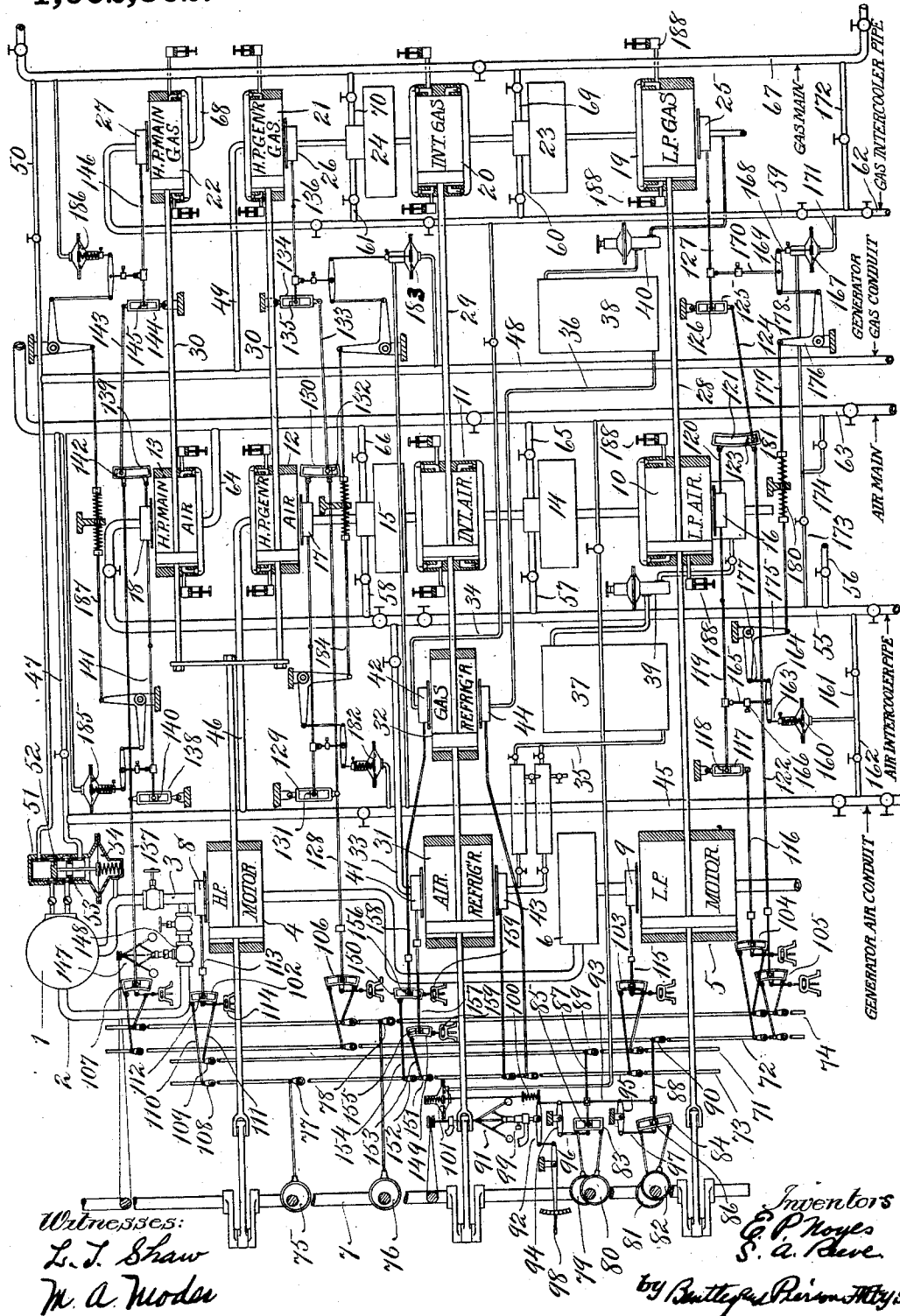


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 PRESSURE FLUID AND POWER SUPPLYING MECHANISM.
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UNITED STATES PATENT OFFICE.

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PRESSURE-FLUID AND POWER SUPPLYING MECHANISM.

1,002,862.

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To all whom it may concern:

Be it known that we, EDWARD P. NOYES, a citizen of the United States, residing at Winchester, county of Middlesex, State of Massachusetts, and SIDNEY A. REEVE, a citizen of the United States, residing at Worcester, county of Worcester, and State of Massachusetts, have invented certain new and useful Improvements in Pressure-Fluid and Power Supplying Mechanism, of which the following specification and accompanying drawing illustrate one form of the invention which we now regard as the best out of the various forms in which the invention may be embodied.

This invention relates to motor-apparatus operating on the modified Joule cycle, where air and fuel are pumped to the working pressure of the system, burned continuously in a closed combustion-chamber, reduced in temperature by evaporating water, and the composite working fluid employed expansively to operate an engine, or operating on some other internal combustion cycle in which the combustion fluids are supplied under pressure to the working cylinder of the engine.

The invention pertains broadly to novel means of controlling an apparatus of this kind according to the load. This load may either be mechanical, such as manifests itself in an increase of resistance to the rotation of the engine shaft or the equivalent means for conveying outside power, or it may be a fluid load such as an abstraction of compressed air for operating air tools and other air-driven apparatus, refrigerating machines, etc.

An apparatus of the class referred to is fitted to furnish pressure fluids for outside use, since it embodies as elements pumps for raising the pressure of the air, fuel and water to the working pressure of the system, and in its broadest aspect this outside supply of pressure fluids may be either of air, of fuel (liquid or gaseous), of steam, or of hot water. For the purpose of illustrating the principle it will be sufficient to assume that air, or gaseous fuel, or both are the fluids demanded for outside consumption.

The object of the invention, generally

speaking, is twofold. It concerns itself first with furnishing improved means of controlling the production of pressure fuel and air in such manner that the pumps which supply these fluids shall be regulated to give as much of the fluids as is required to satisfy the demands of the system and no more. If these fluids supply only the motor, they are regulated according to the demands of the motor, whereas if they are also consumed outside of the system, as in operating compressed-air tools, etc., the regulation must extend to the satisfaction of this outside demand as well as that of the motor. Secondly the invention concerns itself with the production of pressure fluids for consumption outside of the motor and with the regulation of these fluids, either by causing the pumps to furnish just enough (in addition to that required to run the generator) to supply the outside demand and no more, or by suitably controlling and disposing of any excess after it is produced. We prefer the former plan, which involves regulating the performance of the pumps, and have selected this method for illustrating the invention.

