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(54) **OPOC ENGINE**

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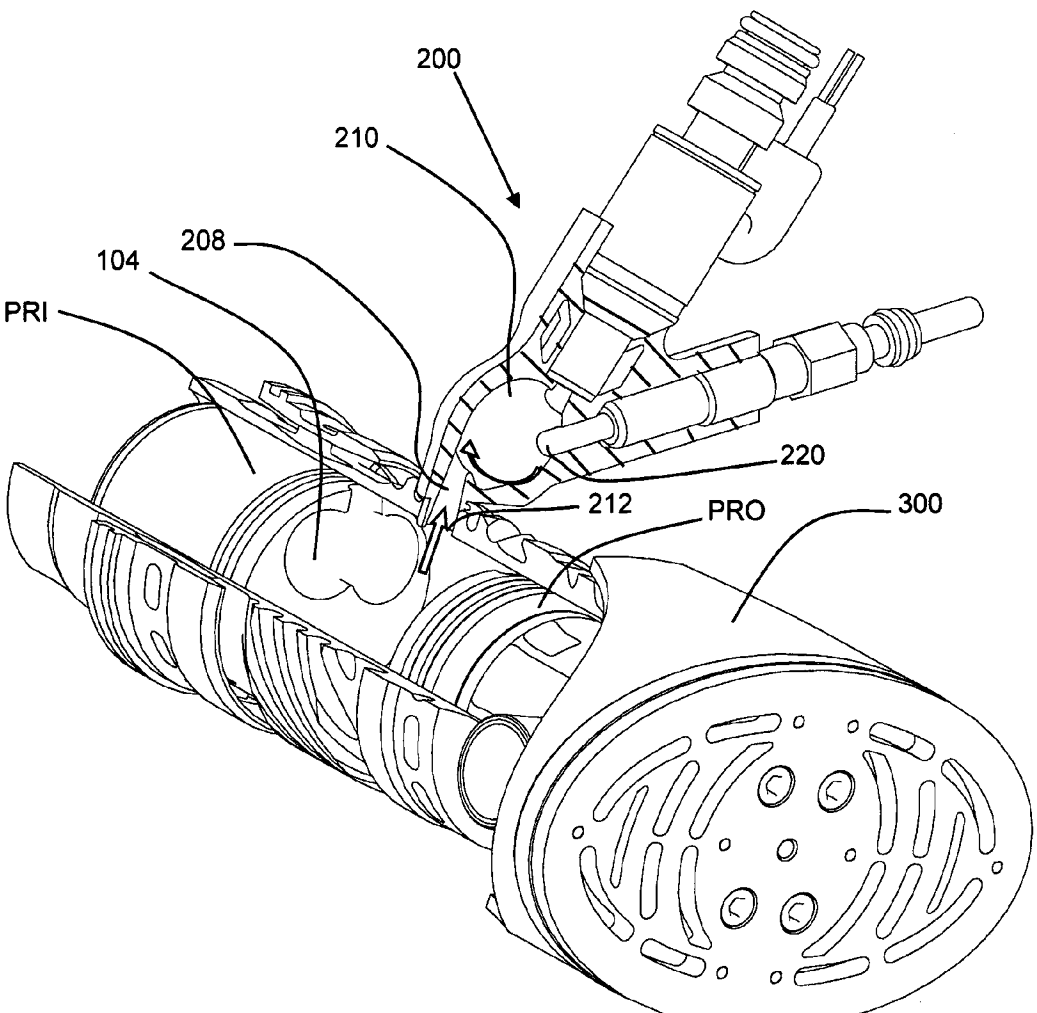
(57) **ABSTRACT**

An Opposing Piston Opposing Cylinder ("OPOC") internal combustion engine combined with an externally mounted pre-ignition assembly with an internal swirl chamber to improve cold start and continuing operation. The pre-ignition assembly contains both a fuel injector and an ignition device that are in communication with the swirl chamber. The inlet/outlet passage opening that extends between the combustion chamber of the engine and the swirl chamber allows fresh combustion air to be forced from the cylinder of the engine into the swirl chamber during the compression stroke and allows the subsequently ignited plasma gases from the swirl chamber to enter into the combustion chamber as to the pistons reach their TDC positions.



