

[54] DUAL COMBUSTION ENGINE AND CYCLE

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[51] Int. Cl. F02b 41/02, F02b 53/08

[58] Field of Search 60/13, 13 N, 15, 39.6,
60/280; 123/1

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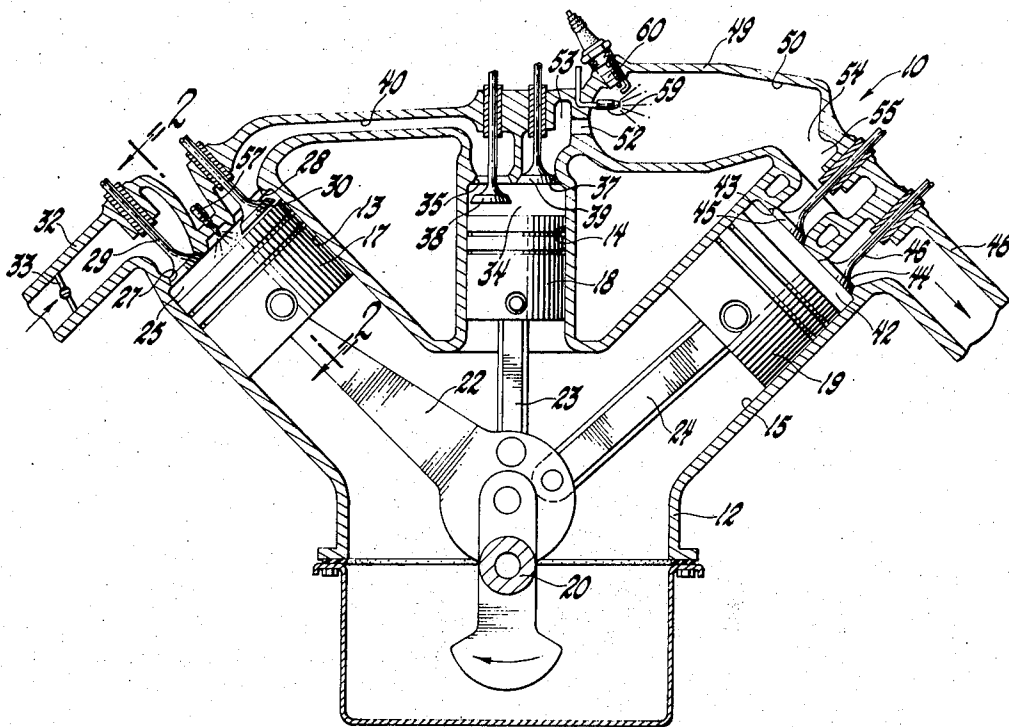
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[57]

ABSTRACT

A dual combustion engine and cycle involving sequential modes of constant volume and constant pressure combustion. A preferred embodiment includes combustion, satellite and expansion cylinders with a constant volume combustion chamber located intermediate the satellite and expansion cylinders. Compression and constant volume combustion take place in the combustion cylinders followed by partial expansion in the satellite cylinders, further combustion at constant volume in the combustion chamber and final expansion in the expansion cylinders. In an alternative embodiment, the satellite cylinders are eliminated and the engine operates at a lower pressure ratio with complete expansion taking place in the expansion cylinders.

