July 29, 1952 B. LOVE 2,604,934

PRESSURE COMBUSTION AND COMPRESSOR

Filed Nov. 3, 1944 2 SHEETS—SHEET 1

FIG. I.

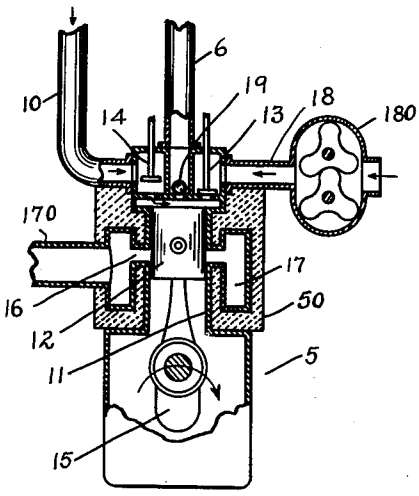
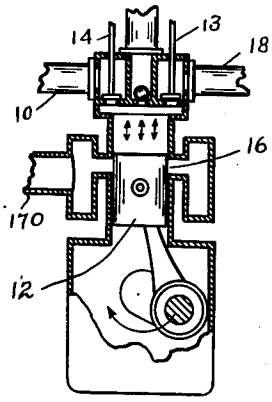


FIG. II.



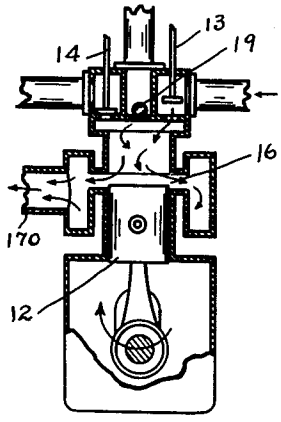


FIG. III.

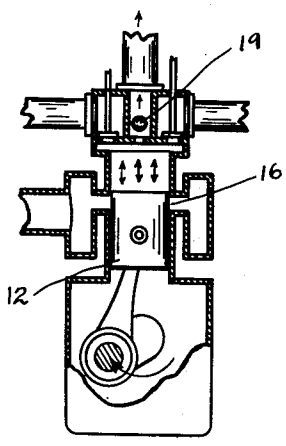
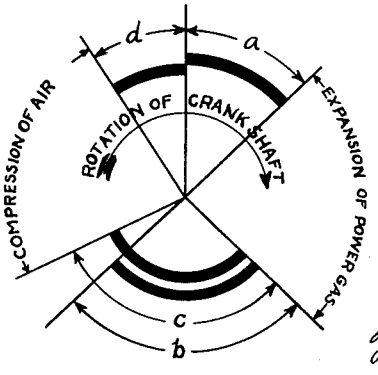


FIG. IV.

FIG. V.



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PRESSURE COMBUSTION AND COMPRESSOR

