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(54) Title: INTERNAL COMBUSTION ENGINE WITH MULTIPLE OPERATING MODES

(57) Abstract: Apparatus for converting an in-line six cylinder engine into a engine having three operational modes including providing (1) a new camshaft which cause the pistons of the inner, outer and intermediate pairs of cylinders which move together to have in phase piston cycles, (2) a new gasket which provides a passage between the inner cylinders and a new computer module which causes the engine with the new camshaft and gasket to selectively operate in the three modes. The method of conversion includes replacing the new apparatus components with existing components of the engine. Also discussed is an inverted V engine having two banks of cylinders converging from separate crankshafts with their combustion chamber closely spaced with passages therebetween.

FIG. 1
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INTERNAL COMBUSTION ENGINE WITH MULTIPLE OPERATING MODES

CROSS-REFERENCE APPLICATIONS

[0001] The present application is a continuation-in-part of U.S. Serial No. 13/839,992, filed March 15, 2013, the entirety of which is incorporated herein by reference.

FIELD OF INVENTION

[0002] This invention relates to internal combustion engines and more particularly to engines having fuel saving operating modes of the type disclosed in US Patent No. 8,443,769.

BACKGROUND OF THE INVENTION

[0003] The fuels saving modes of the '769 Patent involve a step forward in the evolution of "skipping" technology. For the first time, the piston of the skipped piston and cylinder assembly actually enters into the creation of power rather than simply being neutral or requiring power from the rest of the engine to be moved through repeated cycles without cycle events taking place. The skipped piston enters into the creation of power because it shares chambers of two paired assemblies. By means of a passage between the combustion, the increased pressure conditions in the cylinder of its paired assembly resulting from the internally fired power drive stroke therein to undergo a simultaneous shared power drive stroke. Since the skipped piston is directly connected to the crankshaft, its shared power drive stroke creates power in the engine.

SUMMARY OF THE INVENTION

[0004] The present invention has among its non-limiting objects to provide other engine configurations which embody the fuel saving principles of the '796 Patent.

[0005] A non-limiting object of the present invention is to provide modifications to conventional in-line 6 cylinder engines so that the modified engines are capable of increasing their efficiency in operation, preferably by at least 20%, thus making them suitable to satisfy the
market in large trucks and semi tractors which must be created by 2014 in order to meet the
government mandates as to mpg. This objective increase is achieved by the present invention by
modifying the central inner two adjacent piston and cylinder assemblies of the engines so that
they operate in accordance with the principles of the aforesaid patent. The modifications involve
(1) changing the camshaft so that the central inner two adjacent piston and cylinder assemblies
have their four stroke cycles in phase rather than 180° out of phase, (2) providing a
communicating passage between the combustion chambers of the central inner two piston and
cylinder assemblies and (3) modifying either the hardware or programming for the control of the
fuel injectors of the central inner two piston and cylinder assemblies so that one can be
selectively controlled not to inject fuel during the operation cycle thereof. The modifications
contemplate providing a new cam shaft in which not only the cam lobes relating to the central
inner two adjacent piston and cylinder assemblies are modified to change 180° out of phase to in
phase, but the cam lobes relating to the two outer and to the two intermediate piston and cylinder
assemblies are similarly modified in order to provide a somewhat balanced application of the
driving forces during each piston cycle.

[0006] Various options within the invention are as follows.

[0007] The camshaft may be constructed and arranged so that the firing strokes of the
two outer and intermediate assemblies are in phase, the fuel injecting and firing system being
operable to selectively control the injectors of the two outer and intermediate assemblies in a
third mode wherein one injector associated with each of the two outer and two intermediate
assemblies is controlled to inject zero amount of fuel.

[0008] The fuel injecting and firing system may be operable to control an injector to
inject fuel into a cylinder during an associated piston stroke when the compressed air in the
associated combustion chamber has reached an auto ignition pressure so that the igniting of the mixture occurs as a result of the injection.

[0009] The fuel injecting and firing system may be operable to control an injector to inject fuel into a cylinder during an associated piston intake stroke and the mixture of fuel and compressed air in the associated combustion chamber is ignited by energizing a spark plug in communicating relation to the mixture.

[0010] Another aspect of the invention also includes a method and apparatus of, the method comprises: converting an existing in-line six cylinder internal combustion engine having six in line piston and cylinder assemblies each including a cylinder having a crankshaft connected piston mounted therein for movement through successive cycles including a compression stroke and an immediate following power drive stroke into an in-line six cylinder engine having (1) a full power mode with no fuel skipping, (2) an intermediate fuel saving mode skipping fuel in one of a pair of inner cylinders having combustion chambers communicated by a passage, and (3) an increased fuel saving mode wherein, in addition to skipping fuel in one of the inner pair of cylinders, one of each of the remaining outer and intermediate pairs of cylinders are alternately fuel skipped, said apparatus comprising: replacing the camshaft of the existing engine with a new conversion camshaft constructed and arranged so that the cycles of piston movement of two inner assemblies are in phase, providing a communicating passage between the combustion chambers of the two inner assemblies, and modifying the fuel injecting and firing system so that when the cycles of piston movements of the two inner assemblies are in phase and the communicating passage is provided between the combustion chambers thereof, the modified fuel injecting and firing system will cause a selected one of modes (1) (2) or (3) to be in operation and response to predetermined input signals to said system.
The apparatus comprises an apparatus for converting an existing in-line six-cylinder internal combustion engine having six in line piston and cylinder assemblies each including a cylinder having a crankshaft connected piston mounted therein for movement through successive cycles including a compression stroke and an immediate following power drive stroke into an in-line six cylinder engine having (1) a full power mode with no fuel skipping, (2) an intermediate fuel saving mode skipping fuel in one of a pair of inner cylinders having combustion chambers communicated by a passage, and (3) an increased fuel saving mode wherein, in addition to skipping fuel in one of the inner pair of cylinders, one of each of the remaining outer and intermediate pairs of cylinders are fuel skipped, said apparatus comprising: a conversion camshaft to replace any existing camshaft of the existing engine, a conversion head gasket to replace any existing head gasket of the existing engine, and a computer module to replace any existing computer fuel control of the existing engine, constructed and arranged so that when replaced together with the placement of the conversion camshaft and conversion head gasket said conversion is achieved.

Other various options may include the following.

The compression stroke of each assembly may create an auto-ignition compression pressure and wherein the mixture is ignited by injecting fuel into the air under auto-ignition pressure within the associated combustion chamber.

The mixture of air and fuel in the associate combustion chamber by injecting fuel with the intake of air during each intake stroke and the mixture may be ignited by the energization of a spark plug in communication with the mixture.

The new camshaft may control the valves of the two outer and two intermediate assemblies so that cycles of the two outer and two intermediate assemblies are in phase, and the
injectors of the fuel injecting and firing system associated with the two outer and two intermediate assemblies are controlled in a third mode wherein one of the injectors of the two outer and two intermediate assemblies inject a zero amount of fuel.

[0016] The passage may be provided by grinding inwardly of a seal engaging surface of the frame between the cylinders of the two inner assemblies.

[0017] The fuel injecting and firing system may be controlled by a computer and the modification of the system is achieved by reprogramming the computer.

[0018] The fuel injecting and firing system may be controlled by pumping fuel under pressure through individual lines to each injector in timed relation and the modification of the system is achieved by modifying the lines to the injectors.

[0019] The present application is particularly concerned with the apparatus and methods for effecting the modifications. In addition, a significant in-line six cylinder engine embodying the modifying apparatus and method is disclosed.

[0020] It is preferable in accordance with the principles of the present invention to provide a maximum fuel saving mode wherein alternately one of the two cylinders firing is cut off from fuel. It is also an object of the present invention to provide new engines wherein two cylinders fire over 120° of crankshaft rotation constructed to embody the modifications herein provided hereinbefore indicated.

[0021] One non-limiting aspect of an embodiment of the inventor addresses the issue of elongation of opposed cylinder engines. This objective is obtained in accordance with principles of the present invention by configuring the eight piston and cylinder assemblies in what may be termed an inverted v configuration. Although a V-8 configuration is a more common inverted configuration, the invention is not limited to any specific number of piston/cylinder assemblies.
Thus, using the more common V-8 configuration as context, instead of having two banks of four piston and cylinders assemblies which diverge outwardly from a lower centrally located crankshaft, the inverted V configuration of the invention converges outwardly from two spaced crankshafts. The term "converges outwardly" refers to the two banks of cylinders converging toward one another in the directions outward from their respective crankshafts. In this way, the outer or upper combustion chamber ends of each bank of four piston and cylinder assemblies are positioned in close proximity to one another rather than being spaced far apart as in a conventional V-8 engine. Thus, instead of providing two side-by-side piston and cylinder assemblies within each bank capable of operating in accordance with the invention as with the opposed eight, it becomes possible due to the close proximity of the combustion chambers of the piston and cylinder assemblies of each bank with the combustion chambers of the other bank to pair off the corresponding piston and cylinder assemblies of both banks to operate in accordance with the invention. The present invention overcomes the elongation disadvantage of the disclosed opposed eight by means of the V-configuration; even though inverted, and performance is enhanced by providing four pairs of piston and cylinder assemblies operating in accordance with the invention rather than two. The same benefits may be achieved in engine configurations using four, six or any other number of piston/cylinder assemblies.

