cally sealed space of about \( \frac{3}{4} \) in. across. When this space was highly exhausted, air conduction and convection were eliminated, and the heat transference was reduced to one-sixth of its previous amount. When the surfaces were brightly silvered, radiation was also checked and the rate of transference fell to one-thirtieth.

By actual heating of liquid air in a vessel over a flame it was shown that the nitrogen distilled off first and that the residue was liquid oxygen. Smouldering splinters of wood burst into flame in the gas above the liquid, and continued to scintillate brilliantly when plunged below the surface. Similarly the separation by distillation of liquid air floating on the surface of water was shown, with the gradual sinking of large globules of the heavier liquid oxygen as the lighter nitrogen distilled off.

The explosive combustion of cotton wool saturated with liquid oxygen was also shown, as was also the rapid evaporation of liquid air when thrown on the floor, without any "wetting" of the surface, the formation of ice, etc.

A number of other experiments were also given.

**The Combustion of Iron in Oxygen.**

The President said that Mr. Grimwade had shown them what could be accomplished by temperatures of 313 deg. below the zero of the Fahrenheit scale; Mr. Fyvie would give a demonstration of what could be done at temperatures of from 6,000 to 7,000 degrees F. above that point.

They had been shown how oxygen could be produced. They would be shown what it could do. In the meantime he proposed to repeat an old experiment that would serve, in a sense, to connect the two demonstrations, and which would fix the concept that under certain conditions iron was to be considered as a fuel.

Strips of steel about \( \frac{3}{8} \) x \( \frac{1}{5} \) were tipped with a drop of sulphur to serve as a match, and, after the sulphur had been ignited, were immersed in a jar of oxygen-gas, when they burnt brilliantly until entirely consumed.

The experiment was old, but it was the key to the modern systems of metal-cutting. The metal was not merely melted out as wax would be before a candle flame, it was actually burnt, as coal would be, and was a true fuel.

**Abstract of Lecture on Oxy-Acetylene Process of Welding and Cutting Metals.**

Delivered by Wm. Fyvie.

(Member of Council).

The lecturer said he had pleasure in complying with the Council's desire for a demonstration of the use of oxygen and acetylene in high-temperature engineering and metallurgical work.
Welding:

The oxy-hydrogen system of autogenous soldering of lead had long been favourably known. Now the higher temperatures of the oxy-acetylene flame rendered a parallel process applicable to more refractory metals and had constituted it a serious rival of electric welding.

Acetylene (C₂H₂) is nearly as heavy as air, being in the ratio of about 13 to 15. It is endothermic, that is, it decomposes into its elements (carbon and hydrogen) at the moment of combustion with an evolution of heat. The generation of heat from this cause is about 300 B.T.U.'s per cubic foot, the heat derived from the subsequent combustion of the carbon, in oxygen, to carbon dioxide, and of the hydrogen to water vapour, raising the amount to about 1,500 B.T.U.'s per foot.

Theoretically, about 2 1/2 volumes of oxygen are required per volume of acetylene, but in practice about 1.7 volumes give more desirable conditions.

The flame thus produced consists of a small central cone, almost entirely of carbon monoxide, burning at its apex into carbon dioxide with a resultant temperature of about 6,300 deg. F. The surrounding envelope consists of a relatively cool jacket of hydrogen, which cannot combine with the oxygen at that high temperature, and which protects the flame from loss of heat, and the metal being operated upon from oxidation.

The heat is greater than that from any other flame, and it is more concentrated; also, since it is luminous, the work can be directed.

The system shown is of the high-pressure type. Oxygen is supplied from an ordinary trade cylinder, acetylene from a cylinder in which it is absorbed in a liquid hydro-carbon—acetone—saturating a porous inert material. Acetone absorbs about 25 volumes of the gas at atmospheric pressure; proportionately more at higher pressure.

In injector blowpipes the oxygen is supplied under a pressure of from 15 to 40 lbs. per square inch, and draws in the necessary supply of combustible gas in a thoroughly mixed condition and with a sufficient final pressure. This requires very careful designing to give safety and to prevent back-firing and the deposition of carbon in the orifice.

Welding by the process does not supersede forge welding; but it is a very portable system, and in cost compares favourably with brazing or rivetting, and it enables difficult work to be done in situ.

