and Figure 8 shows how accurately the thickest and hardest armour plate can be cut by means of oxygen.

Oxygen is also being extensively used at the fighting front for cutting away wrecked ironwork in bridges, buildings, etc., and for construction and repair of aeroplane parts, and also for saving human lives.

In fact, the Commonwealth Oxygen Co., Ltd., had to send home to England several hundred oxygen cylinders of the sizes used for medical purposes, about the time when we first read of the use of poison gas by the Germans, and I have no doubt that large quantities of oxygen were used in endeavouring to alleviate the sufferings of the victims of the poison gas, as oxygen resuscitating apparatus is always at hand in mines and places where workmen are liable to be overcome by noxious gases or fumes, and when the history of the great war comes to be written, we shall find that in many ways the part played by oxygen was of great importance.

Bibliography.

"Thorpe's Dictionary of Applied Chemistry."

"Handbook on the Use of Compressed Oxygen," by K. S. Murray.

DISCUSSION.

Mr. D. F. J. Harricks, in moving a vote of thanks to the author for his excellent paper and demonstrations, said he had no doubt that it at once proved interesting and instructive to all of them. When we consider the progress that has been made in the Commercial Manufacture of Oxygen, it is useful to remember that it is only a matter of comparatively recent years since this has been successfully done, and when one is reminded that the fractional distillation of liquid air appears to be the method now almost universally adopted for obtaining oxygen on a commercial scale, it must recall to the memory of practically everyone in this room the controversy that took place only a few years ago on the subject of "liquid air."

Perhaps the successful manufacture of oxygen was long delayed because of there being apparently a much lesser need or demand for it than was the case with many other gases; for instance, carbon di-oxide, or carbonic acid gas, which, as every engineer knows, is used for a multitude of purposes. The successful liquification of this gas, which was the first to be liquified, was achieved as far back as 1873, and was principally the result of the efforts of Davy and Faraday.

With regard to the chemical aspect of the author's paper, whilst this has been of very great interest, I am unable to criticise it, but when he states in the second half of his paper the relatively great importance to the gas user of the means adopted for the distribution of the gas, this matter is one of personal interest, as the conditions of handling are very similar to those obtaining with regard to carbon di-oxide, or carbonic acid gas. It is perhaps generally known that this latter gas is very largely manufactured here in Sydney—in fact, practically the whole of the gas used in the Commonwealth is made at the works of the C.S.R. Co., Pyrmont. The gas itself is not merely manufactured, but is given off from molasses when being decomposed under a fermentation process, and during the transformation of the sugar in the molasses into alcohol and carbonic acid the gas is given off from the ferment vats and collected therefrom. The process consists of collecting, washing, purifying, and compressing the gas into liquid form for distributing in the commercial CO^2 tubes, or bottles. The plant is very extensive, and requires expert management and control.

Mr. Bremner has, very rightly, referred to the importance of the very strict regulations that are enforced with regard to the manufacture of CO^2 tubes or bottles, for, when it is remembered that these little vessels contain gas compressed up to, say, 900 lbs. per square inch, it will be realised that they are very potent engines of destruction if, owing to careless construction, they should burst. I think I can safely say that, although many hundreds of bottles of this material are handled every week, and it is distributed all over the Commonwealth, and even beyond the Commonwealth, that a burst bottle is unknown—that is, outside the testing house. This is, of course, the result of the great care that is taken in the manufacture, and care when in use, of the bottles; and, in this respect, although Mr. Bremner has referred to the difference in the thickness of the material used in the construction of the continental bottles as compared with the British, it would be almost impossible to say whether there is any point of superiority in one over the other, and the question of thickness of the metal is important when one considers the extra cost of transport for the same weight of gas carried. The French or German bottles weigh very many pounds less than those constructed according to the British regulations. It is, of course, all a question of the tensile strength of the steel used, and although one would go for the British article, I mention the point to indicate how in a matter of this kind the Continental manufacturers have an advantage, and to show the necessity for our satisfying ourselves that safety and efficiency are not being overstressed if it can be shown that the greater experience of the Continental makers has produced a better article.

