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

DESCRIPTION OF A COLLECTING AND COMPRESSING MACHINE FOR CO_2.

BY
MR. R. MACKENZIE (ASSOCIATE MEMBER).

READ AT
58 ROMFORD ROAD, STRATFORD,
ON
MONDAY, APRIL 10th, 1905.

CHAIRMAN:
MR. W. LAWRIE (MEMBER OF COUNCIL).

THE following paper describes a method of compressing carbonic acid gas (CO_2), and the apparatus used for the purpose. It does not, however, describe the manufacture of the CO_2, which in the works I am connected with forms a by-product of other manufactures.

The gas is drawn from the vats in which it is generated by a fan driven by an electric motor, and is passed through a cylinder or tower 25 ft. high filled with coke. The gas enters at the bottom of the tower and passes through the coke, where it is met by a spray of water, which passes into the tower at the top. After undergoing partial purification by the spray the gas continues its progress into an ordinary gasholder. This gasholder is used merely for the sake of convenience, as the gas could be drawn direct from the vats to the machine. It is then drawn from the holder by the pump forming the first stage of compression. This pump or compressor is fitted with suction and delivery valves on the top and bottom end of cylinder, and the gas is compressed to a pressure of 20 lb. per square inch on a piston 10 in. in diameter by 18 in. stroke.

The gas is discharged from this cylinder into the purifiers, consisting of six horizontal outer tubes or shells, into each of which is fitted an internal tube the full length of the shell. This internal tube is fitted just clear of the outer shell, and has two rows of perforations along the bottom. The gas entering at the bottom outer tube is forced through these perforations against a head of 6 in. of alkali and other purifying reagents —that is to say, the solution is standing up to the centre of the outer shell, and the gas is compelled to bubble through it. After the gas has passed through it is then forced through the solution in the next shell, the outer shell of the one member being connected to the inner tube of the next by an internal branch. In this way the gas is forced through the solution in each shell until it reaches the top one.

At this point the solution is forced into the shells by a force pump connected on to the crank shaft of the compressor. When each shell is filled up to its centre with solution it overflows automatically through cascade connections into each succeeds shell until it reaches the bottom one. This latter, when full, overflows into a trap fitted with a ball-cock so arranged that when it contains solution up to the centre it automatically opens and allows the purifying reagent to escape to the drain, and thus keep a continuous flow of solution through the purifiers. Since the flow of gas is upwards and the flow of solution downwards, any escape of gas along with the reagent is prevented.

To return again to the gas, we reached the top purifier after passing the top member of the purifier. Thereafter it continues its course through a tube or shell called the drier, which is filled with chloride of calcium and a layer of cotton wool for the purpose of absorbing any moisture that the gas may have carried with it from the purifiers. From the drier it is sucked by the pump forming the second stage of compression. This compressor is single-acting, with the suction and delivery valve on top, with an ordinary ram piston, the gas being retained in the cylinder by a cup leather. The compression at the second stage amounts to 150 lb. to the square inch on a piston of 10 in. in diameter by 18 in. stroke. The gas is discharged from this stage into a condenser fitted with a spiral coiled tube. The gas enters this coil at the top and is forced out at the bottom, where a connecting pipe leads it to the suction pipe of the third stage of compression, at which we have now arrived. The suction, as I said, was the delivery from the second stage. This compresser is similar to the second stage—that is, a ram plunger with a suction and delivery valve on top, with a cup leather. In this third or final stage the compression reaches 1,000 lb. per square inch on a piston 3½ in. in diameter by 18 in. stroke. The gas is discharged into two spiral coiled tubes immersed in the same condenser as the second stage coil. The delivery pipe between the compresser and the condenser is a single tube, but to give a greater cooling surface it is divided in a coil box into the two spiral tubes already described, the gas entering at the top and leaving the coils again at the bottom (through a coil box similar to the top) into a single tube which is connected to a receiver. The receiver is hung on a spring balance, which indicates at all times the exact weight of gas in the machine, either whilst at work or stationary. From the receiver the gas passes along to the filling main, which is a tube with six valves attached. Each valve is fitted with two separate spindles, the object being to have the valve which blows to the atmosphere closed when the other valve is opened during the process of filling the portable gas cylinders. Then again, by closing the valve which was open from the machine to the portable cylinder and opening the other valve, it allows air to escape from the cylinder. It further allows the blowing away of gas from the cylinder, so as to bring the gas in the cylinder to the same temperature as the gas in the receiver.

During the process of filling each cylinder is standing on a weighing machine, being connected by copper pipes to the filling main. Thus with the six valves six portable cylinders may be charged at the same time. Each cylinder is charged with 28 lb. of liquid carbonic acid, which is equal to about 228 cubic ft. of gas at normal pressure and temperature.

I have mentioned previously that this CO_2 is obtained as a by-product, and is collected in a very pure state, and, unlike that produced from burning coke, etc., contains very little air —usually the greatest trouble manufacturers of CO_2 have to contend with. This enables us to bottle a very pure and dry gas, and my firm guarantee each cylinder filled with 28 lb. of CO_2 contains 99·8 per cent., or 27·95 lb., of pure CO_2. A gas of this purity, you can understand, is fully appreciated by the large users of this article, especially in the mineral water trade, where the presence of air in the CO_2 causes so much excess pressure in the carbonators. The presence of moisture, also, as you are all aware, causes a great deal of trouble and annoyance in refrigerating plants. These two difficulties have by careful manipulation been entirely overcome. The capacity of each portable cylinder is ·55 cubic ft., and the water capacity 37 lb. The gas liquefies at 0° Centigrade and a pressure of 540 lb. per square inch.

In conclusion I may say that the portable cylinders used for conveying CO_2 are, as a rule, tested to about 3,750 lb. The greatest care ought to be exercised in the handling and use of CO_2. Frequently I have seen engineers applying hot or boiling water to a CO_2 cylinder to force the gas out quickly.

