Aug. 11, 1964 B. W. FOSTER 3,143,850

SUPERCHARGED INTEGRAL COMPRESSION ENGINE

Filed Feb. 13, 1961 4 Sheets-Sheet 1

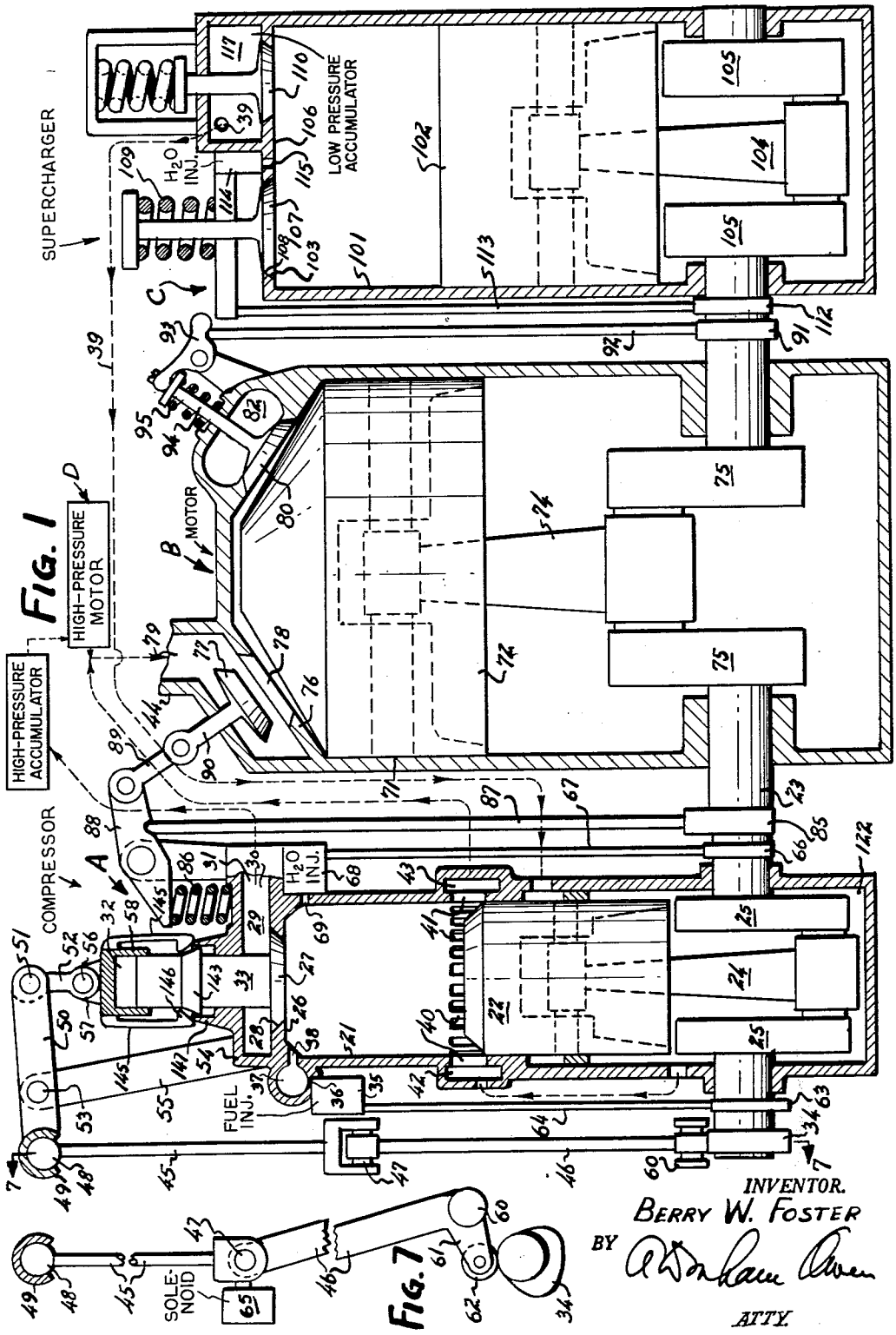


Fig. 1

Fig. 7

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SUPERCHARGED INTEGRAL COMPRESSION ENGINE

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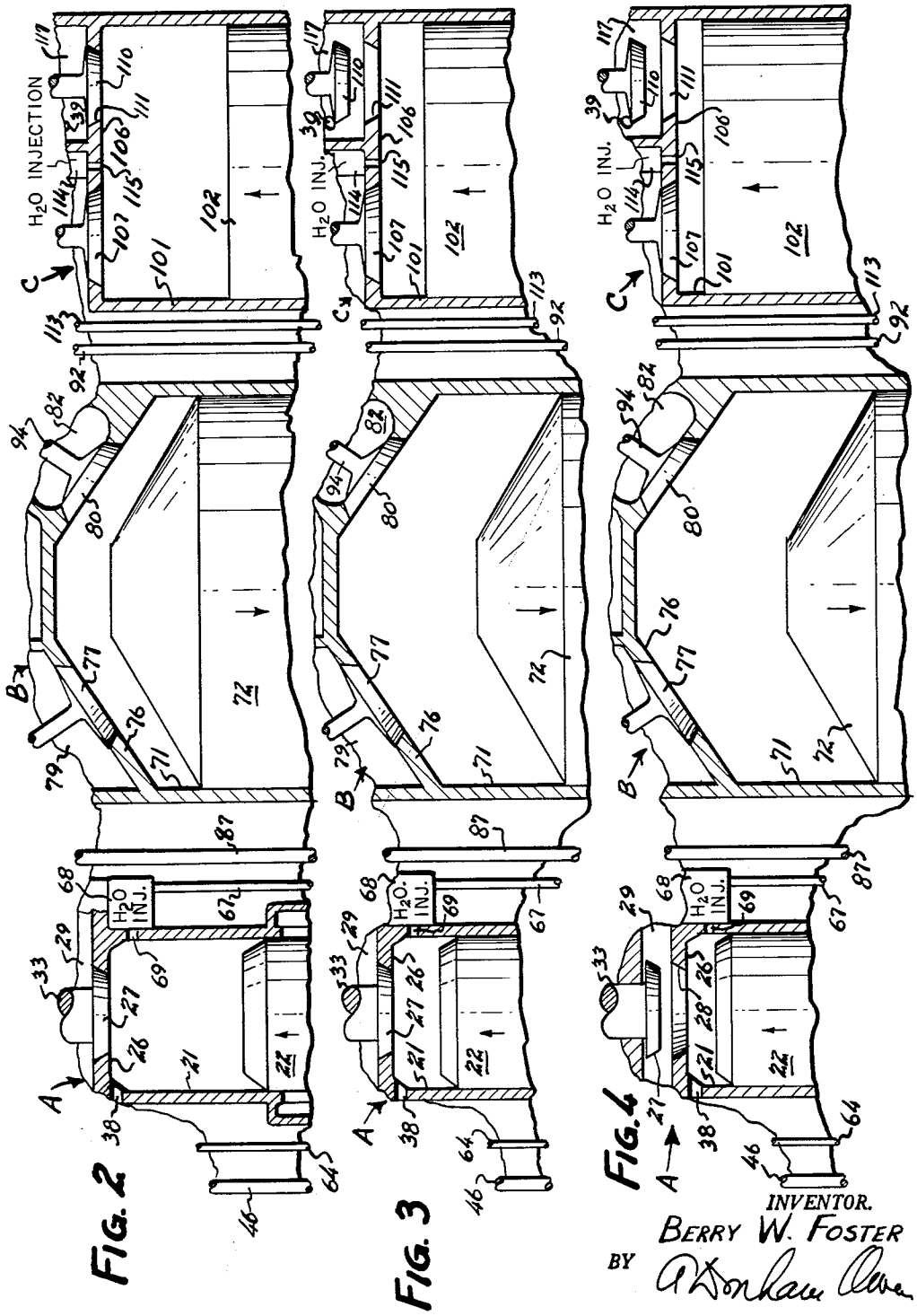


