

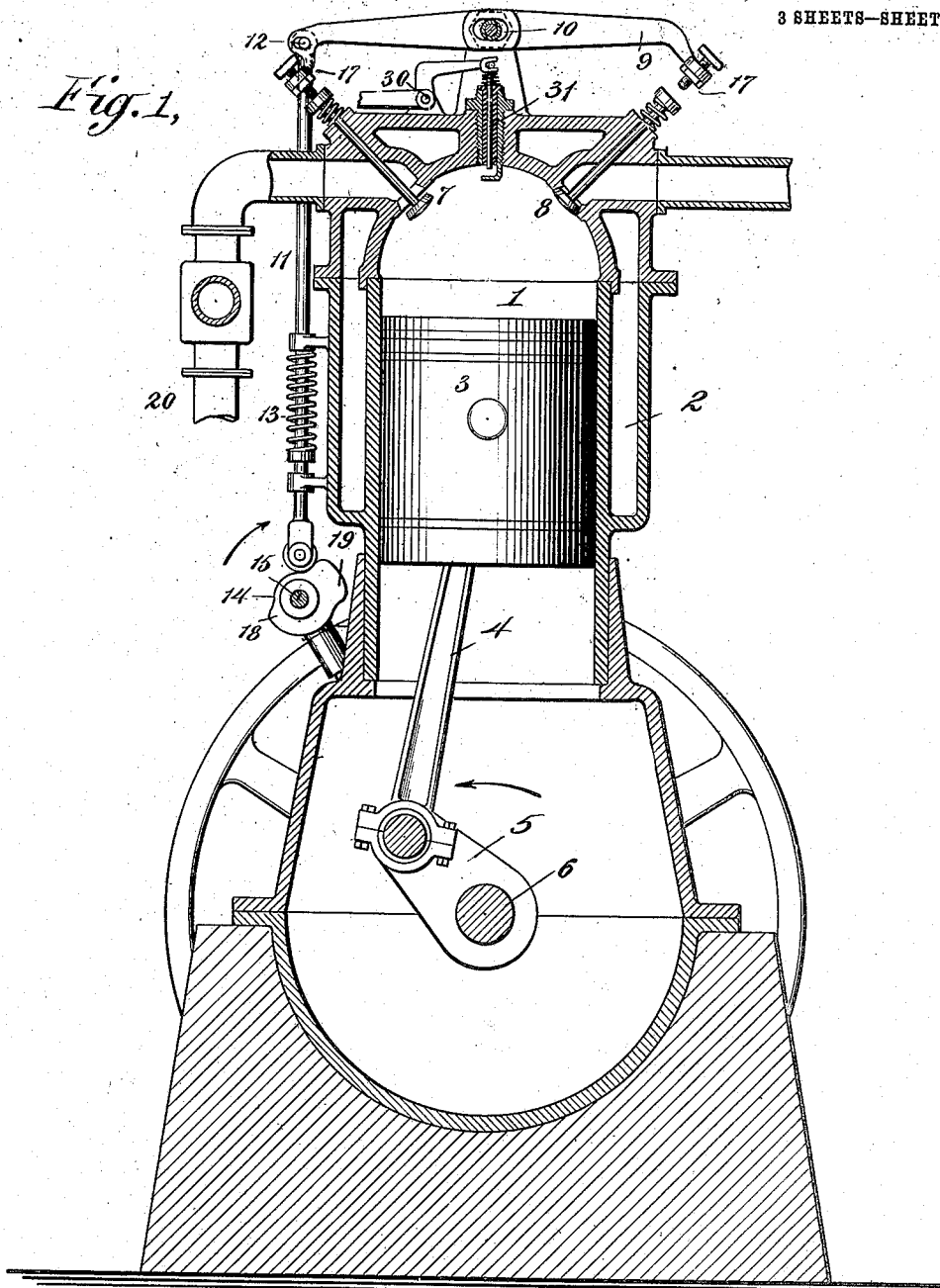
G. M. S. TAIT & C. ELLIS.
INTERNAL COMBUSTION ENGINE.
APPLICATION FILED FEB. 8, 1906.