It is obvious that the most comprehensive usefulness of an apparatus of this kind would make it capable of supplying both mechanical power and pressure fluid, or either one alone if both are not required, and the invention therefore includes means whereby either of the single services or the dual service may be performed. It further includes provision whereby the fluid destined for outside use may be supplied at a pressure superior to, inferior to, or the same as the generator pressure. It will further appear that the mechanical service, the fluid service, or the dual service may be conducted at either a constant or a variable motor-speed, and at either a constant or a variable generator pressure. The invention provides for whatever class of regulation in this respect is best suited to the conditions of operation. For example, when mechanical power alone is wanted, the motor should generally run at a substantially constant speed, in order that variations in the load, manifested through an increase or decrease of shaft-resistance, may, through a

suitable speed-governor, act upon the supply of pressure-fluid which operates the motor. There are exceptional cases where mechanical power would be required at a variable speed, as in operating hoists, rolling-mills, etc., which have been provided for as will hereinafter appear. On the other hand, when pressure fluid alone is wanted, it is usually needed at a constant pressure, and the speed of the motor is immaterial, although there may in this case also be exceptions where the fluid is furnished at variable pressure. When, finally, both mechanical power and pressure-fluid are required, the motor should generally run at substantially constant speed and the fluid be supplied at substantially constant pressure, with exceptional cases where either the speed or the pressure or both may vary.

The invention in its most comprehensive aspect includes an apparatus working according to the latter plan, that it, at a substantially constant motor speed, and furnishing substantially-constant pressure fluid for outside use, and furthermore capable of furnishing this outside fluid at a pressure different from or the same as the generator pressure.

It includes in its subsidiary aspects, means whereby the apparatus may be arranged to give mechanical power alone, or pressure-fluid alone, and means for furnishing either of these single services or the dual service at constant or variable motor-speed or at constant or variable fluid-pressure.

In an elementary form an apparatus of the kind to which the present invention relates may operate successfully on single-stage compression. It has been found however that one of the reasons for the failure of prior attempts to make the Joule cycle a commercial success is the low working pressures which have been employed. This kind of apparatus can operate economically only at a high working pressure and since this high pressure can best be furnished by a plural-stage compression, and since furthermore a compression by stages gives an opportunity to abstract compressed fluid for outside use at an intermediate pressure—sixty to eighty pounds per square inch for example being the usually-employed pressure for air tools, while the pressure of the generator is preferably something like 250 pounds per square inch or more—it is found to be of advantage to control the separate stages of compression, either according to the speed of the engine, or according to the pressure of the fluid, or jointly according to both speed and pressure. For example, if compressed air be abstracted from the air-intercooler for outside use it would then be desirable, generally speaking, to automatically control the intake of the high-pressure compressor, in addition to that of the low-

pressure compressor, in order that the generator may receive its proper quota of air in spite of the extraneous draft. On the other hand control of the low-pressure compressor gives a certain fundamental or initial regulation which is highly desirable.

Reverting to the first-stated object or aspect of the invention, namely that of regulating the system by controlling the compressor-output according to load, it may be stated that in several patents and co-pending applications of S. A. Reeve and E. P. Noyes, various systems of regulation for an apparatus of this kind are described, most of which have for their object to maintain in predetermined pressure-relationship the air and fuel going to the burner, and the regulation there described usually involves the production of an excess of the combustion fluids over what is required to operate the generator. The present invention on the contrary in so far as this aspect of it is concerned involves the production of only so much compressed fluid as is required for use, and regulation of the compressors or the proportions of the compressors themselves is relied on to maintain the delivery of air and fuel to the burner in the proper quantity and pressure-relationship to maintain the desired combustion. Among other things we thereby avoid loss of compression work through released fluid. When one of the compressors has to supply fluid for outside use in addition to that going to the generator, it may be necessary to introduce an automatic mechanism for maintaining the outputs of the air and fuel pumps or compressors in a predetermined relationship, and the invention includes such a mechanism.

The accompanying drawing represents in diagram a modified Joule-cycle motor-apparatus constructed according to the present invention, and of this view it may be stated that some of the parts are shown in a plane at right-angles to that which they would occupy in the actual apparatus if arranged consistently with the rest of the parts. This can be observed with relation to the main shaft 7 and the eccentrics 79, 80, 81, 82 thereon, for example. The arrangement is intended to be more or less diagrammatic and is adopted as best calculated to clearly expose the parts and their relations with each other in a single view.

1 represents a generator, such for example as shown in Reeve Patent No. 588,293, comprising a suitable closed combustion-chamber in which the air and fuel are continuously burned under substantially constant pressure and from which the products of combustion pass by way of pipe 2 or pipe 3 to the engine, first however being passed through or over a body of water to reduce their temperature, the resulting working

fluid being composed of steam and products of combustion. The engine here shown is compound, having high-pressure cylinder 4 and low-pressure cylinder 5, with intermediate receiver 6. Motion is communicated from the piston through pitmen and cranks to the main shaft 7, from which mechanical power may be derived for any use. 8 and 9 represent respectively the slide-valves of the high-pressure and low-pressure cylinders. Hereinafter "high pressure" and "low-pressure" will be abbreviated "H. P." and "L. P."

Compressed air and gas are furnished to the generator 1 by the air and gas compressors or pumps, the latter in the right-hand column of cylinders and the former in the second column from the right. As before stated, the burner-pressure employed is such as to make at least two stages of compression desirable, and since it or the pressure of a part or all of the outside supply of compressed air or gas may be even higher than 200 to 250 pounds per square inch the arrangement here shown is capable of giving three stages of compression.

10 is the L. P. air-cylinder, 11 the intermediate cylinder, and 12 13 the H. P. cylinders, the former of these two H. P. cylinders being assigned to the generator, and the latter to the outside pressure-main. Between L. P. and intermediate cylinders is a first-stage air-intercooler 14, and between intermediate and H. P. cylinders is a second-stage air-intercooler 15. 16, 17 and 18 are respectively the L. P. and H. P. air-compressor admission-valves.

19, 20, 21, 22 are respectively the L. P., intermediate, and H. P. gas-compressor cylinders corresponding to the air-cylinders, 23, 24 the first and second stage intercoolers, and 25, 26, 27 the L. P. and H. P. admission-valves to said cylinders. The air and gas-compressor pistons are driven by direct connection from the motor pistons and the shaft 7 through the rods 28, 29, 30. By reason of this form of direct connection or any suitable equivalent which may be substituted, a varying load on the compressors reacts directly on the engine, and a varying intake of the engine or output of power therefrom reacts directly on the compressors.

As representing one use to which pressure air and gas may be put outside of the main cycle, there are here shown air and gas refrigerating cylinders 31 32 receiving compressed air and gas respectively from the air and gas intercoolers through induction pipes 33, 34 and discharging through eduction pipes 35, 36 and refrigerating chambers 37, 38 to the suction sides of the L. P. air and gas compressors. The pistons of the refrigerating cylinders are connected on the rod 29 and thence by pitmen and crank with the shaft 7. The refrigeration is performed by

expansion of the compressed air and gas in the cylinders 31, 32 while doing work on the pistons, and it takes effect on articles placed in the chambers 37, 38.

39, 40 are reducing-valves in the return-pipes whereby the pressure of the returning air and gas is kept always somewhat above the entering pressure to L. P.

Compressors 10, 19. 41, 42 are the admission-valves and 43, 44 the discharge-valves of the refrigerating cylinders.

Six principal pipes or conduits are here shown for disposing of the outputs of the various compressors. The generator air-conduit whereby compressed air for supplying the generator and engine is provided is represented at 45, receiving its supply primarily from the H. P. air-compressor 12 through branch conduit 46, but also capable of receiving air at a different pressure or from a different stage by way of branch pipe 47 connected with the air main hereinafter described.