This expedient cannot be too severely condemned. It is extremely dangerous (for one bucketful of boiling water will increase by 600 or 700 lb. per square inch the pressure in a cylinder containing 28 lb. of gas) unless a safety valve is fitted to the cylinder to allow any excess pressure to escape. I may mention that my firm have recently put a patent safety valve on the market, which works automatically. It is fitted with a spring relief, and immediately the excess pressure is relieved the valve closes, thus avoiding the total loss of the contents of the cylinder.

Just recently the CO_2 trade has been considerably agitated by the discussion in the Press regarding the consignments of light-weight cylinders containing liquefied carbonic acid which have been shipped into this country from Germany, and are being sold to various consumers in London and elsewhere. These cylinders entirely fail to comply with the Board of Trade regulations.

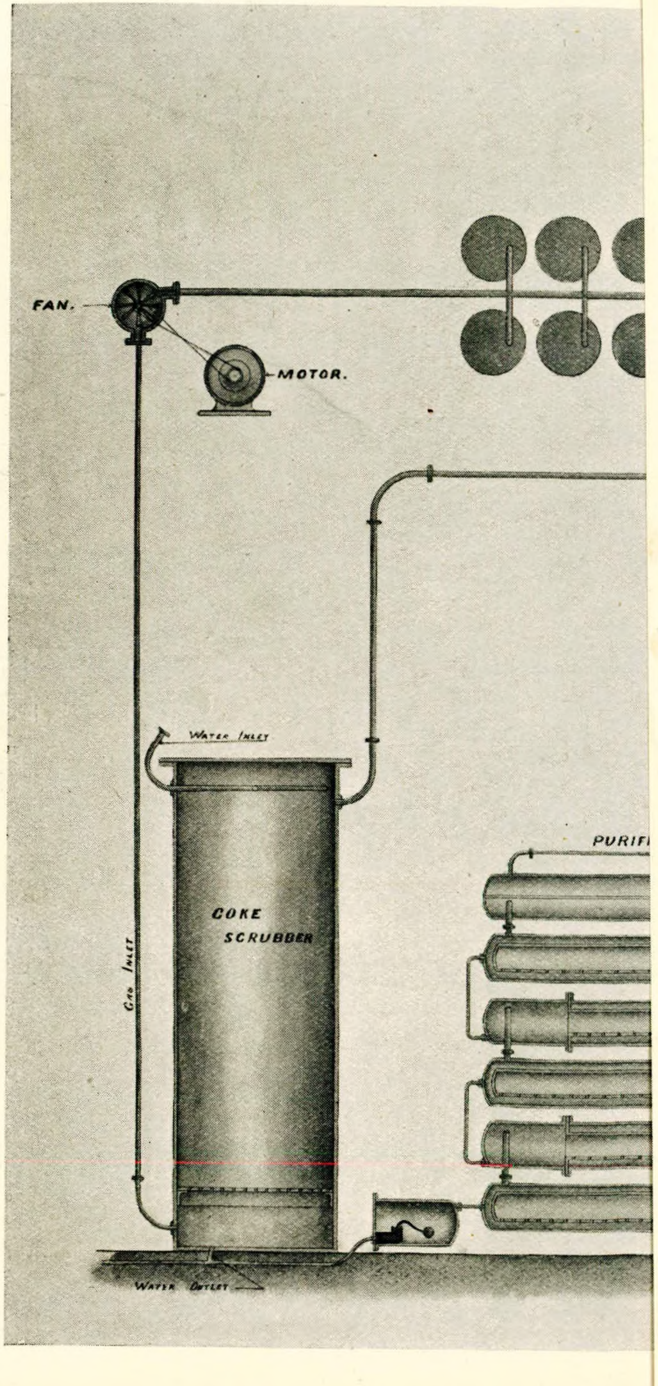
Comparison between actual tests and measurements of German CO_2 cylinders and conditions prescribed by the Home Office Committee of 1896:

Conditions	German cylinders	Committee's recommendations
Thickness of walls ..	·174 in.	·251 in.
Working stress in metal ..	11·9 tons per sq. in. ..	8 tons per sq. in.
Ultimate tensile strength in metal	46·5 tons per sq. in. ..	28 to 33 tons per sq. in.
Carbon in metal	·488 per cent.	Not more than 25 per cent.
Iron in metal	98·226 per cent.	Not less than 99 per cent.
Charge of CO_2	$\frac{4}{5}$ lb. CO_2 per lb. of water	$\frac{3}{4}$ lb. CO_2 per lb. of water

With regard to the last item in above table, it is important to note that although the German cylinder gives a much higher working stress in the metal when internal cylinder pressures are equal, the cylinder actually contains more gas.

Minimum weight which CO_2 cylinders of various sizes should fulfil if made in accordance with British Government specifications:

Maximum weight of CO_2 which cylinders should contain	Minimum weight of cylinder charged CO_2 without valve caps	Minimum weight of cylinder empty without valve caps
22 lb.	82 lb.	60 lb.
24 lb.	88 lb.	64 lb.
28 lb.	98 lb.	70 lb.
45 lb.	175 lb.	130 lb.



FAN.
MOTOR.
WATER INLET
COKE
SCRUBBER
GAS INLET
WATER OUTLET
PURIFI

Mr. MACKENZIE then, by means of diagrams, further explained the method of collecting and compressing the CO_2 gas.

The CHAIRMAN : Mr. Mackenzie has much enhanced his paper by the diagrams he has shown and explained, thus making the subject clearer than it would otherwise have been to those of us who are not experts. I hope that members will take the opportunity of discussing the subject now brought before us, expressing their views and asking questions.

Mr. W. MCLAREN said he could not claim to be an expert in CO_2, but he would like to know something in regard to the question of fuel consumption in comparison with the other processes in use for refrigerating plants, as ammonia or dry air. He congratulated Mr. Mackenzie on giving his paper, and especially in regard to the diagrams, which made it much more explicit. One point which attracted his attention was in regard to boiling water—presumably about 205° on contact—thrown on the cylinder containing 28 lb. of gas. The rise in pressure, mentioned as 600 to 700 lb., seemed to him enormous. It was also mentioned that the CO_2 was a by-product. It would be interesting to know the first stage from which the gas was drawn.