9 Claims, 6 Drawing Figures



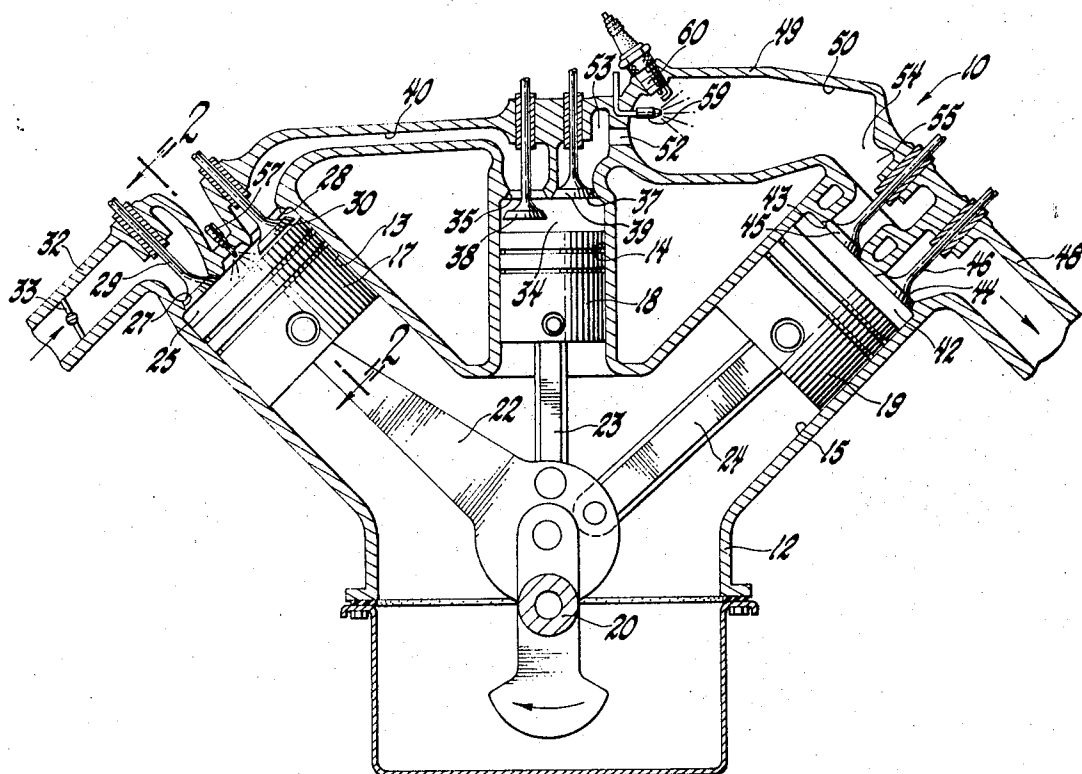


Fig. 1

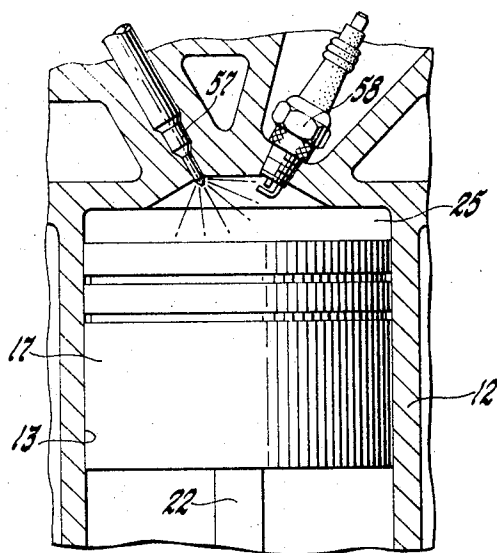