It is found that the strength of the material does not suffer. Welded bars of Staffordshire iron have resisted 29 tons per square inch, and welded plates from 20 gauge and upwards thick have parted elsewhere than at the joint in testing.
The speed varies with the proficiency of the workmen and the size of the flame used. The following are working results:

<table>
<thead>
<tr>
<th>Thickness of plate</th>
<th>Feet runs per hour</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/8&quot;</td>
<td>30</td>
</tr>
<tr>
<td>1&quot;</td>
<td>14</td>
</tr>
<tr>
<td>3/4&quot;</td>
<td>6</td>
</tr>
<tr>
<td>2&quot;</td>
<td>4</td>
</tr>
</tbody>
</table>

These results are for cold plates. If heated, plates from 3/8" thick upwards can be dealt with at rates of from 30 to 50 per cent. quicker.

Repairs to steam boilers, jointing of tubing, welding in many places where brazing is now used, welding of tanks, and plates of boats instead of riveting, are within the scope of the method, as is also the autogenous soldering of copper work.

Demonstration:

The apparatus was described and its action illustrated and explained in detail.

Two pieces of 3/8" thick mild steel plate about 3" long were placed in juxtaposition on a fire-brick. A flame from a small blow-pipe was directed upon the contact edges, and a piece of 3/64" dia. soft iron wire was used as a "solder." The weld was completed in about two minutes. Specimens of 1" bore, 3/8" thick W.I. tube were similarly joined.

Metal Cutting by Flame:

The blowpipes for this purpose consist of an annular orifice through which a jet of mixed acetylene or, alternatively, ordinary coal gas, and oxygen is forced, and a central independently controlled jet of unmixed oxygen. Coal gas is used for new or clean work free from heavy scale. Acetylene is used when there is heavy scale or when the work is difficult of access.

The object of the annular jet is to raise the metal to incandescence; then the oxygen jet is made to impinge on that hot spot when, as the experiment made by the President had shown, the metal itself would become ignited and burn. Strictly speaking, at that stage the annular jet would be no longer required; but in practice it is necessary to continue it to maintain certainty of combustion and to prevent particles of oxide impinging on the oxygen nozzle and choking it.

The cutting operation is very simple and can be mastered by any intelligent workman in a few hours. By the use of guiding devices the cutting may be made to follow straight lines, circles, ellipses, etc., at a speed comparable to hot sawing and with a resultant division equally sharp. Thicknesses up to 8" in. can be dealt with, the pressure of the oxygen—which is about 15 lbs. per square inch for 3/8" work—increasing proportionately.

The following working speeds have been attained:

<table>
<thead>
<tr>
<th>Thickness of plate</th>
<th>Feet runs per hour</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/8&quot;</td>
<td>60</td>
</tr>
<tr>
<td>1&quot;</td>
<td>40</td>
</tr>
<tr>
<td>1 1/2&quot;</td>
<td>30</td>
</tr>
<tr>
<td>2&quot;</td>
<td>20</td>
</tr>
</tbody>
</table>

Instances were cited of methods of boiler repair and of the cutting asunder of steel vessels, in dock, as a preliminary to lengthening.
Demonstration:

Bars of 4" by 3" mild steel were cut by a small blow-pipe with oxygen at a pressure of about one atmosphere, and using coal-gas instead of acetylene. The bar at the first endeavour was severed in 1 minute 2 seconds, in the second trial in 54 seconds. It was explained that the rate for wider plates would be less, as most of the time was occupied in attaining the preliminary incandescence. The cut was about 4" wide and showed sharp edges. As an answer to a question by Mr. A. E. Smith, a hole was punched through a "blind" plate by the use of the flame in about one-half minute.

PAPER.

SOME NOTES ON WATER MAINS.

By Thomas Walker Fowler.
(Member of Council).

When the writer was designing the works for the Water Supply of Warragul (the contracts for which have recently been let), certain points in connection with water mains arose, concerning which some notes may be of interest to the members of this Institute. It speedily became evident that whilst some portions of the main pipe line would be subject to very heavy pressure, a considerable length of it might be located on ground of elevation near to that of the hydraulic grade line. Under these circumstances, the most suitable and economical type of pipe became a matter of serious consideration.