911,345.

Patented Feb. 2, 1909.

3 SHEETS—SHEET 1.

Fig. 1,



WITNESSES:

J. Wares Byrce
may J. Trimble

INVENTORS

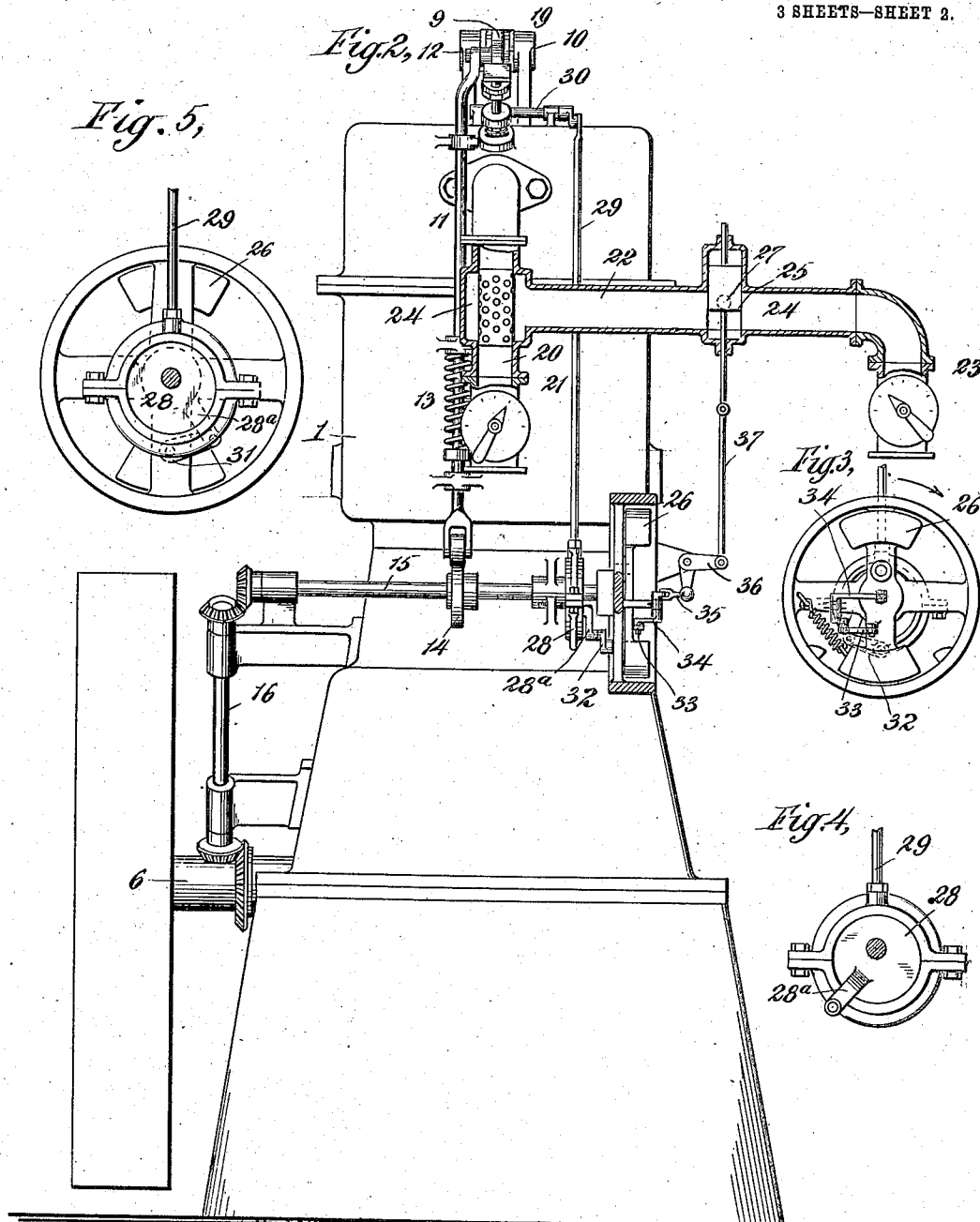
Godfrey M. S. Tait
Carlton Ellis
BY
Marble McElroy
ATTORNEYS

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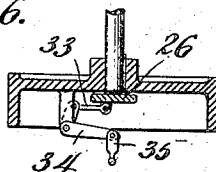
3 SHEETS—SHEET 2.



