tion engine as a commercial possibility, and despite the great advance made in gas engines since that time, the Otto cycle as first developed by Dr. Otto still stands. Of course, many experiments in gas engines were carried out before his time, but he was the first to appreciate the importance of a definite cycle of operation, and particularly the necessity of a definite exhaust phase, thus getting rid of the exhaust gases so as to produce a commercial and economical engine without utilizing outside means for scavenging the exhaust. It is a striking tribute to the efficiency of the gas engine that, while only one stroke out of four is the working stroke, or putting it another way, three parts of the engine's time is wasted, yet in the face of this fearful handicap the gas engine bids fair to beat all rivals in the economical generation of power.

The four operations which go to make up the cycle are:

(1) Suction, (3) Ignition,
(2) Compression, (4) Exhaust.

In the four-cycle engine, which is the type in most common use it takes four strokes of the piston, or two revolutions of the shaft, to complete the cycle, only one stroke being the working stroke, the remaining three strokes being taken care of by the momentum or energy stored up in the fly-wheels. Right at this point is where some confusion frequently arises in the minds of those not familiar with the operation of the gas engine, and where it is made to suffer in comparison with its rival, the steam engine, since in the case of the steam engine only two functions are carried out in the cylinder—the admission, and the exhaust of the steam, the preparation and admission of the fuel being provided for, apart from the engine, by the wasteful and dangerous agency of the steam boiler. It is really the failure to grasp the simplicity of the principle on which the internal combustion engine operates that we so commonly hear the statement, about as follows:—

"Well, gas engines are queer things anyway: when they run, you don't know why they run, and when they stop, you don't know why they stop." As a matter of fact, nothing could be more absurd than a statement of this nature, and in order to realize this, it is only necessary to recall the four factors which go to complete the cycle and, remembering these, to state that, provided an engine draws in a full and proper charge, and that charge is properly compressed, fully ignited, and freely exhausted, no matter how crude the design may be, how indifferent the materials, and how poor the workmanship, the engine will run and continue to run until one of the functions fails which go to make up the cycle. It is impossible to lay too much stress upon this aspect of the matter, as it lies at the very root of the subject, and a proper appreciation and understanding of this fact would save much mental research and often a good deal of physical exercise expended in a vain endeavor to start up an engine by turning over the fly-wheel, the engine having stopped and refusing to start, apparently for no good reason, but, as a matter of fact, through the failure of one of the functions of a cycle to carry out its part.

Starting with the piston at the top of the cylinder, as it descends a vacuum is created, causing the inlet valve to open automatically, admitting the mixture of gasolene and air. This mixture continues to flow in until the piston reaches the end of the first down-stroke. The inlet valve then closes automatically by the tension on the spring, thus confining the charge in the cylinder.

The return stroke, known as the compression stroke, is brought about by the momentum of the fly-wheel, and compresses the charge. This is essential, in order to obtain proper ignition of the charge and to obtain power and economy from the engine. In a general way, and within limits the higher the compression, the greater the power. The amount of compression, however, it is desirable to have is, of course, limited, as, if excessively high compression is carried, there is a tendency to ignite the charge prematurely, setting up severe stresses in the engine, causing it to work very irregularly.

In gasolene engines the larger the engine is the lower the compression will be.

The best accepted practice is to carry a moderate compression of from fifty to eighty pounds on gasolene up to as high as 175 lbs. on producer gas.

The faster the engine is running the higher the compression may be when using producer gas.

The third stroke in the cycle is the working stroke, obtained from the ignition, or explosion of the charge, or, put more correctly, due to the rapid expansion of the charge. It is important to note carefully the point at which the ignition of the charge should take place, so as to get the maximum power from the engine. At first glance, the natural inference would be that ignition should take place just as the crank passes the top centre, and when it is stated that the ignition must take place when the crank pin is about fifteen degrees behind the top centre the natural conclusion would be that the tendency would be to drive the engine in the opposite direction. In practice, however, this is not so, and to get the greatest power the igniter has to be tripped somewhere around this point. The explanation of this is that there is an interval between the time the igniter trips causing a spark at the point before the charge is fully ignited, and by tripping the igniter ahead of the crank the greatest force is given the piston just as it passes the top centre. I may point out that we frequently hear the internal combustion engine referred to as an explosion engine, and in speaking of the ignition of the charge we generally speak of it as an "explosion." Explosion engines were at one time in use, and some small ones are possibly still employed, but to speak of the internal combustion engine as an explosion engine is entirely erroneous, and the fact that ignition has to take place so early in order to obtain the full benefit of its force, proves that what actually does take place is rapid ignition and expansion. The distinction is, perhaps a fine one, but, as a matter of policy, especially in describing the engine to people who are not familiar with the operation and, naturally, somewhat suspicious of gasolene, it is well to avoid the use of the word "explosion" substituting ignition and speaking of the third operation as "the working stroke." The Fourth operation in the cycle is the exhaust stroke, the exhaust valve being mechanically opened at the end of the working stroke, and remaining open until the piston has reached the top, being carried up by the momentum stored up in the fly-wheel, driving out the burned products preparatory to drawing in a fresh charge, and thus completing the cycle.

Fuels.

In considering the fuels in general use in connection with the internal combustion engine, we may sub-divide this general head under three subsidiary heads:

(a) Classes of fuels,
(b) Heat value of fuels,
(c) Consumption of fuels.

The fuels in general use are, gasolene, kerosene, crude oil, illuminating gas, natural gas, producer gas and alcohol. Gasolene, which is the fuel in most common use, is obtained from distilling crude oil, and is classified under two heads,—known to the trade as "engine gasolene of 76 degrees" and "stove gasolene of 67 degrees." Chemically, gasolene is a compound of carbon and hydrogen, or a mixture of several similar compounds. This in a state of vapor or gas is mixed with air, consisting of one part oxygen and four parts of nitrogen. The hydrogen and carbon in the gasolene combine with the oxygen, forming carbon dioxide and water, leaving the inert nitrogen as before. Kerosene is also obtained from distilling crude oil and is a lower grade than gasolene. It differs from gasolene in so far that it is not explosive, and will not give off vapor when exposed to air as gasolene will, but on the other hand it can be readily vaporized. The advantages in the use of kerosene for an engine are that in some sections it is more easily obtained, it is usually cheaper, and it is always possible to get a lower rate of insurance where a kerosene engine is installed. The disadvantages of a kerosene engine are that the engine is