Filed Nov. 3, 1944 2 SHEETS—SHEET 2

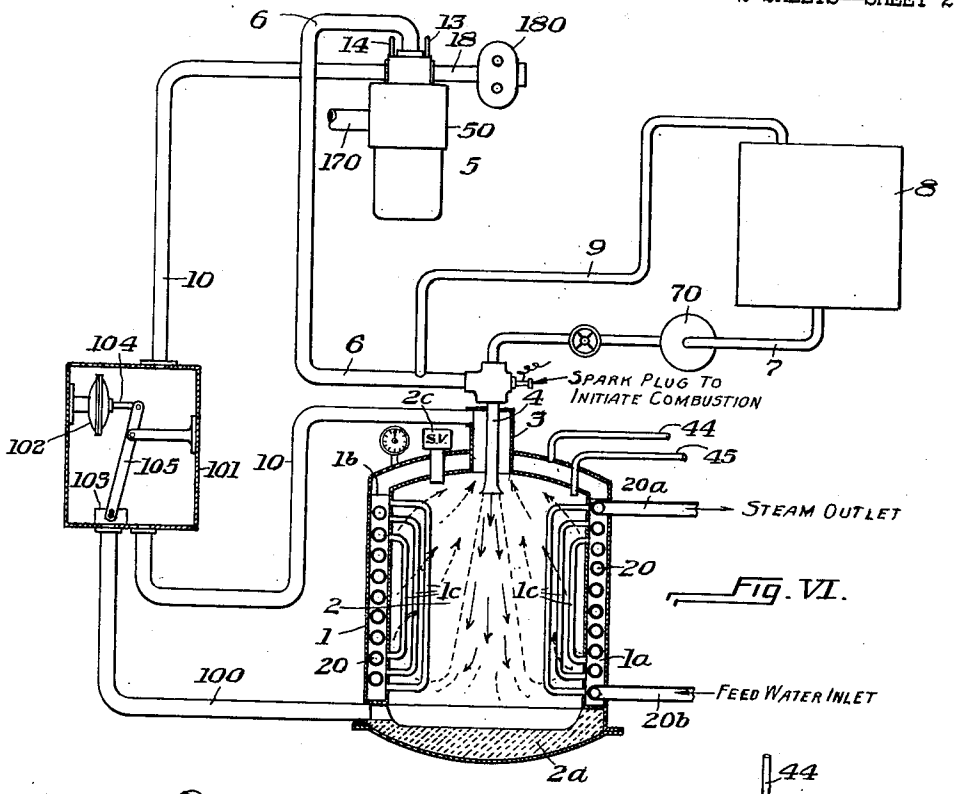


Fig. VI.

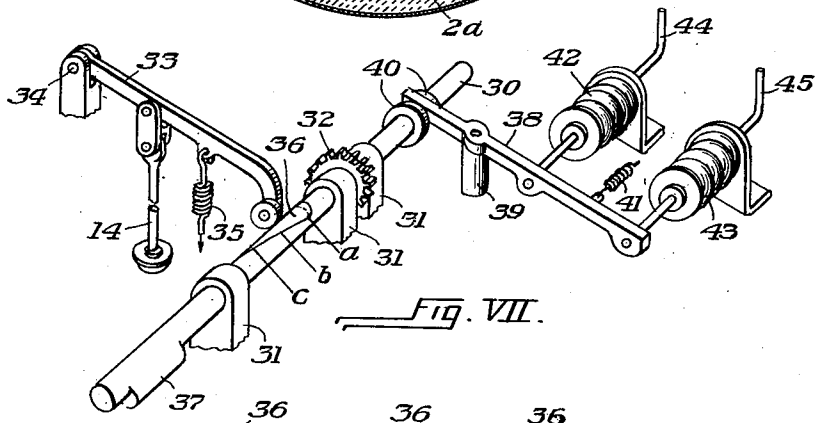


Fig. VII.

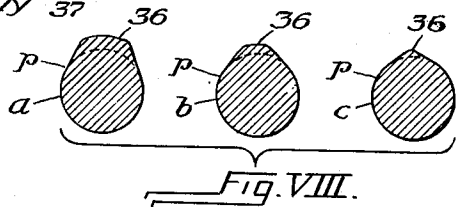


Fig. VIII.

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PRESSURE COMBUSTION AND COMPRESSOR

Ben Love, Carnegie, Pa.

Application November 3, 1944, Serial No. 561,779

4 Claims. (Cl. 158—1)

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My invention relates to the compressing of gas, particularly, though not exclusively, to the compressing of air for sustaining combustion of fuel under superatmospheric pressure. The invention consists in certain new and useful improvements in method and in apparatus, and chief among my objects are the obtainment of increased efficiency and economy in the compression of gas, and increased conservation and utilization of the energy produced by the combustion of fuel.

The invention will be understood upon reference to accompanying drawings, in which:

Figure I is a diagrammatic view of an exemplary reciprocating engine, in which and in the operation of which the objects of the invention may be realized, the view showing the engine partly in side elevation and partly in vertical section;

Figures II, III and IV are views comparable with Figure I, severally illustrating successive stages in the reciprocation of the piston of the engine;

Figure V is a timing diagram of the valves of the engine;

Figure VI is a diagrammatic view, with certain parts shown in vertical section, of steam-generating apparatus in which my improvements in pressure combustion are incorporated and utilized;

Figure VII is a diagrammatic view in perspective of a valve mechanism of the compressor engine; and

Figure VIII shows three cross sectional views of a valve-operating cam of the valve mechanism, the views being taken respectively on planes normal to the axis of the cam shaft, as indicated by the lines *a*, *b* and *c* in Figure VII.

