Oct. 19, 1937. R. E. LASLEY 2,096,184

POWER PLANT

Filed July 16, 1935 5 Sheets-Sheet 1

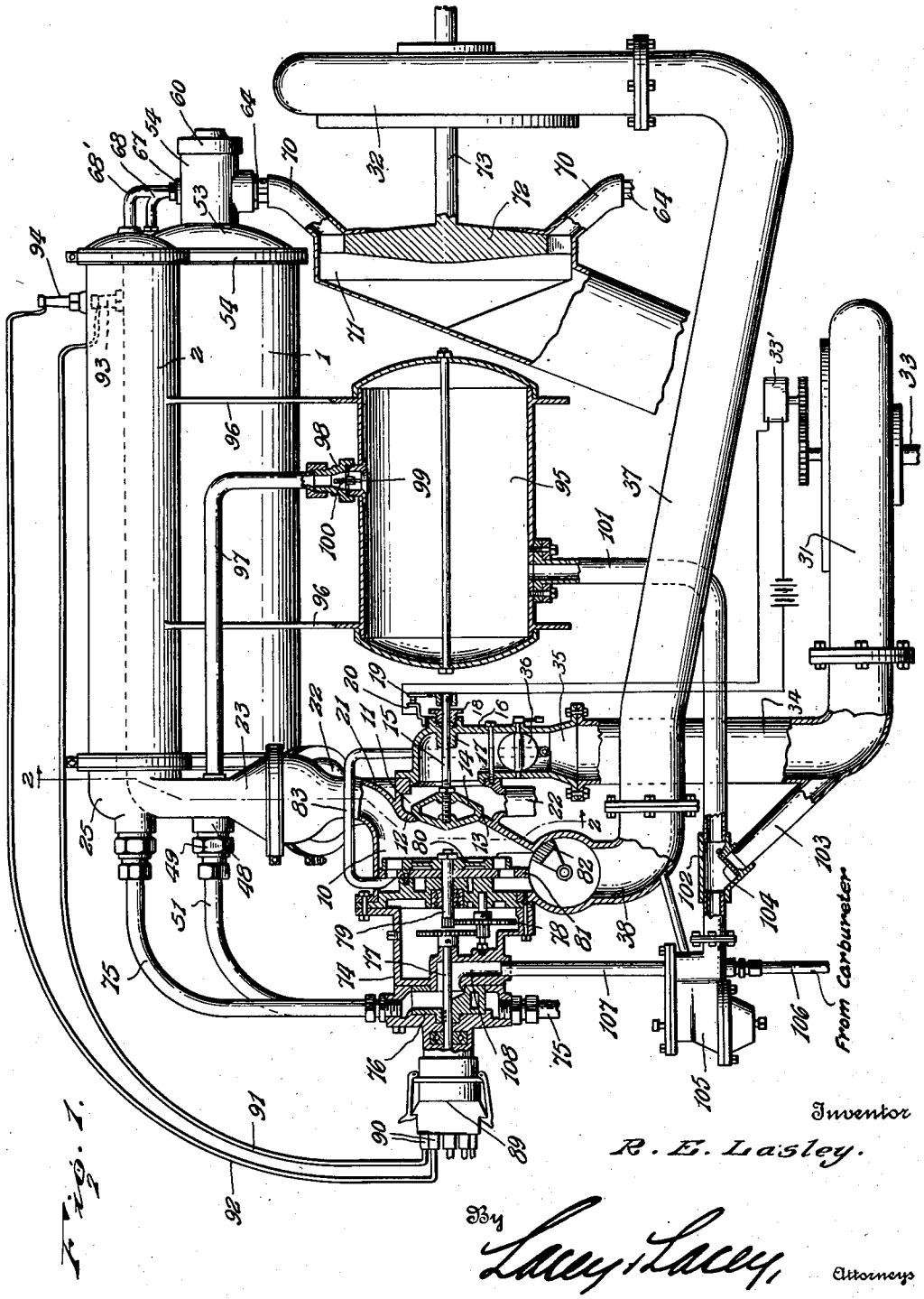


Fig. 1.

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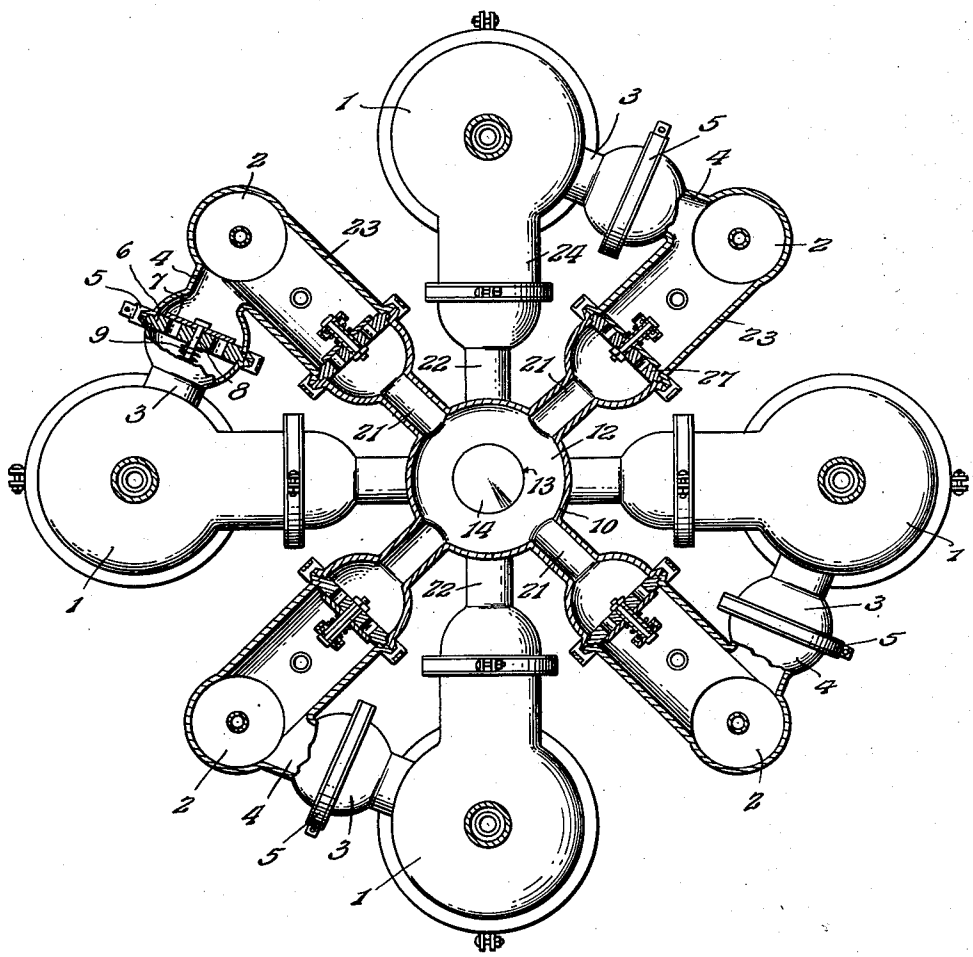
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POWER PLANT

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Fig. 2.



