four vertical outlets, each controlled by a cock as at "E." Below each of these cocks is a length of capillary tube, which is itself connected to a "U" shaped absorption vessel as at "B," "C," "D," and "H," each filled with bundles of glass tubes. The first vessel "B" is filled with a solution of caustic potash, the second "E" with an alkaline solution of pyragallol and the third "D" wih a concentrated solution of cuprous chloride and hydrochloric acid. The fourth vessel "H" is filled with water up to a certain mark, and between it and the cock "E" is inserted the combustion capillary tube "F," which contains a thread of palladium asbestos, and under which is placed a small spirit lamp "G" for heating it, carried on a suitable bracket "I." The supply of gas to be tested is led into the apparatus through the inlet tube "Z," and through the "U" tube "M" filled with cotton wool, which retains any tarry matter. To operate, raise the level bottle "X" and fill the burette "A" to the top, allowing the air to escape through the lower opening from three-way cock "K." Now open "K" to the gas supply and lower the bottle "X," allowing the water to run back out of "A" into "X," thereby drawing the gas into "A." By certain detailed manipulations the level of the water in "A" is brought to zero point, with the imprisoned gas at atmospheric pressure. We then have 100 c.c. of gas in the burette. Now, by raising "X" again, and opening the cock into the first absorption vessel "B," the gas is driven into "B" and the caustic potash therein contained absorbs the carbon dioxide from the gas. The glass tubes in the absorption vessels ensure the gas coming into intimate contact with the absorbing fluid, owing to the thin film of fluid left on the inside and outside of each tube as the level of the liquid is lowered. By lowering "X" the gas is again run back into the burette "A," and at atmospheric pressure the volume in the burette will be found to be less than before. This new volume is read, and, deducting it from the original 100 c.c., will give the amount of carbon dioxide removed from the gas as a direct percentage; thus, if the new level reads 96.5 c.c., the amount of CO_2 present in the gas was 3½ per cent. The same process is repeated with vessel "E," in which the pyragallol solution absorbs the oxygen, and in "D," where the acid cuprous chloride absorbs the carbon monoxide. The last absorption is a some-what lengthy one, and as a result the gas has to be passed backwards and forwards from the burette into the cuprous chloride solution several times for a period of at least 15 to 25 minutes before absorption is complete. After each gas is removed, the level of the water rises in the burette "A" by an amount equal to the volume of gas absorbed, and in ordinary illuminating and producer gas all that remains of any consequence is the hydrogen and nitrogen. To estimate the former, air is now admitted through the three-way cock "K" to the gaseous residue in the burette until the volume again comes as close as possible to 100 c.c. This added air will permit of the burning of two-fifths of its volume of hydrogen; that is, of twice the volume of oxygen in the air, which is sufficient for the amount of hydrogen in ordinary producer gas. For water gas containing large percentages of hydrogen a lessened amount of gas is used in the first place, or oxygen is admitted in place of air for the combustion. The total volume of gas and air is read off in the burette. The lamp "G" is lighted, and the capillary "F" gently heated. The gas is passed through this capillary into the vessel "H" and back again, and this is repeated once or twice until the hydrogen is completely burnt. The residue of the gas is now measured, and two-thirds the loss in volume is calculated as hydrogen, the remaining third, of course, being the oxygen used from the air that was admitted to effect the combustion of the hydrogen. In ordinary cases the determination of the four gases named, that is, carbon dioxide, oxygen, carbon monoxide, and hydrogen, are all that is required, the difference between the sum of their percentages and total of 100 giving us the percentage of nitrogen. Time will not permit of a fuller description of the operation, but from what has been said you will have realised the methods adopted in estimating the four gases named. This apparatus is here charged for operation, and can be described later to anyone interested.