In general it is to be understood that hitherto it has been proposed to introduce charges of gas (or vapor) at super-atmospheric pressure to the cylinders of a reciprocating engine, and, by the expansion of such charges in the cylinders, to drive the pistons of the engine and maintain them in reciprocation. Alternately with respect to the cycles of the pistons, during which the charges of gas are introduced to the engine cylinders and expanded, charges of air (or other gas to be compressed) are introduced to the cylinders and compressed by the so-driven pistons. Thus it is that the same cylinders and pistons of the engine are utilized both as air-compressing instrumentalities and as the operating motor therefor.

It will be understood that during the compression of the successive air charges, heat is generated and yielded to the walls of the engine, as evidenced by the usual practice of providing water jackets upon the cylinders of high pressure air compressors, to prevent them from becoming red hot and failing. Conversely, in the expansion of the successive charges of power gas heat is consumed. Of course, in the usual internal combustion engine, the temperatures developed by the exploding fuel charges are so high that the heat loss due to the expansion of the burning charges is not adequate to keep the engine walls sufficiently cool without the aid of a water jacket, or cooling air circulated over the external walls of the engine.

2

The practice of my invention involves the use of charges of power gas or vapor at a relatively low temperature, whereby the expanded charges are effective to absorb heat imparted to the engine walls during the compression of the air charges—heat which is otherwise dissipated and lost. In accordance with the invention, I establish and maintain substantially a thermal balance between the heat which is yielded to the engine walls by the compression of the air charges and the heat which is absorbed from such walls by the expansion of the charges of power gas.

The heat yielded to the piston body and cylinder walls during the compression of each charge of air, is taken up by the next-ensuing charge of power gas in course of expansion. Thus, the heat of compression of the air is transferred to the power gas, whereby the available and effective energy of such gas is substantially increased; the usual water-jacket of the engine is dispensed with, and the heat otherwise lost is utilized. By virtue of this mode of operation, I not only effect savings in the cost of equipment, but I more nearly approach the ideal conditions of thermal efficiency—achieving, as the physicist would say, a close approximation of an adiabatic cycle.

Referring to the accompanying drawings a reciprocating engine is indicated by the reference numeral 5. For simplicity in description and illustration, the engine 5 is shown to be a single-cylinder engine, and its valves are diagrammatically indicated, with the valve springs and the valve-operating gear omitted, but with the understanding that the valves and their springs and operating gear, as hereinafter set forth, will be so particularly designed as to admit of the operation presently to be described. The gas (or vapor), which under superatmospheric pressure drives the engine, enters the cylinder 11 by way of an inlet pipe 10 leading from a source

of supply, presently to be more fully considered. In Figure I the piston 12 of the engine is shown on dead center, at the upper end of its range of reciprocation; the exhaust port 16 is closed, and the inlet valve 14 for the power gas is in open position. Under the pressure of the power gas admitted to the cylinder the piston is driven downward, and the crank-shaft 15 rotated in clockwise direction, as the arrow indicates. When the piston has moved downward through a certain interval (an interval represented in terms of crankshaft rotation by the angle *a*, Figure V), the inlet valve 14 is closed, and the charge of gas in the cylinder expands, driving the piston through the remainder of its downward stroke, and imparting rotational momentum to the fly-wheel (not shown) and other rotating parts of the engine. As the descending piston passes from the position in which it is shown in Figure II to that in which it is shown in Figure III, the exhaust port 16 opens, and the spent gas is exhausted. The exhaust port of the engine consists in a circumferential opening 16 in the wall of the cylinder, and such opening 16 stands in immediate communication with an exhaust chest 17 connected to an exhaust duct 170. If desired, suction-producing instrumentalities, such as an exhaust-pump (not shown), may be organized with the exhaust duct.

