, to which I once belonged —the Volunteers, and it must not be supposed that they do nothing. They have never yet had occasion to be in active service, but there is a good and a true saying that "They also serve who only stand and wait." (Hear, hear.) I propose to you "The Imperial Forces" in these few but I hope sincere words, and I couple with the toast my friend on my right, Admiral Fremantle, and my friend on my left, General Turner.

Admiral the Hon. Sir E. Fremantle, in responding, said: Sir Marcus Samuel, Mr. Justice Bigham, and gentlemen, the proposer of the toast seems to think that nothing is required to be said in regard to the service to which I have the honour to belong, and for which I am responding. There is one thing that requires to be said, which is that the whole of the Navy ought to be, and must be in future, marine engineers. It was the saying of President Roosevelt, when he was Assistant Secretary of the Admiralty of the United States, that every naval officer must be a fighting engineer, and I entirely agree with him. Our motive power, and much of our fighting power, is due now to, and entirely depends on, engineering. As the great sailor Drake said in the days when we were changing to sailing vessels from galleys and vessels propelled by oars—he said he would have all the soldiers and the gentlemen to "haul and draw with the mariners." So I feel sure it is our duty as naval officers to understand the motive power which drives our ships, and to be as much engineers as we were formerly sailors, and although, undoubtedly, we cannot aspire to make those marine engines which many of you are employed in designing, still we can understand their working. It is our duty, if we are to hold our position in the Navy, to understand how the ship is driven, and to appreciate any damage which may occur. (Hear, hear.) Gentlemen, we have been celebrating Nelson, and we are right to celebrate the great victory of Trafalgar and the death of that great man. What do we learn from him? We learn that we must have self-sacrifice and devotion, and must thoroughly understand our profession. We must make any sacrifice that may be necessary to attain that success at which he aimed. As Mahan says, the artist is greater than his materials, the warrior than his weapons. But it is not enough to look back—"to fear God and keep our powder dry," as was the saying of the Commonwealth soldier. To fear God is good—to keep our powder dry is important. I think it is no use to talk about Nelson, no use to look back, if we are not prepared to look forward as well. We must be up to date in every possible way. It is all very well to criticise the Admiralty, and there are some things in which it may be fairly criticised. But it is right to admit that the Admiralty is prepared to advance with the times—that it is a progressive Admiralty—and I think that I may fairly say that whilst the Navy is permeated with the grand traditions of Nelson it is prepared to advance—it is prepared to consider all modern appliances, and prepared to keep up its equipment. Gentlemen, our ancestors have left us an heritage which none can take away—the realm of the circling sea. We must take care that it does not slip from our nerveless fingers. What of the present state of our Navy? We are bound not to relax our efforts. We cannot admit the German claim which is boldly made of equality in sea-power with that of Great Britain. (Hear, hear.) To do so would be fatal to the Empire. I need not elaborate that subject. It is a claim raised, and one which some people are inclined to admit as reasonable. I cannot do so myself. May I mention that a few days ago a Russian gentleman, one connected with naval people, and one who was in a position to know, to a certain extent, at all events, what he was speaking about, volunteered to me that the little incident of the Dogger Bank was no accident. In his view, at all events, he said it was a deliberate intention, the view being that it was a good thing to bring on a European war. "But," he added, "you were too well prepared." Whether that is so or not, it is certain that since that time we have concentrated very much more largely our battleships in British waters. At the present moment, what between the Mediterranean, the Atlantic, and the Channel Fleets, and the ships in commission in the reserve, we have more than forty battleships. We are prepared, therefore, to meet any reasonable combination which might be formed against us. Let us see that we do not allow ourselves to fall behindhand. It is the case that we are easily first if we choose, and if we do not give way to any cosmopolitan ideas, or to any economical notions—that is to say, if we keep up that power which we have at present, that strong naval power which we possess, and to which we owe our independence and our liberties and all those institutions which we hold dear—we have only to keep up that power, and not to relax in our shipbuilding, to keep up what I believe is being kept up—that is, the efficient condition of the Navy—and we shall retain that command of the seas which was left to us as an heritage one hundred years ago. Unless we do retain that it will be impossible to preserve the British Empire. (Hear, hear.)

