



## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

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| <b>(21) International Application Number:</b> PCT/NZ96/00128<br><br><b>(22) International Filing Date:</b> 14 November 1996 (14.11.96)<br><br><b>(30) Priority Data:</b><br><table border="0"> <tr> <td>280464</td> <td>14 November 1995 (14.11.95)</td> <td>NZ</td> </tr> <tr> <td>280500</td> <td>20 November 1995 (20.11.95)</td> <td>NZ</td> </tr> <tr> <td>280706</td> <td>19 December 1995 (19.12.95)</td> <td>NZ</td> </tr> <tr> <td>280847</td> <td>18 January 1996 (18.01.96)</td> <td>NZ</td> </tr> <tr> <td>286565</td> <td>13 May 1996 (13.05.96)</td> <td>NZ</td> </tr> </table><br><br><b>(71)(72) Applicant and Inventor:</b> TAYLOR, John, Brengle<br>[NZ/NZ]; 14 Pethig Place, Halswell, Christchurch (NZ).<br><br><b>(74) Agents:</b> LYTH, Richard, John et al.; Baldwin, Son & Carey,<br>342 Lambton Quay, Wellington 6001 (NZ).                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                             | 280464                                                                                                                                     | 14 November 1995 (14.11.95) | NZ | 280500 | 20 November 1995 (20.11.95) | NZ | 280706 | 19 December 1995 (19.12.95) | NZ | 280847 | 18 January 1996 (18.01.96) | NZ | 286565 | 13 May 1996 (13.05.96) | NZ | <b>(81) Designated States:</b> AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, CZ (Utility model), DE, DE (Utility model), DK, DK (Utility model), EE, ES, FI, GB, GE, HU, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SK (Utility model), TJ, TM, TR, TT, UA, UG, US, UZ, VN, ARIPO patent (KE, LS, MW, SD, SZ, UG), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG).<br><br><b>Published</b><br><i>With international search report.</i> |
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| <b>(54) Title:</b> IMPROVEMENTS IN COMBUSTION ENGINES                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                             |                                                                                                                                            |                             |    |        |                             |    |        |                             |    |        |                            |    |        |                        |    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| <b>(57) Abstract</b><br><br><p>Improvements to the construction and operation of reciprocating internal combustion engines are described. The invention may have particular application to compression ignition engines. The constructional modifications relate to components designed to be inserted between a cylinder head and piston bore where those components effect a reduction in the combustion volume thereby reducing the geometrical compression ratio of the engine. These components may be integrated with the cylinder head and include a cylindrical sleeve or a spacer plate. These components can further incorporate a heating/cooling system to regulate the combustion chamber temperature during various phases of the engine's operation. A method is described which may be used in conjunction with the modified engine whereby turbulence from a turbo charging unit is preserved in the intake air thus enhancing air/fuel mixing. Further variations are made to the timing regime of the engine including delaying closure of the inlet valves and early opening of the exhaust valves. Further operating modifications include varying the shape of the air/fuel mixture cloud which is injected into the combustion volume so that the mixture is forced symmetrically radially outward from the point of injection and combining this step with turbo charging the intake air in such a manner so as to produce turbulence in the air fuel mixture within the combustion volume. This latter operating regime includes early opening of the exhaust valve and late closure of the inlet valve. Modified piston shapes are described as are modifications to the combustion chamber shape resulting from the use of the spacer place or ring components designed to reduce the geometrical compression ratio of the regime.</p> |                             |                                                                                                                                            |                             |    |        |                             |    |        |                             |    |        |                            |    |        |                        |    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |

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## IMPROVEMENTS IN COMBUSTION ENGINES

The present invention relates to engines and methods of operating engines. More particularly, although not exclusively, the present invention relates to modifications in the construction and operation of internal combustion engines. Specifically, the present invention relates to modifications in the design and construction of combustion chambers used in compression ignition engines and methods of operating them.

### BACKGROUND TO THE INVENTION

To the present time, numerous techniques have been proposed to enhance the efficiency or otherwise modify the characteristics of an engine to achieve a particular effect. The desired effects include reduction in exhaust pollutants and increased fuel efficiencies. Prior art techniques have met with mixed success.

Reference is made to reciprocating piston type internal combustion engines of the type described in International Application Nos. PCT/NZ94/00109 and PCT/NZ95/00104. The disclosure of each of these two documents is herein incorporated by reference.

Fuel efficiency in combustion engines may be increased and the emission of the unwanted by-products reduced by increasing the compression ratio of a compression ignition or conventional internal combustion engine. Such improvements may be effected by boosting the intake charge in conjunction with modified valve timing and/or modification piston head design as described in the abovementioned patent applications.

Generally to increase the compression ration of an engine the separation between the piston and the head is reduced. Such a modification may not be possible in cases where piston

head designs, such as those described in the above specifications, are used. Pistons modified to incorporate a convex upper surface, can be obstructed at the end of their compression stroke by either the fuel injector, cylinder head or valves. Therefore it would be advantageous to modify the engine so that the volume of the combustion chamber is effectively reduced while avoiding bringing the piston upper surface and the valves/fuel injector closer together.

Additional problems have been experienced with engines of this type and others, wherein for low engine loads and during starting excessive engine cooling can occur due to the lower combination temperatures and conduction of heat out of the engine via combustion gases. Further, it is also desirable to isolate the thermal load between the piston and the cylinder wall. Such a thermal load may cause differential heating resulting in excessive ring wear and wear on the piston liner (if installed). It would therefore be an advantage to be able to conduct heat away from the combustion chamber or control the temperature of the combustion chamber by thermal conduction means other than the piston, cylinder and cylinder head.

It is also known to improve the efficiency of an internal combustion engine by enhancing the air/fuel mixing within the combustion chamber. One means of effecting such mixing known in the art is known as in cylinder mixing. In cylinder mixing includes providing a squish landing area on the piston head. Further modifications have included attempts to modify the piston upper surface in order to make the fuel/air mixture conform to a particular combustion chamber geometry. The combustion chamber geometry being defined by the volume interior to the top of the piston and the top of the cylinder head. Such modifications have been applied to otherwise unmodified engines and have met with mixed success.

It is also known to vary the timing regime under which an engine operates. Such variations have generally been effected to alter the timing of an engine as a function of the load or revolutions per minute.

It is an object of the invention to provide alternative methods of construction and operation for combustion engines which, in a preferred embodiment, may be used in conjunction to effectively reduce the combustion chamber volume and increase the compression ratio while providing enhanced air/fuel mixing, or to at least provide the public with a useful choice.

Further objects and advantages will become apparent from the following description which is given by way of example only.

## **DISCLOSURE OF THE INVENTION**

In one aspect, there is provided a reciprocating piston type internal combustion engine incorporating a means adapted to be at least partially inserted into a cylinder bore, wherein said means is further adapted to decrease the volume of at least part of the cylinder bore.

Preferably the means inserted into the cylinder bore comprises a substantially annular element adapted to fit snugly within the cylinder bore and having an interior surface which defines, along with an upper surface of the piston and a cylinder head, a combustion volume.

Preferably the annular element comprises a ring having an internal diameter, an external diameter and longitudinal length wherein said outer diameter is adapted so that the annular element fits snugly within the bore of a cylinder.

Preferably the interior surface forms a substantially cylindrical volume interior to the ring.

In an alternative embodiment the interior surface can be shaped in such a way that it is axially symmetrical and the inner circumference varies along the longitudinal axis of the annular element.

In an alternative embodiment, the interior surface may be concave in longitudinal section.

Preferably the annular element incorporates a lip member located circumferentially around the end of the annular element, said lip having an external diameter greater than the external diameter of the annular element.

Preferably the piston includes a convex upper surface.

Preferably the combustion chamber, defined by the interior volume of the annular element, the piston upper surface and the cylinder head, has dimensions adapted to allow the piston to move freely through all parts of its travel.

In an alternative embodiment, the annular element may be suitably adapted to accommodate valve seats.

Preferably the annular element may have a variable internal circumference.

In a further embodiment, the present invention provides for a modified engine incorporating an annular element inserted into a cylinder bore, wherein the cylinder head and/or annular element is/are adapted so that the combustion chamber formed therein has a shape which accommodates an air/fuel spray pattern produced by a fuel injector.

In an alternative embodiment the present invention provides for a modified engine incorporating:

an annular element inserted into a cylindrical bore;

a plurality of valves, wherein the longitudinal axes of the valves are at an angle greater than  $0^\circ$  and less than  $90^\circ$  to the axis of the cylinder.

In an alternative embodiment, the annular element and cylinder head may comprise a single unit.

In an alternative embodiment, a plurality of annular elements are formed from a substantially flat plate so that they may be inserted into corresponding cylinder bores while remaining held in fixed relation to each other.

Preferably the plurality of annular elements are integral with the cylinder head.

In a further aspect, the invention provides for a modified engine incorporating a means, interposed between a cylinder head and a cylinder, adapted to increase clearance between the piston and the cylinder head while reducing the volume of a combustion chamber formed therebetween.

Preferably the means interposed between the piston head and the cylinder comprises a substantially planar spacer plate incorporating an aperture located and dimensioned so that when the spacer plate is interposed between the cylinder head and cylinder, the aperture allows the piston to travel to the end of its compression stroke without being obstructed by any component of the cylinder head.

Preferably the piston incorporates a convex upper surface.

Preferably the size of the aperture and the thickness of the spacer plate are such that a combustion chamber formed interior to said aperture will allow a piston with a convex surface to move unimpeded through all parts of its travel.

In one embodiment, the aperture may be substantially circular and have a diameter less than, greater than or equal to the diameter of the piston.

Preferably the aperture is located symmetrically in relation to the cylinder.

In an alternative embodiment, the spacer plate may incorporate a cooling/heating means adapted to control or regulate the temperature of the combustion chamber.

Preferably cooling/heating may be effected by means of water, oil, air or similar heat exchange medium.

In a further embodiment, the present invention provides for a modified engine incorporating a spacer plate interposed between a cylinder head and a cylinder, wherein the cylinder head is adapted so that the combustion chamber formed therebetween is of a shape which accommodates an air/fuel spray pattern produced by a fuel injector.

In an alternative embodiment, the present invention provides for a modified engine incorporating:

- a spacer plate interposed between a cylinder head and cylinder;
- a plurality of valves, wherein the longitudinal axes of the valves is at an angle greater than 0° and less than 90° to the axis of the cylinder.

Preferably the spacer plate may be integral with the cylinder head.

Preferably the aperture in the spacer plate may be adapted to accommodate a plurality of valves.

Preferably the circular aperture is relieved at locations on its perimeter in order to accommodate the plurality of valves.

In an alternative embodiment, the aperture may have a curved or otherwise shaped side(s).

In a further aspect, the present invention provides for a compression ignition engine adapted to reduce heat conduction between a volume defined by a cylinder containing a piston substantially at top dead centre, and the engine.