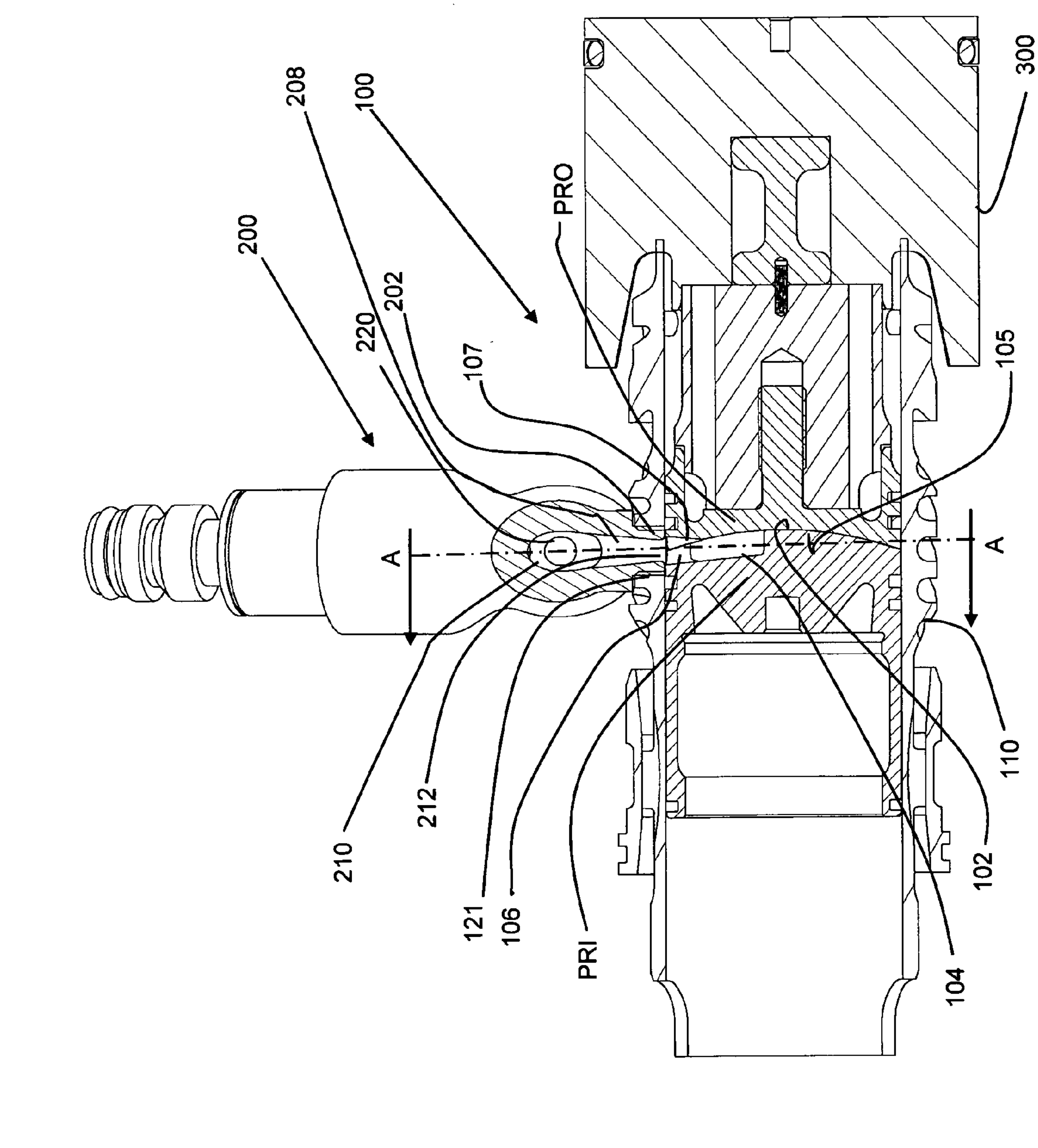

200
208
100
220
202
107
PRO
300
105
A
A
110
102
104
210
212
121
106
PRI

Fig. 1

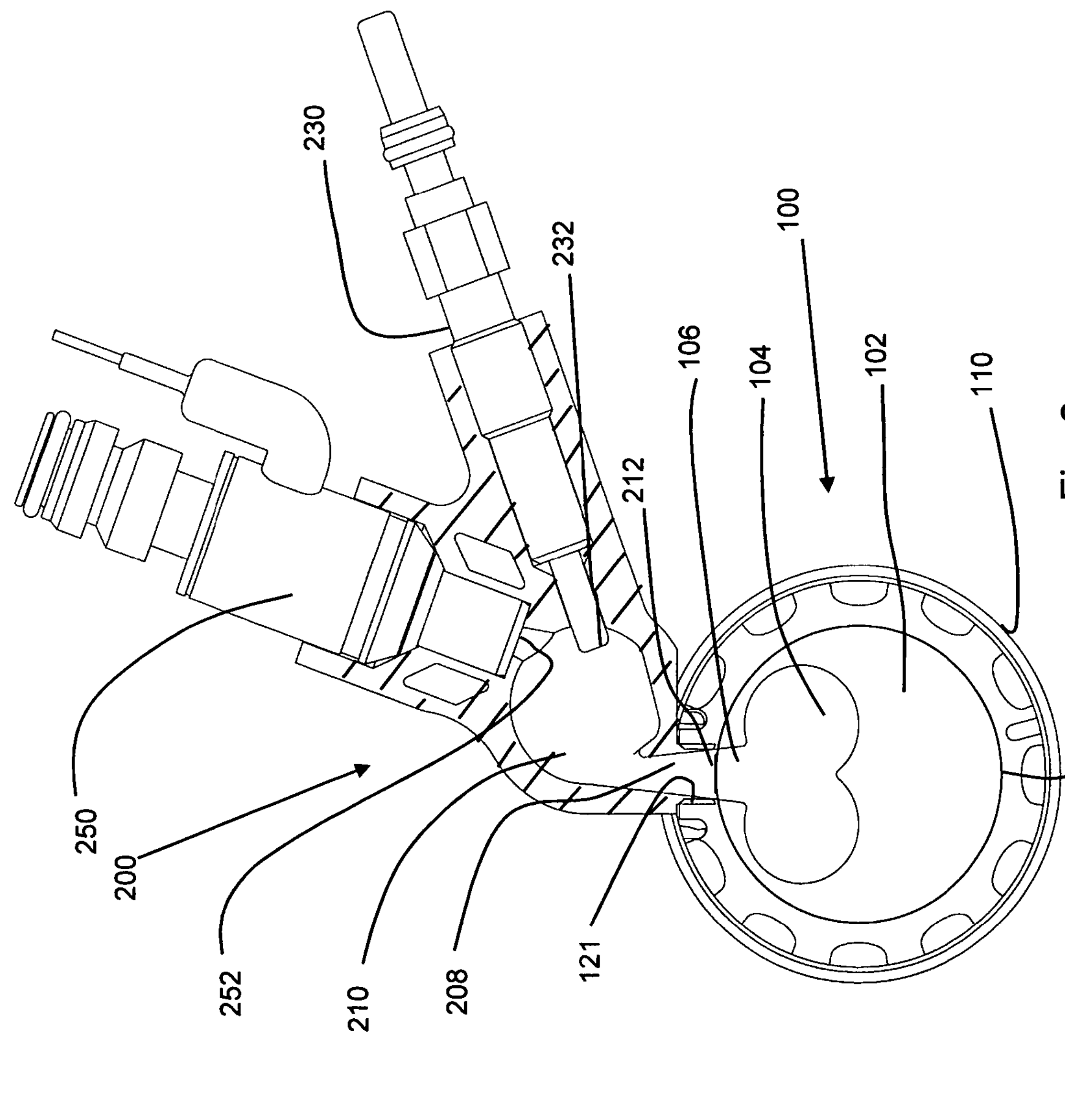


Fig. 2

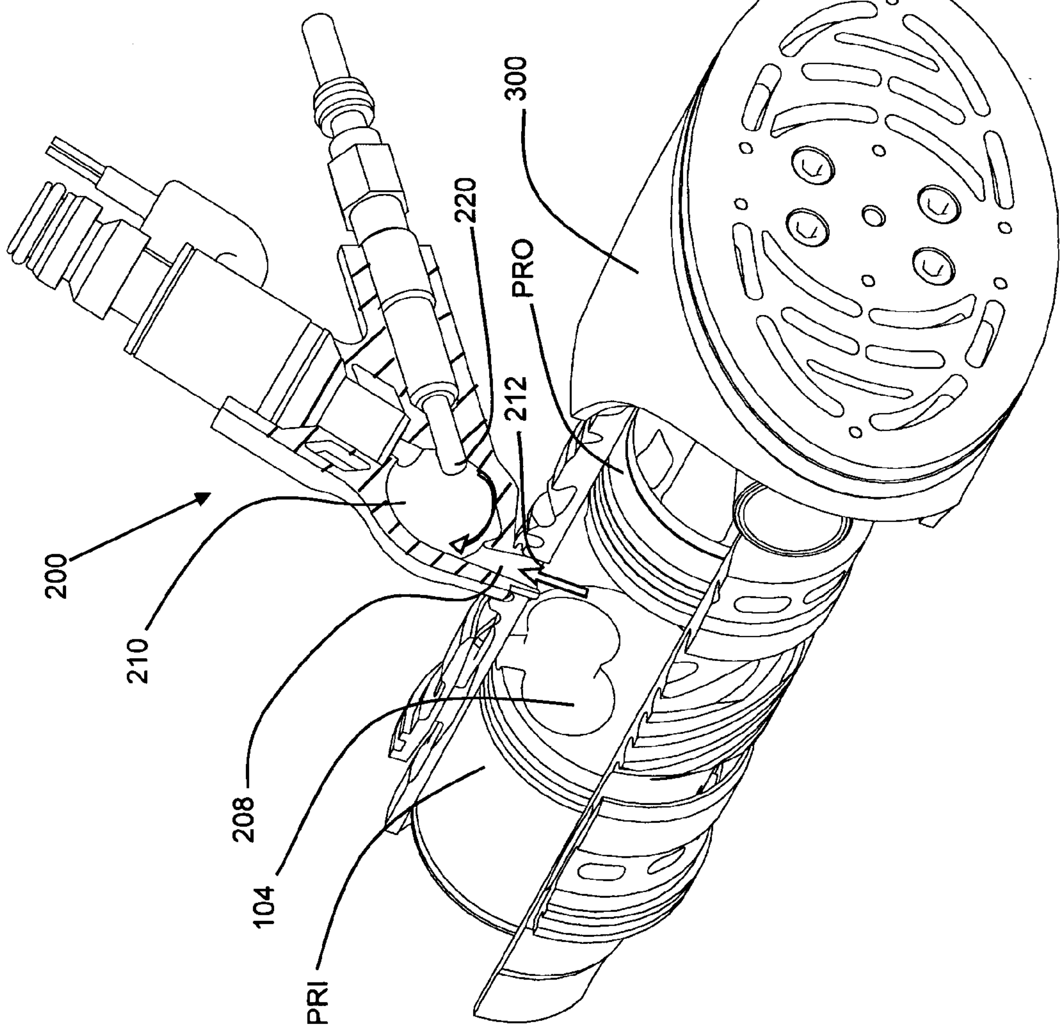


Fig. 3

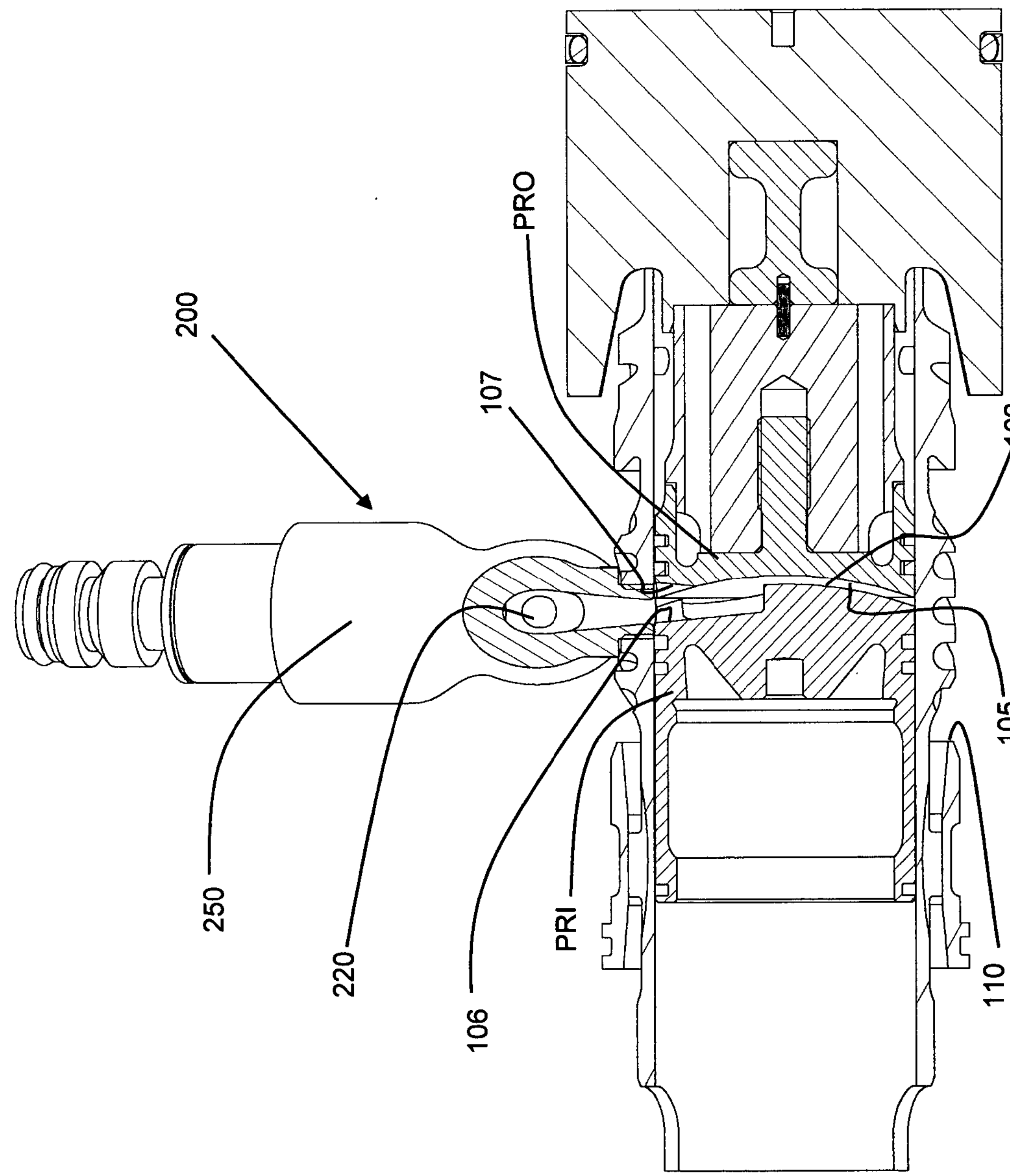


Fig. 4

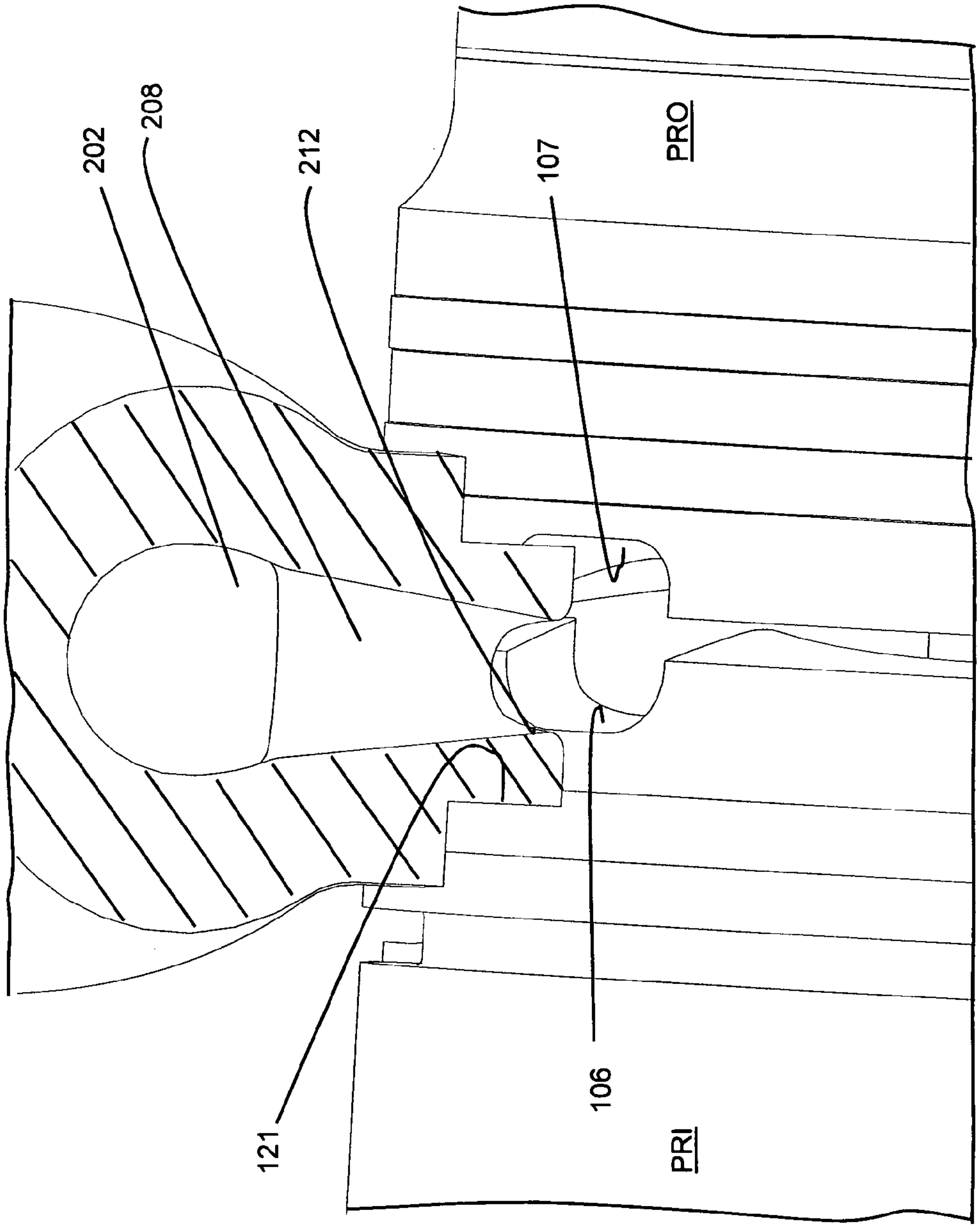


Fig. 5

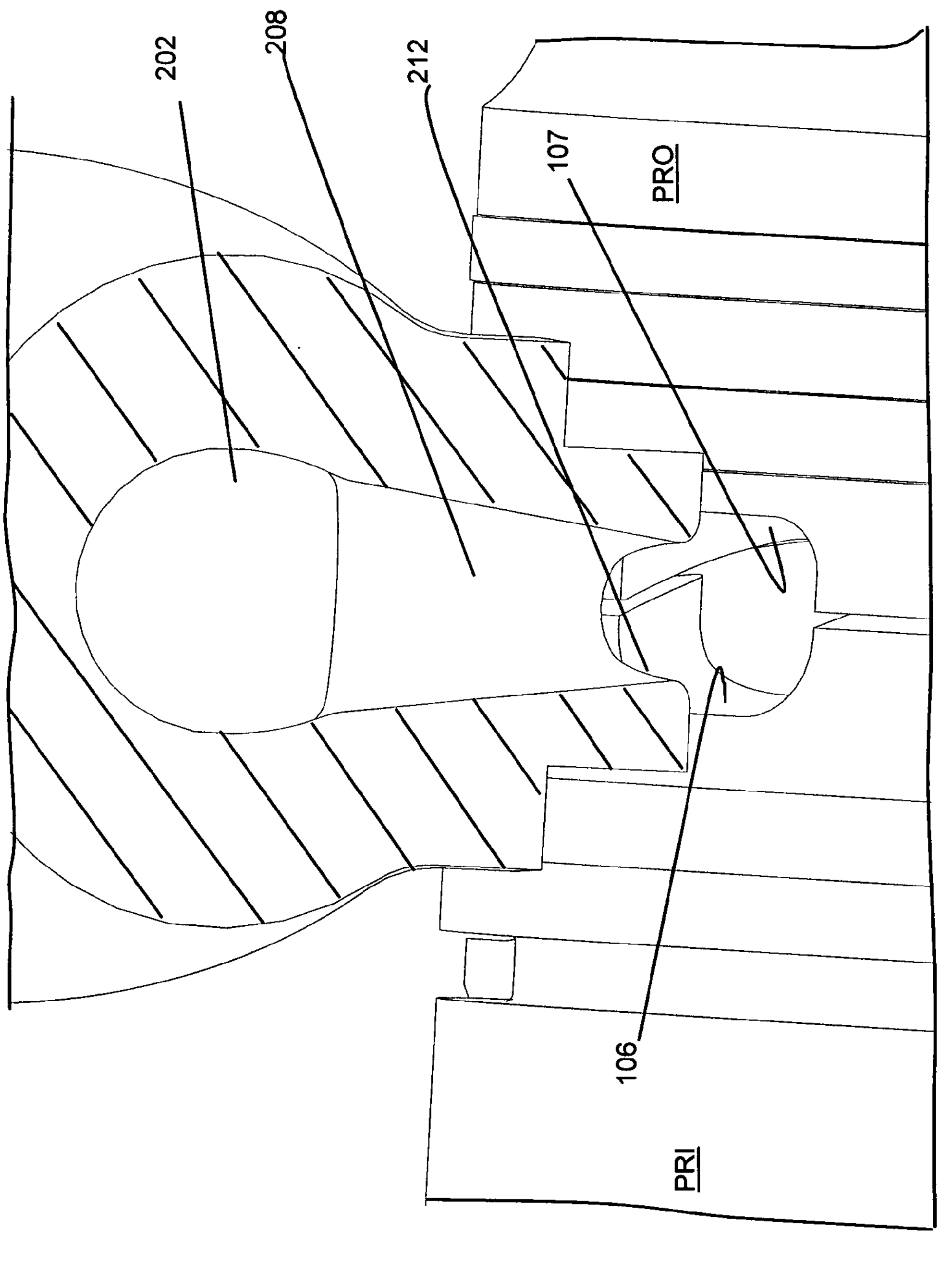


Fig. 6

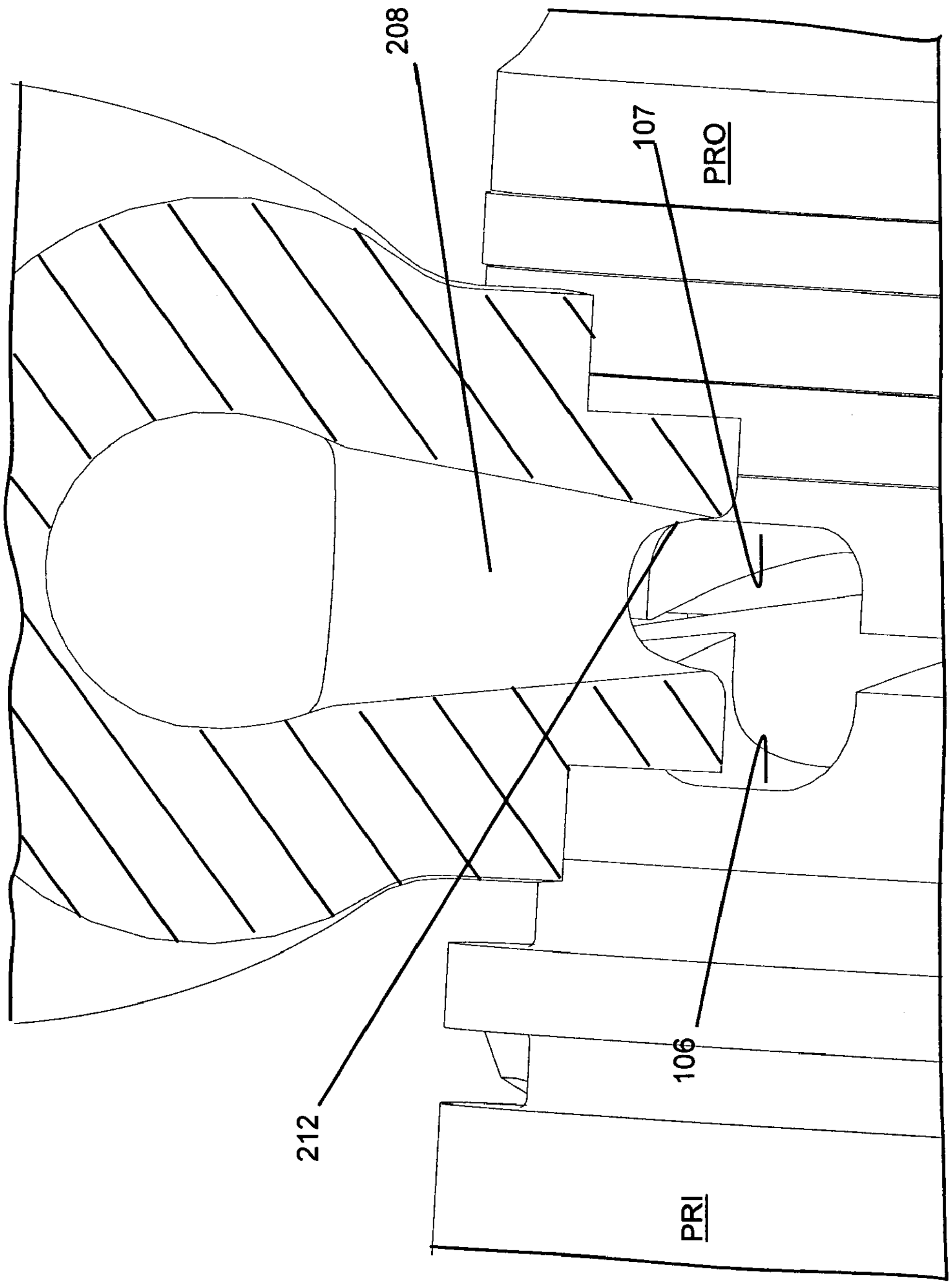


Fig. 7

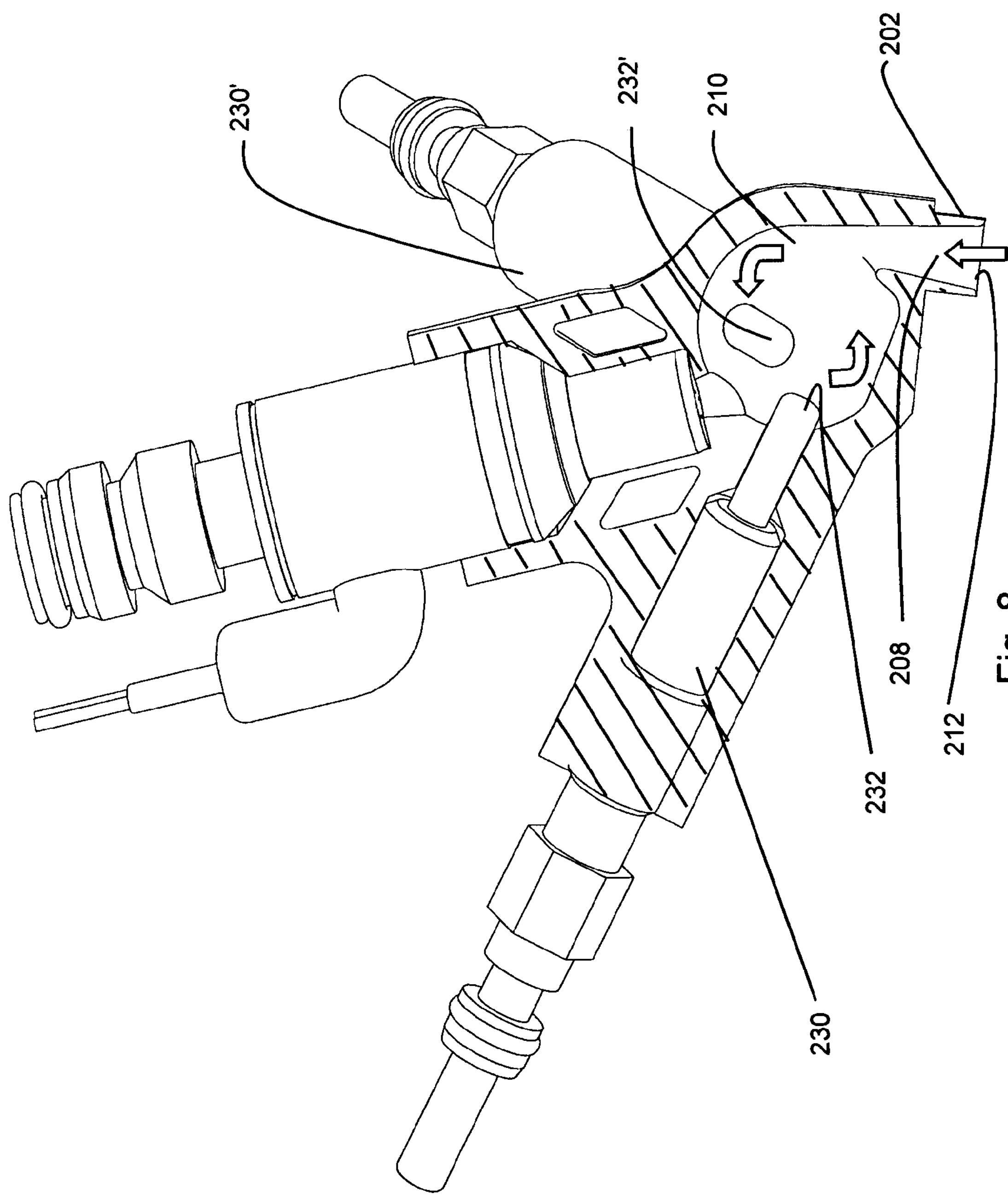


Fig. 8

OPOC ENGINE

RELATED APPLICATION

[0001] This application claims the benefit of U.S. provisional application Ser. No. 60/861,854 filed Nov. 30, 2006.

BACKGROUND

[0002] 1. Field of the Invention

[0003] This invention is related to the field of internal combustion engines and more specifically to a pre-ignition assembly that provides pre-combustion of an fuel/air mixture in an Opposing Piston Opposing Cylinder engine.

[0004] 2. Description of the Prior Art

[0005] In some two-cycle engines, such as the Internal Combustion Engine With A Single Crankshaft And Having Opposing Cylinders And Opposing Pistons in each cylinder ("OPOC engine") described in U.S. Pat. No. 6,170,443 and incorporated herein by reference, there is potential for cold start improvement when such engines are operated as diesel engines.