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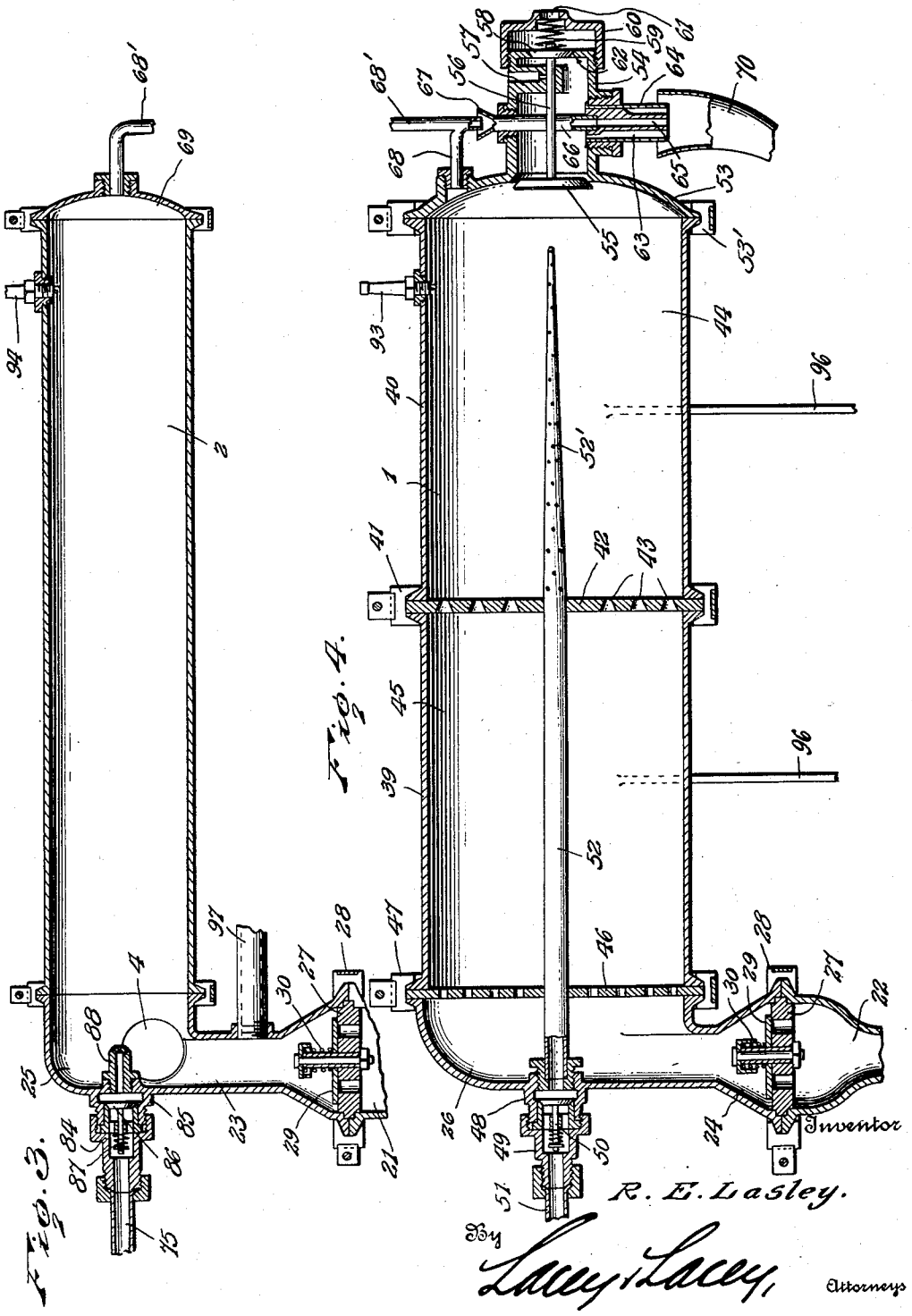


Fig. 3.

Fig. 4.

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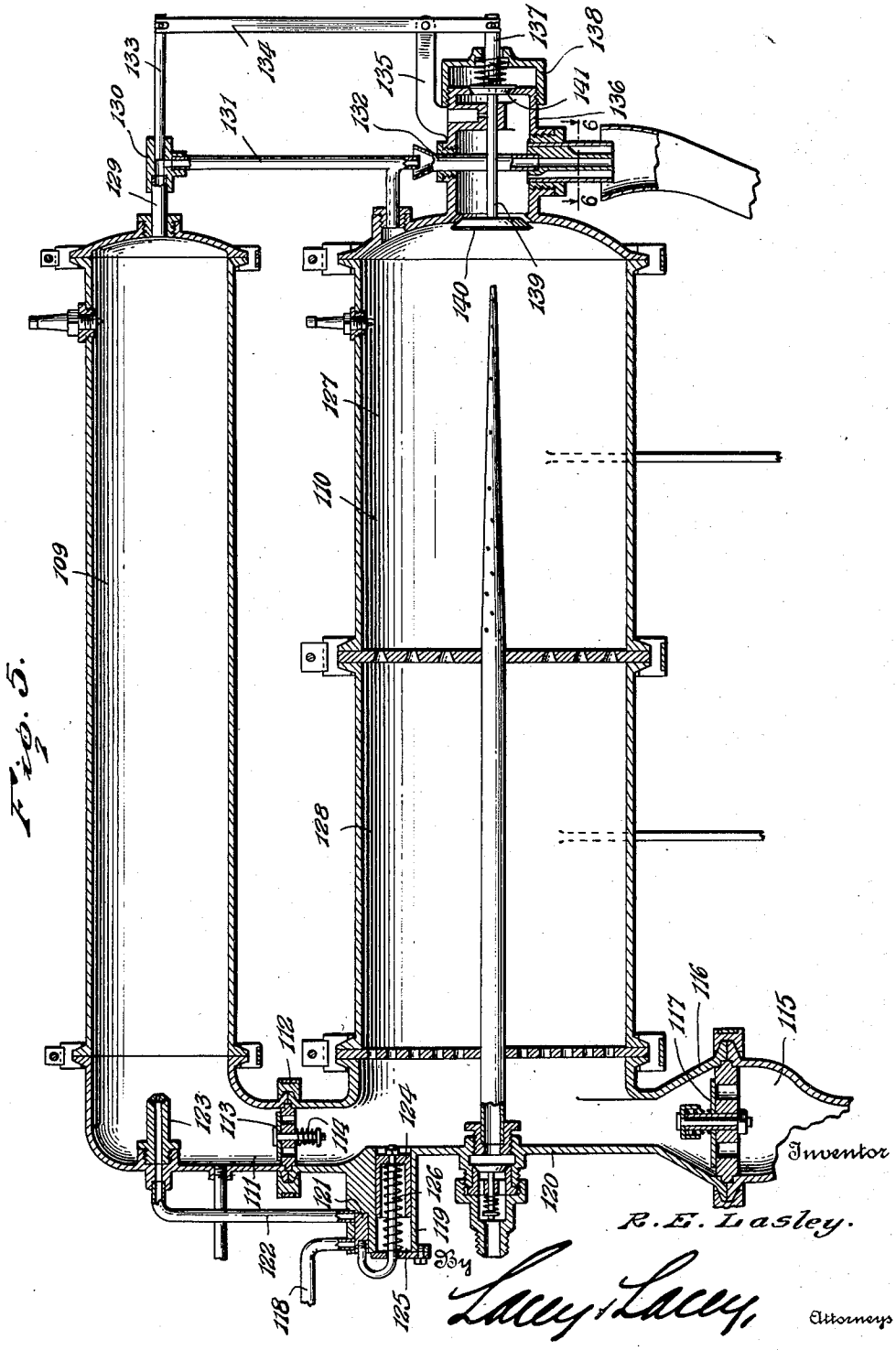