Through the kindness of Professor Fawsitt, there is on view an example of one of the most accurate apparatus for commercial gas analysis, the writer thinks the only one in Australia. This is Sodeau's modification of the McFarlane apparatus, as illustrated in Fig. 3, Plate XXXVIII. In principle it is similar to the Orsat Lunge appliance. Absorbents are used, but the mechanical methods adopted to ensure accuracy are very much more efficiently worked out. Here mercury is used for displacement purposes instead of water. The means for maintaining atmospheric pressure on the column of gas whilst measuring it, the use of the telescope for reading the burette, and the extremely neat application of the auxiliary mercury reservoirs and three-way cock for expelling the gases through pipes and capillaries are all to be noted. The absorption vessels being mounted on separate stands can be removed when filled with the gas, and shaken, so as to ensure thorough absorption. This apparatus is well worthy of inspection, and the writer feels sure that some of the members will show their appreciation of its loan to us by examining it later.

The last apparatus which it is proposed to describe is a calorimeter for experimentally determining the heat value of the gas. This, of course, may be computed from the analysis, but it is always advisable to check such calculations by actual calorimetric tests, since by so doing a direct guarantee is obtained as to the correctness of the analysis, one of the most vital points in the testing of the plant.

Various instruments are in use for the determination of the calorimetric value of gaseous fuels, but the writer unfortunately has none available at the present time to show you.

In one of the best-known, Junker's Calorimeter, the heat developed by combustion of the gas from a special burner is transmitted to a current of water flowing at a constant rate. Measurements are taken of the quantities of gas burned, of water heated, and the amount of water developed in the combustion of the gas. The calorimeter proper consists of two concentric copper vessels connected to one another by a great number of copper tubes running from the top of the inner vessel to the bottom of the other. Through these tubes the products of combustion pass, thereby heating the water, which is flowing in at the bottom of the concentric space containing the tubes, and out at the top. A constant head of water is maintained by means of a small levelling tank, and the temperature of water measured at its inlet to and outlet from the calorimeter proper. The quantity of gas used is determined by a special meter, and the amount of water passing through the calorimeter measured in suitable vessels. The water condensed from the products of combustion is also trapped and measured, this record being subsequently used for correcting the apparent calorimetric value of the gas, or its higher or gross value, as it is called, to obtain the lower or true value. In this lower value a deduction has been made for the latent heat of the steam formed by the combustion of the hydrogen in the fuel, since this heat is of no value in firing the boiler, or in gas engines, as the steam escapes uncondensed. To give an example taken from practice may make the use of this instrument more clear.

The gas used determined by meter, 0.35 cubic feet.

Water calculated, 1.85 litres.

Average temperature of water at in flow, 9.8 degrees C.

Average temperature of water at out flow, 32.5 degrees C.

Rise in temperature, 22.7 degrees C.

Gross heat value of the gas equals $\frac{1.8 \times 22\ 7}{.35}$ equals 125 calories per cubic foot, or 476 B.T.U. per cubic foot.

Amount of water condensed from the products of combustion, 68 c.c. from 3 cubic feet of gas, the latent heat of which equals 16.4 calories or 65 B.T.U.'s. Therefore, the true or lower calorimetric value of the gas was 120 minus 16.4 equals 103.6 calories per cubic foot, or 411 B.T.U 's per cubic foot.

Another modern gas calorimeter is the Simmance-Abady. This is a modified Junker instrument with various improved mechanical details to make it readily applicable and portable.

Time absolutely will not allow the author to further discuss testing appliances, but he had endeavoured to briefly cover the ground. Temperatures, of course, have to be recorded at various points by means of suitable thermometers, and gas and exhaust pressures by a water manometer, such, for instance, as the one that is on view, the length of tube, of course, being lengthened to suit the higher pressures.

The author shall now only quote a few of the general results from gas engine tests, and close with some illustrations of modern plant.

MECHANICAL EFFICIENCIES.

For 4 cycle single cylinder engines of good design, 84 per cent. to 89 per cent.

For 4 cycle two cylinder tandem engines, 82 per cent. to 87 per cent.

For 2 cycle double acting machines of Korting type, 78 per cent. to 85 per cent.

