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(54) **Zündkerze und Gasmotor mit Zündkerze**

(57) Zündkerze, und Gasmotor mit einer solchen Zündkerze, mit einer Außenelektrode (2) und einer Mittenelektrode (3), die durch einen Isolator (4) voneinander getrennt sind, wobei die Außenelektrode (2) an einem axialen Ende der Zündkerze (1) als Außengewinde (5) ausgeführt ist und an diesem axialen Ende zwischen der Außenelektrode (2) und der Mittenelektrode (3) ein Hohlraum (7) gebildet ist, wobei durch die Außenelektrode (2) zumindest ein durchgehender Gaskanal (8) vorgesehen ist, wobei der Gaskanal (8) innen im Hohlraum (7) mündet und außen im Bereich des Außengewindes (5), wobei zwischen der äußeren Mündung und dem axialen Ende der Außenelektrode (2) zumindest ein Gewindegang (14) des Außengewindes (5) vorgesehen ist und der Gaskanal (8) innen auf die Zündungszone (10) im Bereich zwischen der Mittenelektrode (3) und der Außenelektrode (2) der Zündkerze (1) ausgerichtet ist.

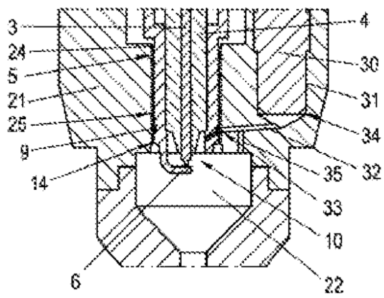

Fig. 4

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Beschreibung

ZÜNDKERZE UND GASMOTOR MIT ZÜNDKERZE

[0001] Die gegenständliche Erfindung betrifft eine Zündkerze mit einer Außenelektrode und einer Mittenelektrode, die durch einen Isolierkörper voneinander getrennt sind, wobei die Außenelektrode an einem axialen Ende der Zündkerze als Außengewinde ausgeführt ist und an diesem axialen Ende zwischen der Außenelektrode und der Mittenelektrode ein Hohlraum gebildet ist, wobei durch die Außenelektrode zumindest ein durchgehender Gaskanal vorgesehen ist, wobei der Gaskanal innen im Hohlraum und außen im Bereich des Außengewindes mündet, wobei zwischen der äußeren Mündung und dem axialen Ende der Außenelektrode zumindest ein Gewindegang des Außengewindes vorgesehen ist. Weiters betrifft die Erfindung einen Gasmotor mit einer Brennkammer und einem Brennkammerkopf, der die Brennkammer zumindest teilweise abschließt, wobei im Brennkammerkopf eine Gewindeöffnung mit einem Innengewinde vorgesehen ist, wobei der Gasmotor mit einer erfindungsgemäßen Zündkerze versehen ist.

[0002] Gasmotoren, die beispielsweise mit Erdgas oder Flüssiggas betrieben werden, haben gegenüber anderen Verbrennungsmotoren den Vorteil der geringeren Emissionen, was Gasmotoren insbesondere für Großmotoren, z.B. auf Schiffen oder in Erdgasverteilnetzen, interessant macht.

[0003] Die bekannten Brennverfahren fremdgezündeter Gasmotoren beruhen auf dem Prinzip, dass entweder brennfähiges Gemisch während des Saugtaktes angesaugt wird, oder während des Verdichtungstraktes durch Einblasung von Brenngas gebildet wird. Nach Verdichtung des Gemisches wird dieses durch Funkenzündung, beispielsweise mittels einer Zündkerze, gezündet. Bekannt ist es auch, den Gasmotor durch Einspritzung einer kleinen Menge von selbstentzündlichem flüssigem Kraftstoff zu zünden. Die Zündung kann dabei direkt im Hauptbrennraum (dem Zylinder) oder in einer Vorbrennkammer erfolgen. Im Fall einer Vorbrennkammer wird ein brennfähiges Gemisch in der Vorbrennkammer gezündet, was einen aus der Vorbrennkammer in die Hauptbrennkammer austretenden Heißgasstrahl verursacht, der das brennfähige Gemisch in der Hauptbrennkammer entflammt. Das brennfähige Gemisch in der Hauptbrennkammer wird anschließend von im Allgemeinen turbulenten Flammenfronten durchwandert. Ein solches Brennverfahren ist beispielsweise in der DE 10 2014 00 229 A1 beschrieben.

[0004] Aus Sicht der Emissionen und des Verbrauchs ist es wünschenswert, den Gasmotor im Magerbetrieb, also mit einen Brennstoff/Luftverhältnis größer Eins zu betrieben. Allerdings neigen Gasmotoren bei Ausmagern des Gemisches zu Fehlzündungen, welche wiederum zu hohen Schadstoffemissionen, schlechten Wirkungsgrad und/oder extremen mechanischen Belastungen des Gasmotors führen können. Solche Fehlzündungen gefährden den sicheren und zuverlässigen Betrieb des Gasmotors. Abgesehen davon ist ein mageres Gemisch erheblich schwieriger zu zünden, als ein fetteres Gemisch. Die Anforderungen an das Zündsystem eines Gasmotors, insbesondere eines bei magerem Gemisch betriebenen Gasmotors, sind daher hoch.