The air to be compressed in the cylinder is introduced through a duct 18, and is subject to the control of an air inlet valve 13. Advantageously, the air is supercharged, that is, it is fed at superatmospheric pressure into the engine, the means to such end consisting in this case of a cycloidal pump 180, geared in manifest way to the rotating shaft of the engine. Upon the opening of the exhaust port 16 by the downwardly moving piston 12, the air inlet valve 13 opens (cf. Figure III). The air streams into the cylinder and sweeps the spent power gas therefrom, and fills the cylinder with a charge of air. The piston 12 (under the influence of the energy stored in the rotating parts of the engine) moves upward, and the air valve 13 and exhaust port 16 close (Figure IV), and the charge of air is compressed. Preferably, the air valve closes after the exhaust port closes, whereby a substantial supercharging of air is obtained. The compressed air is fed from the engine to a receiver, or other point of disposal, by means of a discharge duct 6. Communication between the duct 6 and cylinder 11 is subject to a check valve 19 that is normally held in closed position, save under the conditions now to be described. When the rising pressure of the air being compressed by the upwardly moving piston 12 reaches and slightly exceeds the pressure prevailing in the duct 6, the check-valve 19 is forced open, and the compressed air is discharged. As the piston reaches the upper end of its stroke (Figure I), the inlet valve 14 again opens, and a charge of power gas is again fed from pipe 10 into the cylinder. Such is the operation of the engine in one complete reciprocation of the piston. Of course, in service the operation is repeated, and continues without interruption.

The heat of compression yielded to, and conserved in, the cylinder walls by each air charge is, through the expansion of the next-succeeding charge of power gas, removed from the cylinder walls, with the good effects already described. The engine is enclosed in a heat-insulating jacket 50, Figure I, such jacket providing in this case the means for inhibiting the loss of heat from the engine, to the end that the thermal cycle described may be established and maintained.

It will be manifest to persons skilled in the art that many modifications and variations of the method and apparatus described may be utilized, without departing from the essence of the invention. For example, the air-compressing engine has been illustrated and described as a two-cycle engine: Manifestly a four-cycle engine of generally known sort may be adapted to serve.

It will be understood that the invention will prove valuable in many and widely varied fields of industry. The power gas employed may be steam, or the products of combustion of apparatus in which fuel is burned under superatmospheric pressure, or any other suitable gaseous or vaporous medium under superatmospheric pressure. The invention is not limited to the particular source from which the power gas is obtained. Again, air is not the only gas which may be compressed in the engine. Indeed, it is contemplated that the invention may be applied in the generation and compression of carbon dioxide in the manufacture of Dry Ice; and various other uses will be found in various fields of industry. However, as mentioned in the forepart of this specification, my method is particularly adapted for the combustion of fuel under superatmospheric pressure, and in such field I shall describe an elaboration of the invention.

Referring to Figure VI, I show a heat exchanger, in this case a steam generator, which is fired under superatmospheric pressure. The generator includes a boiler 1, a combustion chamber or fire-box 2, and a flue outlet 3. Fuel and compressed air are introduced to the fire-box through an injector 4, and combustion under superatmospheric pressures up to ten atmospheres or more is sustained in the fire-box. Herein fuel oil provides the fuel, and a jet of such fuel, together with compressed air delivered by a pipe 6, is projected into the fire-box against an incandescent wall or baffle 2*a* of refractory material. The hot body of the baffle 2*a* insures the cracking of the hydrocarbons in the fuel, and consequently the complete combustion of the fuel.

It will be understood that at high pressures the quantity of heat contained at given temperature in a unit volume of gases greatly exceeds the heat contained in the same volume of gases at the same temperature, but at substantially normal atmospheric pressure, and because of such greater heat content per unit volume of gas, plus the fact that heat transfer from the flames and hot gases under the higher pressure is more rapid than under the normal lower pressure, the required heat-transfer surface of a boiler of a given output rating may be much smaller in area than is otherwise possible. Accordingly, a pressure-combustion boiler may be minimized in size for a given boiler rating. In the light of these circumstances, I have conceived an improved pressure-combustion boiler, and have provided a particularly effective organization of such boiler with the compressor.