General Sir ALFRED TURNER also responded to the toast, and said: I am sorry to commence by informing you that whenever I am called upon to make a speech I am reminded of a remark made some years ago which has entirely destroyed my self-confidence. At a *table d'hôte* I was sitting next to an attractive American lady. She entered into conversation with me, and I thought I was getting on very well. After a little while she turned round and said, "I guess you are a British officer." I asked her why she made that surmise, and she replied, "You look so clean, and they are so stupid!" So you see you must not expect much from me. However, on occasions like the present one, when I have the anxious honour of addressing a particularly learned and scientific, and, I am sure, critical audience, I feel, when called upon to speak to the toast of the Army, at a considerable disadvantage in the presence of the following speakers, for, as a rule, they have to speak upon matters which are connected with the blessings of peace and the progress and welfare of mankind, whilst I have to talk of an institution the highest ideal of which is to prepare for and carry on a successful war—war being the greatest curse which can befall humanity, and in preference to which we are told King David selected pestilence; as Martin Luther said, "because he preferred to trust himself and his people to the tender mercies of an incensed Deity rather than to the merciless hands of man." He went on to say that "cannons and firearms are cruel and damnable measures, and I believe them to be the direct instigation of the Devil. Against the flying ball there is no safety, and the soldier is dead before he can see the means of his destruction. If Adam had seen in a vision the terrible weapons which his children were to invent he would have died of grief." I feel quite sure that most thinking men will agree with the spirit of the words of the old reformer, and I am quite certain also that they will approve of the words of Mr. Hay, the eminent Secretary of State of the United States, which words were used by Lord Lansdowne at a recent banquet. He said: "War is the most fatal and vicious of human follies, and it is high time that some other means, less cruel, less stupid, and less savage, should be invented for settling the differences between nations." I added the word "savage" myself, because I feel in this respect that we are not one whit better than primeval savages who manufactured flint-headed arrows for the destruction of neighbouring tribes. Still, wars will be so long as human nature remains as it is. And arms and armies must also be, even if they should crush the taxpayer beyond the limit of toleration. Mr. Balfour has told us that the Army problem of this country is the most difficult and complex in the world, for not only have we the defence of the United Kingdom, which we can well leave to our magnificent Navy, but we have that long line of frontier in India, which we have been told would need 500,000 men if seriously menaced by a foreign Power. That menace is no doubt a possible, but I consider it a most improbable contingency. Four hundred miles of most difficult country has to be traversed in the face of a number of semi-barbarous tribes, who resent the incursion of anyone into their fastnesses, and I think as a result of the recent events in Manchuria, and above all by our alliance with the great country of the Rising Sun, a representative of which is here to-night — (loud applause) — a country whose evolution is one of the greatest wonders that ever has been recorded in the history of the world—I think in those circumstances that that contingency is a very remote one indeed. Anyway, our military problem cannot be solved by conscription. Mr. Balfour has said this on sundry occasions, and Lord Esher has said that on all grounds, morally and politically, it would be most unwise to adopt conscription, because even if we did it would not solve the difficulties of our problem, for you cannot occupy our distant positions by means of conscript soldiers. If the forces of the great military empires are brought against you you must depend, not on the regular Army, but on the readiness of your population of this country, and of our free Colonies in joining you in your efforts to repel the corsairs. How right Mr. Balfour is was proved by the South African war. I know statistics are dry things, but I must give you a few figures. During the war we had about 550,000 officers and men in South Africa. Of this force the Regular Army furnished 424,600, whilst the Militia sent 1,691 officers and 43,875 men. The total number of Volunteers taking part in the war was 71,743. I should like to emphasise this in high quarters when it is said that the Volunteers furnished a very mean contingent to the war—a much less one than they ought to have done. Those figures are taken from the number that went out, and not from the figures which were sent to the War Office; and I think it is rather a curious thing for one Secretary of State to decline—no doubt rightly, perhaps—their services when not wanted, and then for another Secretary of State to state that they offered a very mean and insufficient contingency. That was War Office logic! One would have supposed that everything would have been done to increase the auxiliary forces. But no—the Volunteers and Militia have met with nothing but discouragement and depression ever since the war. Read what was said the other day by Lord Esher, who is a very clever man indeed. I suppose there is no civilian who knows so much of the Army as he does. He was chairman of the committee which made a sudden and forcible change in the administration at the War Office. He said that after the Regular Army had improved—which we are all very delighted to hear—the Volunteers and Militia question was at a deadlock, because Mr. Arnold-Forster had a scheme of Army reform which neither the Army Council nor his colleagues in the Cabinet would accept, even in a modified form; and, further, that while this was blocking the way any progress was impossible. That I call a most unsatisfactory, a most discreditable condition of things. And then we hear people say they blame the British public because they do not take sufficient interest in the Army. What can the British public do? They are perfectly bewildered by the everlasting schemes of reform. What you can do is to put pressure on your Parliamentary candidates to insist that instead of being treated with pinpricks, and wet-blanketing, and illegal orders, which are pronounced illegal in the House of Commons—instead of that the Volunteers should be encouraged for their great patriotic services which they gave the country for nothing. (Hear, hear.) The Lord Chief

