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

SOME EXPERIENCES WITH CO_2 CYLINDERS.

BY

MR. R. MACKENZIE (ASSOC. MEMBER).

READ AT

58 ROMFORD ROAD, STRATFORD,

ON

MONDAY, DECEMBER 11th, 1905.

CHAIRMAN:

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

IN 1896 a report was issued by the Government embodying the recommendations of a committee appointed by them to investigate the conditions under which the trade in compressed and liquefied gases was conducted. The report dealt more especially with gas cylinders. It prescribed a definite quality and thickness of metal to be employed in the construction, as well as other conditions with regard to annealing, testing, and filling, which the trade were strongly recommended to adopt. These recommendations, no doubt, have been fairly well adopted, both by the manufacturers of cylinders and firms engaged in the manufacture and compression of carbonic acid gas, when we consider the number of accidents with CO_2 cylinders, which have fortunately been few, comparatively speaking, and when we consider the enormous amount of cylinders used in conveying compressed gases all over the world. It has occurred to me that there is yet left a large field for improvement for the enforcing of the regulations relating to the CO_2 cylinder, and that the time has arrived when the Government might be well advised to pass a Bill enforcing conditions which, in my opinion, would place the CO_2 trade on a safer footing than it is at the present time. While a CO_2 cylinder may be in a thoroughly safe condition when it leaves the maker's hands, or the hands of the firm which has filled the cylinder, there is no doubt left in my mind as to the serious bad usage CO_2 cylinders are subjected to when being transported from one place to another, also at the hands of persons who do not fully realise the danger there is in the careless handling of cylinders. I could quote many instances of careless handling, but for the purposes of this paper I shall give one, which has been quite recently brought to my notice. An engineer was moving a heavy piece of machinery, and he could not find any suitable rollers, so as a few CO_2 cylinders were close by he used them as rollers. What the result of that might have been I am not prepared to say; but take, for instance, that these cylinders had been sent out for the first time after having been annealed and tested. In all probability these cylinders were damaged by the rough usage. They are refilled and sent out again, and probably they burst. An inquiry would be held into the cause. The cylinder, most likely, would be proved the proper thickness, annealed and tested as per regulations laid down. The cause of the accident is not there, and in all probability it would be laid down to the cylinder having been overcharged with CO_2, when the real cause was through the engineer's carelessness in using that cylinder as a roller. What I wish to point out by this is how difficult it would be to ascribe the true cause of such an accident if one were in ignorance of the usage that the cylinders had been subjected to. Let us look now at the dangers in overcharging cylinders with CO_2. Take, for instance, a cylinder constructed to carry 28 lb. of CO_2—that is, in this country. The general rule is to put in $\frac{3}{4}$ lb. of CO_2 for every 1 lb. of water capacity, which is considered a safe margin for the expansion of the gas due to different temperatures in this country; but if that amount of CO_2 is charged into a cylinder the same size and has to pass through the tropics it is hard to say what the result would be when we take into consideration that in a cylinder charged with 28 lb. of CO_2 at a temperature of 65° F. the pressure will rise in the cylinder about 1,000 lb. more at a temperature of 100° F. The regulations generally adopted specify 20 lb. of CO_2 for cylinders passing through the tropics—that is, 20 lb. into a cylinder that can safely carry 28 lb. in this country; but the danger of having cylinders overcharged is still left if the regulations are not carried out.

Now let me direct your attention to cylinder No. 1 as a sample. This cylinder is a $5\frac{1}{2}$-in. model. It has expanded half an inch in diameter above its original size at an internal hydraulic pressure of 4,470 lb., when it burst, with the result you see. In this case the thickness of metal is supposed to be $\frac{1}{4}$ in., but you will observe, on close inspection, that the metal is of thin section, only being $\frac{3}{16}$ in. thick at the part it has burst open. The bursting of this cylinder at that pressure is due to thin section metal; but I shall deal with that point at a later stage.

Looking at the difference between cylinder No. 1 and 2, this cylinder, No. 2, is also a $5\frac{1}{2}$-in. model. It has expanded $\frac{3}{8}$ in. in diameter above its original size at an internal hydraulic pressure of 6,000 lb. per square inch. In this case the cylinder is of the same thickness of metal as No. 1, yet this cylinder has not burst with 1,530 lb. more pressure, and it has expanded $\frac{1}{8}$ in. less in diameter. The only reason I can assign that both cylinders have not expanded the same is that the cylinders were made at different times and the ingredients for the steel have not been mixed in the same proportion, or the cylinder may not have been properly annealed before it left the maker's hands. The latter view I am inclined to take, because in callipering the cylinder minutely you will find that there are ribs in this cylinder; in some places the metal has expanded $\frac{1}{32}$ in. more than in others, which clearly shows that the metal is harder at different parts of the cylinder.

