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INTERNAL COMBUSTION ENGINES

2,863,426

Filed Aug. 10, 1954

2 Sheets-Sheet 1

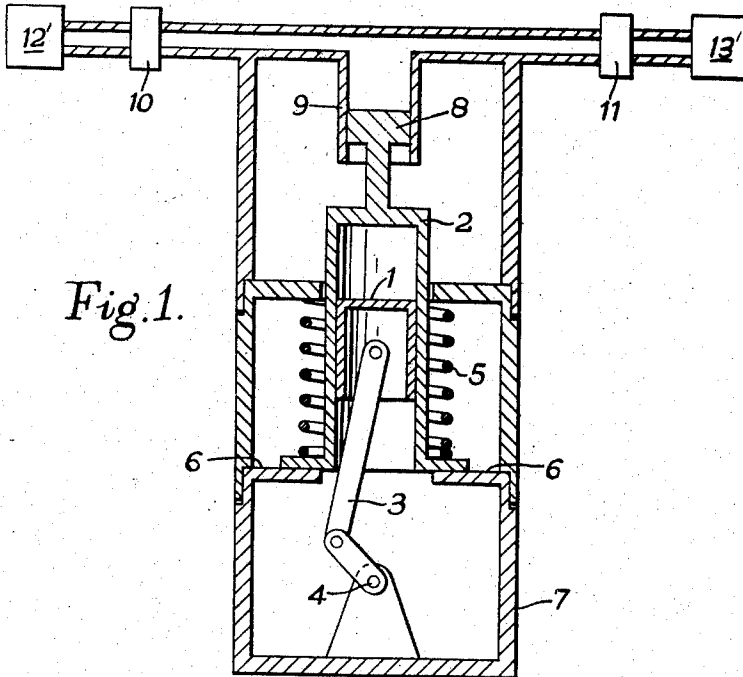
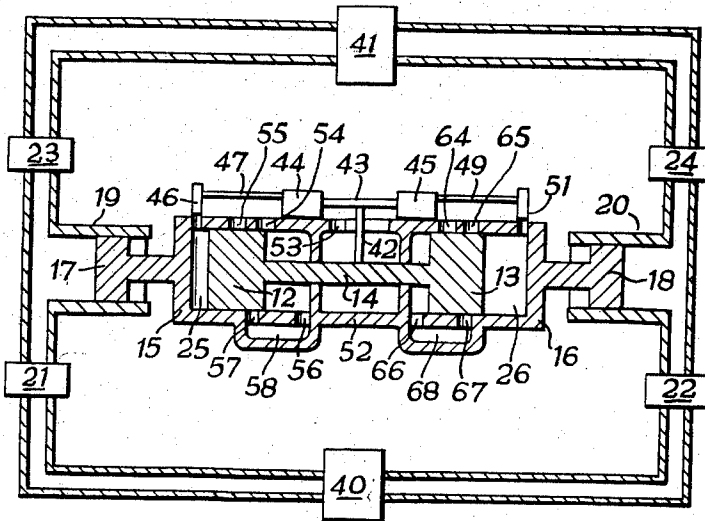


Fig. 2.



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2 Sheets-Sheet 2

Fig. 3.

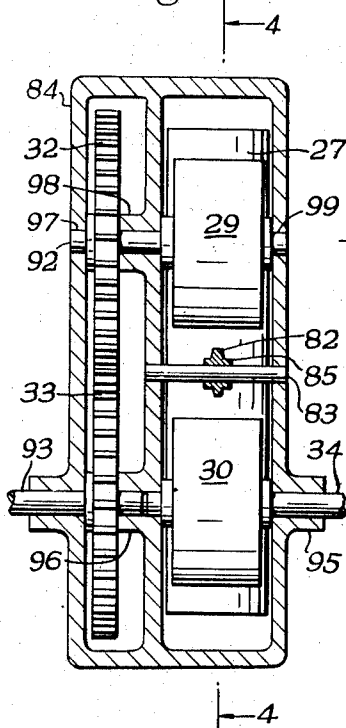


Fig. 4.