SUMMARY OF THE INVENTION

[0006] The present invention provides several improvements to the two stroke OPOC engine by providing a pre-ignition assembly mounted at a location that corresponds to the fuel injection port and includes a swirl chamber in open communication with the injection port. The location of the assembly on each cylinder is where the opposing pistons define the combustion chamber near their respective top dead center ("TDC") positions.

[0007] The pre-ignition assembly is configured to receive fresh air from the cylinder as it is compressed by the opposing pistons moving towards their TDC positions. The air is forced through the injection port on the cylinder and into a communication passage where it enters the hollow swirl chamber and follows a generally circular flow path about a central axis of the chamber. A fuel injector and ignition device, such as a glow plug, are mounted on the pre-ignition assembly and are in communication with the swirl chamber to interact with the air that is forced into the swirl chamber. The injector provides a measured amount of fuel spray from its nozzle prior to TDC which becomes mixed within the swirling air. The swirling fuel/air mixture encounters the heated glow plug which starts the chemical reaction that results in combustion of the fuel/air mixture and the injection of a plasma jet back through the injection port and into the combustion chamber.

[0008] A first embodiment of the pre-ignition assembly has the location of the glow plug such that its tip extends into the swirl chamber so as to be in a position where it is downstream from the fuel injector nozzle and in the generally circular swirl path of the fuel/air mixture.

[0009] A second embodiment of the pre-ignition assembly has the location of the glow plug such that its tip extends into the center of swirl chamber generally orthogonal to the circular swirl path of the fuel/air mixture.

[0010] The pre-ignition assembly is further configured with a communicating passage between the combustion chamber and the hollow portion of the swirl chamber with a port at each end. Each port has an ellipsoid shape that is matched to its respective chamber to provide a smooth and non-interfering transition for both the flow of air to the swirl chamber and the flow of ignited plasma to the combustion chamber.

[0011] It is an object of the present invention to provide an improved indirect injection device for an OPOC engine.

[0012] It is another object of the present invention to provide a pre-ignition assembly for an OPOC engine that provides pre-ignition of a complete fuel/air mixture and subsequent injection of the ignited plasma into the combustion chamber prior to and at TDC.