[0022] Another internal combustion engine embodying the principles of the present invention includes a plurality of pairs of piston and cylinder assemblies mounted in a frame structure each pair of which includes:

[0023] (1) a pair of cylinders each containing a combustion chamber,

[0024] (2) crankshaft connected pistons mounted in the cylinders for simultaneous movements toward and away from the combustion chambers thereof through successive cycles
each including simultaneous compression strokes followed immediately by simultaneous power
drive strokes, and

[0025] (3) fuel injectors for each cylinder for injecting fuel into the associated cylinder
when controlled to do so and a controller for selectively controlling the injectors so that during
each piston stroke each injector undergoes either (1) an injection wherein fuel is injected thereby
into the associated cylinder so that each associated piston undergoes an internally fired power
drive stroke, or (2) a skipped injection wherein no fuel is injected thereby into the associated
cylinder so that each associated piston undergoes a power drive stroke which is not internally
fired,

[0026] the controller is operable to selectively control the injectors so that the engine can
be operated, either

[0027] (1) a first mode wherein the pistons of each of the pairs undergo simultaneous
power drive strokes which are internally fired, or

[0028] (2) a second mode wherein the pistons of each of the pairs undergo simultaneous
power drive strokes one of which is an internally fired power drive stroke and the other of which
is not an internally fired power drive stroke,

[0029] the engine further includes one or more of the following preferred features:

[0030] (1) when the controller is operating the engine in the second mode the one
assembly of the pair with the power drive stroke which is internally fired is alternated with the
other assembly of the pair with the power drive stroke which is not internally fired,

[0031] (2) the power drive stroke which is not internally fired during the second mode
constitutes either: (1) a shared power drive stroke of the pistons of the other assembly by virtue
of sharing the internally fired power drive through a combustion chamber communicating stroke
of the one assembly passage, or (2) skipped power drive stroke of the other assembly which is
moved by the associated crankshaft, and (3) the plurality of pairs of assemblies includes three
pairs of assemblies at least one of which has a shared power drive stroke during the second mode.
In accordance with the principles of the present invention, the engine can be configured to be
fired by compression ignition or by spark ignition. In one exemplary configuration, the engine
has three pairs of piston and cylinder assemblies in a line formation. In another exemplary
configuration, the engine has four pairs of piston and cylinder assemblies in two banks of four
assemblies each, the two banks converging outwardly from two spaced simultaneously driven
crankshafts so that the outer combustion chambers of the cylinders are paired in closely spaced
relation, and intercommunicated by passages extending there between,

[0032] Another aspect of the invention includes a method and apparatus for converting
an existing in line six cylinder engine into an engine having different modes of operation
including those of the '769 Patent.

[0033] Other objects, features, and advantages of the present invention will become
apparent from the following detailed description, the accompanying drawings, and the appended
claims.

**DESCRIPTION OF THE DRAWINGS**

[0034] Figure 1 is a perspective view of a conventional diesel 4 stroke in line six cylinder
engine with parts broken away for purposes of clearer illustration;

[0035] Figure 2 is a perspective view of a first apparatus modification in accordance with
the principles of the present invention in the form of a new camshaft;
[0036] Figure 3 is a fragmentary perspective view of a second apparatus modification in accordance with the principles of the present invention in the form of a passage in the engine block between cylinders 3 and 4;
[0037] Figure 4 is a schematic and block diagrammatic view of a third apparatus modification in accordance with the principles of the present invention in the form of a modified fuel injecting and firing system;
[0038] Figure 5 is a fragmentary cross sectional view showing a cylinder of a L spark ignited in line six cylinder engine embodying the principles of the present invention;
[0039] Figure 6 is a top plan view of a preferred head gasket constructed in accordance with the principles of the present invention;
[0040] Figure 7 is an enlarged sectional view taken along the Line 7-7 in Figure 6;
[0041] Figure 8 is a preferred computer module constructed in accordance with the principles of the present invention;
[0042] Figure 9 is a sectional view through the center lines of two piston and cylinder assemblies of the two banks of four in an inverted V-8 engine embodying the principles of the present invention;
[0043] Figure 10 is a sectional view taken along the line 2-2 of Figure 9;
[0044] Figure 11 is a fragmentary sectional view taken along the line 3-3 of Figure 9;
[0045] Figure 12 is a fragmentary sectional view taken along the line 4-4 of Figure 11;
[0046] Figure 13 is a right side elevational view of the engine shown in Figures 9-12 with the cam drive guard shown in section;
[0047] Figure 14 is a layout view of the gasket of the engine viewed perpendicularly to the two angulated surface thereof;
Figure 15 is a chart designating the direction of piston movement and cycle events for each piston and cylinder assembly of the engine including corresponding cross-sections of the camshaft; and

Figure 16 is a somewhat schematic view of the fuel injecting system and the computer system for controlling the fuel injecting system.

DETAILED DESCRIPTION OF THE INVENTION

Figure 1 shows a prior art four stroke six cylinder in-line diesel engine 10 which includes a main frame 12 having a pan 13 detachably fixed to the lower end of a crankcase portion 14 thereof. Mounted within the crank case portion 14 is a crankshaft 16 journaled in main bearings 18. The crankshaft 16 includes six crank portions providing six crankpin bearings 20 on which the bolt secured split ends of six connecting rods 22 are journaled. The opposite ends of the six connecting rods 22 are journaled in six wristpin bearings 24 mounted within six pistons 26 respectively. The six pistons 26 are in-line oriented slidably sealingly mounted in six in-line oriented cylinders 28 formed by six in-line oriented cylinder liners 30 removably fixed within the frame 12.

The connecting rods 22 are journaled at one end on the bearings 20 of the crankshaft 16 and at the other end on the pistons 26 which causes the pistons 26 to be reciprocated within the cylinder liners 30 through a cycle of four reciprocating strokes while the crankshaft is rotated through two rotations.

The four events which occur within the cylinders 28 during each four stroke cycle include intake, compression, fire, and exhaust. The events in that order are accomplished in response to the operation of a camshaft 32 which is suitably journaled on the frame 12. The camshaft 32 is mounted in a position to be driven by the crankshaft 16. The drive is
accomplished by a gear 34 fixed on the crankshaft 16 to rotate therewith and a meshing gear 36 of twice the size of gear 34 fixed on the camshaft 32 so that the camshaft 32 rotates at half the speed of the crankshaft 16.

[0053] The four events are accomplished by reciprocating inlet valves 38 spring biased to close inlet openings leading into the cylinders 28 above the pistons 26 and outlet or exhaust valves 40 spring biased to close outlet openings leading from the cylinders 28 to an exhaust manifold (not shown) forming a part of an exhaust system including an exhaust pipe (not shown).

[0054] The inlet and outlet valves 38 and 40 are moved into opening relation to the inlet and outlet openings against their spring bias by inlet and outlet cam lobes 42 and 44 on the camshaft 32 which move inlet and outlet lifter rods 46. The inlet and outlet valves 38 and 40 are actively moved by one ends of inlet and outlet rocker arms 47, the other ends of which are moved by the inlet and outlet lifter rods 46.

[0055] The position of the cam lobes 42 and 44 on the camshaft 32 cause (1) the inlet valve 38 associated with each cylinder to be open at an appropriate time so that the inlet opening is open during the inlet stroke event of the piston cycle and (2) the outlet valve 40 associated with each cylinder to be opened at an appropriate time so that the outlet opening is open during the outlet or exhaust stroke event. The inlet and outlet valves 38 and 40 are allowed to remain in their spring biased closed position during the compression stroke event of each cycle wherein the air in the cylinder taken in during the intake stroke event is compressed to an auto ignition pressure. The inlet and outlet valves 28 and 30 also remain closed during the firing or power drive stroke during which diesel fuel is injected into the cylinder by a computer controlled fuel
injecting and firing system, generally indicated at 48; modification of which is shown in Figure 4 and will be described in detail hereinafter.

[0056] It will be understood that the conventional diesel four stroke in-line six cylinder engine also has accessories such as an alternator, fuel and air filters, an oil pump, a turbo charger, a super charger, etc., which remain unmodified in accordance with the principles of the present invention and hence are either not shown in the drawings or described in detail herein.