Mr. BERTRAM : I would like to ask if gas produced by the combustion of coke could be used?

Mr. MACKENZIE : Yes.

Mr. E. J. ALDRICK (Visitor), replying to Mr. McLaren, said the chemical works in question produced two vegetable acids—tartaric and citric acid. The gas was generated by the action of an acid upon chalk, almost in the same manner that all the mineral water makers a few years ago used to make their own gas, and they got a very pure gas. CO_2 is produced by the action of sulphuric acid upon chalk.

Mr. E. W. ROSS (Member) asked whether, when a cylinder was being refilled there was an internal pipe from the bottom of the cylinder, or was the cylinder divided to allow for the escape of air whilst the CO_2 was entering? Might he also ask if when the cylinders came to be refilled they were subjected to any test as a guarantee of their strength after having gone through the vicissitudes of a voyage, before they were refilled, for the question of safety?

Mr. MACKENZIE, replying, said with regard to the first part of Mr. Ross's question there were two valves upon the filiing main. There were not two valves upon the cylinder that was being charged. Two spindles were fitted on to the filling main. When they fixed the cylinder on to the weighing machine they connected a copper pipe on to it. There was a valve on the side for blowing out the air in the cylinder. When they shut that valve and opened the other that valve was open from the compressor straight to the cylinder. If they shut the valve upon the filling main and opened the other one it would blow to the atmosphere, blowing straight through from the flask. With regard to the refilling of cylinders, they were supposed to be tested every two years, and they watched every cylinder that came in to see that they had been tested within two years. If they found a cylinder that had not been tested within that time, then the firm refused to fill the cylinder until it had been tested.

Mr. E. W. ROSS : Is there any chance of escape or loss of the gas by filling the cylinders in the way you describe? The CO_2 goes in at the top and the air goes out at the top. Is there any plan of internal piping to obviate that waste of gas?

Mr. MACKENZIE said there was no internal pipe. The object of blowing away was to bring the temperature in the CO_2 cylinder that was being filled to the same temperature as they had in the receiver. They had two valves on the filling main and one valve in the top of the cylinder. The object of blowing away was to blow the gas back from the cylinder to waste, so that they could get the gas in the cylinder the same temperature as in the receiver. In filling a 28-lb. cylinder they wasted about 2 lb. of gas. That waste was a mixture of CO_2 and air.

Mr. JAMES ADAMSON (Hon. Secretary) said that by the kindness of the firm of Messrs. Bennet, Lawes & Co., to which Mr. Mackenzie had referred, the members would have the privilege of visiting the works on Saturday, May 20th, when, no doubt, they would be able to appreciate better the paper and diagrams which had been shown them that evening. Like Mr. McLaren, he would like to endorse the compliment given to Mr. Mackenzie on the clearness with which he had put his paper before them. It was of the utmost importance to them as engineers that they should get CO_2 pure and uncontaminated with water or air, and it was very interesting to know that so much trouble was taken to supply them with that which they required. There were one or two questions which had occurred to him in connection with the paper, and he would like if the author would give them some idea as to the packings used in the compressor pistons of the machine described. Mr. Mackenzie had referred to the pistons as being ram-pistons, and he had also spoken of cup leathers. It was not quite clear whether the cup leathers were on the pistons or valves, or on both. It would be of interest also to know what kind of lubricant was used on the piston-rods, and what system was adopted to keep the compressor cylinders tight, so that there was no escape of CO_2 in its passage throughout the cycle. The cost of CO_2 was so small that the loss of 2 lb. of gas when re-charging a cylinder was unimportant relatively. He was glad to note the reference made to the importance of the dealing with the charged cylinders. Those who had had experience of CO_2 cylinders, especially in the tropics or in high temperatures, knew the amount of danger there was in handling them, and in some cases there even appeared unjustifiable risk run in the careless way they were handled; fortunately there had been very few cases of burst cylinders, but there were cases on record, and they knew the necessity for care in the treatment of the charged cylinders both in port and at sea, especially in tropical climates. He thought Mr. Mackenzie might explain what was meant by the weight of water relative to the weight of CO_2, as it might not be clear to members who were unacquainted with the handling of the gas. The size of cylinder quoted by the author was rather smaller than that generally used in marine practice, which was a 40-lb. cylinder. He apprehended that the application of hot water, referred to in the paper as reprehensible, was only used when the cylinder was getting about empty and when the valve was open in charging up a machine; so they had not the 28 lb. of CO_2 in the cylinder when they turned the steam on or applied the hot water. When the cylinder became so far exhausted the heat was applied to increase the pressure to get the CO_2 out of the bottle. He did not think that the heat would be applied when the bottle was fully charged. That would be a most dangerous practice. The following figures gave particulars of tests for cylinders supplied to suit marine work and to the regulations: Size of cylinder to contain 40 lb. CO_2: 4 ft. 2 in. long inside, $7\frac{1}{2}$ in. diameter, $\frac{3}{8}$ in. thick. Steel: 28 to 32 tons tensile. Test pieces: size, 1·382; area, ·382; stretching length, 2 in. Tensile tests: actua tons, break 11·2; tons per sq. in. break, 29·3; elongation: total, $\frac{3}{4}$; per cent., 37·5. Cylinders tested to 4,000 lb. per square inch after being annealed.

Mr. MACKENZIE stated the rise in pressure might be 600 lb. or 700 lb., due to a rise in temperature, and said it was a very common occurrence with CO_2 refrigerating machines for the charging valve on the machine to become choked up, and at times a spindle got broken and was sucked back, so that although it might be thought the passage was clear it was not so. The attendant might in such a case open the valve on the cylinder to let the gas out, but he did not try to see whether he had got a clear way to his machine. After this he would probably take a bucket of hot water and pour it over the cylinder. Under such circumstances, from actual tests that he had tried, he could raise the pressure by 650 lb. or 700 lb. on the application of heat. With reference to the packing of the CO_2 cylinders, the first stage cylinder was packed with Tuck's packing. Those two pistons had a cup leather; the pressure of the gas filled out these leathers to the walls of the cylinder. To keep the cylinders cool the trough was filled with water to within about 1 in. of the top. The lubricant used for the piston was glycerine, admitted into the cylinder by the suction valves, and was thus allowed to mix with the CO_2. The cup leathers were the same as those used for hydraulic pressure.