[0005] Um diesen Anforderungen gerecht zu werden, sind bereits Lösungen bekannt geworden, bei denen Brennstoff gezielt zur Zündkerze hin gerichtet, oder zumindest in deren Nahbereich gerichtet, eingeblasen wird. Damit wird die Zone um die Zündkerze mit Brennstoff angereichert, wodurch lokal im Bereich der Zündkerze ein fetteres Gemisch entsteht, das sicherer gezündet werden kann. Auf Grund der möglichen Varianz durch unterschiedliche Lastpunkte des Gasmotors und der lokalen heterogenen Gemischbildung entsteht dabei aber ein höherer Anspruch an die Regelung, um das Potential an Emissionsreduktion und Reduktion der Rußbildung nutzen zu können. Dabei bietet es sich an, den Brennstoff direkt durch die Zündkerze einzubringen.

[0006] In der US 6,481,422 B2 wird beispielsweise gasförmiger Brennstoff während des Verdichtungstaktes durch die Zündkerze in den Zylinder zugeführt und nach der Verdichtung durch die Zündkerze gezündet. Das wird durch eine spezielle Zündkerze realisiert, die aus einem Adapter, der gleichzeitig einen ersten Pol der Zündkerze (Erdung) ausbildet, und einem Innenelektrodenteil, der den zweiten Pol der Zündkerze ausbildet, besteht. Der Adapter wird in das im Zylinderkopf vorgesehene Gewinde für herkömmliche Zündkerzen geschraubt und der Innenelektrodenteil wird in den Adapter geschraubt. Im Adapter oder zwischen Adapter und Innenelektrodenteil ist ein Zuführkanal vorgesehen, der mit einem Gasventil verbunden ist, und über den gasförmiger Brennstoff in den Zylinder zugeführt wird. Durch diese Anordnung ergibt sich durch den Zuführkanal allerdings ein großer Totraum, der während der Gaszuführung mit gasförmigem Brennstoff gefüllt ist. Nach dem Ende der Gaszuführung kann daher im Zuführkanal verbleibender gasförmiger Brennstoff unkontrollierbar in den Zylinder strömen, was die Zündung stören kann. Gleichfalls kann sich die Flammenfront im Zylinder nach dem Zünden auch in den Zuführkanal ausbreiten. Nachdem dort ein sehr fettes Gemisch vorliegen wird, kommt es zu hohen Emissionen, was die Emission des Gasmotors erhöht. Ebenfalls kommt es dadurch zu einer starken Rußbildung, was den Zuführkanal verschmutzen kann. Nicht zuletzt kann auch unverbrannter gasförmiger Brennstoff in den Zylinder nachströmen, der im Ausstoßtakt direkt an die Umgebung abgegeben wird, was ebenfalls unerwünscht ist. Ein weiteres Problem dieser Anordnung ist die schlechte Wartbarkeit, da die Zündkerze nicht getrennt vom Gasventil ausgebaut werden kann. Nachdem eine Zündkerze ein Serviceteil ist, der regelmäßig gewechselt werden muss, ist damit jeder Austausch der Zündkerze aufwendig.

[0007] Die US 4,864,989 A zeigt eine Zündkerze durch die gasförmiger Brennstoff in den Raum zwischen Innenelektrode und Außenelektrode zugeführt werden kann. Dieser Raum dient als Vorbrennkammer, in der sich der gasförmige Brennstoff im Verdichtungstrakt mit dem verdichteten Gemisch im Zylinder mischt und ein zündfähiges Gemisch bildet, das durch die Zündkerze gezündet wird. Der austretende Flammenstrahl zündet das Gemisch im Zylinder. Am Körper der Zündkerze ist eine Düse angeordnet und im Körper ist eine Bohrung vorgesehen, die mit der Düse verbunden ist. Eine ähnliche Anordnung zeigt die US 4,383,198 A. Damit treten in der US 4,864,989 A und in der US 4,383,198 A im Wesentlichen dieselben Probleme wie bei der US 6,481,422 B2 auf.

[0008] Aus der EP 1 143 126 A2 ist eine Vorkammer-Zündkerze bekannt, bei der die Vorkammer mit der Zündkerze fest verbunden ist. Damit ist ein Austausch der Zündkerze alleine nicht möglich. Die Vorkammer-Zündkerze wird über ein Gewinde an der Vorkammer in den Zylinderkopf geschraubt und die Zuführung des Brennstoffes in die Vorbrennkammer erfolgt ungezielt über eine ringförmige Nut im Zylinderkopf und das Gewinde der Vorkammer-Zündkerze. Die Zündkerze sitzt im oberen Ende der Vorbrennkammer, womit sich ein relativ großes Volumen ergibt, das mit Brennstoff gefüllt werden muss, bevor gezündet werden kann.