[0057] It can be seen from Figure 1 the conventional engine 10 includes six in-line crankshaft driven piston and cylinder assemblies, with the components of each being identified by the reference numerals above. In the description relating to Figures 2, 3 and 4, individual components are referred to where six are provided. Each of the six piston and cylinder assemblies includes a cylinder 28, a piston 26 and a connecting rod 22 which in Figures 2-4 are individually identified by adding a numeral 1 through 6 in front of each reference numeral Thus, the components can be referred to as cylinder 128, piston 126 or connecting rod 122, cylinder 228, piston 226 or connecting rod 222, etc., for purposes of clearly identifying each one of six.

[0058] The six crank portions of the crankshaft 16 are arranged so that pistons 126 and 626 move together in cylinders 128 and 628, pistons 226 and 526 move together in cylinders 228 and 528 and pistons 326 and 426 move together in cylinders 328 and 428. A conventional firing order is 153624 which means that the firing stroke event takes place in successive strokes first in cylinder 128; second, in cylinder 528; third, in cylinder 328; fourth, in cylinder 628; fifth, in cylinder 228; and sixth, in cylinder 428. A cycle must take place in each cylinder in two rotations of the crankshaft (four 180° strokes) or one rotation of the camshaft (four 90° strokes). In order for six firing stroke events to take place in four incremental movements of the camshaft
(90° each) or four incremental movements of the crankshaft (180° each) it is conventional that these firing stroke events be initiated 120° apart with respect to the crankshaft rotation. To accomplish the initiation of six successive firing stroke events every 120° (1) the firing stroke event in cylinder 528 is initiated 120° after the initiation of the firing stroke in cylinder 128, (2) the firing stroke event in cylinder 328 is initiated 120° after the initiation of the firing stroke event in cylinder 528, (3) the firing stroke events of cylinders 628, 228 and 428 follow in the same sequence. Also in order to achieve six successive stroke initiations within two revolutions of the crankshaft 32 the cycles of commonly used pistons 126 and 626, 226 and 526 and 326 and 426 are 180° out of phase with respect to one another.

[0059] Referring now more particularly to Figure 2, there is shown therein a first modification for the conventional engine 10 in accordance with the principles of the present invention. The modification shown in Figure 2 is a new or replacement camshaft 50 to replace the conventional camshaft 32. The camshaft 50 is constructed to allow the two adjacent central inner piston and cylinder assemblies (i.e., the third and fourth) to operate in phase rather than 180° out of phase. Compared with a conventional camshaft 32, new camshaft 50 has cam lobes 442 and 444 positioned on the camshaft in angular alignment with cam lobes 342 and 344, as shown, rather than being 180° out of alignment therewith. This alignment of cam lobes 342, 344 and 442, 444 allows pistons 326 and 426 to complete their combustion strokes simultaneously so that selectively (1) both cylinders 328 and 428 will receive an injection of diesel fuel appropriate to fire both during the following simultaneous power drive strokes thereof or (2) alternatively only one cylinder 328 or 428 will receive an injection of diesel fuel in an appropriate amount for one of cylinders 328 and 428 to fire. Alternatively when only one cylinder 328 or 428 is fired, the increased pressure conditions resulting from the one fire is made
to communicate to the other cylinder. When, the pressure generated by fuel injected and ignited in cylinder 326 or 426 is communicated to the other of cylinders 328 or 426 receiving no fuel, the pressure drives both pistons 326 and 426 simultaneously. This generates power from both pistons 326 and 926 with one less injection charge. The above incorporated '769 patent may be referred to for additional details.

[0060] Figure 3 shows a modification used to accomplish the communication. As shown, the modification is simply to remove from the seal engaging surface of the frame 12 extending between cylinders 328 and 428 sufficient materials, as by grinding or other means, to form a passage 52 of a minimum size suitable to enable the communication to take place. Alternatively, a portion of the seal extending from cylinder 328 to cylinder 428 can be removed. Of course, in an engine of original manufacture (i.e., not a retrofit modification), the passage 52 may be formed by any approach, such as in casting, and removal of material is not needed.

[0061] Figure 4 shows the modifications sufficient to enable the mode selection to take place. Figure 4 shows one computerized fuel injecting and firing system, generally indicated at 54, for an in line six cylinder engine operating as a diesel four stroke engine. The system 54 includes a fuel injector 156 through 656 for each cylinder 128-628. Each injector 156-656 has a source of fuel under pressure communicating therewith, which, as shown, includes a power driven pump 58 capable of delivering fuel from a fuel tank 60 to a manifold 62 having a maximum pressure condition determined by a pressure relief valve 64 in a line between the manifold 62 and tank 60. The manifold 62 communicates the fuel pressure therein directly to the six injectors 156-656.

[0062] Each injector 156-656 has a solenoid operated valve 166-666 respectively formed therein for controlling the flow of fuel under pressure communicated therewith outwardly of a
nozzle end thereof. In the case of diesel operation, the nozzle end of each injector 156-656 is positioned to inject fuel directly into the combustion chamber of the associated cylinder 128-628. The solenoid operated valves 166-666 are controlled by electrical signals coming from a computer 68 which signals determine the time and amount of fuel injected by the associated injector 166-666.

[0063] Referring again to Figure 2, there is shown therein a preferred further camshaft modification embodied in the new camshaft 50 enabling a preferred, more balanced application of the forces created by the firing events in the cylinders 28 to the crankshaft 32. Specifically, the further modification is to change the movement of inlet and outlet valves 38 and 40 associated with cylinders 128 and 628 and the inlet and outlet valves 38 and 40 associated with cylinders 228 and 528 so that the cycles in cylinders 128/628 and 228/528 are in phase rather than being 180° out of phase. Compared with camshaft 32, new camshaft 50, preferably in addition to the angular alignment of cam lobes 342-344 with cam lobes 442-444, has cam lobes 642 and 644 angularly aligned with cam lobes 142 and 144 and cam lobes 242 and 244 angularly aligned with cam lobes 542 and 544. With these further modifications the firing stroke event is initiated in two cylinders simultaneously every 240° of rotation of the crankshaft 82.

[0064] As best shown in Figure 4, preferably, the fuel injecting and firing system 48 includes modifications which allow a selected third mode of operation wherein an alternating one of injectors 156 and 656 and an alternating one of injectors 256 and 556 is controlled to inject zero amount of fuel. That is, injectors 256 and 556 are being used in a known "skipping" style where no fuel or pressure from another source is being introduced into the associated cylinder 226 and 526. This third mode where cylinders 328 and 428 are also operating alternately with one injector injecting zero amount of fuel but receiving pressure from the other
cylinder receiving fuel, can be identified as a maximum or increased fuel saving mode (50% saving) whereas the previously identified fuel saving mode can be identified as an normal intermediate fuel saving mode (16-2/3%). The increased fuel saving mode is advantageous because half the cylinders are receiving fuel (since one of each pair 128/628, 228/528, and 328/428 is being omitted fuel), but four cylinders apply force due to the communication between cylinders 328/428.

[0065] In the system 54 shown in Figure 4 the selection of which of the three modes is to operate is left up to the driver of the vehicle. Figure 4 illustrates a box 70 having three buttons 72, 74 and 76 which when pushed provide three different signals to the computer 48.

[0066] Preferably, the signal which activates the computer 68 to emit signals commensurate with the maximum power mode is made by pressing a manual control button 72 although it could be under the control of a sensor that activates when the vehicle is going up a steep grade or the gas pedal has been floor-boarded. Preferably, the signal which activates the computer to emit signals commensurate with the increased fuel savings mode is the separate manual control button 74 or other input although it could be activated when the cruise control button or other input is turned on. It is noted that cylinders 328 and 428 will both fire in the maximum power mode, while only one will fire in the maximum fuel saving mode. And, when neither maximum mode is operating, the cylinders 328 and 428 will fire one alternately (the normal intermediate fuel saving mode).

[0067] Consequently, the preferred operation of the fuel injecting and firing system 48 is to select the intermediate mode at all times (16-2/3% less fuel than max power), as by a third manual control button 76 or other input except when added power is desired or needed (max
power mode) or when the cruise control button is turned on (max fuel saving mode 50% less fuel than max power).

When the computer 48 receives a signal as a result of pushing button 72, the computer 48 is programmed to activate all of the injectors 56 at the appropriate time. When the computer 48 receives a signal as a result of pushing button 74, the computer in proper timed relation activates (1) alternately one of injectors 356 and 456 (2) alternately one of injectors 156 and 656 and (3) alternately one of injectors 256 and 556. When the computer 48 receives a signal as a result of pushing button 76, the computer 48 is programmed to activate in properly timed relation alternately one of injectors 356 and 456 and both injectors 156 and 656 and both injectors 256 and 558.

The modifications of apparatus and method in accordance with the principles of the present inventions are the same whether the engine is diesel compression ignited or spark plug ignited. Figure 5 illustrates the differences in spark ignition as distinguished from the compression ignition described above. In the case of a spark ignited engine the nozzle ends of the injectors 56 are directed along with a variable air supply into the cylinders through the open inlet valve during the intake stroke. While a spark plug is provided in each combustion chamber and a distributor assembly is also provided it is preferable to modify the distributor system so that when both cylinders 328 and 428 are to be fired together only one is fired and the fire in that one is used to fire the other through the communicating passage.

