Present day diesel engines having aluminum piston assemblies are limited to combustion chamber pressures of approximately 12,410 kPa (1,800 psi) whereas the desire is to increase such pressures up to the 15,170 kPa (2,200 psi) range. To reach such levels the instant piston assembly (76) includes a steel piston member (78) having an upper cylindrical portion (96) of a diameter "D" and a compression height "CH". The ratio of the compression height "CH" to the diameter "D" being within the range of from 60 % to 45 %. The piston member (78) is preferably forged and subsequently machined to precisely controllable dimensions. Moreover, the piston assembly (78) is preferably of the articulated type and includes a forged aluminum piston skirt (80) connected to the piston member (78) through a common wrist pin (82). Engine manufacturers are also demanding a smaller engine package size while retaining power output, improve fuel consumption and decreased emissions. The subject piston member (76) provides a simple and inexpensive solution to the increased power output package size relationship. To insure a small engine package, the piston member (78) has a compression height to maximum diameter ratio within the range of from 60 % to 45 %. The piston member (78) is preferably made from a steel forging to insure a reduced porosity over that of existing standard castings.
**FOR THE PURPOSES OF INFORMATION ONLY**

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

<table>
<thead>
<tr>
<th>AT</th>
<th>Austria</th>
<th>ES</th>
<th>Spain</th>
<th>MG</th>
<th>Madagascar</th>
</tr>
</thead>
<tbody>
<tr>
<td>AU</td>
<td>Australia</td>
<td>FI</td>
<td>Finland</td>
<td>ML</td>
<td>Mali</td>
</tr>
<tr>
<td>BB</td>
<td>Barbados</td>
<td>FR</td>
<td>France</td>
<td>MR</td>
<td>Mauritania</td>
</tr>
<tr>
<td>BE</td>
<td>Belgium</td>
<td>GA</td>
<td>Gabon</td>
<td>MW</td>
<td>Malawi</td>
</tr>
<tr>
<td>BF</td>
<td>Burkina Faso</td>
<td>GB</td>
<td>United Kingdom</td>
<td>NL</td>
<td>Netherlands</td>
</tr>
<tr>
<td>BG</td>
<td>Bulgaria</td>
<td>HU</td>
<td>Hungary</td>
<td>NO</td>
<td>Norway</td>
</tr>
<tr>
<td>BJ</td>
<td>Benin</td>
<td>IT</td>
<td>Italy</td>
<td>RO</td>
<td>Romania</td>
</tr>
<tr>
<td>BR</td>
<td>Brazil</td>
<td>JP</td>
<td>Japan</td>
<td>SD</td>
<td>Sudan</td>
</tr>
<tr>
<td>CA</td>
<td>Canada</td>
<td>KP</td>
<td>Democratic People's Republic of Korea</td>
<td>SE</td>
<td>Sweden</td>
</tr>
<tr>
<td>CF</td>
<td>Central African Republic</td>
<td>KR</td>
<td>Republic of Korea</td>
<td>SN</td>
<td>Senegal</td>
</tr>
<tr>
<td>CG</td>
<td>Congo</td>
<td>LJ</td>
<td>Liechtenstein</td>
<td>SU</td>
<td>Soviet Union</td>
</tr>
<tr>
<td>CH</td>
<td>Switzerland</td>
<td>LK</td>
<td>Sri Lanka</td>
<td>TD</td>
<td>Chad</td>
</tr>
<tr>
<td>CM</td>
<td>Cameroon</td>
<td>LU</td>
<td>Luxembourg</td>
<td>TG</td>
<td>Togo</td>
</tr>
<tr>
<td>DE</td>
<td>Germany, Federal Republic of</td>
<td>MC</td>
<td>Monaco</td>
<td>US</td>
<td>United States of America</td>
</tr>
</tbody>
</table>
- 1 -

Description

PISTON ASSEMBLY AND PISTON MEMBER THEREOF HAVING
A PREDETERMINED COMPRESSION HEIGHT TO DIAMETER RATIO

Technical Field

This invention relates generally to a compact engine piston assembly for a high output internal combustion engine, and more particularly to a piston assembly including a steel piston member capable of resisting relatively high combustion chamber pressures and temperatures.

Background Art

The last several years has seen an increasing emphasis placed on vehicle fuel economy, reduced emissions and increased engine power output. This emphasis has also led to the reduction in vehicle and engine package size.