48 is the generator gas-conduit in branch connection through 49 with the H. P. gas compressor 21 and also connected by branch 50 with the gas main hereinafter referred to. The branches 47, 50, constituting extensions of the air and gas conduits, continue to the generator 1 and traverse a regulating mechanism 51 whose purpose is to maintain the air and gas supply initial to the generator always at a slight pressure above the terminal or combustion-chamber pressure and also, when the initial air and gas pressures are equal to each other or in a predetermined relation, to apportion the quantities of air and gas going to the generator. This latter effect is secured by having the apertures for air and gas in a predetermined relation of area. The apertures are varied proportionately by two valves 52, 53 on the same stem, which latter is actuated by a diaphragm 54 having in its upper side the initial air-pressure and on its lower side the terminal generator-pressure of engine-pipe 3 and that of a spring. This spring becomes the measure of difference between the initial and terminal pressures.

55 represents the air-intercooler pipe having an outlet 56 for furnishing outside air at intercooler pressure and connected by branches 57, 58 with the first-stage and second-stage intercoolers, so that from said pipe may be taken air at either the first stage or the second stage of compression. Said pipe also supplies the air-refrigerator cylinder 31 through the branch 33, and further connects with the H. P. air-compressor 13 whereby air may be taken from the intermediate compressor 11 and compressed still higher for outside use.

59 is the gas-intercooler pipe connected to the gas intercoolers 23, 24 through connections 60, 61 and to the H. P. gas-main com-

pressor 22, and likewise connected through the branch 34 with the gas-refrigerator cylinder 32. From intercooler pipe 59 at its outlet 62 may be taken compressed gas for

5 outside use at intercooler pressures.

63 is the air main from which in general compressed-air is taken at the highest pressure which the system furnishes, by way of branch 64 from the H. P. air-main compressor 13, but also having branch connections 65, 66 with the first and second-stage intercoolers 14, 15, so that the main may deliver air at a different pressure or stage of compression. It will be seen that from the intercooler pipe 55 and main 63 compressed air for outside use may be taken simultaneously at different pressures.

67 is the gas main connected by similar branches 68, 69, 70 with the H. P. gas-main compressor 22 and the first and second stage gas intercoolers 23, 24.

With the above arrangement of pipes, conduits and mains, which of course are provided with suitable stop-valves as shown on the drawing for establishing or cutting off their connections, it becomes possible to supply compressed air and gas, or either one singly, for the generator and for outside consumption, at one or more stages of compression. The air and gas for both generator and outside use are compressed in the first instance by the two L. P. compressors 10, 19 and the upper-stage compressors receive only what these lower-stage ones are able to supply. For this purpose the L. P. compressors 10, 19 are made of sufficient capacity to furnish air and gas for the generator 1 to run the engine 4, 5 and drive the compressors and furnish mechanical power from the shaft 7, and also for outside use to supply any power-absorber such as the refrigerator cylinders 31, 32, air-tools and motors, air or gas charging plants, gas illuminating systems, liquid-air producers, etc. If the full number of compression-stages is in operation, the air and gas compressed by the L. P. compressors 10, 19, go to the first-stage intercoolers 14, 23, thence to the intermediate compressors 11, 20, where they are compressed to a higher pressure, thence to the second-stage intercoolers 15, 24, and thence in parallel to the H. P. compressors 12, 13 for air and 21, 22 for gas, from whence a portion of each fluid goes to the generator 1 and a portion to the mains for outside use. These upper-stage compressors are in parallel for the reason that it may be desired to furnish the compressed fluids to the mains for outside use at a different pressure, either higher or lower, from that furnished to the generator. If these two uses require the same pressure, one of the upper-stage compressors for each fluid may be omitted, as for instance the compressors 12, 21, in which case the generator 1 draws from

the mains 63, 67 through the branches 47, 50, or the joint output of both upper-stage compressors may be drawn upon for the appropriate use or uses.

It may here be mentioned that the mains 63, 67 and particularly the air-main 63 act as receivers, from which a supply of compressed fluid may be drawn to effect a start.

Regulation is performed according to speed and according to pressure, and also if necessary, by hand. The speed-regulation may be furnished by the equivalent of a shaft-governor, and for this purpose the drawing shows two variable-motion rockshafts 71, 72, the former controlling the motor-cylinder valves and the latter the compressor intake-valves. In order also that certain of these valves may, if desired, be driven with a fixed motion, there are further provided two fixed-motion rockshafts 73, 74, the former for the motor-valves and the latter for the compressor-valves. The fixed motion is derived from two eccentrics 75, 76 fast on the main-shaft 7, driving rockers 77, 78 on the rockshafts 73, 74. The variable motion is derived from two pairs of eccentrics 79, 80 and 81, 82 for the motor and compressors respectively, driving opposite ends of two links 83, 84, having sliding blocks 85, 86 connected by rods 87, 88 with rockers 89, 90 on the rockshafts 71, 72. The relative elevations of blocks and links are controlled by a fly-ball governor 91 operated from shaft 7 and actuating a rock-lever 92. The latter connects with the sliding blocks on the one side through rod 93 and with the links on the other, through rock-levers 94, 95 and rods 96, 97. When the speed of shaft 7 increases above normal, the governor-balls rise and through the described link and block motion and the variable-motion rockshafts, cause an increased angular-advance and a decreased travel to be imparted to the valves under its control, in a manner well-known in steam-engine governors, whereby the admission to the corresponding cylinders is diminished in volume, that is, a variable quantity of fluid is admitted to said cylinders per stroke or cycle of their pistons.

98 is a hand-lever connected by rod with the left-hand end of lever 92 and having fixed fulcrum and sector. By this means, all of the valves subject to the governor may be put under hand control and the apparatus varied in speed or even reversed at will. According to the set of this lever is determined the normal speed of the machine. The governor has a locking-device 99 whereby it may be thrown out of action when desired. The right-hand end of lever 92 is loaded by a spring 100, and the tension of said spring is controlled by a diaphragm-device 101 having spring-pressure balanced against the pressure of air from the main

63, so that when this device is in commission the normal speed of the machine is determined by the pressure in the air-main.

From the rock-shafts 71, 72, 73, 74, motion is communicated to the motor and compressor valves through the intermediary of links 102, 103, 104, 105, 106, 107, so that each valve may be given either a fixed or a variable motion or one compounded of the two motions. Thus the opposite ends of the link 102 for H. P. motor are driven from rockers 108, 109 on the fixed-motion and variable-motion rock-shafts 73, 71 respectively, through rods 110, 111, and the valve is driven from the block 112 of said link through valve-rod 113. An adjusting device 114 enables the link to be raised or lowered to bring block 112 more or less opposite either rod 110 or 111. The L. P. motor link is similarly driven from the same rock-shafts 73, 71 and operates valve 9 through valve-rod 115. The compressor links 104, 105, 106, 107 are similarly driven from the fixed and variable motion rock-shafts 74, 72 and all of the aforesaid links have adjusting devices similar to the device 114.