[0009] In der US 6,260,546 B1 ist eine Zündkerze beschrieben, die in den Zylinderkopf geschraubt ist und die im Außengewinde eine Öffnung aufweist, die einen Gaskanal mit dem Raum zwischen Innenelektrode der Zündkerze und dem Außengewinde verbindet. Über diese Öffnung kann Brennstoff zugeführt werden. Aber auch hier ergibt sich ein relativ großes Volumen, das mit Brennstoff gefüllt werden muss bis der Brennstoff die Zündungszone erreicht. Eine ähnliche Zündkerze zeigt die JP 2011-222205 A.

[0010] Es ist daher eine Aufgabe der gegenständlichen Erfindung, eine Zündkerze anzugeben, die es ermöglicht, die obigen Probleme zu reduzieren.

[0011] Diese Aufgabe wird dadurch gelöst, dass der Gaskanal innen auf die Zündungszone im Bereich zwischen der Mittenelektrode und der Außenelektrode der Zündkerze ausgerichtet ist. Dadurch, dass der Gaskanal im Bereich des Außengewindes der Zündkerze, also im Bereich des axialen Endes der Zündkerze, vorgesehen ist, ist es möglich, das Totvolumen in der Zündkerze, bzw. allgemein der Gaszuführung, weitestgehend zu reduzieren. Es sind keine langen Gasleitungen und große zusätzlichen Hohlräume in der Zündkerze notwendig, um den gasförmigen Brennstoff zuzuführen. Abgesehen davon ermöglicht das auch, dass eine Standard-Zündkerze verwendet werden kann, in die lediglich der Gaskanal eingebracht werden muss, beispielsweise durch einfaches Bohren des Gaskanals. Auf diese Weise kann eine herkömmliche Zündkerze sehr einfach in eine erfindungsgemäße Zündkerze verwandelt werden. Durch die Ausrichtung des Gaskanals innen auf die Zündungszone der Zündkerze ausgerichtet ist kann der gasförmige Brennstoff gezielt dort eingebracht werden, wo ein fetteres Gemisch benötigt wird und gleichzeitig wird die heiße Zündungszone durch den zugeführten gasförmigen Brennstoff optimal gekühlt. Auf diese Weise kann die Gefahr einer unbeabsichtigten vorzeitigen Zündung des brennfähigen Gemisches durch hohe Temperaturen im Bereich der Zündungszone wirkungsvoll reduziert werden und durch die Temperaturabsenkung des Zündbügels der Außenelektrode auch die Lebensdauer der Zündkerze erhöht werden.

[0012] Vorteilhaft ist es, wenn über den Umfang verteilt eine Mehrzahl von Gaskanälen vorgesehen ist. Dadurch kann die Oberfläche der Gaskanäle erheblich vergrößert werden, was durch den zugeführten Brennstoff zu einer besseren Kühlung im Bereich der Gaskanäle führt. Damit kann eine zu tiefe Flammausbreitung aus dem Brennraum in die Gaskanäle verhindert werden, da eine Flamme an der kühlen Oberfläche sehr rasch und sicher erstickt werden würde.

[0013] Ganz besonders vorteilhaft ist, wenn an der Außenelektrode im Bereich des Außengewindes eine Außenumfangsnut vorgesehen ist und der zumindest eine Gaskanal in die Außenumfangsnut mündet und zwischen Außenumfangsnut und axialem Ende der Außenelektrode zumindest ein Gewindegang vorgesehen ist. Die Außenumfangsnut kann als einfacher Gasverteilring genutzt werden, der mehrere Gaskanäle speisen kann, wobei die Außenumfangsnut nur eine Zuspeisung von gasförmigem Brennstoff benötigt. Eine solche Zündkerze kann daher auch einfach verwendet werden, da es durch die Außenumfangsnut unerheblich ist, in welcher winkelmäßigen Lage (relativ zu einer Zuspeisung von gasförmigem Brennstoff) die Zündkerze eingesetzt ist.

[0014] Es ist ebenfalls besonders vorteilhaft, wenn der Strömungsquerschnitt des zumindest einen Gaskanals kleiner ist, als der Strömungsquerschnitt der Außenumfangsnut. Auf diese Weise kann durch den Gaskanal eine Drosselwirkung bewirkt werden, die mehrere Wirkungen entfalten kann. Einerseits reduziert die Drosselwirkung insbesondere während der Verbrennung und folgender Druckerhöhung im Brennraum die Rückströmung von Abgas in die Außenumfangsnut. Andererseits wird durch die Drosselwirkung die Strömungsgeschwindigkeit des zugführten gasförmigen Brennstoffes erhöht, was die Eindringtiefe des gasförmigen Brennstoffes im Brennraum erhöht und auch für höhere Turbulenzen im Brennraum und damit verbunden zu einer besseren Kühlung durch den gasförmigen Brennstoff führt.

[0015] Wenn der Hohlraum durch die Außenelektrode umschlossen ist und in der Außenelektrode im Bereich des axialen Endes zumindest ein durchgehender Flammkanal vorgesehen ist, der den Hohlraum mit der Umgebung der Außenelektrode verbindet, kann verhindert werden, dass die Einblasung von gasförmigen Brennstoff in die Zündungszone der Zündungskerze durch Turbulenzen im Brennraum gestört wird. Der eingeblasene Brennstoff bleibt in der Zündungszone konzentriert und fettet die Zündungszone effektiv auf, wodurch eine sichere Zündung ermöglich wird. Der Hohlraum bildet auf diese Weise eine Art Minivorkammer aus.