Mr. Mackenzie then explained and exhibited the working of a patent safety valve for use on CO_2 cylinders, fitted with a copper disc, which burst at a pressure of 2,000 lb., and thus eased the pressure. He also exhibited and described another valve of Mr. Berry's and his own design, fitted with a spring relief at 2,000 lb. pressure, and when the excess pressure was relieved from the cylinder the valve closed down, so that it only allowed the loss of about 5 lb. of gas out of each cylinder upon each relief, which was claimed as an advantage for that valve, as by means of the spring they minimised the loss of the contents of the cylinder. With all other types of safety valves he had seen, the whole cylinder of gas would be lost to the amount of 28 lb. or 40 lb. It was their latest practice to fit cylinders with the spring relief valve. Mr. Mackenzie also explained a model of a high-pressure safety valve and a reducing valve combined, also of their own design, which was fixed on the portable steel cylinder, to be charged up from the filling main. Inside they had a valve which was closed by the pressure from the machine or cylinder, as the case might be. That was charged at 1,000 lb., and by adjusting the screw at the top they forced the valve down off the face against the pressure of the gas inside the cylinder. Thus they could fill the cylinder at 1,000 lb. pressure and take it out of the cylinder at 5 lb. pressure through that main by adjusting the screw. They could take the gas from the cylinder at any pressure they desired up to 1,000 lb. With regard to the water equivalent, the way by which they measured the capacity of a cylinder, or how much gas they could safely put into it, was to take the weight of the cylinder when empty, and then fill it with water. They would then have the weight of the water the cylinder would contain, and for every pound of water they allowed $\frac{3}{4}$ lb. of CO_2. On every cylinder they put the date of testing, so that there was always a record when each cylinder was last tested and when it had to be tested again. The Board of Trade required that cylinders should be annealed and tested every three years, although his firm took the precaution of testing every two years.

Mr. G. SHEARER (Member) said he would like to ask which valve was referred to as liable to gag or give way when heat was applied and gave excessive pressure. Was it the stop valve on the bottle, or flask, or was it the inlet valve to the machine? Also, what was the form of valve? If the pressure went in at the back of the valve, he did not know what portion of the valve the author spoke of when it was referred to as being broken. The pressure going in at the back would force the needle or point of the valve into its seating. Of course, if the gas went in in the opposite direction it would blow it out. He had never seen hot water applied except when the cylinder was nearly empty, to increase the pressure, and so drive the gas into the machine. Regarding the air trouble spoken of, the author had said that the CO_2 obtained as a by-product by his firm contained very little air—"usually the greatest trouble manufacturers of CO_2 have to contend with." He had further stated that they were able to bottle a very pure and dry gas, and his firm guaranteed each cylinder filled with 28 lb. of CO_2 to contain 99·8 per cent., or 27·95 lb. of pure CO_2. It was stated in the paper that the addition of air tended to increase the temperature. He would ask, How did air come to increase the temperature of CO_2? Mr. Mackenzie had described the packing of the first and second stage compression cylinders, but had neglected to describe the packing of the ram of the third stage cylinder, which was the most important. With CO_2 machines he had had experience of the difficulty it was in the keeping good the packing of the piston-rod of the machine. That piston-rod was burnished, and if the slightest grit or oxide, or anything else, formed on the piston-rod the packing would at once give way. With the piston-rod it was the ordinary cup leather that was used. The author said, "During the process of filling, each cylinder is standing on a weighing machine, being connected by copper pipes to the filling main. Thus, with six valves six portable cylinders may be charged at the same time. Each cylinder is charged with 28 lb. of liquid carbonic acid, which is equal to about 228 cubic feet of gas at normal pressure and temperature." He would like to ask, What was the normal pressure and temperature?

Mr. MACKENZIE: The pressure, atmospheric pressure—15 lb.; and the normal temperature, about 65 degrees.

Mr. SHEARER, continuing, referred to the difference between the English and German cylinders. He remarked that according to the paper the German cylinders could stand a working stress of metal of 11·9 tons per square inch, whilst the committee's recommendation was eight tons per square inch. The ultimate tensile strength of the metal in the German cylinders was 46·5 tons per square inch, as against the committee's recommendation of twenty-eight to thirty-three tons per square inch. Did not that prove that the German metal was much superior to ours?

Mr. MACKENZIE: No.

Mr. J. THOM said the working pressure in one was double what it was in the other. The margin of safety in one was not half what it was in the other.

Mr. MACKENZIE, in answer to the question which valve it was that was liable to break, said he had referred to the charging valve which was fitted on the evaporator of refrigerating machines. It was a well-known fact that air in CO_2 was not only a trouble to mineral water manufacturers, but also to those who bottled it at one time, but now they had overcome that difficulty. The presence of air increased the working pressure. The working pressure was about 1,000 lb., and they would very soon find out whether they had any air in the system by the fact that they got 500 or 600 lb. pressure extra within ten minutes. They could not bottle it; it stopped dead in the cylinder valve, and they could not move it until they blew it away to the atmosphere. So soon as they got rid of the air the flask would fill up quite easily. With regard to the third stage piston, the packing here was cup leathers, the same as in the second stage. The first stage piston was packed with Tuck's packing, but the second and third were packed with cup leathers.

Mr. W. McLaren asked what clearance there was between the plunger and the cylinders.

Mr. Mackenzie said in the first stage cylinder there was a clearance of $\frac{1}{16}$ in., in the second stage a clearance of $\frac{1}{32}$ in., and in the third stage a clearance of $\frac{1}{64}$ in.