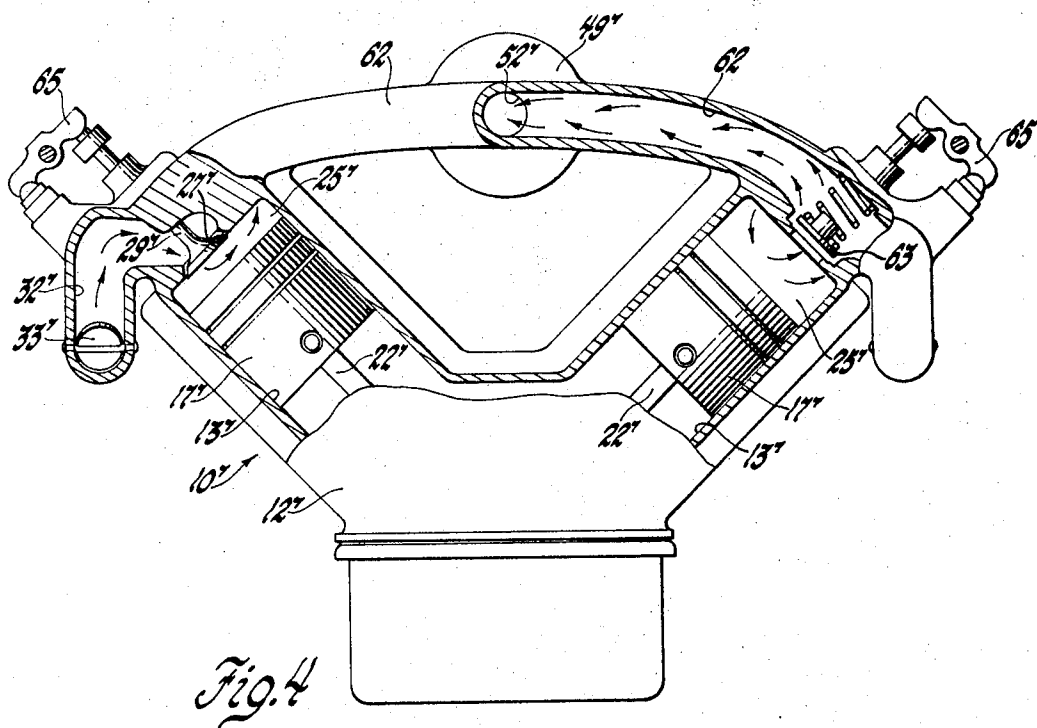
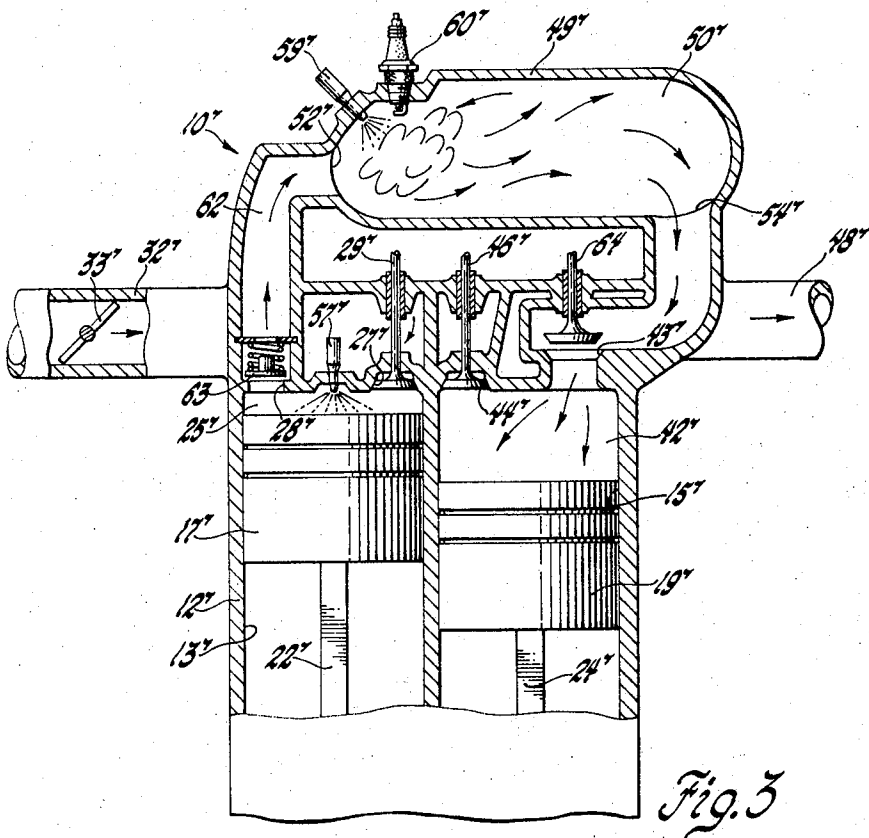