As present day engines which operate with combustion chamber pressures up to about 12,410 kPa (1800 psi) are converted to higher output engines the piston configuration experiences higher combustion chamber pressures and thermal temperatures. The cooled composite piston disclosed in U.S. Pat. No. 4,581,983 issued to Horst Moebus on April 15, 1986, is an attempt to provide a piston that will withstand such increased pressures and temperatures. However, the upper and lower parts of the Moebus piston are joined together by welding, which is a costly process that preferably is to be avoided.
A more desirable construction to overcome the high combustion chamber pressure and thermal temperature is disclosed in U.S. Pat. No. 4,056,044 issued to Kenneth R. Kamman on November 1, 1977. That above mentioned patent teaches the use of a complex two-piece articulated piston assembly. However, it has been found through experimentation that present technology cast piston members will not provide the high strength, factor of safety, and the long life which are required in today's high combustion chamber pressure engines without excessive quality control restraints. Extensive testing thereof has indicated that the practical level of knowledge on casting procedures is insufficient to resist combustion pressures above about 13,790 kPa (2,000 psi). Specifically, an excessive number of the upper cast steel piston members had so much porosity that premature failure resulted in experimental tests. On the other hand, a few cast steel piston members were manufactured with relatively low levels of porosity so that they survived a relatively rigorous testing program. While extensive studies were conducted to minimize porosity levels in the cast members, from a practical standpoint the levels remain too high. Accordingly, for quality control purposes it has been found necessary to X-ray each piston member thoroughly, and this is simply too costly to do.

Secondly, the benefit of grain flow with a cast piston is negligible and adds little if any structural strength to the piston. The increased combustion chamber pressure and thermal temperature cause pistons of this type to fail causing damage to the engine and downtime of the vehicle.

U.S. Pat. No. 4,662,047 issued to Rutger Berchem on May 5, 1987, discloses a one-piece piston
produced by die pressing of a previously forged blank to bend an annular cylindrical collar thereon. However, the patent fails to teach or suggest a relative low ratio of the compression height to the piston diameter, the application thereof in conjunction with an articulated piston, or its used in a high combustion chamber pressure engine.

The U.S. Pat. No. 4,704,950 issued to Emil Ripberger et al. on November 10, 1987, teaches the use of a single piece, extremely light and low friction non-articulated piston having a ratio of the compression height to the piston diameter of from 0.20 to 0.35. The range as taught by this patent fails to be acceptable when used with a high combustion chamber pressure engine due to the lack of sufficient structural integrity. For example, analytical data has shown that the portion carrying the rings could not withstand the loads and would structurally fail.

In addition to porosity considerations, it should be appreciated that the structural shape and strength of each element of an articulated piston is in a continual stage of being modified to better resist higher compressive loads, thermally induced forces and contain costs. For example, Society of Automotive Engineers, Inc., Paper No.770031 authored by M. D. Roehle, entitled "Pistons for High Output Diesel Engines", and presented circa February 28, 1977, is indicative of the great number of laboratory tests conducted throughout the world on the individual elements. That paper also discusses a number of considerations to minimize cracking problems in light alloy or aluminum piston members resulting primarily from thermal constraints. One consideration involves the desirability of increasing the distance between the upper edge of the wrist pin bore to the underside
of the crown to reduce stresses in the pin bore region. However, in marked contradiction, it is becoming more important to reduce the so-called critical height "CH" of the piston member, which is defined by the elevational distance between the top surface thereof and the central axis of the wrist pin in order to provide increased compactness or reduced engine package size and to lower overall costs.

Thus, what is needed is a high output engine piston assembly and piston member therefor which is capable of continuous and efficient operation at combustion chamber pressures above about 13,790 kPa (2,000 psi), and preferably in the region of about 15,170 kPa (2,200 psi). Furthermore, the piston member should be relatively easy to manufacture by having a configuration substantially devoid of complex shapes to allow the manufacturing thereof. Moreover, the upper portion of the piston member should preferably be as smooth and symmetrical as possible to avoid stress risers and/or differential thermal distortion thereof. And still further, the compressive height "CH" of the piston member should preferably be as small as structurally practical for maximizing compactness.

The present invention is directed to overcoming one or more of the problems as set forth above.

