cotton fabrics have been found in Egyptian graves older than the Ptolemaic period; but this does not prove that they were made in Egypt, any more than a

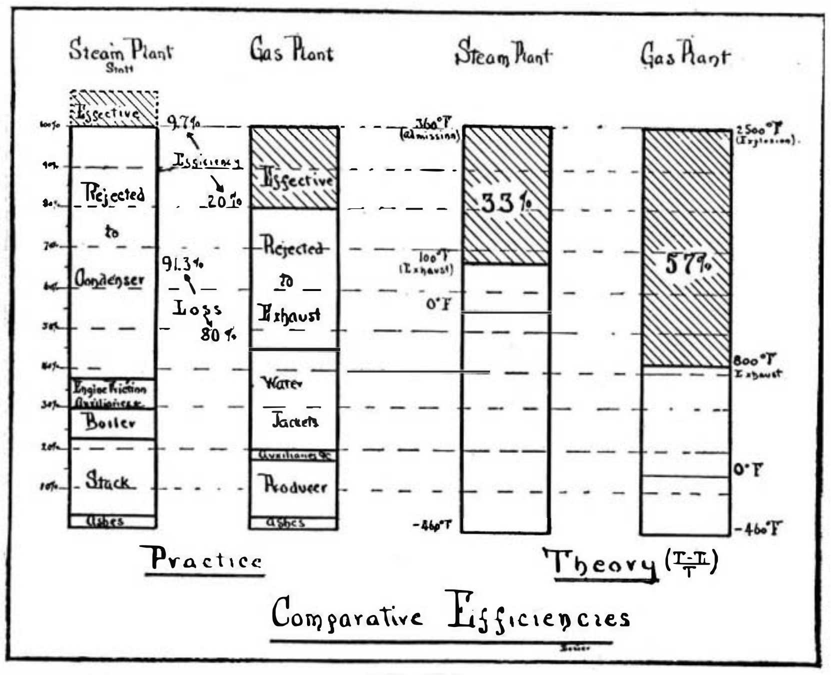

FIGURE 1

silk fabric found in an American grave of the present day would prove it to be American, the probability, amounting almost to certainty, being that it was manufactured in Europe or Asia. Cotton fabrics, however, do not appear to have become popular in Italy. The finer cotton tissues still came from India, and were very expensive; while the coarser ones were hardly so well suited to the Roman climate as linens. Before the Egyptian cotton manufacture became sufficiently improved in quality and cheapened in price to command the Italian market, it fell into the hands of the Arabians, and Rome lost the control of what was destined to become the greatest of the textile industries.

Silk, though it had been imported from the Orient for many centuries, and cultivated to a small extent in some of the Greek islands, was nevertheless so scarce during the Augustan period as to command its weight in gold. The common name for it was *serica*, or *vestis serica*, sometimes *bombycina*, from *bombyx*, the silk-worm. The Roman ladies wore a broad ribbon around the waist called *strophium*, which served for the modern bodice, or stays. This ribbon or sash was made of silk. Soft clinging stuffs of silk for the *stola* were next worn; and finally the *palla* came to be made of the same expensive material. Its use was forbidden to men. Elagabalus is said to have been the first male Roman who wore a robe of pure silk; and Aurelian to have refused the empress, his wife, a garment of this fabric, on account of its exorbitant price. Yet in Pliny's time, which was much earlier, the importation of Indian silks, to be unraveled by Roman girls in order to work up the threads with woolen yarns and so to make from them new and less expensive fabrics, appears to have become an important industry; from which it would seem that stories about the parsimony of distinguished people are not always to be relied upon for historical accuracy.

Hemp is an East Indian plant which was brought into Europe probably during the first Buddhic period. Herodotus mentions a species so closely resembling flax that the Thracian women made fabrics from it