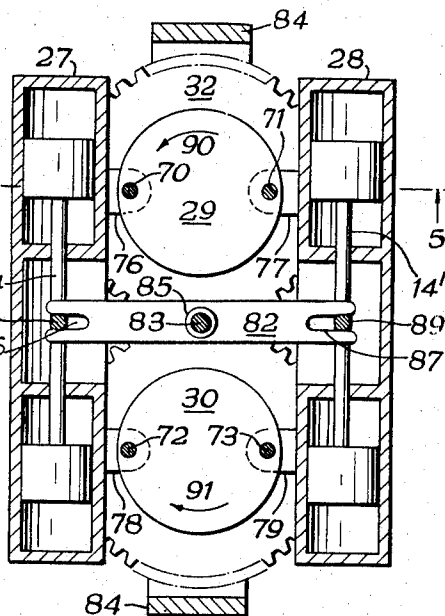


Fig. 6.

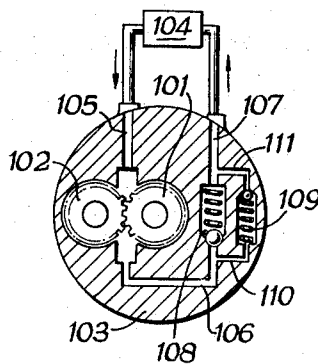
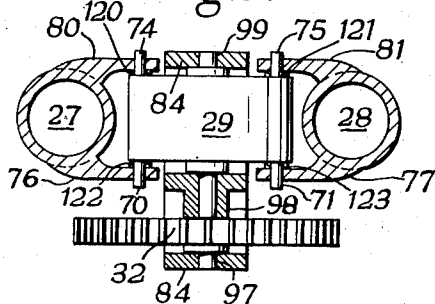


Fig. 5.



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INTERNAL COMBUSTION ENGINES

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12 Claims. (Cl. 123—50)

This invention relates to reciprocating internal combustion engines, that is to say internal combustion engines including at least one cylinder within which a piston is movable in the direction of the principal axis.

In known reciprocating internal combustion engines for a given rate of supply of fuel a certain torque can be developed for every engine speed and the torque which can be developed is least at low and high engine speeds and most at intermediate engine speeds. If the torque required to drive the load is greater than the maximum torque developed by the engine, the piston will be prevented from moving in the cylinder against the load and the engine will stall. Further, if it is desired to drive the load at a certain speed and at the corresponding engine speed insufficient torque can be developed to drive the load, it will be necessary to provide a gear-box so that the engine can run at a speed at which it can develop the necessary torque and the load can be driven at the desired speed.

It is the object of the present invention to provide an engine which is not liable to stall and which will not require a gear-box merely because of the inability of the engine to develop the necessary torque at a desired speed.

The present invention consists in a reciprocating internal combustion engine having at least one cylinder and a piston movable therein in the direction of the principal axis of the cylinder, wherein both the piston and the cylinder are movable with reference to the engine frame in the said direction.

When fuel is burnt in the cylinder the piston and cylinder will be moved in opposite directions with reference to the engine frame, and the space between the piston and the end of the cylinder will enlarge. The movement of the cylinder can be used to do work, for example by driving a reciprocating pump, and the piston can be used to keep the engine running or vice versa. Hereinafter it will be assumed that the movement of the cylinder is used to do work, but it is to be understood that in all cases the piston may be used to do work and accordingly the following description is to be understood as embracing the alternative referred to, the word "piston" being read as "cylinder" and the word "cylinder" being read as "piston" where the context allows.

In one embodiment of the invention the piston is coupled to a flywheel which will store the kinetic energy of the piston and deliver energy to drive the piston back into the cylinder; or the end of the piston remote from the cylinder end may move in a second cylinder so that, as it moves out of the one cylinder, it will move into the second cylinder from which it can be moved back into the one cylinder by the burning fuel in the second cylinder.

As the cylinder moves, it does work against the load the output being proportional to the product of the size of the load and the length of the cylinder stroke. Energy not used in doing work against the load and not lost is stored as kinetic energy in the piston as it accel-

erates. This energy may be used to compress gas in the cylinder preparatory to the next working stroke. If the load is so great that the cylinder cannot move against it, then that energy given up by the fuel which is not lost will be stored in the piston, but as there is nothing preventing movement of the piston, the engine will not stall.