Mr. Bremner has referred to the necessity for fitting safety devices to the valves attached to the bottles containing CO^2, and there is no doubt that he is right in this respect, for, if a vessel filled with liquid CO^2 is subjected to much heat, the expansion of the liquid would result in a burst bottle if this was not fitted with a safety device. Several precautions are taken to prevent such a thing happening: the bottles are never filled full of CO^2 so there is always space for expansion of the liquid, and it is known from long experience that the safety devices are very efficient.

Although I quite understand that oxygen, being a fixed gas, and when under pressure does not require any safety device, I nevertheless feel, although unable to give good reasons, that every vessel containing gas under very high pressure would be better for such a device.

I have brought with me to-night a CO^2 bottle valve containing a bursting device of much ingenuity, and which I thought you would be interested to see.

Referring again to oxygen, as Mr. Bremner has pointed out, the most important use to which this is now applied is in the oxy-acetylene process for welding or cutting metals. The use of this plant has become almost universal, and no modern engineering or machinery shop of any size can be considered complete without a plant of this description. Those of you who have had experience with this plant could doubtless give many examples in which its use has been of immense value in saving time and money. I know that in the various factories of the Colonial Sugar Company the use of the flame has been of very great value, and the fact that we consume approximately an average of 18,000 cubic feet (or 180 bottles) per month of the oxygen turned out by Mr. Bremner's establishment is a sufficient indication of the extent to which we use it.

I would ask Mr. Bremner whether there is any way in which the nitrogen obtained by the rectification of liquid air can be used for some useful purpose? It seems to be so very desirable that, after separation of so large a portion of nitrogen from the air, it would be used for artificial nitrogenous manure, or some other purpose.

At the present time, when explosives are so much in our minds, I would also ask Mr. Bremner if he has had any experience in the application of liquid air, when mixed with powdered charcoal or other finely powdered organic bodies, to form an explosive? I understand that, as an explosive, it is comparable in violence to dynamite, but that it must be prepared on the spot where it is to be used, since the liquid evaporates in a very short time and the explosive power is lost. On the other hand, if a charge should fail to go off, and consequently loses its explosive capacity, it would appear to be a very safe explosive.

It is, no doubt, merely a clerical error, but should not the figures given on page 4 for the boiling temperatures of nitrogen and oxygen by reversed, because, of course, as the author has stated, the boiling point of nitrogen is lower than that of oxygen—in fact, 13%?

Mr. A. W. Tournay-Hinde: It has interested me exceedingly, as I think it has all of us, to have listened to the very excellent paper by Mr. Bremner on the separation of oxygen from the air. Until to-night I have never had an opportunity of seeing liquid air, and therefore Mr. Bremner's experiments were novel and interesting to me, as I have no doubt they must have been to many others.

With regard to one experiment—I was going to say the smoke—the condensation of the moisture in the air of the room around the top of the vessel at the moment boiling took place in the liquid air was quite remarkable. I take it that when the humidity of the air is greater than at the present moment this effect would be still more pronounced.

Mr. Harricks, who moved the resolution for a vote of thanks, has rather cut the ground from the few notes I have made here in connection with Mr. Bremner's paper, and therefore I cannot traverse as much of the paper as I would have wished. I shall be interested to learn what type of valve is used in the air compresser, where the compression of air takes place at such high pressure. Even in the compression of air at much lower pressures than that mentioned the question of the tightness of the valves and piston is of considerable moment, and calls for skill on the part of the designer. Also, I should like to know the methods used for lubrication inside the cylinders.

There is another matter also in connection with the air compressor. I understand that the air is drawn in through certain apparatus for the purpose of purifying the air before it enters the cylinder, and therefore the suction pressure must be below the atmosphtre to a greater extent than which would be the case had the air come direct to the cylinder without having to pass through a mass of material such as lime with a blanket of canvas over the top of it. This would make the question of the air filling the cylinder in the first stage of the compression rather more difficult than is usually the case.