**Disclosure of the Invention**

In one aspect of the present invention, a steel piston member for reciprocable movement in a high combustion chamber pressure engine comprises an upper portion of substantially cylindrical shape and having a preestablished maximum diameter "D", a lower
portion, a compression height "CH", and a
preestablished ratio of the compression height "CH" to
the preestablished maximum diameter "D". The upper
portion has a peripheral top surface, a tubular wall
depending from the top surface, an annular outwardly
facing wall surface and an annular cooling recess.
The lower portion includes a pair of depending pin
bosses blendingly associated with the outwardly facing
wall surfaces. The pin bosses individually define a
wrist pin receiving bore aligned on a common axis.
The compression height "CH" is defined by the
elevational distance between the common axis and the
top surface. The preestablished ratio of the
compression height "CH" to the preselected maximum
diameter "D" is within the range of from 60% to 45%.

In another aspect of the invention, an
articulated piston assembly for reciprocateable
movement in a high combustion chamber pressure engine
comprises a steel piston member having an upper
portion having a preestablished maximum diameter "D"
and a lower portion, a compression height "CH", a
preestablished ratio of the compression height "CH" to
the preselected maximum diameter "D" being within the
range of from 60% to 45%, a skirt and a wrist pin.
The upper portion has a peripheral top surface, a
tubular wall depending from the top surface, an
annular outwardly facing wall surface and an annular
cooling recess. The lower portion includes a pair of
depending pin bosses blendingly associated with the
outwardly facing wall surfaces. The pin bosses
individually define a wrist pin receiving bore aligned
on a common axis. The skirt is of generally or
slightly elliptical shape. The skirt is slidably
positioned on the lower portion and has a pair of
wrist pin receiving bores aligned with the common
axis. The wrist pin is slidably disposed in the pair of wrist pin receiving bores.

In another aspect of the invention, an articulated piston assembly is adapted for use in a high combustion chamber pressure engine having a combustion chamber pressure in excess of about 13,790 kPa (2000 psi) comprises a steel piston member having an upper portion having a preestablished maximum diameter "D" and a lower portion, a compression height "CH", a preestablished ratio of the compression height "CH" to the preselected maximum diameter "D" being within the range of from 60% to 45%, a skirt and a wrist pin. The upper portion has a peripheral top surface, a tubular wall depending from the top surface, an annular outwardly facing wall surface and an annular cooling recess. The lower portion includes a pair of depending pin bosses blendingly associated with the outwardly facing wall surfaces. The pin bosses individually define a wrist pin receiving bore aligned on a common axis. The skirt is of a generally or slightly elliptical shape and also has a pair of wrist pin receiving bores aligned with the common axis. The wrist pin is slidably disposed in the two pairs of wrist pin receiving bores.

In another aspect of the invention, an articulated piston assembly having a relative low compression height to diameter ratio adapted for use in a high combustion chamber pressure engine having a combustion chamber pressure of about 13,790 kPa (2000 psi) comprises a steel piston member having an upper portion and a lower portion which are integrally formed of steel, a skirt of slightly elliptical shape having a top surface in non-contacting relationship to the upper portion is slidably positioned about the
lower portion and has a wrist pin slidably connecting the skirt to the piston member.

The present invention provides structural members which represent a simple, inexpensive, and lightweight solution to resist the increasing combustion pressures and combustion temperatures of today's and future engines.

**Brief Description of the Drawings**

Fig. 1 is a diagrammatic, fragmentary, transverse vertical sectional view of an engine piston assembly constructed in accordance with the present invention;

Fig. 2 is a longitudinal vertical sectional view of a portion of the piston assembly illustrated in Fig. 1 as taken along the line II-II thereof;

Fig. 3 is an enlarged fragmentary portion of the top peripheral region of the piston member shown in Fig. 1 and 2 to better show details of construction thereof;

Fig. 4 is a top view of the piston member shown in Fig. 2 as taken along line IV-IV thereof;

Fig. 5 is a top view solely of the piston skirt shown in Fig. 2 as taken along line V-V thereof;

Fig. 6 an enlarged fragmentary cross sectional view of the top peripheral region of the piston member shown in Figs. 1 and 2 which shows the flow lines of a simple forged piston member with only a portion of the cooling recess forged; and

Fig. 7 is an enlarged fragmentary cross sectional view of the top peripheral region of the piston member shown in Figs. 1 and 2 which shows the flow lines of a forged piston member with a deeply forged cooling recess.
Best Mode for Carrying Out the Invention

Referring now to Figs. 1 and 2, an internal combustion engine 10 of the multi-cylinder type includes a bottom block 12, a top block or spacer portion 14, and a cylinder head 16 rigidly secured together in the usual way by a plurality of fasteners or bolts 18 which pass through the head and block and are screwthreadably received in the bottom block. A mid-supported cylinder liner 48 has an upper portion 52 positioned in the top block portion 14 and is provided with coolant flow therearound. The engine 10 could be of any conventional design.