Fig. 2



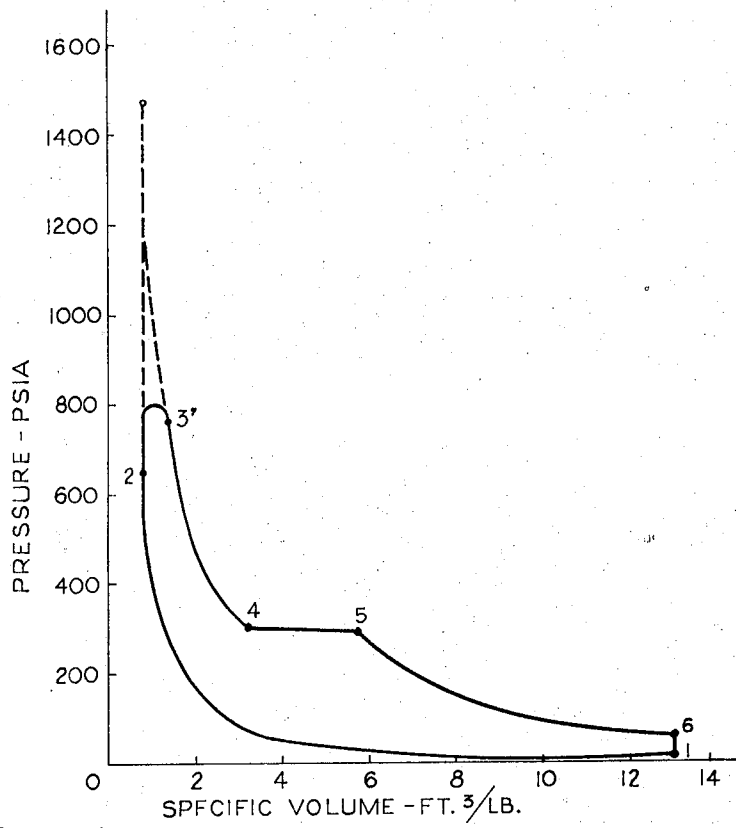


Fig. 5

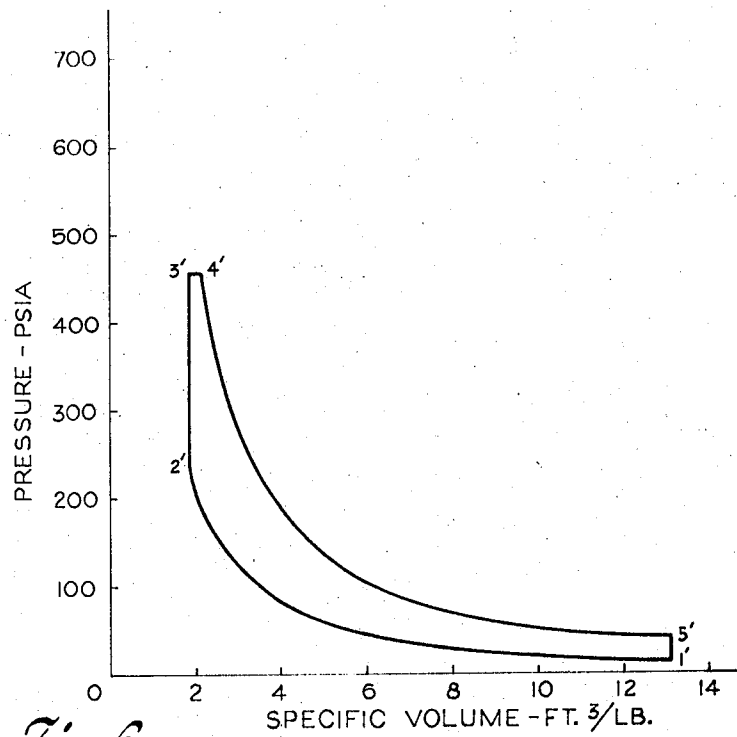


Fig. 6

DUAL COMBUSTION ENGINE AND CYCLE

FIELD OF THE INVENTION

This invention relates to combustion engines and, more particularly, to engines having positive displacement means for compression and expansion of the working charge, combined with dual combustion phases, including initial combustion at constant volume, followed by final combustion at constant pressure.

SUMMARY OF THE INVENTION

The present invention provides an improvement in combustion engines which combines the constant volume burning of the Otto cycle with the constant pressure burning of the Brayton cycle to yield a dual combustion cycle engine utilizing positive displacement means for compression and expansion of the working charge. The invention takes advantage of the improved combustion control and emission characteristics possible in a fixed volume constant pressure burner while retaining in part the advantage of the higher efficiency of constant volume combustion for heating and compressing the charge.

Numerous variations of engine physical arrangements, components and cycle variations are possible within the scope of the overall fuel combustion concept. However, a preferred embodiment involves the use of interconnected piston-cylinder arrangements for positive displacement, compression and expansion of the working charge. Additional satellite expansion cylinders may be utilized to partially expand a charge following constant volume combustion, after which constant pressure combustion and final expansion occur. Alternatively, the satellite cylinders may be deleted and the engine arranged for a lower initial compression ratio with constant volume combustion in the compression and combustion cylinders, being directly followed by constant pressure combustion in the fixed volume combustion chamber.

These and other features and advantages of the invention will be more clearly understood from the following description of certain preferred embodiments, chosen for purposes of illustration, taken together with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings:

FIG. 1 is a diagrammatic cross sectional view illustrating the arrangement of one embodiment of an engine according to the invention;

FIG. 2 is a cross sectional view of a combustion cylinder of the engine of FIG. 1 taken in the plane generally indicated by the line 2—2 of FIG. 1 and showing the location of the fuel injection and ignition means;

FIG. 3 is a longitudinal cross sectional view showing diagrammatically the relations of elements of an alternative embodiment of engine, according to the invention;

FIG. 4 is a transverse cross sectional view showing other constructional aspects of the engine of FIG. 3; and

FIGS. 5 and 6 are graphical presentations of pressure-volume diagrams comparing the cycle differences of the embodiments disclosed in the drawings.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring first to FIGS. 1 and 2 of the drawings, numeral 10 generally indicates a dual combustion engine formed according to the invention. Engine 10 includes a cylinder block 12 having a plurality of cylinders, including combustion cylinders 13, satellite cylinders 14 and expansion cylinders 15. The various cylinders are arranged in three banks, each made up of a plurality of the same type of cylinder and each preferably having at least three cylinders, only one of which is shown.