Cylinder No. 3 shows a cylinder which was in use before the Government inquiry of 1896. Prior to that date cylinders were made of $\frac{3}{16}$-in. steel, but the steel was of a much harder quality. This cylinder burst with an internal hydraulic pressure of 4,000 lb. per square inch. The danger of having the walls of a cylinder of a thin section and brittle material is here clearly shown—that if the cylinder had burst when charged with CO_2 the results would have been disastrous, no doubt, because the fragments would have spread in every direction. The testing of CO_2 cylinders is a point which has to be very carefully and closely watched when under pressure. One can tell fairly well if a cylinder is sound by pumping it up to a pressure of, say, 2,000 lb. per square inch, and then subjecting it to a hammer test; but I do not think this is a sure test. Personally, I would not condemn a cylinder on the hammer test, because, in the case of a cylinder having a ring shrunk on the bottom, a false sound is produced if the shrunk ring is not perfectly tight on the cylinder. There is a very simple way of testing cylinders which is absolutely safe and accurate. That is, the cylinder to be tested is placed in a vessel which forms a water-jacket. To this vessel a pipe with a glass tube is connected, after the cylinder has been filled with water, and connected to the pipe leading from the testing-pump by a union which is inside the vessel forming the water-jacket. A cover is screwed on to the top of the vessel. The level of the water in the jacket is shown in the glass tube—that is, before any pressure has been put on to the cylinder. The water-level in the vessel having been ascertained, a pointer is fixed at that level. Internal pressure is then put on the cylinder by means of a hydraulic pump, and with each stroke of the pump one can see the water rising in the glass tube—that is, the water in the jacket being forced up the glass tube, caused by the expansion of the cylinder. When the internal pressure on the cylinder reaches to 3,750 lb. per square inch the pump is stopped, and the displacement of water in the glass tube is measured from the pointer to the level the water reaches with 3,750 lb. pressure on cylinder. That gives the elastic expansion of the cylinder. Small permanent sets generally take place in this test, but if the water column in the glass tube does not return when the pressure is taken off to within 5 per cent. of the elastic expansion that cylinder is thrown out of service as dangerous. But opinions differ somewhat on this point. Some firms say if the water column returns to within 10 per cent. of the elastic expansion the cylinder could be passed; others say 15 per cent. is quite safe if the cylinder were reannealed. Personally, to be on the safe side, I would condemn every cylinder if the water column did not return to exactly the point where it started from, because I believe that if once the cylinder is strained it ought not to be reannealed to give back the elasticity which has been taken from it by being overstrained. Of course, I would make the test pressure lower to meet this. In fact, I would discontinue the practice entirely of reannealing cylinders, for this reason, that cylinders are transported all over the world, and by that means they are subjected to various temperatures and very often overheated. To make the point more clear, take a CO_2 cylinder which has been overcharged with liquid carbonic acid, and at the same time it has been overheated. The pressure may have risen almost to bursting point. I believe that if that cylinder were reannealed it would pass the stretch test without being detected, because the testing pressure would be very much less than the pressure that was put on that cylinder by the pressure when overheated. What proof have we, then, that that cylinder will not burst if a pressure of, say, 4,000 lb. is put on it again by being overheated, if it is not retested? On the other hand, if that same cylinder had not been reannealed, but tested only, it would at once show it had been overstrained, because when it was put under pressure again, although not so high a pressure, it would stretch further permanently, which would at once show by the water column not returning to its former position. On that account the cylinder should be discarded; but if it were annealed it would pass the stretch test, and by that means a damaged cylinder might be put in circulation.

The committee of 1896 recommended $\frac{5}{16}$ in. as the thickness of the walls of cylinders used for carrying liquid carbonic acid. Some firms accept that as the standard for safety; others say $\frac{1}{4}$ in. is quite safe, and they adopt $\frac{1}{4}$ in. as their standard. It is here that a great danger lies, as it is to the firm's benefit to have as light a cylinder as possible, and I think that firms may be tempted to have a light cylinder, which means it will be a brittle cylinder, otherwise it would not pass the stretch test; so on that account a standard thickness ought to be enforced.

