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THE SUCTION GAS PRODUCER—ITS DEVELOPMENT AND ECONOMICAL APPLICATION.

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A few months ago an interesting paper on Gas Producers, dealing particularly with the "Dowson" system, was read before our Association. Since great developments have taken place in gas producers in recent years, the author has selected for his subject the "Suction" gas producer, as distinct from the "pressure" producer. The enormous field opened up by this question will preclude his dealing with structural details or descriptions of all the various producers in the market. He will endeavour to deal as lucidly as his limited abilities will allow, with the developments of gas generators, and more particularly with the "Deutz" suction gas producer which he has had an opportunity of studying theoretically as well as practically, and also give comparative tables of the cost of working suction gas producers and steam engines provided with superheater. When speaking of heat obtained from any given fuel, he will always refer to calories.

The attention bestowed upon gas engines by the technical engineering world had been enormously increased of late years, owing to the utilisation of the lower priced heating gases such as furnace gas, coke gas, generator gas, etc. The combination of a gas generator with the motor had supplied the means to convert a higher percentage of the heat contained in coal into power than was possible by the steam engine.

There was no doubt that the generator plants working under ordinary conditions had long ago proved superior to steam power as well as gas engines when of more than 10h.p, but of late years improvements had been effected that might almost be called epoch-making, in so far as an entirely new principle had been evolved under the name of "suction" gas producer, with the result that this new principle was to-day rivetting the attention of the intellectual engineering world.

The Gas Motoren Fabrik "Deutz," founded and carried on for many years by Dr. Otto, the inventor of the four-cycle principle so well known throughout the world by his name, had taken this matter in hand in their usual happy method of blending science with industry, and their efforts have proved most eminently successful. The new "Otto" gas motors employed direct coupled with the suction gas producer had also undergone important changes that were of great interest to the practical and progressive engineer.

Before entering upon his subject proper, the author desired to review the development of gas generators. A gas generator was an apparatus containing glowing coal or coke, into which steam was forced by constant pressure. Two distinct processes took place here, inasmuch as that carbonic-oxide was generated by the admixture of the oxygen of the air with the carbon, and the oxygen and hydrogen of the water were separated. The resultant gas burnt with a non-luminous flame, and had a heat value of about 121 calories per cubic foot, which was about a quarter of the value of lighting gas, and half that of water gas. In the former systems of pressure generators, the steam was obtained from an ordinary steam boiler with a pressure of from 50lb. to 75lb. to the square inch. The steam with a requisite quantity of air entered the ash-pit of the generator, and being forced through the glowing fuel was converted into a highly explosive gas, which after passing through some cleansing apparatus was discharged into an ordinary inverted bell gasometer, from whence it was taken according to requirements. The fact that two distinct firings, one for the boiler and one for the generator had to be maintained was not considered satisfactory from an economical point of view, and a never ceasing effort to reduce the fuel bill had resulted in the abolition of the steam boiler altogether. Engineers were also conscious of the danger of this highly explosive gas under pressure escaping through any possible leakage in the service.

As early as 1891, a Frenchman by the name of Benier secured English and French patents for a generator and a motor, the latter taking its supply of gas from the generator by suction instead of by pressure as previously described. Through the suction of the engine a partial vacuum was created which caused air to enter the generator under atmospheric pressure, thus forming gas in the process of so doing, the necessary steam being produced by a water jacket surrounding the lower part of the generator, from whence it was conducted to the ash-pit by a small tube. This then may be taken as the first step in the evolution of this most interesting and economical power producer, which was destined to occupy the minds of our leading thinkers for some time to come. Though Benier's invention caused a stir at the time it very soon proved a commercial failure, probably owing to the fact that he introduced a new two-cycle motor, with a peculiar gas and air pump to work in connection with it.

Maurice Taylor, of Paris, was more successful when a few years later he again took up Benier's generator in conjunction with the ordinary, well-proved four-cycle gas engine. The results attained were very encouraging, since the inverted bell gasometer, as well as the steam boiler had been eliminated, and the working expenses thus considerably reduced.