My next note refers to the question of nitrogen, which Mr. Harricks has already asked a question about. It has occurred to me that where so much oxygen was separated from the air, a considerably larger quantity of nitrogen would, of course, remain, and, to the uninitiated, it does seem a pity to return that to the air without trying to make commercial use of it. I suppose the manufacture of nitrate of potash is not possible on account of the absence of alkali manufacturing plants in Australia. I would ask the author if a small plant for the manufacture of hydrogen were added would it not be possible to produce ammonia in some form that would be commercially possible?

Before sitting down, I should like again to express my appreciation of the paper. It is a paper dealing with very recent commercial chemistry, and relates to a subject upon which most of us have no opportunity of getting first-hand information. I am sure we all appreciate the generosity of a member of this Association who has prepared a paper so explicit and full of detail as that which we have had from Mr. Bremner this evening.

I have very much pleasure in seconding the resolution.

MR. WILLIAM POOLE said that, as a question had been asked about a possible use of nitrogen, perhaps he might throw out the suggestion that as it was practically a dead gas, containing no oxygen to any appreciable extent, it might be used for the purpose of fumigation.

MR. B. GALE: I am not a member of the Association, but I am very grateful at being here by invitation. Two or three gentlemen have raised a question as to the utilisation of nitrogen. Nitrogen is a very inert substance chemically, and has a very strong objection to combining with anything. That is, it prefers to exist as nitrogen, and nothing else.

In Germany, and I think, in Sweden, where they have other power (water power), and where labor is cheap, they can convert nitrogen into oxides of nitrogen, and also into ammonia, by electrical means. They pass the nitrogen and oxygen, or nitrogen and hydrogen, through pipes in which is an electric arc, and some of the nitrogen then combines with some of the oxygen or hydrogen, forming oxide of nitrogen, or ammonia. Nitric acid is very largely used in making explosives. Probably the Germans have been hard put to find nitric acid for war uses.

There is one other point I should like to ask Mr. Bremner about, and that is with regard to the purity of the waste nitrogen. He made the remark that a process was perfected by which the nitrogen comes away almost pure. That is a very curious thing, and I should like to know, as a matter of curiosity, to what extent the oxygen is recovered—say, out of 20% of oxygen in the air, how much is actually recovered? Is it 16%, or 18%, or what?

There is one other little point: I noticed, in the diagram of the separator, two outlets—one for the oxygen vapour at the bottom, going out into the inter-cooler; the other for nitrogen vapour, at the top. How is that supply of oxygen regulated? They can either blow it easily through the inter-cooler pipe or else bottle it up and force it to bubble up through the liquid air.

I should like to express my deep thanks to Mr. Bremner for his very interesting paper; it has been most instructive. It is the first time I have seen liquid air myself, although I have read about it very often.

MR. J. McNAMARA: I am sorry that the author touched so lightly upon the electrolytic process of manufacturing oxygen, but perhaps he is of the opinion that the production of this commodity by the electrolytic process is not a payable one in Australia owing to the cost of electric power.

We certainly are at a disadvantage here in this respect, for although power at 1½d. per unit is, on the surface, a fairly reasonable figure, for such purposes as the one referred to, even this charge is prohibitive. I would like the author, if possible, to say if it is this initial cost for electric power that is the drawback to this process, for it seems to me that for small plants up to, say, 1000 cubic feet capacity per day, that there is no simpler or more satisfactory method.

As far as I can gather, a cell of 500 amperes capacity is capable of generating at least 50 cubic ft. of oxygen per day of 24 hours, and, as each cell must have at its terminals an E.M.F. of at least two volts to set up the decomposition of the water, on account of the affinity of hydrogen to oxygen being in a neighbourhood of 1.47 volts, we have the two factors that determine the power input to each cell, and can reasonably arrive at the cost of production if the cost per unit of the power supply be known.

I do not think the other apparatus in an electrolytic plant is any more elaborate than a liquid air plant, and perhaps any difference in the motive power mentioned by the author is brought about in the first instance by the use of a motor generator for the production of the low voltage current required to operate the electrolytic cells. I would like to know if this is the case. This, of course, might be overcome by use of a low voltage dynamo, in the first instance in the case of a firm generating their own power supply and re-using their steam for other purposes, as for example the C.S.R. Company and other manufacturers.