In view of the extensive and successful use of reinforced concrete in other classes of work, its suitability for use in the pipe line was a matter to be enquired into. The writer was aware that pipes of this class had been most successfully used in connection with the Paris Water Supply, where, in 1904, 170 kilometers (105 miles) of such pipes were in use with great success, the diameters varying from 0.30 m. to 2 m., or from say 10 inches to 6.8 inches. Working pressures of 33 m. (105 feet) were taken with pipes in which cement alone was depended on to secure watertightness, higher pressures (55 m. working and 118 m. test) were taken with pipes built on the Bonna system, in which a thin metal tube is depended on for watertightness, being covered with layers of reinforced concrete, both inside and outside. The interior coating being to resist corrosion, whilst the reinforcing of the outer coating would no doubt assist in raising the bursting pressure of the metal tube, as well as protecting it from corrosion. Further enquiries showed that reinforced concrete pipe lines had been used successfully under considerable pressures, one of the most notable being that at Swansea, with a working head of 185 feet, and 19.7 inches diameter. Investigation also showed that reinforced concrete pipes had been used on parts of the Coliban system, and at Mildura; the maximum pressure being 50 feet. Accordingly, the writer made enquiries amongst Australian
DISCUSSIONS.

THE COMMERCIAL PRODUCTION OF OXYGEN.
(W. RUSSELL GRIMWADE.)

THE OXY-ACETYLENE PROCESS OF CUTTING AND WELDING METALS.
(W. FYVIE.)

On the suggestion of the President, and with the concurrence of the Authors, these notes were discussed conjointly.

The President said that Mr. Grimwade had mentioned the discoverer of oxygen—Priestly. The description of the original processes and the plates illustrating them, contained in Priestly's original work, might interest members [the volume was exhibited]. There were several points in the paper which he would like to refer to briefly:

First, as to the concentration of the oxygen of the air by repeated absorptions by water as outlined in the notes, i.e., "In 1869 Mallet endeavoured to effect a separation by working on the difference of solubility of the two gases, oxygen and nitrogen. Oxygen was nearly twice as soluble in water as nitrogen and by a process of pumping under pressure, blowing off, and exhausting, an atmosphere of enhanced oxygen contents was obtained." The approximation given (double solubility) was correct, but only under limitations that had not been expressed, i.e., if the temperatures were constant and the absorption was, in each case, from an atmosphere of the pure unmixed gas. Now atmospheric air consisted, broadly, of 21 parts by weight (or pressure) of oxygen and 79 parts by weight (or pressure) of nitrogen. So the matter stood thus:

First Absorption:

Oxygen pressure, 21 x (co-eff. of absorption, = 2), = 42
Nitrogen pressure, 79 x (co-eff. of absorption, = 1), = 79
Ratio of absorption of O to N = 42:79, = 1:2, nearly

Therefore the absorption of oxygen as compared with nitrogen in the first stage would be one-half only, not twice that of nitrogen, although as the number of stages was multiplied the latter figure would be approximated as an ultimate condition. Some data in this connection would be found in a paper by himself on "Air in Relation to Boiler Feeds," published in the "Proceedings"* of the Institute.

As to "centrifling," Mr. Grimwade had found that the rotation of a 4 ft. dia. drum running at 1,000 r.p.m. gave a barely detectable increment of the oxygen. That result was to be anticipated at that speed; but the effect would rise very rapidly with increment

*Vol. v., pp. 57, 89; 1904.
in speed, in accordance with the well-known laws relating to centri-
fugal tendency. It was quite possible to run a 2 ft. disc at 30,000
r.p.m. That was thirty times quicker than the rate attained in
Mr. Grimwade’s experiment, and the effect varied as the square
of the r.p.m. for equal diameters, therefore were the disc 4 ft.
dia., the effect would be increased 900 fold, but as a 2 ft. disc was
assumed, the effect would be enhanced by half that amount only,
equal to 450 fold. It was quite possible that such figures might be
within the limits of commercial application.