For 2 cycle Oechelhauser machines, 79 per cent. to 86 per cent.

Here, as already pointed out, the four cycle machine at present excels the two cycle owing to the higher pump losses in the latter machine. In the figures for indicated thermal efficiencies, that is, the ratio between the power developed in the engine cylinder and the heat value of the fuel burnt, great discrepancies occur, but the following are average values at or about full load. For single or multi-cylinder four cycle machines of good design results of from 24 per cent. to 33 per cent. are usual. The highest result recorded to my knowledge was obtained on a Guldner 20 h.p. 4 cycle suction gas plant, which, at full load, gave an indicated thermal efficiency of 42.7 per cent., a figure which in steam practice is quite unobtainable. For two cycle machines from 23 per cent. to 32 per cent. are the usual figures, although higher has been obtained, a 500 h.p. Oechelhauser giving a result of 38.6 per cent. on coke oven gas.

It follows that brake thermal efficiencies, that is, the ratio between the brake h.p. developed and the fuel burnt also vary greatly. Mathot obtained a result of 26.9 per cent. on a Tangye suction gas engine and plant. The actual average figures for this factor can be obtained from the indicated thermal efficiencies, and the mechanical efficiencies already quoted, but modern highclass plants occasionally reach figures of from 32 per cent. to 33 per cent.

The average calorific value of gases used in gas engines are as follows, all on the lower scale:—

Illuminating Gas ..	520 to 650	B.T.U.	per	cubic	foot
Oil Gas	850 ,, 980	,,	,,	,,	,,
Natural Gas	900 ,, 1000	,,	,,	,,	,,
PRODUCER:					
On Anthracite Coal ..	140 ,, 150	,,	,,	,,	,,
On Bituminous Coal	155 ,, 160	,,	,,	,,	,,
On Coke	130 , 140	,,	,,	,,	,,
SUCTION GAS:					
On Anthracite	137 ,, 156	,,	,,	,,	,,
On Coke	130 ,, 145	,,	,,	,,	,,
Mond Gas	150 ,, 155	,,	,,	,,	,,
Coke Oven Gas . ..	400 ,, 650	,,	,,	,,	,,
Blast Furnace Gas ..	100 ,, 105	,,	,,	,,	,,

These figures, and particularly those for producer and suction gas from coke are for generation from good average fuel. We here have coke of various qualities, some good, some particularly bad. Frequently suction gas analyses from some of our coke gas here give results below 115 B.T.U., but even with this low figure the efficiency of a good plant is remarkably high per pound of fuel burnt. The average consumption of various power gases per Brake H.P. are approximately as follows at full loads:—

Illuminating Gas	14 to 18	cubic	feet
Producer Gas	75 ,, 85	,,	,,
Coke Oven Gas	20 ,, 50	,,	,,
Blast Furnace Gas	100 ,, 120	,,	,,

With regard to uniformity of speed and reduced cyclical variations, as already pointed out, two cycle machines are considerably superior to four cycle, but the actual results obtained in each case depend upon the weight of fly wheel and the arrangement of cylinders, etc., and may, with either type, be made to meet any requirements by suitable design.

The author fears that he has already trespassed greatly upon the good nature of the members in his having made this paper so long, but the magnitude of the subject must be his excuse, and a few words must now close this review.