Figures 6 and 7 illustrate a head gasket 84 constructed in accordance with the principles of the present invention which is preferably used as modifying apparatus to provide the passage 52 in lieu of the construction shown in Figure 3 and described above. As shown, the gasket 84 is formed of solid material, such as a suitable metal. A laminated structure is also
contemplated in which interior surfaces are covered by a lower sheet being bent upwardly and over the interior edges. The gasket 84 includes openings 186, 286, 286, 486, 586 and 686, which register with the upper ends of the six cylinders 28 repetitively. The passage 52 is provided in the gasket 84 by removing the material of the gasket 84 between the openings 386 and 486. The gasket 84, when used, simply replaces the head gasket of the conventional engine being modified.

[0071] Figure 8 illustrates modifying apparatus in the form of a computer module, generally indicated at 88, which can be used with existing engines having a computer controlled injection system capable of being controlled in response to electrical signals coming from the computer.

[0072] As shown, the module 88 includes a module frame 89 providing three buttons 90, 92 and 94. The buttons 90, 92 and 94 are connected to provide three different signals to a computer 96 with leads 97 extending therefrom capable of energizing the computer 96 from the vehicle battery. Connected to the computer 96 is a programmed chip 98 having leads (99) which extend to the six injectors 56.

[0073] The chip 98 is programmed to send signals to the injectors 56 in the manner previously described depending upon which of the three buttons, 90, 92 or 94, are manually activated.

[0074] The gasket 84, the computer module 88 and camshaft shown in Figure 2 constitute the preferred apparatus for modifying the newer models of existing in line six cylinder engines whether compression ignited or spark ignited. The method of modifying the existing engines is simplified in that it becomes necessary merely to replace the existing camshaft and head gasket and to revise the leads of the module to the vehicle battery and the six injectors.
Figures 9-16 show another embodiment in the non-limiting form of an inverted V-eight cylinder internal combustion engine, generally indicated at 10', which embodies the principles of the present invention. The engine 10' includes a frame structure, generally indicated at 12', which includes a main block section 14', a lower pan section 16' and an upper head assembly 18'. The lower pan section 16' serves as a support for the main block section 14'. As shown in Figures 9 and 10, the pan section 16' includes a bottom wall 20' having spaced side walls 22' extending upwardly therefrom and spaced end walls 24' extending upwardly from the bottom wall 20' between the ends of the side walls 22'. As best shown in Figure 10, extending between the side walls 22', inwardly of the end walls 24' are four equally spaced parallel inner walls 26'.

The end walls 24' and parallel inner walls 26' of the lower pan section 16' have upwardly facing planar surfaces interrupted by longitudinally aligned spaced pairs of upwardly facing 180° arcuate bearing engaging surfaces 30'.

The main block section 14' includes a lower portion defined by exteriorly flanged upwardly and inwardly sloping side walls 32' vertically aligned with the side walls 22', upright end walls 34' vertically aligned with the end walls 24' of the lower pan section 16' and four interior walls 36' vertically aligned with the four inner walls 26' of the lower pan sections. The vertically aligned walls 32', 34' and 36' of the block section 14' have downwardly facing surfaces which engage the upwardly facing wall surface of pan section 16'. Suitable fasteners 38' extending through the flanges of the exteriorly flanged upright walls 32' of the lower portion of the block section 14' and into the aligned side walls 24' of the lower pan section 16 serve to fixedly the block section 14' on the lower pan section 16'.
The lower portion of the main block section 14' does not have downwardly facing surfaces which engage the 180° arcuate surfaces 30' of the lower pan section 16', instead the lower portion of the block section 14' has downwardly facing 180° arcuate bearing engaging surfaces 38 in alignment with the arcuate surfaces 30' of the lower pan section 16'.

The main block section 14' also includes a main upper portion configured to receive therein two banks of piston and cylinder assemblies, generally indicated at 40' which diverge downwardly from the top of the block section 14'. Each of the two banks include four cylinders 42'. The lower end of each cylinder 42' seats in surfaces 44' provided in the block section 14' to engage the lower end surface and exterior marginal lower end surface of each cylinder 42'.

The upper extremities of the cylinders 42' are fixedly engaged within openings formed in a sheet metal plate 46'. The plate 46' is essentially rectangular in shape bent along its longitudinal center line to form two longitudinally elongated areas having upper surfaces forming a shallow angle therebetween.

As best shown in Figure 9, each piston and cylinder assembly 40' also includes a piston 48' mounted within an associated cylinder 42' for reciprocating axial movement in sealing engagement with the interior surface thereof as by piston rings 50'. Each piston 48' is pivotally connected, as by wrist pins 52', with the upper end of a piston rod 54'. The lower end of each piston rod 54' is pivotally connected to a shaft bright portion of a U-shaped crank section 56' of a crankshaft, generally indicated at 58'. Extending in vertical alignment with the legs of each U-shaped crank section 56' are counter-weight sections 60'. Since the piston and cylinder assemblies 40 diverge downwardly in two banks, there are two duplicate crank shafts 58', one for each bank.
Each crankshaft 58' includes axially aligned cylindrical bearing sections 62' at each end thereof and between adjacent crank sections 56'. The cylindrical bearing sections 62' have exterior surfaces thereof engaged with the interior surfaces of special separable bearings 64'. The exterior surfaces of which are engaged by corresponding mating 180° arcuate surfaces 30' and 38'. In this way, the two horizontally spaced crankshafts 58' are mounted for rotational movement on the frame structure 12' about parallel horizontally extending axes.

Referring now more particularly to Figures 10 and 13, it can be seen that the cylindrical section 62' at the right end of each crankshaft 58' extends beyond the associated end walls 24' and 32' and has a spaced extremity supported on a wall extension 66'. Between the end walls 24' and 32' and the wall extension 66', each cylindrical end section 62' has mounted thereon a gear 68' and spacer 70'.

As best shown in Figures 12 and 14, a main output stub shaft 72' has an inner end thereof suitably journed between the end walls 24' and 32' in spaced relation between the crankshafts 58' and extends outwardly beyond the wall extension 66'. Mounted in vertical alignment with the wall extension 66' is an end cap wall extension 74' which, when fixed to the wall extension 66', provides with the wall extension 66' bearing support for the outwardly extending end of the stub shaft 72' as well as the associated extremities of the two crankshafts 58'.

Fixed on the stub shaft 72' in meshing relation between the two gears 68' on the crankshaft 58' is a third gear 76' enabling the stub shaft 72' to act as a main rotational output for the engine 10' when the crankshafts 58' are operated by the operation of the two banks of piston and cylinder assemblies 40'.
As best shown in Figure 13, the stub shaft 72', which rotates at the same speed as the crankshafts 58', is used to drive a cam shaft 78' at a speed one half the common speed of the stub shaft 72' and crankshafts 58'. A sprocket and chain assembly may be used for this purpose, however, as shown in the assembly employed is a timing gear and pulley assembly including a small timing gear 80' fixed to the stub shaft 72', a double size timing gear 82' fixed on the camshaft 78' and an endless timing belt 84' trained about the timing gears 80' and 82'. The entire timing belt assembly 80', 82' and 84' is encased in a flanged timing belt guard 86' fixed to the associated end wall 32'.

Referring now more particularly to Figure 11, the camshaft 78 is journaled in and forms a part of the head assembly 18'. The head assembly 18 includes a lower slightly angulated flat slab 88' having a lower surface which is complementary to the upper surface of the angulated plate 46'.

In accordance with the principles of the patented invention, an angulated gasket, generally indicated at 90', is fixed by suitable fasteners between the upper angulated surface of the plate 46 and the lower angulated surface of the slab 88'.

Referring now to Figure 14, the gasket 90' is in angulated plate form and includes a series of four paired openings 92'. Extending between each pair of openings 92' is a passage forming cut out 94', when the gasket 90' is in final fixed relation between the plate 46' and slab 88', the four paired openings 92' communicate respectively with the upper ends of the four paired cylinders 42' so that the cut outs 94 provide a passage between each pair of paired cylinders 42. That is, instead of the passage communicating a pair of adjacent cylinders 42 within the same bank, the passage herein communicates a pair of closely spaced cylinders (combustion chamber) from the two different banks.
Again referring to Figures 9 and 11, the slab 88', which closes the upper end of the cylinders 42', has formed therein an inlet opening 96' leading into a combustion chamber portion in the upper end of each cylinder 42' and a spaced outlet opening 98' leading from the combustion chamber in the upper end of each cylinder 42'.

Extending over each outlet opening 98' from the upper surface of the slab 88' is a tubular structure 100' along the upper surface of slab 88' which leads inwardly to a central longitudinally extending tubular structure 102' defining an exhaust manifold for the engine.