WITNESSES:

J. W. Bryce
May 9. Trimble

Fig. 6.



INVENTORS

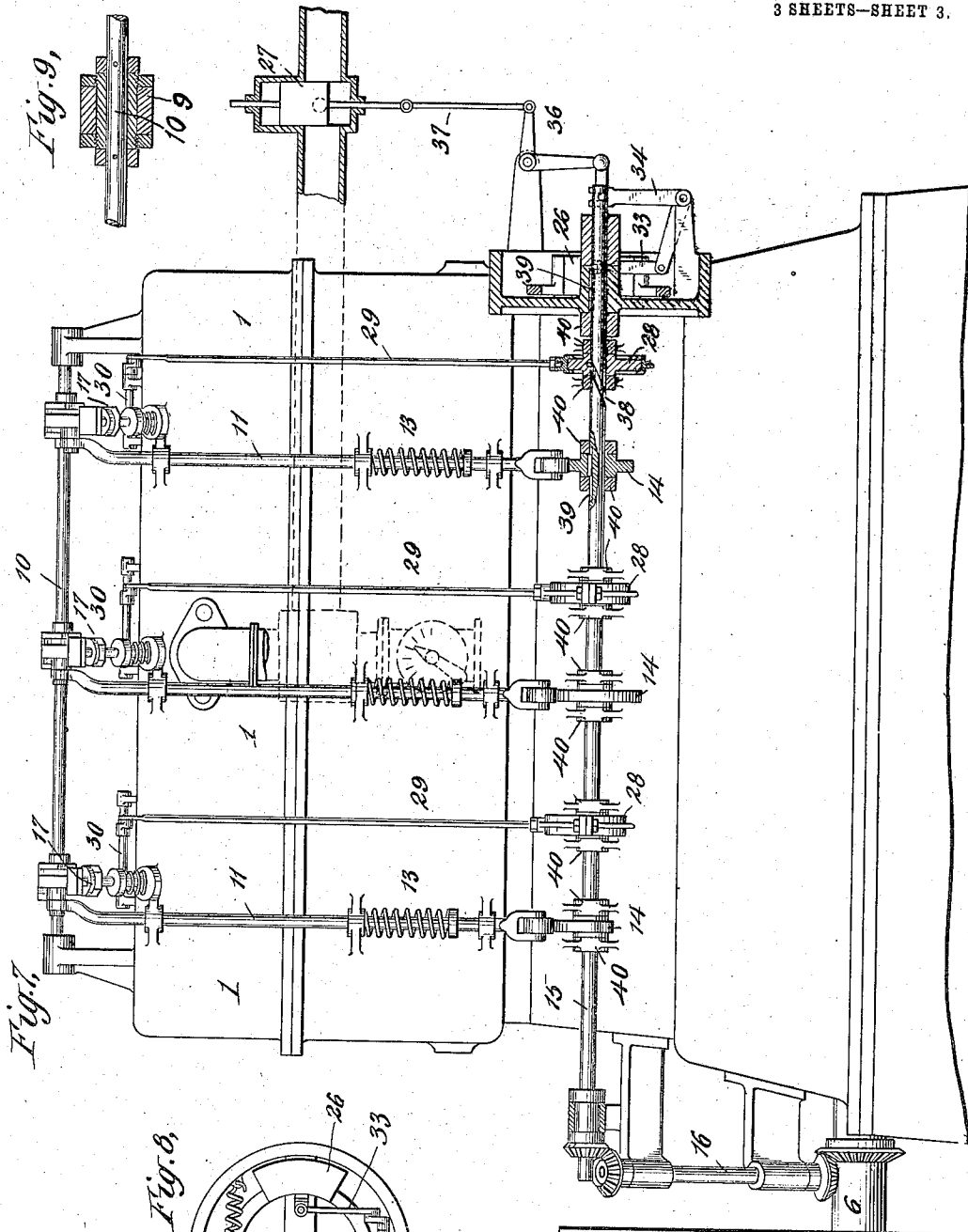
Godfrey M. S. Tait
Carlton E. Ellis
BY *Marble & McElroy*
ATTORNEYS

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3 SHEETS—SHEET 3.