Preferably the cylinder incorporates an insulating material bonded to a portion of the cylinder wall between the cylinder head and the piston when substantially at top dead centre.

In an alternative embodiment, the insulating material may be fitted as an insert ring.

Preferably the insulating material is a ceramic compound.

Preferably the insert ring may have a similar diameter to the cylinder bore or alternatively have a diameter slightly less than the diameter of the cylinder bore.

According to a further aspect of the invention, there is provided a method of varying valve timing in a reciprocating piston type internal combustion engine including:

delaying closure of one or more inlet valves until  $25^{\circ}$  -  $50^{\circ}$  after bottom dead centre following the induction stroke.

In a further aspect, the present invention provides for a method of varying valve timing in a reciprocating piston type internal combustion engine including:

opening one or more exhaust valves  $70^{\circ}$  -  $80^{\circ}$  before bottom dead centre.

Preferably the modified operating regimes are applied to engines modified as described hereinbefore.

According to a further aspect of the invention, there is provided a method of increasing turbulence in an internal combustion engines combustion chamber, said method being to reduce the geometric compression ratio and compensate for this with heavily turbo charged intake air.

The invention further provides for a method of increasing the turbulence in an internal combustion engines combustion chamber, the method comprising delaying the opening of an inlet valve until such time as the piston is moving down on the induction strokes so as to provide a pressure differential across the inlet valve sufficient to significantly enhance the turbulence associated with the air fuel mixture entering the combustion chamber via the inlet valve.

Preferably the piston may be  $20^{\circ}$  -  $30^{\circ}$  down on its induction stroke before the inlet valve opens.

The present invention further provides for a method of increasing turbulence in an internal combustion engine's combustion chamber comprising heavily turbo charging intake air and providing said intake air to an internal combustion engines combustion chamber in such a manner to substantially preserve turbulent motion imparted by the impellers of the turbo charging unit.

The present invention further provides for a method of increasing turbulence in an internal combustion engine combustion chamber comprising combinations of the abovementioned operating regimes.

According to a further aspect of the present invention, there is provided a compression ignition engine including a piston having a dome shaped convex protrusion located centrally on the piston's top surface;

turbo charging means adapted to enhance the turbulence in a combustion volume defined by the piston top surface and a cylinder head, wherein one or more exhaust valves associated with the combustion volume are opened substantially  $50^\circ$  before bottom dead centre and one or more inlet valves are closed substantially  $40^\circ$  after bottom dead centre.

In an alternative embodiment, the piston incorporates a substantially flat upper surface.

In a further aspect, the present invention provides for a method for operating a compression ignition engine including the steps of:

injecting a fuel mixture into a combustion volume in such a manner to force the air/fuel mixture substantially symmetrically radially outward from the point of injection;

turbo charging intake air so as produce turbulence in the air/fuel mixture within the combustion volume;

opening exhaust valve substantially  $50^\circ$  before bottom dead centre and closing inlet valve substantially  $40^\circ$  after bottom dead centre.

Preferably the air/fuel mixture is forced substantially radially outward from the point of injection by means of the action at a modified piston upper surface, said modification comprising and incorporating a protruding convex dome surface located substantially centrally on the top surface of the piston.

Preferably the engines operating regimes as hereinbefore defined are used in conjunction with the engine modifications as hereinbefore defined.

## **BRIEF DESCRIPTION OF DRAWINGS**

The present invention will now be described by way of example only and with reference to the drawings in which:

Figure 1: illustrates a modified cylinder and cylinder head arrangement;

Figures 2a, 2b, and 2c: illustrate alternative aperture shapes adapted to accommodate one or more valves;

Figures 3a, 3b and 3c: illustrate alternative aperture diameters in relation to the piston and cylinder;

Figure 4: illustrates an alternative embodiment of a cylinder and cylinder head construction.

Figure 5 illustrates an annular element and cylinder bore.

Figure 6 illustrates a top view of an annular element relieved to accommodate two valves;

Figure 7 illustrates a modified cylinder and cylinder head arrangement;

Figure 8 illustrates an alternative embodiment providing for a plurality of annular elements fixed to a plate.

Figure 9 illustrates a schematic diagram of cylinder incorporating an insulating material.

Figure 10 illustrates schematically a cross-section of a cylinder incorporating a piston with a domed upper protrusion;

Figure 11 illustrates schematically a cross-section of a cylinder incorporating a piston with a flat upper surface; and

Figure 12 illustrates a timing diagram for use in conjunction with a modified piston/cylinder.

Referring to figure 1, a piston 14 modified in accordance with PCT/NZ95/00104, and/or New Zealand Patent No: 280464 and/or New Zealand Patent No: 280500 travels in a cylinder bore 103. A cylinder liner 101 may optionally be located in the cylinder bore 103 between the piston and the cylinder. The piston 14 in Figure 1 is shown at the end of its compression stroke. A spacer plate 10 is interposed between the cylinder 12 and the cylinder head 13 and a combustion chamber 100 is formed therebetween by the aperture 104. Inlet and exhaust passages 19 and 18 respectively, feed into the combustion chamber 100 via valves 17 and 16 respectively. Fuel is provided by means by fuel injector 15 which supplies the fuel under high pressure as is known in the art thereby producing a fuel mist or spray in the combustion chamber 100.

The present invention is described in the context of a compression ignition engine (ie a diesel engine). However, it is envisaged that modifications in accordance with the present invention may be made to other types of engines.

Aperture 104 in the spacer plate 10 is, in the embodiment described herein, substantially circular in shape when viewed from above. The diameter of the aperture in the illustrated embodiment is less than the piston diameter but does not encroach on the valves 17 and 16. By reducing the diameter of the aperture, the compression ratio is increased without necessitating a reduction in the clearance between the fuel injector, or other cylinder head components, and the upper surface of the piston. In this manner, the separation between the piston and the upper engine components can be held substantially constant while varying the diameter of the aperture in order to produce the required compression ratio. Alternatively, the thickness of the spacer plate may be adjusted, along with the diameter of the aperture so as to produce a optimal combustion chamber geometry.

It is envisaged that an engine modified in accordance with the present invention will incorporate pistons modified in accordance with the abovementioned specifications. The convex piston upper surface shape 102 is adapted to accommodate the air/fuel spray geometry as well as improving mixing in the combustion chamber. The abovementioned specifications, particularly PCT/NZ95/00104 are referred to in this regard.

The geometry of the combustion chamber may thus be adapted so that the fuel/air mist or aerosol is spread as uniformly as possible throughout the combustion chamber volume without stalling on internal engine components. Any turbulent flow resulting from the high pressure entry of the fuel mist into the chamber hitting an obstruction will reduce the homogeneity of the air/fuel mixture and lead to incomplete combination and reduced fuel efficiency.

This effect is shown more clearly in the alternative embodiment shown in figure 4. Here, the valves 47 and 46 are angled at approximately  $50^\circ$  to the axis of the cylinder and piston. This allows for a reduced aperture diameter which can accommodate a more prominent convex piston head surface. The convex protrusion 402 is exaggerated for the purposes of illustration in figure 4.

The air/fuel spray pattern 405 is shown schematically by the dotted lines. The divergence angle of the fuel/air spray can be matched appropriately by the spacer plate dimensions as well as the piston head design. In this way a more uniform distribution of the air/fuel mixture through the combustion volume can be achieved thereby enhancing the fuel efficiency.

A conventional cylinder head and cylinder design (ie - excluding the spacer plate) would not easily accommodate a modified piston 44. In this case the cylinder head 43 would lie

flush with the cylinder head gasket 405 and the piston 44 would, at the end of its compression stroke, be necessarily lower in the cylinder. Accordingly, by the present invention, a longer piston stroke can be achieved while incorporating the modified piston head design described in the abovementioned specifications.

The aperture need not necessarily be of a smaller diameter than that of the piston. As shown in figures 3a, 3b and 3c, the aperture diameter may be equal to or larger than the piston diameter. For a constant spacer plate thickness, increasing the diameter of the spacer plate aperture will lower the compression ratio. Accordingly, the geometry of the combustion chamber can be tailored to a particular fuel injector divergence angle, and in accordance with other combustion parameters as required.

As shown in figure 1, if the spacer plate aperture has a diameter sufficiently large so as to not encroach on the valves 17 and 16, it may be of a circular shape. However, if a smaller combustion chamber volume is desired, it may be necessary to allow for valve clearances as shown in figure 2b by numerals 20 and 21. Similarly, figure 2c illustrates an example where four valves are accommodated by the spacer plate aperture. The circular aperture shape is a particular embodiment and other shapes may be appropriate depending upon the spray shape of the air/fuel mixture as well as other mechanical considerations which may arise.

Referring again to figure 1, the aperture is shown substantially as a uniform cylindrical aperture in the spacer plate 10. In alternative embodiments the inner surface 104 may be of a curved or other shape in section.

The spacer plate 10 may be further usefully adapted so as to conduct heat away from the combustion chamber 100. This may be achieved by constructing a water, oil or similar jacketing arrangement in the spacer plate region proximate the inside surface of the aperture

104. This will reduce the thermal load between the piston 14 and the cylinder 12 thereby leading to reduced ring wear. Further, the temperature of the combustion chamber can be regulated or controlled if required. To this end, the heat exchange media may be adapted to heat the combustion chamber.

The parameters which can effect the chosen geometry of the plate aperture include the divergence angle of the fuel spray, the distance from the injector to the inner surface of the combustion chamber and the velocity of the fuel spray and compression ratio.

The ability to conduct heat away via a spacer plate 10 may be advantageously exploited by varying the cooling characteristics of the spacer plate in accordance with the changing combustion chamber and operating conditions. This may be effected by water, oil or similar pumping means controlled by an engine management computer.

Alternatively, the spacer plate may be independently heated thereby allowing precise control over the combustion chamber temperature. Such heating may be useful during starting where the air/fuel vapour can condense onto the side walls of the combustion chamber leading to incomplete combustion.

The spacer plate 10 may be composed of an alloy and incorporate interstitial cavities to accommodate oil, water or a similar cooling medium.

While the particular embodiment shown incorporates a separate spacer plate 10, it is envisaged that the spacer plate could be incorporated into the cylinder head 13. The spacer may be 0.7 to 0.8 of an inch thick. Typical air/fuel spray divergence angles are between 15° and 60° and the geometrical configuration of the spacer plate and arrangement of the valves may be tailored to suit accordingly.

Referring to Figure 5, an example of an alternative means of reducing the combustion chamber is shown. An annular element comprises a ring member 51 and a lip member 52 which is located around the circumference of one end of the ring 51. The interior surface 53 defines the shape of the combustion volume which is interior to the annular element. The external surface 57 is of a circumference which allows the annular element to be snugly inserted into a cylinder bore 56 in a cylinder 55. The embodiment shown in Figure 5 incorporates a cylinder liner 54. However, the annular element of the present invention could be used in a cylinder bore without a liner 54.