The "Otto" gas engine works in Philadelphia, U.S.A. (a branch establishment of the "Deutz" Motor Works), constructed a gas producer in 1890 that also did away with the steam boiler. It was still on the pressure principle, where steam and air were forced into the generator by means of a fan, the steam being generated by a spray of cooling water running over the coke in the scrubber, heated by the gas passing through the latter on its way to the motor. The fan had in its turn been abolished, with the advantage that no escape of gas was possible, owing to the whole system being below atmospheric pressure.

A "principle" not being a subject matter for letters patent, the construction of suction gas generators was taken in hand in various parts of the world with more or less success, the aim of all constructors being the same, viz., to cause an inflow of steam and air into the fire-box through the exhausting action of the engine, The utilisation of the heat in the fire-box or of the gas in its passage to the motor for the generation of the required steam was also common to them all, but the construction in the methods of producing the steam and bringing about the proper admixture of air differed considerably. The "Deutz" motor works were the very first to take up and develop this promising field, and they had maintained the lead right along the line, and the palm was ungrudgingly given to them by the unbiassed and well informed engineer; but before he spoke of their achievements, he would endeavour to give a brief description of the suction producer as placed before the world by Maurice Taylor, and then, without touching upon all the intermediary systems, which were more or less on the pressure principle, he would deal with the "Deutz" suction gas producer of to-day in the light of the theoretical as well as practical experience that he had the privilege of having had with the products of this firm.

The Taylor Producer (Plate xii.) consisted of the generator A, and the tubular boiler B—if he might be permitted to use such an expression in connection with this system. The generated gas in passing through the tubes, heated up the water and produced steam. This steam was constant in volume, depending as it did upon the regular heating of the gas passing through the tubes, whereas the inrush of air into the generator varied with the varying load on the engine. This unvarying generation of steam formed the weak point in Taylor's system.

To bring about a condition whereby the steam as well as the air might enter the generator in anything approaching requisite balance, so as to meet the varying demands of an uneven load, the following system was adopted. The steam generator B was supplied with an escape pipe C, the outlet of which was just within the inlet of pipe D. The newly-generated steam would rise in making its efforts to escape into the open by means of the outlet C, but every inrush of air into pipe D, caused by each suction stroke of the engine would carry the escaping steam with it into the ash-pan and through the glowing fuel. This method did not prove at all satisfactory, and soon the necessity forced itself upon the leading engineering minds, that something better was required to regulate the proportions of steam and air. The first improvement effected was the addition of cock

E to tube D, the object being to place it within the power of the attending engine-driver to increase or decrease the inrush of air at will. This gave the Taylor Producer an impetus, and some installations on that principle were in existence to this day; but another and very serious defect of this system was, that it was not practical, more especially for smaller plants, to generate steam in an air-tight vessel by means of small tubes, since it was well-known that the gas passing through them did not possess great heating properties. To avoid any possible loss of this heat it was necessary to have the tubes close together, and as large a heating surface as possible. To attain this, tubes of ¾in. diameter, and composed of very thin material were employed; but since the gas passed through the tubes before undergoing any cleansing process, it stood to reason that a heavy deposit on the inner walls of the tubes took place, which in its turn had the inevitable result of lessening the steam generation. What the daily scraping of these tubes means will be readily understood by every engineer, and need not be further dilated upon.

The "Deutz" System.—As already mentioned the "Deutz" Motor Works took up the systematic study and development of the gas producer after the steam boiler had been dispensed with for this purpose at their branch establishment at Philadeplphia, U.S.A. They had carried on continuous experiments with their wonted thoroughness in happily blending science and industry, and the two cardinal points in their efforts were, that the gas must not pass through any narrow sections, and that the requisite admixture of steam and air should be maintained without any outside interference or manipulations by the attending engineer or driver. As the name denoted, the action must be a sucking one, with the desired result that the gas produced was under less than atmospheric pressure. A partial vacuum in the motor was used to draw the required quantity of steam and air necessary to produce the gas through the generator, so that an escape of gas through any leakage was impossible.