Similarly, each inlet opening 96' has a tubular structure 104' disposed thereover on the upper surface of the slab 88'. The tubular structures 104' in one bank of cylinders extend away from the tubular structures 104' in the other bank. The outward ends of each bank of tubular structures 104' communicate with a manifold defining longitudinally extending tubular structure 106'.

As best shown in Figure 11, an exhaust pipe 108' is connected to an open end of the exhaust manifold structure 102' and extends beyond the left end of the head assembly 18'. The two parallel inlet manifold structures 106' have one end correspondingly open to which are connected elbow pipes 110' leading to a centrally located inlet air filter assembly 112'.

Each inlet opening defines a downwardly facing frustoconical valve seat. An inlet valve 114' is mounted for movement with respect to each seat between an open position spaced from the seat and a closed position engaging the seat. Each inlet valve 114' includes a valve stem 116' extending upwardly therefrom through the associated inlet tubular structure 100. Surrounding the outwardly extending end of each inlet valve stem 116' between a washer fixed on the outward extremity of the valve stem 116' and the exterior of the associated inlet tubular
structure 100' is a coil spring 118' which serves to spring bias the associated inlet valve 114' into its closed position.

In a similar manner, an outlet valve 120' with valve stem 122' and surrounding coil spring 124' is spring bias into a closed position with respect to each outlet opening 98'.

The inlet valves 114' and outlet valves 120' are moved out of their spring biased closed positions into their open positions by the operation of the camshaft 78'.

As best shown in Figure 11, the camshaft 78' is rotatably supported in the head assembly 18' by a plurality of longitudinally spaced split supports 126' which also serve to fixedly support two rocker shafts 128' in a parallel relation to the camshaft 178' on opposite sides thereof.

The four inlet valves 114' in each bank are moved into their open positions by a corresponding four inlet rocker arms 130' pivotally mounted on an associated rocker shaft 128' and the four outlet valves in each bank are moved into their open positions by four outlet rocker arms 132' pivotally mounted on an associated rocker shaft 128'. To enable side by side rocker arms on each shaft to actuate longitudinally aligned valves of a valve engaging end of one of the adjacent rockers includes a longitudinally bent end.

The rocker arms 130' and 132' are mounted on their associated rocker shaft 128' so that the pivotal axis of each extends through a central portion thereof so that opposite free ends thereof can be engaged with the camshaft 78' and the washer fixed to the upper end of an associated valve 114' or 120'.

Each inlet valve 114' is moved into its open position at an appropriate time in the normal four stroke cycle occurring in the associated cylinder when the associated inlet rocker arm 130' is engaged by an inlet cam lobe 134' on the camshaft 78 and each outlet valve 120' is
moved into its open position at an appropriate time in the normal four stroke cycle occurring when the associated outlet rocker arm 132' is engaged by an outlet cam lobe 136 on the camshaft 78'.

[0101] The head assembly 18' including the air inlet system up to the elbow pipes 110', the exhaust system up to the exhaust pipe 108', the camshaft 78' and mount 126' up to the end on which timing gear 82' is mounted and all of the rocker arms 130' and 132', the rocker shafts 128', valve stents 116' and 122' and valve springs 118' and 124' are enclosed within a cover member 137' having its lower open end provided with an exterior peripheral mounting flange through which the cover member 137' is bolted to the upper periphery of the slab 88'.

[0102] Referring now more particularly to Figure 15; there is shown therein a chart showing for each of four consecutive 180° rotational movements of the crankshafts 58', the direction of piston movement, either up-U or down-D, for each piston and cylinder assembly 40' and the cycle event - CE (F=fire, E=exhaust, I=inlet, C=compression) occurring in each piston and cycling assembly 40'.

[0103] The chart also includes for each piston and cylinder assembly 40', an illustrations of the configuration of the camshaft. The illustrations show the relative circumferential position on the camshaft of the exhaust cam lobes in cross section and the related inlet cam lobes in elevation to indicate the opening of the exhaust valves during the exhaust event and the opening of the inlet valves during the inlet event without regard to their exact beginning or end which is in accordance with accepted practice.

[0104] Each communicated pair of piston and cylinder assemblies 40' is fired together for one 180° turn during each of four consecutive 180° turns of the crankshafts 58' and the
firings of a different pair take place in each of the four consecutive 180° turns. As shown, the
order of firing is 1-3-4-2.

[0105] Referring now more particularly to Figure 16, there is shown therein the manner
in which fuel injection skipping is applied to each double firing event of each pair of piston and
cylinder assemblies 40' in accordance with the invention.

[0106] Figure 16 illustrates an injector 138' for each piston and cylinder assembly 40' in
their relative positions, each injector 138' is preferably of the type having a cylindrical body with
a conical ejecting nozzle which is opened and closed by an electrically actuated solenoid valve.
As shown each injector body has angulated exterior circular mounting flange which fits within a
mating recess in the upper surface of the slab 88'. A nozzle recess extends from each mating
recess through the slab 88. In this way, the nozzle of each injector 138' is positioned to inject
fuel therethrough into the associated combustion chamber in the direction of a swirl chamber
142' formed in the upper surface of the associated piston 48 when in its top dead center position.

[0107] Injecting fuel into a swirl chamber 142' in the piston 48' is characteristic of diesel
operation. Wherein the compression ratio of each piston and assembly 40 is such that at the end
of the compression event, the air in the combustion chamber is at a temperature and pressure to
cause auto ignition when the fuel is injected therein.

[0108] While the engine 10' is shown as being diesel operate with compression ignition,
the engine could be made to operate on a conventional spark ignition basis with a lesser
compression ratio and a positioning of the fuel injectors with mating air injectors to direct an
appropriate air fuel mixture into the combustion chamber through the open inlet valve during the
inlet stroke.
It will also be understood that while the engine is disclosed as inverted V-8, it could be made into an inverted V-6 by appropriate changing the crank portions of the crankshafts from the 180° shown to 120°. Other numbers of pistons/cylinders are possible.

Referring now back to Figure 16 of the drawings, the cylindrical end of each injector 138 opposite of its nozzle is connected to a fuel containing manifold 144'. The fuel in the manifold 144' is maintained at a predetermined pressure by the output of a pump 146' drawing fuel from a supply 148' which is connected to manifold through a pressure relief valve 150'.

The opening and closing of the solenoid valves determines the amount of fuel injected by each of the injectors 138'. The solenoids are normal spring biased into a closed position and opened when the solenoid valves are electrically energized.

The further descriptions of the skipping control assume that the engine is installed as the motive power of a vehicle. The solenoid actuating electrical energy comes from the battery of the vehicle shown at 152' in Figure 16. As shown, the battery 152' is connected to a computer 154'. The computer 154' is programmed either by software or circuit logic to receive one of three activating input signals. The three input signals come from either a three button manual switch assembly 156' or a number of automatic vehicle condition sensors or both. The sensors, utilized, for example, can be a sensor 160' which senses when the vehicle is on an upward incline or a downward incline, or a sensor which senses the actuation of the accelerator pedal or the actuation of the brake pedal.

In any event, preferably there are at least three input signals that achieve three different skipping patterns. A first skipping pattern is simply no skipping in which case the computer 154' is programmed to activate all of the solenoid valves at the appropriate time. This
constitutes a full power mode which is desirable when, for example, the vehicle is going up a hill. This full power mode can be input into the computer 154' either by manually pushing button 158' of the three button assembly 156' or by the actuation of a level sensor 160'.

A second skipping pattern is one which can be referred to as a normal operating mode. The input to the computer is by manually pushing button 162' of the three button assembly 156' or by a sensor 164' which senses the turning on of the engine. When the computer 156' receives the normal mode input signal, the computer, 156' is programmed to alternately skip during consecutive 2 full rotations of the crankshafts between the injectors 138 of one bank of piston and cylinders 40' and then the injectors 138' of the piston and cylinder assemblies 40' of the other bank. In short, normal mode operation involves the saving of one half of the fuel used in the full power mode. However, because of the double expansion which takes place because of the passages 94' enabling the combustion comparison in one cylinder of a communicated pair to drive the piston in the other cylinder of the pair, more than one half power is maintained as discussed in the '769 patent. Alternatively, not all the injectors of one bank are skipped simultaneously. In some embodiments, some of the skipped (i.e., those not receiving a fuel injection) are in one bank, while some are in the other bank, this better balances out the combustion locations within the engine frame structure.

A third skipping pattern can be termed a coasting mode. The input for this mode can come from, for example, manually pushing button 166 of the three button assembly 156 or from the actuation of sensor 168 sensing release of the accelerator pedal. When the computer receives this signal two of the four pairs of piston and cylinder assemblies (e.g. 1 and 2) are alternately skipped as in the normal mode while the other two (e.g. 3 and 4) are both skipped entirely, in this mode, there is a double fire every 360° of the crankshaft turning and a fuel saving
of three quarters of the full power mode. Again, the power loss should be less than three quarters of full power.