[0016] Gleichfalls ist es eine Aufgabe der gegenständlichen Erfindung einen Gasmotor mit einer solchen Zündkerze und ein Zündverfahren anzugeben, sodass eine sichere Zündung eines Gasmotors möglich wird.

[0017] Diese Aufgabe wird für den Gasmotor gelöst, indem in eine Gewindeöffnung eine erfindungsgemäße Zündkerze eingeschraubt ist, und im Brennkammerkopf beabstandet von der Gewindeöffnung eine Ventilausnehmung vorgesehen ist, deren axiales Ende über einen Stichkanal mit einem Gasverteilring zwischen der Zündkerze und dem Brennkammerkopf verbunden ist, wobei der Gasverteilring durch eine Innenumfangsnut am Innengewinde und/oder durch die Außenumfangnut an der Zündkerze gebildet ist und der zumindest eine Gaskanal in den Gasverteilring mündet, wobei zwischen dem Gasverteilring und dem axialen Ende der Zündkerze zumindest ein Gewindegang des Außen- und Innengewindes vorgesehen ist.

[0018] Durch die beabstandete Anordnung des Gasventils und der Zündkerze ist es möglich, beide Bauteile getrennt und unabhängig voneinander zu tauschen, wodurch der Gasmotor leichter zu warten ist. Für eine Wartung eines der beiden Bauteile müssen nicht mehr beide ausgebaut werden, sondern nur mehr der Bauteil, der gewartet werden muss. Abgesehen davon kann dadurch das Zündsystem auf einfache Weise angepasst werden. Beispielsweise kann auf einfache Weise eine andere Zündkerze eingesetzt werden, ohne das Gasventil tauschen zu müssen. Ebenso kann ein anderes Gasventil verwendet werden, ohne die Zündkerze tauschen zu müssen. Auf diese Weise kann der Gasmotor auch auf einfache Art an unterschiedliche Anforderungen angepasst werden.

[0019] Die beabstandete Anordnung des Gasventils erlaubt es aber auch, das Gasventil so nah wie möglich am Gasverteilring anzuordnen, Das reduziert die Länge der Stichleitung und damit auch das Totvolumen der Gaszuführung.

[0020] Durch den Gasverteilring ist es unerheblich, wie die Zündkerze in das Gewindeloch eingeschraubt wird. Über den Gasverteilring, der mit der Stichleitung verbunden ist, ist immer sichergestellt, dass die Gaskanäle mit gasförmigen Brennstoff versorgt sind.

[0021] Die gegenständliche Erfindung wird nachfolgend unter Bezugnahme auf die Figuren 1 bis 6 näher erläutert, die beispielhaft, schematisch und nicht einschränkend vorteilhafte Ausgestaltungen der Erfindung zeigen. Dabei zeigt

[0022] Fig.1 ein erfindungsgemäße Zündkerze mit Außenumfangsnut,

[0023] Fig.2 ein Schnitt durch die erfindungsgemäße Zündkerze ohne Außenumfangnut,

[0024] Fig.3 und 4 die Anordnung der Zündkerze in einer Vorkammer als Brennraum und

[0025] Fig.5 und 6 die Anordnung der Zündkerze mit Schirmung in einem Zylinder als Brennraum.

[0026] In Fig. 1 und in Fig.2 ist eine erfindungsgemäße Zündkerze 1 dargestellt. Wie bei einer herkömmlichen Zündkerze bekannt, besteht die Zündkerze 1 aus einer Außenelektrode 2, die an einem axialen Ende als Außengewinde 5 ausgeführt ist. Die Außenelektrode 2 umschließt eine Mittenelektrode 3, die durch einen elektrischen Isolator 4 von der Außenelektrode 2 getrennt ist. Von der Außenelektrode 2, die normalerweise elektrisch geerdet ist, steht ebenfalls in bekannter Weise ein elektrisch mit der Außenelektrode 2 verbundener Zündbügel 6 ab, der zur Ausbildung der Funkenstrecke am axialen Ende der Zündkerze 1 axial gegenüber der Mittenelektrode 3 angeordnet ist. Zwischen dem Zündbügel 6 und der Mittenelektrode 3 entsteht der Zündfunke, wenn an die Mittenelektrode 3 eine ausreichende Zündspannung angelegt wird. Am axialen Ende der Zündkerze 1 ist zwischen der Mittenelektrode 3, bzw. dem die Mittelelektrode 3 umgebenden Isolator 4, und der Außenelektrode 2 (zu der auch der Zündbügel 6 gehört) ein Hohlraum 7 ausgebildet.

[0027] Im Bereich des Außengewindes 5 mündet ein erstes Ende eines durchgehenden Gaskanals 8. Das zweite Ende des Gaskanals 8 mündet in den Hohlraum 7. Der Gaskanal 8 geht damit durch die Außenelektrode 2 im Bereich des Außengewindes 5 hindurch und verbindet den Hohlraum 7 mit der äußeren Umfangsfläche der Zündkerze 1 im Bereich des Außengewindes 5. Durch den Gaskanal 8 kann von außen ein gasförmiger Brennstoff in den Hohlraum 7 zugeführt werden kann. Unter gasförmigen Brennstoff wird auch ein zündfähiges Brenngasgemisch oder ein Brennstoff/Luft-Gemisch verstanden. Über den Umfang des Außengewindes 5 verteilt können auch mehrere Gaskanäle 8 angeordnet sein, wie in Fig.1 durch die Mündungen angedeutet.