As illustrated in Figure VI the boiler 1 is double walled throughout its cylindrical sides and dome-shaped top, forming between the two walls a container for a body 1*a* of liquid of high vaporizing point, such as mercury, or a low-melting-

point metal, or other suitable material. In such body the boiler tubes **20** are submerged. The water, or other liquid of relatively low boiling point, to be converted into steam is injected. The boiler tubes **20** in this case comprise a helical coil of steel tubing, having a feed water inlet **20***b* at the lower end of the coil and a steam outlet **20***a* at the upper end, as illustrated. The heat generated by combustion within the fire-box **2** is transferred to the bath of mercury and the boiler tubing submerged therein. The water introduced to the boiler tubing is converted to steam, which is delivered through outlet **20***a*. An advantage of this use of mercury, or the like, is that all of the surface of the boiler tubing **20** is heated uniformly, whereby the tendency for hot spots to develop is minimized. The problem of boiler water treatment (to eliminate the formation of boiler scale on the inner surface of the tubing) is simplified, if not eliminated, since any precipitates forming in the boiler tubing are carried out of the tubing by the high pressure steam.

The boiling point of mercury is approximately 675° F., and at this temperature saturated steam has a pressure of about 2600 pounds per square inch, a pressure too high for usual industrial applications. However, the boiler is operated as a "flash" boiler, in which the quantity of water supplied to the boiler tubing is regulated to maintain the steam pressure at any desired practical pressure, say a pressure up to 1200 pounds. This saturated steam at 1200 pounds pressure has a temperature of only 567° F., while the temperature of the mercury may, and ordinarily will be, substantially higher, with the effect that the steam generated at 1200 pounds pressure in the boiler will be superheated.

In order to promote uniform temperature throughout the body of mercury, as well as to expedite heat transfer thereto from the hot flames and gases within the pressure-combustion chamber or fire-box **2**, I provide banks of vertical tubes **1***c* that interconnect the top and bottom portions of the confined body of mercury. The banks of tubes extend into the fire-box, as shown. The banks of tubes are provided throughout the circumference of the fire-box, and promote maximum heat absorption by the mercury. The flames and hot products of combustion or gases rebound from the incandescent baffle **2***a* against which the fuel jet plays, and sweep upward in spreading stream over and between the tubes as indicated by the dotted arrows. A thermally induced circulation of the mercury is thus maintained. As the upwardly flowing gases reach the top of the fire-box they flow to the outlet **3**, sweeping against the inner of two walls of the boiler body.

The body of mercury **1***a* does not fill the space between the two walls of the boiler body, but has its level at such plane **1***b* that a space for mercury vapor is provided at the top of the fire-box, it being noted that mercury vapor is generated in the operation of the boiler, and is sealed or confined in this space. As will presently appear, the pressure of this mercury vapor is utilized in effecting a control of certain phases of the operation of the apparatus.

The compressed air for sustaining combustion in the fire-box **2** is, as has been said, delivered to the injector **4** by means of the compressed air line **6** extending from the engine **5**. The fuel oil is delivered to the injector through a pipe **7** leading from a supply tank **8**. A branch line **9** extends from the compressed air line to the fuel tank, so that a pressure equal to the pressure of the air in line **6**, is maintained above the body of liquid fuel in the tank. In most cases, a fuel pump **70** will be arranged in the fuel supply line, to insure the delivery of fuel at a properly metered rate.

The waste products of combustion in the steam generator provide the power gas for the engine **5**, it being understood that such waste products are under the same pressure (ten atmospheres pressure in this case) as is maintained in the fire-box. And it will further be understood that, although such waste gases or products of combustion have yielded great quantities of their heat to the mercury in the boiler, they are nevertheless at a superatmospheric temperature, in this case a temperature substantially in excess of 675° F. The inlet duct **10** of the engine is connected to the outlet **3** of the steam generator.