WITNESSES:
J. Ward Dyer
May 9. Tremble

INVENTORS
Godfrey M. S. Tait
Carlton Ellis
BY
Marble McElroy
ATTORNEYS

UNITED STATES PATENT OFFICE.

GODFREY M. S. TAIT, OF MONTCLAIR, NEW JERSEY, AND CARLETON ELLIS, OF WHITE PLAINS, NEW YORK.

INTERNAL-COMBUSTION ENGINE.

No. 911,345.

Specification of Letters Patent.

Patented Feb. 2, 1909.

Application filed February 8, 1906. Serial No. 300,107.

To all whom it may concern:

Be it known that we, GODFREY M. S. TAIT, a British subject, residing in Montclair, Essex county, New Jersey, and CARLETON ELLIS, residing in White Plains, Westchester county, New York, have invented certain new and useful Improvements in Internal-Combustion Engines, of which the following is a specification.

Our invention relates to improvements in internal combustion engines, and involves features particularly valuable in engines intended to be operated by producer gas and similar gas of low or variable thermal value or comprising gaseous ingredients having quite different properties as regards self-ignition, flame-propagation etc.

The engine herein described carries out the process of regulating the development of power in internal combustion engines, forming the subject matter of the application for Letters Patent, filed by us on November 14th, 1905, Sr. No. 287,240.

Our invention consists in novel means for regulating the operation of internal combustion engines; in improvements in the value gear and igniting gear, and in means for automatically adjusting the same in accordance with variation of speed of the engine, and in other features of invention, all as hereinafter described and particularly pointed out in the claims.

The methods heretofore employed for regulating the operation of internal combustion engines have all proved unsatisfactory. The "hit-and-miss" method of regulation produces excessive speed fluctuations, so that it is entirely impracticable in many cases, and in many of its forms is extremely wasteful of fuel. All methods of regulating involving variation in the quantity of gas and air taken into the cylinder, such as throttling and variable opening or closing of the admission valve (the latter method, sometimes termed "variable cutoff") produce extreme variation in the compression pressure, such pressure increasing at different rates according to the quantity of gas and air taken into the cylinder. Such variation in compression is extremely detrimental as regards economy, for it is well known that for highest efficiency high compression is

necessary, and obviously an engine which at light loads compresses only to relatively low pressures, is uneconomical at such light loads and low compression pressures. Variation of the compression is particularly detrimental, however, in the case of engines operating on producer gas, or similar gas of low or variable thermal value. Such gases require high compression to insure thorough and prompt ignition, or even to insure ignition at all. If the engine be regulated by varying the amount of fluid taken into the cylinder, it may easily, and frequently does, happen, that at light loads and low compression pressures, ignition is uncertain or fails altogether. It is of course substantially impracticable to supply a richer mixture to an engine when operating at light load than when operating at heavy load, and to do so would still further decrease the efficiency at light loads. The extreme of this disadvantage of varying the quantity of fluid taken into the cylinder is experienced when the engine is supplied with gas by a single producer the only, or substantially the only, function of which is to supply gas to that particular engine. Irregularities in the quality of gas furnished by the producer then produce their maximum effect, and if it happens, as is apt to be the case, that the producer furnishes the poorest gas when the engine is running on light load and with low compression pressure, the engine is apt to stop. When starting up such an engine, also, the gas from the producer is apt to be of especially low thermal value, and since the engine is then without load, usually, and its valve gear is adjusted so that the compression is low, it is often difficult to start an engine operating on producer gas. All of these difficulties we obviate by taking into the cylinder substantially the same quantity of fluid at all times, regulation being effected by varying the richness of the charge by automatically varying the amount of air admitted, or by admitting and similarly regulating a neutral diluent gas, such as products of combustion. The compression is then substantially the same at all loads. To compensate for the variation in the rate of flame propagation with-varying amounts of air or neutral diluent gas in the charge,

we automatically vary the point of ignition to correspond with the variation in the amount of diluent. In this way we are able to employ very high compression pressure at all loads, with resulting gain in economy, and to realize nearly the same economy at light loads as at full load.