[01 16] The description above refers to alternating the one cylinder receiving the injection when two cylinders are operatively receiving an injection and a skipped injection. This alternating method of proceeding is preferred because it achieves more uniform heat balance and more even part wear between the two assemblies involved. The alternation preferably is programmed to take place every predetermined number of piston cycles. The predetermined number of cycles can be any number. A preferred range of number of cycles is 1-10 with five being a preferred number.

[01 17] It will be understood that the engine may be provided with a conventional lubricating and cooling system.

[01 18] It should be appreciated that the foregoing embodiment(s) have been illustrated solely for the purposes of illustrating the structural and functional advantages of the present invention and is not intended to be limiting. To the contrary, the present invention includes all modifications, alterations, substitutions and equivalents within the spirit and scope of the appended claims.

[01 19] In addition, to the in-line six engine, the invert v-8 and comparable, v-6, a conventional v-8 can be converted in a similar manner as the in-line six so long as it is of the in-line axis construction racing rather than the more usual cross-line axis construction. To convert the in-line axis v-8, (1) a camshaft for each bank is provided capable of causing the inner or adjacent two of each middle piston and cylinder assemblies bank to have their cycles phase with one another and of causing successive cycles of the outer two piston and cylinder assemblies of
each bank to be in phase with one another but 180° out of phase with respect to the two inner assemblies.

[0120] (2) A replacement head gasket for each head gasket of the existing each gasket, providing passages between the combustion chambers of the adjacent inner piston and cylinder assemblies and

[0121] (3) a computer unit with a reprogrammed chip capable of causing two piston power drive strokes every 180°. Preferably first the pistons of two outer assemblies of a first bank, then the pistons of two inner assemblies of the second bank; then the two adjacent inner assemblies of the first bank; and finally, the two outer assemblies of the second bank.

[0122] It is within the contemplation of the present invention to provide apparatus for reconditioning an existing inverted v-8 or v-6 constructed as indicated above simply by providing (1) a replacement camshaft for each existing camshaft constructed as previously described, (2) a replacement gasket for each existing gasket constructed as previously described and (3) a computer unit with a reprogrammed chip constructed as previously described.

[0123] It is within the contemplation of the invention to operate the engines thus far described in ways other than those already indicated. For example, the inverted V-8 engine could be operated in the coasting mode all of the time with varying speed being obtained solely by the amount of fuel injected in the four assemblies receiving the fuel. Similarly, the in line six engine could be operated in its coasting mode at all times with speed being obtained solely by the amount of fuel injected, this alternative mode of operation has the advantage of a smoother operation as compared with those modes previously described.

[0124] The controller is constructed and arranged to control the amount of fuel injected during an injection in the usual fashion utilized in vehicular mounts. The determination of the
amount of fuel injected is originated by the operator of the vehicle, typically, while actuating the accelerator pedal. The position in which the pedal is pushed transmits variable electrical signals to the controller variable which processes the signals to cause a variable corresponding amount of fuel to be injected.
WHAT IS CLAIMED:

1. An internal combustion engine comprising:

   a frame structure;

   a plurality of pairs of piston and cylinder assemblies carried by said frame structure,

   each of said pairs of piston and cylinder assemblies including (1) cylinders having portions thereof defining combustion chambers, (2) crankshaft connected pistons mounted in the cylinders of each pair of assemblies for movement between limiting positions therein through repetitive cycles each including simultaneous compression strokes and immediately following simultaneous power drive strokes, (3) fuel injectors for each cylinder constructed and arranged to be controlled to undergo during each piston cycle either (a) an injection wherein fuel is injected thereby into the associated cylinder or (b) a skipped injection wherein no fuel is injected thereby into the associated cylinder,

   a controller for said injectors constructed and arranged to control said injectors so that the engine can be operated selectively in any one of the following modes (1) a first mode in which the injector associated with each cylinder is controlled to undergo an injection so that the pistons of each pair of assemblies undergo simultaneous internally fired power drive strokes and (2) a second mode wherein the injectors associated with one cylinder of each pair of assemblies are controlled to undergo an injection so that the pistons of said one cylinders undergo internally fired power drive strokes while the injectors of the other cylinder of each pair of assemblies are controlled to undergo a skipped injection so that the pistons of said other cylinders do not undergo internally fired power drive strokes,

   at least one pair of assemblies of said plurality of assemblies have the combustion chambers of the cylinders thereof disposed in closely spaced relation and intercommunicated by
a passage so that during said second mode when the injector of the other cylinder of said at least one pair undergoes a skipped injection, the other cylinder can share the increased pressure conditions in the one cylinder of said at least one pair undergoing an internally fired power drive stroke resulting in the piston associated with said other cylinder undergoing a shared power drive stroke simultaneously therewith.

2. The internal combustion engine of claim 1, wherein the injectors of each pair of assemblies which undergo injection and the injectors of each pair of assemblies which undergo skipped injections are alternated during the second mode wherein the alternation takes place each predetermined number of piston cycles.

3. The internal combustion engine of claim 2, wherein the injectors of each pair of assemblies which undergo injection and the injectors of each pair of assemblies which undergo skipped injections are alternated during the second mode wherein the alternation takes place each predetermined number of piston cycles.

4. The internal combustion engine of claim 3, wherein the number of piston cycles is a number between 1 and 10, the injectors of each pair of assemblies which undergo injection and the injectors of each pair of assemblies which undergo skipped injections are alternated during the second mode wherein the alternation takes place each predetermined number of piston cycles.
5. The internal combustion engine of claim 1, wherein the plurality of pairs of assemblies includes at least three pairs of assemblies which are mounted in said frame structure in a line formation including an inner pair of assemblies constituting said at least one pair of assemblies, an intermediate pair of assemblies and an outer pair of assemblies.

6. The internal combustion engine of claim 5, wherein said intermediate and outer pairs of piston and cylinder assemblies are configured so that the combustion chambers of the cylinders thereof are spaced apart in non-communicating relation so that when the injectors thereof are controlled by said controller to undergo an injection and a skipped injection, respectively, the associated pistons thereof undergo simultaneous internally fired and skipped power drive strokes respectively.

7. The internal combustion engine of claim 6, wherein said controller is constructed and arranged to control the injectors of said assemblies so that the engine can be operated in other modes wherein the injectors of said at least one pair of assemblies are controlled so that the pistons thereof undergo simultaneous internally fired and shared power drive strokes and the injectors of the remaining pairs are controlled so that the pistons thereof selectively undergo either simultaneous internally fired power drive strokes or simultaneous internally fired and skipped power drive strokes.

8. The internal combustion engine of claim 1, wherein the plurality of pairs of assemblies include at least three pairs of assemblies said three pairs of assemblies are being mounted in said frame structure in an inverted V configuration with the combustion chambers of
the cylinders thereof in closely spaced relation and intercommunicated by a passage therebetween so that during said second mode the pistons of each pair of assemblies undergo simultaneous internally fired and shared power drive strokes.

9. The internal combustion engine of claim 8, wherein said controller is constructed and arranged to control the injectors of said assemblies so that the engine can operate in other modes wherein selectively (1) the injectors of said at least one pair of assemblies are controlled so that the pistons of said at least one pair of assemblies undergo simultaneous internally fired and shared power drive strokes and the injectors of the remaining pairs of assemblies are controlled so that the pistons thereof undergo simultaneous internally fired power drives strokes, or (2) the injectors of all of said pairs of assemblies except for different one pair are controlled from said at least one pair so that the pistons thereof undergo simultaneous internally fired and shared power drive strokes and the piston of said different one of said pairs are controlled so that the pistons thereof undergo simultaneous internally fired power drive strokes.

10. An apparatus for converting an existing in-line six cylinder internal combustion engine having six in line piston and cylinder assemblies each including a cylinder having a crankshaft connected piston mounted therein for movement through successive cycles including a compression stroke and an immediate following power drive stroke into an in-line six cylinder engine having (1) a full power mode with no fuel skipping, (2) an intermediate fuel saving mode skipping fuel in one of a pair of inner cylinders having combustion chambers communicated by a passage, and (3) an increased fuel saving mode wherein, in addition to skipping fuel in one of the
inner pair of cylinders, one of each of the remaining outer and intermediate pairs of cylinders are fuel skipped, said apparatus comprising:

a conversion camshaft to replace any existing camshaft of the existing engine,

a conversion head gasket to replace any existing head gasket of the existing engine, and

a computer module to replace any existing computer fuel control of the existing engine,

constructed and arranged so that when replaced together with the placement of the conversion camshaft and conversion head gasket said conversion is achieved.

11. An apparatus of claim 10, wherein said conversion camshaft includes an inner pair of axially spaced cam surfaces associated with an inner pair of said six cylinders, an outer pair of axially spaced cam surfaces associated with outer pair of said six cylinders, and an intermediate pair of axially spaced cam surfaces associated with an intermediate pair of said six cylinders, the axially spaced cam surfaces of each pair being of the same configuration and the same angular position on said conversion camshaft.