The suction gas producer plant (Plate xiv.) consisted of generator A, scrubber B, and gas-pot C. The generator A was connected with scrubber B by means of a pipe K. Scrubber B being again connected with the gas-pot C, and through it with the motor D. The generator was provided with a hopper for replenishing the fuel, and surrounded by a water-jacket E, which was supplied with an open elbow F at one side, and a tube FL connecting it with the ash-pan H at the other. The water-jacket was only provided for producers up to 70h.p., beyond that, a special evaporator was supplied, as illustrated in Plate xiii.

Assuming now we were to inspect a generator plant, of, say, 50h.p. in operation, we would find the generator alight, the service pipes full of gas, and the engine in working order. It was evident that every suction of the motor must withdraw a certain amount of gas from the service pipes, thereby causing a fall of pressure therein, this being replenished from the scrubber, and the scrubber by the generator, the generator from the space in the ash-pan, the space in ash-pan by the steam from the water-jacket, and the air flowing in through the elbow from the atmosphere. Reversing the illustration, the air entered the elbow of the water jacket by atmospheric pressure, carrying the generated steam down the pipe FL into the ash-pan, and following the onward pressure through the glowing fuel, thus generating the gas. This was, of course, provided that all ingress of air excepting through the elbow mentioned had been shut off, and for this reason ventilator valve 3 and air valve 2 would have to be closed. The gas after being generated passed through the scrubber. This was a cylindrical vessel filled with coke over which a fine spray of water flowed, the object being to cleanse the gas, and also cool it. After leaving the scrubber, it passed through the gas-pot D into the "Deutz" patent tar extractor, and from thence in an almost pure condition to the gas engine.

The tar-extractor (Plate xv.) consisted of a set of sheet iron rings and discs arranged alternately, the rings were smaller in diameter than the service pipe leading into the extractor, which caused the gas to rush through it with an increased speed and striking the solid disc, deposit the tar in its passage over it. This process was repeated with every disc, and the gas was practically pure by the time it entered the engine. Two sets of discs were required, so that they could be changed every day for cleansing purposes.

The positions of the various members of a plant when in full working order were as illustrated in Plate xiv. Ventilator valve (3) was shut down, the steam-air cock (1) was open, the connecting pipes were closed by means of the valve cone (4), whereby also valve cone (5) opened the connecting pipe to the scrubber. This double-acting valve will be described in detail later on. The generator was a cylindrical apparatus lined with fire-brick, between which and the outer casing was a layer of non-conducting material, so as to guard against any undue loss of heat by radiation, the upper portion being surrounded by the water jacket already mentioned, and the whole surmounted by a hopper capable of carrying fuel lasting for several hours.

A fan as shown on illustration was arranged to be worked by either hand or power, for the purpose of creating the necessary draught in starting the fire in the generator.

That the "Deutz" gas motor works have succeeded in maintaining their principle that the requisite admixture of steam and air was maintained without any attention from the driver would be seen, and that their efforts had been crowned with complete success was illustrated by the following description.

If the air entering the elbow of the water jacket under atmospheric pressure did not become sufficiently saturated with steam, it was absolutely inevitable that the heat in the generator would be raised accordingly, with the result that the temperature of the water in the jacket was raised proportionately, thus generating steam more rapidly. The greater inflow of steam into the glowing coal in its turn would lower the temperature therein, with its natural sequence of lessening the steam generation in the water jacket. To control this, an automatic regulator was fitted, working with great accuracy.

Now, in order that we might see what provision had been made to secure convenience and safety in the working of this suction gas generating plant, the author suggested the following questions.

First, had provision been made to prevent the possibility of gas from the generator entering the scrubber and other cleansing apparatus during the time that the fire in the generator was being started, or whilst the engine was temporarily at rest?

Secondly,—Were explosions possible that might prove dangerous to life and property?

Thirdly,—Could the air become vitiated through any escaping gas?