The committee recommended that cylinders should be reannealed every four years and tested every two years. That rule is certainly not enforced by a few gas-compressing firms; and the firms who do enforce it lose their trade, simply because the firm requiring their cylinders filled can send them elsewhere and have them filled without having the extra cost of testing to pay for. Of course, a firm which cares for its reputation can well afford to lose a customer who has no regard for the public safety. But, as I said previously, I would not insist on reannealing cylinders, but I would favour compulsory testing once every two years. Another point I wish to draw your attention to is the regulations enforced by railway companies that all cylinders shall be enclosed in wooden cases or other suitable packing. I believe the railway companies are further adding to the dangers, because the pressure is internal, and if a cylinder did burst it would simply blow the case to pieces, and there would be more fragments flying about than if it had not been enclosed in a case. If the railway companies would dispense with the regulations in regard to cases, and specify metal of a certain thickness and quality, then I believe we would have perfect precautions in regard to safety. Not only that; the compressing firms could then afford to put a better quality of metal in their cylinders with the capital spent on providing cases and the continual outlay in keeping cases in repair. Further, it would be more to the benefit of everyone concerned to have a good cylinder carried without a cover than a bad cylinder enclosed in a case.

In conclusion, I believe the question of safety could be easily met if the Government would pass a Bill enforcing:

1. A standard thickness of metal—say $\frac{5}{16}$ in.
2. A standard quality of steel to be used.
3. A maximum amount of CO_2 to be charged into cylinders of different sizes for use in this country—say $\frac{3}{4}$ lb. CO_2 for every 1 lb. water capacity.
4. A maximum amount of CO_2 to be charged into cylinders of different sizes passing through the tropics.
5. That all cylinders shall be tested once every two years to a pressure of 2,500 lb., and if permanent stretch is shown at that pressure they shall be condemned for use with CO_2.
6. That all condemned cylinders shall be stamped by the inspector, so that if these cylinders should reach the gas-compressing firms they shall be readily detected.
7. All cylinders, when being made, to be under Government supervision, and to be annealed and tested to 3,700 lb. pressure per square inch, and, if any permanent stretch is shown, to be condemned.
8. All compressing firms and firms testing cylinders to be under the same regulations, and that each firm shall have a private testing mark, and that all condemned cylinders be clearly stamped "Condemned" upon the neck of the cylinder.

DISCUSSION

AT

58 ROMFORD ROAD, STRATFORD, E.,

ON

MONDAY, DECEMBER 11th, 1905.

CHAIRMAN:

MR. W. C. ROBERTS (CHAIRMAN OF COUNCIL).

MR. W. LAWRIE (Member of Council) said that as he had had no experience with CO_2 cylinders he was hardly in a position to say much. But what appealed to him was the decided want of system altogether. Although a Government committee had made certain recommendations, which appeared to be rather inadequate, it seemed to him that there was no power for carrying those recommendations into effect. So far as he could gather from reading the paper, the makers were very much in the position of studying their own requirements. In the last paragraph but one the author had suggested that the cylinders should be made under Government supervision. Well, when they saw cylinders such as those which Mr. Mackenzie had brought down for their inspection—cylinders that might be liable to explode at any time or burst, and possibly cause loss of life—it seemed to him that the time had quite arrived when their construction ought to be under some Government supervision. He understood that foreign firms were sending cylinders into this country which hardly came up to the British standard. That, he thought, was a question in which the Government ought to make a move in one way or another. It seemed a remarkable thing that the Government, dealing with such a matter, should not put it ship-shape, so that they could have some standard rule to rely upon. They were very smart in some things, and he thought this was a matter where they ought to study the interests of the people and put the matter on something like a systematic basis, so that there should be a standard for those cylinders to meet all possible requirements. From the examples before them it was evident that there was no guarantee in the quality of the metal used. It looked so to him, and those members who knew something about it would be able to further enlighten them, and then the author would, no doubt, be able to help them when replying to the questions raised.