Justice, who was long a member of this present Government, said it was the duty of the Government to encourage every sound young man to become a Volunteer, and still more so after the Edinburgh review, where the King saw 43,000 Scottish Volunteers. After praising them the King sent a message to say that he hoped the result of the review would be an incentive to others to join a force whose patriotism was so greatly to be praised. There is the King's opinion of the Volunteers, and this should act as an antidote to the wet-blanketing of which we were talking just now. The King's message was tantamount to an expression of desire that the position of the Volunteer should be acknowledged and everything possible done for this patriotic citizen army. (Hear, hear.)

The toast of "The Institute of Marine Engineers" was given by Sir W. H. WHITE, K.C.B., LL.D., F.R.S. He said: Mr. President and gentlemen, at the desire of the committee which has arranged this dinner I have great pleasure in proposing for your acceptance the toast of "The Institute of Marine Engineers." The Institute, as you all know, is now approaching the age which in girlhood is known as "sweet seventeen." I think it may be said that those who were its parents are quite satisfied with its progress. Parents are apt to be partial. I daresay most of us are parents, and we endorse that sentiment; but making allowance for parental pride, and taking the facts simply into account, we will all agree that those who conceived the original scheme for the foundation of this Institute, and who worked at its organisation—many of whom we have the pleasure of seeing here to-night—must feel unmixed pleasure when they look back over these seventeen years and think what has been the result of the modest circular that was issued in November, 1888. Here we have one of the youngest engineering institutions in the country which has grown to a membership of about 1,000, and has maintained that level, with some fluctuations, for several years. Personally I am disposed to think the membership ought to be larger. When one remembers what the number must be of marine engineers actively engaged in this country ashore and afloat, I do not consider that 1,000 should be looked upon as the maximum number by the members of this Institute. (Hear, hear.) In saying that I am only echoing the feelings of those who founded and have watched over its growth hitherto. Of course, in the history of every institute there must be fluctuations. We none of us have lives that are unmixed with sadness and disappointment, and the history of any institution is the same as the history of individuals. To-day I have been reading the last issued report, and I see that there are some features in it which are to be regretted because hopes have not been absolutely fulfilled nor expectations realised. But that is no ground for discouragement. If we were to lie down, and take it lying down, every time we met with difficulties in professional work we should not go far. Marine engineers are accustomed to encounter difficulties, and those temporary difficulties which have arisen in this Institute, and to which I need not allude further, should only nerve the arms and strengthen the courage of those who have done so much in its development, and make them determined to go on to still greater success. Gentlemen, when I had the honour of being President of this Institute, some eleven years ago, it was in its infancy. I well remember the occasion of the annual dinner during my presidential year. I well remember the infliction that I bestowed upon you, for at that time it was held to be the rule of this Institute that the President should deliver his annual address in the middle of the dinner. Talk of General Turner's apology for a long speech! Why on that occasion I fear I occupied about twenty-five minutes of my discourse with a matter which you could occupy twenty-five years in talking about, namely, the influence of the "human element" in marine engineering. That was the fundamental idea of my address, and I tried to impress on you all, as men charged with the management of marine engines, that your behaviour, skill, and ability and devotion had more to do with the success of the great mercantile marine of this country than all the skill of all the theorists that ever breathed. The older I get the more convinced I am of that fact. I am no despiser of scientific advance; yet still the human element must be cultivated, and every man in a profession must do his best, if the best which is possible is to be realised for the country's service to which we belong. Eleven years ago I told you some stories based on personal experience, showing the great influence on results of skill and care in the management of marine engines. Now I will tell you a story illustrating what may happen in practice. Some time ago a learned body of engineers went out on a trial trip which was to determine the relative economy of coal consumption in a particular type of boiler as compared with another type. The