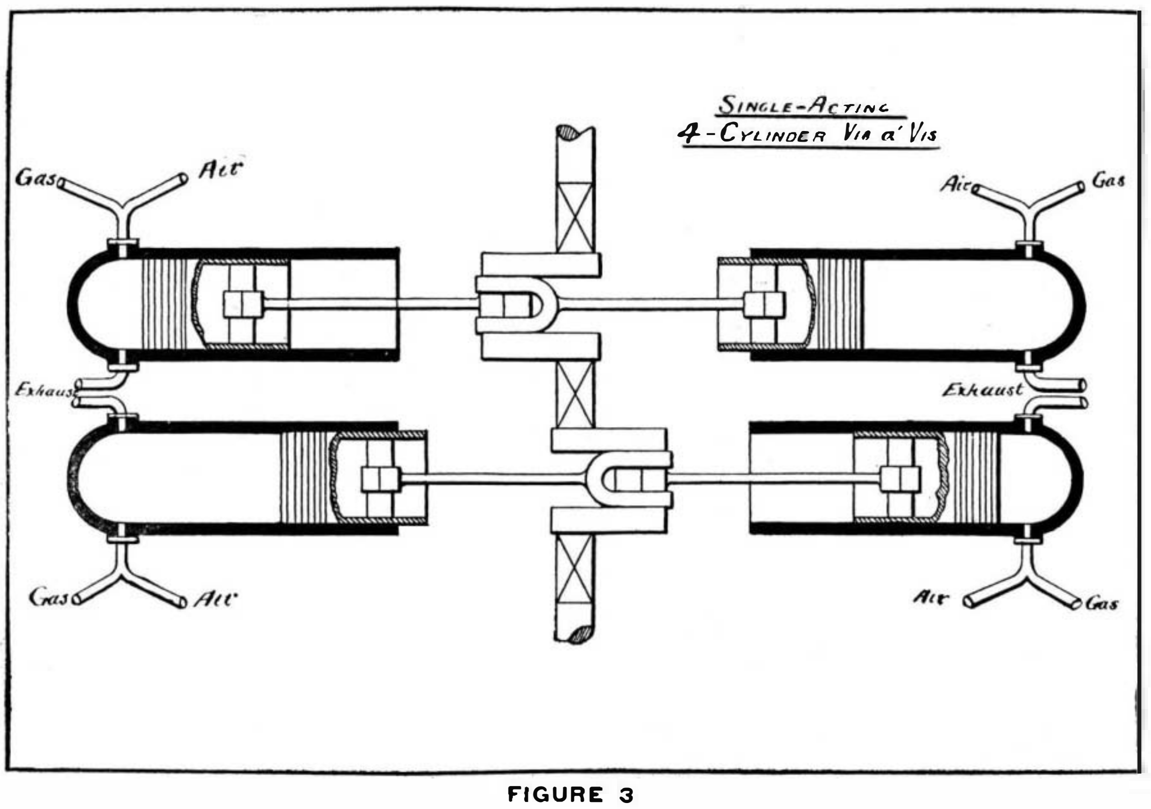

FIGURE 3

which could hardly be distinguished from linen. The best hemp known to the Romans was grown at Alabanda, on the banks of the Meander, and the next best at Mylasa, near the Gulf of Jasus, both of these places being in Asia Minor. In Italy it was chiefly cultivated in the territory of the Sabines, a very ancient people. Hemp was at first employed for the ropes and rigging of ships. Moschion, about 200 B. C., records the use of hempen ropes for rigging the ship "Syracusia," built for Hiero II. some fifty years previously. Twine, hunting nets, and finally coarse fabrics, for household use, were successively made of it. The various machines and devices for retting, heckling, combing, spinning, and weaving this staple were applied to flax when that textile came to be manufactured in Rome.

Human hair was also employed as the basis of several Roman industries, chiefly by wig-makers and jewelers. A Roman matron's wig, of a beautiful brown color, full, rich, glossy, and ending in a heavily plaited chignon, is preserved among the curiosities of the York Museum. Although 1,800 years old, it can scarcely be distinguished from a modern peruke of the most fashionable design.

The grass fibers employed by the Roman weavers, such as esparto, corn-husks, and straw, the latter for ladies' hats, were as numerous as they are at the present day. Many of them were also used for stuffing mattresses and upholstering furniture—for example, corn-husks, wool-flocks, and grasses of various sorts.

Asbestos, like many other substances which formed the bases of Roman industries, was originally obtained from India, but afterward from Arcadia. The Greeks gave it the name of *asbestinon*, which means inextinguishable; while the Romans called it *vivum*, or live (linen). They made table-napkins of it, which could be cleansed during the meal, by throwing them for a minute or so into the fire. Shrouds for the dead were also made of this substance, though it was so excessively dear that only the wealthiest people could afford to purchase it. In the year 1702 there was dug up near the Nævian Gate at Rome a funeral urn, in which human remains of the classical period were found wrapped in asbestos cloth, many yards in length. This interesting example of Roman textile art is still preserved in the Museum of the Vatican.

FUNDAMENTAL PRINCIPLES OF GAS ENGINES AND GAS PRODUCERS.*

By Robert T. Lozier.

The first question that occurs to one entering the gas-engine subject is perhaps the following:

Do steam engines and gas engines belong to the

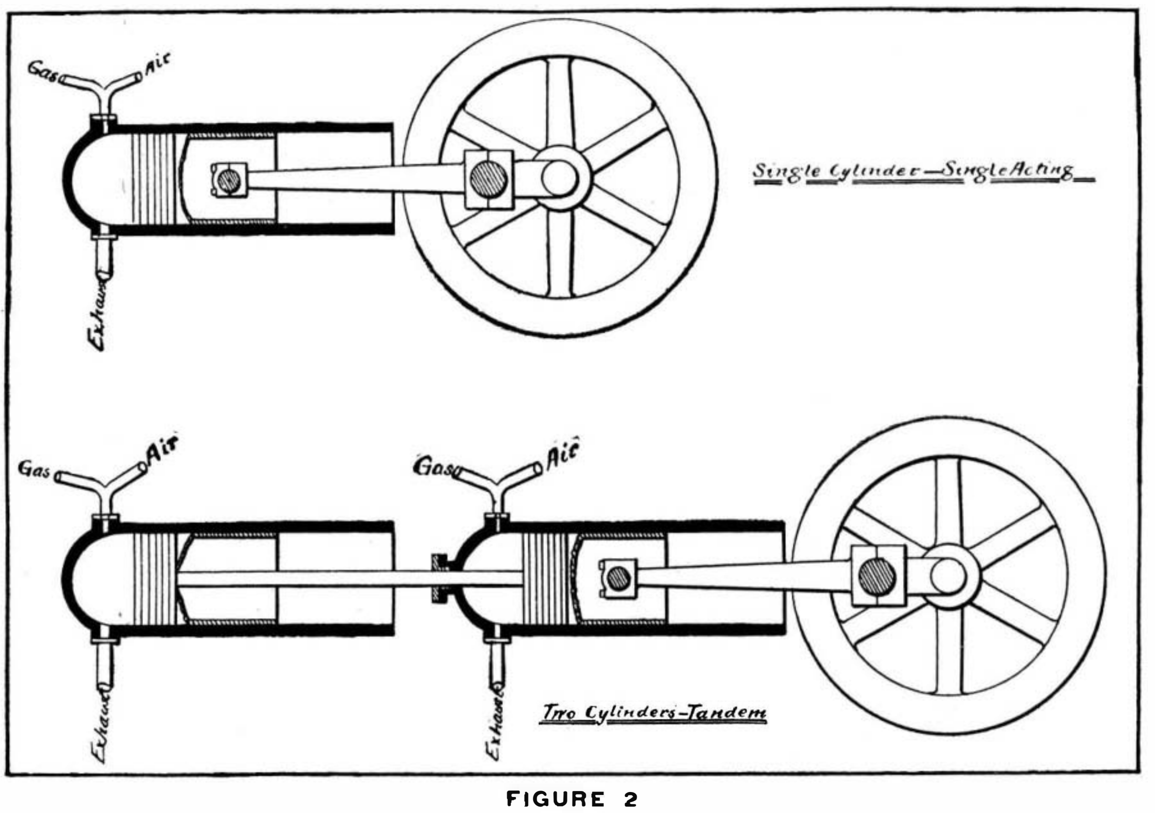

FIGURE 2

same general class? They do in so far as they are both heat engines, which depend for their operation upon that well known principle which Prof. Rankin covers in the definition he gives of the first law of thermo-dynamics as follows: "It is a matter of ordinary observation that heat, by expanding bodies, is a source of mechanical energy." That is to say, if we take a cylinder containing a charge of fluid against which rests a piston, and apply heat to the cylinder, the expansion will push the piston out, and make it do work. This fluid may be steam, or gas, or air, etc. So that in this respect gas engines and steam engines are the same, in that they are both heat engines. In what respect then does a gas engine vary from a steam engine? The answer is that with the steam engine the fuel is burned in the fire box of a boiler, located apart from the engine, while with the gas engine, the fuel is burned directly in the engine cylinder. In the case of the steam engine, we find that much of the heat of the fuel is wasted in changing water from its liquid state into a vapor that will expand and give pressure as the temperature is raised. This heat so used is called latent heat, and consumes nine hundred and sixty-six British thermal units, to change one pound of water into steam. Then again, in order to transmit the steam to the engine it must be kept down in temperature so that the pressure can be confined by the steam pipe lines and their fittings. With a gas engine, the gas may be transmitted to the engine at practically atmospheric pressure and temperature. Its heat is not developed until it is safely within the engine's cylinder, which is the exact point where the work is to be performed, and where it is fired. Therefore, gas engines are called "internal combustion engines."

Having found the difference between these two types of hot air engines, the next question is, which is the most desirable? It is generally understood that fuel is the greatest single factor in the cost involved in delivering power, and represents from 50 per cent

* Paper read before the New York Electrical Society and published in its Transactions.

in small plants to 60 per cent in large plants of that cost as has been determined by actual operation. In gas plants the fuel is only from 25 to 33 per cent of the cost of the power, but in order to bring out this point of efficiency most clearly, let us first develop it from the beginning by taking the theoretical view of the case, and having found out what this is, we can then see how far it is followed out in practice.

The unit representing the calorific values most used, when dealing with gas engines, gas producers, gases and fuel, is the British thermal unit, abbreviated to "B. T. U." A British thermal unit represents the quantity of heat required to raise the temperature of one pound of water 1 deg. F. at 39 deg. F. One B. T. U. equals 778 foot-pounds, and there are 2,564 B. T. U. contained in a horse-power. It will be seen that in considering the efficiency of a heat engine the temperatures involved are necessarily the governing factors. The theoretical efficiency of a perfect heat engine of any type is determined by the simple formula