When the load is zero, the cylinder will move during a working stroke but will do no work, and if the piston and cylinder have the same mass and there is no opposition to movement of either, they will move by equal amounts. The length of cylinder stroke against a zero load will be the maximum length of stroke for the cylinder and for a load between zero and the smallest load against which the cylinder cannot move (full load) the length of the cylinder stroke will be less than the maximum length; the length will be greater with smaller loads.

As the load falls below full load, the length of the stroke of the cylinder increases and the engine will at first do more work against the load. Similarly as the load increases above no-load, the length of the stroke of the cylinder decreases, but again the engine will at first do more work against the load.

Thus the engine will do most work against the load, for a given rate of supply of fuel, at a load between no-load and full load and for loads greater and less than this load will do less work, while at no-load and full load or greater than full load it will do no work.

For a given load, not greater than full load, and a given rate of supply of fuel, the engine will run at a speed to develop the torque appropriate to the load and, if the load increases, the speed will either decrease or increase so that sufficient torque is developed to overcome it. If, however, the load becomes so great that the engine cannot develop sufficient torque to drive it, the cylinder will remain stationary, but the engine will not stall but will continue running, though without doing work on the load.

With a given load the speed of the engine can be varied by varying the quantity of fuel supplied in each cycle.

The invention will be more clearly understood by reference to the following description of three embodiments with reference to the accompanying drawings in which:

Figure 1 is a sectional view of a single cylinder engine, Figure 2 is a sectional view of an engine with two opposed cylinders,

Figure 3 is a plan view partly in section of an engine with two pairs of opposed cylinders of the kind shown in Figure 2,

Figure 4 is a sectional view of the engine shown in Figure 3 on the line 4—4 looking in the direction of the arrows,

Figure 5 is a sectional view of the engine shown in Figures 3 and 4 on the line 5—5 of Figure 4 looking in the direction of the arrows, and

Figure 6 is a diagrammatic view of a free-wheel for use in an engine of the kind shown in Figures 3, 4 and 5.

One embodiment of the invention is shown in Figure 1. A piston 1 is free to slide in a cylinder 2 and is connected to a connecting rod 3, which is itself connected to a crankshaft 4 which in turn drives a flywheel (not shown). Cylinder 2 is pressed by a spring 5 against a step 6 mounted on the frame 7 of the engine. Cylinder 2 carries a piston 8 of a hydraulic pump 9. The pump communicates with a fluid reservoir 12' through a non-return valve 10 and with a hydraulic motor 13' through a non-return valve 11.

The operation is as follows. If the load on the hydraulic motor 13' is so great that cylinder 2 cannot be moved upwards against spring 5, the cylinder 2, piston 1, connecting rod 3 and crankshaft 4 can be considered

3

as an unloaded conventional internal combustion engine. Valves and means for admitting and igniting fuel in the cylinder have not been shown in the drawing since they may be of any conventional type. The engine may operate on either a two or a four stroke cycle and may employ either spark or compression ignition.

The condition in which cylinder 2 does not move occurs when the load torque is greater than the peak torque which can be developed by the engine. Although the engine cannot drive the load, it will not stall because the load does not prevent movement of the piston. If the load is reduced below the maximum load that the engine can drive (full load), the cylinder 2 will move upwards against the force of spring 5 and the force due to the hydraulic pressure in the cylinder of pump 9 necessary to drive the load. This power is supplied by the engine to drive the load and the distance cylinder 2 moves in each cycle depends on the magnitude of the load. Hence the distance the load is moved depends on the magnitude of the load and variable gearing will not be required. The load can be driven at any speed, if the fuel supply in each cycle is sufficient.

A further embodiment of the invention is shown in Figure 2. Heavy pistons 12 and 13 are joined by rod 14 and are free to slide in cylinders 15 and 16 respectively, which are rigidly joined together by means of a framework 52 and are of mass comparable with that of the pistons. Pistons 17 and 18 of hydraulic pumps 19 and 20 are attached to cylinders 15 and 16 and the cylinders of pumps 19 and 20 are rigidly attached to the engine frame (not shown). The pumps 19 and 20 are connected to a fluid reservoir 40 by way of non-return valves 21 and 22 and to a hydraulic motor 41 by way of non-return valves 23 and 24. Means not shown are provided to allow the hydraulic fluid to drain back from the outlet of the motor 41 to the reservoir 40.