Desirably the apparatus will be so designed and the parts so proportioned and operated that all of the products of combustion generated in the fire-box will be utilized in driving the air-compressing engine. If, however, the products of combustion should in some cases exceed the requirements of the engine, a safety valve **2***c* will open and relieve the excess pressure. The effect of this safety valve will also serve in conjunction with the valve mechanism described below to govern or limit the maximum speed of the engine.

In starting the operation of the apparatus, the air-compressing engine may be driven by compressed air delivered from any suitable source to the pipe **10**. Alternatively, an electric starting motor, such as the motor normally used in starting an automobile engine, may be used. In order that the starting motor need not be run until the boiler is brought up to operating temperature, I provide a branch pipe **100** that leads from the fire-box to a valve-chest **101** included in the duct **10**. When the apparatus is being set in operation the duct **10** above the valve-chest is closed, and the hot products of combustion are passed immediately from fire-box (before they have yielded heat to the heat exchange elements of the boiler) to the chest **101** and thence to the air-compressing engine **5**, whereby the engine is adapted more quickly to be brought up to the point for operation by the waste gases of the boiler. As the fire-box and boiler approach normal operating temperatures, the duct **10** above the valve-chest is gradually opened and the branch **100** gradually closed. The apparatus is thus set in normal operation.

Means may be provided for accomplishing all of this automatically. In exemplary way, I provide in the valve-chest **101** a diaphragm or bellows device **102**, which is adapted to expand and contract and to shift a stem **104** according as the temperature within the chest **101** rises and falls. The stem **104** is articulated to the upper end of a lever **105**, and such lever carries a valve-block **103** that is adapted to control the flow of the waste gases from ducts **10** and **100**. When the apparatus is being brought up to normal operation, the temperature in duct **10** is low, and, under such circumstances, the valve mechanism within the chest **101** operates to throw the valve from illustrated position, in which duct **100** is closed and the line **10** between the outlet **3** and the engine is open, into a position in which such line is closed at the chest and the duct **100** is open. The hot waste gases or products of combustion are then led immediately from the fire-box **2** to the valve chest, whence they are

delivered to the engine 5. As the temperatures and pressures within the system approach operating values, the valve 103 is gradually returned to normal position, closing the branch 100 and opening the line 10.

If any of the heat generated by the compression of the air charges in the engine is not taken up by the engine body, it is retained by the air fed to the fire-box, giving the effect of preheating the air for combustion. It will be seen that the power gas (products of combustion) which drives the engine must contain more heat or pressure energy than that which is needed for the compression of the air, to compensate for the unavoidable friction, etc., losses encountered in the operation of the engine. The inlet temperature and pressure of the products of combustion or power gas will in the main control the pressure to which the air charges may be compressed, and the compression temperature in the engine will approach the temperature of such power gas, there being a temperature differential due to said losses in the engine.

If, in the normal operation of the system, the pressure of the waste gases of the steam generator should suddenly fall below effective value (due to a sudden and extraordinary withdrawal of steam from the boiler), the temperature of the gases flowing through chest 101 falls and the mechanism in the chest operates to shift the valve 103, thereby short-circuiting hot gases from the fire-box to the engine 5, and accelerating engine operation. However, in order to maintain the apparatus in the state of operation in which the heat yielded to the engine walls during the compression of the air charges substantially equals the heat absorbed from such walls during the expansion of the charges of power gas, another device (and in many cases such device is self sufficient) is provided for the automatic regulation of the quantity of gas in the power gas charges relatively to the quantity of air in the air charges. In this case such effect is gained by holding the air charges substantially uniform, while automatically increasing or decreasing the individual power gas charges.