$$\frac{T - T1}{T} = \text{Efficiency},$$

in which T is the acquired temperature from absolute zero, or the temperature of the power transmitting element at the time of expansion figured from absolute zero (which is 460 degrees below Fahrenheit's zero), and $T1$ the final absolute temperature after expansion. The difference between T and $T1$ is known as "The Temperature Range." The ratio that this temperature range bears to the total temperature taken from absolute zero is the percentage of thermal efficiency that the engine has. It will be seen that we work down to absolute zero. In Fig. 1 we have worked out practical cases, having assumed for the gas engine that the temperature of the gas mixture at explosion is 2,500 deg. above F. zero, which, when added to 460 deg. below that zero, gives a total absolute temperature for the explosion of 2,960 deg., which is the heat that the engine received. The exhaust has a temperature of 800 deg. F., which, when added to 460, gives 1,260 degs. This, when deducted from the original temperature of 2,960 degs., leaves 1,700 degs., as a credit to the engine, or an efficiency (thermal) of 57.5 per cent, provided the engine is a perfect translator of energy. Now for the steam engine. I choose to take the temperatures of the engine cited by Mr. Henry G. Stott in his paper before the American Institute of Electrical Engineers in January, 1906, because I desire to use them in the commercial comparison that I will make next. He assumes a temperature for the steam at point of admission of 367 degs. F., which when added to 460 degrees gives an absolute temperature of 827 degs., while the temperature of the exhaust is given as 100 deg. F., plus 460, or an absolute temperature of 560 deg. exhaust. Deducting this from the total temperature of 827 deg., we have for this steam engine a temperature range of 267 deg., which is 32.3 per cent of 827 deg., the total range, and 32.3 per cent in this case represents the thermal efficiency of the steam engine. It will be remembered we found the thermal efficiency of the gas engine to be 57.5 per cent. Some writers elect to put gas and steam engines on the same basis of comparison by assuming, for theoretical purposes, that they will both exhaust at atmospheric temperature, say 60 deg. F. On this assumption the steam engine will figure out a theoretical thermal efficiency of 37 per cent, and the gas engine, with an explosion temperature of 2,500 deg. F., a theoretical thermal efficiency of 82 per cent. But whether you take it on a theoretical assumption, or whether you use temperatures that may be expected in practice, it is plainly evident that the gas engine has a very much higher thermal efficiency than the steam engine, because the power-conveying medium can be eventually used at greatly higher temperatures. The foregoing assumptions as stated have been worked out on the principle that both the gas and steam engines were perfect devices for transforming or translating their useful temperature ranges entirely into useful work. Of course, in practice a proportion of this temperature that is represented by what I have called useful temperature range is used to overcome the friction of the engines, and is also lost in radiation, etc. Then again, in considering the over-all efficiency of a practical commercial plant as taken from the coal pile to