Secured to the rod 14 is a shaft 42 which passes through a slot 53 in the framework 52 and is rigidly connected to a cross-shaft 43 which drives a pair of fuel injector pumps 44 and 45. Pump 44 operates to supply fuel from a source (not shown) to a spring-loaded fuel injector nozzle 46 through a pipe 47. Similarly pump 45 operates to supply fuel from the source through a pipe 49 to a spring-loaded injector nozzle 51. Cylinder 15 is provided with an air inlet port 54, an exhaust port 55 and transfer ports 56 and 57, which communicate through the transfer passage 58. Similarly cylinder 16 is provided with an air inlet port 64, an exhaust port 65, and transfer ports 66 and 67, which communicate through a transfer passage 68.

Each of the piston-cylinder combinations 12—15 and 13—16 operates as a normal two-stroke compression ignition engine. Thus in the case of piston-cylinder combination 12—15, as piston 12 moves to the left relatively to cylinder 15 during the compression stroke, port 54 is uncovered and air is drawn into the end of the cylinder containing the piston rod. When the piston 12 moves to the right during the power stroke, the air remaining in the cylinder after the port 54 is covered by the piston is compressed and some of it is delivered under pressure through the port 56 to the transfer passage 58. When the piston has moved sufficiently far to the right to uncover the port 57 the air is admitted to the left-hand end of the cylinder 25. This air assists in scavenging the cylinder and some of it passes out through the exhaust port which is uncovered at this stage, with the products of combustion. As the direction of relative motion between the piston and the cylinder again reverses at the beginning of the compression stroke, the ports 57 and 55 are successively closed. The air remaining in the space 25 is then compressed and towards the end of this stroke the injector pump 44 operates to spray fuel into the space 25 through the nozzle 46. The temperature of the compressed air in the space is by this time high enough to ignite the fuel which burns to provide the power to return the piston

4

12 towards the right. It has been found that in some cases it is desirable to arrange that the spring-loaded nozzle 46 operates to cut off the supply of fuel when the pressure in the space 25 exceeds a pre-determined value. Towards the end of the power stroke the exhaust port 55 is uncovered and the products of combustion pass out through it.

The piston-cylinder combination 13—16 functions in a similar manner, the compression stroke of the combination coinciding in time with the power stroke of the combination 12—15.

If piston 12 and 13 are initially moved to the left relatively to cylinders 15 and 16 so that the air in space 25 becomes compressed, fuel admitted to space 25 is ignited and by expanding drives pistons 12 and 13 to the right relatively to cylinders 15 and 16, thus compressing air in space 26 so that fuel is ignited in space 26 returning the pistons 12 and 13 to the left relatively to cylinders 15 and 16. Thus the pistons 12 and 13 are kept in oscillatory motion relatively to cylinders 15 and 16 by the alternate burning of fuel in spaces 25 and 26.

Consider conditions when cylinders 15 and 16 are fixed (i. e. the torque required to drive the load on motor 41 is greater than the torque that can be developed in the engine). The frequency with which pistons 12 and 13 oscillate depends on the quantity of fuel burnt in each cycle and will be such that the energy lost in each cycle (for example by friction) is equal to the energy supplied from the fuel. An increase in the quantity of fuel supplied per cycle will therefore result in an increase in frequency in the energy lost in each cycle. This increase in frequency must be accompanied by an increase in the maximum acceleration of the pistons 12 and 13 and therefore by an increase in the peak pressures in cylinders 15 and 16.

If the load on the motor 41 is progressively reduced, the assembly of cylinders 15 and 16 and pump pistons 17 and 18 will move and supply fluid to drive the motor 41 during those parts of the cycle when the pressure in spaces 25 and 26 is sufficiently large. During each cycle, therefore, some energy is supplied to the load and the frequency of oscillation of pistons 12 and 13 must therefore be reduced until the sum of friction and other losses in each cycle and the useful work done in each cycle is equal to the energy supplied in each cycle from the fuel.

As the torque required to move the load is further reduced, the useful work done in each cycle will increase and the frequency of oscillation will decrease until the forces necessary to accelerate the cylinder limit the movement of the load during one cycle to such a value that the work done against the load in each cycle decreases as the load decreases. There will thus be an increase in piston frequency as the load decreases.