The sliding block of link 104 through rod 116 drives a rocker 117 having a radially-sliding block 118 which in turn drives the valve 16 of the L. P. air-compressor through rod 119. From said valve rod 120 continues the motion to one end of a link 121. The other end of the latter is driven from the sliding block of link 105 through rod 122. The sliding-block 123 of link 121 may be placed opposite either rod 119 or 122 and communicates motion through rod 124, rocker 125, radially-sliding block 126 thereon, and rod 127 to the valve 25 of the L. P. gas-compressor. The result of this arrangement is that the valves 16, 25 may both receive either fixed or variable motions according to the set or links 104, 105, or one may receive a fixed motion while the other receives a variable motion, according to the adjustment of said links 104, 105 and the link-block 123, and also that the gas valve 25 may be subjected to or removed from the influence of a pressure-actuated diaphragm hereinafter referred to.

The H. P. generator air and gas compressor valves 17, 26 receive their motion from the sliding block of link 106 by way of rod 128 driving rocker 129 and the lower end of link 130. The radial-sliding block 131 of link 129 drives the H. P. air-compressor valve 17 and the motion is extended to the upper end of link 130. The sliding block 132 of the latter through rod 133 drives rocker 134 and the radial-sliding block 135 of said rocker drives the H. P. gas-compressor valve 26 through rod 136. The result is that gas valve 26 may receive the same motion as air valve 17 subject to the influence

of a pressure-controlled diaphragm hereinafter described, or it may receive motion direct from link 106.

A mechanism quite similar to the foregoing for driving the H. P. main air and gas compressor valves 18, 27 includes rod 137 driven from the sliding block of link 107 and driving rocker 138 and one end of link 139, radial block 140 in rocker 138, rod 141 therefrom driving valve 18, block 142 in link 139, rod 143 therefrom, rocker 144 driven by 143, radial block 145 in rocker, and rod 146 from block to gas-valve 27.

From the foregoing it is evident that any of the low or high-pressure compressor intake-valves may receive either a fixed or a speed-varied motion or a motion compounded of the two.

Additional speed-regulation is furnished by an emergency fly-ball governor 147 controlling a throttle-valve 148 in the engine-pipe 2 and operated from shaft 7. When conduit 2 is in use conduit 3 will in general be closed. This governor acts to limit excessive speed in case the governor 91 fails and also furnishes safety-regulation when the latter is out of use and the apparatus running at variable speed as later described.

Of the refrigerating cylinders 31, 32, which are essentially motor cylinders, the exhaust valves 43, 44 are driven from the fixed-motion rock-shaft 73. The admission valves 41, 42 are similarly driven, but preferably have an adjustment, shown consisting of links 149, 150 driven by rockers 151, 152 and rods 153, 154 from rock-shaft 73, the link-blocks 155, 156 connecting with the valve-rods 157, 158. Each link has an adjusting-device 159 for raising and lowering it so as to give the valves a greater or less travel or no travel at all, in which latter case the refrigerator-cylinders are put out of commission.

Pressure-controlled regulators are provided for varying the travel of the compressor admission-valves according to the pressure of the fluids furnished by the compressors. These regulators as shown are of two types, each employing a diaphragm or equivalent having fluid-pressure on one side and on the other side spring-pressure or equivalent in the one case and fluid-pressure in the other case. For convenience the types may be termed respectively "spring-balance diaphragm" and "pressure-balance diaphragm." These devices are of course only representative and are selected as one of the simplest forms of construction for effecting the desired control, but the same idea of means could be embodied in various other constructive devices. For regulating the admission-valve 16 of the L. P. air compressor one of the spring-balance type of diaphragm devices is employed, 160 being a diaphragm receiving on its lower side the pressure of

the air-intercooler pipe 55 through branch 161, or for certain purposes that of the generator air-conduit 45 through branch 162. On its upper side the diaphragm receives
 5 the counterbalancing pressure of a spring and is connected by stem 163 with a lever 164 fulcrumed at its right-hand end, said lever connecting by rod 165 with the guide of valve-rod 119. When air-pressure under
 10 the diaphragm has reached a point predetermined by the tension of its spring, the diaphragm raises the radial block 118 in link 117 and thereby shortens the stroke of admission-valve 16. Thus this valve is under
 15 the joint control of speed and pressure so that an increase of either factor beyond a certain point will tend to diminish the output of compressor 10. Diaphragm-stem 165 has a locking-device 166 to put said diaphragm
 20 out of commission, and the various other diaphragm regulators hereinafter described are similarly equipped, making it possible to disable any one of them when it is not desired to have the corresponding pressure-control take effect. A similar result can be
 25 obtained by closing the stop-valves in the branch-pipes through which fluid-pressures reach the diaphragms.

To cause the gas-pressure to follow the
 30 air-pressure a pressure-balance diaphragm 167 imposes its control on the valve-rod 127 by connections 168, 169, 170 similar to those of the diaphragm 160. On its lower side diaphragm 167 receives the pressure of the
 35 gas intercooler-pipe 59 through branch 171 (or of the gas-main 67 through cross-connection 172 and on its upper side the pressure of air-intercooler pipe 55 through branch 173 (or of air-main 63 through additional
 40 branch 174). When the air-pressure above the diaphragm predominates, the radial block 126 in rocker 125 descends and imparts an increased travel to the L. P. gas compressor valve 25, causing said compressor
 45 to compress more gas until the gas-pressure equals the air pressure. Should the gas-pressure below the diaphragm exceed the air-pressure above it, the block 126 rises and the travel of valve 25 decreases until the
 50 pressure of the gas has fallen to that of the air. Thus the intercooler pressure or the main pressure of air and gas are so controlled as to remain the same, insuring a proportionate feed of air and gas to the generator, by controlling the intake of the L. P. gas-compressor.

Provision is made so that should the outdraft of either air or gas to the external power-consumer exceed the capacity of its
 60 compressor to supply this demand in addition to that of the generator, the proportions of the two fluids will not be disturbed, but the other compressor will have its output diminished conformably and the resulting decrease of power will simply slow down

the engine and thus give notice of overload. For this purpose a cross connection between the diaphragm 160 and 167 is established including bell-cranks 175, 176 connected by
 70 rods 177, 178 with the fulcrum-ends of the levers 164, 169 and by a rod 179 with each other. Springs 180, 181 seated against a fixed abutment exert opposite longitudinal pressures on rod 179 and tend to centralize it.

Suppose that an outdraft of air from the main 63 or conduit 55 exists in excess of the capacity of L. P. compressor 10 to supply it in addition to the draft of the generator, while the L. P. gas-compressor 19 is able to
 80 supply the demand on it. This is a condition of overload, and it tends to upset the equality of air and gas pressures going to the burner, and consequently put out the flame and cause a sudden stop of the engine. The
 85 diaphragm 160 sinks until link-blocks 118 can descend no farther, but as the air-pressure continues to decrease on account of the outdraft of air, diaphragm 160 continues to sink and in so doing, since the middle pivot
 90 of lever 164 now acts as a fixed fulcrum, it raises the right-hand end of said lever, swinging the bell-cranks 165, 176 against the tension of spring 181 and thus raising the block 126 and diminishing the output of
 95 L. P. gas-compressor 19. The pressures of air and gas thus tend to remain equal and the engine slows down without the flame in the generator being extinguished.