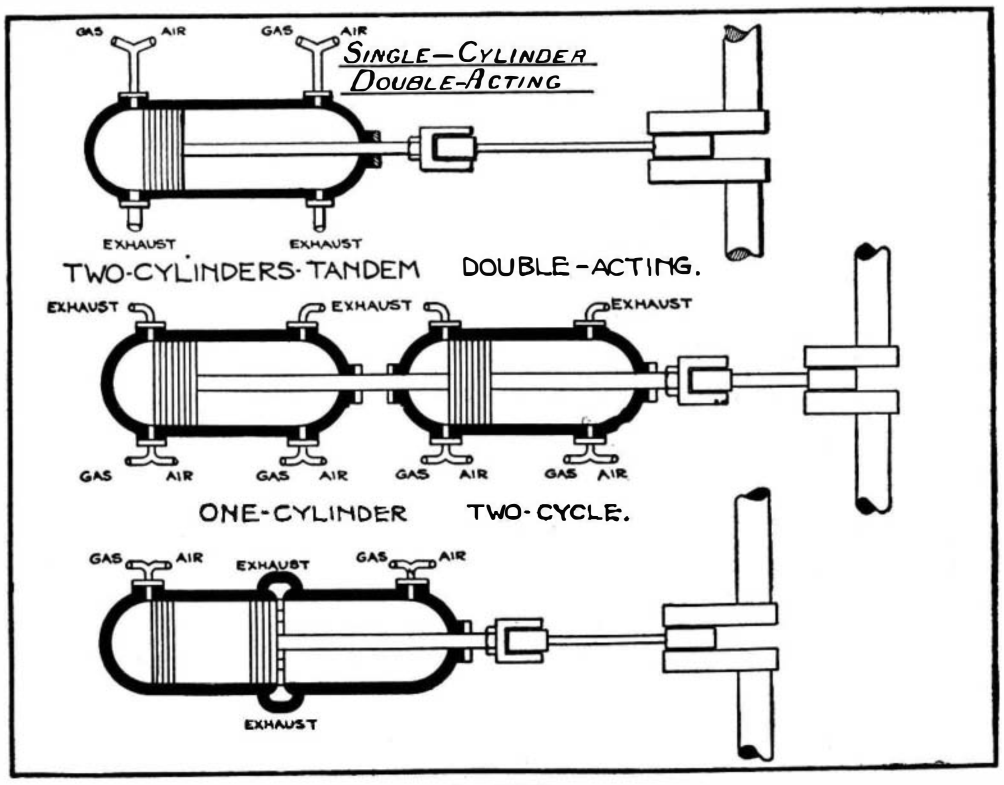

FIGURE 4

the engine wheel, you must include the losses of piping, auxiliaries, boilers with stacks, or producers, as the case may be, and we find that in this respect the gas engine is again more efficient, because it has a commercial efficiency from coal pile to driving wheel of 20 per cent, while the very best steam practice in America as given by Mr. Stott is but 9.7 per cent, and in Europe is 8 per cent, and in Great Britain 7 per cent, as given by Mr. H. M. Hobart. Furthermore, the commercial efficiency which I have just given for the gas engine plant is obtained by even the small installations, while those given for the steam plants represent the very highest results that have so far been obtained from the largest and most economical central stations equipped with the very latest apparatus.

Having determined these commercial efficiencies, let us see just what differences in actual pounds of coal consumption they represent. This is easily done. We will divide 2,564 B. T. U., the theoretical quantity required to produce one effective horse-power, by the per cent efficiencies that we have just determined for each kind of engine respectively. We then find that the gas engine requires at 20 per cent 12,820 B. T. U. in order to supply one B. H. P., and there being 13,500 B. T. U. in an average pound of coal, we easily develop one B. H. P. at the engine from one pound of coal burned in the producer. With the steam engine, dividing 2,564 B. T. U. by 9.7 per cent efficiency, we must have 26,500 B. T. U. to get one B. H. P., so that the steam engine will require 2 pounds of coal burned in the boiler to develop one B. H. P.; at 8 per cent efficiency 2½ pounds; and 7 per cent 2¾ pounds of coal. These coal consumptions which we have cited represent the very highest engineering practice in their respective countries; other steam plant coal consumptions will run as high as nine and ten pounds of coal per B. H. P. in small central stations and industrial plants in which the installations are inefficiently installed and operated. With the gas plant not only is the apparatus itself inherently more efficient, but its operation is far more simple, and eliminates to a much greater degree the personal equation of the operators, so that one pound of coal per B. H. P. is easily attained in even the smallest gas plants against ten pounds of coal by steam plants of equal size. The cost of maintenance is less and the cost of operating large gas engines and producer plants is one-half that of steam plants, and where the gas is supplied from an outside source, such as natural gas, blast furnace gas, etc., the labor is only one-third that of a steam plant of corresponding capacity. As concerns repairs, it is possible that for the engines they may now be slightly higher, due to the newness of the art, but with a producer plant and its auxiliaries repairs are far lower than in the corresponding departments of a steam plant, so that the total repairs are less. As concerns overload capacity, a characteristic feature of the gas engine is that its maximum capacity is reached when taking its maximum charge of gas and air combined in the right mixture, and exploded at just the right time. This means, that if the commercial rating of the engine is set 15 per cent below this most economical point, it is not possible to carry more than 15 per cent overload without slowing down the engine. This condition can be easily met in several ways: By installing additional gas engine capacity, by running in connection with the gas engines a steam turbine which readily takes up the load changes, or by a storage battery. The additional saving in total cost of power accomplished by the gas engine should be sufficient to more than offset the expenditure necessary to take care of this overload factor. If it is not, then the case is not a good one for gas engines.

As to the first cost, this is very difficult to state exactly because the conditions vary so largely; but it is, possibly, safe to assume that the complete gas plant, including producers, will cost say 20 per cent more than a corresponding steam plant, and with coal at $2.50 a ton, it is not difficult to earn a handsome return on this additional investment. Important factors are therefore (a) the cost of coal, (b) the number of hours a day that the plant is run, (c) the load factor of the plant, i. e., the percentage of its average load to its rated load. The higher these values, the more is it to the advantage of the gas engine plant.

The gas engine itself is very simple, and its working parts are easily understood, and adjusted by the operators in charge, once they have become familiar with the running conditions. The engine may consist of one or more cylinders, in which the gases are burned at initial pressures of about 300 pounds per square inch, the gas being admitted at atmospheric pressures and compressed to about 100 or 120 pounds, the resulting mean effective pressure after explosion ranging from 60 to 75 pounds. Piston speeds run about 600 to 850 feet per minute.

Gas engines are divided into four general classes: as concerns cylinders, single acting and double acting; and four cycle and two cycle, as concerns explosions. Gas engines are built vertically with one, two, or three cylinders, where the weights of the pistons and length of crankshafts permit, and horizontally, with one cylinder, two cylinders *vis-à-vis*, or tandem, and four cylinders, *vis-à-vis* or tandem in the larger sizes.