FIG. 2

FIG. 3

FIG. 4

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SUPERCHARGED INTEGRAL COMPRESSION ENGINE

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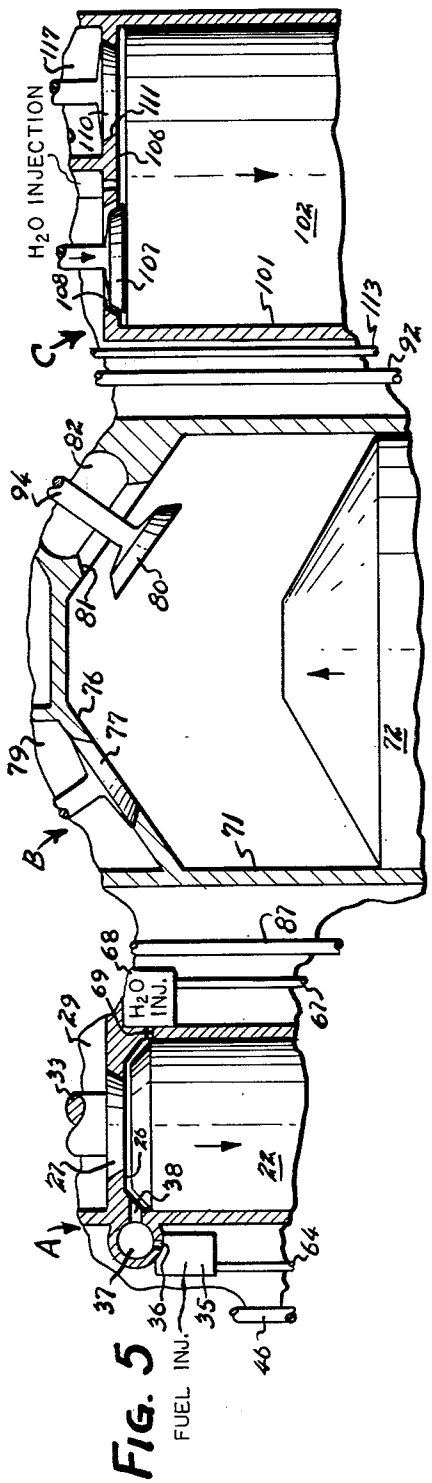