[0013] It is a further object of the present invention to provide improved cold start characteristics for an OPOC diesel engine.

[0014] With these objects in mind the invention is described in greater detail in the following sections.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015] FIG. **1** is a cross-sectional view of the present invention installed on the right cylinder of an OPOC engine showing the opposing pistons at their TDC positions.

[0016] FIG. **2** is a cross-sectional view of the present invention installed on the right cylinder taken along section lines A-A of FIG. **1**.

[0017] FIG. **3** is a perspective cross-sectional view of the present invention installed on the right cylinder of an OPOC engine showing the opposing pistons approaching TDC from their bottom dead center ("BDC") positions.

[0018] FIG. **4** is a cross-sectional view of the present invention installed on the right cylinder of an OPOC engine showing the opposing pistons at positions before their TDC positions.

[0019] FIG. **5** is an enlarged view of a first port of the pre-ignition assembly in communication with the combustion chamber defined by the opposing pistons just prior to TDC.

[0020] FIG. **6** is an enlarged of a first port of the pre-ignition assembly in communication with the combustion chamber defined by the opposing pistons at TDC.

[0021] FIG. **7** is an enlarged of a first port of the pre-ignition assembly in communication with the combustion chamber defined by the opposing pistons just after TDC.

[0022] FIG. **8** is a cross-sectional view of the pre-ignition assembly of the present invention showing an alternative embodiment for mounting the glow plug on the chamber housing.

DETAILED DESCRIPTION OF THE INVENTION

[0023] While the present invention is summarized above as being applicable for a two-cycle OPOC engine, it may be found to have application in other engines as well.

[0024] In FIGS. **1** and **2**, a single right cylinder assembly **100** of a multi-cylinder OPOC engine is shown. In an OPOC engine, there are normally identical opposing cylinder assemblies that are designated "left" and "right" of a common crankshaft. For instance, in the incorporated patent referenced above, details of the OPOC engine and its conventional operation are shown and described. There, it can be seen that a right cylinder "**200**" with outer and inner pistons is paired with a left cylinder "**100**" that also contains outer and inner pistons.