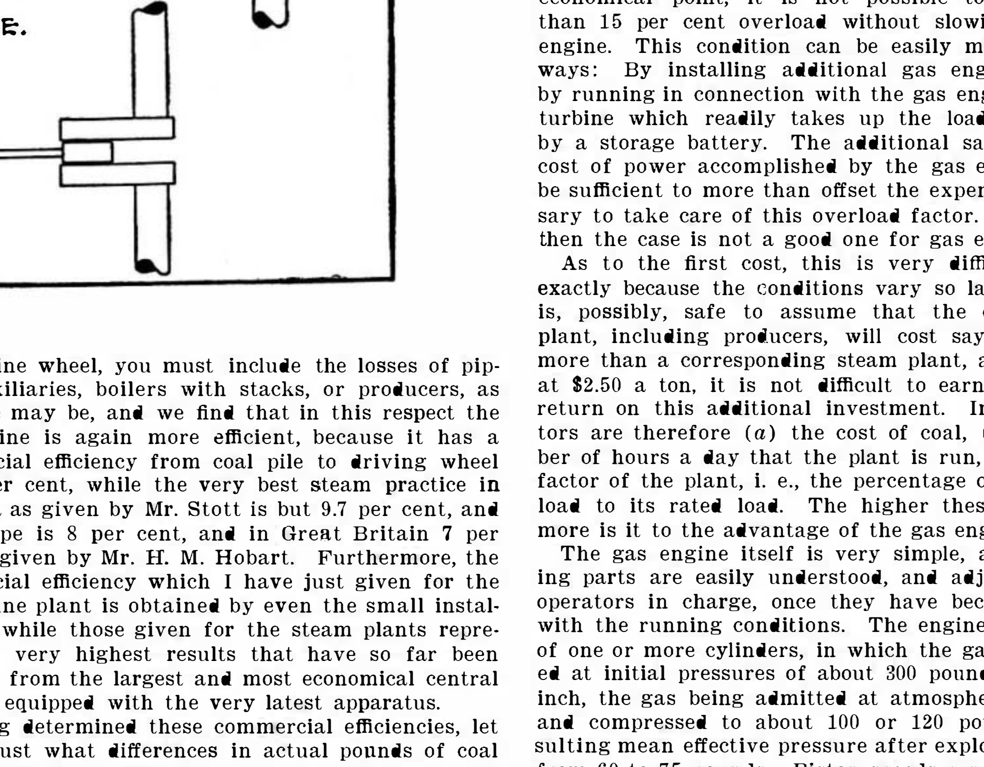

FIGURE 5

EXPLOSIONS PER STROKE PER REVOLUTION

In a single-acting engine the explosion takes place at only one end of the cylinder; with the double-acting engine, the explosions take place at both ends of the cylinder.

When we speak of a four-cycle engine, we mean that four strokes of the piston are taken to complete the cycle from one explosion to the next. The first stroke, called the "suction" or "charging stroke," sucks in the charge. The return of that stroke, called the "compression," compresses it. At the beginning of the third stroke, or "power stroke," the charge of gas is exploded, and on the fourth, or "exhaust" (sometimes called "scavenging stroke"), the cylinder is scavenged of the products of combustion. The four-cycle movement is called the "Otto" cycle or "Beau de Rochas."

With the two-cycle engine the charging stroke and the scavenging stroke are eliminated, the piston's duty being performed by a subsidiary means external to the engine, and either attached to it, or operated as an independent auxiliary.

As concerns the working parts of the engine, it is provided with a governor, operated on the same general principles as a steam engine governor, and with about the same degree of regulation.

The valves of a four-cycle engine consist of the following: First: Gas and air valves, which determine the proportions of gas and air that are to enter into the mixture. These are simple cocks, placed in the gas and air mains, with dials, showing the extent they are open, and are only changed at the will of the engineer. Second: The hit-and-miss cut-off valve, which admits the amount of gas determined by the gas valve into the mixing chamber, unless the governor of the engine makes it lose a cycle. The hit-and-miss regulation is only used below one-quarter load with close governing engines. Third: The cut-off valve with its inlet valve. This cut-off either varies throughout the stroke the opening through which the gas mixture enters the cylinder, or else acts as a straight throttling valve, by maintaining a fixed opening during charging stroke. In either case it is adjusted by the governor to suit the load. Its inlet valve closes the port as soon as the charge has been admitted. Fourth: The exhaust valve, which because of the high temperature of the exhaust is water cooled. I might say that the mixing chamber, which is a simple pocket, is located between the hit-and-miss valve and the cut-off valve. Now these four valves are of the simplest type and require but little engineering skill to keep in repair. They are positively opened against springs by cams or eccentrics carried on a side shaft, geared to the engine's crankshaft. These cams and eccentrics are so set as to perform their respective operations at the proper time. This side shaft also operates the igniters. Ignition is obtained in two ways: one by bringing a small portion of the main gas charge in contact with a red-hot tube operating as a Bunsen burner, or preferably by means of a "fat" electrical spark, the latter having survived the former in this country. This spark is either of the make-and-break type or is a jump-spark. The terminals in either case protrude directly into the clearance of the engine cylinder, which contains the gas. Modern practice tends to double ignition plugs so as to always have one as a standby. The current for supplying the spark can be obtained from vibrating magnetos placed across each spark point, or from revolving magnetos or small generators, or from primary or storage batteries, preferably the latter, but a standby source should always be available. I should like to point out the importance of always having an independent relay or standby source of current entirely independent of the main source.

in the gas burns at low temperatures, so that the pressure to which any gas can be compressed is limited by the amount of hydrogen that that gas contains, and it is interesting to know that while the gas may be rich in B. T. U., it may not be as efficient as a leaner gas with less hydrogen, which can be worked at a higher compression.