The cycle of operations for an electrolytic plant is simple and is as follows:—Upon leaving the electrolytic cells, the oxygen is passed along to the gas holder, which is of the standard type, in which an inverted bell is suspended over water by means of a counterweight. As the oxygen enters the gas holder the bell rises, and when it has reached a predetermined limit—or when the gas holder is filled to its capacity—an automatic switch is thrown, which starts the electric power that drives the oxygen compressor. This results in pumping oxygen out of the gas holder and compressing it in the oxygen pressure tanks. These tanks are usually arranged for a maximum pressure of 300 pounds per square inch, and when this has been obtained a pressure regulator of the Bourdon spring type, which is located on the switchboard, throws a relay that, in turn, trips the compressor motor switch and stops the compressor.

While the compressor is in action it will be evident that oxygen is being withdrawn from the gas holder, with the result that the bell descends; and when the bell has reached the lower limit of its travel—so that practically all of the oxygen has been pumped out of the holder—an independent electric switch will be thrown to stop the compressor motor. When the compressor is stopped in this way, the motor generator continues to run, so that the supply of oxygen from the electrolytic cells is continued until the gas holder is filled to its capacity. When this result is obtained the normal sequence of events would be for the switch which governs the compressor motor to be thrown over in order to start the compressor. It may happen, however, that the pressure in the oxygen tanks is at the maximum of 300 pounds per square inch; when such is the case means are provided to make it impossible for the switch to be thrown to start the compressor motor. Under such conditions an automatic switch is thrown, which stops the motor generator and cuts off the generation of oxygen in the electrolytic cells. As soon as the oxygen in the pressure tanks has been partially consumed, thus lowering the pressure, the compressor motor automatically starts to deliver more oxygen to the pressure tanks, with the result that the gas holder starts to descend. This, in turn, closes the switch controlling the motor-generator set, which re-starts the motor generator and causes the electrolytic cells to begin to generate more oxygen.

The President: During the course of the wizard-like experiments which Mr. Bremner has been kind enough to show us in the course of his lecture, I could not help thinking of the old proverb, "There is nothing new under the sun," for did not our old friend Shahrada, in the "Arabian Nights," forecast something of a similar kind when describing the genii shut up in a bottle who could do all sorts of things if people only knew how to ask him. I do not think that even one of the old wizards had more interesting demonstrations to give than Mr. Bremner has given us to-night.

Very little has been said about the practical application of the oxy-acetylene process, but I should like to tell you of an interesting case which came under my notice recently. The shell of a boiler cracked just where the flame of the furnace beat most fiercely on the joints. Two or three cracks developed through the rivet holes. The rivets were cut out, and a V-shaped notch cut out the full length of the crack, with the top of the V downwards; this notch was then run in with metal by means of the welding process, and so satisfactorily was this done that, although the working pressure of the boiler was originally fixed by the inspector at 150 lbs. per square inch, he was quite ready after the welding up had been done to allow the working pressure to remain at 150 lbs. Possibly many members have had similar experiences.

I have much pleasure in passing to you, Mr. Bremner, the vote of thanks, and I ask you to be kind enough to reply to the points raised by the several speakers.

MR. J. F. HOWARTH: I am a bit late in stepping in, but as Mr. Bremner is going to reply, I would like to ask him if he has, in the course of his experience, seen or heard anything of an engine in which liquid air was used as motive power?—I remember some years ago reading an article in the "English Mechanic," when liquid air was first brought into existence, that an engine had been designed in which liquid air was used. I have retained all my numbers of the "English Mechanic" from 1880 upwards, and I think I could turn it up, but I understand in those times very decent results were obtained from liquid air as a motive power.

Treating of nitrogen, as a consulting engineer, I have been approached in connection with an invention. Twenty years ago some very interesting experiments were made in connection with it, but the conditions not being complied with, the results were abandoned. I think it will be a good outlet for nitrogen gas.

Mr. Howarth also referred to the difference in the strength of the British and German cylinders, and said that he thought the British standard was to be preferred every time.