[0025] For ease of understanding, only one cylinder of the engine is described in detail here to exemplify the invention and its operation. However, it is intended that such description applies equally to the opposing cylinder and the invention operates there in a manner that compliments the operation of the described cylinder—later in the cycle.

[0026] The right cylinder assembly **100** depicted in FIGS. **1** and **2**, includes an outer piston PRO and an inner piston PRI shown at their TDC positions in right cylinder **110**.

[0027] Pistons PRO and PRI are mounted for reciprocating motion within cylinder **110** and are connected to a single crankshaft through piston rods (not shown here). The outer piston PRO is connected to a piston connector rod assembly **300**. Piston PRO includes a piston face **105** that opposes a piston face **102** on inner piston PRI. Here, piston face **105** is configured to be spherically concave and piston face **102** is configured to be spherically convex. The spherical radii of the two piston faces are selected to be equal in this embodiment in order to provide a "nesting" or close fit when the two pistons are at their TDC positions. In order to accommodate the advantages of the present invention, piston face **102** includes a depression **104** that provides additional space between the piston faces when they are at their TDC positions. And passage **106** is formed in the depression at the outer edge of piston PRI to provide continuous communication between the depression **104** and the side of the piston PRI. Piston face **105** of piston PRO is shown with a sloped passage **107** (also shown in FIG. **6**) that extends from the face **105** to the side of piston PRO and is opposing passage **106**.

[0028] An injection port **121** is formed in the cylinder **110** in a position that corresponds to the location of the passages **106** and **107** when pistons PRI and PRO reach their TDC positions.

[0029] An indirect injection assembly **200** with a nose end **202** is connected to cylinder **110**. The indirect injection assembly **200** provides mounting for a fuel injector **250** and a glow plug **230**. Assembly **200** also includes an internal swirl chamber **210**, and a nose end **202** that is tightly fitted into the injection port **121**. Nose end **202** of assembly **200** contains an opening **212** that is located at the outer end of a passage **208** between injection port **121** and swirl chamber **210**. In this location on cylinder **110**, opening **212** always remains open because the pistons are configured to prevent closure. In this embodiment, opening **212** is formed to have a curved oval shape with its shortest dimension being aligned parallel to the movement of the pistons and its axis of symmetry lying in a curve that corresponds to the circular curve of the inner cylinder wall.

[0030] As can be seen in FIG. **2**, swirl chamber **210** is generally an ovoid that has a circular cross-section in this view and a single opening that is in communication with opening **212**.

[0031] The fuel injector **250** contains an injection nozzle **252** that is in direct communication with the swirl chamber **210**. The glow plug **230** has an igniter tip **232** that extends into the swirl chamber **210**.

[0032] In FIG. **3**, a cut-away view of the right cylinder illustrates the two pistons PRO and PRI approaching from their Bottom Dead Center ("BDC") positions in a compression stroke which causes air to be forced into swirl chamber **210** through opening **212** and passage **208**. As air is forced in to swirl chamber **210**, it is compressed and swirled as indicated by the arrows.

[0033] In FIGS. **4** and **5**, the pistons PRI and PRO are shown in positions approaching their TDC respective positions. When piston PRI reaches its TDC position, as shown in FIG. **5**, the opening **106** on the face of the piston PRI is aligned and flush with the edge of opening **212** so as not to interfere with the air being compressed by the pistons and forced into swirl chamber **210**. As can be seen further in FIG. **5**, the shape and size of opening **106** is substantially the same as that portion of the opening **212** that it becomes aligned with. At this point in the movement of the pistons towards each other during the compression stroke, the opening **107** of piston PRO is not aligned with opening **212**, but is also no in an interfering position. That is due to the asymmetric timing of the pistons unique to the OPOC engine. In this context, the inner piston PRI reaches its TDC position before the outer piston PRO. As a result, piston PRO reaches its TDC position as piston PRI is beginning to return to the left and starts its power stroke. However, when piston PRO reaches its TDC position, as shown in FIG. **6**, the compression chamber as defined between the faces of pistons PRO and PRI is at its minimum volume. At this point in the cycle, the fuel has been injected into the swirling air within the swirl chamber and the fuel/air mixture has been ignited by the glow plug as it swirls over the tip of the heated glow plug. The plasma created by the explosive expansion of the fuel/air mixture undergoing the chemical reaction to the ignition process is jetted out of the swirl chamber and through passage **208** and opening **212** into the combustion chamber and passes openings **106** and **107**.

[0034] The positions of the edges of openings **106** and **107** are such that they do not interfere with the injected plasma exiting opening **212** and therefore do not create unwanted hot spots at those locations.

[0035] In FIG. **7**, the positions of the pistons PRI and PRO are shown just past their TDC positions with the outer piston PRO having moved towards the left to a point where the opening **107** comes just even with the edge of opening **212**, but not sufficient to offer an edge that would cause a hot spot to the escaping plasma from swirl chamber **210**.

[0036] In operation during the compression stroke, the fresh air that is allowed to enter the chamber is compressed between pistons PRI and PRO and is also forced into swirl chamber **210**. At a point that corresponds to approximately 25° before TDC, a fuel mist is released from injector nozzle **252** into the swirl chamber **210** to create an fuel/air mixture. The glow plug tip **232** is located down stream from injector nozzle **252** so that the swirling fuel/air mixture and is heated sufficiently to cause the chemical reaction of combustion to commence. Due to the delay in the chemical reaction, complete ignition of the fuel/air mixture takes place at approximately 10°-15° before TDC. As the combustion reaction progresses, an expanding plasma is created which exhausts through the passage **212** and through opening **202** into the combustion chamber defined between the faces of pistons PRI and PRO. The additional space created by depression **104** allows a greater amount of plasma gas to enter between the shrinking combustion chamber and to spread over a greater area of the piston face as the two pistons reach their TDC positions. As the combustion gases expand, they create forces which overcome the inertia of the pistons and cause the power cycle to commence after TDC. Near the end of the power cycle, the combustion gasses are allowed to substantially escape from the swirl chamber due to the reduced pressures, leaving very little residual gases to affect combustion of the fresh fuel/air mixture in the next compression stroke.

[0037] In FIG. **8**, two embodiments of the swirl chamber are illustrated which show alternative locations for the glow plug mounting and extension into the chamber **210**. In the first alternative embodiment, the glow plug **230** is located so as to present the tip **232** in the general plane and downstream of the generally planar swirl flow path of the fuel/air mixture as described above. In the second alternative embodiment, the glow plug **230'** is located so as to present its tip **232'** perpendicular to the swirl flow path so as to provide an ignition point near the center of the chamber.