Before describing such device in detail, attention will be directed to the valve-timing diagram of Figure V. The sequential operation of the valves 13, 14, 16 and 19 of the engine are respectively denoted by the arcs *c*, *a*, *b* and *d*. While I have indicated that the air inlet valve 13 opens at the same instant as the exhaust port 16 opens, it is to be noted that the air inlet valve may open either immediately before or immediately after the exhaust port opens. And it will be understood that the difference between the angles *b* and *c* in the valve diagram of Fig. V indicates the interval of lag between the closing of the exhaust port and the closing of the air inlet valve, in which interval the supercharging of air into the cylinder is effected. The power gas valve 14 and the air valve 13 may be severally operated by means of rocker-arms cooperating with cams on a cam shaft geared in known manner to be driven from the rotating crank-shaft of the engine, and by elaboration of known valve mechanism of this general type, or the like, the timing of the power gas inlet valve relatively to that of the air inlet valve may be automatically modified, for the purpose mentioned.

Turning to Figure VII the cam shaft 30 of the valve mechanism is indicated. The shaft is journaled for rotation in bearings 31, and is equipped with a gear 32 that meshes with the conventional cam-shaft drive (not shown) of the engine. The valve-operating rocker arm 33 is arranged to swing on its pivot 34, and to open and close the power gas valve 14, under the effect of a tension spring 35 and a cam 36 engaging, as the shaft rotates, the roller-equipped distal end of the rocker arm. It will be understood that a similar rocker arm device is arranged to open and close the air valve 13, only the gas-valve-operating cam 37 being shown. The cam shaft is journaled not only for rotation in the bearings 31, but for axial movement as well, a feathered or splined sliding union being provided between the shaft and gear 32.

Both of the cams 36 and 37 are elongate, extending axially of the shaft, so that the valve-operating rockers of both valves 13 and 14 may remain in valve-operating engagement with the cams as the cam shaft is axially shifted, as it is, by means of a lever 38, pivoted intermediate its ends to a stationary post 39, and engaged on one side of the pivot between two collars 40 fixed to the rotary shaft, and on opposite side of the pivot by a tension spring 41 and the plungers of two metallic bellows 42 and 43. The interior of the bellows 42 communicates through tube 44 with the mercury vapor chest at the top of the steam generator, while the bellows 43 is similarly connected by a tube 45 to the interior of the combustion chamber or fire-box 2. Normally, the aggregate thrust of the plungers of the two bellows, produced by the cumulative effect of the pressures prevailing in the mercury vapor chest and the fire-box, is equal and opposite to the effect of spring tension upon the lever 38, whereby the shaft rotates in an intermediate position in its range of axial movement. When this condition obtains, the power gas charges bear a constant relation to the air charges, such a relation as produces and maintains the described thermal balance within the engine. On the other hand, when the conditions of operation of the steam generator change, due to variations in the demand for steam and for change in firing rate, or any other reason, the physical condition (pressure and/or temperature) of the waste gases vary, and the aggregate effect of the pressures acting upon the bellows 42 and 43 is increased or decreased, as the case may be; the lever 38 swings in one direction or the other and correspondingly shifts the cam shaft axially. Whereas the cam 37 that operates the air valve is of uniform throw throughout its extent, the throw of the cam 36 is varied longitudinally of the shaft, from a maximum throw at its right-hand, Figure VII, to a zero or substantially zero throw at its left-hand end; cf. the cross sections *a*, *b* and *c* in Figure VIII. While there is this variation in the throw of the cam 36, it is to be noted that the point *p* at which the cam initiates the opening of the power gas valve 14 bears a constant relation to the axis of the shaft throughout the extent of the cam. From the foregoing it will be seen that the duration of opening of the air valve, and the quantity of air in the successive air charges admitted to the engine, remain constant throughout the range of shift of the cam shaft, while the duration of opening of the power gas valve is varied, with consequent variation in the quantity of gas in the power gas charges introduced to the engine. When the heat or intrinsic energy in combustion gases drops below a normal value, the fact is reflected in a drop in pressure in either or both of the bellows 42 and 43, with the effect that the spring swings the lever 38 and

shifts the shaft **30** in right-to-left direction and increases the effective throw of the cam **36** which in turn is effective to increase the duration of opening of the power gas valve **14**. The quantity of power gas admitted to the engine in each charge is increased to maintain the thermal balance. Conversely, when the heat of the products of combustion rises above normal value, the pressures effective in the bellows predominate over the tension of spring **41**, and the lever swings and shifts the shaft in left-to-right direction, reducing the effective throw of the cam **36** and reducing the quantity of gas in the engine-driving charges, to maintain the thermal balance.