Mr. Bremner (in reply) said:—

To Mr. Harricks: Nitrogen obtained by the rectification of liquid air is not put to any practical use in our works here, except as stated: that its cold is utilised in cooling the incoming air. It contains from 6 per cent. to 9 per cent. of oxygen. I have been approached by medical gentlemen to supply them with pure nitrogen, which, I understand, is used in cases of lung trouble, but the demand would be so small that it would not pay to put down compressing plant to deal with it.

Liquid air has been used as an explosive, and I believe an English company uses it to manufacture metal cartridges, which explode when the internal pressure has sufficiently increased; and favourable results are obtained in working mines where explosives producing flame could not be used without danger. An explosive is made with coal and liquid air. Liquid air was used as an explosive in making the Mount Cenis tunnel in Italy.

Mr. Harricks is correct as regards the boiling temperatures of oxygen and nitrogen. Oxygen boils at 91.5 degrees absolute, and nitrogen at 77.5 degrees absolute. The figures are incorrectly stated in the uncorrected proof before you.

To Mr. Tournay-Hinde: The type of valve used in the air compressor is a flat disc valve. These valves have to be very accurately ground up and bedded. The valves in the oxygen compressor are of the mitre type, which, however, require a good deal of attention, as they wear a good deal. Oxygen cylinders are pumped to a higher pressure than 1800 lbs. per square inch to allow of the contraction of the gas in cooling to normal temperature. Pressure gauges record each stage of the compression, and there is a gauge on the filling pipe attached to the cylinder being pumped up, as a check on the high pressure gauge on the compressor.

There is not much resistance or increase to the suction pressure of the air in being drawn through the lime purifier. We have made tests, which show that the lime does not offer much resistance to the passage of the air through it.

The lubrication of the 2nd, 3rd and 4th stage plungers is effected by means of ratchet feed lubricators worked off the crossheads.

Liquid air is sold at 15/- per litre, and the vacuum flasks (which we send it out in) are expensive. Liquid air cannot be kept for long periods even in silvered vacuum vessels. It evaporates from them at the rate of from 5% to 15% per 24 hours, depending on the size of the vacuum flask.

As you suggest, ammonia could be produced by the addition of a hydrogen plant to deal with the escaping nitrogen, were the nitrogen pure, but this has not been done as far as I know in any of our works.

To Mr. Poole: I do not recall any case where nitrogen has been used for purposes of fumigation.

To Mr. Gale: The escaping nitrogen contains a small percentage of oxygen, and, to overcome this, Claude, the French scientist, made a modification in the apparatus which gave practically pure oxygen and nitrogen. What the actual percentages recovered are, I am not prepared to say exactly.

Mr. Gale's second question: After a few hours' continuous working the pressure of the incoming air is lowered in the separator coils, as the separator becomes cooled down. The working of the separator is controlled partly by the expansion valve, by means of which the height of liquid oxygen in the vapourizer is regulated, and to a certain extent also by the valve through which the oxygen leaves the separator on its way to the gas-holder.

To Mr. McNamara: The reason why the electrolytic process for the manufacture of oxygen is not more widely used in Australia at present is not so much the high cost of electricity as the fact that, up to the present time, there has been no great demand for hydrogen here. By this process two volumes of hydrogen are produced to one of oxygen. The principal means by which hydrogen may be utilised is in its catalytic use for the conversion of raw oils into stearine products for making soaps and candles, and for edible fats, a large amount of hydrogen being used in these processes.

I believe there is an electrolytic plant for the production of oxygen in Victoria, but I do not know if there be a large outlet for the hydrogen. Hydrogen is also used in the manufacture of metallic filament electric incandescent lamps, to envelop the filament in the course of its preparation. Nitrogen is also employed for this purpose, and there are extensive works in Sweden where nitrogen is used in the conversion of calcium carbide into calcium cyanamide, which is used as a fertiliser, and, although there is no factory producing nitrogen for this purpose as yet in England, there probably will be such before long.

To Mr. Howarth: Liquid air has been used as a motive power, and a cab driven by liquid air has run on the streets of London, and was exhibited at the Paris Exhibition in 1900, which was proof that liquid air could be employed as a motive power; whether it was an economical and paying proposition is another question.

I thank you, Mr. President and gentlemen, for the way you have received my paper.

The proceedings terminated.