Control of the admission-valve 17 of the
 100 H. P. generator air-compressor according to the pressure of the output of said compressor is effected by a spring-balance diaphragm 182 similar to 160, piped to the generator air-conduit 45 and acting on the
 105 block 131 in a manner already described for diaphragm 160 and block 118, with the result of diminishing the intake of the compressor 12 when the generator air-pressure has reached a predetermined maximum. A
 110 pressure-balance diaphragm 183 controlled differentially by the pressures of the generator air and gas conduits 45 and 48 and acting on the block 135 in a manner already described for diaphragm 167 and block 126,
 115 varies the travel of H. P. generator gas-compressor valve 26 so as to cause the generator gas-pressure to follow the generator air-pressure, this control and that of diaphragm 182 being exercised conjointly with
 120 the speed-control of the valves 17, 26 by the shaft-governor 91. A cross-connection 184 similar to 179, etc., performs a function similar to that of 179.

The travel of intake-valves 18, 27 of the
 125 air and gas-main H. P. compressors 13, 22 is controlled according to the pressures furnished by said compressors, through the medium of spring-balance diaphragms 185, 186, pressure connected to the mains 63, 67, these
 130

diaphragms acting on the blocks 140, 145 to diminish the travel of valves 18, 27 when the pressure in the main exceeds a predetermined amount, said diaphragms having
5 a cross-connection 187 similar in construction and function to 179 and 184.

On each end of the double-acting compressor-cylinders are shown hand-controlled clearance-variators 188 for adjusting the
10 clearance and hence the amount of the intake per stroke of each of the compressors.

The operation of the apparatus, assuming that it is furnishing both mechanical power from the shaft 7 and compressed air
15 and gas for outside use at both high and low pressures from the intercooler pipes 55, 59 and the mains 63, 67 respectively, and assuming that both of these services are regulated automatically according to the demand
20 for each, is as follows: Air and gas are taken in by the L. P. compressors 10, 19 and compressed into the intercoolers 14, 23. From said intercoolers the intermediate compressors 11, 20 draw these fluids and
25 compress them to a higher stage into the intercoolers 15, 24, and from the latter, the two H. P. compressors 12, 13 for air, and 21, 22 for gas, take the fluids and compress them still higher for the generator 1 and
30 for the mains 63, 67 leading to some external absorber of the power of the compressed air or gas. Compressed air and gas are taken at a lower pressure from either the first-stage intercoolers 14, 23 or the
35 second-stage intercoolers 15, 24 and utilized in some outside power-absorber, concretely represented in the drawing by the refrigerator-cylinders 31, 32. In the generator, the fluids are burned and increased in
40 volume by the heat. Their excess temperature is absorbed by water in the cooling-chamber of the generator and the resulting mixed motive-fluid, composed of steam (usually superheated by the gases) and products
45 of combustion, passes to the H. P. motor-cylinder 4, and from the exhaust of the latter to the receiver 6 and L. P. motor-cylinder 5, from whence it is exhausted to the atmosphere or otherwise disposed of.
50 The motor and refrigerator pistons drive the shaft 7 and through it the compressor-pistons, and the said shaft also operates the governors 91, 147 and the rock shafts 71, 72, 73, 74 for actuating the various compressor and motor valves. The capacity of
55 the apparatus for supplying all these services depends primarily upon the amount of air and gas admitted to the L. P. cylinders by their admission-valves 16, 25. As these
60 are under the control of the speed-governor 91 through connections which have been described, the amount of air and gas taken in will be only that requisite for keeping the speed of the entire machine constant, the
65 influence of other modifying factors being

for the moment neglected. One of these modifying factors is the pressure existing in the air intercooler 14, which it may be assumed is to be maintained practically constant in order to give a substantially constant pressure to the generator to maintain
70 its efficiency, and a constant pressure to the outside power-absorber. This intercooler-pressure acting on diaphragm 160 accomplishes such variation in the travel of the
75 admission-valve 16 to the L. P. air-compressor as to maintain the intercooler-pressure substantially constant.

When the "load" is a fluid one, for example a consumption of compressed-air outside of the generator and engine, it might be supposed that the intake of the H. P. air and gas compressors should be proportional to that of the L. P. compressors, but this assumption neglects the loss by friction of
80 the apparatus and the fixed heat-losses involved in combustion. The action of the diaphragm 160 adjusts for these losses. As the demand for outside air becomes less, the demand of the H. P. compressors does not
85 decrease in proportion, for even when this outside demand reduces to nothing, the H. P. compresses must still handle enough air and gas to keep the generator hot and the engine in motion at normal speed. Hence a
90 governing action which would readjust the H. P. valves sufficiently to keep the speed normal upon a decrease in load would also reduce the L. P. air intake, but would not
95 reduce it to a point actually corresponding to the decreased demand for outside air. The accumulating intercooler-pressure then acts on diaphragm 160 to reduce the air-intake still further.

Another element of importance in the regulation is to insure that the intake of the
105 L. P. gas compressor 19 shall be so apportioned to that of the air-compressor 10 that the combustion in the generator 1 may be perfect, and the first step in this direction
110 is accomplished by the pressure-balance diaphragm 167, which being controlled differentially by the pressure in the air and gas intercoolers 14, 23, insures a gas-intercooler pressure equal to that of the air-
115 intercooler.

If no lateral outdraft occurs from the compressing lines, the equal pressures in intercoolers 14, 23 will be drawn upon by the
120 H. P. compressors, and, supposing the latter to have a relative capacity proportionate to the relative quantities of air and gas necessary for perfect combustion, these H. P. compressors will act as meters, furnishing
125 higher-stage compressed air and gas to the generator in combustible proportions. In case of an outdraft from the intercoolers however, such as that of the refrigerator-cylinders 31, 32, it is desirable that the H. P. compressor-valves 17, 26 have their motion
130

regulated so that the cylinders 12, 21 shall draw upon the intercooler supply of fluids in such measure as to maintain the pressure in the generator 1 constant irrespective of the control exercised by diaphragm 160. To this end the action of diaphragm 182 enters. In event of a disproportionate draft from the air and gas intercoolers for outside use, or a draft of only one of these fluids, the pressure-balance diaphragm 184 maintains the generator gas-pressure equal to generator air-pressure independently of the control exercised by diaphragm 167.

Should the demand for mechanical power vary the resistance to rotation of shaft 7, the reaction of the governor 91 on the valves 17, 26, will vary the travel of these valves so as to admit a quantity of fluid to the compressors 12, 21 such as to restore the speed of the engine to normal independently of the speed-governing of the L. P. valves. In this way the speed is immediately controlled in a manner which is found to be advantageous where an outside draft from the intercooler exerts more or less of a disturbing effect upon the conditions of regulation.