The engine 10 further includes a cooling oil directing nozzle 74 as is shown in the lower right portion of Fig. 1. This nozzle is rigidly secured to the bottom block 12 and is operationally associated with a conventional source of pressurized oil, not shown, to supply oil or the like to an articulated piston assembly 76.

The piston assembly 76 of the engine 10 includes an upper steel piston member 78 and a lower aluminum piston skirt 80 which are rockably mounted on a common wrist pin or gudgeon pin 82 having a longitudinally oriented central axis 84. The wrist pin is also of steel material and has an external cylindrical surface 86, and a cylindrical bore 88 therethrough for weight reduction purposes. A conventional connecting rod 90 of a tepee configuration has an upper eye end 92, and a steel-backed bronze sleeve bearing 94 therein is operationally connected to, and driven by, the wrist pin.

The steel piston member 78 has an upper portion 96 of substantially cylindrical shape and a
preselected maximum diameter "D" as is illustrated in Fig. 2. The upper portion 96 has a peripheral top surface 98 that is flat, or is located on a plane perpendicular to the central axis 66, and a crown surface 100 that in the instant example is a fully machined surface of revolution about the central axis 66. In general, the crown surface has a centrally located apex portion 102 elevationally disposed below the top surface, a peripheral or radially outer land portion 104 that is substantially cylindrical and an annular trough 106 that smoothly blends with the apex and outer land portions. The combination of the apex portion 102, the annular trough 106 and the outer land portion 104 greatly improves combustion efficiency.

As is shown best in Fig. 3, the piston member 78 further includes a tubular wall 108 that depends from the outer edge of the top surface 98 and defines in serially depending order fully around the periphery thereof a top land 110, a top ring groove 112 having a keystone or wedge-like shape in cross section, an upper intermediate land 114, an intermediate ring groove 116 of rectangular cross section, a lower intermediate land 118, a bottom ring groove 120 of rectangular cross section, and a bottom land 122 that is terminated by a lower end surface 124. An annular radially inwardly facing wall surface 126 is also delineated by the wall 108 and extends upwardly from the end surface 124. The upper portion 96 is additionally defined by an annular radially outwardly facing wall surface 128 and a downwardly facing transition portion 130 that is blendingly associated with the wall surfaces 126 and 128 to collectively define an annular cooling recess 132 of a precisely defined cross sectional shape. In actuality, the wall surface 128 is defined by an upper
fully conical portion 134 having an inclination angle 
"A" with respect to the central axis 66 of 
approximately 12 degrees as is shown in Fig. 3, and a 
fully cylindrical portion 136 below it. On the other 
hand the wall surface 126 is fully conical and has an 
inclination angle "B" of approximately 1.7 degrees. 
As an alternative, the annular cooling recess 132 
could be of any configuration to be forged such as the 
shallow recess shown in Fig. 6 or as an alternative 
the deep recess as shown in Fig. 7. As further shown 
in Figs. 6 and 7, the grain flow obtained with a 
forging are shown by use of phantom lines.

The steel piston member 78 further includes 
a lower portion 158 including a pair of depending pin 
 bosses 160 blendingly associated with the outwardly 
 facing wall surface 128 of the upper portion 96, and 
 blendingly associated also with a downwardly facing 
 concave pocket 162 defined by the upper portion. The 
 concave pocket is spaced substantially uniformly away 
 from the apex portion 102 of the crown surface 100 so 
 as to define a crown 164 of generally uniform 
 thickness "C" of about 4 or 5mm as is shown in Figs. 2 
 and 3. Moreover, these figures also illustrate and 
 define a relatively thin and substantially conically 
 oriented web 166 of a minimum thickness "W" of about 4 
 to 7mm between the trough 106 and juxtaposed land 
 portion 104 of the crown surface 100, and the 
 outwardly facing wall surface 128. Each of the pin 
 bosses 160 has a bore 168 therethrough which are 
 adapted to individually receive a steel-backed bronze 
 bearing sleeve 170 therein. These bearing sleeves are 
 axially aligned to receive the wrist pin 82 pivotally 
 therein.