FIG. 5

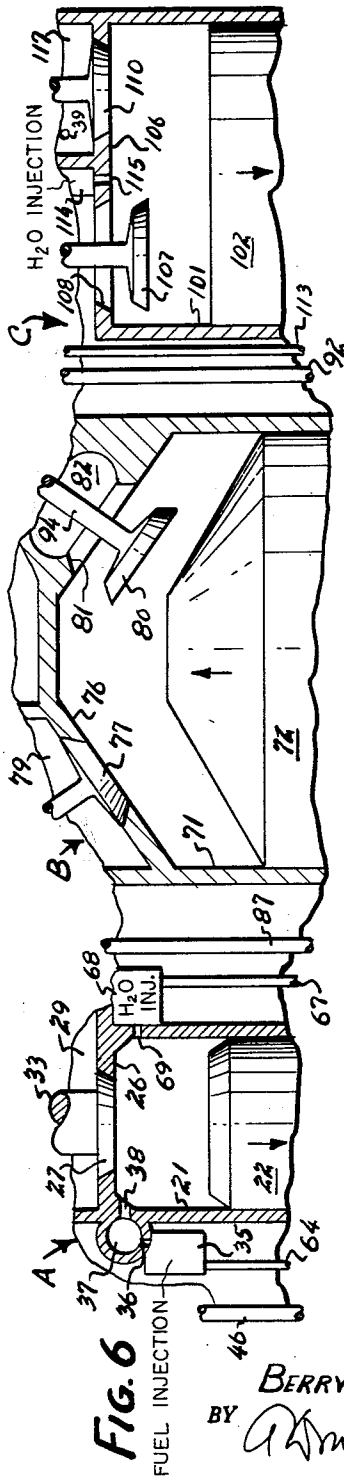


FIG. 6

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SUPERCHARGED INTEGRAL COMPRESSION ENGINE

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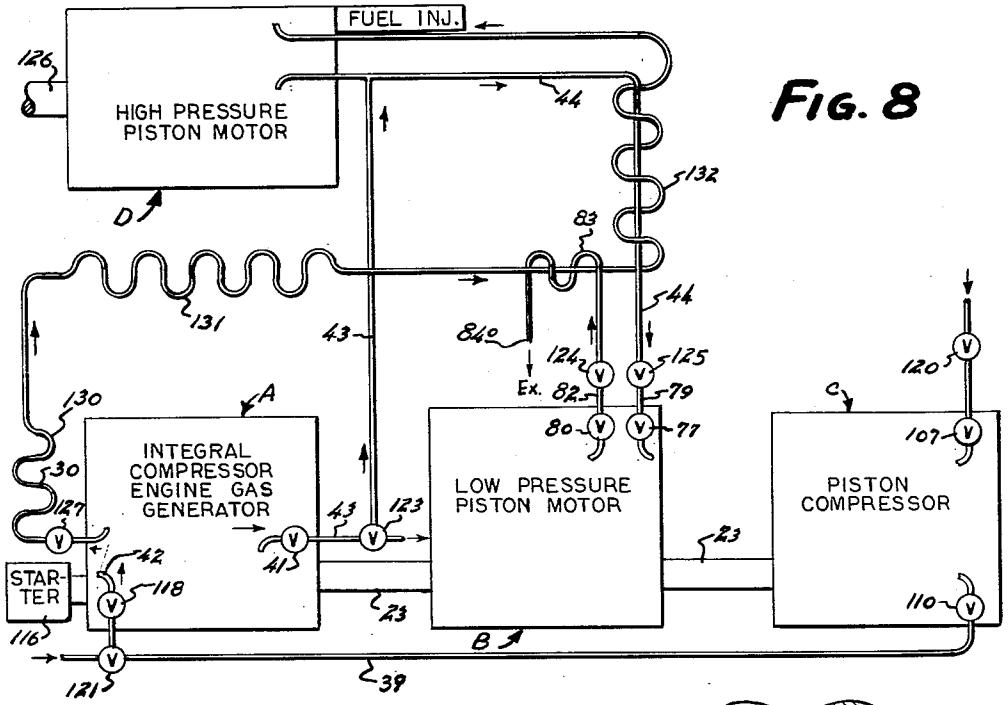


FIG. 8

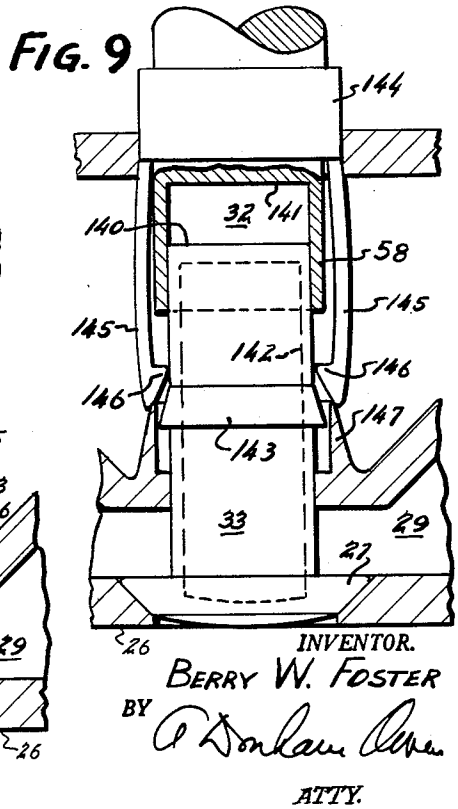


FIG. 9

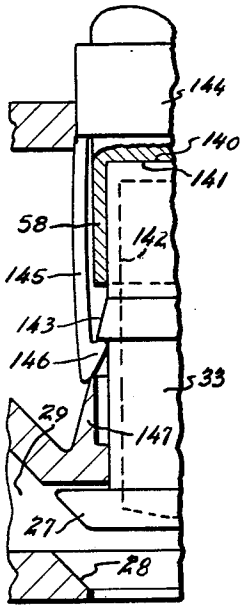


FIG. 10

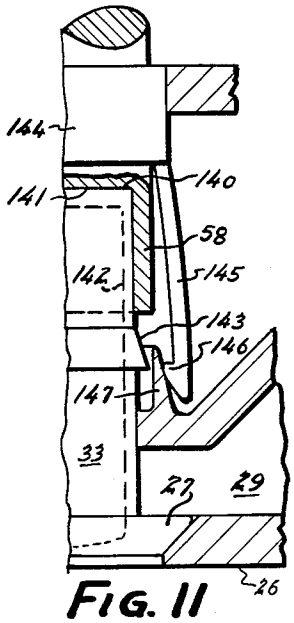


FIG. 11

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3,143,850
SUPERCHARGED INTEGRAL COMPRESSION ENGINE

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Filed Feb. 13, 1961, Ser. No. 89,056
18 Claims. (Cl. 60—15)

This invention relates to a novel three-cylinder gas generator, including a single-piston supercharger, a single-piston motor, and a single-piston integral compressor engine, all three being connected to a common crankshaft.

The cylinders for the three pistons may be fabricated from a single block, or each may be made from a separate block and the three blocks rigidly assembled together. In early stages of development and production, a standard single-cylinder piston compressor may be used as the supercharger; the piston motor may be adapted from a single-cylinder four-stroke engine; and the integral compressor engine may be adapted from a two-stroke or a four-stroke diesel engine.

The primary function of this three-cylinder gas generator is to produce high pressure gases or air. It uses an integral compressor-engine of the type described by Patent 2,928,584 in combination with a piston supercharger and a low-pressure piston motor. The piston supercharger and low-pressure piston motor are analogous to a turbocharger; however, for small power plants they may be more efficient and have a higher supercharger pressure than a turbocharger. Most of the power generated by the low-pressure motor is used to drive the piston supercharger, which is used to supercharge the integral compressor-engine; also most of the power generated by the integral compressor-engine is used to produce high-pressure air which is separated from it on the compression stroke. The high-pressure air that is produced by this gas generator represents the main source of energy for doing useful work in a device such as a high-pressure piston motor which is free running with respect to the three-cylinder gas generator. The three-cylinder gas generator may also produce some shaft power, which is of secondary importance in comparison to the energy of the high-pressure gases. This power plant arrangement is analogous to a gas turbine in which part of the high-pressure discharge air from the compressor is separated from the gas turbine and is heated to expand in a turbine that is free running in respect to the compressor or gas generator turbine. The free-running piston motor and the free-running gas turbine might be classified as power convertors; they have a wider speed and torque range than the conventional torque convertor that is used with the present crank and rod engines. As the primary function of the three-cylinder gas generator is to produce high-pressure gases, it can be called a gas generator; when it is used in combination with a high-pressure motor, the combination can be called a power plant. Like other engines, the power range of the power plant described in this invention may be increased by using a turbocharger. The centrifugal compressor discharge air can be led into the piston supercharger, and the low-pressure motor exhaust gases can be expanded through the gas turbine for the turbocharger.