[0028] Unter gasförmigen Brennstoff wird auch ein zündfähiges Brenngasgemisch oder ein Brennstoff/Luft-Gemisch verstanden. Als Brenngas kommt beispielsweise Erdgas, Flüssiggas oder Wasserstoff zum Einsatz. Mit der erfinderischen Zündkerze 1 können auch noch solche Brenngase sicher gezündet werden.

[0029] An der Außenelektrode 2 kann im Bereich des Außengewindes 5 eine um den Umfang umlaufende Außenumfangsnut 9 (Fig.1, 4) vorgesehen sein. Vorzugsweise ist die Außenumfangsnut 9 über den Umfang geschlossen. In diesem Fall münden die vorhandenen Gaskanäle

8 außen an der Zündkerze 1 in die Außenumfangsnut 9.

[0030] Zwischen den Mündungen der vorhandenen Gaskanäle 8 und dem axialen Ende des Außengewindes 5 ist zumindest ein dichtender Gewindegang 14 des Außengewindes 5 vorgesehen.

[0031] In den Fig.3 und 4 ist die Anordnung einer erfindungsgemäßen Zündkerze 1 in einem Gasmotor 20 dargestellt, wobei die Fig.4 eine Detailansicht dieser Anordnung zeigt. In diesem Ausführungsbeispiel ist der Gasmotor 20 mit einer Brennkammer 22 in Form einer Vorkammer zum Zünden und einem Zylinder 40, in dem die Hauptverbrennung stattfindet, ausgeführt. Die Brennkammer 22 ist in bekannter Weise über Strahlkanäle 23 mit dem Zylinder 40 verbunden. Die Brennkammer 22 ist durch einen Brennkammerkopf 21 abgeschlossen und der Brennkammerkopf 21 ist in bekannter Weise in einem Zylinderkopf 42 des Gasmotors 20 angeordnet. Im Brennkammerkopf 21 ist eine Gewindeöffnung 24 mit einem Innengewinde 25 vorgesehen. Die Zündkerze 1 wird mit deren Außengewinde 5 in das Innengewinde 25 der Gewindeöffnung 24 geschraubt, sodass das axiale Ende der Zündkerze 1 mit dem Zündbügel 6 und der gegenüberliegenden Mittenelektrode 3 in den Brennraum 22 ragt. Im Bereich dieses axialen Endes bildet sich die Zündungszone 10 aus, in der ein brennbares Gemisch in der Brennkammer 22 durch Funkenzündung gezündet wird. Nach Zündung tritt ein Heißgasstrahl durch die Strahlkanäle 23 in den Zylinder 40 aus, der das brennbare Gemisch im Zylinder 40 zündet. Bekanntermaßen kann mit einer solchen Vorkammerzündung bei gleicher Zündenergie das Gemisch im Zylinder 40 magerer sein, als bei einer direkten Zündung im Zylinder 40.

[0032] Im Brennkammerkopf 21 ist beabstandet von der Gewindeöffnung 24, und damit auch beabstandet von der Zündkerze 1, eine Ventilausnehmung 31 vorgesehen, in der ein Gasventil 30 angeordnet ist, mit dem der gasförmige Brennstoff zugeführt wird. Das Gasventil 30 kann als mechanisches Ventil oder auch als elektronisches Ventil ausgeführt sein. Die Ventilausnehmung 31 ist über einen Stichkanal 32 mit einem Gasverteilring 33 verbunden. Der Stichkanal mündet dazu im Bereich des axialen Endes der Ventilausnehmung 31 in die Ventilausnehmung 31, vorzugsweise zwischen einer Auslassdüse 34 des Gasventils 30 und dem axialen Ende der Ventilausnehmung 31. Der Gasverteilring 33 ist zwischen dem Brennkammerkopf 21 und der Zündkerze 1 vorgesehen, insbesondere zwischen dem Außengewinde 5 der Zündkerze 1 und dem Innengewinde 25 der Gewindeöffnung 24 des Brennkammerkopfes 21. Im gezeigten Ausführungsbeispiel ist der Gasverteilring 33 durch die Außenumfangsnut 9 am Außengewinde 5 der Zündkerze 1 ausgebildet. Gleichermaßen könnte der Gasverteilring 33 auch durch eine Innenumfangsnut am Innengewinde 25 der Gewindeöffnung 24 ausgebildet sein. Ebenso könnten eine Außenumfangsnut 9 und eine Innenumfangsnut vorgesehen sein, die gemeinsam den Gasverteilring 33 ausbilden. Im Fall einer Innenumfangsnut sind die Gaskanäle 8 in der Zündkerze 1 so angeordnet, dass die Gaskanäle 8 in die Innenumfangsnut münden. Gleichfalls ist auch im Falle einer Innenumfangsnut vorgesehen, dass zwischen Innenumfangsnut und dem axialen Ende des Innengewindes 25 zumindest ein dichtender Gewindegang 14 verbleibt.