Cylinders 13, 14, 15 are each provided with reciprocable pistons 17, 18, 19, respectively, which are connected with one of the throws of the engine crankshaft 20 by means of connecting rods 22, 23, 24, respectively. In this manner, reciprocation of the pistons on a predetermined cycle relative to one another is provided.

Combustion cylinders 13 and pistons 17 together define variable volume working or combustion chambers 25, which are provided with inlet and outlet ports 27, 28 controlled by inlet and outlet valves 29, 30, respectively. Inlet port 27 connects through passage means 32 controlled by a throttle 33 with a source of air, not shown.

Satellite cylinders 14 and their respective pistons 18 together define working chambers 34 having inlet and outlet ports 35, 37, controlled by inlet and outlet valves 38, 39, respectively. Inlet ports 35 of the satellite cylinders connect through transfer passages 40 with the outlet ports 28 of their respective combustion cylinders.

Expansion cylinders 15 and their respective pistons 19 together define expansion chambers 42, having inlet and outlet ports 43, 44 controlled by inlet and outlet valves 45, 46, respectively. Outlet ports 44 communicate with an exhaust passage 48 which may be connected with suitable muffling and/or exhaust treatment means, not shown.

Intermediate the cylinder banks containing the satellite cylinders 14 and the expansion cylinders 15, there is provided a walled enclosure 49 defining a fixed volume combustion chamber 50. Combustion chamber 50 includes a plurality of inlet ports 52, which connect through transfer passage means 53 with the outlet ports 37 of the respective satellite cylinders. The combustion chamber 50 has at the end opposite the inlet ports, a plurality of outlet ports 54 which connect through suitable transfer passages 55 with the inlet ports 43 of the respective expansion cylinders 15.

Fuel supply means and ignition means are provided for both the combustion chambers of cylinders 13 and the fixed volume combustion chamber 50. These include injection nozzles 57 and spark plugs 58, located in the walls of the respective combustion chambers 25 and fuel injection nozzle 59 and spark plug 60 located in the wall 49 of the fixed volume combustion chamber 50. In each case, the fuel injection nozzles and the spark plugs from the respective chambers are located such that a relatively small fuel spray from the injection nozzles will form a locally rich fuel mixture that may be ignited by the spark plug, regardless of the amount of fuel present in the remaining portions of the combustion chamber.

Although not shown, it should be understood that the engine further includes suitable means for operating the various fuel supply means and ignition means in

timed relation with the movement of the engine pistons in order to carry out the intended operating cycle of the engine, as will be subsequently fully described.

OPERATION

In operation, the various pistons, inlet and exhaust valves, and fuel injection and ignition means are operated in timed relation upon rotation of the crankshaft 20. Upon the downward motion of each piston 17, its inlet valve 29 opens, permitting a charge of air to be drawn into the combustion chamber 25 through the inlet passage means 32. Valve 29 then closes and piston 17 moves upwardly, compressing the air charge until the piston reaches a position near top dead center. A small charge of fuel is then injected into the combustion chamber 25, forming a combustible mixture which is ignited by the spark plug 58. The burning of the fuel-air mixture further compresses and heats the charge. However, the amount of fuel injected is sufficient to combine with only a small part of the air in the charge so that a mixture of excess air and combustion products is formed by the combustion in cylinder 25.

Following and/or during the combustion, which occurs in chamber 25 at approximately constant volume, the exhaust valve 30 is opened, allowing the heated and compressed charge of air and combustion products to escape through a transfer passage 40, passing through the then open inlet valve 38 into the relatively large clearance space forming the working chamber 34 of the associated satellite cylinder 14. Valves 30 and 38 then close and the gases in chamber 34 are partially expanded as the satellite piston 18 moves downwardly. It will be noted that the satellite cylinders and their respective pistons are smaller in diameter than the associated combustion cylinders and pistons in order to provide for this partial expansion of the charge. At the end of the downward stroke of piston 18, the outlet valve 39 is opened. The charge is exhausted from each satellite cylinder on the upward stroke of its respective pistons, passing through the respective transfer passage 53 and port 52 into the fixed volume combustion chamber 50.