Gas engines cannot start with a full load, and require a clutch where such load is say more than one-quarter of their capacity, although I have seen an 865-horse-power engine start and reach full speed with a load of 300 horse-power in less than forty seconds. Of course, when driving electric generators it is necessary only to open the switch. Starting is obtained by applying compressed air to the engine at about 100 to 120 pounds pressure, or by motoring the generator which it drives. There are two elements that enter into gas engine operation which are not found in steam engines; one is that when running, a charge of gas may fail to ignite, and will enter the exhaust unburnt; there it is just possible that it will come in contact with particles of incandescent carbon and explode; this explosion is called a "back-fire." Then again a charge may enter the cylinder and because it is richer than the adjustment of the compression provides for, the heat resulting from that compression may prematurely fire it, or there may be particles of incandescent carbon in the cylinders that will fire it. This is called a "premature." The result of either one of these two actions is not in any way serious, and only momentarily tends to slow the engine down. Engines properly cared for may run for days without having an occurrence of either kind.

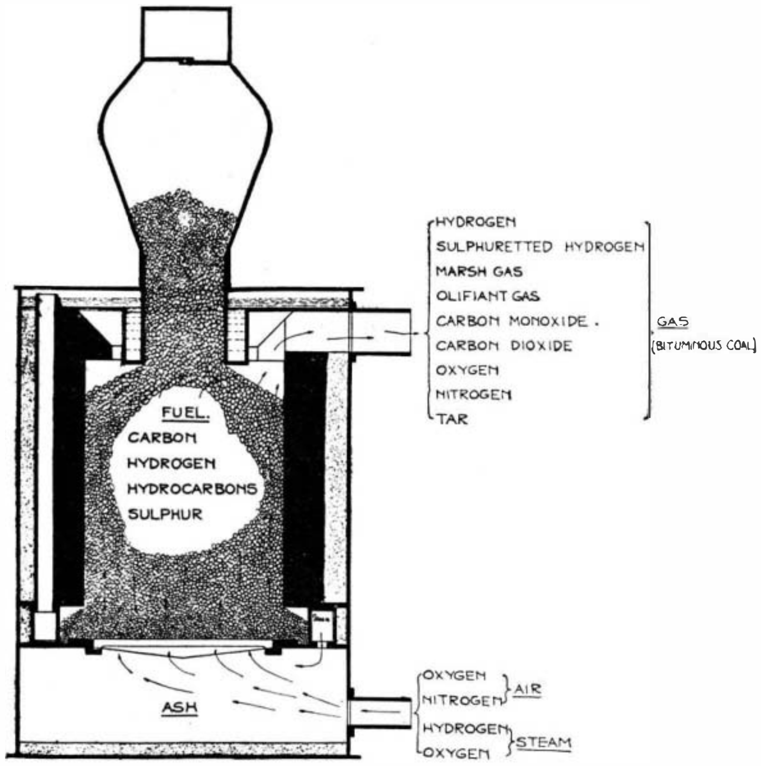

FIGURE 7

overcome if the gases in the turbines are to be direct acting. The first is that the thin blades of the turbine are not able to stand the high temperatures of combustion, which would run about 2,500 deg. F. The other factor in the problem and of most serious consideration is that it is not possible to get compression before igniting the gas, and as we have pointed out, this compression is necessary to the efficiency of the engine. It might appear from what I have just said that the turbine with a secondary expansion chamber will be the direction in which we can look for developments along this line, although nothing promises in this direction at this time, and the engineers are fully occupied in developing the reciprocating gas engine, which already approximates the performance of the best reciprocating steam engine, and which they hope to improve still further, because of the simplicity of the principles involved.

So much for the engine.

(To be continued.)