[0033] Der Gasverteilring 33 erstreckt sich vorzugsweise über den gesamten Umfang, wodurch die Zündkerze 1 beliebig in das Innengewinde 25 geschraubt werden kann. Der Gasverteilring 33 verteilt damit den über den Stickkanal 32 zugeführten gasförmigen Brennstoff auf die Gaskanäle 8.

[0034] Nachdem das Gasventil 30 und die Zündkerze 1 voneinander beabstandet und getrennt im Brennkammerkopf 21 angeordnet sind, können diese auch separat und unabhängig voneinander entfernt und getauscht werden, was die Wartbarkeit ganz erheblich erleichtert.

[0035] Abgesehen davon kann auch das Totvolumen der Gaszuführung reduziert werden, da das Gasventil 30 im Brennkammerkopf 21 sehr nahe an der Zündkerze 1 angeordnet werden kann und keine langen Zuführleitungen (wie der Stichkanal 32) notwendig sind. Das Totvolumen begrenzt sich damit auf den Stichkanal 32 den Gasverteilring 33 und die Gaskanäle 8.

[0036] Vorzugsweise sind über den Umfang der Zündkerze 1 mehrere Gaskanäle 8 verteilt angeordnet. Damit kann die gesamte Oberfläche der Gaskanäle 8 bei gleichem Strömungsquerschnitt erheblich vergrößert werden. Nachdem der gasförmige Brennstoff in der Regel kühl (im Vergleich zu den Verbrennungstemperaturen in der Brennkammer 22) zugeführt wird, wird dadurch auch eine wirkungsvolle Kühlung der Zündkerze 1 im Bereich der Gaskanäle 8 kurz vor Zündzeitpunkt bzw. Flammausbreitungszeitpunkt rückführend in die Gaskanäle 8 erzielt. Durch die dadurch erzielte niedrige Temperatur, im Bereich der Gaskanäle 8 kann die Gefahr der Flammenausbreitung aus der Brennkammer 22 durch die Gaskanäle 8 in den Gasverteilring 33 und den Stichkanal 32 wirkungsvoll reduziert werden, da sich ausbreitende Flammen noch in den Gaskanälen 8 erstickt werden. Eine solche Flammenausbreitung könnte zu starker Rußbildung und Verschmutzung in den Gaskanälen 8, den Gasverteilring 33 und dem Stichkanal 32 führen, was vermieden werden soll.

[0037] Durch die Gaskanäle 8 kann darüber hinaus auch eine Drosselwirkung erzielt werden, wenn der Strömungsquerschnitt der Gaskanäle 8 kleiner ist, als der effektive Strömungsquerschnitt des Gasventiles bzw. des Stichkanals 32 bzw. des Gasverteilrings 33, was normalerweise immer der Fall ist. Die Drosselung reduziert insbesondere während der Verbrennung und folgender Druckerhöhung in der Brennkammer 22 die Rückströmung von Abgas in den Gasverteilring 33 bzw. den Stichkanal 32.

[0038] Es kann in der Zündkerze 1 auch ein Spülkanal 35 (Fig.4) vorgesehen sein, der die Brennkammer 22 mit dem Stichkanal 32 verbindet. Der Querschnitt des Spülkanals 35 wird dabei so ausgelegt, dass sich ein größtmögliches Druckgefälle zwischen dem Spülkanal 35 mit dem höheren Druck und dem Gasverteilring 33 ergibt. Dazu mündet der Spülkanal 35 in der Brennkammer 22 vorzugsweise in einem Bereich, in dem eine hohe Strömungsgeschwindigkeit herrscht. Der Druck muss dabei natürlich kleiner bleiben als der Druck des zugeführten gasförmigen Brennstoffes. Damit kann während der Verbrennung in der Brennkammer 22 eine Spülung des Stichkanals 32, des Gasverteilringes 33 und der Gaskanäle 8 erzielt werden. Während der Zuführung des gasförmigen Brennstoffes über das Gasventil 30 wird eine geringe Menge an gasförmigen Brennstoff über die Spülkanal 35 in die Brennkammer 22 strömen, was aber nicht störend ist.

[0039] Die Gaskanäle 8 sind vorzugsweise so ausgerichtet, das der zugeführte gasförmige Brennstoff auf die Zündungszone 10 im Bereich zwischen der Mittenelektrode 3 und der Außenelektrode 2 (mit Zündbügel 6) gerichtet ist. Damit wird durch die niedrigen Temperaturen des zugeführten gasförmigen Brennstoffes die Zündkerze 1 im Bereich der heißesten Zone um die Zündungszone 10 aktiv gekühlt. In Verbindung mit der zuvor beschriebener Drosselwirkung wird weiters eine höhere Eindringtiefe bzw. höhere lokale Strömungsgeschwindigkeit des gasförmigen Brennstoffes erreicht, sodass der Strahlkegel der Brennstoffeinblasung gerichtet auf die Zündungszone 10 höhere Turbulenzen und folglich effektivere Kühlung im Bereich der Zündungszone 10 erzielt. Auf diese Weise kann die Gefahr einer unbeabsichtigten vorzeitigen Zündung des brennfähigen Gemisches durch hohe Temperaturen im Bereich der Zündungszone 10 wirkungsvoll reduziert werden. Insbesondere kann auch durch die Temperaturabsenkung des Zündbügels 6 der Außenelektrode 2 die Lebensdauer der Zündkerze 1 signifikant erhöht werden.