After the last meeting some members had questioned whether
in the combustion experiment (steel in oxygen) he had himself
shown, the effect was not largely due to the carbon in the steel.
Of course the carbon exercised an effect, but it was exceedingly
small. Thus one pound of iron had a fuel value of about 28,55
B.T.U.’s, whilst the figure for carbon was about 14,500 B.T.U.’s.
But in each pound of the steel in question there was only about one
per cent. of carbon, therefore there would be only about 145
B.T.U.’s. liberated by its combustion. The iron was practically
the sole fuel.

Mr. Fyvie had stated in regard to the oxy-acetylene flame
that: ‘‘The surrounding envelope consists of a relatively cool jacket
of hydrogen, which cannot combine with the oxygen at that high
temperature [6,300 deg. F.], and which protects . . . the
metal being operated upon from oxidation.’’ Was not this an
intentional condition, brought about for the purposes of the
method by the fact previously mentioned in the paper that, ‘‘Theo-
retically, about 2½ volumes of oxygen are required per volume of
acetylene, but in practice about 1.7 volumes give more desirable
conditions?’’ Was there not uncombined hydrogen owing to an
intentional defect of oxygen?

Mr. J. Alfred Griffiths (Soc. Chem. Industry, Vic.) drew
attention to the Jouber process of oxygen production, which ob-
viated the necessity for the use of compressed oxygen for casual
purposes, when using only moderate quantities of gas.

Instead of decomposing the usual peroxidised chemicals in a
retort by external heat, the chemicals were made into a slow
burning briquette, or cartridge, with a small percentage of carbon
and a diluent mineral to prevent complete liquefaction and ex-
plosion. The ingredients used were potassium and sodium per-
chlorates, oxides and nitrates, 3 to 5 charcoal and 20 to 50 per
cent. of kieselguhr.

The briquettes, or cartridges, were placed in a closed cylinder
and ignited, and the gas was gradually formed and used as re-
quired, and the carbonic acid was removed by alkali. In the
latest apparatus the combustion chamber had the lower half filled
with pumice soaked in alkali, was enclosed in a strong external
shell, and was provided with taps for exchanging connections
without interrupting the supply.

Mr. P. Avdall (Society of Chemical Industry) said Linde had
done a great deal towards the production of oxygen from liquid air. In 1895 he separated oxygen from liquid air by simple evaporation of the nitrogen. That process was wasteful and produced oxygen of a purity of only fifty per cent.

In 1902 he discovered the process of making oxygen from liquid air by distillation in a Coffey still. A Coffey still combined a number of rectifications in one series—each tray might be considered a still. Relatively it was just as if the ordinary Coffey still had to be worked in a red hot room. By this process Linde produced oxygen of a purity of 98 per cent.

Claude had discovered a process similar to that of Linde, which consisted of two rectifying columns, one above the other. By this means he obtained pure oxygen and also pure nitrogen.

The President said he took it that the "nitrogen" included argon.

Mr. Avdall said it was nitrogen and the gases associated with it.

The President called on Mr. Grimwade to reply to that portion of the discussion which concerned him.

Mr. W. Russell Grimwade said regarding the President's reference to Mallet's process, he had not had an opportunity of going into that fully at the previous meeting. He had merely stated that the principle was the difference of solubility of the two gases in water and that a point of differentiation between the two gases had been found. That (a point of differentiation) seemed to be the difficulty, because we were unfortunately situated in having two gases in our atmosphere which had most of their principal factors so close to one another that the slightest difference had to be taken account of. All these physical processes necessitated a great number of cycles being put through to effect anything like a complete separation of the two gases.

With reference to the allusion to centrifling air, the President had certainly been able to put a very enhanced value on his rough experiment. But he would point out it was not entirely centrifugal action which obtained on the air undergoing the process. The particles could hardly be separated by centrifling as particles of milk were in a separator. It was a far more complicated process. He thought the President's enhanced values would be modified if the complicated details were worked out.

As to the Joubert process, he had not seen it in operation; he had heard of it. The only allusion he could make to it was that although it did away with the necessity of compressing oxygen, he hardly thought it would stand in the matter of economy with the liquid air process. The oxygen could be produced by liquid air at a rate which entirely put out of court the employment of even the cheapest chemicals.