The gas generator of this invention may be used to supply fluid power for high-pressure hot-gas piston motors, preferably in the 10 to 300 horsepower range. It is approximately as light and compact as the corresponding Otto engine, and it has about the same number and kinds of parts as the corresponding four-stroke engine. For a power plant and power converter combination, it has fewer and simpler parts that the corresponding Otto engine with a torque converter. Moreover, the present invention has the following advantages over conventional

Otto and diesel engines: (1) my high-pressure piston motor is free running and acts as an automatic power converter; (2) using heat regeneration, the thermal efficiency of this gas generator and motor combination is better than 60%—considerably better than the approximately 40% of a diesel engine; (3) a double-acting high-pressure piston motor has less rotating inertia than an Otto or diesel engine with the same power output; (4) my high-pressure piston motor has a higher mean effective pressure acting on it than does a comparable Otto or diesel engine, so that the high-pressure piston motor of this invention can accelerate a load to a given speed more quickly than can comparable Otto or diesel engines.

Water injection may be used during the compression process to give nearly constant temperature compression, thereby requiring less work than the adiabatic compression used in the Otto and diesel engines. The cold, high-pressure air and steam generated by the gas generator may be used to externally cool the engine and motor cylinders and then may be heated in an exhaust heat exchanger. This regenerative heating gives a cycle similar to the Ericsson cycle, and its thermal efficiency is close to that of the Carnot cycle.

The invention also provides means for locking the separating valve open during the separating process in an integral compressor engine gas generator of the type described in Patent 2,928,584; thus the flow losses through the valve port can be reduced.

Other objects and advantages of the invention will appear from the following description of some preferred embodiments thereof.

In the drawings:

FIG. 1 is a view in elevation and in section of a three cylinder gas generator embodying the principles of the invention, some parts being broken off in order to conserve space. The device is shown in the position where the integral compressor-engine cylinder is being scavenged, its piston starting up on the engine compression stroke; low pressure gas is being introduced into the motor cylinder, its piston starting down on the power stroke; and air trapped in the supercharger is being compressed, its piston starting to move up.

FIG. 2 is a fragmentary view in section of a portion of the three cylinder gas generator of FIG. 1 with the pistons in a different position: the integral compressor-engine piston and the supercharger piston are moving up on their compression strokes during which water may be injected to simulate a constant temperature compression, and the intake valve for the motor has closed.

FIG. 3 is a view similar to FIG. 2 with the pistons in a different position where the supercharger has compressed its air to a prescribed pressure and its discharge valve has just opened to let the supercharged air flow into an accumulator.

FIG. 4 is a view similar to FIG. 3 with the pistons shown in the position where the integral compressor engine has compressed the gas to a prescribed pressure, and its separating valve is opening to let the high pressure gas flow into the accumulator.

FIG. 5 is a view similar to FIG. 4 with the compressor and supercharger pistons just starting their downward stroke; the separating valve is closed, and fuel has just been injected and ignited in the air trapped in the integral compressor-engine cylinder, so that the heated gas will expand and force the compressor piston down and the motor piston up. The exhaust valve of the motor cylinder is opened, so the motor gas flows out the exhaust port as the motor piston moves up. The intake valve for the supercharger is opening.

FIG. 6 is a view similar to FIG. 5 with the compressor piston moving down on its power stroke, the motor piston moving up on its exhaust stroke, and the supercharger

piston moving down on its intake stroke, with its intake valve fully open.

FIG. 7 is a view in section taken along the line 7—7 of FIG. 1, with a portion broken in the middle to conserve space.

FIG. 8 is a flow diagram for a high-pressure hot-gas piston motor powered by an integral compressor engine gas generator of this invention with a piston supercharger and low-pressure piston motor.

FIG. 9 is a fragmentary view in section of the separating valve in its position during the beginning of the compression stroke for the compressor engine.

FIG. 10 is a fragmentary view in section of the separating valve in its position during the separating process.

FIG. 11 is a fragmentary view in section of the separating valve in its position at the end of the separating process and during the combustion process in the integral compressor engine.

The three cylinder gas generator of FIGS. 1–7 comprises an integral compressor-engine A, a low-pressure gas motor B, and a piston supercharger C.

The integral compressor-engine A is similar to the gas generator described in Patent 2,928,584, having an engine cylinder **21** in which a piston **22** reciprocates. The piston **22** is connected to a crankshaft **23** by a connecting rod **24** and a crack **25**. The cylinder **21** has a head end **26** with a separating valve **27** which opens and closes a port **28** leading to a chamber **29**. From the chamber **29** a conduit **30** leads the high-pressure gas into an accumulator **31** or other means for storing compressed gas. A pneumatic spring **32** (or an equivalent mechanical spring, if desired) acts on the end of a stem **33** for the valve **27** and urges the valve **27** to its closed position. When the piston **22** moves toward the head **26**, it builds up pressure in the cylinder **21**. When the pressure on the cylinder **21** side of the valve **27** over-balances the spring **32** and the pressure on the chamber **29** side of the valve **27**, the valve **27** is forced open. Compressed gas, or air and steam, is then forced out through the port **28** at substantially constant pressure until a cam **34** (FIGS. 1 and 7) forces the valve **27** closed.

When the cam **34** has forced the valve **27** closed (as in FIG. 5), a fuel injector **35** sends a charge of fuel through a nozzle or port **36** into a precombustion chamber **37**, where the gases are ignited and exploded and whence they are forced through a port **38** into the cylinder **21**, where there is further combustion and heating of the gases in the cylinder **21**, and they expand to do work on the piston **22** and force it from its FIG. 5 position to its FIG. 1 position. As the piston **22** approaches the crank end position of FIG. 1, the piston **22** uncovers an engine intake sleeve port **40** and an engine exhaust sleeve port **41**. The piston supercharger C then sends fresh air to the intake port **40** through conduits **39** and **42** (FIG. 8), and the exhaust gases are scavenged out through the exhaust port **41** through a conduit **43** connected to an exhaust conduit **44** from a high-pressure gas motor D (FIG. 8), as described later. The combined hot exhaust gases, which are at a pressure slightly less than the discharge pressure of the supercharger C, may be expanded through the low presure piston motor B to help power the gas generator A.

Since the explosion of the charge in the cylinder **21** builds up considerable pressure, a toggle mechanism such as that described in Patent 2,928,584 is used to hold the valve **27** closed against this pressure. The cam **34** may be driven by the crankshaft **23**, which is used to synchronize and transmit the power from the engine and motor pistons to the compressor pistons. Toggle links **45** and **46** (FIGS. 1 and 7) are pivotally joined by a central pin **47**. A ball **48** on the toggle link **45** is pivoted at a socket **49** to one end of a lever **50**, the other end of the lever **50** having a pin joint **51** connected to a link **52**. The lever **50** has a fulcrum **53**, which is pinned to the engine

block **54** by an arm **55**. The link **52** is pivoted by a pin **56** to the yoked end **57** of a tubular sleeve **58**, providing a lost motion connection between the stem **33** and the sleeve **58**.