Mr. D. S. LEE, R.N.R. (Member) said he could endorse Mr. Lawrie's remarks that a Government inspector ought to see those cylinders, and see that a proper quality of metal was put in. He also thought the cylinders should be made to a standard size. The specimens before them were all of different sizes. He did not know whether they were regulated to standard sizes at the present time—say $5\frac{1}{2}$ in. in diameter. He would also like to know the temperature during the annealing process that the cylinder was subjected to. Also, was a gas flame or coke fire used? Were cylinders always tested after being annealed? Mr. Mackenzie had referred to the water capacity of the cylinders and $\frac{3}{4}$ lb. of CO_2 equalling 1 lb. of water. How was the water got out again and the cylinder perfectly dried? If those cylinders were exported containing gas, and were not perfectly dry, they knew the dampness was likely to cause freezing in the coils of the machine. An important question was as to the temperature of CO_2 at its greatest density. In the second part of his paper Mr. Mackenzie said: "What proof have we, then, that that cylinder will not burst if a pressure, say, of 4,000 lb. is put on it again by being overheated, if it is not retested?" If a 4,000 lb. pressure had been put on the cylinder once, would the author say that it ought to be tested so as to render it safe in the future? Mr. Mackenzie also went on to say: "On the other hand, if that same cylinder had not been reannealed, but tested only, it would at once show it had been overstrained, because when it was put under pressure again, although not so high a pressure, it would stretch further permanently." He thought that was a very debatable point, because if it had been strained once, and had attained its maximum limit of stress, he did not see that it was going to show any further expansion until it actually burst, it did not matter what pressure they put on it; for instance, if they got a certain stretch on a piece of iron, and took that as the maximum, it would not stretch again, although they tested with the same instrument. Another question he would like to ask was, Why was it a benefit to have light instead of heavy cylinders? He would say that when light cylinders were used they would be able to put in more gas, and as the weight of the cylinder was taken as the measure of the quantity of gas put in, that firm would be putting more gas into the cylinders than they should. Then, in regard to the packing of cylinders in cases, he had seen cylinders that had rope lagging around them instead of a wooden case, and the rope lagging had struck him as a very good medium for preventing pieces of iron from flying about should the cylinder burst. It was impossible to cut through the rope if it were of sufficient thickness. He thought that would be a very good plan instead of having the cylinders packed in wooden cases.

Mr. BERTRAM (Hon. Minute Secretary) said he had had no experience with CO_2 cylinders, and Mr. Lee had touched upon most of the points. He was of opinion that there ought to be some Government supervision, and he thought that they as an Institute ought to bring the matter before some of the Members of Parliament.

Mr. W. E. FARENDEN (Assoc. Member) said the author had referred to the danger of careless handling of CO_2 cylinders, and had quoted a recent case. He would like if Mr. Mackenzie would read the Government regulations, so as to let them know the method of annealing, and also in regard to the thicknesses and testing of those cylinders in which CO_2 passed through this country and also through the tropics. Did the same regulations hold good? Mr. Mackenzie had also referred to the danger of overcharging CO_2 cylinders, and had said that for every 1 lb. of water they put in $\frac{3}{4}$ lb. of CO_2, so as to give a safe margin for the expansion of the gas due to the different temperatures of this country; and Mr. Mackenzie then went on to say: "But if that amount of CO_2 is charged into a cylinder the same size and has to pass through the tropics it is hard to say what the result would be when we take into consideration that in a cylinder charged with 28 lb. of CO_2 at a temperature of 65° F. the pressure will rise in the cylinder about 1,000 lb. more at a temperature of 100° F." Would Mr. Mackenzie give them a table showing the rise in pressures due to the increase of temperature for cylinders that had to pass through the tropics, starting at 60° and rising by 10° up to 150°, and the corresponding pressures from those increasing temperatures? The author had given an example of an increase of 1,000 lb. due to a rise of only 35° in temperature. He understood that all those cylinders were fitted with a patent safety valve, but the author had not referred to that in his paper. Those safety valves were fitted to take off any great accumulation of pressure, and he would like to know what was the factor of safety for the cylinders. The author had also referred to the thickness of the walls of the cylinders as being $\frac{5}{16}$ in., but in another part of his paper he referred to $\frac{3}{16}$-in. walls. Was it a recognised thing with those cylinders that the walls should be $\frac{5}{16}$ in. thick? It was very important that the metal should be of uniform thickness with those high pressures.

Mr. J. ROBERTSON (Member) said, in reference to the Government testing of cylinders, that he had no doubt that in the Navy, where they had CO_2 machines, the firms contracting with the Navy had all their work and machinery tested and supervised by Government inspectors. In regard to other outside firms, who did not contract with the Navy, he had no doubt that their cylinders would also be accepted by the Government inspectors. He did not think they should be outside Government control altogether in regard to inspection and testing.