[0040] Mit der Fig.5 und 6 ist eine weitere Ausgestaltung der erfindungsgemäßen Zündkerze 1, hier im Zusammenhang mit der Anordnung der Zündkerze 1 im Zylinderkopf 42 eines Zylinders 40 eines Gasmotors 20. In diesem Fall ist der Zylinder 40 die Brennkammer 22. Im Zylinder 40 ist in bekannter Weise ein Kolben 41 angeordnet. Der Brennkammerkopf 21 schließt die Brennkammer 22 in dieser Ausführung teilweise ab. Um den Brennkammerkopf 21 kann auch ein von Kühlmedium durchströmter Kühlmantel 43 vorgesehen sein, um den Brennkammerkopf 21 aktiv zu kühlen. Der Brennkammerkopf 21 ist im Wesentlichen wie mit Bezugnahme auf die Figuren 3 und 4 erläutert ausgeführt. Selbstverständlich wäre es auch möglich, die Zündkerze 1 und das Gasventil 30 direkt im Zylinderkopf 42 des Gasmotors 20 anzuordnen. In diesem Fall wäre der Zylinderkopf 42 gleichzeitig der Brennkammerkopf 21.

[0041] Die Zündkerze 1 ist im dargestellten Ausführungsbeispiel mit einer Außenelektrode 2 ausgeführt, die den Hohlraum 7 am axialen Ende der Zündkerze 1 im Bereich der Zündungszone 10 in Form einer Schirmung 12 kappenförmig umschließt. Selbstverständlich könnte aber auch eine Zündkerze ohne Schirmung 12 eingesetzt werden. Der Hohlraum 7 wird damit durch die Schirmung 12 der Außenelektrode 2 nach außen abgegrenzt. Am axialen Ende der Außenelektrode 2 sind eine Anzahl von Flammkanälen 11 vorgesehen, die den Hohlraum 7 mit dem die Zündkerze 1 umgebenden Raum, die Brennkammer 22, verbinden. Wird im Hohlraum 7 ein gasförmiges Gemisch gezündet, treten durch die Flammkanäle 11 Heißgasstrahlen aus, die das brennfähige Gemisch in der Brennkammer 22 zünden. Ähnlich wie bei einer Vorkammerzündung, kann das Gemisch in der Brennkammer 22 magerer sein, als bei einer direkten Zündung. Durch die Schirmung des Hohlraumes 7 durch die Außenelektrode 2 werden auch zu große Turbulenzen im Hohlraum 7 im Bereich der Zündungszone 10 verhindert, was die sichere Zündung ebenfalls unterstützt.

[0042] Im Ausführungsbeispiel nach der Fig.6 ist der Gasverteilring 33 als Innenumfangsnut 13 im Bereich des Innengewindes 25 im Brennkammerkopf 21 ausgeführt.

[0043] Zwischen Gasverteilring 33 und dem axialen Ende des Außengewindes 5 bzw. des Innengewindes 25 ist jedenfalls zumindest ein dichtender Gewindegang 14 vorgesehen, der verhindert, dass sich eine, zumindest nicht zu große, unkontrollierte Leckage von gasförmigen Brennstoff über das Gewinde in die Brennkammer 22 ausbildet. Je nach Druckniveau des zugeführten gasförmigen Brennstoffes kann auch mehr als ein dichtender Gewindegang 14 erforderlich sein.

[0044] Mit einer erfindungsgemäßen Zündkerze 1 kann sowohl die Haupteinblasung von gasförmigem Brennstoff, als auch eine Mehrfacheinblasung von gasförmigem Brennstoff realisiert werden.

[0045] Die Haupteinblasung ist insbesondere interessant, wenn die Zündkerze 1 in einem Zylinder 40 als Brennkammer 22 angeordnet ist. Dabei wird der für die Hauptverbrennung benötige gasförmige Brennstoff über die Zündkerze 1 zugeführt. Selbstverständlich könnte der für die Hauptverbrennung benötigte gasförmige Brennstoff auch auf andere Weise zugeführt werden, beispielsweise in herkömmlicher Weise durch Ansaugung im Saugtakt des Gasmotors 20.