In use, the annular element 50 is slid into the cylinder bore 56 so as to snugly engage the outer surface 57 of the annular element and the interior surface 58 of the cylinder bore. The annular element is prevented from moving downward into the cylinder by means of the lip 52 which protrudes over the edge of the cylinder bore.

A top view of the annular element is shown in Figure 6. In this particular embodiment the annular element is relieved at 63 and 61 to accommodate valves. It is to be understood that this particular embodiment illustrates an accommodation for two valves. However, it is envisaged that similar modifications may be made to accommodate any number of valves in accordance with the particular valve geometry and the cylinder head arrangement.

A side view section of an annular element in use is shown in figure 7. Referring to figure 7, a piston 76, modified in accordance with PCT/NZ95/00104 and/or New Zealand Patent No: 280464 and/or New Zealand Patent No: 280500, is shown moving in a cylinder bore 76. A cylinder liner 101 may optionally be located in the cylinder bore 77 between the piston and the cylinder. The construction shown in Figure 7 is a schematic intended only to illustrate the general configuration of the modifications provided by the present invention and is not intended to be practical working diagram. Some of the dimensions are exaggerated to illustrate the

particular construction herein. The annular element 71 is inserted into the top of the cylinder bore as shown. A combustion chamber 100 is formed therebetween and is bounded by the interior surface 73 of the annular element, the upper surface of the piston 79, valves 17 and 16 and cylinder head. Inlet and exhaust passages 19 and 18 respectively, feed into the combustion chamber 100 via valves 17 and 16 respectively. Fuel is provided by means of fuel injector 15 which supplies fuel under high pressure. The fuel provided under pressure by the injector 15 produces an air/fuel aerosol or vapour in the combustion volume 100.

When viewed from above, the annular element, in the embodiment described herein, is substantially circular in shape. The inner diameter of the annular element in this embodiment is less than the piston diameter but does not encroach on the valves 17 and 16. A smaller diameter may be implemented by arranging the valves and cylinder head as shown in New Zealand Patent No: 280706.

While the example shown in Figure 7 employs an annular element having an inner surface diameter which is constant along the longitudinal axis of the annular element, it is envisaged that the inner surface may be some other shape than that corresponding to a cylindrical surface. For example, the lower portion of the inner surface 73 may be machined to be concave in order to match the shape of the fuel mist or spray produced by the fuel injector. Other internal surface shapes are envisaged such as tapering, curved or the like.

In conjunction with the use of the annular element, it is envisaged that the engine incorporating this component may incorporate pistons modified in accordance with the abovementioned specifications. The convex surface shape 79 of the piston is particularly adapted to accommodate the air/fuel spray geometry, as well as improve mixing in the combustion chamber. Reference is made to PCT/NZ94/00104 in this regard.

Therefore, it can be seen that the geometry of the combustion volume may be tailored to suit the geometry of the fuel/air mist or aerosol produced by the fuel injector 15. This ensures that the fuel/air aerosol is spread as uniformly as possible throughout the combustion chamber volume without encountering internal engine components. If the vapour stalls on internal engine components, in some operating regimes, the fuel may condense and have difficulty igniting. Any inhomogeneity in the air/fuel mixture caused by internal turbulence will lead to incomplete combustion because density variations in the air/fuel mixture may result in condensation or fuel being forced into threads or cracks between the combustion chamber components. Such effects will be minimised in the implementation of the present invention.

The cylinder head is machined around the area immediately above the cylinder bore to accommodate the lip element 72. The lip 72 extends around the upper circumference of the cylinder bore to ensure that the annular element 71 does not move downward into the cylinder bore.

Further, the existence of the lip may aid in mechanically positioning the annular element 71 prior to assembly of the cylinder head and cylinder.

It is envisaged that the particular dimensions and interior surface shape of the annular element may be varied to suit the particular combustion chamber volume required and/or the particular fuel/air mist geometry produced by the fuel injector. The lip 72 dimensions may be varied as required and it is also envisaged that the annular element itself may be machined into the cylinder head in a permanent manner.

While the examples shown in figure 7 illustrate a ring shaped annular element, it is possible that the inner surface diameter of the annular element may increase so as to taper

towards the cylinder wall or cylinder lining. This may reduce turbulence in the combustion volume. However, this represents a trade off of combustion volume and air/fuel homogeneity.

It is also envisaged that a plurality of annular elements may be attached to or formed from a flat plate where the cylindrical inserts protrude from the plate. This embodiment is shown in figure 8 (shown inverted for clarity) where a plate 81 incorporates four annular elements 80. By this construction, the plate is positioned between the cylinder and cylinder head and the cylindrical protrusions are located coincident the cylinder bores. This particular embodiment provides the advantage of enabling the simultaneous location of a plurality of annular elements. In a further embodiment, a plurality of annular elements may be constructed integral with the cylinder head.

A further aspect of the present invention is concerned with methods for varying the valve timing in internal combustion engines as well as a technique in construction for preventing the overcooling of a cylinder. It is envisaged that the operating regimes will be implemented in conjunction with the modified engine constructions discussed above.

When an engine such as that described in PCT/NZ95/00104 is lightly loaded, the fuel efficiency falls off as a result of the lower compression ratio. This effect can be mitigated by increasing the cylinder compression by means of turbo charging and the valve timing techniques described below.

It has been found that by modifying the variable valve timing technique described in PCT/NZ95/00104, the abovementioned problem may be overcome or at least mitigated.

To this end, the closure of at least one inlet valve per cylinder may be delayed until 20 to 50 degrees of crankshaft rotation after bottom dead centre following the induction stroke. This will ensure sufficient admission of air to the cylinder.

Alternatively or in combination with the delayed inlet valve closure, one or more exhaust valves may be opened earlier. For example, the exhaust valve may be opened 70 to 80 degrees before bottom dead centre. This ensures that sufficient energy arrives at the turbo unit turbine wheel.

When an engine is lightly loaded, the cylinder may become excessively cool, leading to difficulty in the engine warming up or retaining cylinder heat. Referring to Figure 9, when the piston is at top dead centre (ie, the piston is at its closest point of approach to the cylinder head), there is an area of exposed cylinder wall 90 above the piston line 91. This surface, the cylinder head and piston crown define a volume 92. To reduce the amount of heat conducted away from the engine by the ignition gases in this operating regime (light engine loading), the engine is thermally insulated from the volume 92 by coating the surface 90 with a heat insulating material. Alternatively an insert ring of insulating material may be fitted.

The insert ring could have a similar diameter to that of the cylinder or a slightly smaller diameter than the cylinder bore.

The insulating material must exhibit physical characteristics which enable it to withstand extremes of pressure and temperature. A suitable material may be in the form of a ceramic compound.

It is known that the efficiency of an internal combustion engine is enhanced significantly by providing thorough air/fuel mixing in the combustion chamber prior to ignition.

Such techniques are known to be applied to conventional internal combustion engines as well as diesel compression ignition engines.

Enhanced air/fuel mixing may be effected by increasing the turbulence levels of the gas/fuel mixture as it enters the combustion chamber. It has been found by experimentation that the turbulence provided by heavily turbo-charged intake air can be utilised. Turbulence is created at the impellers of the turbo-charging unit whereby air vortices are formed as the impellers rotate. The intake air is transmitted down a diffuser tube and to the inlet valve while preserving its turbulent characteristics. Such turbulent characteristics embody high velocity vortices and similar transmittable air movements.

The increased levels of turbulence are imparted to the air/fuel mixture which is forced into the combustion chamber by the differential pressure across the inlet valve.

It has also been found that by increasing this pressure differential this technique may be used in conjunction with heavily turbo-charged intake air.

The pressure differential across the inlet valve may be increased by delaying the inlet valve opening until the piston is moving downward on an induction stroke. For example, the inlet valve opening may be delayed until the piston is 20 to 30 degrees down on the induction stroke. This increased pressure differential will force the already turbulent air into the combustion chamber causing it to expand while still preserving the turbulent characteristics of the initial intake charge thereby enhancing the mixing of the air/fuel.

Generally diesel compression ignition engines have a geometric compression ration of 16:1 or greater. Engines operating in the modified manner described above have been found to have geometric compression ratios of 10:1 to 14:1.

A further aspect of the present invention combines constructional modifications and modifications to the methods of operation of a compression ignition engine. Broadly, the general aim of the invention is to enhance mixing in the air/fuel mixture injected into the combustion volume.

Referring to figure 10 a modified piston is shown. A piston 101 incorporates a domed protrusion 102 located centrally on the upper surface of the piston 101. The domed protrusion 102 is surrounded by an annular flat ring 106. In figure 10, 103 and 104 correspond to exhaust and inlet valve respectively.

The piston 101 moves in a cylindrical bore 107 and is shown at the end of its compression stroke. A fuel injector is shown injecting a fuel mixture centrally into the top of the combustion volume 100. The fuel mixture is shown schematically by the number 108 and, using known injectors, causes the mixture to be sprayed radially outwards to the extremities of a combustion volume 100. This provides one component of the enhanced mixing method as described herein.

In conjunction with this modification to the piston, the intake air is turbocharged. Conventionally, turbo charging is used to augment the geometrical compression ratio thus increasing the effective compression ratio. However, the present technique uses turbo charging in such a manner to enhance the turbulence in the combustion volume 100. Mixing is further enhanced by using turbocharging in conjunction with the valve timing method described as follows.

The modified valve timing method comprises opening the exhaust valve approximately  $50^{\circ}$  before bottom dead centre and closing the inlet valves approximately  $40^{\circ}$  after bottom dead centre. These figures are preferred values and it is envisaged that opening and closure may

occur up to  $\pm 10^\circ$  from each of these values. Reference is made to Figure 12 which corresponds to a timing diagram.

It is envisaged that the above modified methods and constructional modifications are intended to be performed in conjunction with one another. The overall effect being to enhance the uniformity and mixing of the air/fuel vapour in the combustion volume.

Prior art diesel engines generally provide efficiencies of approximately 254 grams of diesel fuel per kw.h. Utilising the invention as set out above, fuel consumption as low as 194 grams of diesel fuel per kw.h have been observed.

Referring to the particular engine load conditions under which the best results may be obtained, the improvements in efficiencies are not dramatic when the diesel engine is idling. In fact, the efficiency may, on some occasions, be worse than that exhibited by standard or unmodified engines when at idle. However, the greatest efficiency improvements are shown when the engine is placed under stress or load. Such situations occur when the vehicle is accelerating, decelerating or travelling at uniform speed with a load. It is estimated that a standard large truck travelling on an highway at approximately 50-60 mph would correspond to a two thirds engine load and thus exhibit significant fuel savings using the modified engine and method of operation. Clearly, this will be highly significant in applications such as long distance haulage and the like. In these situations the truck or the vehicle spends relatively little time at idle or accelerating. The bulk of the time is spent at cruise where the optimum fuel efficiencies may be obtained using the method and modifications as set out above. In these situations, the slight deterioration in efficiency when the engine is idling would be overcome by the enhanced efficiencies at load.