Referring now to the piston skirt 80, it has 
a top peripheral surface 172 in close non-contacting
relationship with the lower end surface 124 of the upper portion 96 of the piston member 78 with a fully annular, upwardly facing oil trough 174 defined therein. It further has a slightly elliptical external surface 176 therearound which depends from the top surface. The skirt 80 further has a maximum diameter 177 and a minimum diameter 177a. A pair of aligned wrist pin receiving bores 178 are formed through the piston skirt and are axially aligned with the minimum diameter 177a, and each of the bores has a snap ring receiving groove 180 therein. The piston skirt is thus pivotally mounted on the wrist pin 82 which is slidably insertably positioned in both bores. Excessive movement of the wrist pin is prevented along the axis 84 by a pair of split retaining rings 182 individually disposed in the grooves 180.

A pair of axially oriented bosses 184 are defined within the skirt 80 so that a corresponding pair of lubrication passages 186 can be provided fully axially therethrough. The lubrication passages are positioned diagonally opposite each other so that the skirt can be mounted on the wrist pin 82 in either of the two possible positions, and so at least one of them will be axially aligned with the oil jet nozzle 74. The skirt is also provided with diagonally opposite, semi-cylindrical recesses 188 which open downwardly at the bottom of the skirt to provide clearance from the nozzle when the skirt is reciprocated to its lowest elevational position.

**Industrial Applicability**

The steel piston member 78 in this application is used with an articulated piston assembly 76. The articulated piston assembly is used
in a high combustion chamber pressure engine 10 having a combustion chamber pressure of 15,170 kPa (2200 psi). The articulated piston assembly 76 allows the power output to be increased and reduces the engine package size. As shown in Fig. 1, the articulated piston assembly 76 is used with an engine 10 having a mid-supported cylinder liner 48 and a two piece cylinder block 12,14 construction. Liquid cooling is positioned in only the top block 14 of the two piece block and provides excellent cooling or heat dissipation for the piston assembly.

In operation, the articulated piston assembly 76 reciprocates downwardly to bottom dead center whereupon the nozzle 74 directs lubricating oil into the skirt passage 186 aligned therewith. The oil jet continues upwardly whereupon it makes contact with the surfaces of the cooling recess 132 of the piston member 78 and is splashed peripherally in opposite directions. A significant portion of the oil is caught by the skirt trough 174 as the piston assembly is reciprocated and further more evenly distributed around the interior of the piston member.

Referring to Fig. 3, it may be noted that the top of the cooling recess 132 is elevationally disposed directly underneath the peripheral top surface 98 of the piston member, and within an elevational distance therefrom identified by the letter "E" of about 5mm. It has been concluded that the ratio of the distance "E" to the piston diameter "D" should be below about 0.10, and preferably should be between about 0.04 and 0.06. In one embodiment the diameter "D" was 124mm, and the distance "E" was 5.5mm which provides a ratio thereof of approximately 0.044.

In the same embodiment the elevational distance "CH" between the top surface 98 and the wrist
pin axis 84 was 70mm. Therefore, the ratio of "CH" to "D" was about 0.56. It was subsequently concluded that the ratio of "CH" to "D" should be below about 0.60, and preferably should be between about 0.60 and 0.45.

In addition to the dimensional constraints mentioned above, it is to be appreciated that the articulated piston assembly 76 is preferably manufactured in a particular way and by using certain materials. For example, the upper steel piston member 78 is preferably forged from an alloy steel which is basically 4140 modified steel.

The lower aluminum piston skirt 80 is likewise preferably forged from a modified aluminum which is basically SAE 321-T6 modified aluminum.

The aforementioned alloy steel is particularly adaptable to a Class II forging, and can provide an austenitic grain size 5 or finer which is highly desirable to resist the high combustion pressures associated with the high combustion chamber pressure engine. Thus, the grain flow, primarily in the web 166, as shown in Figs. 6 and 7, and grain size allows the forces to be resisted or transmitted and provides the high strength, factor of safety and long life which is required in today's high combustion chamber pressure engines.