The pressures in the mains 63, 67 supplied by the H. P. compressors 13, 22 are kept constant by the action of diaphragm 185, 186 on their admission-valves 18, 27, this control being independent of other controlling actions in the machine except that of course there is an interaction between the pressure which effects this control and the other regulating devices which determine what that pressure shall be. The speed-control of H. P. motor-valve 8 (and also, if required, of the L. P. motor valve 9) by governor 81 exercises, in addition to the usual regulation according to load as found in steam-engine practice, a certain novel action in view of such regulation being effected by the same speed-governor, or one similarly adjusted, as that controlling the compressor-valves. Thus, for example, neglecting other regulating actions intermediate between the L. P. compressor and H. P. motor valves, it is evident that since these valves have their motion varied in common, the motor-valve will automatically adjust itself to take at each stroke only a volume proportionate to that admitted to the compressors, and hence the generator-pressure will tend to remain constant.

The governor 147 controlling throttle-valve 148 in the engine-pipe is set to operate at a higher speed than that which actuates the governor 91, and when the latter is in use therefore operates principally as an emergency device. When the apparatus operates at variable speed, this device will prevent the speed from becoming excessive.

The foregoing description of operation

applies to a multiplex set of duties imposed upon the apparatus, all of which duties it is capable of performing simultaneously under automatic regulation as described. For less diverse requirements the regulation may be somewhat simplified and the automatic action of certain of the regulating devices dispensed with, which is easily performed by means of the various adjustments and locks already described, or by any suitable equivalents for these devices. In order that this may be more readily understood we will describe a series of concrete cases involving the action of less than the whole number of regulating devices. It will be understood that various other cases may arise within the scope of the invention and that we have not attempted to set forth all the modes of its use, our purpose being merely to illustrate the principle of the invention by describing a few of the several ways in which it may operate.

Case I.—The L. P. compressor-valve 16, 25 are under control of the speed-governor 91. Other controlling devices are out of action. This case is suited to a demand for mechanical power alone, and for a nearly constant load, where the variations, if any, are slow in character. The capacities of the compressors are proportioned to the correct quantity-ratio of gas and air required to maintain perfect combustion in the generator, and they act as meters for these fluids. The generator-pressure is anything necessary to maintain normal speed and differs for each different load, but does not vary so widely as the load, because of the quantities of air and gas which it is always necessary to compress in order to overcome the "fixed charges" of friction and heat-losses.

Case II.—The speed-governor 91 controls that L. P. and H. P. compressor-valves 16, 25, 17, 26, and the H. P. motor valve 8. This case is also for mechanical power alone. The efficiency is more constant than in Case I, because generator-pressure is practically constant, the intake of valve 8 being proportioned to that of valves 16 and 25. More violent fluctuations of load may be handled in this than in Case I on account of the latent capacity of the engine when under light load to handle a heavier load when it comes. It may be modified by omitting speed-control of the H. P. motor-valve 8, in which case burner-pressure will fluctuate. It may also be modified by retaining speed-control of valve 8 and dispensing with that of H. P. compressor-valves 17, 26.

Case III.—Air-intercooler pressure controls the L. P. compressor-valve 16 and air-intercooler versus gas-intercooler controls the L. P. gas-compressor valve 25, through diaphragms 160, 167. The upper-stage cylinders are in parallel, that is, drawing in

common from the intercoolers, for the generator and mains respectively. Valves 16, 25, 17, 26 may be hand-controlled by lever 98. Excessive speed may be prevented by the throttle-governor 147. This arrangement is adapted for a lateral draft from the intercoolers or a draft from the mains, or both drafts. The intercooler pressures are maintained constant, and equal for air and gas. The H. P. compressors act as meters. This case may be modified by giving automatic speed-control to the H. P. motor-valve 8, which fits it for automatically regulating according to a variable mechanical load.

Case IV.—Air-intercooler pressure controls the H. P. air-compressor valve 17 through diaphragm 182, and air-intercooler against gas-intercooler pressure controls the H. P. gas-compressor valve 26 through diaphragm 184. The valves 16, 25, 17, 26 may have hand-control through lever 98, or preferably the governor 91 acts at a safety-limit to avoid over speeding. A substitute to this end would be the throttle-governor 147. This case supplies compressed air from the intercoolers and the speed of the machine follows the fluid load, being that which is necessary to keep the intercooler-pressures constant. The generator-pressure varies, though not widely since it must always be materially above intercooler-pressure. Gas-intercooler-pressure is maintained equal to air-intercooler pressure and the H. P. compressors 12, 21 meter to the generator according to their relative capacities.

Case V.—The compressor and motor valves 16, 25, 17, 26 and 8 are automatically speed-controlled by governor 91. The L. P. compressor valves 16 and 25 are respectively spring-balance controlled and pressure-balance controlled by the intercooler-pressures acting through diaphragms 160, 167. H. P. generator compressor-valve 26 is pressure-balance controlled through diaphragm 184 by the pressures in the generator conduits 45, 48. This case is adapted to furnish both mechanical power and fluid-pressure. It will be noted that diaphragm 182 is here locked so that, since the speed is constant, generator pressure will vary, though it will not vary widely and is always in stable equilibrium. A less delicate but useful regulation is obtained by also locking diaphragm 184, in which case the H. P. compressors 12, 21 meter to the generator.

Case VI.—Valves 16, 25, 17, 26 and 8 are hand-controlled. L. P. valves 16, 25, are respectively spring-balance controlled and pressure-balance controlled through diaphragms 160, 167 by the pressures in the generator-conduits 46, 48. H. P. gas-compressor valve is also pressure-balance controlled through diaphragm 184 by the pres-

ures in these conduits. Here the speed varies. Modification may be made by locking the diaphragm 184 and causing the compressors 12, 21 to act as meters.

Case VII.—The compressor-valves 16, 25, 17, 26 and motor-valve 8 are speed-controlled by governor 91. The H. P. generator and main compressors are united so as to furnish a common output by opening the stop-valves in branches 47, 50. Diaphragms 182, 184, 185, 186 are locked. L. P. air-compressor valve 16 is under control of diaphragm 160 receiving the common pressure of the generator air-conduit 45 and air-main 63. The L. P. gas-compressor valve 25 is balance-controlled through diaphragm 167 receiving the common pressure of air-conduit and main and of gas-conduit and main on its opposite sides. As the whole output of the H. P. compressors in this case does not go to the generator, the relative proportions of air and gas reaching the generator depends upon the relative sizes of the air and gas orifices. Thus if the generator-conduits were of equal apertures throughout (neglecting the friction due to their length), equal quantities of air and gas would go to the generator, since the pressures are equal. The device 51, having air and gas orifices in the desired proportion, and automatically varying said orifices proportionately, properly apportions the air and gas. Fixed orifices may be used instead. The generator-pressure in this case is kept closely constant and the air and gas pressures in the mains and conduits are kept equal. Both mechanical and fluid loads may be imposed.

Case VIII.—The L. P. air and gas valves 16, 25, 17, 26 are under spring-balance and pressure-balance control respectively by the pressures of the air and gas mains served by the H. P. compressors 13, 22. The H. P. generator gas-compressor valve is pressure-balance controlled by generator conduit pressures. The principal load is a fluid draft from the mains for the outside use, only small quantities of mechanical power or none at all being demanded. The speed follows the fluid load. The emergency-governor 147 may limit excessive speed. A modification can be made by omitting diaphragm control of the H. P. generator gas-compressor valve. The H. P. generator compressors then act as meters.