Fig. 5.

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POWER PLANT

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Fig. 6.

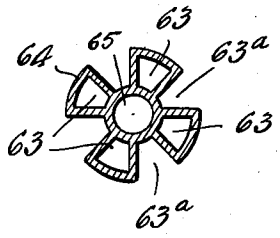


Fig. 7.

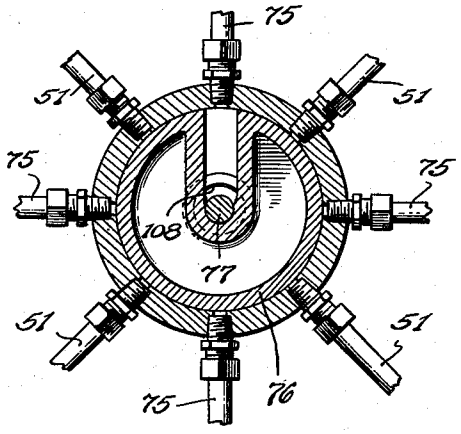
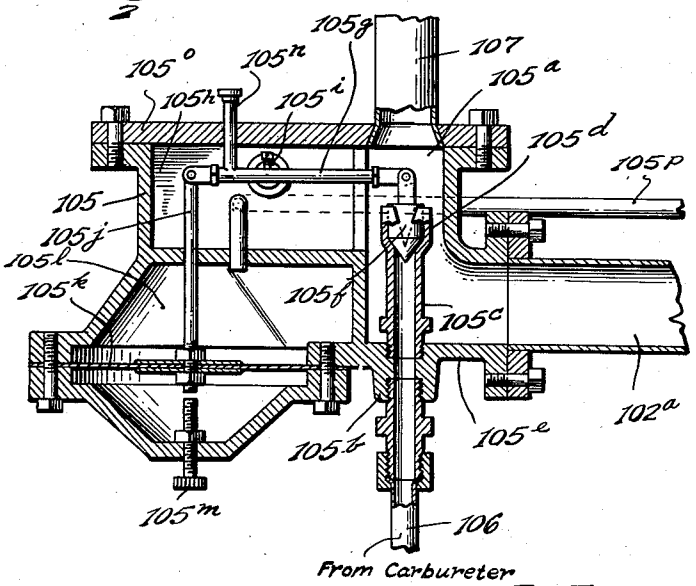


Fig. 8.



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Patented Oct. 19, 1937

2,096,184

UNITED STATES PATENT OFFICE

2,096,184

POWER PLANT

Robert E. Lasley, Waukegan, Ill.

Application July 16, 1935, Serial No. 31,686

8 Claims. (Cl. 60—41)

This invention relates to power plants of the gas turbine type disclosed in my co-pending application, Serial No. 23,775, filed May 27, 1935, and one object of the invention is to provide a power plant of the general type referred to above which includes low and high pressure cylinders so arranged that when an explosion takes place in a low pressure cylinder, air will be forced from a chamber of the low pressure cylinder into a companion high pressure cylinder and build up an increased pressure in the high pressure cylinder and thus cause the major portion of combustible mixture to be exploded at a much higher compression ratio, thus greatly increasing the thermo efficiency of the plant. The work of increased compression being performed adiabatically, greatly contributes to the increased efficiency. This increased compression, of course, greatly increases the velocity of the product of combustion discharged from the chambers and resultant kinetic energy of the motive fluid when the fluid is impinged on the blades of the turbine rotor, to be actuated by the product of combustion from both the low and high pressure cylinders.

Another object of the invention is to so arrange the low and high pressure cylinders that both cylinders may be initially charged with air at an even pressure and rich charges of fuel delivered into the two cylinders to form combustible mixtures therein which are to be exploded in proper timed relation to each other so that products of combustion from the low pressure cylinder will be first delivered to the turbine for rotating the turbine and products of combustion then delivered to the turbine from the high pressure cylinder.

Another object of the invention is to so form the low pressure cylinder that a plurality of chambers will be formed therein, one of which is to be charged with a combustible mixture and the other with substantially pure air which is to be forced into the high pressure cylinder when the combustible mixture in the low pressure cylinder is exploded and thus make it unnecessary to provide other less efficient means for building up pressure in the high pressure cylinder.

Another object of the invention is to so arrange and construct the low and high pressure cylinders that when explosions take place the products of combustion from the two cylinders will be all delivered through a discharge nozzle into an inlet spout of a turbine casing and air taken up and added to the products of combustion and, by reason of the difference in the specific heat of atmospheric air and the product of combustion, retain the heat energy in the motive fluid at such weight and temperature that the turbine will be rotated efficiently at very high speed and without danger of the turbine being damaged by overheating.

Another object of the invention is to provide the power plant with low and high pressure cylinders having their outlets for products of combustion provided with an improved arrangement of valves for controlling flow of gases through the outlets.

Another object of the invention is to provide low and high pressure combustion chambers provided with fuel pump plungers so arranged as to be actuated by air pressure in such time and manner as to inject fuel into and mix with the air in the chambers in timed and metered relation to the filling of the chambers with air and, simultaneously with the completion of fuel injection, to apply ignition thereto.

The invention is illustrated in the accompanying drawings, wherein

Figure 1 is a view showing the improved power plant partially in elevation and partially in longitudinal section.

Figure 2 is a sectional view taken transversely through the power plant along the line 2—2 of Figure 1.

Figure 3 is an enlarged view showing a pressure cylinder of the power plant in longitudinal section.

Figure 4 is a similar view of a low pressure cylinder.