Mr. JAMES ADAMSON (Hon. Secretary) said he would like to ask Mr. Mackenzie what was the *modus operandi* in regard to cylinders coming back to the works to be recharged. He had recently read of a case where a cylinder had come into the works to be recharged, and the man to whom it was delivered, along with others, had been, apparently, engaged in recharging cylinders for, he thought it was stated, seven or eight years. The man heated the cylinder under the impression that it was empty, and he apprehended that the valve must have been closed, as the cylinder, it appeared, was not empty, and it burst. He did not suppose that it was known what pressure was on that cylinder when it burst. Possibly Mr. Mackenzie had noticed that case.

Mr. MACKENZIE : Yes, I read of it.

Mr. ADAMSON, continuing, said it would be interesting to know what precautions were usually taken when cylinders were delivered to the works for recharging to see that they were empty before an attempt was made to recharge them. In Mr. Mackenzie's former paper on the subject there were some particulars given as to the sizes, thicknesses, and test pressures of cylinders generally used in marine practice, and he was not aware that there was any Government supervision over the manufacture or testing. He thought the usual practice was to simply accept the firm's guarantee that the cylinders had been tested to a certain pressure. The tensile strength of the steel, the thickness, the test pressure, and sizes were specified; the rest was left to the makers. He had a curious case not very long ago, where there were thirty-five cylinders ordered from a firm. They were delivered to the gas-charging firm, and he had a wire from them to say that there were no marks whatever on the cylinders to indicate that they had been tested. He wired to the suppliers of the cylinders, and received a reply that the cylinders had all been tested, but, in consequence of the short time they had at command to deliver the cylinders, to save a train time they had not got them stamped, and so the cylinders had been delivered without the stamp marks to show that they had been tested. The position the gas firm took up was that they dare not charge those cylinders without having a stamp on them. Under the circumstances, as time was invaluable, he wired to the gas-charging firm desiring them to test the cylinders and stamp them with their own mark, and go on charging and deliver. Subsequently he had some correspondence with both firms on the subject, and it ended in the firm supplying the cylinders paying for the testing and marking of the cylinders by the firm that filled them. Now, had there been Government supervision, and a necessity for testing those cylinders in the same way as a boiler would be tested, those cylinders would have all been passed by the surveyor before they left the works, and the gas-supplying firm would not have had to consider as to the responsibility of filling the cylinders, knowing that the Government inspector had passed them. He apprehended that there was a general understanding in the trade that no firm should charge a cylinder unless they had the guarantee of the supplying firm stamped on each cylinder —at least, such was his impression from that particular case. When cylinders were retested the date and distinguishing mark were put on them by the firm that tested them. He saw that Mr. Mackenzie had the copy of the "Blue-book" with him, and so would be able to supply Mr. Farenden with a reply to his question from the recommendations of the committee.

Mr. FARENDEN asked if there was any difficulty in getting all the gas out of the cylinders. He knew a case where some cylinders were supplied to a ship, and those cylinders were supposed to have a capacity of 40 lb. each, but they could never get more than 36 lb. out of each of those CO_2 cylinders. There always seemed to be 4 lb. of gas left in each cylinder which could never be got out. The makers always charged for 40 lb., but only 36 lb. were used, and the makers got the benefit of those 4 lb. It was a complaint that they could never get all the CO_2 out of those cylinders.

Mr. LEE asked if Mr. Mackenzie could tell them how the cylinders were made. Where they cast or drawn, or how?

Mr. MACKENZIE then replied to the points which had been raised during the discussion. The thickness of the cylinders should, in his opinion, be a standard thickness. That was his contention, and he would like to read to them an extract from a paper on the subject written by Mr. K. S. Murray. Mr. MACKENZIE then read the following extract:

"During the last few months, however, competition has begun to assume another and more serious form. Consignments of those very cylinders so severely criticised in this new German report are being shipped into this country from Germany charged with CO_2, which is sold in them direct to the consumer by London agents. The difficulty here to the British CO_2 compressor is obvious. So far as active interference is concerned he can do nothing, for the agents will take good care that these German cylinders do not wander into his factory. They are promptly returned to Germany to be refilled. The Government cannot help him, because the British committee's report has never been legalised. The German importers meet all his arguments as to safety by pointing proudly to the German eagle on their cylinder, which registers the official test, that may have affected it beyond its limits of strength, so that it may be considered theoretically as already broken; whilst the consumer, to whom any idea of danger in connection with a CO_2 cylinder is novel, assumes, when appealed to, that trade hostility is at the root of the whole business, and is influenced solely by the argument of £ s. d. This is the situation which exists to-day. Sound and well-established British trade regulations are set at defiance; and, shielding themselves behind an official test, the rottenness of which appears to be at length officially recognised, irresponsible dealers are able to strike at a well-conducted business industry a blow which goes beyond all bounds of legitimate competition. This article is not written in a spirit of prejudice. There are just as good and responsible cylinder-makers in Germany as in England, and good German cylinders have for years circulated in this country. These cylinders, however, comply with British regulations; they have never been used in Germany, and do not bear the incriminating stamp of official testing."

Mr. MACKENZIE said he thought that extract answered pretty well the question which had been asked in regard to the thickness of those cylinders and the advisability of having some regulations binding upon every maker. He believed it was the makers that they had first of all to "drop on to," because they would make the cylinders as ordered. If they gave an order for a $\frac{1}{4}$, $\frac{3}{16}$, or $\frac{5}{16}$-in. thick cylinder, it would be made to the required thickness. There was no regulation against that. If the gas-producer wanted a thin cylinder, the maker would make it. It was with him that the danger of passing brittle cylinders into circulation lay. If the Government made a standard of $\frac{5}{16}$ in. it would not be necessary to have the compressing firms under supervision. He would advocate that the testing firm be required to hold a Government license; then, of course, they could deal with them, and every compressing firm could accept each other's marks. At the present time one firm might test a cylinder, and the next firm to whom that cylinder went might say, "We have not tested this cylinder, and we cannot accept your last test." If there were some official testing they would be bound to accept each other's tests. He would advocate that cylinders be tested once a year, or at the end of two years, but not more frequently. In regard to the water capacity of cylinders, they filled the cylinder with water, and then took the weight of the cylinder so filled and the weight when empty. For every pound of water which the cylinder contained they would allow $\frac{3}{4}$ lb. of gas. The remaining $\frac{1}{4}$ lb. was allowed for safety. That was the system of dealing with the cylinders when they were brought into the factory. The valve was taken out of every cylinder, and they were steamed out first, and then rinsed out with cold water. Then they were turned upside-down in a room at a temperature of 100° to 110° F., so that they quickly dried and did not rust. No water was left inside the cylinders. He could not say that every firm did that—not by any means—but such was the rule that his firm went by. Every cylinder, whether their own or not, had the valves taken out, and was turned upside-down so that no water should remain in it. Thus there was no danger of getting water in their CO_2 gas, and so there was no danger of it freezing up through water being in the cylinder. If water were in the cylinder it would simply mix with the gas and freeze up the valve.