In the specification of an application for Letters Patent filed by G. M. S. Tait on Oct. 31, 1905, Sr. No. 285,245, the difficulties experienced in the use, in high compression engines, of fuels which are not homogeneous as to combustible constituents, are pointed out, particularly the difficulties attending the use in high compression engines of gas containing a considerable percentage of hydrogen; the hydrogen being apt to ignite automatically during the compression stroke, thus producing excessive back pressure against the piston, causing the engine to do negative work, and greatly lowering the efficiency of the engine. Such trouble is termed "preignition". When using a fuel containing ingredients, such as hydrogen, which tend to cause preignition, or irregular combustion (as when one or more ingredients burn largely or entirely before the others), we commonly use a mixture of air and products of combustion as a diluent, the products of combustion having a marked effect in holding back ignition of hydrogen or other gases tending to ignite spontaneously under high compression. When the gas used is homogeneous or nearly so, we may use air alone as the diluent.

The objects of our invention are, to regulate the development of power in internal combustion engines in an improved manner, to obtain higher economy of operation at all loads, but particularly at light or variable loads, to avoid variation in the compression with variation in load or speed, to prevent pre-ignition, to insure complete ignition, and to permit the use of fuel of low and variable thermal value, and to make the mechanism by which the above objects are accomplished, simple, compact and efficient.

We will now proceed to describe our invention with reference to the accompanying drawings, illustrating one form of internal combustion engine embodying our invention.

In the said drawings: Figure 1 shows a central vertical section of the engine on a plane transverse to the crank shaft; Fig. 2 shows a side view of the engine, a portion of the governor mechanism and associated parts being shown in section; Fig. 3 shows a front view of the governor; Fig. 4 shows a detail view of the eccentric, Fig. 5 shows a detail view of the governor and eccentric looking from the left of Fig. 2; Fig. 6 shows a detail top view of the bell crank and associated parts of the governor mechanism; Figs. 7 and 8 show the application of our invention to a multi-cylinder engine, Fig. 7 showing a

side view of a three cylinder engine provided with our improved valve gear and regulating mechanism.

In the said drawings 1 designates the engine cylinder, and 2 the cooling jacket thereof, 3 the piston, 4 the connecting rod, 5 the crank and 6 the crank shaft; these parts being all of substantially common construction.

7 designates an admission valve and 8 an exhaust valve. These valves are operated by a rocker 9 pivoted at 10 and vibrated by means of a valve rod 11 connected to said rocker 9 at 12 and itself actuated by a spring 13 and by a cam 14 on a counter shaft 15, said shaft 15 being driven in the construction shown from the crank shaft 6, by means of suitable gearing and a shaft 16. The particular engine shown, is supposed to be of the so called four cycle type, and therefore the gearing by which shaft 15 is driven is of such ratio that shaft 15 revolves at half the speed of the crank shaft. The rocker 9 alternately presses in first one of the said valves and then the other, and is adjustable longitudinally at its pivotal point 10 for varying the time of opening and closing of the valves. Its two ends are further provided with adjustment screws 17 by means of which a certain adjustment of the operation of the valves may also be obtained. As will be obvious from inspection of the drawings, the operation of this valve gear is as follows: In Fig. 1 the parts of the valve gear are shown in the position occupied near the beginning of the admission stroke, piston 3 descending and admission valve 7 being open, the lowest portion of the cam 14 being opposite the end of the valve rod 11. When the piston nears the end of its downward stroke, the rise 18 of the cam 14 lifts rod 11 somewhat, moving rocker 9 sufficiently to permit the valve 7 to close. At the beginning of the exhaust stroke the rise 19 of the cam moves the valve rod 11 and rocker still farther, causing valve 8 to open and at about the end of the exhaust stroke, the valve rod 11 slips off from rise 19 to the lowest portion of the cam, causing valve 8 to close and valve 7 to open. By adjusting the rocker 9 longitudinally the relative periods of opening and closing of the two valves may be varied, and by means of the screws 17 the time of opening and degree of opening of said valves may also be varied.