If the load is completely removed, the pistons 12 and 13 and cylinders 15 and 16 will oscillate in antiphase with amplitudes inversely proportional to their respective masses and the frequency of oscillation will be approximately the same as that which occurs when the load torque is larger than can be moved by the engine.

An engine with a single oscillation member as shown in Figure 2 will however apply an oscillating load to the supports for pumps 19 and 20 and will cause undesirable vibration. Hence a practical arrangement preferably includes a plurality of units such as that shown in Figure 2, the pistons and cylinders of which are coupled by suitable linkages so that the resultant loads applied to the supports are reduced.

A preferred embodiment of the invention is shown in Figures 3, 4 and 5. This embodiment comprises essentially two piston-cylinder units of the type illustrated in Figure 2, arranged to drive a pair of coaxial shafts through free wheels. The two output shafts may be used for instance to drive the driving road wheels of a road vehicle. As the two shafts are not directly con-

5

nected, their angular speeds can be different if necessary, e. g., when the vehicle is cornering.

The engine is mounted in a frame 84 which is formed with suitable bearings 94, 95 and 96 for the two output shafts 93 and 34. Carried on the output shaft 93 is a gear-wheel 33 and carried on the shaft 34 is a free-wheel 30, the shaft being rigid with the driven part of the free-wheel. Mounted in bearings 97, 98 and 99 in the frame 84 is a shaft 92 on which are carried a gear wheel 32 which meshes with and, is the same size as, the gear wheel 33, and a free-wheel 29, the driven part of which is rigid with the shaft.

The cylinder units 27, 28 of two oscillating piston engines of the kind shown in Figure 2 are mounted on the driving parts of the two free-wheels 29, 30 by means of pins 70—75 (and two further pins not visible in the drawings) and brackets 76—81 (and two further brackets not visible in the drawings). The brackets 76, 78, 80 and one of the brackets not visible in the drawings are welded to the unit 27 and the brackets 77, 79, 81 and the other bracket not visible in the drawings are welded to the unit 28. The pins 70—75 are rigidly secured to the driving parts of the free-wheels 29 and 30 and are rotatable in bearing brushes (not shown) in the brackets 76—81. Side-play between the brackets 76, 77, 80 and 81 and the driving part of the free-wheel 29 is eliminated by means of spacers 120—123 and side-play between free-wheel 30 and its associated brackets is eliminated by similar spacers (not shown).

The piston rods (14 and 14') of the two engines are coupled by means of a link 82 which is pivoted at its centre point on a pin 83 fixed in the engine frame 84, a bearing bush 85 being provided in the link. U-shaped slots 86 and 87 are provided in the ends of the link and pins 88 and 89 fixed to the piston rods 14 and 14' respectively are arranged to rotate and slide in these slots. Thus the piston rods are constrained to move in anti-phase relative to the engine frame.

The free-wheel 29 has its driving and driven parts locked when the angular velocity of the driving part is not less than the angular velocity of the driven part in the direction of the arrow 90, and the free-wheel 30 has its driving and driven parts locked when the angular velocity of the driving part is not less than that of the driven part in the direction of the arrow 91. The units 27 and 28 of the device operate in a manner similar to that described with reference to Figure 2 and the output torques of the two units produce a torque during one half cycle driving the output shaft 93 through free-wheel 29 and gears 32 and 33 and during the next half cycle driving the output shaft 34 through free-wheel 30.

In view of the difficulty of designing strong and reliable free-wheels of the ratchet and pawl type, the free-wheels 29 and 30 can conveniently consist of conventional gear pumps modified as explained hereinafter. The driving part may be the case and the driven part the normal input shaft, or vice versa.

A free-wheel of this type, in which the driving part is the case, as illustrated diagrammatically in Figure 6 and comprises a pair of meshing gear wheels 101 and 102 rotatably mounted in bearings in a casing 103 which constitutes the driving part of the free-wheel. The shaft on which gear wheel 101 is mounted is extended outside the casing and constitutes the driven part of the free-wheel. It thus corresponds to shaft 92 or shaft 34.