Referring to Figure 11, a flat topped piston embodiment is shown at the end of its compression cycle. In this case, the fuel injector 15 is adapted so that the air/fuel spray is directed substantially symmetrically radially outward from the injection point. This modification coupled with turbo charging the intake air so as to enhance the turbulence and the combustion volume along with the modified timing valve regime results in similar efficiencies as those set out above.

Where in the foregoing description reference has been made to elements or integers having known equivalents, then such equivalents are included as if they were individually set forth.

Although the invention has been described by way of example and with reference to a particular embodiment, it is to be understood that modifications and/or improvements may be made without departing from the scope or spirit of the invention.

**CLAIMS**

1. A reciprocating piston type internal combustion engine incorporating a means adapted to be at least partially inserted into a cylinder bore, wherein said means is further adapted to decrease the volume of at least part of the cylinder bore, the means inserted into the cylinder bore comprising a substantially annular element adapted to fit snugly within the cylinder bore and having an interior surface which defines, along with an upper surface of the piston and a cylinder head, a combustion volume.
2. A reciprocating piston type internal combustion engine as claimed in claim 1 wherein the annular element comprises a ring having an internal diameter, an external diameter and longitudinal length wherein said outer diameter is adapted so that the annular element fits snugly within the bore of a cylinder.
3. A reciprocating piston type internal combustion engine as claimed in any preceding claim wherein the interior surface forms a substantially cylindrical volume.
4. A reciprocating piston type internal combustion engine as claimed in claim 1 or claim 2 wherein the interior surface is shaped in such a way that it is axially symmetrical and the inner circumference varies along the longitudinal axis of the annular element.
5. A reciprocating piston type internal combustion engine as claimed in claim 1 or claim 2 wherein the interior surface is concave in longitudinal section.
6. A reciprocating piston type internal combustion engine as claimed in any one of claims 1 to 5 wherein the annular element incorporates a lip member located circumferentially around

the end of the annular element, said lip having an external diameter greater than the external diameter of the annular element.

7. A reciprocating piston type internal combustion engine as claimed in any one of claims 1 to 6 wherein the annular element is suitably adapted to accommodate valve seats.

8. A reciprocating piston type internal combustion engine as claimed in any one of claims 1 to 7 wherein the annular element has a variable internal circumference.

9. A reciprocating piston type internal combustion engine as claimed in claim any one of the preceding claims wherein the piston includes a convex upper surface.

10. A reciprocating piston type internal combustion incorporating an annular element inserted into a cylinder bore, wherein the cylinder head and/or annular element is/are adapted so that the combustion chamber formed therein has a shape which accommodates an air/fuel spray pattern produced by a fuel injector.

11. A reciprocating piston type internal combustion engine as claimed in any preceding claim incorporating:

an annular element inserted into a cylindrical bore;

a plurality of valves, wherein the longitudinal axes of the valves are at an angle greater than  $0^\circ$  and less than  $90^\circ$  to the axis of the cylinder.

12. A reciprocating piston type internal combustion engine as claimed in claim 10 or claim 13 wherein the annular element and cylinder head comprise a single unit.

13. A reciprocating piston type internal combustion engine as claimed in claim 10 or claim 11 wherein a plurality of annular elements are formed from a substantially flat plate so that they may be inserted into corresponding cylinder bores while remaining held in fixed relation to each other.
14. A reciprocating piston type internal combustion engine incorporating a means, interposed between a cylinder head and a cylinder, adapted to increase clearance between the cylinder and the cylinder head while reducing the volume of a combustion chamber formed therebetween.
15. A reciprocating piston type internal combustion engine as claimed in claim 14 wherein the means interposed between the cylinder head and the cylinder comprises a substantially planar spacer plate incorporating an aperture located and dimensioned so that when the spacer plate is interposed between the cylinder head and cylinder, the aperture allows the piston to travel to the end of its compression stroke without being obstructed by any component of or retained in the cylinder head.
16. A reciprocating piston type internal combustion engine as claimed in claim 15 wherein the piston includes a convex upper surface.
17. A reciprocating piston type internal combustion engine as claimed in claim 15 or claim 16 wherein the size of the aperture and the thickness of the spacer plate are such that a combustion chamber formed interior to said aperture allows a piston with a convex surface to move unimpeded through all parts of its travel.

18. A reciprocating piston type internal combustion engine as claimed in any one of claims 15 to 17 wherein the aperture is substantially circular and has a diameter less than, greater than or equal to the diameter of the piston.
19. A reciprocating piston type internal combustion engine as claimed in any of claims 15 to 18 wherein the aperture is located symmetrically in relation to the cylinder.
20. A reciprocating piston type internal combustion engine as claimed in any one of claims 15 to 19 wherein the spacer plate incorporates a cooling/heating means adapted to conduct heat away from or to the combustion chamber.
21. A reciprocating piston type internal combustion engine as claimed in claim 20 wherein cooling/heating is effected by means of water, oil or similar means.
24. A reciprocating piston type internal combustion as claimed in any of claims 14 to 21 engine incorporating a spacer plate interposed between a cylinder head and a cylinder, wherein the cylinder head is adapted so that the combustion chamber formed therebetween is of a shape which accommodates an air/fuel spray pattern produced by a fuel injector.
23. A reciprocating piston type internal combustion engine as claimed in any of claims 14 to 22 incorporating:
- a spacer plate interposed between a cylinder head and cylinder;
  - a plurality of valves, wherein the longitudinal axes of the valves is at an angle greater than  $0^{\circ}$  and less than  $90^{\circ}$  to the axis of the cylinder.

24. A reciprocating piston type internal combustion engine as claimed in either claim 22 or claim 23 wherein the aperture in the spacer plate is adapted to accommodate a plurality of valves.
25. A reciprocating piston type internal combustion engine as claimed in any one of claims 22 to 24 wherein the aperture is circular and relieved at locations on its perimeter in order to accommodate the plurality of valves.
26. A reciprocating piston type internal combustion engine as claimed in any one of claims 22 to 24 wherein the aperture may have a curved or otherwise shaped side(s).
27. A reciprocating piston type internal combustion engine adapted to reduce heat conduction between a volume defined by a cylinder containing a piston substantially at top dead centre, and the engine.
28. A reciprocating piston type internal combustion engine as claimed in claim 27 wherein the cylinder incorporates an insulating material bonded to a portion of the cylinder wall between the cylinder head and the piston when substantially at top dead centre.
29. A reciprocating piston type internal combustion engine as claimed in claim 28 wherein the insulating material is fitted as an insert ring.
30. A reciprocating piston type internal combustion engine as claimed in claim 29 wherein the insulating material is a ceramic compound.

31. A reciprocating piston type internal combustion engine as claimed in claim 29 wherein the insert ring has a similar diameter to the cylinder bore or alternatively has a diameter slightly less than the diameter of the cylinder bore.
32. A method of varying valve timing in a reciprocating piston type internal combustion engine as claimed in any preceding claim including:  
delaying closure of one or more inlet valves until  $25^{\circ}$  -  $50^{\circ}$  after bottom dead centre following the induction stroke.
33. A method as claimed in claim 32 of varying valve timing in a reciprocating piston type internal combustion engine including:  
opening one or more exhaust valves  $70^{\circ}$  -  $80^{\circ}$  before bottom dead centre.
34. A method of varying valve timing as claimed in claim 32 or claim 33 wherein the modified operating regimes are applied to engines modified as described hereinbefore.
35. A method of increasing turbulence in an internal combustion engines combustion chamber(s), said method being to reduce the geometric compression ratio and compensate for this with heavily turbo charged intake air.
36. A method of increasing the turbulence in an internal combustion engines combustion chamber(s), the method comprising delaying the opening of an inlet valve of each chamber until such time as the piston is moving down on its induction stroke so as to provide a pressure differential across the inlet valve sufficient to significantly enhance the turbulence associated with the air fuel mixture entering the combustion chamber(s) via the inlet valve.

37. A method as claimed in claim 36 wherein each piston is 20° - 30° down on its induction stroke before the inlet valve opens.
38. A method of increasing turbulence in an internal combustion engine's combustion chamber(s) as claimed in claim 36 wherein heavily turbo charging intake air is provided to an internal combustion engines combustion chamber(s) in such a manner to substantially preserve turbulent motion imparted by the impellers of the turbo charging unit.
39. A method of increasing turbulence in an internal combustion engine combustion chamber(s) comprising combinations of any one of claims 32 to 34 with any one of claims 35 to 38.
40. A reciprocating piston type internal combustion engine including:  
a piston having a dome shaped convex protrusion located centrally on the piston's top surface; and  
turbo charging means adapted to enhance the turbulence in a combustion volume defined by the piston top surface and a cylinder head, wherein one or more exhaust valves associated with the combustion volume are opened substantially 50° before bottom dead centre and one or more inlet valves are closed substantially 40 ° after bottom dead centre.
41. A reciprocating piston type internal combustion engine as claimed in claim 40 wherein the piston has a substantially flat upper surface.
42. A method for operating a reciprocating piston type internal combustion engine including the steps of:  
injecting a fuel mixture into a combustion volume in such a manner to force the air/fuel mixture substantially symmetrically radially outward from the point of injection;

turbo charging intake air so as produce turbulence in the air/fuel mixture within the combustion volume;

opening exhaust valve substantially 50° before bottom dead centre and closing inlet valve substantially 40° after bottom dead centre.

43. A method as claimed in claim 42 wherein the air/fuel mixture is forced substantially radially outward from the point of injection by means of the action at a modified piston upper surface, said modification comprising and incorporating a protruding convex dome surface located substantially centrally on the top surface of the piston.

44. A reciprocating piston type internal combustion engine substantially as herein described with reference to the accompanying drawings.