Fuel is supplied to the engine through a pipe 20, which may be provided with suitable regulating means 21 as indicated in Fig. 2. This pipe may be considered to be a pipe connected to a gas producer.

22 designates a pipe for supplying air for combustion and also for the dilution of the charge for the purpose of automatic regulation. Pipe 22 may also have some custom-

any regulating device 23. Pipe 22 terminates in a collar 24 surrounding pipe 20, the latter being perforate within said collar, so that the fluid from pipe 22 is mingled thoroughly with gas entering through pipe 20.

The amount of diluting fluid flowing from pipe 22 to pipe 20, is regulated automatically by a valve 25 adjusted by a speed governor 26 mounted upon shaft 15, as hereinafter described. This valve 25 also controls a port 27, indicated in dotted lines in Fig. 2, which port may be understood to be connected to a source of supply of products of combustion, such, for example, as the exhaust pipe of the engine. The governor 26 not only adjusts valve 25, but also controls the operation of the igniting device, varying the time of ignition to correspond with variation in the quality of the gas or the amount of diluent admitted. We may, of course use any suitable igniting device, and for purposes of illustration have indicated a touch spark igniter 31, operated by an eccentric 28 on counter shaft 15, and an eccentric rod 29 and bell crank 30. To vary the time of ignition, we vary the lead of the eccentric 28 by the direct action of the governor. Without limiting ourselves to any particular type of governor for the purpose we have indicated a well known combined inertia and centrifugal governor. This governor may be caused to vary the lead of the eccentric by any suitable mechanism. In Figs. 1 to 6 inclusive, we have illustrated one mechanism for the purpose, applicable principally to single cylinder engines and comprising a link 32 connecting the governor weight with an arm 28^a projecting from the eccentric 28. As will be seen, when the position of the governor weight changes, the angular position of the eccentric 28 with reference to the shaft 15, will be changed. In the case of a multiple cylinder engine, we ordinarily employ somewhat different mechanism to vary the advance of the eccentrics by the action of the governor. The same governor 26, which controls the time of ignition, also operated the valve 24. For this purpose the governor weight is connected by means of a link 33 with a bell crank 34 revolving with the governor and connected at the center of rotation to a link 35, itself connected to a bell crank 36 and thence by a rod 37 to valve 25.

In the case of a multi-cylinder engine, we customarily employ means whereby, by the action of a single governor and the movement of a single operating member, the angular advance of all of the igniter eccentrics is varied simultaneously and to the same extent. One convenient means for doing this is shown in Fig. 7. As there shown, the governor is arranged to move the shaft 15 axially, and said shaft is provided with spiral key ways 38, which the several eccentrics engage. It will be seen

therefore that longitudinal motion of the shaft varies the angular advance of all eccentrics simultaneously and to the same extent. In this construction the carrying wheel of the governor and the several valve operating cams 14 are connected to the shaft 15 through straight key ways 39 and run between stationary stops 40 which prevent them from moving endwise with the shaft.

The method of regulating the development of power is as follows: Supposing the engine to be operating under maximum load, valve 25 will be substantially half open as regards passage of air from pipe 22 to pipe 20, and a charge of maximum richness will enter the engine cylinder during each admission stroke, and will there be compressed, ignited, and caused to expand, in the ordinary way. If now the load on the engine be reduced, the centrifugal governor 26 will open valve 25 still farther, admitting more air from pipe 22 to pipe 20, and also opening port 27 and admitting products of combustion, which mingle with the air and gas, diluting the latter and retarding the combustion of hydrogen and similar substances until the final ignition of the charge. The total amount of fluid taken into the cylinder remains the same, it will be seen, whatever the load, and therefore the compression is substantially the same at all loads; but the richness of the charge will be decreased. The rate of combustion being thereby changed, the governor 26 automatically advances the point of ignition to compensate for the decreased speed of combustion. Conversely, when the load on the engine is again increased, the automatic governor will reduce the amount of diluent admitted and will retard ignition to correspond with the increased rate of combustion of the charge. The governor 26 also varies the point of ignition to correspond with the change in rate of flame propagation through the mixture due to dilution of the charge, by varying the angular advance of the eccentric or eccentrics 28. It will be seen therefore, that by the action of the two automatic governing devices the character of the charge and the point of ignition will be varied to suit the load on the engine and to maintain constant speed, without varying the compression. We are enabled, therefore, to employ very high compression at light loads as well as at intermediate and heavy loads, and to employ fuel of low thermal value at all loads, the ignition of such fuel being relatively certain because of the very high compression employed. This compression we prefer to be from say 9½ to 16 atmospheres, preferably not below 11 atmospheres. At this high compression mixtures which cannot be depended upon to ignite at lower pressures ignite readily.