Figure 5 is a sectional view showing a modified arrangement of companion high and low pressure cylinders.

Figure 6 is a sectional view taken transversely through the discharge nozzle along the line 6—6 of Figure 5.

Figure 7 is a sectional view through the fuel distributer.

Figure 8 is a sectional view upon an enlarged scale taken longitudinally through the mechanism for controlling the supply of fuel.

This improved power plant has a plurality of low pressure cylinders 1 and companion high pressure cylinders 2, which in Figure 2 have been shown arranged in a circular path with each high pressure cylinder disposed at one side of its companion low pressure cylinder in transverse spaced relation thereto. Necks 3 and 4 extend from confronting side portions of the companion cylinders and are secured in abutting relation to each other by a clamping ring 5 and at the abutting ends of the necks is mounted a perforated partition 6 carrying a valve disc 7 having its stem 8 encircled by a spring 9 which yieldably holds the

valve closed but permits the valve to be moved to an opened position when subjected to the force of an explosion in the low pressure cylinder. It will thus be seen that each high pressure cylinder communicates with its companion low pressure cylinder through a valve controlled passage or conduit and that the force of an explosion within the low pressure cylinder may open the valve to permit air under pressure to be forced into the high pressure cylinder to build up pressure therein but when an explosion takes place in the high pressure cylinder, the valve will prevent the force of this explosion passing to the low pressure cylinder.

The cylinders are disposed about a drum or manifold having front and rear chambers 10 and 11 defined by a partition 12 having a large opening 13 formed therein to establish communication between the chambers but at times closed by a valve 14, the stem 15 of which projects forwardly out of the chamber 11 and through an elbow 16 which is secured to the manifold at the rear end thereof. This valve stem is slidable through a bearing 17 and packing gland 18 and at its protruding rear or outer end carries a contact 19 which engages a stationary contact 20 when the valve is in position to close the opening 13 and closes a circuit through a motor 33' for a starting blower to be hereinafter referred to. This arrangement keeps the circuit for the motor 33' closed until pressure of air in the chamber forces the valve 14 back from the opening 13, at which time the circuit is broken and operation of the motor 33' and the starting blower stops. Necks 21 and 22 extend radially of the drum from the chambers 10 and 11 of the manifold and are coupled to ends of necks 23 and 24 leading from the heads 25 and 26 of the high and low pressure cylinders, and upon referring to Figures 3 and 4 it will be seen that perforated partitions 27 are secured between the abutting ends of the necks when the necks are clamped to each other by rings 28. A valve 29 is carried by each of the partitions 27 and yieldably held closed by a spring 30 and, therefore, while air may force its way through the conduits formed by the united necks to fill the cylinders, the force of an explosion cannot work back through the conduits to the manifold. I have, therefore, provided an arrangement wherein air may be delivered to the low and high pressure cylinders at an even pressure and when an explosion takes place in the low pressure cylinder, air is forced therefrom into the high pressure cylinder to greatly build up the pressure in the high pressure cylinder.

In order to supply air under pressure to the manifold and from the manifold to the cylinders, there has been provided a starting compressor 31 and a main or working compressor 32. These compressors are in the form of rotary fans and the starting compressor has a shaft 33 which will have rotary motion transmitted to it by the electric motor 33' having circuit wires leading to the contacts 19 and 20 so that when the valve 14 is moved away from the partition 12 to uncover the opening 13, the contact 19 will be moved away from the contact 20 and the starting motor shut off. The contact 19 and valve stem may be manually shifted to close the switch formed by the contacts 19 and 20 when the starting motor is to be set in motion. A conduit 34 leads from the housing of the starting compressor to a coupling 35 which connects it with the elbow 16 so that air from the starting compressor will be delivered into the chamber 11 of the manifold, and in the coupling is mounted a butterfly valve 36 which may be manually adjusted in order that flow of air from the starting compressor into the chamber 11 of the manifold may be regulated. The valve 14 is initially in position to close the opening 13 and, therefore, air from the starting compressor will be only delivered to the low pressure cylinders, but when the valve 14 is opened by air pressure built up in the chamber 10 by the main compressor, air which is delivered from the main compressor through the conduit 37 and elbow 38 into the chamber 10, will pass from the chamber 10 into the chamber 11, as well as through the conduits leading from the chamber 10 to the high pressure cylinders and air at an even pressure will be delivered to all of the cylinders.

Each of the low pressure cylinders consists of front and rear sections 39 and 40 which are held in alinement with each other by a clamping ring 41 and between the adjoining ends of these sections is disposed a partition 42 formed with perforations 43 which are distributed throughout the area of the partition, as shown in Figure 4 and taper so as to provide flaring openings establishing communication between a combustion chamber 44 formed by the rear section 40 and an air chamber 45 formed by the section 39 of the cylinder. There has also been provided a perforated partition 46 between the abutting portions of the section 39 and the head 26 of the low pressure cylinder to prevent uneven yielding of air from products of combustion pressure which would cause turbulence. The partition 46 is held in place when the clamping ring 47 is tightened and attention is called to the fact that the openings of the partition 46 are of an even diameter instead of being tapered. A neck 48 extends outwardly from the center of the head 26 and to this neck is secured a coupling 49 which holds a valve 50 in place and is engaged by a fuel pipe 51. It will thus be seen that vaporized fuel may pass inwardly through the coupling 49 and the neck 48 to enter an elongated tubular nozzle 52 but the valve 50 will prevent the force of an explosion from passing outwardly through the neck and coupling. The tubular nozzle extends axially of the low pressure cylinder through openings formed at centers of the partitions 42 and 46 and has a tapered end portion 52' extending from the partition 42 toward the outer or rear end of the combustion chamber and this tapered portion of the nozzle is perforated in order that the vaporized fuel may be discharged toward all portions of the combustion chamber to mix with air in the chamber during operation of the power plant.

The head 53 at the rear end of the cylinder is formed with a discharge neck 54 which is located centrally of the head and the head is secured to the cylinder section 40 by a clamping ring 53'. A valve 55 which controls passage of fuel into the discharge neck has its stem 56 slidably mounted through a bearing 57 in the neck and at its outer end carries an auxiliary valve 58 engaged by a spring 59 mounted in a cap 60 carried by the outer end of the neck. This cap is formed with an air passage 61 and from an inspection of Figure 4 it will be seen that when the valve 55 is moved to a closed position by the initial force of an explosion in the combustion chamber, the valve 58 will be opened so that air may enter the discharge neck through the opening 61 and through the opening 62 which is normally closed by the valve 58 and