The aforementioned forged aluminum alloy has a high hardness, excellent wear resistance, and a relatively low coefficient of thermal expansion.
Claims

1. A steel piston member (78) for reciprocatable movement in a high combustion chamber pressure engine (10) comprising:
   an upper portion (96) of substantially cylindrical shape and having a preestablished maximum diameter "D", a peripheral top surface (98), a tubular wall (108) depending from the top surface (98), an outwardly facing wall surface (128) and a downwardly facing annular cooling recess (132);
   a lower portion (158) including a pair of depending pin bosses (160) blendingly associated with the outwardly facing wall surface (128), said pin bosses (160) individually defining a wrist pin receiving bore (168) aligned on a common axis (84);
   a compression height "CH" defined by the elevational distance between the common axis (84) and the top surface (98); and
   a preestablished ratio of the compression height "CH" to the preselected maximum diameter "D" being within the range of from 60% to 45%.

2. The piston member (78) of claim 1 wherein said upper portion (96) and lower portion (158) are an integrally formed forging.

3. The piston member (78) of claim 1 wherein said annular cooling recess (132) is located elevationally beneath the top surface (98).

4. The piston member (78) of claim 1 wherein said upper portion (96) has a crown surface (100).
5. The piston member (78) of claim 4 within said crown surface (100) has an centrally located apex portion (102) and an annular trough (106) blending therewith.

6. An articulated piston assembly (76) for reciprocable movement in a high combustion chamber pressure engine (10) comprising:
   a steel piston member (78) having an upper portion (96) and a lower portion (158);
   the upper portion (96) being substantially cylindrical in shape and having a preestablished maximum diameter "D", a peripheral top surface (98), a tubular wall (108) depending from the top surface (98), an annular outwardly facing wall surface (128) and a downwardly facing annular cooling recess (132);
   the lower portion (158) including a pair of depending pin bosses (160) blendingly associated with the outwardly facing wall surface (128), said pin bosses (160) individually defining a wrist pin receiving bore (168) aligned on a common axis (84);
   a compression height "CH" defined by the elevational distance between the common axis (84) and the top surface (98);
   a preestablished ratio of the compression height "CH" to the preselected maximum diameter "D" being within the range of from 60% to 45%;
   a skirt (80) positioned about the lower portion (158) and having a pair of wrist pin receiving bores (88) aligned with the common axis (84); and
   a wrist pin (82) slidably disposed in the pair of wrist pin receiving bores (88,168) of the skirt (80) and the lower portion (158).
7. The piston assembly (76) of claim 6 wherein said upper portion (96) and lower portion (158) are an integrally formed steel forging.

8. The piston assembly (76) of claim 6 wherein said annular cooling recess (132) is located elevationally beneath the top surface (98).

9. The piston assembly (76) of claim 7 wherein said upper portion (96) has a crown (100).

10. The piston assembly (76) of claim 9 wherein said crown surface (100) has a centrally located apex portion (102) and an annular trough (106) blending therewith.

11. The piston assembly (76) of claim 6 wherein said skirt (80) is generally or slightly elliptical shaped.

12. The piston assembly (76) of claim 11 wherein said skirt (80) further has a maximum diameter and a minimum diameter and said pair of wrist pin receiving bores (178) are positioned in alignment with the minimum diameter.

13. The piston assembly (76) of claim 12 wherein said skirt (80) further has a top surface (172) in close non-contacting relationship with the lower end surface (124) of the upper portion (96).

14. The piston assembly (76) of claim 13 wherein said skirt (80) further has a generally annular recess (174) in the top surface (172) and a
pair of passages (186) for communicating a cooling fluid thereto.

15. The piston assembly (76) of claim 14 wherein said recess (174) stores the cooling fluid and splashes it during reciprocation of the piston assembly (76) against the recess (174).

16. The piston assembly (76) of claim 15 wherein each of said pair of wrist pin receiving bores (178) forms an inner surface and each of the surfaces has an annular ring groove (180) therein.

17. The piston assembly (76) of claim 16 further includes a snap rings (182) positioned in each of the grooves (180) in order to retain the wrist pin (82) therebetween.