Producer gas such as we especially con-

template using has for its principal combustible constituent, carbon monoxid; but many types of producers or generators of fuel gas produce large quantities of hydrogen as well, giving rise to the pre-ignition trouble above mentioned when the engine operates with high compression. When the gas used contains little or no hydrogen, we commonly employ air alone as the diluent, it being understood that any excess of air mixed with the gas above that required for combustion is a mere diluent, and is substantially neutral. When the gas used contains considerable quantities of hydrogen or other readily igniting gases which tend to give rise to pre-ignition troubles, we preferably mix more or less products of combustion with the air. Such products of combustion may be drawn from the exhaust pipe of the engine, or from the stack of any convenient furnace or the like, and are preferably cooled before being mixed with the air and gas, on account of the greater density at low temperature. The specific heat, by volume, of products of combustion is relatively high, as compared with air, and such products exert a marked influence tending to hold back the ignition of hydrogen and like constituents which tend to ignite prematurely under the conditions of heat and pressure prevailing in the engine cylinder during compression; such holding back being due, probably, in great measure to the presence of considerable quantities of carbon dioxide in the products of combustion. By properly diluting the charge to correspond with the load on the engine, without varying the amount of the charge, by correspondingly varying the point of ignition, and when necessary holding back the ignition by employing greater or less quantities of products of combustion in the charge, we are able to insure proper ignition, without so much combustion before the piston reaches the end of its compression stroke as results in excessive back pressure on the piston and the doing of negative work; and thereby we are enabled to use, at all loads, very cheap fuel gas of low thermal value, or containing considerable proportions of ingredients having widely different rates of combustion, and are thus enabled to obtain very high commercial and thermo-dynamic economy.

Hitherto it has been generally considered that the effect of products of combustion in the charge of an explosion engine is highly prejudicial, as tending to make ignition irregular or to prevent it altogether, and very often elaborate measures have been taken to produce very complete scavenging of the cylinder; but we have found that the objections heretofore found to be unavoidable or the unintentional retention of a portion of the products of combustion within the cylinder do not apply when the products of combustion are used in carefully regulated

proportions and are thoroughly mixed with the entering air and gas, but that to the contrary very decided advantages result from the proper mixing of suitably regulated proportions of products of combustion with the charge, as before stated.

In the case of engines which operate by the injection of fuel into the cylinder or combustion chamber of the engine, the products of combustion for diluting the mixture and retarding combustion will be introduced, ordinarily, with the entering charge of air.

What we claim is:—

1. In an internal combustion engine, the combination of a combustion chamber, means for supplying thereto a combustible charge and a diluent gas, and regulating means controlling both the supply of diluent and ignition, and arranged to vary the point of ignition and supply of diluent correspondingly.

2. In an internal combustion engine, the combination of a combustion chamber, means for supplying thereto a combustible charge and a diluent gas, and automatic governing means controlling both the supply of diluent and ignition, and arranged to vary the point of ignition and supply of diluent correspondingly.

3. In an internal combustion engine, the combination of a combustion chamber, means for supplying thereto a combustible charge and a diluent gas, and an automatic speed governor controlling both the supply of diluent and ignition, and arranged to vary the point of ignition and supply of diluent correspondingly.