As shown by FIG. 7, the toggle link **46** is connected to a torsion spring **60** mounted upon the engine crankcase. Rigidly secured to the toggle link **46** is a lever **61**, which has a roller bearing **62** at its end. The torsion spring **60**, which may be a torsion bar, forces the roller **62** to follow the cam **34** closely. At the proper time for closing the valve **35**, the cam **34** forces the roller **62** to rotate the toggle links **45** and **46**, forming them into a rigid rod well able to hold the valve **27** closed against the explosion pressure in the cylinder **21**. Immediately after closure of the valve **27**, a cam **63**, which is also driven by the crankshaft **23**, engages a tappet **64** that actuates the fuel injector **35**. When the engine is idling, a solenoid **65** may be used to force the toggle links **45** and **46** into their rigid position; thus the separating valve **27** is held closed at the times when the engine is idling.

A cam **66** driven by the crankshaft **23** may be timed so that it will act on a tappet **67** during the compression stroke of the piston **22** and cause a water injector **68** to spray a prescribed amount of water through a port **69** into the engine cylinder **21** during the compression stroke; thus the compression process can be made to approach a constant temperature process.

The low pressure gas motor B has a cylinder **71** in which a piston **72** is forced to reciprocate by means of a connecting rod **74** and a crank **75** on the crankshaft **23**. The head end **76** of the cylinder **71** has an intake valve **77** which opens and closes a port **78** leading to a channel **79**. The channel **79** connects to the conduit **44** carrying exhaust gases from the integral compressor engine A and the exhaust gases from a high pressure gas motor D or other high pressure device. Also, the head end **76** of the cylinder **71** has an exhaust valve **80**, which opens and closes a port **81** to join the cylinder **71** to a channel **82** and to separate them. The channel **82** leads to an exhaust heat exchanger **83** and then to the atmosphere at a port **84** (FIG. 8).

A cam **85** is driven by the crankshaft **23** timed to open the intake valve **77** at the head end position of the piston **72** and to hold the valve **77** open on the intake stroke until a prescribed amount of gas from the channel **79** has been introduced into the cylinder **71**. Then the cam **85** moves so that a spring **86** will force the valve **77** closed. The opening mechanism for the valve **77** may comprise, in addition to the cam **85**, a tappet **87**, a rocker arm **88**, a link **89**, and a valve stem **90**. The exhaust valve opening mechanism may consist of a cam **91** driven by the crankshaft **23**, a tappet **92**, a rocker arm **93**, and a valve stem **94**. A spring **95** acts on the valve **80** to hold it closed during the down stroke or expansion stroke of the piston **72**.

The piston supercharger C has a cylinder **101** in which a piston **102** is forced to reciprocate by means of a connecting rod **104** that is connected to the crankshaft **23** by a crank **105**. The head end **106** of the cylinder **101** may have an intake check valve **107** which opens and closes a port **108** leading to the atmosphere or other air source. Normally, a spring **109** holds the valve **107** closed. Also, the head end **106** of the cylinder **101** may have a discharge check valve **110** which opens and closes a port **111** to join the cylinder **101** with a compressed air accumulator **117** and to separate the cylinder **101** from the accumulator **117**. The check valves **107** and **110** may be of any design such as reed valves, poppet valves, etc. A cam **112** may be driven by the crankshaft **23** and timed to act through a tappet **113** on an injector **114** during the compression process and inject water through a port **115** into the cylinder **71** during the compression process.

The cranks **25** and **105** are arranged on the crankshaft **23** so that the pistons **22** and **102** travel in the same direction at the same time, while the crank **75** is arranged on

the crankshaft 23 to be 180° out of phase with respect to cranks 25 and 105. The weight of the piston 72 may be made equal to the sum of the weights of the pistons 22 and 102, and the weight and weight distribution of the connecting rod 74 may be made equal to the sum of the weights of the connecting rods 24 and 104. The piston stroke may be made the same for all three pistons; thus they will all operate at the same maximum piston speeds for a given crankshaft speed. With this arrangement the three-cylinder gas generator has the same degree of balance as a four cylinder inline engine.

Auxiliary power such as a generator, fuel pumps, etc. may be driven by the crankshaft 23, but this is kept to a minimum, as most of the power is delivered by the high-pressure gases. A conventional starter 116 (shown only as a labeled box in FIG. 8) may be used on the crankshaft 23 to start the gas generator.

Operation of the Three-Cylinder Gas Generator of FIGS. 1 to 8

As shown in FIG. 8, the invention has especial utility in connection with a hot-gas high-pressure motor D, which is shown only diagrammatically since the motor D may be any of various structures, including those made by Clevite Ordnance and Vickers, Inc., or the high-pressure internal combustion engine shown in U.S. Patent 2,939,922. In fact, a high-pressure superheated steam engine may be used as the motor D, or a motor like motor B in this application but with much smaller displacement, preferably with a conventional fuel injector and combustion chamber added.

(1) *Starting cycle.*—A conventional starter 116 may be used on crankshaft 23 to start the gas generator. A valve 120 (FIG. 8) may be held closed, so that no air will flow into the compressor C. A valve 121 (FIG. 8) may be turned so that atmospheric air flows through a valve 118 directly into the crankcase 122 of the engine A and then through the sleeve port 40 into the cylinder 21. A valve 123 may be turned so that the exhaust gases from the engine A are dumped directly to the atmosphere. A check valve 124 may be put into operation so that it will not let atmospheric air flow into the motor cylinder 71, and the valve 125 is closed to prevent any air from flowing through the port 78. The solenoid 65 (FIG. 7) is actuated to force the toggles 45, 46 to hold the separating valve 27 closed. The engine A starts like a diesel engine which is scavenged by atmospheric air pumped in its crankcase. After several rotations of the crankshaft 23 by the starter 116, the supercharger C and the motor B will be at vacuum pressures; thus there will be very small gas loads on their respective pistons. When the engine A starts as a two-stroke diesel engine, it will only have the piston friction drag load and the auxiliary devices such as generators to power. The engine may be made to idle, with low fuel consumption in this valve arrangement.