The sources of the world's fuel supply have never yet been accurately estimated, but they are far from limitless, and the present annual consumption has reached stupendous figures. In the United States alone the consumption of coal for the one item of power generation alone now exceeds 100,-000,000 tons per annum, the total coal developed power now available in that country exceeding 18,000,000 horse power. It must be apparent to all that anything tending to economy in the use of our fuel is of vast importance to the world in general, and from this aspect alone the enormous development in the use of internal combustion engines with resultant economy in fuel consumption must be of interest to all of us. Recent research by competent authorities has shown that in gas-producers average bituminous coal, as well also as lignite and peat will yield from two to three times as much pow r as they have given under boilers of equivalent capacity, and further, that many low grade fuels, refuse from tanneries, sawdust, and similar materials can be used with excellent results in the generation of gas, although almost valueless under steam boilers. Such gas may, of course, be used for firing steam boilers, but it has now been overwhelmingly demonstrated that they are very much more economically utilised by direct combustion in the cylinders of gas engines. In such utilization many and serious failures have occurred in the past, and will occur in the future, and these, unfortunately, are the cases one hears of most frequently. But, there are a vastly greater number of gas engine plants, large and small, now in use in various parts of the world, and giving every possible satisfaction both as regards reliability and efficiency. Whilst the overwhelming benefits conferred on mankind by the use of steam cannot be over estimated, yet the many great advantages attending the use of internal combustion engines must not, therefore, be overlooked. The abolishment of the smoke nuisance, the production in the generation of the gas of nitrogenous manures, and the greatly increased efficiency from fuel to power are all of moment. And further than this, the evolution of gas power has, through its efficiency in small units, put the small and large producer on an equal footing as regards efficiency of output. So complete an output is the evidence as to the reliability of small gas driven plant, and notably of suction gas plant, when properly installed, and operated with ordinary intelligence, that one can but deplore the publication of such onesided and hopelessly inaccurate matter on the subject as appeared in the columns of one of our periodicals here some months ago, under the title of "The Suction Gas Fiasco."

Fig. 1, Plate XXXIX., shows a group of 25 twin tandem four cycle four cylinder Allis Chalmers gas engines, each of 3,500 h.p., making a total in installation of 87,500 horse power. Seventeen of these units being direct coupled to D.C. generators, the remaining eight to blowing cylinders. This plant is installed at the Indiana Steel Company's Works to utilize blast furnace gases, and affords an instructive and convincing example of the development of the gas engine, and of the confidence now reposed in them. A recent authority stated that there are on order, or running, in the United States alone over 400,000 horse power in large gas engine units, and that there are now running over 1,000 units of 1,000 horse power and more in Germany and America. We are apt to view with suspicion any revolutionary encroachment upon our pre-conceived ideas on any subject, and are wont to stick too closely to the devil we do know, rather experiment with the devil we don't. But this tendency frequently prevents an impartial consideration of new appliances, and as a result, frequently retards the employment of new and improved methods with consequent continued inefficiency. It was, the author thought, our duty as engineers, to closely watch developments, each in his own particular branch of the profession, and, even at some risk to our reputations, to take the opportunity of adopting new and improved methods wherever it offers, rather than stick to old, obsolete appliances, which we certainly know to be safe, but which also we are fairly convinced are not the best available. And in closing, let me quote some recent words on this subject by a prominent American engineer:—

"Engineers who have as yet hesitated to abandon traditional methods of power generation on account of the fresh investment required to bring their plants up to modern demands should remember that within the past 26 years, which represent an era of unparalleled industrial developmen, 50% of the world's capital has been destroyed through the supercedure of apparatus still in working order, but no longer profitable. And they should bear in mind that no small part of the enormous fortunes which have been aggregated by the captains of industry in this country were gained through the courage and readiness with which they discarded inferior apparatus before their competitors would realise that what Andrew Carnegie has termed 'Depreciation due to the advance of the art, or the destruction of fixed capital,' is more than compensated by the prompt instalment of improved machinery."

Before closing, the author wishes to acknowledge his indebtedness to the following gentlemen for the loan of apparatus and other assistance in connection with this paper. To Professor Fawsitt for the Sodeau Apparatus, to Professor Barraclough for the Optical Indicators and Horn's Tachograph, Mr. A. H. Stewart, of the Technical College, for the Orsat Apparatus, Messrs. Wildridge & Sinclair, Gas Engine Indicator, to various representatives of Gas Engine manufacturers for illustrations, etc., and to Messrs. Schaeffer & Donaldson for considerable work in the preparation of lantern slides.

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