Mr. J. Thom said they wanted to know all they could about the cylinders. Engineers went to sea with CO_2 in cylinders on board, and they wanted to know what was to happen if the temperature rose. It was a very easy matter filling cylinders here with an atmosphere of, say, 60 deg. temperature, and the water less than 60 deg. He was afraid that if engineers of refrigerating machines went to sea with cylinders made for only working under these conditions they would not find much CO_2 when in the tropics. The machine described was only for filling cylinders; it was not a refrigerating engine. It had the duty of liquefying CO_2 from a gas. If air entered with the CO_2 the pressure rose, and they would also find the machine was doing much less work, consequently would not bring the brine down if a refrigerating machine. Then when the pressure rose so high the leathers gave way owing to the high temperature. The pressure rose at higher temperatures by hundreds of pounds per square inch. So long as the CO_2 was pure they would get the liquefying of the gas at the ordinary temperature at which it should liquefy with water at a certain temperature. Reference had been made to the practice of throwing hot water on the cylinders when they were being emptied. The CO_2 was in a liquid state in the cylinder, but it did not come out in a liquefied state altogether, consequently it required to get heat from the outside, and if you were pumping it out faster than it could pick up heat it lowered its temperature and froze, and they could not get it out of the cylinder except by pouring hot water on it. Then with regard to the water equivalent of $\frac{3}{4}$ lb. The liquid filled up the cylinder to a certain space, but it was not all liquid. There was a certain amount of gas, and the ¼ lb. space was the only place it had to relieve itself into by the variation of temperature. If they filled the cylinder up chock-full of liquid it would rise by hundreds of pounds per square inch. Suppose they had a cylinder quite full at a temperature of 60 deg. to 64 deg. Then let that cylinder be taken to the tropics, where the temperature would perhaps be 90 deg., and the water also 90 deg. What would the pressure become in that cylinder? Suppose, further, it was down in the engine-room or store-room, or in a place where a fire might break out—and it must be remembered that there were dozens of cylinders carried for a spare charge—to what temperature could those cylinders be raised before bursting? They would burst if the temperature rose high enough, then the side of the ship would suffer, or the decks rise. He thought, however, they were just as safe under careful precautions and supervision with those cylinders of CO_2 as with steam boilers. He had known of ships being on fire whilst CO_2 bottles were adjoining where the fire was, and they had thought it advisable to put the fire out as quickly as possible. With change of temperature they must have great rises of pressure, no matter what chemical was used, and it would be interesting if the author could tell them what to expect when a cylinder which had been filled in the ordinary way was taken from the ordinary temperature away to the tropics on board ship. Did the Board of Trade rules and regulations take into consideration the temperature of a ship's engine-room when in the tropics or in hot countries? Cylinders had been known to explode and do great damage. He was of opinion that the tests which the author had spoken of as being applied to cylinders did not apply to the average cylinders used on board ship. The cylinders to which the author had referred seemed to be much smaller than the cylinders which were sent to sea, although the same system of testing might apply. If Mr. Mackenzie could give him an idea as to what would happen under the conditions he had mentioned it would be interesting to all of us.

Mr. MACKENZIE, replying, said they had their water at 70 deg. It would be rather a difficult thing to say what pressure might be got if they had a cylinder quite full under the conditions stated. The estimate of 75 per cent. was simply to give a safe margin. In the engine there was sometimes a temperature of over 90 deg., that, generally speaking, was taken into account. In the actual practice that he had spoken of a

28-lb. cylinder, made to specification, was, after filling, put into a drying-room, at a temperature of 70 deg., the atmosphere outside being 60 deg. In half an hour they found the pressure had gone up 500 lb. That was at 10 a.m. By 10 a.m. the next morning it reached 1,924 lb., which was a rise of 924 lb., or practically double the pressure. With regard to German cylinders, these were tested to something like 4,000 lb. under Government regulation. The British cylinders, according to the specification of the Home Office, had to be made of soft steel, so that if the pressure became too high it would open out instead of bursting, thus minimising the area of risk and danger, while the German cylinders would undoubtedly fly, because they were so much more brittle.

Mr. THOM: You test the cylinders by internal pressure? Do you put them into a press or gauge to find out if they are altering their shape?

Mr. MACKENZIE replied that when testing cylinders they put them into a water tank, and then connected up with a hydraulic pump. There is a lid on the top of the water tank which was screwed up, and the water gauge showed how much water was displaced. That shows exactly the amount of alteration in the cylinder, and whether it has returned to its normal condition when the internal pressure is taken off.

Mr. J. CLARK (Companion) asked if the top diagram was an actual sketch of the compressor, and if the compressors were all driven off one crank shaft. He knew of a three-stage compressor where the intermediate compressor took the thrust on the opposite side of the piston to the first and third stage compressors. The effect of balancing them seemed to be a good point, and tended to a low up-keep cost in connection with the wearing parts. He supposed, from what had been said, that CO_2 was of little value, so that leakage past the piston was not of much moment, but in some compressors, where the gases were of value, it would mean that the escaped gases would be led into the suction. Did they do that with the CO_2 compressors? Another interesting feature was the weighing of the cylinders, and he would like to ask what sort of flexible connection they used when weighing the bottles, especially working under such high pressure. He would suppose that sometimes, if it were an ordinary union, it would give trouble. Leakage was another important question in connection with the whole system working under a pressure of 1,000 lbs., which needed to be very carefully looked after. Was there any means of testing that, and what was the permissible percentage of leakage that they allowed for, before they considered it necessary to stop and overhaul. Did they look to the gauge, and if that did not give them what they expected, did they look for a leak? In regard to the temperature, and the pressure rising, the compression of gas was a very interesting subject. For instance, those "bombs" (sparklets) for aerated waters were said to be filled with gas at 900 lb. pressure. The note of warning had been wisely sounded in connection with the extreme increase of pressure that took place when CO_2 or any gas was warmed up. Mr. Thom had put the matter concisely. In regard to the air causing the pressure to rise in the cylinders, was it not that the increased temperature of the compressed air caused an increased temperature to the CO_2 and also caused it to rise? The temperature of air compressed to 67 or 68 atmospheres, or 1,000 lb., was something like 1,750 deg. absolute. The temperature of CO_2 compressed to the same pressure was about 1,400 deg. absolute, or as 17 to 14. He presumed the gas charged at 60 deg. temperature gave the pressure quoted as in the cylinders when delivered, which would be about 780 lb., and by increasing 45 deg. more the pressure came to 600 lb. more, while an increase of 54 deg. would add 750 lb. pressure. By still increasing the pressure up to 122 deg. Fahr. the pressure would be brought up to 1,690 lb., or 910 lb. additional to what it orginally was. At 122 deg. the pressure, roughly speaking, would be 1,700 lb. Well, a pressure of 1,700 lb. on a test pressure of something like $2\frac{1}{2}$ times as much was, comparatively speaking, low, because, to start with, the cylinders were tested to an extraordinary pressure. Mr. Thom had urged that precautions should be taken where those cylinders were sent out for use in hot climates. The authors of papers could not be too precise, and if CO_2 compression were a hobby of his he would endeavour to get hold of all the information possible, and the first thing he would want to know would be in regard to the temperatures and pressures. He thought the safety valve that Mr. Mackenzie had referred to was a very interesting one, and was really more than an ordinary safety valve. In reality it was better as an appliance for the purpose intended when seen than one would have gathered from the description.