(2) *Transition to power cycle.*—After the engine warms up, the valve 120 may be opened; thus the compressor C will build up the supercharger pressure in the accumulator 117. When the supercharger pressure reaches a prescribed value, the valve 121 may be automatically turned so that the supercharger air will be introduced into the intake ports 40. Simultaneously the solenoid 65 is released; thus high pressure gas flows into the chambers 29 and 30 near the end of the compression stroke. Simultaneously, the valve 123 is turned to connect the exhaust gases from the port 41 with the intake channel 79 of the hot gas motor B, and the valves 124 and 125 are opened so that the motor B will act as a hot gas motor.

(3) *Power cycle.*—FIGS. 1 to 6 illustrate the cycle of the gas generator. In the FIG. 1 position, the engine A is being scavenged, and the exhaust gases from the engine A and the high-pressure motor D are being introduced into the cylinder 71 through the port 78. The supercharger C is starting to compress the air.

The valve 77 remains open until the pistons move to the FIG. 2 position; then it closes, and the gases trapped in the cylinder 71 expand and do work on the piston 72, as shown by FIGS. 1 to 4. On the up stroke of the piston 72 (FIG. 5 to FIG. 6 to FIG. 1), the exhaust valve 80 is forced open, and the exhaust gases flow through the port 81 and dump into the atmosphere. Near the end of the exhaust stroke of the motor cylinder 71, the valve 80 is closed, and the gas trapped in cylinder 71 is precompressed up to the pressure of the gases in the channel 79 before the intake valve 77 is opened, as in FIG. 1.

Water may be injected into each of the cylinders 101 and 21 during the compression process; thus the compression process will tend to simulate a constant temperature process.

When the supercharger pressure in the cylinder 101 reaches a prescribed pressure, the valve 110 opens and compressed air flows through the port 111 into the accumulator 117 as the piston 102 moves up (FIGS. 3 and 4). On the down stroke of the piston 102, the valve 107 is opened, and atmosphere air flows into the supercharger cylinder 101.

When the integral compressor-engine compresses the gases to a prescribed pressure (FIG. 4) the separating valve 27 is forced open, and high-pressure gas flows through the port 28 into the high-pressure gas accumulator 31, for use as desired. At the end of the compression stroke, the separating valve 27 is forced closed and held closed during the combustion and expansion process (FIG. 5). Fuel is injected into the cylinder 21 and is ignited and heats the gas trapped in the cylinder 21; these hot gases expand and do work on the piston 22 (FIGS. 5, 6, and 1). Then the supercharger scavenges the engine cylinder 21, as shown by FIG. 1.

Since the engine piston 22 and the motor piston 72 are 180° out of phase with respect to each other, there will be two alternate power strokes on each cycle of the gas generator.

When the power plant is delivering power at a shaft 126, the valves 120, 124, 125 and a valve 127 are held open, and the valves 121 and 123 are turned so the atmospheric outlets are closed and the intake and exhaust pipes are connected to their respective channels.

Atmospheric air flows through the intake port 108 into the piston compressor C, where it is compressed with water injection during the compression process; the compressor discharge pressure into the accumulator 117 may be from 3 to 8 atmospheres. The cold supercharged air from the accumulator 117 is introduced through the valve port 118 into the engine crankcase 122 when the piston 22 is at the head end. When the piston 22 moves to the crank end and uncovers its intake and exhaust sleeve ports 40 and 41, the cold supercharged air trapped in the crankcase 122 of the engine A will scavenge the engine cylinder 21. The hot exhaust gas from the engine is led through the line 43 to the high-pressure motor exhaust line 44, where the two gas streams are combined and mixed together. The cold supercharged air trapped in the engine cylinder 21 is compressed with water injection, until its pressure ratio is about 30 to 80 atmospheres. Then the separating valve 27 of the engine A is opened, and part of this high-pressure gas is forced to flow through the separating port 28 into the compressed gas accumulator 31. Near the end of the compression stroke of engine A, the separating valve 27 is forced closed and held closed during the combustion and expansion process of the gas trapped in the engine cylinder 21. The high-pressure steam and air that is separated from the engine A is cold; thus it may be used to externally cool the engine A and the high-pressure gas motor D by flowing it via the conduit 30 through respective engine cooling means 130 and motor cooling means 131.

The high pressure air and steam then flows through the

low pressure motor exhaust heat exchanger **83**, and an engine exhaust heat exchanger **132**. By using this engine-cooling heat and the exhaust heat in the regenerators, the high pressure air and steam will be close to the engine exhaust temperature just before it is introduced into the high-pressure motor D. These high pressure gases will flow into the motor cylinder and absorb some more heat from the hot cylinders and head; then they may be heated further by internal combustion in the motor cylinder after the intake valve has cut off the flow of high-pressure gas to the motor cylinder. The heated high-pressure motor gases expand and do work on the motor piston to produce useful shaft power at **126**. The high pressure motor gases are exhausted into the line **44** and mixed with the engine exhaust gases in the line **43**. The mixed engine exhaust gases flow through the heat exchanger **132** to the low pressure motor B to expand and help produce high pressure gas. After these gases are expanded in the motor B, they are exhausted through the heat exchanger **83** and then are dumped into the atmosphere at a fairly low temperature. If desired, the high pressure gases may be heated by combustion before introducing them into the piston motor B.

When the power plant is not producing shaft power at **126**, the valves are automatically set to the position described in the starting of the engine; in this arrangement the engine A will act as a simple diesel engine which is idling with low fuel consumption; the piston supercharger C and the low pressure piston motor B will be operating at vacuum pressures; so they will consume very little power.

Description of the Separating Valve of FIGS. 9 to 11

As stated before, the separating valve **27** opens and closes the port **28** to join the engine combustion chamber **21** (and the interior of the integral compressor-engine cylinder) with a chamber **29** and to separate them. The chamber **29** has the outlet **30** for high-pressure gas into the accumulator **31** or other output for compressed gas. The pneumatic spring **32** acts on an end **140** of the valve stem **33** for the valve **27** and urges the valve **27** to its closed position. The tubular sleeve **58** acts as a cylinder for the valve stem **33** to slide in; thus a pneumatic spring is produced by the gas compressed between the end **140** of the stem **33** and the inner end **141** of the tubular passage in the sleeve **58**, the end **140** of the stem **33** and the inner end **141** of the tubular passage in the sleeve **58** providing a lost motion connection between the stem **33** and the sleeve **58**. In order to make the valve **27** and the stem **33** light in weight so that the valve **27** can be accelerated open rapidly, the stem **33** is preferably made hollow, as shown by the broken lines **142**.

The mechanisms for synchronizing the integral compressor-engine pistons and closing the separating valve may be the mechanism described in Patent No. 2,928,584.