[0038] From the foregoing, it can be seen that there has been brought to the art an improvement in the operation of an internal combustion engine. The preceding description of the embodiments is merely illustrative of some of the many specific embodiments that represent applications of the principles of the present invention as defined by the following claims.

We claim:

1. A pre-ignition assembly for use in an OPOC engine containing a first pair of opposing pistons in a first cylinder and a second pair of opposing pistons in a second opposing cylinder, wherein opposing cylinders are configured to allow said pistons to operate in opposing and complementary stroke cycles;

said pre-ignition assembly includes a fuel injector, an ignition device and a pre-ignition chamber;

a pre-ignition assembly being mounted on each said opposing cylinder at a location that provides communication between said pre-ignition chamber and the interior of the cylinder at the location of a combustion chamber defined between opposing pistons;

said pre-ignition chamber having a passage with an opening in communication with the interior of the cylinder to allow combustion air compressed by said pistons during a compression stroke to enter said pre-ignition chamber,

said fuel injector containing an injector nozzle that is in communication with said pre-ignition chamber to inject a predetermined amount of fuel into said pre-ignition chamber to form a fuel/air mixture; and

said ignition device containing a fuel/air ignition element that extends into the fuel/air mixture within said chamber.

2. A pre-ignition assembly as in claim **1**, wherein said assembly is mounted on to be in communication with the fuel injection port in the cylinder of said engine.

3. A pre-ignition assembly as in claim **1**, wherein said pre-ignition chamber of said assembly is configured to generate a generally circular flow path for said combustion air as it enters said chamber from the cylinder.

4. A pre-ignition assembly as in claim **1**, wherein said pre-ignition chamber is configured to define a generally circular swirl flow path for combustion air entering from the cylinder.

5. A pre-ignition assembly as in claim **4**, wherein said ignition device is a glow plug that has an ignition tip and said tip is positioned in said pre-ignition chamber to intersect the flow of the fuel/air mixture downstream from said injector nozzle.

6. A pre-ignition assembly as in claim **1**, wherein said ignition device is a glow plug and said glow plug has an ignition tip positioned in said pre-ignition chamber to be in the approximate center of said pre-ignition chamber.

7. A pre-ignition assembly as in claim **1**, wherein said passage is oriented generally orthogonal to the cylinder axis and said passage opening has a generally oval shape that conforms to the inner circular surface of the cylinder; and

the faces of said pistons within the cylinder are formed with depressions to accommodate the flow of plasma from said opening to enter said combustion chamber without interference.

8. A pre-ignition assembly as in claim **1**, wherein said opening in the passage of said pre-ignition chamber provides continuous open communication between said pre-ignition chamber and the interior of the cylinder throughout the entire stroke cycle of said engine.

9. A pre-ignition assembly as in claim **8**, wherein said passage in said pre-ignition chamber functions both to allow said air to enter said pre-ignition chamber and to allow a plasma of ignited fuel/air mixture to escape said pre-ignition chamber and enter the combustion chamber of the cylinder.

10. A method of providing a plasma of pre-ignited an fuel/air mixture to the combustion chamber within a cylinder of an OPOC engine containing a first pair of opposing pistons in a first cylinder and a second pair of opposing pistons in a second opposing cylinder, wherein said first and second opposing cylinders are configured to allow said pistons to operate in opposing and complementary stroke cycles, comprising the steps of:

providing a pre-ignition assembly that includes a fuel injector, an ignition device and a pre-ignition swirl chamber;

mounting a pre-ignition assembly on a cylinder at a location that provides communication between its pre-ignition swirl chamber and the interior of the cylinder at the location of a combustion chamber defined between opposing pistons;

providing said pre-ignition swirl chamber with a passage having an opening in communication with the interior of the cylinder to allow combustion air to enter the pre-ignition chamber,

providing the fuel injector with an injector nozzle that is in communication with the pre-ignition chamber;

injecting a predetermined amount of fuel into the pre-ignition chamber to be swirl mixed with said air;

providing said ignition device with a fuel/air ignition element that extends into the flow path of fuel/air mixture within said chamber;

igniting said fuel/air mixture in said pre-ignition chamber prior to said pistons reaching their respective top dead center positions in said stroke cycle to generate a plasma which escapes said pre-ignition chamber into said combustion chamber as a first one of said pistons passes its top dead center position.

11. An improved OPOC engine containing a first pair of opposed pistons in a first cylinder and a second pair of opposed pistons in a second cylinder, wherein said first and second cylinders are configured to allow said pistons to operate in opposing and complementary stroke cycles along a cylinder axis;

said improvement includes a pre-ignition assembly mounted externally to each cylinder at a location corresponding to a fuel injection port on each cylinder;

said pre-ignition assembly includes a fuel injector, an ignition device and a pre-ignition chamber;

said pre-ignition chamber having a passage in open communication between said pre-ignition chamber and the interior of the cylinder through the fuel ignition port to allow combustion air to enter said pre-ignition chamber;

said pre-ignition chamber being configured to define a circular swirl flow path for air entering from said cylinder;

said fuel injector being mounted on said assembly and containing an injector nozzle in communication with said chamber to inject a predetermined amount of fuel into said chamber to be swirl mixed with said air; and

said ignition device being mounted on said assembly and containing an ignition element that extends into the fuel/air mixture flowing within said chamber.

12. An improvement as in claim **11**, wherein said ignition device is a glow plug that has an ignition tip and said tip is positioned in said pre-ignition chamber to intersect the flow of the fuel/air mixture downstream from said injector nozzle.

13. An improvement as in claim **11**, wherein said ignition device is a glow plug and said glow plug has an ignition tip positioned in said pre-ignition chamber to be in the approximate center of said pre-ignition chamber.

14. An improvement as in claim **11**, wherein said passage is oriented generally orthogonal to the cylinder axis and said passage opening has a generally oval shape that conforms to the inner circular surface of the cylinder; and

the faces of said pistons within the cylinder are formed with depressions to accommodate the flow of plasma from said opening to enter said combustion chamber without interference.

15. An improvement as in claim **11**, wherein said opening in the passage of said pre-ignition chamber provides continuous open communication between said pre-ignition chamber and the interior of the cylinder throughout the entire stroke cycle of said engine.

16. An improvement as in claim **15**, wherein said passage in said pre-ignition chamber functions both to allow said air to enter said pre-ignition chamber and to allow a plasma of ignited fuel/air mixture to escape said pre-ignition chamber and enter the combustion chamber of the cylinder.

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