45. A modified engine substantially as herein described with reference to the accompanying drawings.

46. A compression ignition engine substantially as herein described with reference to the accompanying drawings.

47. A method of varying valve timing substantially as herein described with reference to the accompanying drawings.

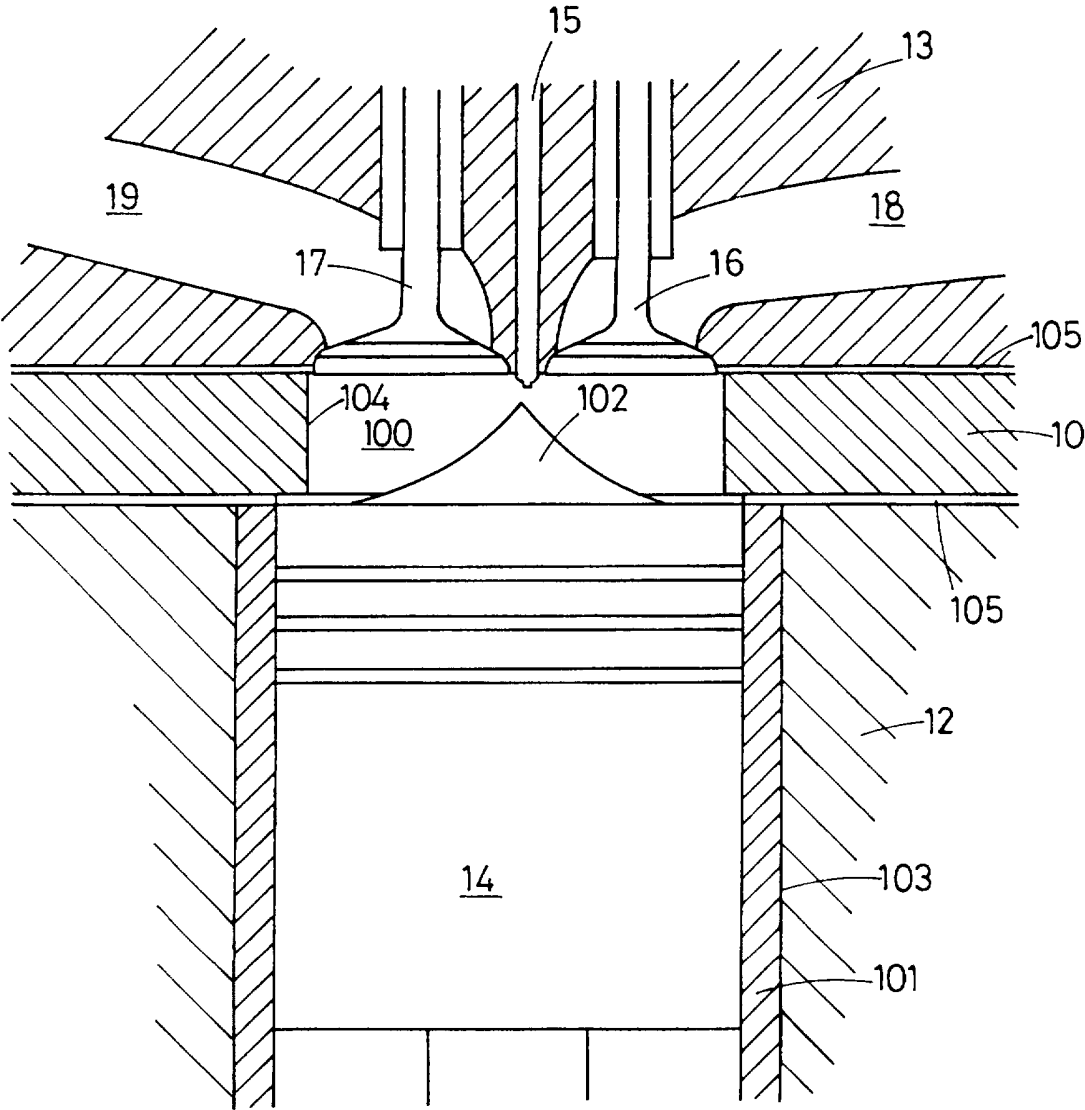


FIG.1

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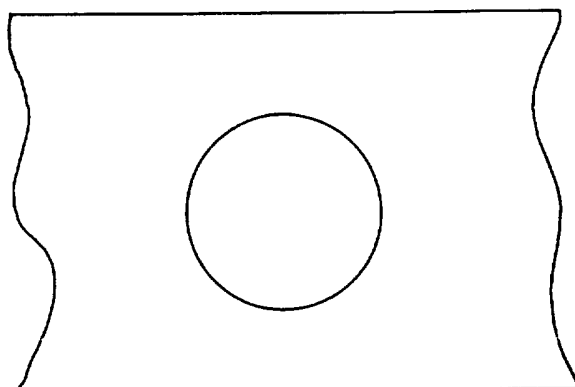


FIG. 2a

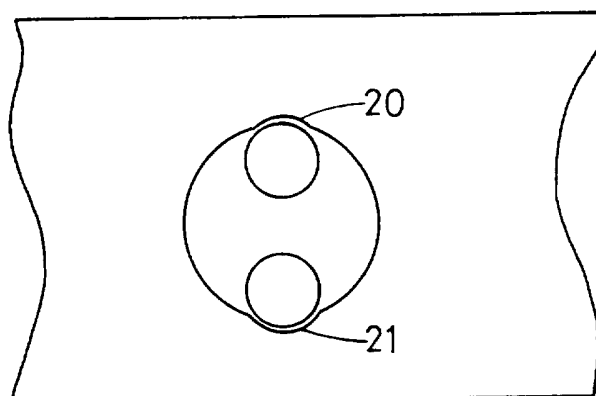


FIG. 2b

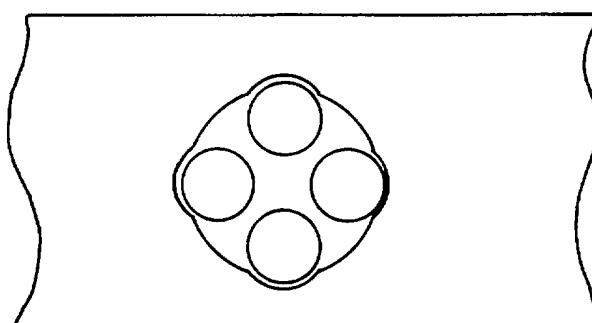


FIG. 2c

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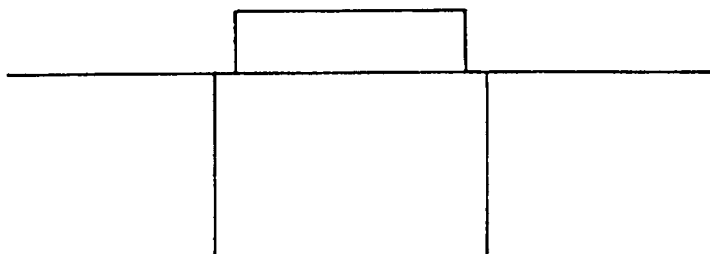


FIG. 3a

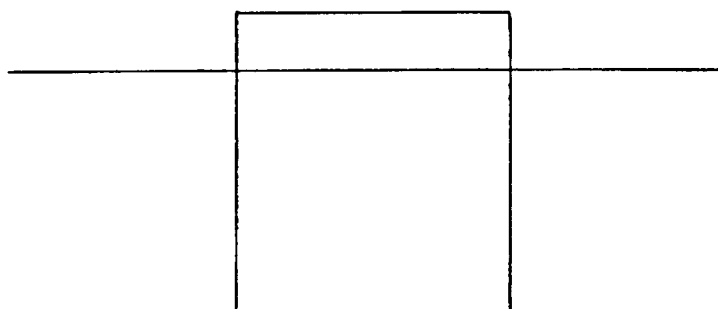


FIG. 3b

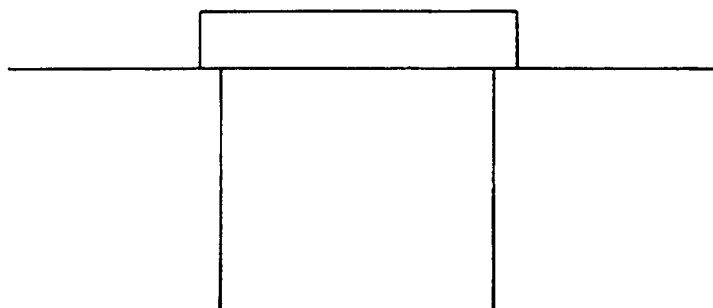
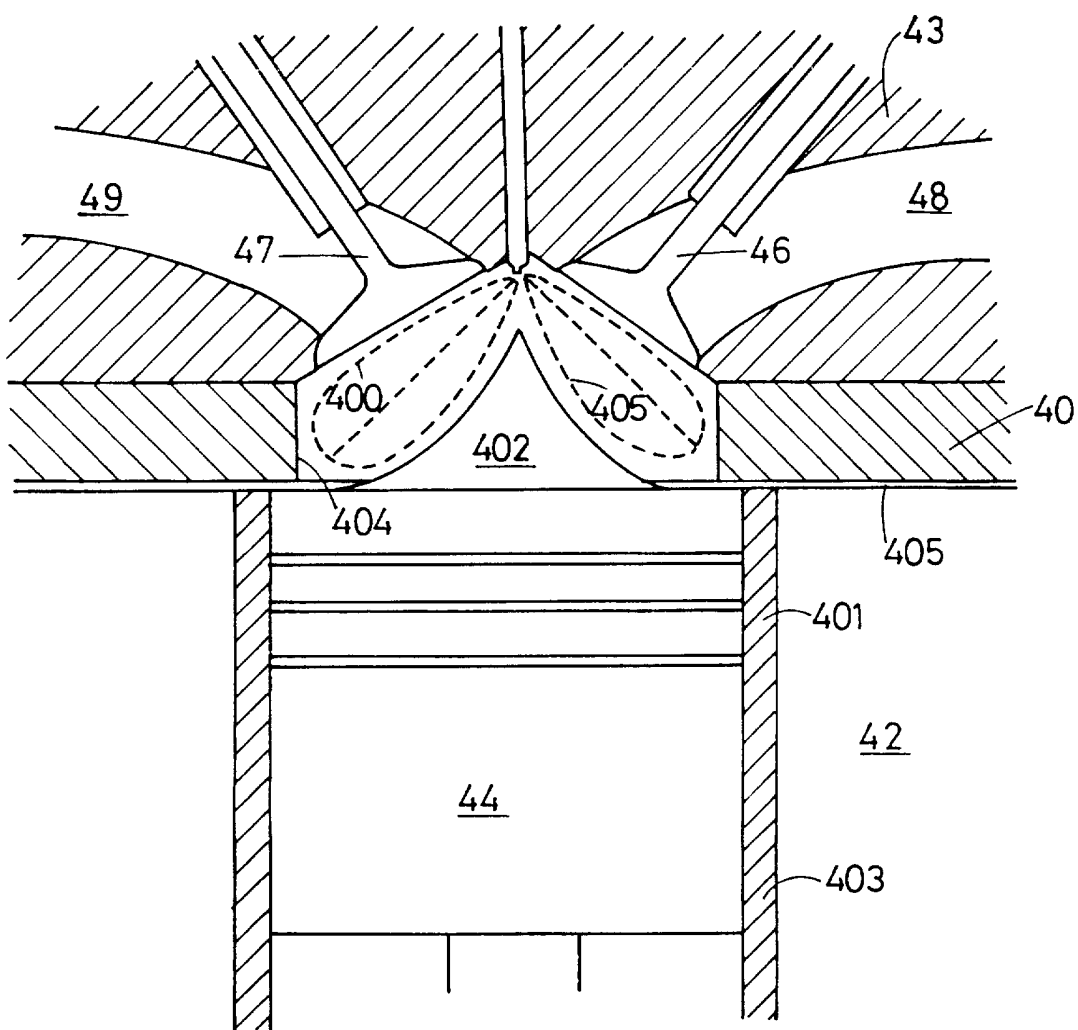
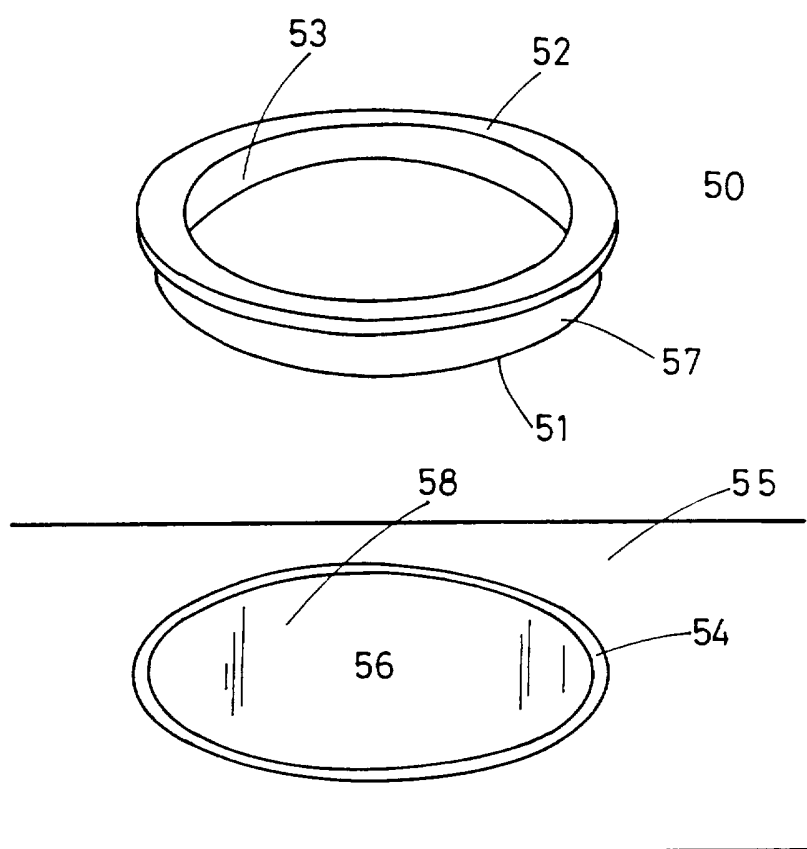