When gear wheel 101 is rotated clockwise with respect to the casing 103, so that gear wheel 102 is driven anti-clockwise, the pump operates to drive fluid from a reservoir 104 through the circuit constituted by pipes 105, 106 and 107 in the direction of the arrows. Inserted in series between pipes 106 and 107 is a spring-loaded non-return ball valve 108, which is arranged so that the ball is displaced from its seating by fluid pressure in the direction indicated by the arrows. Thus when the drive to the driving part (the casing) of the free-wheel is anti-

6

clockwise (so that gear wheel 101 tends to rotate clockwise with respect to the casing), fluid is pumped round the closed circuit and little torque is applied to the driven part (the gear wheel 101). When, however, the direction of the driving part is reversed, fluid pressure operates to close the valve 108 and thus to prevent circulation of the fluid. As a result relative rotation between the gear wheels and the casing is substantially prevented and the driving torque is then transferred from the casing to the gear wheel 101. To limit the maximum pressure which may be produced in the pump and in the hydraulic circuit, a relief valve 109 is provided in parallel with the non-return valve 108. This valve also comprises a ball held against a seating by a spring and is arranged so that the ball may be lifted off its seating by fluid pressure in the pipe 107. The pipes 110 and 111 connecting the relief valve to the main circuit are of smaller bore than the remaining pipes and the strength of the spring is such that it holds the ball against its seating until the maximum safe pressure in the system is exceeded.

Although in the arrangement so far described pure couples are produced on the driving parts of the free-wheels 29 and 30, oscillating forces will be produced on the frame 84 due to the reversing gear 32, 33. The effects of these forces in producing vibration can be reduced by mounting the frame 84 in bearings coaxial with bearings 94 and 95 and restraining it from rotating about these bearings by means of a low-rate suitably damped elastic member. The out of balance moments then tend to oscillate the frame about the axis of the shafts 34 and 93, but the vibration transmitted to the supports (or the vehicle frame in which the frame 84 is mounted) is considerably reduced.

While the invention has been described with reference to certain specific embodiments, it is to be understood that it embraces all modifications which fall within the scope of the claims. As previously mentioned one possible modification is for the pistons to be used instead of the cylinders to do work. In this case in the embodiment described with reference to Figures 3, 4 and 5 of the drawings the two pairs of cylinders will be coupled through the link 82 while the two pairs of pistons will be coupled to the driving part of the free-wheel.

Further, although the engine illustrated in Figures 3, 4 and 5 is shown with two separate output shafts 34 and 93, it is not essential from a broad standpoint that such shafts be separate.

What is claimed is:

1. An internal combustion engine comprising a first free wheel the driven part of which is connected to an output shaft; a second free wheel the driven part of which is coupled to said output shaft through a reversing gear; a first pair of coaxial cylinders rigidly connected together and mounted on the driving members of said first and second free wheels so that axial movement of said first pair of cylinders in one direction tends to rotate said output shaft; a second pair of coaxial cylinders rigidly connected together and mounted on the driving members of said first and second free wheels so that axial movement of said second pair of cylinders in the direction opposite to said one direction tends to rotate said output shaft; a first pair of coaxial pistons rigidly connected together and slidable in said first pair of cylinders; a second pair of coaxial pistons rigidly connected together and slidable in said second pair of cylinders; and a lever pivoted on the frame of the engine and interconnecting said first pair of pistons and said second pair of pistons.

2. An internal combustion engine comprising a first free wheel the driven part of which is connected to an output shaft; a second free wheel the driven part of which is coupled to said output shaft through a reversing gear; a first pair of coaxial pistons rigidly connected together and mounted on the driving members of said first and second free wheels so that axial movement of said first

7

pair of pistons in one direction tends to rotate said output shaft; a second pair of coaxial pistons rigidly connected together and mounted on the driving members of said first and second free wheels so that axial movement of said second pair of pistons in the direction opposite to said one direction tends to rotate said output shaft; a first pair of coaxial cylinders rigidly connected together and surrounding said first pair of pistons; a second pair of coaxial cylinders rigidly connected together and surrounding said second pair of pistons; and a lever pivoted on the frame of the engine and interconnecting said first pair of cylinders and said second pair of cylinders.