Such is the construction and mode of operation of a pressure-combustion apparatus of my invention. And it will be perceived that if the power gas or vapor for operating the compressor engine **5** be some other medium than the products of a pressure combustion system, a regulation of the power gas or vapor may, in the light of this disclosure, be provided by the engineer.

It remains to be noted that where it is desirable to operate the steam generator described at temperatures lower than those required to produce mercury vapor at substantial superatmospheric pressure in the chest at the top of the fire-box **2**, a fluid lighter than, and having a lower vaporizing point than, mercury may be provided on top of the body *1a* of mercury in the boiler unit. Such a known liquid as Dowtherme, or certain petroleum distillates of higher boiling point than water, may be mentioned in exemplary way. It will also be understood that the conventional water tube boiler may be used in the place of the steam generator disclosed herein, and may be arranged to be fired by pressure combustion, such for example as the boiler shown in Letters Patent No. 2,227,666 granted January 7, 1941, to one W. G. Noack, and the connection **44** for the bellows **42** of my apparatus may be made at a point exposed to the steam pressure in such boiler.

The rocker-arm valve mechanism described in the foregoing specification is illustrative of the several known equivalent valve mechanisms that the engineer may adapt to the operation of the air and power gas valves of the engine in the manner and for the purpose indicated. These and other modifications are within the spirit of the invention defined in the appended claims.

In Figures I and VI, I show the engine **5** to be covered with an insulating jacket **50**, and it will be manifest that the steam generator **1** and the entire system of ducts and tubes **6**, **10**, **44**, **45**, **100** and **101** may be incased with insulation.

The application for this patent comprised a continuation-in-part of an application, Serial No. 393,996, filed by me May 17, 1941, and now abandoned.

I claim as my invention:

1. In an expansible-chamber heat engine and gas compressor including a cylinder and a piston reciprocable therein, a connection to a source of power gas, a valve controlling admission of gas from said source to said cylinder, an exhaust port for relieving expanded power gas from said cylinder, a connection to a source of another gas to be compressed, a valve controlling admission of said other gas to said cylinder, a connection to said cylinder for delivering said other gas to a point of use when compressed, means periodically opening said first-mentioned valve and means responsive to the increase or decrease in pressure of the power gas for adjusting the valve-opening means to conversely decrease or increase the time during which the valve is held open.

2. In an expansible-chamber heat engine including a cylinder and a piston reciprocable therein, a combustion chamber and a valve controlling the admission of fluid from the chamber to the cylinder, the combination therewitn of a mechanism for periodically opening said valve for a variable length of time, means for adjusting said mechanism to vary the length of time the valve is held open and means responsive to the increase or decrease in pressure in said chamber for shifting said adjusting means to conversely decrease or increase the time of said periodic opening.

3. The combination defined by claim 2 characterized by said chamber having a boiler associated therewith, and said shifting means including means responsive to the increase or decrease in pressure in said boiler.

4. The combination defined by claim 2 characterized by said mechanism including a sliding shaft having an elongated tapered cam thereon to effect said variation.

BEN LOVE.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
1,840,588	Knox	Jan. 12, 1932
1,847,260	Pardee	Mar. 1, 1932
1,849,347	Dale	Mar. 15, 1932
1,948,536	Noack	Feb. 27, 1934
2,101,412	Pescara	Dec. 4, 1937
2,102,121	Janicke	Dec. 14, 1937
2,227,666	Noack	Jan. 7, 1941
2,227,896	Fitzgerald	Jan. 7, 1941

FOREIGN PATENTS

Number	Country	Date
496,692	France	Aug. 12, 1919
511,356	France	Sept. 23, 1920
239,150	Great Britain	1925
239,434	Great Britain	1925
30,554	France	Mar. 30, 1926
675,693	France	1930