Mr. MACKENZIE then explained the method of testing the cylinders by means of the instrument designed for that purpose, a model of which he had brought to the Institute with him. When so tested, if the cylinder did not come back to within 5 per cent. of the elastic stretch it was condemned. But that 5 per cent. might be the rule of one firm, whilst other firms might not condemn cylinders which came back to within 10, or even 15, per cent. of the elastic stretch. What were they to do? There was nothing compulsory, and they could take such a percentage as they chose. Many might say that if a cylinder kept within 10 per cent. they would pass it. Personally, he did not consider it right to pass a cylinder, even supposing it only showed 5 per cent. of permanent stretch, because that cylinder had been strained. If it did not return exactly to where it had been started, the cylinder has been strained permanently. If they took that cylinder and annealed it well they would get it to come back. They softened the metal, and it would come back; but they knew that that cylinder had had a permanent stretch in the metal, and that might go on. If they were going to test that cylinder once every two years perhaps the swelling might not take effect exactly in the same place. Then they would have a cylinder liable to give out at any of the different parts that had been strained. He thought that was a point which ought to be enforced—viz., that every cylinder which showed a permanent stretch at 3,750 lb. pressure ought to be totally condemned. If they were going to let a cylinder be in circulation for ten or twelve years he thought they were expecting too much of it if at the end of that time they expected it on test to come back to the same position. In any case why should they accept a strained cylinder from the makers? The makers ought to be able to supply them with cylinders which would go back to their strong position after being tested at 3,750 lb. If they got a cylinder which had been properly tested at 3,750 lb. it would not be necessary for the compressing firms to test higher than 2,500 lb. after the second year. One of the cylinders (No. 2) which he had with him had been tested to 6,000 lb. pressure, and he believed that if that cylinder were reannealed and then put under the stretching test it would come back to its normal position. Yet they knew that that cylinder had been strained. Would it be safe to send such a cylinder out, knowing it had been strained, even though it could pass the stretch test? Then, in regard to packing cases, if they got a good cylinder that would stand the pressure and come back to its normal state after the stretch test at 3,750 lb., he did not see what would be the use of having a packing case. They would simply be adding more pieces to fly about if an accident should occur. There was very little chance of a good cylinder breaking. If they were going to accept cylinders $\frac{1}{4}$ in. thick, or under, made of metal such as some German cylinders were made of, they were going to get a brittle cylinder. If a good soft metal cylinder did burst they would get a tear, and there would not be so much danger as would arise where a brittle cylinder burst and the pieces were flying about. In regard to taking the gas out of cylinders, he thought he had said in his previous paper that the gas could be got out to within 3 or 4 lb. That was possible. They could warm the cylinder to raise the pressure, although to warm a cylinder was a thing he would condemn. He would far sooner lose 4 lb. of gas than warm a cylinder. Mr. Adamson had referred to an accident that had happened a few days ago, where a man had been killed by a cylinder bursting. He did not think that was a CO_2 cylinder, although he was not sure. If it were a CO_2 cylinder it might have happened through it being overcharged with gas. He had seen some cylinders brought into the works containing 30 lb. of gas when they were only supposed to carry 28 lb. Possibly the cylinder to which Mr. Adamson had referred was overcharged, and the accident might have been caused by a blow from a hammer.

Mr. ADAMSON: It was stated that the man heated the cylinder.

Mr. MACKENZIE said he had not heard of the man heating the cylinder. He must have been experimenting with the cylinder in some way or another, unless it were some other gas. Except the man had been experimenting with the cylinder he could not see how he could burst the cylinder by heating it simply to get it ready for refilling.

Mr. ADAMSON: How would you propose to get gas out of a cylinder without heating it?

Mr. MACKENZIE said although they wanted to get all the gas out of the cylinder it was not advisable to heat it. Still, there was very little danger in warming a cylinder after 10 or 12 lb. had been taken out of it. The only way to get all the gas out of a cylinder was to warm it so as to bring the pressure in the cylinder higher than that in the refrigerating machine.

Mr. ADAMSON: I should say that nearly every cylinder used in marine work is heated to get the gas out, after a certain amount has been taken out and the pressure thus reduced.

Mr. MACKENZIE said that was a point he had always been very strong upon. It seemed to be the practice of marine engineers to heat the cylinders. It was a practice more common on sea than on land. Marine engineers seemed to take a bucket of hot water so that they could get the gas quickly out of the cylinder. He did not think that was the right thing to do. They ought to consider the pressure they were working with before they started throwing hot water on those gas cylinders. If they looked at the rules and regulations of Messrs. J. & E. Hall & Co. they would find that customers were advised to warm the cylinder after 8 lb. of gas had been taken out, but to keep on the safe side he did not think that makers of machines should advise heating cylinders. Then, in regard to safety valves, Hall & Co. of Dartford supplied a safety valve which burst at 1,800 lb. pressure and allowed the gas to escape. There was also another safety valve by the Scotch and Irish Company, of Glasgow, which was much about the same as Hall's. It had a bursting disc, and the gas escaped through the spindle. His firm had a safety valve which worked with a spring relief. That valve relieved at 1,800 lb. and allowed a certain amount of gas to escape from the cylinder, and then it automatically closed, so that they did not lose the whole of the contents of the cylinder, as would be the case with the J. D. Hall or the Scotch and Irish Company's valve. The cylinders were solid-drawn tubes.

Mr. LEE : Put in a mandrill, I suppose.

Mr. MACKENZIE : They are pressed through a die, which makes them the same diameter all the way through.

Mr. FARENDEN referred to the increase of pressure due to the increase of temperature from 65° to 100° F., where the pressure increased 1,000 lb. What increase of pressure would result if a higher temperature — say 150° — were existing?

Mr. MACKENZIE said the various pressures arising from increasing temperature from 60° to 120° were given in his previous paper on " The Description of a Collecting and Compressing Machine for CO_2."