4. In an internal combustion engine the combination of a combustion chamber, means for supplying thereto a combustible charge and products of combustion, and regulating means controlling both the supply of products of combustion and ignition, and arranged to vary the point of ignition and supply of products of combustion correspondingly.

5. In an internal combustion engine, the combination of a combustion chamber, means for supplying thereto a combustible charge and products of combustion, and automatic governing means controlling both the supply of products of combustion and ignition, and arranged to vary the point of ignition and supply of products of combustion correspondingly.

6. In an internal combustion engine, the combination of a combustion chamber, means for supplying thereto a combustible charge and products of combustion, and an automatic speed governor controlling both the supply of products of combustion and ignition, and arranged to vary the point of ignition and supply of products of combustion correspondingly.

7. In an internal combustion engine, the combination of a combustion chamber, 130

means for supplying thereto a combustible mixture and also air and a different diluting gas, and regulating means controlling the supply of both.

5 8. In an internal combustion engine, the combination of a combustion chamber, means for supplying thereto a combustible mixture and also air and a different diluting gas, and automatic governing means
10 controlling the supply of both.

9. In an internal combustion engine, the combination of a combustion chamber, means for supplying thereto a combustible mixture and also air and a different diluting gas, a valve controlling the supply of
15 both the latter, and an automatic speed governor for adjusting said valve.

10. In an internal combustion engine, the combination of means for supplying a combustible mixture and also air and products
20 of combustion to the engine, a valve controlling such supply of air and products of combustion, and an automatic governor for adjusting said valve.

25 11. In an internal combustion engine, the combination of means for supplying a combustible mixture and also air and carbon dioxid to the engine, a valve controlling such supply of air and carbon dioxid, and
30 an automatic governor for adjusting said valve.

12. In an internal combustion engine, the combination of means for supplying a combustible mixture and a diluent gas to the
35 engine, a valve controlling such supply of diluent gas, igniting means, and automatic governing means controlling said valve and igniting means correspondingly.

13. In an internal combustion engine, the combination of means for supplying a combustible mixture and a diluent gas to the engine, a valve controlling such supply of
40 diluent gas, igniting means, and a single speed governor adjusting both said valve and the point of ignition correspondingly.

14. In an internal combustion engine, the combination of means for supplying a combustible mixture and a diluent gas to the engine, igniting means, a shifting eccentric
50 for operating the same, regulating means which shifts said eccentric to vary the point of ignition, and means operated by said regulating means for varying the supply of

diluent in harmony with the change in point of ignition.

15. In an internal combustion engine, the combination of a combustion chamber, means for supplying a combustible mixture and thereto a combustible mixture and air
60 and a further diluent gas and for varying the proportion of diluent while maintaining substantially constant the total amount of gas, and means for compressing the gas in said chamber to between $9\frac{1}{2}$ and 16 atmospheres, approximately, and causing combustion
65 thereof.

16. In an internal combustion engine, the combination of a combustion chamber, means for supplying thereto a combustible mixture and air and a further diluent gas, 70 means for compressing the gas in said chamber to between $9\frac{1}{2}$ and 16 atmospheres approximately, and for causing combustion thereof, and automatic regulating means comprising means for varying the proportion
75 of diluent and for varying the point of ignition accordingly.

17. In an internal combustion engine, the combination of a combustion chamber, means for supplying thereto fuel and combustion-supporting gas and products of
80 combustion, means for compressing the contents of the chamber, and for causing ignition thereof, and automatic regulating means comprising means for varying the proportion of products of combustion and for varying the point of ignition correspondingly.

18. In an internal combustion engine, the combination of a combustion chamber, 85 means for supplying thereto fuel and combustion-supporting gas and carbon dioxid, means for compressing the contents of the chamber, and for causing ignition thereof, and automatic regulating means comprising
90 means for varying the proportion of carbon dioxid and for varying the point of ignition correspondingly.

In testimony whereof we hereunto affix our signatures, in the presence of two witnesses. 100

GODFREY M. S. TAIT.
CARLETON ELLIS.

Witnesses:

H. M. MARBLE,
FLETCHER P. SCOFIELD.