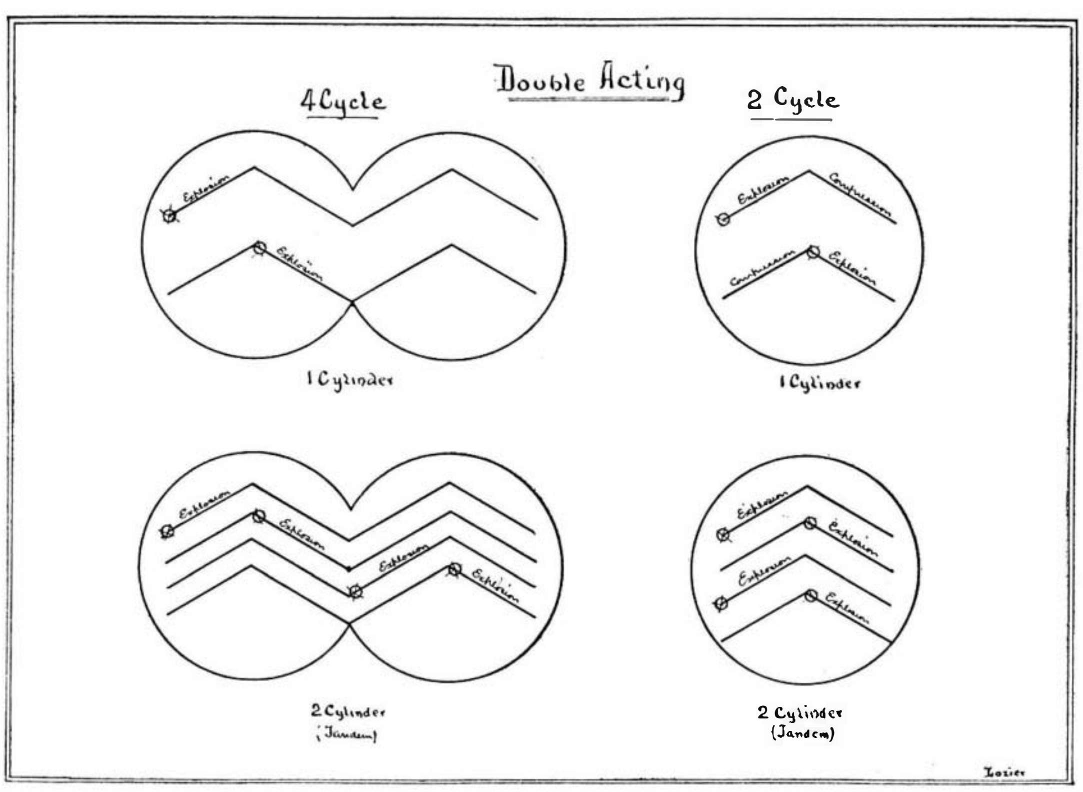

FIGURE 6

EXPLOSIONS PER STROKE PER REVOLUTION

The time of ignition can be adjusted at will, but it is generally set to take place just when the engine piston reaches the highest point of compression.

Gases are compressed before exploding in order to increase their efficiency. The molecules when pressed tightly together operate with greater force on explosion in the same manner that burning gunpowder becomes effective when it is confined in the gun barrel. Compressing the gas generates heat, and the hydrogen

Indicator cards are taken in identically the same manner as with steam engines, and are figured in identically the same way. Eccentricities in the cards, however, have not the same significance as the steam engine cards, nor it it so easy to trace their origin.

Now as concerns gas turbines. At first glance these appear to have the same advantages over the reciprocating engine that the steam turbines have. There are, however, two very serious obstacles first to be

CONTEMPORARY ELECTRICAL SCIENCE.*

Calibration of Gold-Leaf Electrometers.—The gold-leaf electroscope is being widely employed in measurements of ionization. It is calibrated by applying known potentials to it. But H. W. Schmidt points out that it is not as a rule used for measuring differences of potential, but for measuring currents by noting the variation of the potential. To obtain the best results, therefore, another principle of calibration should be employed. The relative difference of potential between two scale divisions may be obtained by exposure to the β and γ rays of a radium preparation fused into the glass wall, and noting the times taken by the leaf to traverse successive divisions. If there is a saturation current, these times are proportional to the differences of potential. If the shape of the electroscope leaves a doubt as to whether there is a saturation current, it is only necessary to connect the electroscope with an air condenser which is not too small, and to expose this alone to the radium rays. The author believes that with a well-calibrated leaf electrometer as good results may be obtained as with a quadrant electrometer. It has besides the great advantages of simplicity, small capacity, and independence of external electric disturbances.—H. W. Schmidt, Physikalische Zeitschrift, March 1, 1906.

Recombination of Salt Ions.—G. Moreau has determined the coefficient a in the equation

$$dn/dt = -an^2,$$

which expresses the manner in which the recombination of ionized salt vapors depends upon the number n of ions present in the unit of volume. The method employed was the same as that employed by Townsend for gases ionized by Röntgen rays. Determinations were made at two different temperatures, 80 and 15 deg. The comparative recombination coefficients were 415 and 78 for potassium iodide, 410 and 10.6 for chloride, and 421 and 0.84 for bromide. The ratio of recombinations to collisions was found to range 56 per cent for potassium chloride at 80 deg. to 99 per cent for potassium bromide at 15 deg. The mobility of these vapor ions is smaller than that of ordinary gaseous ions. The average proportion of recombinations at 80 deg. is two-thirds, whereas at lower temperatures it often happens that every collision results in a recombination. This is due to the great mass of the ions, which are positive atoms surrounded by several layers of neutral atoms, thus approaching the constitution of the heavy ions produced by phosphorus, which might perhaps be called charged droplets rather than ions.—G. Moreau, Comptes Rendus, February 12, 1906.

Origin of Terrestrial Magnetism.—A. Pflüger discusses the interpretation of terrestrial magnetism as

* Compiled by E. E. Fournier d'Albe in the Electrician.