stokers were instructed to do their best. Coal which was supposed to be ample for the run was weighed and put on the stokehold plates, so as to determine what was used. One stoker present was told that the coal near his furnace would probably be used but was not to be exceeded. When they went to look for him he had disappeared at a very early stage of the proceedings. On seeking for him they found him in bed. Looking into the furnace, they found it choked with coal. He had put it all in and then retired. That was intended to be a scientific experiment, but the human element sadly interfered with the result. I do not think that is representative of marine engineering practice or of stokers in general, but that greater skill and discipline on the part of stokers is desirable in the British mercantile marine there can be no doubt. A leading German engineer not long ago informed me that he considered the superior qualities and stricter discipline of German stokers to be worth at least 10 per cent. increase in power developed on an Atlantic liner. He was familiar with British practice, and from other facts that have come to my knowledge I am inclined to agree with his estimate. Men as well as officers of the engineering department must be trained higher under modern conditions. Advantages which might be obtained are thrown away when there is lack of discipline and lack of control of men employed in such important work. This is an example of what this Institute was intended to do and has done. The objects of the Institute were set out in this way: "To promote the science and practice of marine engineering in all its branches, to enable marine engineers to meet and correspond, and to facilitate the interchange of ideas, and to interest itself in the study of marine engineering." It is impossible to over-estimate what this Institute has done during its existence in fulfilling those objects. I have been speaking with my friend, who remembers the early dinners of this Institute, and the difference in these gatherings now as compared to what they were at the start is enormous, and indicates a real advance. Then there is the work that has been done at Romford Road. We all know what that has been on the educational side—how young men have been interested in the scientific side of their work! They have learned more than they would ever have known any other way, for by the interchange of ideas much benefit has been secured. Gentlemen, go on with this good work! Try to make the mark and weight of the Institute felt more and more throughout the whole of the great British mercantile marine of which we are so proud. The maintenance of its supremacy depends in no small measure on the members of this Institute; and I would say in conclusion that I congratulate those who founded the Institute—

amongst whom I am proud to mention the Honorary Secretary, Mr. James Adamson—(hear, hear)—its first President, who sits facing me, and Mr. Manuel, who has emerged from his retirement and his agricultural operations to look once more on his friends of the Institute of Marine Engineers. This country, and the world, has reason to be grateful to those who bestowed time, effort, and untiring pains in developing this Institute. There is one feature which is singular—at least, I think it is; that is, the "expectation of life" of Past-Presidents of this Institute. I have been looking through the list to-night. There have been sixteen Presidents besides myself. In that list there are names famous in many ways. The name of Lord Kelvin is one to conjure with anywhere, not merely in the world of science, but in engineering. Then, if you come to shipowners, you have names like Sir Thomas Sutherland, the late Sir Edwyn Dawes, and Sir James Mackay — who is here to-night. (Hear, hear.) Amongst the names of practising engineers and shipbuilders there is our revered friend Peter Denny, who, after long labour, has gone to his rest. We have Sir John Durston, Sir Fortescue Flannery, and Dr. Inglis and Mr. Dunlop — both of whom are here to-night. So that the list of your Past-Presidents is an excellent one. But the expectation of life is the great thing which strikes one. Of the sixteen Past-Presidents there are only two who are dead, and of the fourteen survivors no less than nine are here to-night—and, I have no doubt, have eaten a good dinner. The immediate Past-President, the Hon. C. A. Parsons, is unfortunately absent, and his name fitly ends the list. The fact that you have been served by such men as these has done much, in my opinion, to establish and raise the status of this association. I have no doubt the success which has been achieved in the past will be continued and extended in the future; and in joining your name, Sir Marcus, with this toast may I say, without anticipating what will be said later, that we who have an interest in this Institute are delighted to find you occupying that chair, and I am sure you will be a worthy successor in every way to the men who have gone before you. (Loud applause.)