12. An apparatus as defined in claim 11 wherein said conversion head gasket includes a pair of spaced openings positioned so that after replacement said pair of spaced openings communicate with said inner pair of cylinders, said passage extending in said gasket between said pair of spaced openings.

13. An apparatus as defined in claim 12 wherein said computer module includes a controller connected to control fuel injectors for said assemblies each of which is capable of being controlled to undergo either (1) an injection wherein fuel is injected into the associated
cylinder thereby to establish the fuel-air mixture therein ignited to cause the associated piston to undergo an internally fired power drive stroke or (2) a skipped injection wherein no fuel is injected thereby so that the piston of the associate cylinder does not undergo an internally fired power drive stroke, said computer when replaced as aforesaid being constructed and arranged to selectively control said injectors to select one of the modes (1) (2) or (3) in response to select input signals.

14. An apparatus as defined in claim 13, wherein said select input signals are provided by a manually operated three button switch forming a part of said computer module

15. An apparatus as defined in claim 10, wherein said conversion head gasket includes a pair of spaced openings positioned so that after replacement said pair of spaced openings communicate with said inner pair of cylinders, said passage extending in said gasket between said pair of spaced openings.

16. An apparatus as defined in claim 15, wherein said computer module includes a controller connected to control fuel injectors for said assemblies each of which is capable of being controlled to undergo either (1) an injection wherein fuel is injected into the associated cylinder thereby to establish the fuel-air mixture therein ignited to cause the associated piston to undergo an internally fired power drive stroke or (2) a skipped injection wherein no fuel is injected thereby so that the piston of the associate cylinder does not undergo an internally fired power drive stroke, said computer when replaced as aforesaid being constructed and arranged to
selectively control said injectors to select one of the modes (1) (2) or (3) in response to select input signals.

17. An apparatus as defined in claim 16, wherein said select input signals are provided by a manually operated three button switch forming a part of said computer module

18. An apparatus as defined in claim 10, wherein said computer module includes a controller connected to control fuel injectors for said assemblies each of which is capable of being controlled to undergo either (1) an injection wherein fuel is injected into the associated cylinder thereby to establish the fuel-air mixture therein ignited to cause the associated piston to undergo an internally fired power drive stroke or (2) a skipped injection wherein no fuel is injected thereby so that the piston of the associate cylinder does not undergo an internally fired power drive stroke, said computer when replaced as aforesaid being constructed and arranged to selectively control said injectors to select one of the modes (1) (2) or (3) in response to select input signals.

19. An apparatus as defined in claim 18, wherein said select input signals are provided by a manually operated three button switch forming a part of said computer module

20. An apparatus as defined in claim 10, wherein the compression stroke of each assembly creates air under an auto ignition compression pressure and wherein the mixture accomplished and is ignited by injecting fuel into the air under auto-ignition pressure within the associated combustion chamber.
21. An apparatus as defined in claim 10, wherein the mixture of air and fuel is establish in the combustion chamber of each assembly by injecting fuel and air into the associate cylinder during an intake preceding the compression stroke and the mixture is ignited by the energization of a spark plug in communication with the mixture.

22. A method for converting an existing in-line six cylinder internal combustion engine having six in line piston and cylinder assemblies each including a cylinder having a crankshaft connected piston mounted therein for movement through successive cycles including a compression stroke and an immediate following power drive stroke into an in-line six cylinder engine having (1) a full power mode with no fuel skipping, (2) an intermediate fuel saving mode skipping fuel in one of a pair of inner cylinders having combustion chambers communicated by a passage, and (3) an increased fuel saving mode wherein, in addition to skipping fuel in one of the inner pair of cylinders, one of each of the remaining outer and intermediate pairs of cylinders are alternately fuel skipped, said method comprising:

   replacing the camshaft of the existing engine with a new conversion camshaft constructed and arranged so that the cycles of piston movement of two inner assemblies are in phase,

   providing a communicating passage between the combustion chambers of the two inner assemblies, and

   modifying the fuel injecting and firing system so that when the cycles of piston movements of the two inner assemblies are in phase and the communicating passage is provided between the combustion chambers thereof, the modified fuel injecting and firing system will
cause a selected one of modes (1) (2) or (3) to be in operation and response to predetermined input signals to said system.

23. A method as defined in claim 22, wherein the compression stroke of each assembly creates air under an auto ignition compression pressure and wherein the mixture accomplished and is ignited by injecting fuel into the air under auto-ignition pressure within the associated combustion chamber.

24. A method as defined in claim 22, wherein the mixture of air and fuel is establish in the combustion chamber of each assembly by injecting fuel and air into the associate cylinder during an intake preceding the compression stroke and the mixture is ignited by the energization of a spark plug in communication with the mixture.

25. A method as defined in claim 22, wherein the new conversion camshaft controls is configured to cause the piston cycles of the two outer and two intermediate assemblies to be in phase and the modified fuel injecting and firing system is configured to cause the pistons of said two intermediate and two outer assemblies to undergo simultaneous internally fired and skipped power drive strikes during mode (3).

26. An internal combustion engine comprising:

   a frame structure, at least three pairs of piston and cylinder assemblies mounted in said frame structure, each said pair of piston and cylinder assemblies including:

   (1) a pair of cylinders each having a combustion chamber contained therein,
(2) Crankshaft connected pistons mounted in said pair of cylinders for simultaneous movements toward and away from the combustion chambers thereof through successive cycles each including simultaneous compression strokes immediately followed by simultaneous power drive strokes, and

(3) A fuel injector for each cylinder positioned to inject fuel onto the associated cylinder when controlled to do so,

a controller for said injectors constructed and arranged to selectively control each injector to undergo during each piston cycle either (1) an injection wherein fuel is injected thereby into the associated cylinder so that each piston associated therewith under goes a power drive stoke which is internally fired or (2) a skipped injection wherein no fuel is injected thereby into the associated cylinder so that each piston associated therewith undergoes a power drive stroke with is not internally fired,

said controller being constructed and arranged to selectively control said injectors so that the engine can be selectively made to operate either in (1) a first mode wherein the pistons in each pair of assemblies undergo simultaneous power drive strokes, which are internally fired or (2) a second mode wherein the pistons of each pair of assemblies undergo simultaneous power drive strokes one of which is internally fired and the other, which is not internally fired,

at least one of said pairs of piston and cylinder assemblies having the combustion chambers thereof disposed in closely spaced relation and intercommunicated by a passage extending there between so that during said second mode the pistons of said at least one pair of assemblies undergo simultaneous power drive strokes, one of which is internally fired and the other of which is a shared power drive stroke wherein the increased pressure conditions of the internally fired power drive stroke are shared by means of said passage.
27. An internal combustion engine comprising:

a frame structure,

a plurality of pairs of piston and cylinder assemblies carried by said frame structure, each of said pairs of piston and cylinder assemblies including:

a pair of cylinders each containing a combustion chamber,

crankshaft connected pistons mounted in said cylinders for movement toward and away from the combustion chambers thereof through successive simultaneous cycles each including simultaneous compression strokes immediately followed by simultaneous power drive strokes, and

a fuel injector for each cylinder constructed and arranged to inject fuel into the associated cylinder when controlled to do so,

a controller connected in controlling relation with said injectors constructed and arranged to selectively control each injector during each piston cycle to undergo either (1) an injection wherein fuel is injected thereby into the associated cylinder causing the associated piston to undergo an internal fired power drive stroke or (2) a skipped injection wherein no fuel is injected thereby into the associated cylinder causing the associated piston to undergo a power drive stroke which is not internally fired,

said controller being constructed and arranged to control the injectors so that an injector associated with one cylinder of each pair of assemblies undergoes an injection and an injector associated with another cylinder of each pair of assemblies undergoes a skipped injection,

at least one pair of piston and cylinder assemblies being mounted on said frame structure with the cylinders thereof disposed in closely spaced relation and intercommunicated by a passage extending therebetween so that, when the injectors associated therewith are controlled as
aforesaid an injector associated with the other cylinder of said at least one pair of assemblies which undergoes a skipped injection causes the piston associated with said other cylinder to undergo a shared power drive stroke by virtue of the increased pressure conditions resulting from the internally fired power drive stroke of the piston associated with the one cylinder being shared therewith through said passage,

aid controller bring constructed and arranged to control the amount of fuel injected by an injector when controlled to undergo an injection in response to variable operator originated signals fed to said controller to thereby control the speed and power that the engine produces while half of the injectors are undergoing skipped injections.

28. An internal combustion engine as defined in claim 27 wherein said plurality of pairs of assemblies includes three pairs mounted in said frame structure in an in line configuration with an inner pair constituting said at least one pair, an outer pair and an intermediate pair, said outer and intermediate pair of assemblies having their cylinder mounted in said frame structure so that the combustion chamber of each pair are spaced apart and not intercommunicated so that the injector associated with the other cylinder of each outer and intermediate pair which under goes a skipped injection causes the associated piston to undergo a skipped power drive stroke driven by the associated crankshaft.