FIG. 3c

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FIG. 4

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FIG. 5

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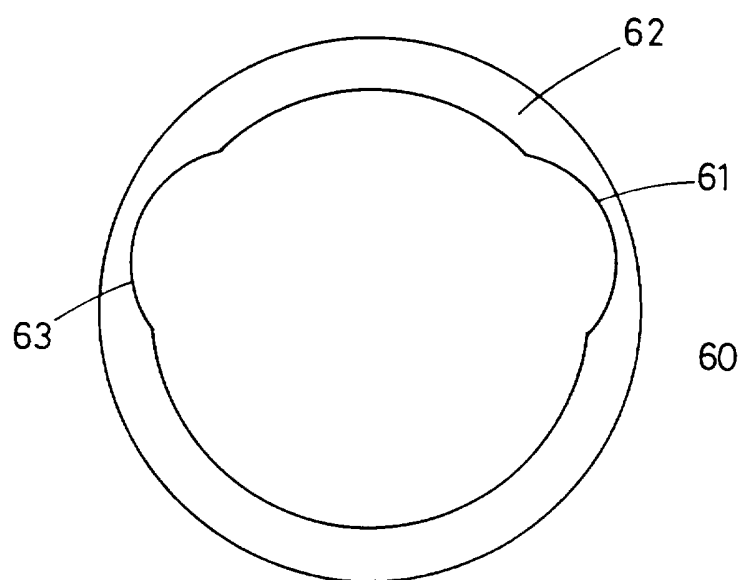


FIG. 6

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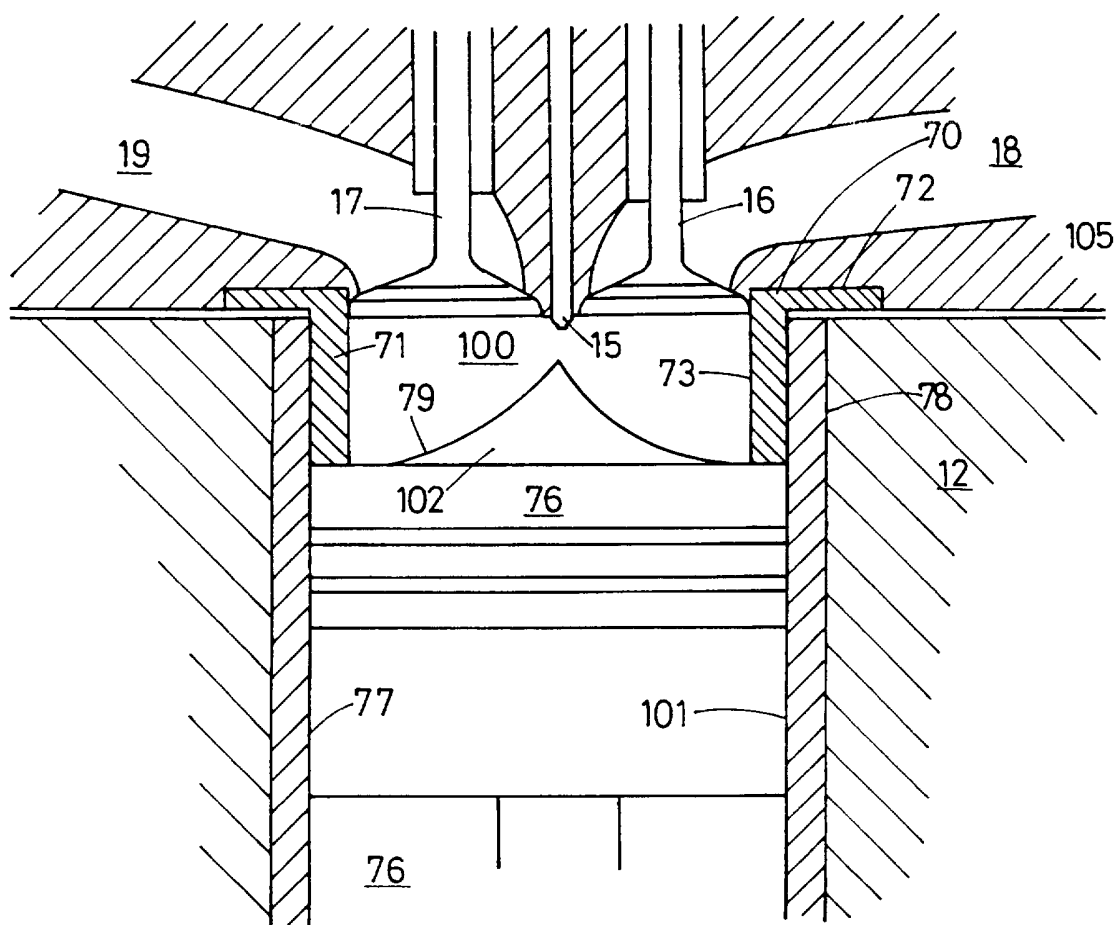


FIG.7

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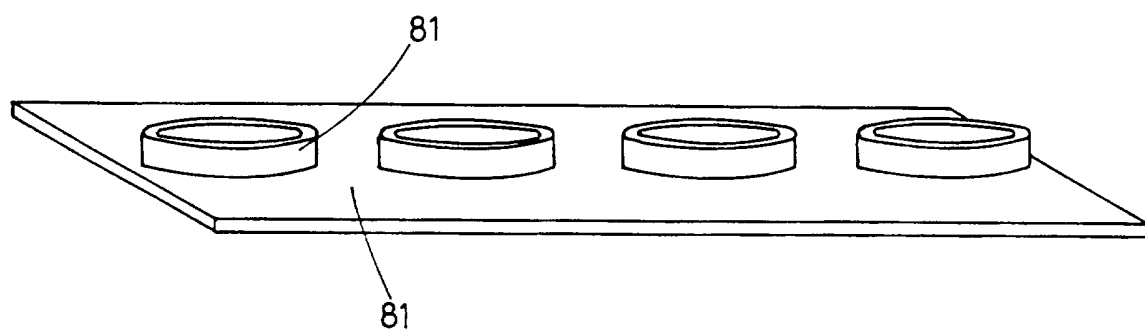


FIG. 8

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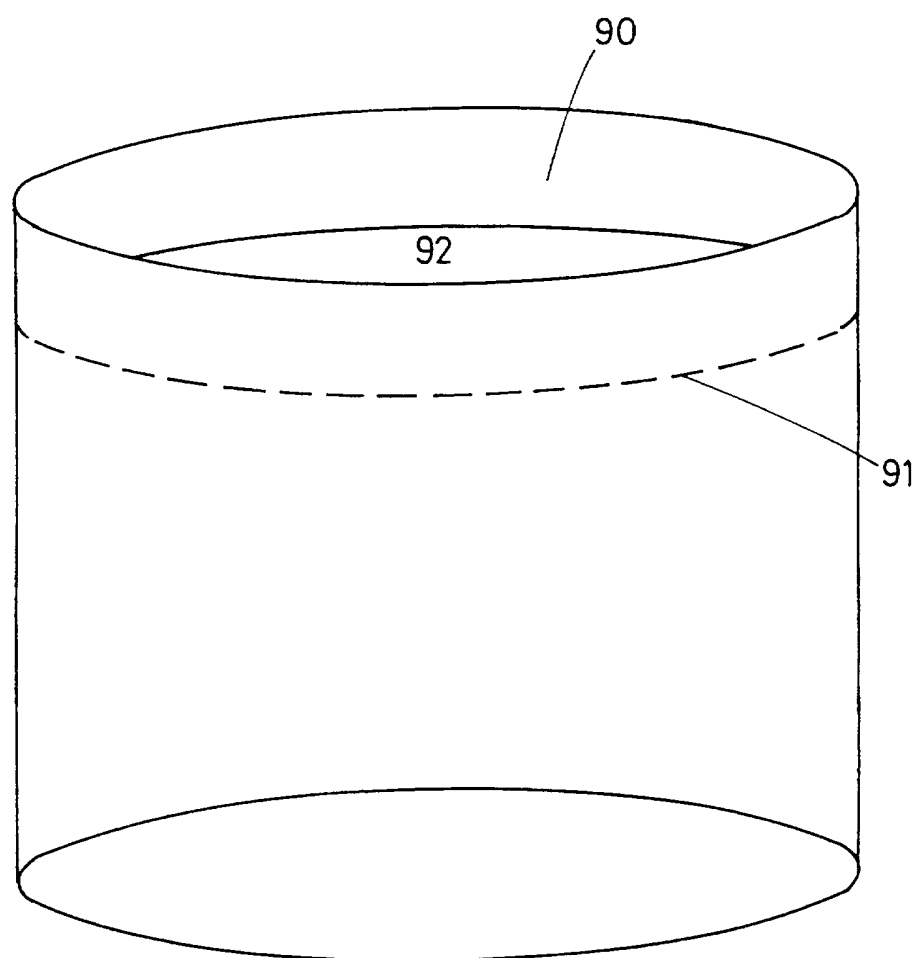