The President, responding, said: Sir William White and gentlemen, I hardly know whom to congratulate the most upon the changes wrought by time. I should certainly have felt very sorry for myself and regretful for you had I been compelled to deliver, and you to hear, an annual address to-night. I think on the whole I must have been fortunate in having been born somewhere at the end of the nineteenth century, because when I was elected an alderman of the City of London my sponsor called attention to the fact that at one time when the state of affairs was extremely turbulent in civic circles the Lord Chancellor of that day had said to the king that they would never have any change until they had hanged one or two aldermen. I am sure you will all be pleased to hear that this danger never threatened me. Alluding to what you have said of the Past-Presidents, I am sure I have fulfilled the wish of all of you here to-night in sending in your name a telegram of congratulation to Sir John Durston, whose birthday it is. Had it not been for that pleasing fact, and the desire that he felt, naturally, to spend the evening in the midst of his family, he desired me strongly to say that he would have been with us this evening. I suppose you will expect me to give you a few details of this society. Again I think our positions might have been reversed, for Sir William White is far more competent to speak of the past of this Institute than I am, although I think I can assure you I feel it a great honour to be your President, and, so far as I can further the interests of this most excellent institution, it will always afford me the greatest pleasure possible to do so. The need for it became very manifest in the year 1888. There were great changes then hanging over the marine world—changes which have since become consummated facts. But it is one of the most charming attributes of marine engineering that there is no finality at all. As in 1888 we were confronted with the preparation which had to be made for the introduction of steam at a much higher pressure than had prevailed before, so we see to-day in the development of the turbine that progress is still rampant; and I trust that that will be continued for many ages to come, and that marine engineers will never be satisfied to rest upon their laurels, but aim always at going forward. The enormous number of auxiliary engines that now have to be attended to by the marine engineer makes itself a claim upon their skill and ability which certainly, from my own experience as a shipowner, I can say is always willingly and readily met—such claims as were undreamed of but a very few years ago. As a single instance I give you the extensions which have taken place and the improvements in electric lighting and power. You will know as well as I do that in this there is scope for the energy and brains of the many able men who I know are here to-night. It is certainly a desirable thing that the work initiated by your Honorary Secretary, Mr. James Adamson, in 1888 should continue and meet the success which it has constantly found, because from the small gathering which was held in 1889 the Institute was inaugurated by renting premises and reading-rooms, and soon after the first paper was read the certificate of incorporation was granted. That was in July, 1889. The first annual meeting was held in 1890, when the number of members was 253 and the number of papers read 11. The first published volume was in 1890, and the balance-sheet showed a receipt of £499 10s. and an expenditure of £302 18s. It is very significant and satisfactory to find that £44 was collected for a library, then in course of formation, by the engineers of the British India Company. If I may venture a word of advice, it would certainly be to continue to add to that library, because although I agree with what Sir William White has said, that an ounce of practical work is worth tons of theory, yet there is knowledge to be gained from books which every man going through life finds at some time or other he can utilise with the greatest advantage. So I hope that library may grow to very large dimensions indeed. Well, the society continued to increase, and freehold premises were purchased and furnished, and you removed from hired premises into your own in 1892. Those were enlarged and improved in 1893; then a lawn for tennis was made at the rear of the premises, and a club started; and in 1899 a workshop and facilities for fuel-testing were instituted. I believe that great practical good has arisen from those experiments. There is undoubtedly a great deal to be said for the work of men as compared with mere mechanical effort, and in order that men may be directed it is absolutely necessary that their chief should understand the technique of stoking, or, as one day may be the case, the method of burning liquid fuel, and I am glad to say that experiments in that direction have also been conducted. The sixteenth annual report was issued in 1905, and although Sir William White has told you that the progress of this Institute, seeing the very large number of men who are engaged in your profession, is not all that it might be, yet, perhaps, comparing the figures that you had when you started, you will find it wholly satisfactory to hear that your active membership roll has increased to 928. Five papers have been read and three lectures delivered, whilst your financial position is one of which your friends may congratuate you, for the receipts amounted to £1,288, and the expenditure was £1,083, giving a balance of £205 at January 31st, 1905, and you are in possession of premises and stock valued at over £3,000. Further progress has been made since January, for fifty-three new members have been elected, four papers read, and two lectures delivered. Further experimental work has materially increased, and I am sure you will be pleased to hear that the attendance at all the meetings has shown a great increase over previous years. Four summer visits—in June, July, August, and September—were also paid to works. It is intended, when funds permit, to erect a hall, or extended room, which is much required for specimens and unique samples and curios sent by members from all parts of the world. From my knowledge of sailors I should think that might be a most interesting museum. I remember a story that you may also have heard of a sailor-boy who came home to his mother, and he told her that as they went through the Red Sea the ship stopped, and the anchor brought up a wheel of one of Pharaoh's chariots—and if this museum had existed no doubt that wheel would have found a place therein. The youth went on to observe that a flying-fish jumped on board the ship. His mother reproached him, saying, "You ought to be ashamed of yourself for trying to take your mother in like that. I believe the chariot wheel, but not a word of that flying-fish." (Laughter.) If you institute that museum you may expect to find some interesting specimens in it. I can only hope that the means may be forthcoming, and that your membership may increase, and that you may continue to find in the future Presidents who are both able and willing to assist; and whilst I claim the latter attribute I regret I do not possess the former, but so far as I possibly can I shall watch the progress of this Institute always with pride and pleasure, and with the utmost sincerity I have every wish for its progress and success. (Loud cheers.)