Case IX.—The upper-stage cylinders are united to furnish the same pressure for both generator and mains. Valves 16, 25, 17, 21 and 8 are hand-controlled. Diaphragms 160, 167 controlling the L. P. valves receive the common pressure of generator conduits and mains. Generator pressure is constant, but speed varies. The draft from the mains must not exceed the spare capacity of the compressor department as modified by

speed-control exercised through hand-lever 98. The above may be modified by putting the H. P. motor valve 8 under control of the governor 91, unlocking the hand-lever 98 and controlling the same by diaphragm 101 receiving the pressure of the air-main. This reduces the apparatus to a simple form for use where fluid-draft is the sole load imposed. The apparatus operates at variable speed under control of diaphragm 101, the speed being merely sufficient to keep a predetermined pressure in the air main.

While the particular form of internal-combustion motor herein described is one employing a separate combustion chamber 1 through which the pressure fluids are supplied to an engine of the steam-engine type, as described for example in Reeve Patents Nos. 588,178 and 588,293, it will be understood that the invention applies to various other internal-combustion or heat-engine cycles in which the combustion chamber of the motor is supplied by compressors, and we use the term "internal-combustion" in the broad sense as denoting these several types, whether operating with continuous or intermittent flame at constant pressure within or without the working cylinder, or by explosion.

What we claim as new and desire to secure by Letters Patent is:

1. In power-generating apparatus, the combination of stage compressors for supplying combustion-fluid, an internal-combustion motor operating said compressors and supplied by one stage of compression, an external power-delivering conduit supplied by another stage of compression, and means for independently regulating the outputs of said stages.

2. In power-generating apparatus, the combination of stage compressors for supplying the combustion-fluid, an internal-combustion motor operating said compressors and supplied by a later stage of compression, an outlet from the compression-line between the stages for supplying a less-pressure fluid for outside use, and means for independently regulating the outputs of said stages.

3. In power-generating apparatus, the combination of a combustion-chamber, a lower-stage compressor for supplying combustion-fluid, a plurality of upper-stage compressors supplied by said lower-stage compressor, one of said upper-stage compressors supplying the combustion-chamber, and a discharge-conduit from the other upper-stage compressor for external fluid-supply.

4. In power-generating apparatus, the combination of a combustion-chamber, a lower-stage air-compressor, a plurality of upper-stage air-compressors supplied thereby and one of them supplying the combustion-chamber, and a discharge-conduit from another upper-stage compressor for external air-supply.

5. In power-generating apparatus, the combination of a combustion-chamber, a lower-stage fuel gas-compressor, a plurality of upper-stage fuel gas-compressors supplied thereby and one of them supplying the combustion-chamber, and a discharge-conduit from another upper-stage compressor for external fluid-supply.

6. In power-generating apparatus, the combination of an internal-combustion motor, a pump having capacity to regularly supply said motor and also to supply an external pressure draft, valve-mechanism for regularly charging the motor from said pump, an outlet for said external draft, and means sensitive to the load on said motor for controlling the quantity per stroke of said fluid delivered by the pump.

7. In power-generating apparatus, the combination of an internal-combustion motor, an air-pump discharging thereto, valve mechanism for regularly supplying the air-ingredient of the combustible charge from said pump to said motor, said pump having excess capacity enabling it to supply an external draft, an outlet for said external draft, and means sensitive to the pressure of the pump output for regulating the intake of the pump.

8. In power-generating apparatus, the combination of an internal-combustion motor, a compressor driven by the motor and discharging thereto, valve mechanism for regularly supplying the motor from said compressor, an outside power-conduit supplied by said compressor, and means controlled by the speed of the motor for varying the performance of said compressor.

9. In power-generating apparatus, the combination of an internal-combustion motor, a pump driven by said motor, valve mechanism for regularly charging the latter with combustion fluid from said pump, said pump having capacity to supply an external draft, an outlet for said external draft, and regulating means sensitive both to the speed of the motor and the pressure of the pump output for regulating said output jointly according to the demands of the motor and of the external draft.

10. In power-generating apparatus, the combination of an internal-combustion motor, an air-compressor operated by the motor and discharging thereto, valve mechanism for regularly supplying said motor from said compressor, an outside-power conduit supplied by said compressor, and means controlled jointly by the speed of the motor and the pressure of the air for varying the performance of said compressor.

11. In power-generating apparatus, the combination of an internal-combustion

motor, a fuel gas-compressor operated by said motor and discharging thereto, valve mechanism for regularly supplying the motor from said compressor, an outside power-conduit supplied by said compressor, and means controlled jointly by the speed of the motor and the gas-pressure for varying the performance of said compressor.

12. In power-generating apparatus, the combination of an internal-combustion motor, a pump having capacity to regularly supply said motor and also to supply an external draft, valve-mechanism for regularly charging the motor from said pump, an outlet for said external draft, and regulating means controlling the supply from said pump to the motor, and the intake of the pump, and sensitive to the load on the motor.

13. In power-generating apparatus, the combination of an internal-combustion motor, a pump discharging thereto and also having capacity to supply an external draft, valve-mechanism for regularly charging the motor from said pump, an outlet for said external draft, a speed governor controlling the supply from said pump to the motor, and a governor sensitive to the pressure of the pump output for regulating the intake of the pump.

14. In power-generating apparatus, the combination of an internal-combustion motor, means for supplying pressure fuel and air to the motor, an outside power-conduit supplied by one of said fluids, and means controlled differentially by the pressures of the air and fuel for varying the relative quantities of said pressure fluids produced.

15. In power-generating apparatus, the combination of an internal-combustion motor, air and fuel gas compressors for supplying said motor, an outside power-conduit supplied by one of said compressors, and means controlled differentially by the pressures of the air and gas for varying the relative performance of said compressors.

16. In power-generating apparatus, the combination of an internal-combustion motor, compressors for supplying air and fuel gas to said motor, one of said compressors having a capacity to deliver an excess of its fluid for outside use, and means controlled differentially by the air and gas pressures for varying the performance of the other compressor.

17. In power-generating apparatus, the combination of an internal-combustion motor, air and fuel gas compressors supplying said motor, the air compressor having a capacity to deliver an excess of air for outside use, and means controlled differentially by the air and gas pressures for varying the performance of the gas-compressor.

18. In power-generating apparatus, the combination of an internal-combustion motor, stage compressors supplying combustion-fluid to said motor, and means controlled jointly by the speed of the motor and the pressure of the fluid for controlling one of the stages of compression.

19. In power-generating apparatus, the combination of an internal-combustion motor, stage air-compressors for supplying said motor, and means controlled jointly by the speed of the motor and the air-pressure for controlling one of the stages of compression.

20. In power-generating apparatus, the combination of an internal-combustion motor, stage fuel gas-compressors supplying said motor, and means controlled jointly by the speed of the motor and the gas-pressure for controlling one of the stages of compression.

21. In power-generating apparatus, the combination of an internal-combustion motor, stage air and fuel gas compressors supplying said motor, and means controlled jointly by the speed of the motor and the fluid pressure for controlling one of the stages of compression for both air and gas.