FIG.9

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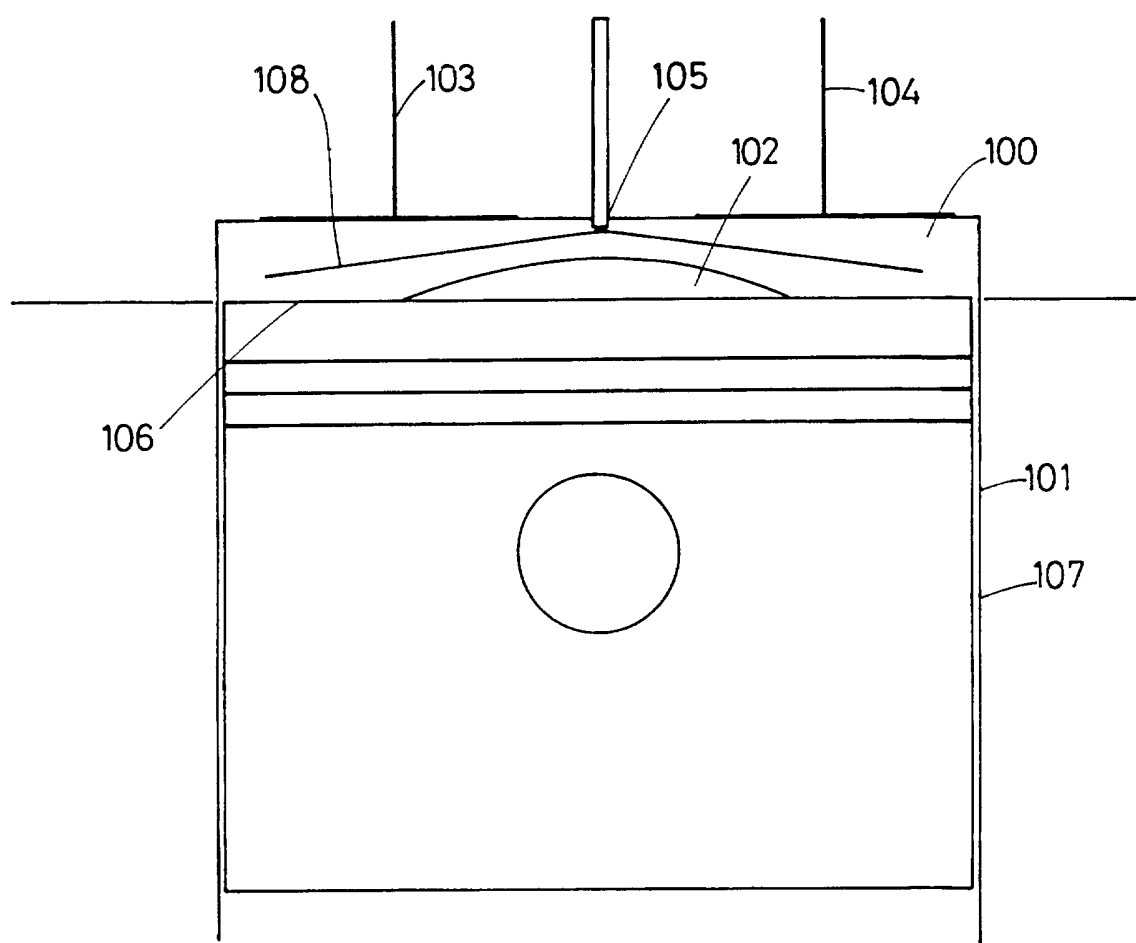
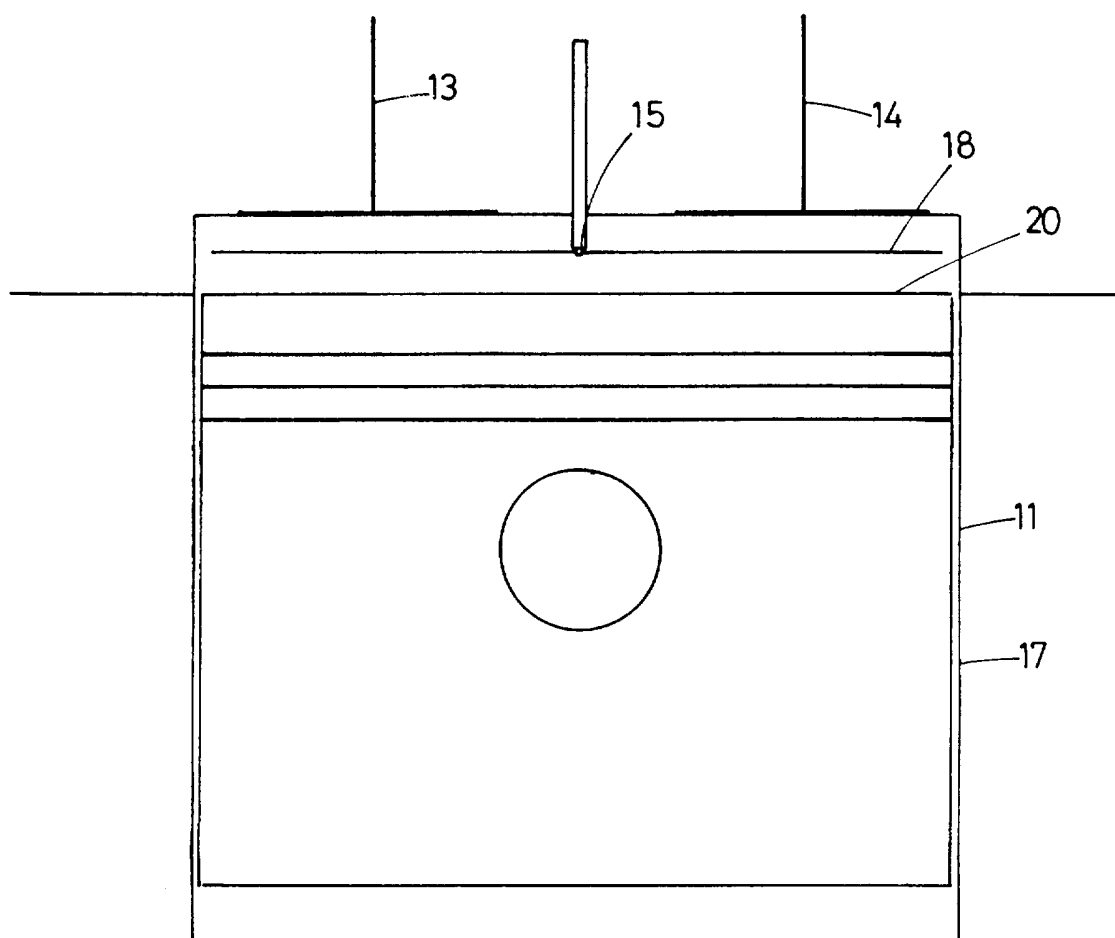