18. An articulated piston assembly (76) adapted for use in a high combustion chamber pressure engine (10) having a combustion chamber pressure in excess of above 13,790 kPa (2000 psi) comprising:

   a steel piston member (78) having an upper portion (96) and a lower portion (158);

   the upper portion (96) being substantially cylindrical in shape and having a preestablished maximum diameter "D", a peripheral top surface (98), a tubular wall (108) depending from the top surface (98), an annular outwardly facing wall surface (128) and a downwardly facing cooling recess (132);

   the lower portion (158) including a pair of depending pin bosses (160) blendingly associated with the outwardly facing wall surface (128), said pin bosses (160) individually defining a wrist pin receiving bore (168) aligned on a common axis (84);
a compression height "CH" defined by the elevational distance between the common axis (84) and the top surface (98);

a preestablished ratio of the compression height "CH" to the preselected maximum diameter "D" being within the range of from 60% to 45%;

a skirt (80) of generally or slightly elliptical shape slidably positioned on the lower portion (158) and having a pair of wrist pin receiving bores (168) aligned with the common axis (84); and

a wrist pin (82) slidably disposed in the pair of wrist pin receiving bores (168).

19. An articulated piston assembly (76) having a relative low compression height to diameter ratio adapted for use in a high combustion chamber pressure engine (10) having a combustion chamber pressure of about 13,790 kPa (2000 psi) comprising:

a steel piston member (78) having an upper portion (96) and a lower portion (158) being integrally formed of steel;

a skirt (80) of slightly elliptical shape having a top surface (172) in close non-contacting relationship to the upper portion (96) and slidably positioned about the lower portion (158); and

a wrist pin (82) slidably connecting the skirt (80) to the piston member (78).

20. The articulated piston assembly (76) of claim 19 wherein said upper portion (96) has a top surface (98) and a preselected maximum diameter, said lower portion (158) has a pair of wrist pin receiving bore (168) aligned on a common axis (84), said skirt (80) has a pair of wrist pin receiving bores (178) aligned with the common axis (84), a compression
height "CH" is defined by the elevational distance between the common axis (84) and the top surface (98) and a preselected ratio of the compression height "CH" to the preselected maximum diameter "D" being within the range of from 60% to 45%.
**INTERNATIONAL SEARCH REPORT**

**I. CLASSIFICATION OF SUBJECT MATTER**

According to International Patent Classification (IPC) or to both National Classification and IPC

**IPC4:** F 02 F 3/00

**II. FIELDS SEARCHED**

<table>
<thead>
<tr>
<th>Classification System</th>
<th>Classification Symbols</th>
</tr>
</thead>
<tbody>
<tr>
<td>IPC4</td>
<td>F 01 P; F 02 F; F 16 J</td>
</tr>
</tbody>
</table>

Documentation Search other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched

**III. DOCUMENTS CONSIDERED TO BE RELEVANT**

<table>
<thead>
<tr>
<th>Category</th>
<th>Citation of Document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to Claim No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>US, A, 4180027 (TAYLOR) 25 December 1979, see the whole document</td>
<td>1-20</td>
</tr>
<tr>
<td>X</td>
<td>DE, C2, 3210771 (ELSBETT, LUDWIG, ELSBETT GÜNTER) 7 July 1988, see column 5, line 3 - line 23; figure 6</td>
<td>1-20</td>
</tr>
<tr>
<td>A</td>
<td>DE, A1, 3742616 (MAHLE GMBH) 28 July 1988, see the whole document</td>
<td>1,6,18, 20</td>
</tr>
</tbody>
</table>

* Special categories of cited documents: 10

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing data or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"A" document member of the same patent family

**IV. CERTIFICATION**

Date of the Actual Completion of the International Search: 5th June 1989

Date of Mailing of this International Search Report: 14.06.89

International Searching Authority: EUROPEAN PATENT OFFICE

Signature of Authorized Officer: [Signature]

Form PCT/ISA/210 (second sheet) (January 1985)
This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report.
The members are as contained in the European Patent Office (EPO) file on 03/03/99.
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

<table>
<thead>
<tr>
<th>Patent document cited in search report</th>
<th>Publication date</th>
<th>Patent family member(s)</th>
<th>Publication date</th>
</tr>
</thead>
<tbody>
<tr>
<td>DE-C2- 3210771</td>
<td>07/07/88</td>
<td>EP-A-B- 0106935</td>
<td>02/05/84</td>
</tr>
<tr>
<td></td>
<td></td>
<td>JP-A- 59058137</td>
<td>03/04/84</td>
</tr>
<tr>
<td></td>
<td></td>
<td>US-A- 4593660</td>
<td>10/06/86</td>
</tr>
</tbody>
</table>

For more details about this annex: see Official Journal of the European Patent Office, No. 12/82.