29. An internal combustion engine as defined in claim 28 wherein the controller is constructed and arranged to cause the injector of each pair of assemblies which undergoes an injection and the injector of each pair of assemblies which undergoes a skipped injection to alternate in accordance with a predetermined manner.
30. An internal combustion engine as defined in claim 27 wherein said plurality of pairs of piston and cylinder assemblies includes four pairs of assemblies mounted in said frame structure in two banks of four assemblies each with two banks converging outwardly from spaced simultaneously driven crankshaft so that the outer ends of the cylinders containing the combustion chambers thereof are disposed in closely spaced pairs and intercommunicated by a passage extending there between.

31. An internal combustion engine as defined in claim 30 wherein the controller is constructed and arranged to cause the injector of each pair of assemblies which undergoes an injection and the injector of each pair of assemblies which undergoes a skipped injection to alternate in accordance with a predetermined manner.

32. An internal combustion engine comprising:
   a frame,
   six piston and cylinder assemblies mounted in line in said frame,
   a crankshaft,
   a connecting rod between said crankshaft and a piston of each of said six assemblies constructed and arranged so that the pistons of two inner adjacent assemblies, two outer assemblies and two intermediate assemblies move through repetitive cycles of reciprocating movement offset with respect to one another by 120° of crankshaft rotation and in which each cycle has four strokes of piston movement alternately in opposite directions which take place during four successive 180° rotational movements of said crankshaft,
   inlet and outlet valves for each assembly movable between opening and closing relation with respect to a cylinder of an associated assembly,
a camshaft for controlling the movements of said inlet and outlet valves in successive cycles corresponding with the successive cycles of said pistons so that (1) during each cycle of said pistons air is taken into a cylinder of each assembly during an intake stroke and compressed within a combustion chamber therein to a compression pressure during an immediately following compression stroke, and (2) the compression strokes of the pistons of the two inner assemblies occur simultaneously,

a passage communicating the combustion chambers of the two inner piston and cylinder assemblies, and

a controlled fuel injecting and firing system including an injector for each assembly for injecting fuel into a cylinder during a stroke of an associated piston therein so that a mixture of fuel and compressed air in the combustion chamber thereof can be ignited to affect a power stroke of the assembly immediately following the compression stroke thereof,

said controlled fuel injecting and firing system being operable to selectively control the injectors associated with said inner piston and cylinder assemblies (1) in a normal mode wherein fuel is injected into both cylinders of said inner assemblies during a stroke of both pistons of the inner assemblies so that a mixture of fuel and compressed air in the combustion chambers thereof can be ignited to affect simultaneous internally fired power drive strokes of both pistons or (2) in a fuel saving mode wherein fuel is injected into one of the cylinders of said inner assemblies during a stroke of the associated piston so that a mixture of fuel and compressed air in the combustion chamber of the one inner assembly can be ignited with the resultant increase in pressure therein being shared by said passage with the compressed air in the combustion chamber of the other inner assembly to affect the simultaneous internally fired and shared power drive strokes of the pistons of both said inner assemblies.
33. A method of increasing the efficiency of a six cylinder in line engine having six piston and cylinder assemblies mounted in line formation within a frame, the assemblies having pistons connected to a crankshaft so that the pistons of two inner adjacent assemblies, two outer assemblies and two intermediate assemblies move through repetitive cycles of reciprocating movement offset with respect to one another by 120° of crankshaft rotation in which each cycle has four strokes of movement alternately in opposite directions which take place during successive 180° rotational movements of said crankshaft, a camshaft for controlling inlet and outlet valves to allow air to be taken into a cylinder during an intake stroke of each assembly and to be compressed into a combustion chamber within a cylinder of each assembly during an immediately following compression stroke of each assembly and a fuel injecting and firing system including an injector for each assembly operable to supply fuel during a stroke of the assembly so that when a charge of air under pressure mixed with fuel is ignited within a combustion chamber the resultant increase in pressure in the associated cylinder affects a power stroke of an associated piston immediately following the compression stroke of the assembly, said method comprising:

replacing the camshaft of the engine which controls the valves of the inner assemblies with a replacement camshaft constructed and arranged so that the cycles of piston movement of said two inner assemblies are in phase,

providing a communicating passage between the combustion chambers of the two inner assemblies, and

modifying the fuel injecting and firing system so that the injectors for the two inner assemblies are selectively operable to operate (1) in a normal mode wherein the injectors
associated with both inner assemblies operate to supply fuel during a stroke of both assemblies so that when a charge of air under pressure mixed with fuel is ignited within both combustion chambers the resultant increase in pressure in both cylinders affects simultaneous internally fired power drive strokes of the pistons in both cylinders or (2) in a fuel saving mode wherein the injector associated with one of said inner assemblies operates to supply fuel during a stroke of the associated piston so that when a charge of air under pressure mixed with fuel within the combustion chamber of the one of said inner assemblies is ignited, the resultant increase in pressure in the combustion chamber of the one of the inner assemblies is communicated through the passage with the air under pressure in the combustion chamber of the other of said inner assemblies to affect the power stroke of both assemblies.

34. An internal combustion engine as defined in claim 32 wherein said camshaft is constructed and arranged so that the firing strokes of the two outer and two intermediate assemblies are simultaneous, said fuel injecting and firing system is constructed and arranged to control the injectors being operable to selectively control the injectors of the two outer and two intermediate assemblies in a third mode wherein one injector associated with each of said two outer and two intermediate assemblies is controlled to inject zero amount of fuel.

35. An internal combustion engine as defined in claim 34 wherein said fuel injecting and firing system is operable to control an injector to inject fuel into a cylinder during an associated piston stroke when the compressed air in the associated combustion chamber has reached an auto ignition pressure so that the igniting of the mixture occurs as a result of the injection.
36. An internal combustion engine as defined in claim 34 wherein said fuel injecting and firing system is operable to control an injector to inject fuel into a cylinder during an associated piston intake stroke and the mixture of fuel and compressed air in the associated combustion chamber is ignited by energizing a spark plug in communicating relation to the mixture.

37. An internal combustion engine as defined in claim 32 wherein said fuel injecting and firing system is operable to control an injector to inject fuel into a cylinder during an associated piston stroke when the compressed air in the associated combustion chamber has reached an auto ignition pressure so that the igniting of the mixture occurs as a result of the injection.

38. An internal combustion engine as defined in claim 32 wherein said fuel injecting and firing system is operable to control an injector to inject fuel into a cylinder during an associated piston stroke when the compressed air in the associated combustion chamber has reached an auto ignition pressure so that the igniting of the mixture occurs as a result of the injection.

39. A method as defined in claim 33 wherein the compression stroke of each assembly creates an auto-ignition compression pressure and wherein the mixture is ignited by injecting fuel into the air under auto-ignition pressure within the associated combustion chamber.
40. A method as defined in claim 33 wherein the mixture of air and fuel in the associate combustion chamber by injecting fuel with the intake of air during each intake stroke and the mixture is ignited by the energization of a spark plug in communication with the mixture.

41. A method as defined in claim 33 wherein the new camshaft controls the valves of the two outer and two intermediate assemblies so that cycles of the two outer and two intermediate assemblies are in phase, and the injectors of the fuel injecting and firing system is constructed and arranged to control the injectors associated with the two outer and two intermediate assemblies in a third mode wherein one of the injectors of the two outer and two intermediate assemblies inject a zero amount of fuel.

42. A method as defined in claim 33 wherein said passage is provided by grinding inwardly of a seal engaging surface of the frame between the cylinders of the two inner assemblies.
FIG. 4

SUBSTITUTE SHEET (RULE 26)
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**FIG.15**

SUBSTITUTE SHEET (RULE 26)
A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - F02B 75/02 (2014.01)
USPC - 123/21

According to International Patent Classification (IPC) or to both national classification and IPC.

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC(8) - F02B 1/00, 3/08, 4/100, 41/06, 75/02, 75/18; F02D 13/02 (2014.01)
USPC - 123/21, 52.3, 58.8, 64, 70R, 90.15, 295, 299, 305

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
CPC - F02B 41/06, 2075/025; Y02T 10/18, 10/146 (2013.01)

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
PatBase, Google Patents, Google

C. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
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<tr>
<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
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<td>US 4,172,434 A (COLES) 30 October 1979 (30.10.1979) entire document</td>
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Further documents are listed in the continuation of Box C.

- **A** document defining the general state of the art which is not considered to be of particular relevance
- **E** earlier application or patent but published on or after the international filing date
- **L** document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- **O** document referring to an oral disclosure, use, exhibition or other means
- **P** document published prior to the international filing date but later than the priority date claimed
- **T** later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- **X** document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
- **Y** document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
- **&** a member of the same patent family

Date of the actual completion of the international search: 20 March 2014

Date of mailing of the international search report: 21 APR 2014

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