Mr. W. C. Roberts (Chairman of Council) gave the toast of "Our Guests." He said: Mr. President and gentlemen, I am entrusted with a most important toast to propose—that of "Our Guests." Important, I may say, on account of the large number of distinguished gentlemen we have to grace our table to-night. You will see from the table plan that nine of our Past-Presidents are with us, and we are always delighted to see them, as by their presence they show the interest they take in the Institute, and encourage us still to make further progress. We have also Admiral Fremantle and General

Turner, whom you have just heard speak. We have also other gentlemen occupying high offices for the good of this and other countries; and last, but not least by any means, we have, for the first time in the history of the Institute, two of His Majesty's judges, and with their presence we consider ourselves highly honoured. Without saying more to commend this toast for your acceptance, I give you "Our Guests," and couple it with the names of Mr. Justice Walton and Captain Kaburaki, Naval Attaché to the Japanese Navy.

Mr. Justice WALTON, in responding, said: Gentlemen, I have much honour and much pleasure in responding on behalf of such a distinguished body as your guests of this evening to the toast which has been so kindly proposed and so kindly received by all of you. I am glad to express our appreciation of and our gratitude for the generous hospitality and kindly welcome which we have received here this evening. At this time of the night I am not quite sure that I ought to say very much, especially when I am to be followed by the gentleman with whom I am proud to be associated in acknowledging this toast, Captain Kaburaki. However, looking through the list of your guests for this evening, it has occurred to me that we are a somewhat representative body. I may say that we, in a sense, represent the public in its relations to your great profession; and speaking, if I may, in that capacity, perhaps I may add just one word more. I should like to dwell for one moment upon all that this country—that England, Great Britain, the United Kingdom—owes to the great profession of engineering, of which you represent, perhaps, the most important department. And to express what I have in my mind I have to go back for a moment—although I know people in these days are a little intolerant of it—to ancient history. I would ask you to look back, not such a very long way, but—well, to look back a good many years, some generations, to what this country was—England, Scotland, and Ireland—in the latter part of the eighteenth century. Just to take a period, take the reign of George III.—who, after all, was not a very ancient person. What was this country when George III. came to the throne? What were our industries? What were our means of communication? What was Glasgow? What was Liverpool? What was Manchester? What was Leeds? What was Birmingham? Now take a jump in your recollections to the end of that period which I have taken, which is measured by the reign of King George, which brings us down to the twentieth year of the last century—1820. What is the change? We pass from a state of things which it is scarcely an exaggeration to say was mediæval; we pass suddenly into modern times—into modern England, modern Scotland, modern Ireland. We find all our great industries in their full vigour in those centres, which they have converted into places of great importance. What a change—what a contrast! Now if one asks, What was that due to?