3. An internal combustion engine comprising a frame, first and second relatively reciprocable members enclosing a combustion chamber said members being axially movable in mutually opposite directions in response to the combustion of fuel in said chamber, operative driving means connecting one of the members to a load, and means for returning said members towards each other after each has travelled a distance relative to the frame that depends on the magnitude of the load.

4. A compression ignition engine comprising a frame, a first pair of coaxial cylinders which are relatively immovable but are reciprocable with reference to said frame and are operatively connected to a load; a first pair of coaxial pistons, one in each of said first pair of cylinders, rigidly connected together and reciprocable with reference both to said cylinder and to said frame; a second pair of coaxial cylinders which are relatively immovable and are so connected to the said load and to said first pair of cylinders that any axial movement of said first pair of cylinders is accompanied by an axial movement of equal magnitude and opposite sense of said second pair of cylinders; and a second pair of coaxial pistons, one in each of said second pair of cylinders, rigidly connected together and reciprocable with reference both to said cylinder and to said frame, and so interconnected with said first pair of pistons that any axial movement of said first pair of pistons is accompanied by an axial movement of equal magnitude and opposite sense of said second pair of pistons.

5. A compression ignition engine comprising a frame, a first pair of coaxial cylinders which are relatively immovable but are reciprocable with reference to said frame; a first pair of coaxial pistons one in each of said first pair of cylinders, rigidly connected together, reciprocable with reference both to said cylinder and to said frame and operatively connected to a load; a second pair of coaxial cylinders which are relatively immovable and are so connected to said first pair of cylinders that any axial movement of said first pair of cylinders is accompanied by an axial movement of equal magnitude and opposite sense of said second pair of cylinders; and a second pair of coaxial pistons, one in each of said second pair of cylinders, rigidly connected together and reciprocable with reference both to said cylinders and to said frame, and so connected to said load and to said first pair of pistons that any axial movement of said first pair of pistons is accompanied by an axial movement of equal magnitude and opposite sense of said second pair of pistons.

6. A reciprocating internal combustion engine comprising first and second relatively reciprocable members jointly defining an expansive combustion chamber, frame means supporting the respective members for reciprocation independently of each other, means driven by and imposing a load on said first member, the inertia of the said second member opposing reciprocation of said second member, whereby the length of stroke of the first mem-

8

ber varies in accordance with the magnitudes of said load from a maximum at zero load to a minimum at full load, and the stroke of said second member increases with the magnitude of the load.

7. The combination of claim 6 wherein said means driven by the first reciprocable member comprises a fluid pump, and a fluid motor in circuit with said pump.

8. The combination of claim 7 wherein said fluid pump is of the reciprocable type including a piston connected to said first member for reciprocation therewith.

9. An internal combustion engine as defined in claim 6, in which said first and second members respectively comprise a cylinder and piston reciprocably therein.

10. An internal combustion engine as defined in claim 6, including a pair of said expansive combustion chambers, the said first and second members of each such chambers comprising a cylinder and piston assembly, the cylinders and pistons of both pairs of said combustion chambers being disposed for reciprocation along a common axis, means rigidly interconnecting said pistons for reciprocation as a unit, and means rigidly interconnecting said cylinders for reciprocation as a unit.

11. An internal combustion engine comprising a frame, two cylinders which are relatively immovable but are reciprocable together with reference to the engine frame, means operatively connecting said cylinders to drive a load, and two pistons so interconnected that when one piston enters one cylinder the other piston is withdrawn from the other cylinder and so mounted that they are reciprocable relatively to the frame and that their inertia provides the main opposition to their reciprocation, whereby the length of the stroke of the cylinders varies in accordance with the magnitude of the load from a maximum at zero load to a minimum at full load, while the stroke of the pistons increases with the magnitude of the load.

12. An internal combustion engine comprising a frame, two coaxial cylinders which are relatively immovable but are reciprocable together with reference to the engine frame in the direction of their common axis, means connecting said cylinders to a load, and two pistons, one in each cylinder, rigidly connected together and acceleratable relative to said cylinders and also to said frame in response to the expansion of fuel burnt in said cylinders, the inertia of the pistons providing the main opposition to their reciprocation, whereby as the magnitude of the load increases the length of the stroke of the cylinders decreases while the length of the stroke of the pistons increases.

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