Mr. MACKENZIE replied that for the filling of the cylinders there was a long sweep of copper pipe from the filling main to the cylinder, so that they could get the exact weight of the gas.

Mr. THOM asked if they might be assured that all the air could be expelled from the cylinder. The CO_2 was put in to cool out the cylinder, but could they be sure that all the air was got out. Was the cylinder exhausted to as perfect a vacuum as they could get before filling? It would be very advisable to do so.

Mr. MACKENZIE said that the small amount which was blown away was hardly worth considering, although, of course, it would be better to have no waste at all. The air was got out of the cylinders simply by blowing it away, and they could get 99 per cent. of pure CO_2 drawn from the cylinder, and he was satisfied they got all the air out. The pressure went down immediately if they had a leakage. That leakage might be caused by the slightest bit of grit getting on the leather or piston and making a cut. Of course, they could not afford to run for twelve hours with a little gas blowing away from the compressor. That had to be remedied, or it would amount to a good few bottles before the end of the day's run.

Mr. SHEARER asked if, when filling the bottles, they allowed any time for the CO_2 to settle down. They all knew that it was heavier than air, and would therefore fall down. There must be an agitation in the bottle, and he would like to know if any time was allowed for settlement before blowing the air out of the bottle. In connecting up a cylinder to the filling main that cylinder would be full of air, which must get away somewhere. If they put the pressure on to the bottle they must be mixing up that air with the CO_2, and he questioned if it would not be advisable to have a tap on the top of the bottle, so that when they had a certain pressure and a certain settlement of the CO_2, by opening that tap, they could blow the air away. Of course, according to the diagram, he could see that when the pressure was let in during the operation of filling there was not the slightest doubt that the air would find its way into the receiver, being above the level. But he thought it would be better to give it a slight rest, so that any disturbance between the air and the CO_2 would have an opportunity of separating them more thoroughly.

Mr. MACKENZIE said that immediately they opened the valve on the top of the cylinder the cylinder did get full of air, but immediately they connected up, and opened one of the two valves he indicated on the drawing, all the liquid fell to the bottom, the air being all on top. That was the air they were blowing away by means of the double spindle to which he had referred.

Mr. SHEARER said he had understood that that valve was on top of the filling main.

Mr. MACKENZIE said the valve with the two spindles was fitted on to the filling main; they had a valve on the top of the cylinder as well. Immediately that valve on the top of the cylinder was opened it was filled with air. When they opened the valve from the filling main to the cylinder they allowed the liquid CO_2 to pass into the flask. If they did not blow-away air in the system the pressure would rise in the machine. If they shut off the valve from the filling main and opened the valve on the side which blew all the air out of the top of the cylinder, that allowed more room for the liquid.

Mr. SHEARER said he did not suppose any of them had ever seen the interior of a bottle when it was being charged. It was the outside they noticed. But, so far as he could understand, the condition of the material was that it consisted simply of globules. The CO_2 simply became like water, and formed a volume of globules.

Mr. E. J. ALDRICK said that a little while back they had considered the matter of getting rid of the air which was always in empty cylinders, by means of vacuum, before attempting to re-charge. They found it rather difficult to do. If there was very little air in the cylinder when it was returned to them they could get the 28 lb. of CO_2 into the cylinder without blowing-away. If the cylinder was full of air they could charge it with 24 lb. of CO_2.; when it was three parts full of liquid gas and the other part full of a mixture of gas and air, by opening the valve they got rid of the bulk of air in a very short time. But immediately they took any relief off the cylinder the whole of the contents were moving about, and it was impossible for the air to separate entirely. Although it might have settled, immediately they opened the valve agitation took place, and they got a mixture of air and gas. If it settled for twenty-four hours, and there was 2 per cent. of air with the gas, analysis showed that the top of the flask would contain 70 per cent. of CO_2. It was simply impossible to blow-away any large percentage of air. If the cylinders were returned with a small amount of gas in them they were able to re-charge them without once blowing-away, which showed that the gas, as they made it, was practically pure. When the receiver had 30 to

40 lb. of CO_2 stationary in the bottom, and the drawing off took place at the bottom, the only thing they could get out was pure CO_2. They could not get the mixture which was on top when there was a layer of CO_2 below it.

The CHAIRMAN said the subject had been fairly well discussed. Many interesting points had been raised, but he should like to know what steps the Board of Trade took to enforce the regulations with regard to foreign cylinders coming into this country. Was anything done to prevent them evading our regulations, and what steps were taken, not only in relation to foreign importers, but also what regulations were carried out with reference to our own manufacturers?