pass out through passages 63 formed longitudinally through the discharge nozzle 64. This discharge nozzle has a plurality of passages 63 arranged about a central passage 65, in the inner end of which is fitted a tube 66 which extends diametrically through the discharge neck and has one end portion projecting from the neck and terminating in a flared mouth 67 into which extends a tube or pipe 68 which is secured through the head 53 in radial spaced relation to the neck 54. This pipe or tube 68 has a portion 68' which extends to and is secured through the center of the head 69 of the high pressure cylinder 2 and, therefore, the exhaust from the high pressure cylinder, as well as the initial exhaust from the low pressure cylinder, may pass through the tube 66 and out through the central passage of the nozzle 64. The nozzle 64 extends into the flared end of a spout 70 leading radially from a casing 71 in which is mounted a turbine rotor 72 carried by the shaft 73 of the main compressor and also constituting the main power take-off shaft of the power plant. It is to be understood that each low pressure cylinder has its discharge nozzle extending into a flared spout 70 of the turbine casing so that when the power plant is in operation, the productions of combustion discharged from all of the cylinders will act upon the vanes of the rotor 72 and impart rotary motion to the rotor and main shaft. By forming the discharge neck and the tubes 66 and 68 and nozzle 64, as shown, the products of combustion will draw air through the internal passages 63 and also through the external passages 63a, which air becomes intermingled with the products of combustion, thus adding weight and also maintaining the products of combustion at such a temperature that, as they pass from the spout 70 into the turbine casing across the blades or vanes of the rotor, the rotor will be turned over at a very high speed and without danger of the rotor being damaged by excessive heat.

In order to supply gaseous fuel to the cylinders, there has been provided a distributer 74. This distributer is mounted at the front of the power plant and is bolted or otherwise firmly secured to the manifold. The fuel pipes 51 of the low pressure cylinders and the fuel pipes 75 of the high pressure cylinders extend from peripheral portions of the distributer and are alternately arranged so that when the nozzle 76 of the distributer is turned about its axis, it will alternately register with passages from which the fuel pipes lead and, therefore, fuel will be first delivered to a low pressure cylinder and then a companion high pressure cylinder. The shaft 77 which carries the nozzle 76 is journaled in the distributer casing and is connected by gearing 78 with a drive shaft 79 which extends into the manifold and carries a disc or wheel 80 formed with diagonally extending openings which move into and out of registry with openings formed in a partition 81 during rotation of the disc. This partition is disposed midway the width of an opening which establishes communication between the coupling or elbow 38 and the manifold and there has been provided a valve 82 mounted for movement into a position to control passage of air from the elbow into the manifold. By properly setting the valve, proportionate quantities of the air may be allowed to pass directly into the chamber 10 of the manifold and other portions caused to pass through the openings of the partition 81 and through the diagonally extending openings of the disc to rotate the disc and shaft 79 from which rotary motion will be transmitted to the shaft 77 and thus cause the distributer nozzle 76 to move at a desired speed. A tube 83 which leads from the coupling 35 below the valve 36 and enters the manifold in front of the partition is provided in order that when the starting compressor is in operation, air may pass through this pipe or tube to the manifold and through openings of the disc or rotor 80 to operate the shaft 79. It will thus be seen that as the rotor or disc 80 is rotated by air entering the manifold, the speed at which the shaft 77 and nozzle 76 move will be controlled by flow of air into the manifold and the fuel will be fed to the cylinders in timed and correct proportionate relation to flow of air into the cylinders. This is accomplished by adjusting the valve 82 so as to allow the proper proportion of air to pass through the timer and the distributor turbine 80 to rotate the distributor once during the time it takes to fill one chamber with air. If the air pressure varies, the speed of the turbine will vary accordingly. The tube 75 communicates with a coupling 84 carried by the neck 85 of the high pressure cylinder and an inwardly opening valve 86 which is yieldably held closed by a spring 87 is disposed between the coupling and the nozzle 88 so that while fuel may be discharged into the high pressure cylinder, danger of loss of compression and back firing through the tube 75 will be eliminated.

The timer 89 is carried by the distributer and actuated by the shaft 77 and is provided with a suitable number of terminals 90 from which conductors 91 and 92 lead. These conductors are connected to the spark plugs 93 and 94 of the low and high pressure cylinders and as the movable contact or terminal of the distributer is carried by or actuated from the shaft 77, the spark plug will be energized in proper timed relation to charging of the cylinders with air and fuel and the companion low and high pressure cylinders will be fired in proper sequence and timed relation to each other.

The tank 95 which corresponds to the storage tank for air under pressure forming part of the power plant covered by the co-pending application has been shown suspended from a high pressure cylinder in centered relation to the cylinders by hangers 96 and air under pressure is fed into this tank by pipes 97 one of which leads from each of the necks 23 of the high pressure cylinders. Each of these pipes 97 is secured to a neck 98 leading from the storage tank and within this neck is mounted an inwardly opening valve 99 which is yieldably held closed by a spring 100. When the explosion takes place in the chamber 44, the products of combustion are caused to expand so evenly through the flaring orifices 43 that air in the chamber 45 is pushed back into the high pressure chamber as a body without becoming detrimentally mixed with the products of combustion. The fuel nozzle 88 extends into the cylinder 2 across the neck 23 and as the fuel is discharged towards the rear end of the high pressure chamber and an explosion occurs practically immediately there will be a certain amount of air in the front end of the cylinder 2 and the neck 23 which is substantially free from fuel, this being particularly true as the air moves into the cylinder 2 from the neck 23 at high pressure and carries the fuel with it towards the opposite end or front end of the cylinder. When the explosion occurs, air is forced from the cylinder 2 through the pipe 97 into the cylinder 95. A pipe 101 leads from the tank 95 and extends rear-

wardly of the power plant with its rear end engaged in a coupling 102 formed with a side arm or branch in which is secured a pipe 103 leading from the pipe 34 of the blower 31. A check valve 104 which is mounted to open into the coupling 102 is provided at the inner end of the side arm of the coupling and, therefore, when the power plant is first started, air may enter the coupling from the branch pipe 103 but when operation of the power plant causes air from the tank 95 to pass through the pipe 101 into the coupling 102, the valve will be held closed and shut off communication between the coupling and the pipe 103. From a coupling 102 the air passes through a pipe section 102^a into the vertically extending chamber 105^a of a regulator 105. A tube 106 which leads from a carbureter is connected with the lower end of the chamber 105^a and a delivery tube 107 leads from the upper end of this chamber to the inlet passage 108 of the distributer. From the inner end of the neck 105^b to which the tube 106 is connected extends a vertically disposed nozzle 105^c having its upper end enlarged to form a discharge mouth 105^d which is disposed above the side arm 105^e of the chamber to which the pipe section 102^a is connected. A valve 105^f which tapers downwardly and fits into the mouth 105^d controls flow of gasified fuel from the nozzle 105^c and this valve is pivoted to one end of a rocker arm 105^g which extends longitudinally in a chamber 105^h formed in the upper portion of the regulator casing. The rocker arm is pivotally mounted by a shaft 105^i extending transversely in the chamber 105^h and is pivoted to a stem 105^j rising from a diaphragm 105^k mounted in the lower chamber 105^l of the casing. This diaphragm tends to shift the stem 105^j upwardly and rock the arm 105^g about its pivot to move the valve 105^f towards a closed position, but when air under pressure entering the chamber 105^l through the pipe 105^p forces the diaphragm downwardly, pull will be exerted to open the valve. Therefore, flow of gaseous fuel from the nozzle will be controlled by pressure applied to the diaphragm. By adjusting the screw 105^m vertically it may act as a stop to engage the diaphragm and cause the valve 105^f to remain open a desired extent when the power plant is operating at a predetermined speed. There has also been provided a stem 105^n rising from the rocker arm and projecting through the cover 105^o so that, when necessary, pressure may be manually applied to the stem to rock the arm 105^g about its pivot and move the valve in an opening direction and temporarily supply a richer gas mixture. It will be readily seen that air entering the chamber 105^a through the elbow at the bottom thereof will pass upwardly about the nozzle 105^c and create a suction through the nozzle and the tube 106 so that vaporized fuel will be drawn out of the nozzle to mix with the air and form a very rich fuel mixture which passes upwardly through the pipe 107 into the passage 108 from which it enters the hub of the distributer 76 and flow from the distributer into the pipes 51 and 75 during operation of the power plant.