22. In power-generating apparatus, the combination of an internal-combustion motor, stage compressors for supplying combustion-fluid to said motor, and means controlled jointly by the speed of the motor and the fluid-pressure for controlling the lower stage of compression.

23. In power-generating apparatus, the combination of an internal-combustion motor, stage compressors for supplying combustion-fluid to said motor, and means controlled jointly by the speed of the motor and the fluid-pressure for controlling an upper stage of compression.

24. In power-generating apparatus, the combination of an internal-combustion motor, stage compressors for supplying combustion-fluid to said motor, and means controlled jointly by the speed of the motor and the fluid-pressure for controlling successive stages of compression.

25. In power-generating apparatus, the combination of an internal-combustion motor, stage air-compressors supplying said motor, and means controlled jointly by the speed of the motor and the air-pressure for controlling the lower-stage compression.

26. In power-generating apparatus, the combination of an internal-combustion motor, stage fuel gas-compressors supplying said motor, and means controlled jointly by the speed of the motor and the gas-pressure for controlling the lower stage of compression.

27. In power-generating apparatus, the combination of an internal-combustion motor, stage air-compressors supplying said motor, and means controlled jointly by the speed of the motor and the air-pressure for controlling an upper stage of compression.

28. In power-generating apparatus, the combination of an internal-combustion motor, stage fuel gas-compressors supplying said motor, and means controlled jointly by the speed of the motor and the gas-pressure for controlling an upper stage of compression.

29. In power-generating apparatus, the combination of an internal-combustion motor, stage air and fuel gas compressors supplying said motor, and means controlled jointly by the speed of the motor and the fluid-pressure for controlling successive stages of compression for both air and gas.

30. In power-generating apparatus, the combination of an internal-combustion motor, stage compressors driven by said motor for supplying combination-fluid to said motor, means for controlling the performance of one of said compressors by the pressure of a stage other than that of the compressor controlled, and an external power-conduit supplied by the pressure of said other stage.

31. In power-generating apparatus, the combination of an internal-combustion motor, stage compressors driven by said motor for supplying combustion-fluid thereto, means for controlling the performance of the lower-stage compressor by the pressure furnished by the higher-stage compressor, and an external power-conduit supplied by the higher-stage fluid.

32. In power-generating apparatus, the combination of a combustion-chamber, stage compressors supplying combustion fluid thereto, and means for controlling the performance of a higher-stage compressor by the pressure furnished by a lower-stage compressor.

33. In power-generating apparatus, the combination of a combustion-chamber, stage compressors furnishing combustion-fluids thereto, and means controlled differentially by the pressure of said fluids for controlling the relative quantities of fluids produced by one of the stages.

34. In continuous combustion power-generating apparatus, the combination of a combustion-chamber, stage air and fuel gas compressors supplying the same, and means controlled differentially by the pressures of air and gas for controlling the relative performance of the lower-stage compressors.

35. In continuous combustion power-generating apparatus, the combination of a combustion-chamber, stage air and fuel gas compressors supplying the same, and means controlled differentially by the air and gas pressures for controlling the relative performance of higher-stage compressors.

36. In power-generating apparatus, the combination of a combustion-chamber, stage air and fuel gas compressors supplying the same, one of the stages furnishing an excess

for outside use, and means controlled differentially by the air and gas pressures for varying the performance of the lower-stage compressor of the other fluid.

37. In power-generating apparatus, the combination of a combustion-chamber, stage air and fuel gas compressors supplying the same, one of the stages furnishing an excess of one of the fluids for outside use, and means controlled differentially by the air and gas pressures for varying the performance of the higher-stage compressor of the other fluid.

38. In power-generating apparatus, the combination of a combustion-chamber, stage air and fuel gas compressors supplying the same, one of the stages of air-compression furnishing an excess for outside use, and means controlled differentially by the air and gas pressures for varying the performance of the lower-stage gas-compressor.

39. In power-generating apparatus, the combination of a combustion-chamber, stage air and fuel gas compressors supplying the same, one of the air-compressors furnishing an excess for outside use, and means controlled differentially by the air and gas pressures for varying the performance of the higher-stage gas-compressors.

40. In power-generating apparatus, the combination of an internal-combustion motor, stage compressors supplying combustion-fluid to said motor, an outside power-conduit supplied by the compression-line between stages, and means for automatically regulating the higher-stage compressor according to the demand of the motor.

41. In power-generating apparatus, the combination of an internal-combustion motor, stage air-compressors supplying said motor, an outside power-conduit supplied from the compression-line between stages, and means for automatically regulating the higher-stage compressor according to the demand of the motor.

42. In power-generating apparatus, the combination of an internal-combustion motor, stage fuel gas-compressors supplying said motor, an outside gas-conduit supplied from the compression line between stages, and means for automatically regulating the higher-stage compressor according to the demand of the motor.

43. In power-generating apparatus, the combination of an internal-combustion motor, stage air and fuel gas compressors supplying said motor, outside air and gas conduits supplied from the compression-lines between stages, and means for automatically regulating the higher-stage compressors according to the demand of the motor.

44. In power-generating apparatus, the combination of an internal-combustion motor, stage compressors driven by the motor

for supplying combustion-fluid to said motor, an outside power-conduit supplied from the compression-lines between stages, and means for automatically regulating the higher-stage compressor according to the speed of the motor.

45. In power-generating apparatus, the combination of an internal-combustion motor, stage compressors for supplying combustion-fluid to said motor, an outside power-conduit supplied from the compression-lines between stages, and means controlled by the fluid-pressure for automatically regulating the higher-stage compressor.

46. In power-generating apparatus, the combination of an internal-combustion motor, stage compressors operated by said motor for supplying combustion-fluid to the motor, an outside power-conduit supplied from the compression-line between stages, and means for automatically regulating the higher-stage compressor jointly according to the speed of the motor and the fluid-pressure.

47. In power-generating apparatus, the combination of an internal-combustion motor, stage air and fuel gas compressors supplying said motor, an outside power-conduit supplied from one of the compression-lines between stages, and means controlled differentially by the air and gas pressures for controlling the lower-stage compressor of the other compression line.

48. In power-generating apparatus, the combination of an internal-combustion mo-

tor, stage air and fuel gas compressors, supplying said motor, an outside power-conduit supplied from one of the compression-lines between stages, and means for automatically equalizing the pressures in said compression lines between stages.

49. In power-generating apparatus, the combination of an internal-combustion motor, a compressor supplying said motor, and means controlled by the speed of the motor for jointly controlling the intakes of said compressor and motor.

50. In power-generating apparatus, the combination of an internal-combustion motor, air and fuel gas compressors supplying said motor, an outside power conduit supplied from one of the compression-lines, means controlled differentially by the air and gas pressures for varying the relative performance of said compressors, and a cross-connection between the compressors for maintaining their relative performance when the range of the differential device is exceeded.

In witness whereof we have hereunto set our hands before the subscribing witnesses, the 1st day of November, 1904, and the 14th day of October, 1904.

EDWARD P. NOYES.

SIDNEY A. REEVE.

Witnesses to E. P. Noyes' signature:

R. M. PIERSON,

ALBERT KLYVES.

Witnesses to signature of S. A. Reeve:

R. M. PIERSON,

L. T. SHAW.