Mr. ALDRICK said he could give them the whole facts, so far as they had gone at present, which, he thought, were very satisfactory to the CO_2 manufacturers. The matter had been finally settled only the previous Friday, and the following is a report of what was done:

"At the request of the united railway goods managers a deputation of the CO_2 trade attended a meeting at the Railway Clearing House, Euston Station, and after lengthy discussion explained to the members of the committee the whole position with regard to the foreign cylinders now being imported, and in some instances tendered to the railway companies for traffic. They resolved that the clause in the consignment note stipulating the carbon limit should be abolished, and a clause substituted to the effect that all cylinders carried under this traffic must comply in every respect with the recommendations of the Government Cylinder Committee of 1896. The chairman also informed us that the trade had the railway companies' full sympathy and support; that the importers would be personally warned that their traffic could not be accepted. He furthermore promised that anyone contravening or making a false declaration would be prosecuted by the railway company at their expense. They understood that that regulation would come into force forthwith. As a result of a lengthy correspondence with the Home Office, they had received an official notification that a circular to the trade in London and neighbourhood would be issued almost immediately, recommending every user of compressed gas in cylinders to obtain from the firm supplying him a certificate stating that the cylinders supplied complied with the recommendations of the Cylinder Committee of 1896."

It was intimated to them that if that certificate could not be produced the factory inspector would be authorised to deal with the matter. There had been a good deal of correspondence with the Board of Trade, and as a result they had now received an official intimation.

The CHAIRMAN, after referring to the visits to be paid to various works during the summer, and also to the annual meeting, called upon Mr. McLaren to move a vote of thanks to Mr. Mackenzie for his paper.

Mr. W. MCLAREN said it gave him great pleasure, after hearing the discussion on the CO_2 question, to move that a hearty vote of thanks be accorded Mr. Mackenzie for his interesting paper. They would all go away that evening with a better knowledge of CO_2. He had a lot to do with refrigeration and the ammonia system, but he had nothing to do with the CO_2 system. He thought the questions relating to temperature which had been raised should go home to them. It was a matter in which a great deal of care ought to be taken. He considered the members ought to be very thankful to Mr. Mackenzie for putting the subject before them in the way he had done. They ought also to thank his firm in anticipation for the visit they were to pay to the works to see the apparatus described in action, and which, he was sure, would be very instructive.

Mr. FRANKLIN seconded the motion, which was at once carried.

The CHAIRMAN said they must also express their thanks to Mr. Aldrick for the kind explanations he had given them.

Mr. ALFRED COOK proposed and Mr. SHEARER seconded a vote of thanks to the Chairman, which was carried unanimously.

The CHAIRMAN said he quite agreed with Mr. McLaren that they would go away with a much clearer idea of the manufacture and compression of CO_2. He was sure they had all spent a very pleasant evening.

The meeting then closed.

On Saturday, May 20th, about forty members of the Institute visited Messrs. John Bennet, Lawes & Co.'s Atlas Chemical Works, West Ferry Road, Millwall, where they were received by the managing director and his assistants, who kindly conducted the party over the works and explained the various processes of manufacture in detail. The visitors were given the opportunity of seeing the process of manufacture of tartaric and citric acids in its various stages, from the handling of the raw material as it arrives from abroad to the point at which the finished products are sent out for use, as the case may be, in the preparation of baking powder, aerated waters, etc.

In the course of the process carbonic acid gas, CO_2, is liberated by the treatment of the acid liquors with calcium carbonate. This is collected and drawn through a series of purifiers and dryers to the compressing machinery, where it is liquefied and filled into steel cylinders for use, chiefly by aerated-water makers and in connection with refrigerating works. All the by-products that can be utilised are turned to good account. From the sulphate of lime, of which a large quantity is produced, fire-resisting plaster and non-conducting compositions for boiler and steam-pipe coverings, which have been lately patented and placed upon the market under the name of "Gypo," are made. The plant and machinery are thoroughly up-to-date, and include steam and gas engines, dynamos for the generation of electricity used for lighting the premises and for motors, Dowson's gas-producing plant, and all that is required for the efficient and economical working of an important business.

The Author's further reply: The interest taken in and the questions asked in reference to my paper on a CO_2 collecting and compressing machine have brought several new points before my notice which I had omitted. I fear the note sounded in reference to the use of CO_2 has conveyed a meaning I did not quite intend, as CO_2 is just as safe to use as steam from a boiler. What I did wish to point out was the danger in careless handling of CO_2 cylinders, and it occurs to me to ask how many engineers know the nature of the gas they are using day by day in refrigerating machines. Probably 70 per cent. of sea-going engineers do not fully realise the extent of the danger there is in pouring hot water over these cylinders containing CO_2, and if asked whether they knew the risk run in pouring hot water over a cylinder, in all probability the answer would be, "Yes, I know it is a bit dangerous until you get 6 lb. or 8 lb. out of the flask; then the danger is past." The mere fact that he knew there was danger until 6 lb. or 8 lb. of gas had left the cylinder does not convince me that that engineer knows the nature of the gas he is dealing with, as although 6 lb. or 8 lb. have been taken from the cylinder, the danger is not past. With still 32 lb. of gas left in a 40 lb. flask, that 32 lb. will expand by the application of heat just as 40 lb. would do, provided you apply enough heat to the flask. I may make this point clearer by instancing an engineer about to put a charge of gas into a refrigerating machine. The valve on the CO_2 flask is first opened to see that there is a clear outlet before connecting up to the evaporator, but seldom is the charging valve on the evaporator opened before connecting up to ascertain if there is a clear passage into it—a precaution, I consider, that ought never to be neglected. It may be that that charging valve has got disconnected from its spindle. In that case the passage into the evaporator is blocked, and when a stoppage does take place a drop of methylated spirits and a bucket of hot water may be used to clear an obstruction, if such is caused by freezing; but if it is not caused by freezing, herein lies the danger. Engineers, when in a hurry, are apt to disregard instructions that may be sent out, but I am sure if they were fully conversant with the nature of the gas and the possibility of raising the pressure by a bucket of boiling water 700 lb. or 800 lb. above the normal, they would think twice before applying water even when in a hurry. Of course, if there is a clear passage into the machine, then I would not hesitate to apply hot water to expel the gas from the cylinder. In fact, it is necessary to do so to expel the last few pounds, because the pressure in the refrigerating machine would be equal to that in the flask. In regard to the lubrication of the pistons and valves, this plays a most important part in the efficient working of the compressing machine. The lubricators are fixed on the suction pipe of each compressor; by that means the gas carries the glycerine, which is used as a lubricant, through to the piston-rod, and lubricates the valves in its passage through them. This is a very important point as regards the valves, because the glycerine adheres to the valves, and so seals them that no leakage of gas from the high stage compressor can be returned to the lower pressure compressor. With proper attention the cup leathers of the second and third stage compressors give very little trouble. The leathers now in both these cylinders have seen nine months service; but I make a point of taking the leathers out once every month to soften them and to clean away any grit that may have lodged on them.