When this power plant is in operation, the contact 19 is manually shifted into engagement with the contact 20 to close a circuit through the motor 33' and set the starting compressor in motion and air passes through the elbow 34 and coupling 35 into the chamber 11 of the manifold. Air from this chamber is prevented from entering the chamber 10 by the valve 14 which is moved into closing relation to the opening 13 when the contact 19 is normally moved into engagement with the contact 20 and, therefore, the air in the chamber 11 passes through the necks 22 and 24 after forcing the valves 29 open and enters the low pressure cylinders. The air completely fills the low pressure cylinders and as a portion of the air passes through the tube 83 to operate the rotor 80, the distributer will be actuated to feed gaseous fuel to the nozzle 52 of each low pressure cylinder. A portion of the air passes through the necks 3 and 4 to fill the high pressure cylinder and since the outlet pipes 68 and 68' are formed of small tubing of much less diameter than the inlet, the high pressure cylinder and the low pressure cylinder will be filled with air which is at an even pressure and preferably at a pressure of fifteen pounds per square inch. When an explosion takes place in the combustion chamber of a low pressure cylinder, the initial force of the explosion closes the valve 55 and the expansion which takes place will cause a portion of the products of combustion to pass through the flaring openings 43 of the partition 42 and act upon the air in the chamber 45 to force air from this chamber through the necks 3 and 4 into the high pressure cylinder. Although a certain quantity of the products of combustion may be mixed with the air, it will not be enough to interfere with proper operation of the power plant. Therefore, the pressure in the high pressure cylinder will be built up from fifteen pounds per square inch to approximately sixty pounds, and when the spark plug 94 is energized, the combustible mixture in the high pressure cylinder will be exploded and discharged through the pipe 68' with great force. During the time the force of the explosion in the combustion chamber of the low pressure cylinder is forcing air under pressure into the high pressure cylinder, the valve 55 will be closed and products of combustion will pass through the pipe 68 and through the tube 66 to the center passage of the nozzle 64, but when the initial force of the explosion in the combustion chamber has expanded itself to a predetermined pressure, the valve 55 will be again opened and the valve 58 will be closed so that air no longer enters the discharge neck through the opening 62. Therefore, the products of combustion will leave the chamber 44 through the neck 54 and pass out through the passages 63 of the nozzle and as the explosion in the high pressure cylinder takes place immediately after the pressure has been built up in the high pressure cylinder and the valve 55 again opened, products of combustion from the high pressure cylinder will be passing through the center passage of the nozzle. Air is mixed with the products of combustion through the flared end 67 of the tube 66 and also through side passages 63 of the nozzle and through the flared end of the spout 70, thus adding weight to the products of combustion and establishing a desired temperature which will permit the products of combustion to act upon the blades of the turbine 70 and rotate this turbine without its blades being damaged by excessive heat. As the turbine rotates, the main or working compressor will be set in motion to force air through the pipe 37 and the elbow 38 into the chamber 10 of the manifold and this air will pass through the necks 21 and 23 into the high pressure cylinders. The pressure gradually builds up until the valve 14 is moved to an opened position and as the contact 19 will be moved out of engagement with the contact 15, the circuit for the motor of the starting compressor will be opened and operation of the starting

compressor discontinued. The air will now be fed from the manifold to both the low pressure and high pressure cylinders at a pressure of approximately fifteen pounds per square inch and gaseous fuel delivered into the combustion chamber of the low pressure cylinder through the nozzle 52 where it will mix with the air and form a combustible mixture which is immediately exploded by the spark plug 93. When this mixture explodes the valve 55 is shut and the expanding gases move through the openings of the partition 42 to drive the air out of the compartment 45 and through the necks 21 and 23 into the high pressure cylinder to build up the pressure of air from fifteen to sixty pounds. As previously explained, a portion of the products of combustion pass through the outlet tube 68 and through the tube 66 and the passage 65 of the nozzle into the spout 70 and as the pressure in the chamber 44 is reduced, the valve 55 again opens so that the remaining products of combustion may pass directly through the neck 54 and through the passages 63 of the nozzle. The air under high pressure is prevented from escaping from one end of the high pressure cylinder by the valves 7 and 29 and the small diameter of the tube 68' prevents material reduction of the pressure before gaseous fuel is discharged into the high pressure cylinder through the nozzle 88 to intermingle with the high pressure air and form a combustible mixture which explodes with great force when the spark plug 94 is energized. This explosion of the combustible mixture in the high pressure cylinder takes place at approximately the time the pressure in the combustion chamber of the low pressure cylinder has been reduced to a point at which the valve 55 opens and the products of combustion pass through the pipe 68' and the tube 66. The products of combustion which are discharged through the neck 54, tube 66, and nozzle 64 pick up an approximately equal weight of air and the turbine 72 will be rotated at high speed without likelihood of damage due to overheating. The capacity of the chamber 45 is substantially the same as the capacity of the high pressure cylinder and, therefore, when air in the chamber 45 is forced into the high pressure cylinder, the air in the high pressure cylinder will be under very high pressure. While it has been stated that the initial pressure of air in the two cylinders is approximately fifteen pounds to the square inch and is built up to sixty pounds in the high pressure cylinder, it will be understood that other initial pressures could be employed and the pressure built up to any pressure desired. This power plant is so constructed that when it is initially put in operation, the low pressure cylinders serve as starting cylinders and after pressure has been built up sufficiently to move the valve 14 out of closing relation to the passage 13 in the partition 12, air and gaseous fuel is fed to all of the cylinders and the low and high pressure cylinders successively fired in proper timed relation to each other so that the products of combustion discharged from the high pressure cylinders will be discharged through the tube 68' slightly later than discharge of products of combustion from the low pressure cylinders. All of the products of combustion are discharged through the nozzle or air injector 64 and air passes through the passages 63 when the valve 55 is closed and the valve 58 opened, while only products of combustion pass through the passages 63 when the valve 55 again opens and the valve 58 is closed. When the valve 58 is closed the air is drawn inwardly through the flared mouth 67 of the tube 66 and into the spout 70 about the nozzle of the injector.