Mr. LEE asked Mr. Mackenzie how he arrived at the test pressure of 3,750 lb. What was the reason that that particular pressure should be used as the test pressure? Mr. Mackenzie had also recommended testing once every two years. Did he base that advice on practical experience or for any particular reason ? Assuming the cylinders were away for six or eight months in a ship, they would only be thrice filled in two years. Or would he depend on the number of times they were refilled—say six or ten times, as the case might be—for testing?

Mr. MACKENZIE said the Government recommendations were that cylinders should be tested every two years and annealed every four years. It was from that recommendation that he took the period of two years, although many firms tested the cylinders every year. Those firms would not fill a cylinder unless it were tested once a year. Any strange cylinders that came into the works were not filled unless they were tested annually.

Mr. FARENDEN : Are the safety valves set at 1,800 lb. before they leave?

Mr. MACKENZIE said the safety valves were set at 1,800 lb. with the spring relief. After 3 to 5 lb. had been blown out, the valve automatically closed. The 3,750 lb. pressure was, practically speaking, four times the working pressure. The pressure at which the cylinders were filled was 1,000 lb. If a cylinder were tested to 2,500 lb. he would consider that quite adequate, as they were allowing 50 per cent. margin over the highest pressure they would have from the highest temperature of sun-heat in this country. The highest pressure with 28 lb. of gas could be 1,900 lb. It was not often that they got 100° in the sun in this country. But, allowing it to come up to a sun temperature of 100°, the pressure in the cylinder would be 1,900 lb., or just a little over. So if they allowed 500 lb. over the highest working pressure, due to temperature, that ought to be sufficient. That was his opinion. He would like to hear anything that would be to the benefit of the trade generally. He would like to hear something said about the annealing question ; that was a subject which he would like to hear discussed. He could not exactly say what was the temperature in annealing, but the cylinders were brought to a cherry-red heat. They were put into a furnace eight or ten at the same time. The furnace had a fire-brick bottom, with the flame passing over the top. Then they were put into another furnace below, and they were not taken out of that furnace until they were black. Then they were brought out and cooled down in the open. That was the way annealing was done. But, he would ask, was that reannealing necessary if the cylinder had been properly annealed in the first instance? The regulations said they ought to be reannealed every four years; but the question was, was it necessary to do so?

The CHAIRMAN said they were much indebted to Mr. Mackenzie for drawing their attention to the interesting subject of gas cylinders. Those cylinders seemed to be coming very generally into use nowadays in ships where they had refrigerators, and he thought every precaution should be taken, as there seemed a danger of their giving way from time to time. They should be under some Government supervision, the same as boilers—(hear, hear)—as they were boilers in a sense, and they ought to be subject to the same inspection as boilers. Also, they ought to be tested for their safety, and a record kept in a book. Each cylinder should be tested periodically, in order to safeguard life. He saw no reason why they should be limited to any thickness at all, as that should be regulated by the pressure. They should be strapped from end to end at certain distances apart to strengthen them, and he did not think the weight of the cylinder should be brought into the question. Strapping the cylinder would, he thought, be a good plan. CO_2 cylinders were a new invention since he was at sea, and he had had no experience of them either personally or otherwise.

Mr. LEE said he would like to draw attention to the fact that people who purchased German cylinders and German gas could never depend on the quality of the gas. The cylinders, in the first place, were weak, the metal not being sufficiently thick. The cylinders were far more heavily stressed than steel ought to stand. He knew of a case where they used to buy German gas, and it cost something like £3,000 to make up what the coils had suffered. The gas had a quantity of water in it.

Mr. W. LAWRIE said he had very much pleasure in proposing a vote of thanks to Mr. Mackenzie. His previous paper had been on CO_2, but he thought they were very much indebted to him for the information he had given them. Had the night been better he had no doubt they would have had a wider discussion. He had dealt very fully with all the questions put to him.

Mr. LEE seconded the proposition in the fullest sense of the word. In respect to annealing, he thought that as engineers they might take it that any article—such as a chain on plate—was by annealing restored to its former elasticity. The annealing of cylinders would restore what had been taken out of them by the extra pressure. That was his own experience; and the Board of Trade enforced annealing in every instance in regard to chains and articles of that description. In thanking Mr. Mackenzie he felt sure he was voicing the feelings of the Institute.

The proposition was carried unanimously.

A vote of thanks to the Chairman, proposed by Mr. FARENDEN, seconded by Mr. GIRVIN, and unanimously agreed to, concluded the meeting.