—I have been thinking whether I am right, and I cannot find that I am wrong if one asks one's self what that was due to—is it not a true answer, to the wonderful achievements of the engineers? What else had happened? That was a period during which we lost our American colonies, during which we were passing through disastrous wars in America and France, which only came to an end very shortly before the termination of the period which I have referred to. It was the period during which the country was exhausted almost beyond its resources. At the commencement of that period we had those natural resources—indeed, more of those natural resources than we have now—our coal and our iron. We had a population which was ready to produce the most competent and ablest artisans in the world. What was it made the change? There came in 1769, if I am right, the invention of the steam engine by Watt. That was followed by mechanical inventions which created the industry of the northern part of this island. The inventions of Arkwright and others created our manufacturing industries. And they were followed within a year or two, at the beginning of the last century, by Miller and Symington, who launched the first steam vessel, and, just before the battle of Waterloo, by Stephenson running the first practical locomotive. What does all that indicate? It seems to me to indicate this—that, so far as the extraordinary growth and development and increase of the wealth of this country which took place in the earlier years of last century is concerned, it is attributable specifically and more really than to any other cause, as I have said, to the wonderful achievements made during those forty or fifty years by the engineers of those days. Therefore I am glad on this occasion, not merely for myself and fellow-guests, to express our personal obligation for the way you have entertained us this evening, but also to express on behalf of the general public of this country the great obligation it owes to your great profession. What you have done you are still doing, and will continue to do. What we have owed to you in the past we shall owe to you in the future—and not only we, but they who will come after. Let me thank you for the kind way in which you have received us to-night, and for the toast which has been so kindly proposed, and which you have so kindly received. (Loud applause.)

Captain Makoto Kaburaki also responded, and said: First of all I am afraid I cannot express what I desire to say, owing to my imperfect knowledge of English. I have been also invited to respond, but it was only last evening that I received this invitation to respond to this toast, and I have had no time to prepare for it, and I have also been somewhat unwell since this morning. However, I will try to make you understand what I have to say. I feel it a great honour and a great pleasure that I am here as representing the Japanese Navy —(hear, hear)—and to be received in such a cordial manner, especially on the centenary of the great Trafalgar victory. That is one of the greatest achievements of the British Navy, and was carried out by one of Britain's most glorious heroes—Lord Nelson. (Cheers.) It is strange that on this centenary year of Trafalgar the two nations, Great Britain and Japan —the Far West and the Far East—have been allied. Do you know that the Japanese Navy owes very much to your Navy, and to marine engineers in particular? And the renewed alliance which was published some time ago may secure the permanent peace of the Far East—rather, I wish to say, of the world. (Cheers.) I wish to conclude my speech by thanking you very heartily for your past kindness and present sympathy towards my country. I dearly hope the relationship between our two nations will be stronger than ever. As you know, Japan is a very small country, and I must ask your great help to make our navy to improve. Here is my old friend and teacher, Mr. W. J. Harding, who taught me trigonometry, English, and everything else when I was a youngster in Japan. I feel so much indebted to you for your services to Japan, and I thank Mr. Harding, for our nations both have reason to be proud of each other. I thank you for the cordial manner in which you received this toast, and I hope the prosperity of the marine engineers of Great Britain will ever continue. (Loud applause.)