Preferably, the combustion chamber 50 will be supplied by at least three satellite cylinders, each associated with a combustion cylinder and the pistons of these satellite and combustion cylinders will be sequentially timed so that the admission of air and combustion products into the combustion chamber 50 is more or less continuous. In the combustion chamber 50, additional fuel is admitted to the working charge through the fuel nozzle 59 and the mixture formed is ignited by spark plug 60 and burned at constant pressure, further heating and expanding the charge.

From the fixed volume combustion chamber 50, the gases then pass through the various expansion cylinders, to which they are admitted by the opening of the respective inlet valves 45 when the pistons 19 are near their respective top dead center positions. The products are then expanded by the downward motion of the pistons 19 in the expansion cylinders, with the admission of gases being cut off by closing of the inlet valves at a suitable point in the expansion stroke, which may, if desirable, be made adjustable in much the same manner as the cutoff point of the steam engine inlet valve may be made variable. When each piston 19 reaches its downward position, the respective exhaust valve 46 is

opened and the piston moves upwardly, forcing out the expanded combustion products.

It should be noted that the partial expansion of the charge in the satellite cylinders and the final expansion of the gases in the expansion cylinders both result in the development of useful work which is transmitted to the engine crankshaft in conventional fashion, some of this work being absorbed in the operation of the combustion pistons 17, as well as the other engine components.

In FIG. 5 there is shown a pressure-volume diagram which illustrates the operation of the above-described cycle of the embodiment of FIGS. 1 and 2. Line 1-2 represents the compression of the charge in cylinders 13. Line 2-3 represents theoretical adiabatic constant volume combustion in these cylinders with line 2-3' indicating the curve as modified by heat losses. Line 3'-4 represents the partial expansion of the charge in satellite cylinders 14. Line 4-5 represents the constant pressure combustion in chamber 50, while line 5-6 represents the final expansion of the gases in the expansion cylinders. Line 6-1, of course, represents the return to atmospheric pressure due to the exhausting of the charge and intake of a fresh air charge.

ALTERNATIVE EMBODIMENT

In FIGS. 3 and 4, there is illustrated an alternative embodiment of dual combustion engine, which is generally indicated by numeral 10'. While the arrangement of the components in engine 10' varies in a number of ways from the arrangement of similar components in the embodiment of FIGS. 1 and 2, the use and operation of the components present is sufficiently similar to those of the first embodiment that it is necessary to discuss only the differences in construction and operation between the two embodiments. Accordingly, primed numerals have been utilized in FIGS. 3 and 4 to indicate components corresponding in operation and function to like elements of the embodiment of FIGS. 1 and 2.

The construction of engine 10' differs from that previously described in that the two cylinder banks each contain both a combustion cylinder 13' and an expansion cylinder 15'. It should also be noted that the satellite cylinders are completely eliminated and the longitudinally extending fixed volume combustion chamber 50' communicates directly with the combustion chambers 25' of the combustion cylinders 13' through transfer passages 62, which are controlled by spring-biased check valves 63. The compression ratio of the combustion cylinders is reduced in view of the absence of satellite cylinders. Another variation in design is that the inlet valves 64 of expansion cylinders 15' are arranged to open outwardly in the fashion of a steam engine. Rocker means 65 are illustrated for actuating the inlet and exhaust valves of the combustion and expansion cylinders, respectively.

The operation of the alternative embodiment is like that of the embodiment first described in many respects. A charge of air is drawn into the combustion cylinders 13' and compressed, followed by the injection of a small amount of fuel and burning of the charge at substantially constant volume conditions. This causes further heating and compression, forcing the charge out through check valve 63 and into the fixed volume combustion chamber 50', at which point additional fuel is added and the mixture is ignited for burn-

ing at constant pressure. The remaining gases are then transferred into the expansion cylinders 15' and expanded in the manner previously described, with the resultant work output.

FIG. 6 shows a pressure-volume diagram illustrating the cycle of the alternative embodiment of FIGS. 3 and 4. Line 1'-2' represents the compression of the charge in cylinders 13'. Line 2'-3' represents constant volume combustion in these cylinders. Line 3'-4' shows constant pressure combustion in chamber 50'. Line 4'-5' illustrates expansion of the gases in the expansion cylinders 15' and Line 5'-1' shows the return to atmospheric pressure through exhausting of the charge.