The valve stem **33** may be provided with a conically shaped catch **143**, which may be used to hold open the separating valve **27**. A ring **144** may be secured to the outside of the sleeve **58**; two or more springs **145** may be cantilevered to the ring **144** and a hook **146** provided at the end of each spring **145**. Each spring **145** will force its hook **146** to snap below the catch **143** when the separating valve **27** is forced open. The engine housing may be provided with a cone **147**, which will force the hook **146** free from the catch **143** when the separating valve **27** is being forced closed.

Operation of the Separating Valve of FIGS. 9–11

At the beginning of the compression stroke for the integral compressor-engine, the separating valve **27** is in the position illustrated by FIG. 9. The pneumatic pressure of the spring **32** will act on the valve stem **33**, and the gas pressure in the chamber **29** will act on the top side of the valve **27** to hold it closed. When the gas pressure in the cylinder **21** is slightly less or equal to the gas pressure in the chamber **29**, the pressures and effective areas are designed so that there is a force that tends to accelerate the separating valve **27** up and open. Once the valve **27** is opened, the valve stem **33** has a force equal to its area times the difference in pressure between the chamber **29** and the spring **32**, acting on it; this pressure difference may vary from 4 to 60 atmospheres, depending upon the operating conditions and the design. This high pressure force on the valve stem **33** forces the valve **27** to accelerate open in a fraction of its separating stroke.

When the valve is accelerated open to its FIG. 10 position, the hooks **146** snap under the catch **143** and hold the valve **27** open. The recoil action of the spring **32** forces the valve to decelerate and stop. The valve **27** will remain in the FIG. 10 position during a large portion of its separating stroke.

At the end of the separating process, the mechanism described in Patent 2,928,584, or any other appropriate mechanism, may be designed to act on the sleeve **58** and force the valve **27** closed to its FIG. 11 position. As the valve **27** assembly is forced down, the cone **147** acts on the hooks **146** and releases them from the catch **143** on the valve stem **33**. The mechanism of 2,928,584 is timed to move the sleeve **58** assembly up to the FIG. 9 position after the pressure in the cylinder **21** is reduced sufficiently so that the spring **32** and gas pressure in the chamber **29** will hold the valve **27** closed; this is near the end of the engine expansion stroke. The valve **27** and its drive mechanism are now in a position ready to repeat the cycle as long as the engine is operating.

To those skilled in the art to which this invention relates, many changes in construction and widely differing embodiments and applications of the invention will suggest themselves without departing from the spirit and scope of the invention. The disclosures and the description herein are purely illustrative and are not intended to be in any sense limiting.

I claim:

1. A power plant comprising
   - a supercharger having a cylinder with an outlet for supercharged air and a piston;
   - a high-pressure compressor-engine having a second cylinder with an inlet connected to said supercharger outlet for scavenging and supercharging said compressor-engine and having an exhaust and a piston, a chamber adjacent one end of said second cylinder and connected to said second cylinder by a port, means for closing said port to separate engine air in said second cylinder from compressor air in said chamber near the end of the compression stroke and while under high pressure, combustion means for burning fuel in said high-pressure engine air in said second cylinder after said separation, so that the heated product expands in said second cylinder and drives said piston;
   - a motor having a piston, a cylinder with an intake connected to said exhaust, for expanding the exhaust gases from said compressor-engine, the inlet gas pressure to said motor being equal to or less than the discharge pressure from said piston supercharger;
   - and a common crankshaft to which the pistons for said supercharger, said compressor-engine, and said motor are all connected.

2. A power plant comprising
   - a supercharger having a cylinder with an outlet for supercharged air and at least one piston;
   - a high-pressure compressor-engine having a second cylinder with an inlet connected to said supercharger outlet for scavenging and supercharging said compressor-engine and an exhaust and having at least one piston, a chamber adjacent one end of said second cylinder and connected to said second cylinder by a separating port, a separating valve for said port, means of opening said separating valve after

said piston has compressed the trapped cylinder gases to a prescribed pressure, means for closing said port by said valve to separate engine air in said second cylinder from compressor air in said chamber near the end of the compression stroke and hold said separating valve closed while under high pressure during the combustion and expansion process, combustion means for burning fuel in said high-pressure engine air in said second cylinder after said separation, so that the heated product expands in said second cylinder and drives said piston;

a motor having a piston, a cylinder with an intake connected to said exhaust, for expanding the exhaust gases from said compressor engine, the inlet gas pressure to said motor being equal to or less than the discharge pressure from said piston supercharger;

and a common crankshaft to which the pistons for said supercharger, said compressor-engine, and said motor are all connected.

3. The device in claim 2 in which said supercharger and said compressor-engine pistons are in phase with each other, said motor piston being 180° out of phase with them.

4. A power plant comprising

a supercharger having a piston and a cylinder with an intake for atmospheric air and an outlet for supercharged air, and an automatic cutoff valve for said intake, said cutoff valve only being used during starting and idling conditions;

a high-pressure compressor-engine having a second cylinder with an inlet and an exhaust, a crankcase with inlet means for said supercharged air and means to conduct said air to said second cylinder;

a piston, a chamber adjacent one end of said second cylinder and connected to said second cylinder by a separating port, separating valve means for said port, means of opening said separating valve after said piston has compressed the trapped cylinder gases to a prescribed pressure, means for closing said port to separate engine air in said second cylinder from compressor air in said chamber near the end of the compression stroke and while under high pressure, combustion means for burning fuel in said high-pressure engine air in said second cylinder after said separation, so that the heated product expands in said second cylinder and drives said piston;

a conduit connecting said supercharger outlet to said cmpressor-engine inlet for scavenging and supercharging said compressor-engine;

a cutoff valve for cutting off said inlet from said conduit and for introducing atmospheric air into said crankcase when the compressor-engine is being operated as a diesel during the starting and idling;

a motor having at least one piston and a cylinder with exhaust means and inlet means connected to said compressor-engine exhaust for expanding the low pressure exhaust gases from said compressor engine, the inlet gas pressure to said motor being equal to or less than the discharge pressure from said piston supercharger;

means to cut off said exhaust from said motor inlet means and to dump exhaust gases from said engine cylinder into said atmosphere when the compressor-engine is being operated as a diesel during the starting and idling;

check valve means for said motor exhaust means;

means for locking said separating means closed while operating said compressor-engine as a diesel engine; and

a common crankshaft to which the pistons for said supercharger, said compressor-engine, and said motor are all connected.

5. The device of claim 4 wherein said supercharger and said compressor-engine pistons are in phase with each other, said motor piston being 180° out of phase with them.