In further reference to the importation of German CO_2 into this country, the ordinary question of competition was not the point I was aiming at, but rather one of personal and public safety. I may point out to you that a firm of German CO_2 agents have been sending out circulars which contain a series of misleading statements. The statement that the committee's experiments, as far as they went, proved rejected cylinders to be of excellent quality and perfectly safe is incorrect. Their experiments proved exactly the reverse. Further, the German regulations are notoriously inadequate, as they specify neither quality nor thickness of metal. The committee, in their recommendations, specified both, thus introducing a vital condition of safety which overshadows all others in its importance, and it has until lately been sufficient to check the use in this country of light and brittle German cylinders. You must not lose sight of this point—that in all probability the firm I refer to may have never filled nor tested a cylinder in their lives, yet they are not only opposing the practice of every established gas compressor in this country, but also the regulations drawn out after careful investigation by a committee of the highest standing, who were specially selected by the Government for this very purpose.

In conclusion I would like to draw your attention to the expression "natural carbonic acid," often used to consumers. This is a mere expression introduced to obscure the point at issue. Carbonic acid is the same whether the reaction which produces it takes place above or below the earth's surface, and in each case it has to be separated from impurities before it can be used. The use of the terms "natural" and "artificial," therefore, either display ignorance of the true nature of carbonic acid or a deliberate intention to mislead the consumer.

ALL RIGHTS RESERVED.

INSTITUTE OF MARINE ENGINEERS

INCORPORATED.

SESSION 1905-1906.

President—SIR MARCUS SAMUEL.

Volume XVII.—Part II.

REPORTS ON SUMMER VISITS, SATURDAY AFTERNOONS.
May 20th, June 17th, July 15th, August 12th, September 16th, 1905.

ONE HUNDRED AND TWENTY-FOURTH PAPER.
OBSERVATIONS ON THE LEAD ACCUMULATOR.
By Mr. A. WAHTER (Member).
Monday, October 9th, 1905.

ONE HUNDRED AND TWENTY-FIFTH PAPER.
STEAM PIPE EXPERIENCES.
By Mr. D. S. LEE, R.N.R. (Member).
Monday, October 23rd, 1905.

ANNUAL DINNER.
Wednesday, October 25th, 1905.

LECTURE.
DEMONSTRATION ON PHOTO-ENLARGEMENT.
By Mr. H. LEASK.
Monday, November 6th, 1905.

ONE HUNDRED AND TWENTY-SIXTH PAPER.
DECIMAL AND METRIC SYSTEMS.
By Mr. F. COOPER, R.N.R. (Member of Council).
Monday, November 27th, 1905.

ONE HUNDRED AND TWENTY-SEVENTH PAPER.
SOME EXPERIENCES WITH CO_2 CYLINDERS.
By Mr. R. MACKENZIE (Assoc. Member).
Monday, December 11th, 1905.

ONE HUNDRED AND TWENTY-EIGHTH PAPER.
THE VALUE OF ANNEALING.
By Mr. JAS. ADAMSON (Hon. Secretary).
Monday, January 8th, 1906.

ONE HUNDRED AND TWENTY-NINTH PAPER.
FLUID WAVES.
By Mr. A. E. BATTLE (Member).
Monday, January 15th, 1906.

PRESIDENT'S ADDRESS.
Monday, January 22nd, 1906.

NOTICE.

The Institute as a body is not responsible for the statements made or for the opinions expressed in the following pages.

J. A.

CONTENTS.

LIST OF OFFICERS.

PRESIDENT:

SIR MARCUS SAMUEL.

COUNCIL:

W. C. ROBERTS (*Chairman*).

*W. LAWRIE (*Library*), (*Vice-Chairman*).

J. BLELLOCH.
J. CLARK.
*F. COOPER (*Press Cuttings*).
*J. E. ELMSLIE (*Issue of Transactions*).
J. G. HAWTHORN.
J. HULME.
*J. MCLAREN (*Reading Room*).
C. W. MURRAY.
*J. R. RUTHVEN (*Papers*).
*S. C. SAGE (*Property*).
*W. I. TAYLOR (*Recreation*).

H. BERTRAM (*Hon. Min. Secretary*).
E. W. ROSS (*Hon. Fin. Secretary*).
A. H. MATHER (*Hon. Treasurer*).
JAS. ADAMSON (*Hon. Secretary*).

VICE-PRESIDENTS:

J. K. AITKEN (Africa).
J. C. ANDERSON (China).
W. BIRKETT (Bombay).
W. BLACK (Callao).
JAS. BLAKE (London).
A. BOYLE (Southampton).
W. BROCK (Dumbarton).
A. B. BROWN (Edinburgh).
G. W. BUCKWELL (Barrow).
P. T. CAIRD (Greenock).
ENGINEER CAPTAIN R. EDWARDS, R.N.
PROFESSOR A. C. ELLIOTT (Cardiff).
C. H. GILBERT (Valparaiso).
JAS. GIRVIN (Chief Engineer).
J. MCF. GRAY (London).
W. B. HARE (Queensland).
R. LESLIE (London).
J. LOCKIE (Leith).
*W. MCLAREN (London) (*Experimental*).
E. O. MURPHY (China).
JAS. NEILSON (Calcutta).
W. J. PRATTEN (Belfast).
J. W. RICHARDSON (Liverpool).
H. T. RICHARDSON (Vancouver).
JAS. SHIRRA (New South Wales).
C. SLATER (Chief Engineer).
J. STEVENSON (Chief Engineer).
J. STEWART (Newcastle).
JAS. WEIR (Glasgow).

* *Conveners of Committees.*

Resident Officer in Charge of Premises:

GEO. RUMSEY.