In Figure 5 there has been shown a modified construction wherein the high pressure cylinders 109 are carried by the low pressure cylinders 110 and each communicates with its companion low pressure cylinder through conduits 111 formed by united necks projecting toward each other from the cylinders and secured by a clamping ring 112 with a valve 113 disposed between the connected ends of the necks. This valve opens toward the high pressure cylinder and is yieldably held closed by a spring 114. The high pressure cylinders 109 do not have direct communication with the manifold from which air passes through the connected necks 115 and 116 into the low pressure cylinder past the valve 117 which is yieldably held closed and opens toward the low pressure cylinders. It will thus be seen that a power plant provided with the arrangement of low and high pressure cylinders shown in Figure 5 may have twice as many low pressure cylinders as shown in Figure 2 and that each low pressure cylinder will carry a high pressure cylinder which receives its supply of air through the companion low pressure cylinder instead of directly from the manifold. The cylinders which receive their supply of air from the chamber 11 of the manifold will serve as starting cylinders and the remaining cylinders will not receive air direct from a compressor until the main compressor has gained sufficient speed to supply them through the chamber 10. When the main compressor has gained sufficient speed to move the valve 14 away from the partition 12 all of the cylinders will be charged with air from the main compressor during operation of the power plant. Attention is further called to the fact that in this embodiment of the invention the fuel tube 118 which corresponds to the fuel tube 75 leads to a valve housing 119 projecting from the head 120 of the low pressure cylinder. A valve block 121 is slidably mounted in the housing 119 for movement from the closed position shown in this figure in which it blocks ends of the fuel tubes or pipes 118 and 122 to an open position in which it is moved outwardly and permits fuel to pass from the tube 118 to the tube 122 and flow from this tube into the nozzle 123 for discharge into the high pressure cylinders. A plunger 124 which is slidably mounted in a chamber 125 formed in the valve housing 119 is yieldably held in the position shown in Figure 5 by a spring 126 and the stem of this valve projects outwardly and is curved as shown so that it may have connection with the valve 121. It will thus be seen that when an explosion takes place in the combustion chamber 127 of the low pressure cylinder and air is forced from the chamber 126 of this cylinder through the conduit 111 into the high pressure cylinder, the air pressure will cause the plunger to be moved against action of the spring 126 to open the valve 121 and allow fuel to pass through the tube 122 for discharge from the nozzle 123. As soon as pressure in the chamber 126 has been reduced sufficiently, the spring will return the plunger 124 to its normal position and close the valve. This arrangement eliminates any likelihood of fuel being prematurely discharged into the high pressure cylinder as the valve 121 will remain closed until the plunger 124 is moved by air which is forced under high pressure from the chamber 126 into the high pressure cylinder. There has also been provided an arrangement for control-

ling passage of products of combustion from the high pressure cylinder. In this embodiment of the invention, the discharge pipe 129 is connected by a coupling 130 to the tube 131 leading to the flared end of the tube 132. The coupling is a T-coupling and through its outer end slidably receives a valve plunger 133, the outer end of which is pivoted to the forked upper end of a rocker bar 134 disposed vertically and pivoted in spaced relation to its lower or inner end to a bracket 135 carried by and extending longitudinally from the discharge neck 136 of the low pressure cylinder. The inner end of the rocker bar is also forked and has pivotal connection with the outer end of a plunger 137 which projects outwardly through the cap 138 of the discharge neck and at its inner end is connected to the outer end of the stem 139 carrying the valve 140 and valve 141. It will be readily understood that when the valve 140 is closed by the initial force of an explosion in the combustion chamber 127 and the valve 141 moved to an open position so that air may enter the discharge neck through the central opening of the cap, the rocker bar 134 will be swung about its pivot to move the valve plunger 133 inwardly and close the upper end of the tube 131. Therefore, air may not escape through the tubes 129 and 131 and air may be built up to high pressure in the cylinder 109. The tension on the valve spring 140 determines how low the pressure must drop before the valve is opened. When the explosion closes the valve 140 it also closes the valve 133. As pressure is balanced between the low and high pressure cylinders 128 and 109, fuel is injected into the high pressure chamber and ignited just as the pressure in the chamber 128 subsides, which allows the valve 140 to be opened by the spring on the valve 141 which also opens the plunger valve 133 at the same time that an explosion takes place in the high pressure cylinder and the plunger valve 133 will be moved to the position shown in Figure 5 to uncover the upper end of the tube 131 and permit the products of combustion to pass through the tube 131. If, for any reason, opening of the valve 140 should be slightly delayed, the force of the explosion in the high pressure cylinder will act against the inner end of the valve plunger 133 to move it to an open position and allow the products of combustion to escape through the tube 131. As the operation of this embodiment of the invention is substantially the same as previously described, it is thought that it will be fully understood and need not be set forth in detail.

Having thus described the invention, what is claimed as new is:

1. In a power plant, a manifold, a compressor for delivering air to said manifold, a shaft for said compressor having a turbine operatively associated therewith, companion low and high pressure cylinders having valve controlled communication with said manifold whereby the cylinders may be filled with air under low pressure, a partition dividing the low pressure cylinder into an air chamber and a combustion chamber, said partition having openings flaring towards the air chamber whereby combustion products may enter the air chamber as a mass, means for delivering charges of fuel into the combustion chamber of the low pressure cylinder to mix with air therein and form a combustible mixture, means for exploding the mixture, valve controlled communication being provided between the high pressure cylinder and the air chamber of the low pressure cylinder whereby a mass of combustion products entering the air chamber through the openings of the partition may force air from the air chamber of the low pressure cylinder into the high pressure cylinder to build up pressure therein, means for delivering fuel into the high pressure cylinder as air is forced therein from the companion low pressure cylinder and form a combustible mixture, means for firing the mixture in the high pressure cylinder, means for conducting products of combustion from the cylinders and effecting mixture of air therewith and delivering the mixture to the turbine for rotating the turbine, a valve for controlling passage of products of combustion from the low pressure cylinder, and a valve for the high pressure cylinder actuated by the valve of the low pressure cylinder to control gas discharged from the high pressure cylinder.