6. A power plant comprising

a supercharger having a piston and a cylinder with an outlet for supercharged air, and a cutoff valve for said outlet;

a high-pressure compressor-engine having a second cylinder with an inlet and an exhaust, a crankcase with inlet means for atmospheric air and means to conduct said air to said second cylinder, a piston in said second cylinder, a chamber adjacent one end of said second cylinder and connected to said second cylinder by a port having a check valve that is opened by the compression of air and gas in said second cylinder, separating means for closing said port to separate engine air in said second cylinder from compressor air in said chamber near the end of the compression stroke and while under high pressure, combustion means for burning fuel in said high-pressure engine air in said second cylinder after said separation, so that the heated product expands in said second cylinder and drives said piston;

a conduit connecting said outlet to said inlet for scavenging and supercharging said compressor-engine;

a cutoff valve for cutting off said inlet from said conduit and for introducing atmoshperic air into said inlet;

a motor having a piston and a cylinder with exhaust means and inlet means connected to said compressor-engine exhaust for expanding the low pressure exhaust gases from said compressor-engine, the inlet gas pressure to said motor being equal to or less than the discharge pressure from said piston supercharger;

means to cut off said exhaust from said motor inlet means and to dump exhaust gases from said engine cylinder into said atmosphere;

cutoff means for said motor inlet means;

check valve means for said motor exhaust means;

means for locking said separating means closed while operating said compressor-engine as a diesel engine; and

a common crankshaft to which the pistons for said supercharger, said compressor-engine, and said motor are all connected.

7. A power plant comprising

a piston supercharger, a piston motor, and a high-pressure piston compressor-engine in combination,

said supercharger having an output connected to said compressor engine and serving as means to scavenge and supercharge said compressor-engine;

said compressor-engine having a cylinder and at least one piston to compress both engine air and compressor air together as a mixture in said cylinder, and means for separating the engine air from the compressor air near the end of the compression stroke and while under high pressure, and combustion means for burning fuel in said high-pressure engine air in said cylinder after said separation, so that the heated product expands in said cylinder and drives said piston;

said motor expanding the exhaust gases from said compressor engine and driving said power plant,

the discharge pressure from said piston supercharger being greater than the inlet gas pressure to said motor.

8. A power plant using heat regeneration, comprising

at least one piston-compressed gas generator and at least one piston motor;

said gas generator having means for injecting water during its compression process so that high-pressure gases are generated at a fairly low temperature,

means for using said high-pressure low temperature gas to cool said gas generator cylinder and to cool said piston gas motor;

an exhaust heat exchanger for thereafter heating said high-pressure gases by regeneration;

said high-pressure gases thereafter expanding in said piston motor;

means for thereafter circulating said gases through said heat exchanger as the medium to heat said high-pressure low temperature gases;

a second piston motor;

a second heat exchanger; and

said gases thereafter expanding to approximately atmospheric pressure in said second piston motor and exhausting them to the atmosphere through a second heat exchanger.

9. The device of claim 8 having means for heating said high-pressure gases by internal combustion in said one piston motor.

10. The device of claim 8 having means for heating said high-pressure gases by combustion before introducing them into said one piston motor.

11. A power plant using heat regeneration, comprising

a piston-compressed gas generator with a cylinder and an exhaust;

first and second piston motors;

first and second heat exchangers;

means in said gas generator for injecting water during its compression process so that high-pressure gases are generated at a fairly low temperature;

means for using said high-pressure low temperature gas to cool said gas generator cylinder and to cool first piston gas motor;

said high-pressure gases being thereafter heated by regeneration in said first and second heat exchangers,

said high-pressure gases thereafter expanding in said first piston motor;

the exhaust gases from said first piston motor and the exhaust gases from said gas generator circulating through said first heat exchanger in heat exchange relation with said high-pressure gases;

said gases expanding to approximately atmosphere pressure in said second piston motor; and

said gases then being expanded to the atmosphere through said second heat exchanger.

12. The device of claim 11 having means for heating said high-pressure gases by internal combustion in said first piston motor.

13. The device of claim 11 having means for heating said high pressure gases by combustion before introducing them into said first piston motor.

14. A power plant using heat regeneration, comprising

at least one piston-operated compressed gas generator and at least one piston motor;

said gas generator having means for generating high-pressure gas;

an exhaust heat exchanger; and

means for heating said high-pressure gas by regeneration in said heat exchanger, introducing said gas into said piston motor for further expansion, and then sending the resultant gas through said heat exchanger in heat-exchange relation with said high-pressure gas.

15. The device of claim 12 having means for heating said high-pressure gases by internal combustion in said piston motor.

16. A three cylinder high-pressure gas generator connected with at least one-high-pressure, hot gas piston and cylinder motor to produce shaft power;

said three cylinder high-pressure gas generator comprising a piston supercharger, a low-pressure piston motor, and a high-pressure piston compressor-engine;

said piston supercharger having output means for scavenging and supercharging said piston compressor-engine with air;

said piston compressor-engine having a cylinder and at least one piston;

means for separating the compressed mixture into two portions near the end of the compression stroke of said compressor-engine, one portion being trapped in said cylinder as engine gas;

combustion means for burning fuel in said gas which is trapped in said compressor-engine cylinder after said separation;

means for expanding said heated high-pressure engine gas in said cylinder to drive said piston and help to power said gas generator;

an exhaust heat exchanger having first and second sides in heat-exchange relationship with each other;

means for exhausting the engine exhaust portion of said mixture through said first side of said exhaust heat exchanger;

means for using said other portion to help externally cool said compressor-engine and said high-pressure piston motor;

means for subsequently heating said other portion by regeneration in said second side of said exhaust heat exchanger and then introducing it into the cylinder of said high-pressure motor;

means for heating said introduced gas by internal combustion in said high-pressure motor cylinder, so that said heated gas expands and does work on the motor piston to generate shaft power at a variable speed, which may be independent of the gas generator speed;

means for exhausting the gas from said motor cylinder through said first side of said exhaust heat exchanger; and

means for mixing said motor exhaust gas and said engine exhaust gases and expanding them through said low pressure piston motor to produce power, which helps to produce said compressed gases.

17. The device of claim 16 wherein said piston-compressor engine has means for injecting water into its said cylinder during the compression process, whereby said compressor-engine compresses both said air and steam together as a mixture in said cylinder.

18. The device of claim 7 with a common synchronizing means to which the piston for said supercharger, said compressor-engine, and said motor are all connected.

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