While the invention has been described by reference to certain preferred embodiments, it should be apparent that numerous changes could be made in the manner of utilizing the inventive concepts disclosed in the arrangement and construction of combustion engines. Accordingly, it is intended that the invention not be limited except by the language of the following claims.

I claim:

1. A dual combustion engine comprising first and second expansible chamber defining means movable through successive steps of expansion and contraction, combustion chamber means defining a fixed volume combustion chamber connected with and intermediate said expansible chambers, first and second fuel supply means connected to supply fuel to said first expansible chamber and said combustion chamber, respectively and means cyclically inter-relating operation of said expansible chamber and fuel supply means to receive and compress an air charge in said first expansible chamber, to heat and further compress said charge by combustion of a small quantity of fuel in said first expansible chamber, to transfer the compressed charge to the combustion chamber for the addition of further fuel and combustion with the remaining air and to expand the resulting products in said second expansible chamber with a resulting work output, said inter-relating means causing each of said expansible chamber means to operate on a repetitive two-stroke cycle.

2. The engine of claim 1 and further comprising third expansible chamber defining means connected intermediate said first expansible chamber and said combustion chamber, said third expansible chamber means being connected with said inter-relating means and operable on a two-stroke cycle to receive the charges of compressed air and combustion products during their transfer from said first expansible chamber to said combustion chamber and to partially expand said charges to obtain useful work, subsequently delivering each charge to said combustion chamber at a reduced pressure for said further fuel addition and combustion.

3. In a combustion engine adapted to operate on a two stroke dual combustion cycle including separate constant volume and constant pressure combustion steps,

first expansible chamber means adapted to receive and compress a charge of air,

first fuel delivery means connected with said expansible chamber to deliver a limited amount of fuel into said air charge so as to create a combustible air-

fuel mixture in a small portion of said compressed charge,

first ignition means connected with said expansible chamber to ignite said air-fuel mixture for burning at substantially constant volume within said expansible chamber to heat and further compress said charge,

fixed volume combustion chamber means connected with said first expansible chamber to receive the compressed and heated charge of air and combustion products therefrom,

second fuel delivery means connected with said combustion chamber to deliver additional fuel to said charge so as to create a combustible air-fuel mixture with the remaining air in said charge,

second ignition means connected with said combustion chamber to ignite the combustible mixture therein for burning at substantially constant pressure, and

second expansible chamber means connected with said combustion chamber to receive the combustion products therefrom and expand such products with a resultant output of useful work.

4. In a combustion engine adapted to operate a two-stroke dual combustion cycle including separate constant volume and constant pressure combustion steps,

first expansible chamber means adapted to receive and compress a charge of air,

first fuel delivery means connected with said expansible chamber to deliver a limited amount of fuel into said compressed air charge for combustion with a small portion of said compressed charge at substantially constant volume within said expansible chamber to heat and further compress said charge,

second expansible chamber means connected with said first expansible chamber to receive the compressed and heated charge of air and combustion products therefrom, said second expansible chamber being operative to partially expand said charge with an output of useful work and to exhaust the compressed and heated charge of air and combustion products at a lower temperature and pressure than received,

fixed volume combustion chamber means connected with said second expansible chamber to receive therefrom the compressed and heated charge of air and combustion products,

second fuel delivery means connected with said combustion chamber to deliver additional fuel to said charge so as to create a combustible air-fuel mixture with the remaining air in said charge,

ignition means connected with said combustion chamber to ignite the combustible mixture therein for burning at substantially constant pressure and

third expansible chamber means connected with said combustion chamber to receive the combustion products therefrom and expand such products with a resultant output of useful work.

5. The method of burning fuel in a dual combustion work producing cycle, said method comprising the steps of

positive displacement compression of a charge of air,

admission and burning of a first small charge of fuel in said air charge, said first fuel charge being suffi-

cient to combine with only a small portion of the oxygen in said air charge and said burning being performed under conditions approximating constant volume combustion,

subsequent admission and burning of a second charge of fuel in the resulting mixture of air and combustion products, said burning of said second fuel charge being performed under conditions approximating constant pressure combustion, and positive displacement expansion of the resulting products with a resultant work output.

6. The method of claim 7 and comprising the additional step of positive displacement partial expansion of the mixture of air and combustion products resulting from the burning of said first small fuel charge, said step of partial expansion resulting in an output of work and being performed before the admission and burning of said second fuel charge.