In dealing with the first question we found an ingenious contrivance composed of a rod with two cone-edged valve covers (Figs. 4 and 5), and a weighted lever (M) at the extreme end, as illustrated in Plate xiv. In disconnecting the scrubber and engine from the generator, it was only necessary to turn the weighted lever M, when the rod would be raised, thereby opening valve 4, establishing a direct flue from the generator to the exhaust pipe, and at the same time closing valve 5 and breaking the connection between the generator and the scrubber. But the possibility still remained that the attendant might neglect to disconnect the generator, to guard against this contingency, a swivel valve was inserted in the down pipe (FL) of Plate xiv. (also shown in detail in Plate xvi.). This valve being nicely balanced would open with a current downwards, but would close with the current going up. Supposing now that the engine stopped, and the unavoidable after-generation raised the pressure until it became greater than that of the atmosphere, it would fill every vacant space until it ascended from the ash-pit up the air and steam-pipe (FL), where it would close up the swivel valve, and being blocked in its effort to follow the line of least resistance, it must return. It would be noticed in Plate xiv., that connecting pipe (K) had an extremity (KL) leading into the overflow basin for the scrubber water, and there formed a water seal. This was the point of least resistance, and the pressure would be relieved.

In dealing with the second and third questions it should be remembered, firstly, that the engine through its sucking action produced only the amount of gas that was demanded by the force of its own load. Secondly, that the plant was under less than atmospheric pressure when the engine was at work, and that an escape of gas through leakage was impossible. Thirdly, that any gas generated immediately after the engine had been stopped, could not find its way into the engine-room for reasons already given. Fourthly, that no gas was generated if the engine was at rest.

We had already seen that a leakage in the service-pipes did not permit of an escape of gas into the building, but that on the contrary, it would admit air into the producer. The question now arose whether sufficient air could find its way in to form an explosive mixture within the generator? Theory might say—Yes; but practice said decidedly—No; because the power in the engine failed long before the admixture of gas and air reached the point of dangerous explosiveness.

To start the generator, it was first of all necessary to see that the weighted lever (M) was turned over so as to shut the scrubber off and have a direct draught through pipe K and up to the exhaust pipe, then light a fire and gradually feed with coke, using the fan to create a draught. In from 10 to 20 minutes (according to size) the whole coke would be aglow, the lever M should now be reversed, and a few turns of the flywheel would complete the operation. The generator would hold sufficient fuel for about two hours, but it was more satisfactory to attend to it every hour, and at the same time use the poker to avoid caking. The ash-pan had, of course, also to be emptied periodically.

A most notable feature of the producer gas was that the efficiency covered nearly 87 per cent. of the total heat of the coke, of which the engine developed 24 per cent., equalling about 21 per cent. of the total heat of the fuel. This meant a consumption of 1lb coke (297 cal. per lb. approx. per actual h.p. hour). The very latest results showed a development as high as 25 per cent. of the total heat.

The efficiency diagram (Plate xvii.) illustrated the position clearly:—

Efficiency in fuel		100
Efficiency of generator		86.82
Loss in scrubber	8.93	

Loss in heating the gas	0.64	
Loss by heating scrubber water ..	0.66	
Loss by radiation	2.95	
		13.18

This left an efficiency of 86.82 per cent. at the disposal of the engine. Of this

Resistance and radiation of engine and the exhaust absorbed ..	32.61	
Loss through heating of the cooling water	31.14	
Loss by friction	2.46	
Actual power available	20.61	86.82
		100.00 per cent.

These figures spoke for themselves, when we considered that a steam engine, under most favourable conditions, would not develop more than from 10 per cent. to 15 per cent.

If we examined the exhaust gas from a hygienic standpoint, it was found that the constituents were very similar to those, as if the same fuel had been consumed in any other system of power production, such, for instance, as in the steam boiler. These constituents are carbonic acid gas, moisture, nitrogen, and in some instances sulphuric acid; if, however, through some defect the combustion was not complete, carbonic oxide would be discharged.

Carbonic oxide was an intermediary product of combustion when the fuel was converted into carbonic acid gas in the generator, and where it was formed together with hydrogen by a peculiar chemical process, that might be described as "incomplete" combustion. Carbonic oxide was next to hydrogen, the principal constituent of the generator gas, owing as much as 25 per cent. of the total. With the requisite admixture of air, it was exploded in the