Sir J. Fortescue Flannery, in giving the toast of "The President," said: Gentlemen, most of the previous speakers have referred to the extraordinary and unprecedented success of this Institute, and I venture to claim that no feature of our constitution has contributed more to our success than the long line, comparatively, of distinguished Presidents who have guided the deliberations of the Institute from year to year. Sir William White has referred to Lord Kelvin, one of the most remarkable discoverers that the world has ever seen ; and whether it be in the domain of pure science, such as his, or of applied engineering, such as that of the Hon. C. A. Parsons, or of shipbuilding, such as that of Dr. Peter Denny, or of mercantile shipping, such as that of Sir Thomas Sutherland—in all these walks and departments we have had the very best possible men. And I re-echo what Sir William White has said, that in our Presidents, good and great as they are, we have a worthy successor in our present President, Sir Marcus Samuel. I suppose I have been selected to propose this toast by the committee presided over by that never-failing member of our Institute and Chairman of the Committee, Mr. W. I. Taylor, whose services in connection with this dinner are beyond all praise.—I suppose I have been selected to propose this toast because for so many years I have had the advantage of intimate association with our President. Well, gentlemen, it is not necessary for anyone to bear testimony to his merits. He has had a distinguished career as Lord Mayor and in other walks of life, and for tact, ability, probity, and success he is able to rank with any one of the merchant princes of Great Britain. Let us ever remember that the work of the marine engineer must be initiated by the enterprise of the shipowner. (Hear, hear.) Without that we should have no work to do. When I recall the commencement of my acquaintance with Sir Marcus Samuel I remember that he has laid the foundation of a great improvement which will extend, I believe, as the work goes on, and may create a revolution in the work of the marine engineer. I refer to the use of liquid fuel. But for the initiation and capability and enterprise of shipowners, led by our President, we should not have opportunities such as we have had. Sir John Durston, whose name has been mentioned, has written a letter, which I will venture to read to you :

"Dear Mr. Taylor,—I regret that a previous engagement prevents my accepting the kind invitation of the President. I beg to take this opportunity of congratulating the Institute on its new President, who has so untiringly engaged on the revolution in fuel for marine boilers, and who is following so closely on the Hon. C. A. Parsons, who is revolutionising the marine engine. Thus the Institute is marching in the forefront of progress; and long may it continue its successful career.—Yours faithfully, (Signed) "A. J. DURSTON."

Gentlemen, this is the largest dinner in the history of the Institute—the largest in attendance, and certainly not inferior in its representative character to any dinner of the Institute which I remember. This is largely due to the popularity of our President, as well as to the progress of the Institute, and I give you his health with the utmost confidence that you will give him the best possible reception for the promise he has made—a promise which I know will be fulfilled—that every interest of the Institute will have his care, and that he will do his best for us in promoting its prosperity. (Cheers.)

The PRESIDENT, in acknowledging the toast, said: Gentlemen, I have to thank Sir Fortescue Flannery for the extremely kind terms—the all too flattering terms—in which he has proposed my health, and I should be very ungrateful if I did not endorse what he has said as to the great assistance which has been rendered me—in fact, the whole work of this dinner has been done by Mr. Taylor, Mr. Adamson, and Sir Fortescue. I join my thanks to yours for their having secured what I hope has been a pleasant evening and a most excellent dinner. It is somewhat hard upon those who have worked so much for this Institute and for kindred institutions that custom has ordained that a figure-head be selected on occasions such as this, but when the request was preferred to me to become your President I can only assure you that I felt it much too high an honour to decline, and the year in which I have fulfilled the office will also be remembered by me. It appears that virtue —if, indeed, this be virtue—is to have its own reward, for Sir William White has told you that great longevity is the fate of those who occupy the headship of your Institute. I shall consider all the members most excellent engineers if they can manage to obtain this result for me. I hope that your society will continue on its prosperous career, and I thank you most sincerely for the way in which you have received the toast of my health.

"AULD LANG SYNE."

The following Past-Presidents were present: A. Beldam, G. W. Manuel, Sir W. H. White, Sir J. F. Flannery, John Inglis, LL.D., Sir Jas. E. Mackay, D. J. Dunlop, Sir J. Gunn. Col. J. M. Denny was unable to remain, having to leave for Scotland by night train.