The allusion to nitrogen and argon was interesting. Speaking from memory he brought out a point of difference in the Claude and the Linde machines, which operated on almost identical lines.
They, however, each had enough difference to obtain patents for their respective countries, and to appear on opposite sides in a court of law, as they had done recently over the oxygen generated from liquid air. The nitrogen carried away the argon and other gases in the atmosphere. The Royal Institution, wishing to investigate these rare gases of the atmosphere, evaporated some twenty tons of liquid air in order to get enough to work upon.

The President called upon Mr. Fyvie to reply to those portions of the discussion concerning his notes.

Mr. WM. Fyvie said he thought the President was right with reference to the object of keeping the amount of oxygen low in the combustion of acetylene. It was for the purpose of preventing the oxidation of the material, and the long flame that was observed playing round and enveloping the part that was being welded also prevented the oxygen in the atmosphere getting into contact with the weld.

There was a point upon which he had not touched at the previous meeting in connection with the use of this process. With regard to repairs to marine and other boilers, where considerable local wasting away of material occurred, a matter with which most mechanical engineers were familiar, the trouble was got over by cutting away the piece altogether and welding in a patch, or alternatively, thickening up the weak place. He had seen some remarkable repairs on a small scale; and they were done very nicely and effectively. [The case of repair of a boiler end in parts of which the material had wasted away was illustrated on the blackboard.] Having cleaned away the oxidised material, by means of the blowpipe they built it up to about its original thickness, and in some cases a little thicker, to make sure. In one case about two cwt. of steel were put on inside a boiler to make up wasted parts, which otherwise would have had to be cut out. He knew of a case of a tubular boiler in which the plates had wasted away to half their original thickness in places. They cleaned it out and built the metal up to the original thickness by just fusing the metal and using a piece of good Swedish iron wire or mild steel to make good. It was a slow process; but in many cases where the old method was employed boiler flues and other portions would have to be cut out and renewed at great cost, as well as necessitating hanging up the vessel, whereas by the oxy-acetylene method it was done in a few days and the vessel was enabled to get away again. The Board of Trade and Lloyd’s had recognised this process of repair, provided the repairs were carried out under the supervision of their own officers. They could understand that unless the metal was thoroughly knit together it would be a delusion and a snare; but there was no difficulty to an expert with the blowpipe to make it absolutely sound, and as good as it was in the beginning. He saw in one case a piece of metal come right out.
They put in a new piece and welded it up solid without any extra thickness in the plate.

With regard to the cutting of metal, there had been some very fine work done in connection with vessels in collision, and where bows had been stove in. A large vessel was so badly damaged that the bows had to be cut right off. He understood that one man with the blowpipe cut that piece right through to the keel in 18 hours, rendering the vessel ready for affixing new bows. In the case of a vessel on the rocks they could cut to about the water line, but below that they would have to resort to dynamite.

The President said he took it that the distinction between the unskilled man and the skilled was chiefly the ability of the skilled man to finish the work without setting up “internal strain.”

Mr. Fyvie said that was so. Unless the man had had some experience, and a good many failures, he was not to be thoroughly depended on. There was a great deal of skill required in the work, especially on a flat surface. In the case of a circular outline it could accommodate itself to a certain extent by bending. The greatest skill was required in repairing cast iron sections, where there was a liability of the shrinkage of part of the piece and practically no elastic extension.

The President said they had already formally thanked the lecturers. It now only remained to declare the discussion closed.

LECTURES AND DEMONSTRATIONS.

The President said that there would be three brief lectureettes and two demonstrations, as follows:—

Low Pressure Calorimetry, by Mr. G. Lorimer.
High Pressure or ‘Bomb’ Calorimetry, by Mr. H. R. Harper.
The Relation of Thermal and Commercial Fuel Values, the latter by himself. Mr. Lorimer and Mr. Harper would demonstrate their several methods. They all knew that calorific value was a matter of supreme importance to the engineer, and all information, whether relating to laboratory methods or running tests was to be welcomed. Mr. Lorimer’s apparatus was that actually used by the Victorian Railway Department, and it would be manipulated by the officers who carried out the routine work in daily practice. Mr. Harper would exhibit the method on which he depended as regarded the fuel supply of his Department—the Melbourne City Electric Supply.

He would ask Mr. Lorimer to proceed.

Mr. G. Lorimer said the calorimeter used by the officers of the Victorian Railway Department to determine the heat values of the various fuels supplied for locomotive use had no particular