7. In a combustion engine adapted to operate on a two-stroke dual combustion cycle including separate constant volume and constant pressure combustion steps,

an engine block including first and second angularly disposed cylinder banks and mounting a crankshaft,

a plurality of cylinders in each of said banks, each cylinder having a piston reciprocally disposed therein and defining an expansible chamber therewith, said pistons being connected with said crankshaft, each cylinder having inlet and outlet passages and valves controlling said passages,

the cylinders in said first bank comprising combustion cylinders, having their inlet passages connected with a source of air and being provided with fuel supply means and ignition means,

the cylinders in said second bank comprising expansion cylinders, and

means defining a fixed volume combustion chamber having inlet and outlet passage means, fuel supply means and ignition means, said inlet passage means being connected with the outlet passages of said combustion cylinders to receive mixed air and combustion products therefrom and said outlet passage means being connected with the inlet passages of said expansion cylinders to deliver combustion products thereto,

said pistons, valves, fuel supply means and ignition means being operably related through said crankshaft to cause said engine to perform an operating cycle including the steps of:

- a. air admission to the combustion cylinders during the intake strokes of their respective pistons,
- b. compression of air in the combustion cylinders during the compression strokes of their respective pistons,
- c. admission of small charges of fuel, ignition and burning in the combustion cylinders in a near constant volume process which further heats and compresses the remaining air and gas,
- d. transfer of the compressed and heated gases to the fixed volume combustion chamber,
- e. admission of additional fuel, ignition and burning thereof with the remaining air in the fixed volume chamber in a near constant pressure process which further heats the gases,
- f. transfer of the compressed and heated gases to the expansion cylinders and expansion of the

gases on the expansion strokes of the respective pistons with a resultant output of work, and g. exhaust of the spent gases on the exhaust strokes of the respective pistons.

8. A combustion engine according to claim 7 and further comprising

a plurality of satellite cylinders with reciprocating pistons therein connected with said crankshaft and defining with their respective cylinders variable volume working chambers, said working chambers each having inlet and outlet passages controlled by valves, each of said satellite cylinders being connected intermediate an associated one of said combustion cylinders and said fixed volume combustion chamber, with said satellite cylinder inlet passages each connecting with the outlet passage of the associated combustion cylinder and the satellite cylinder outlet passages connecting with the fixed volume combustion chamber inlet means,

the pistons and valves of said satellite cylinders being arranged with respect to the other engine components to cause gases being transferred in step "d" from the various combustion cylinders to the fixed volume combustion chamber to be partially expanded in the respective satellite cylinders on the expansion strokes of the respective pistons with a resultant work output.

9. In a combustion engine adapted to operate on a two-stroke dual combustion cycle including separate constant volume and constant pressure combustion steps,

an engine block including a plurality of angularly disposed cylinder banks and mounting a crankshaft, first and second cylinders in each of said banks, each cylinder having a piston reciprocally disposed therein and defining an expansible chamber therewith, said pistons being connected with said crankshaft, and each cylinder having inlet and outlet passages and valves controlling said passages,

said first cylinders of each bank comprising combustion cylinders having their inlet passages connected with a source of air and being provided with fuel supply means and ignition means,

said second cylinders of each bank comprising expansion cylinders, and

means defining a fixed volume combustion chamber having inlet and outlet passage means, fuel supply means and ignition means, said inlet passage means being connected with the outlet passages of said combustion cylinders to receive mixed air and combustion products therefrom and said outlet passage means being connected with the inlet passages of said expansion cylinders to deliver combustion products thereto,

said pistons, valves, fuel supply means and ignition means being operably related through said crankshaft to cause said engine to perform an operating cycle including the steps of:

- a. air admission to the combustion cylinders during the intake strokes of their respective pistons,
- b. compression of air in the combustion cylinders during the compression strokes of their respective pistons,
- c. admission of small charges of fuel, ignition and burning in the combustion cylinders in a near constant volume process which further heats and compresses the remaining air and gas,

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- d. transfer of the compressed and heated gases to the fixed volume combustion chamber,
- e. admission of additional fuel, ignition and burning thereof with the remaining air in the fixed volume chamber in a near constant pressure process 5
- which further heats the gases,
- f. transfer of the compressed and heated gases to

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- the expansion cylinders and expansion of the gases on the expansion strokes of the respective pistons with a resultant output of work, and
- g. exhaust of the spent gases on the exhaust strokes of the respective pistons.

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