FIG.10

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FIG.11

SUBSTITUTE SHEET

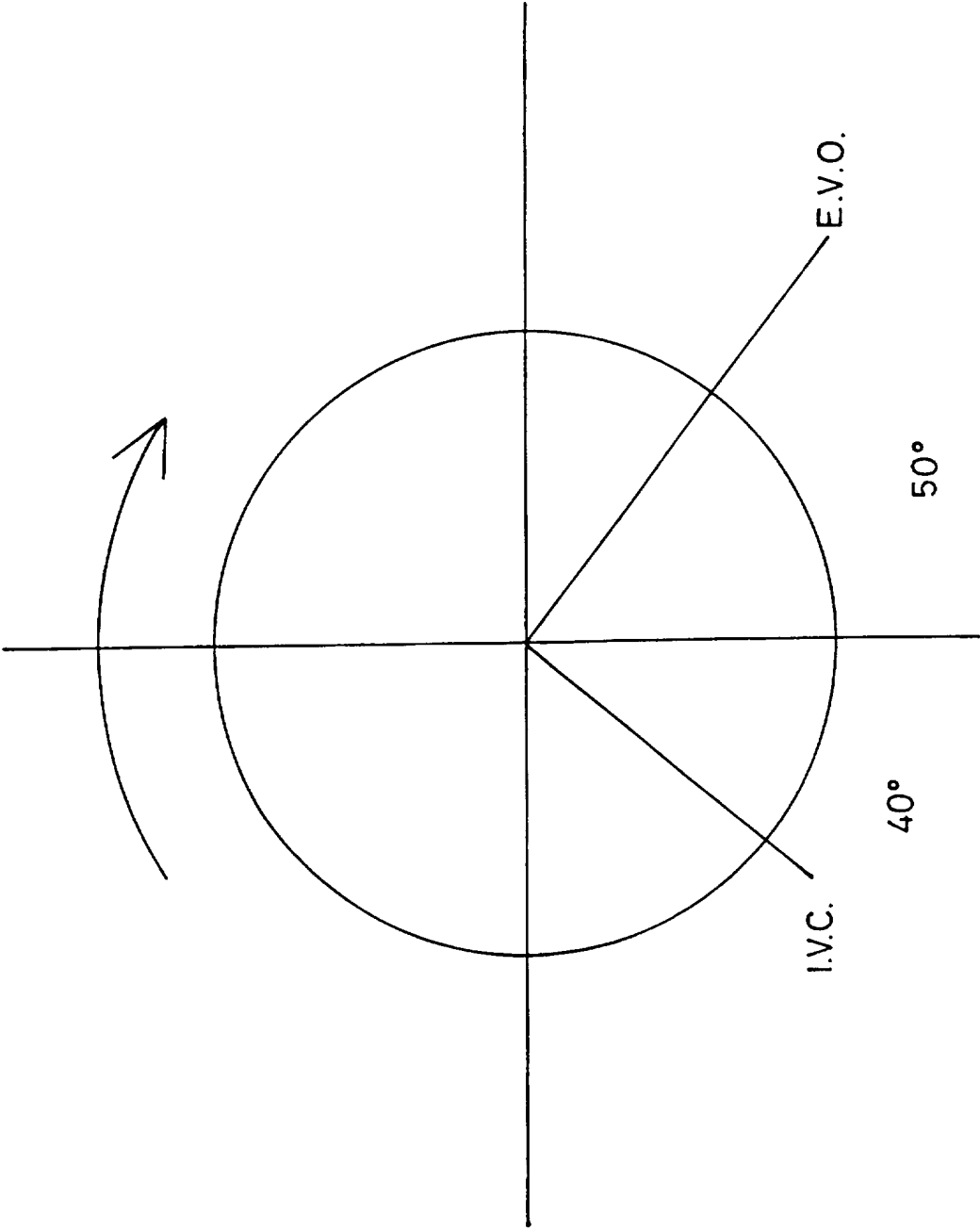


FIG.12

# INTERNATIONAL SEARCH REPORT

International Application No.  
PCT/NZ 96/00128

| <b>A. CLASSIFICATION OF SUBJECT MATTER</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                                                                                                                                                                                                                  |                                                                                    |                                                                                                          |                                                                                                                                                                                                     |                                                                              |                                                                                                                                                                              |                                                                                                                                                                         |                                                                                                                                                                                                                                                  |                                                                              |                                               |                                                                                                        |  |
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| <b>B. FIELDS SEARCHED</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                                                                                                                                                                                  |                                                                                    |                                                                                                          |                                                                                                                                                                                                     |                                                                              |                                                                                                                                                                              |                                                                                                                                                                         |                                                                                                                                                                                                                                                  |                                                                              |                                               |                                                                                                        |  |
| Minimum documentation searched (classification system followed by classification symbols)<br>IPC F01B 31/14 F16J 10/04                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                                                                                                                                                                                                  |                                                                                    |                                                                                                          |                                                                                                                                                                                                     |                                                                              |                                                                                                                                                                              |                                                                                                                                                                         |                                                                                                                                                                                                                                                  |                                                                              |                                               |                                                                                                        |  |
| Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                                                                                                                                                                                                  |                                                                                    |                                                                                                          |                                                                                                                                                                                                     |                                                                              |                                                                                                                                                                              |                                                                                                                                                                         |                                                                                                                                                                                                                                                  |                                                                              |                                               |                                                                                                        |  |
| Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                                                                                                                                                                                  |                                                                                    |                                                                                                          |                                                                                                                                                                                                     |                                                                              |                                                                                                                                                                              |                                                                                                                                                                         |                                                                                                                                                                                                                                                  |                                                                              |                                               |                                                                                                        |  |
| <b>C. DOCUMENTS CONSIDERED TO BE RELEVANT</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                                                                                                                                                                                                  |                                                                                    |                                                                                                          |                                                                                                                                                                                                     |                                                                              |                                                                                                                                                                              |                                                                                                                                                                         |                                                                                                                                                                                                                                                  |                                                                              |                                               |                                                                                                        |  |
| Category*                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | Citation of document, with indication, where appropriate, of the relevant passages                                                                                                                                                               | Relevant to claim No.                                                              |                                                                                                          |                                                                                                                                                                                                     |                                                                              |                                                                                                                                                                              |                                                                                                                                                                         |                                                                                                                                                                                                                                                  |                                                                              |                                               |                                                                                                        |  |
| X<br>Y                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | US 4770133 (SCHIBALSKY) A 13 September 1988<br>See Abstract                                                                                                                                                                                      | 1-3, 6<br>9                                                                        |                                                                                                          |                                                                                                                                                                                                     |                                                                              |                                                                                                                                                                              |                                                                                                                                                                         |                                                                                                                                                                                                                                                  |                                                                              |                                               |                                                                                                        |  |
| X<br>Y                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | US 4474147 (HOOPES) A 2 October 1984<br>See Abstract                                                                                                                                                                                             | 1-3, 6<br>9                                                                        |                                                                                                          |                                                                                                                                                                                                     |                                                                              |                                                                                                                                                                              |                                                                                                                                                                         |                                                                                                                                                                                                                                                  |                                                                              |                                               |                                                                                                        |  |
| X<br>Y                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | US 3489130 (POLIDAN) A 13 January 1970<br>See Figure 2                                                                                                                                                                                           | 1-3<br>9                                                                           |                                                                                                          |                                                                                                                                                                                                     |                                                                              |                                                                                                                                                                              |                                                                                                                                                                         |                                                                                                                                                                                                                                                  |                                                                              |                                               |                                                                                                        |  |
| <input checked="" type="checkbox"/> Further documents are listed in the continuation of Box C <input checked="" type="checkbox"/> See patent family annex                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                                                                                                                                                                                  |                                                                                    |                                                                                                          |                                                                                                                                                                                                     |                                                                              |                                                                                                                                                                              |                                                                                                                                                                         |                                                                                                                                                                                                                                                  |                                                                              |                                               |                                                                                                        |  |
| <p>* Special categories of cited documents:</p> <table border="0"> <tr> <td>"A" document defining the general state of the art which is not considered to be of particular relevance</td> <td>"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</td> </tr> <tr> <td>"E" earlier document but published on or after the international filing date</td> <td>"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</td> </tr> <tr> <td>"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)</td> <td>"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</td> </tr> <tr> <td>"O" document referring to an oral disclosure, use, exhibition or other means</td> <td>"&amp;" document member of the same patent family</td> </tr> <tr> <td>"P" document published prior to the international filing date but later than the priority date claimed</td> <td></td> </tr> </table> |                                                                                                                                                                                                                                                  |                                                                                    | "A" document defining the general state of the art which is not considered to be of particular relevance | "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 | "E" earlier document but published on or after the international filing date | "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 | "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) | "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 | "O" document referring to an oral disclosure, use, exhibition or other means | "&" document member of the same patent family | "P" document published prior to the international filing date but later than the priority date claimed |  |
| "A" document defining the general state of the art which is not considered to be of particular relevance                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | "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                                              |                                                                                    |                                                                                                          |                                                                                                                                                                                                     |                                                                              |                                                                                                                                                                              |                                                                                                                                                                         |                                                                                                                                                                                                                                                  |                                                                              |                                               |                                                                                                        |  |
| "E" earlier document but published on or after the international filing date                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | "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                                                                     |                                                                                    |                                                                                                          |                                                                                                                                                                                                     |                                                                              |                                                                                                                                                                              |                                                                                                                                                                         |                                                                                                                                                                                                                                                  |                                                                              |                                               |                                                                                                        |  |
| "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)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | "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 |                                                                                    |                                                                                                          |                                                                                                                                                                                                     |                                                                              |                                                                                                                                                                              |                                                                                                                                                                         |                                                                                                                                                                                                                                                  |                                                                              |                                               |                                                                                                        |  |
| "O" document referring to an oral disclosure, use, exhibition or other means                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | "&" document member of the same patent family                                                                                                                                                                                                    |                                                                                    |                                                                                                          |                                                                                                                                                                                                     |                                                                              |                                                                                                                                                                              |                                                                                                                                                                         |                                                                                                                                                                                                                                                  |                                                                              |                                               |                                                                                                        |  |
| "P" document published prior to the international filing date but later than the priority date claimed                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                                                                                                                                                                                                  |                                                                                    |                                                                                                          |                                                                                                                                                                                                     |                                                                              |                                                                                                                                                                              |                                                                                                                                                                         |                                                                                                                                                                                                                                                  |                                                                              |                                               |                                                                                                        |  |
| Date of the actual completion of the international search<br>5 February 1997                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                                                                                                                                                                                  | Date of mailing of the international search report<br>13 FEB 1997                  |                                                                                                          |                                                                                                                                                                                                     |                                                                              |                                                                                                                                                                              |                                                                                                                                                                         |                                                                                                                                                                                                                                                  |                                                                              |                                               |                                                                                                        |  |
| Name and mailing address of the ISA/AU<br>AUSTRALIAN INDUSTRIAL PROPERTY ORGANISATION<br>PO BOX 200<br>WODEN ACT 2606<br>AUSTRALIA Facsimile No.: (06) 285 3929                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                                                                                                                                                                                                                  | Authorized officer<br><br><b>VINCE BAGUSAUSKAS</b><br>Telephone No.: (06) 283 2110 |                                                                                                          |                                                                                                                                                                                                     |                                                                              |                                                                                                                                                                              |                                                                                                                                                                         |                                                                                                                                                                                                                                                  |                                                                              |                                               |                                                                                                        |  |

# INTERNATIONAL SEARCH REPORT

International Application No.  
**PCT/NZ 96/00128**

| <b>C (Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT</b> |                                                                                    |                       |
|-------------------------------------------------------------|------------------------------------------------------------------------------------|-----------------------|
| Category*                                                   | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
| A,P<br>Y,P                                                  | WO 96/15362 (TAYLOR) A1 23 May 1996<br>See whole document                          | 1, 14, 32<br>9        |
| A,P<br>Y,P                                                  | WO 96/01939 (TAYLOR) A1 25 January 1996<br>See whole document                      | 1, 14, 32<br>9        |

# INTERNATIONAL SEARCH REPORT

International Application No.

PCT/NZ 96/00128

## Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:  
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:  
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☐ Claims Nos.:  
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a)

## Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

See continuation sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims
2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:  
1 to 9, 14 to 26, 32 to 34

### Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest.
- ☐ No protest accompanied the payment of additional search fees.

# INTERNATIONAL SEARCH REPORT

International Application No.

PCT/NZ 96/00128

## Box Continuation of Box II

The international application does not comply with the requirements of unity of invention because it does not relate to one invention or group of inventions so linked as to form a single general inventive concept. In coming to this conclusion the International Searching Authority has found that there are five inventions:-

1. Claims 1 to 9 and 14 to 26 and 32 to 34 are characterised by a first "special technical feature"; that is a means to change the compression ratio of a reciprocating type internal compression engine.
2. Claims 10 (in particular) to 13 are characterised by a second separate "special technical feature"; that is that the combustion chamber has a shape that accommodates an air/fuel spray pattern in a reciprocating type internal compression engine.
3. Claims 27 (in particular) to 31 are characterised by a third separate "special technical feature"; that is a heat conduction reducing means in a reciprocating type internal compression engine.
4. Claim 35 is characterised by a fourth separate "special technical feature"; that is that heavily turbo charged air is used with reduced compression ratio in an internal combustion engine.
5. Claims 36 (in particular) to 43 are characterised by a fifth separate "special technical feature"; that is that the valve timing is modified to increase turbulence in the air fuel mix in an internal combustion engine.

Since the above groups of claims do not share the identified technical features, a "technical relationship" between the inventions as defined in PCT Rule 13.2 does not exist. Accordingly the international application does not relate to one invention or single inventive concept.

# INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No.

PCT/NZ 96/00128

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

| Patent Document Cited in Search Report |          | Patent Family Member |         |
|----------------------------------------|----------|----------------------|---------|
| DE                                     | 3543668  |                      |         |
| FR                                     | 2591280  |                      |         |
| GB                                     | 2186343  |                      |         |
| IT                                     | 1199694  |                      |         |
| JP                                     | 62139952 |                      |         |
| SE                                     | 8605237  | US                   | 4770133 |
|                                        |          |                      |         |
|                                        |          |                      |         |
|                                        |          |                      |         |
| END OF ANNEX                           |          |                      |         |