2. In a power plant, a manifold, a compressor for delivering air to said manifold having a drive shaft equipped with a driving turbine, companion low and high pressure cylinders receiving air under low pressure from said manifold, a transverse partition dividing the low pressure cylinder into an air chamber and a combustion chamber, said partition having openings flaring towards the air chamber whereby combustion products may enter the air chamber from the combustion chamber as a mass, means for delivering charges of fuel into the combustion chamber to mix with air therein and form a combustible mixture, means for exploding the mixture, a valve controlled conduit connecting the high pressure cylinder with the air chamber of the low pressure cylinder and having its valve opening towards the high pressure cylinder whereby a mass of combustion products created by an explosion in the combustion chamber and entering the air chamber through the openings of the partition may force air from the air chamber through the conduit into the high pressure cylinder to build up pressure therein, means for delivering fuel into the high pressure cylinder as pressure is built up in the high pressure cylinder, means for firing the high pressure cylinder, and means for conducting products of combustion from said cylinders to said turbine for operating the turbine.

3. In a power plant, a manifold, a compressor for delivering air to said manifold having a drive shaft equipped with a driving turbine, companion low and high pressure cylinders having valve controlled inlets connected with said manifold whereby air under low pressure may be fed from the manifold into the cylinders, a valve controlled conduit connecting said cylinders and having its valve opening towards the high pressure cylinder whereby air may pass from the low pressure cylinder into the high pressure cylinder, a partition dividing the low pressure cylinder to provide an air chamber having the said valve controlled conduit leading therefrom and a combustion chamber, said partition having openings whereby a mass of expanding gases resulting from an explosion in the combustion chamber may enter the air chamber and force air therefrom into the high pressure cylinder to build up pressure therein, means for delivering fuel into the combustion chamber of the low pressure cylinder to form a combustible mixture, means for firing the mixture, means for delivering fuel into the high pressure cylinder as pressure is built up therein, means for firing the high pressure cylinder, a discharge neck for the low pressure cylinder having its inner end communicating with the cylinder and having its

outer end provided with an air inlet, a double valve movable to alternately close the air inlet and the inner end of the neck, a nozzle leading from said neck, a tube extending from said nozzle transversely through the nozzle and having a flared outer end, exhaust tubes leading from said cylinders to the flared end of the last mentioned tube, and an inlet tube for the turbine having a flared end about said nozzle.

4. In a power plant, a turbine to be driven by the exhaust from cylinders, and companion low and high pressure cylinders, a perforated partition extending transversely in the low pressure cylinder to form an air chamber and a combustion chamber, said cylinders having air inlets controlled by inwardly opening valves, the air chamber of the low pressure cylinder being connected with the high pressure cylinder by a conduit controlled by a valve opening toward the high pressure cylinder, means for delivering fuel into the combustion chamber of the low pressure cylinder to form a combustible mixture, means for firing contents of the combustion chamber and creating an explosion serving to drive air out of the air chamber into the high pressure cylinder, the products of combustion then escaping through the exhaust of the low pressure cylinder, means for delivering fuel into the high pressure cylinder as air is driven therein from the low pressure cylinder and form a combustible mixture, means for firing the combustible mixture in the high pressure cylinder, and means for conducting exhausting products of combustion from the high and low pressure cylinders to the turbine for driving the turbine.

5. In a power plant, a turbine adapted to be driven by exhaust from cylinders, and companion low and high pressure cylinders, the low pressure cylinder being divided by a transversely extending perforated partition to form an air chamber and a combustion chamber, the perforations being flared towards the air chamber, said cylinders having air inlets controlled by inwardly opening valves, means for delivering fuel into the combustion chamber of the low pressure cylinder to mix with air and form a combustible mixture, means for firing contents of the combustion chamber, the air chamber of the low pressure cylinder being connected with the high pressure cylinder by a conduit controlled by a valve opening toward the high pressure cylinder whereby a mass of gases resulting from an explosion in the combustion chamber and moving through the flared openings into the air chamber may force air from the air chamber into the high pressure cylinder to build up pressure therein, means for delivering fuel into the high pressure cylinder as air is forced therein from the low pressure cylinder and form a combustible mixture, means for exploding the combustible mixture in the high pressure cylinder, and means for conducting products of combustion from the cylinders to the turbine for driving the turbine.

6. In a power plant, a turbine adapted to be driven by exhausts from cylinders, and companion low and high pressure cylinders having controlled means associated with their exhaust outlets for delivering products of combustion to the turbine for rotating the turbine, means dividing the low pressure cylinder into an air chamber and a combustion chamber and being formed with perforations flaring towards the air chamber, the air chamber having valve controlled communication with the high pressure cylinder and having a valve controlled air inlet, means for delivering fuel into the combustion chamber to mix with air therein and form a combustible mixture, means to fire contents of the combustion chamber and create a mass of expanding gases which enter the air chamber through the flaring perforations and serve to force air from the air chamber into the high pressure cylinder and build up pressure therein, means for delivering fuel into the high pressure cylinder as air is forced therein from the air chamber, and means for firing contents of the high pressure cylinder.

7. In a power plant, a turbine adapted to be driven by exhausts from cylinders, and companion low and high pressure cylinders having controlled means associated with their exhaust outlets for delivering products of combustion to the turbine for rotating the turbine, a partition dividing the low pressure cylinder into a combustion chamber and an air chamber, the air chamber having valve controlled communication with the high pressure cylinder, the partition being formed with a multiplicity of perforations flaring towards the air chamber whereby expanding gases resulting from an explosion in the combustion chamber may enter the air chamber and move through the air chamber as a mass to drive air under pressure into the high pressure cylinder and build up pressure therein, means for delivering fuel into the combustion chamber to mix with air therein and form a combustible mixture, means for firing contents of the combustion chamber, means for delivering fuel into the high pressure cylinder as air is forced therein from the air chamber and mix with air to form a combustible mixture, and means for firing contents of the high pressure cylinder.

8. In a power plant, a turbine adapted to be driven by exhausts from cylinders, and companion low and high pressure cylinders having controlled means associated with their exhaust outlets for delivering products of combustion to the turbine for rotating the turbine, a perforated partition dividing the low pressure cylinder into a combustion chamber and an air chamber, the air chamber having valve controlled communication with the high pressure cylinder, the perforations of the partition being flared towards the air chamber whereby expanding gases resulting from an explosion in the combustion chamber may enter the air chamber and form a substantially solid mass of gases moving away from the partition and serving to drive air under high pressure into the high pressure cylinder to build up pressure therein, a tubular nozzle extending longitudinally through the air chamber from the outer end of the low pressure cylinder and through said partition into the combustion chamber axially of the cylinder and both chambers, the portion of the nozzle in the combustion chamber extending longitudinally thereof for a major portion of the length of the combustion chamber and being tapered from the partition and perforated whereby fuel will be sprayed from the nozzle to mix with air in the combustion chamber and form a combustible mixture, means for firing contents of the combustion chamber, means for delivering fuel into the high pressure cylinder as air is forced therein from the air chamber and to mix with air therein and form a combustible mixture, and means for firing contents of the high pressure cylinder.

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