[0046] Ganz besonders interessant ist die erfindungsgemäße Zündkerze 1 aber für eine Zündeinblasung. Dazu kann unmittelbar vor Zündung eine benötigte Menge an gasförmigen Brennstoff über die Zündkerze 1 in die Zündungszone 10 zugeführt werden, um das Gemisch im Bereich der Zündungszone 10 aufzufetten, was die Zündung erleichtert. Das ermöglicht es auch, zuerst in einer ersten Einblasung nur wenig gasförmigen Brennstoff zuzuführen, sodass ein derart mageres Gemisch entsteht, das nicht zündfähig ist. Erst kurz vor der Zündung wird das Gemisch durch eine zweite Einblasung gezielt in der Zündungszone 10 aufgefettet. In diesem Zusammenhang ist es auch denkbar, das ein mageres Gemisch in der Brennkammer 22 erzeugt wird, das direkt durch Funkenzündung nur schwer oder gar nicht zündbar wäre. Ein solches Gemisch wird beispielsweise im Kompressionstakt aus dem Zylinder 40 in eine damit verbundene Vorkammer als Brennkammer 22 gedrückt oder aus dem Zylinder 40 in den Hohlraum einer Zündkerze 1 nach der Fig.5. Aufgrund des mageren Gemisches wird eine Fehl- oder Vorzündung verhindert. Erst kurz vor dem Zündzeitpunkt wird gasförmiger Brennstoff über die Zündkerze 1 in die Zündungszone 10 der Zündkerze 1 zugeführt, um das Gemisch in diesem Bereich gezielt aufzufetten, was die Zündung durch Funkenzündung erleichtert oder überhaupt erst ermöglicht.

Patentansprüche

1. Zündkerze mit einer Außenelektrode (2) und einer Mittenelektrode (3), die durch einen Isolator (4) voneinander getrennt sind, wobei die Außenelektrode (2) an einem axialen Ende der Zündkerze (1) als Außengewinde (5) ausgeführt ist und an diesem axialen Ende zwischen der Außenelektrode (2) und der Mittenelektrode (3) ein Hohlraum (7) gebildet ist, wobei durch die Außenelektrode (2) zumindest ein durchgehender Gaskanal (8) vorgesehen ist, wobei der Gaskanal (8) innen im Hohlraum (7) und außen im Bereich des Außengewindes (5) mündet, wobei zwischen der äußeren Mündung und dem axialen Ende der Außenelektrode (2) zumindest ein Gewindegang (14) des Außengewindes (5) vorgesehen ist, **dadurch gekennzeichnet, dass** der Gaskanal (8) innen auf die Zündungszone (10) im Bereich zwischen der Mittenelektrode (3) und der Außenelektrode (2) der Zündkerze (1) ausgerichtet ist.

2. Zündkerze nach Anspruch 1, **dadurch gekennzeichnet, dass** über den Umfang des Außengewindes (5) verteilt eine Mehrzahl von Gaskanälen (8) vorgesehen sind.

3. Zündkerze nach Anspruch 1 oder 2, **dadurch gekennzeichnet, dass** an der Außenelektrode (2) im Bereich des Außengewindes (5) eine Außenumfangsnut (9) vorgesehen ist und der zumindest eine Gaskanal (8) außen in die Außenumfangsnut (9) mündet und zwischen Außenumfangsnut (9) und axialem Ende der Außenelektrode (2) zumindest ein Gewindegang (14) des Außengewindes (5) vorgesehen ist.

4. Zündkerze nach Anspruch 2 und 3, **dadurch gekennzeichnet, dass** der Strömungsquerschnitt des zumindest einen Gaskanals (8) kleiner ist, als der Strömungsquerschnitt der Außenumfangsnut (9).

5. Zündkerze nach einem der Ansprüche 1 bis 4, **dadurch gekennzeichnet, dass** der Hohlraum (7) durch die Außenelektrode (2) umschlossen ist und in der Außenelektrode (2) im Bereich des axialen Endes zumindest ein durchgehender Flammkanal (11) vorgesehen ist, der den Hohlraum (7) mit der Umgebung der Außenelektrode (2) verbindet.

6. Gasmotor mit einer Brennkammer (22) und einem Brennkammerkopf (21), der die Brennkammer (22) zumindest teilweise abschließt, wobei im Brennkammerkopf (21) eine Gewindeöffnung (24) mit einem Innengewinde (25) vorgesehen ist, **dadurch gekennzeichnet, dass** in die Gewindeöffnung (24) eine Zündkerze (1) nach einem der Ansprüche 1 bis 5 mit deren Außengewinde (5) eingeschraubt ist, und im Brennkammerkopf (21) beabstandet von der Gewindeöffnung (24) eine Ventilausnehmung (31) vorgesehen ist, deren axiales Ende über einen Stichkanal (32) mit einem Gasverteilring (33) zwischen der Zündkerze (1) und dem Brennkammerkopf (21) verbunden ist, wobei der Gasverteilring (33) durch eine Innenumfangsnut (13) am Innengewinde (25) und/oder durch die Außenumfangnut (9) an der Zündkerze (1) gebildet ist **und dass** der zumindest eine Gaskanal (8) in den Gasverteilring (33) mündet, wobei zwischen dem Gasverteilring (33) und dem axialen Ende der Zündkerze (1) zumindest ein Gewindegang (14) des Außen- und Innengewindes (5, 25) vorgesehen ist.

7. Gasmotor nach Anspruch 6, **dadurch gekennzeichnet, dass** ein Spülkanal (35) vorgesehen ist, der die Brennkammer (22) mit dem Stichkanal (32) verbindet.

Hierzu 3 Blatt Zeichnungen

1/3

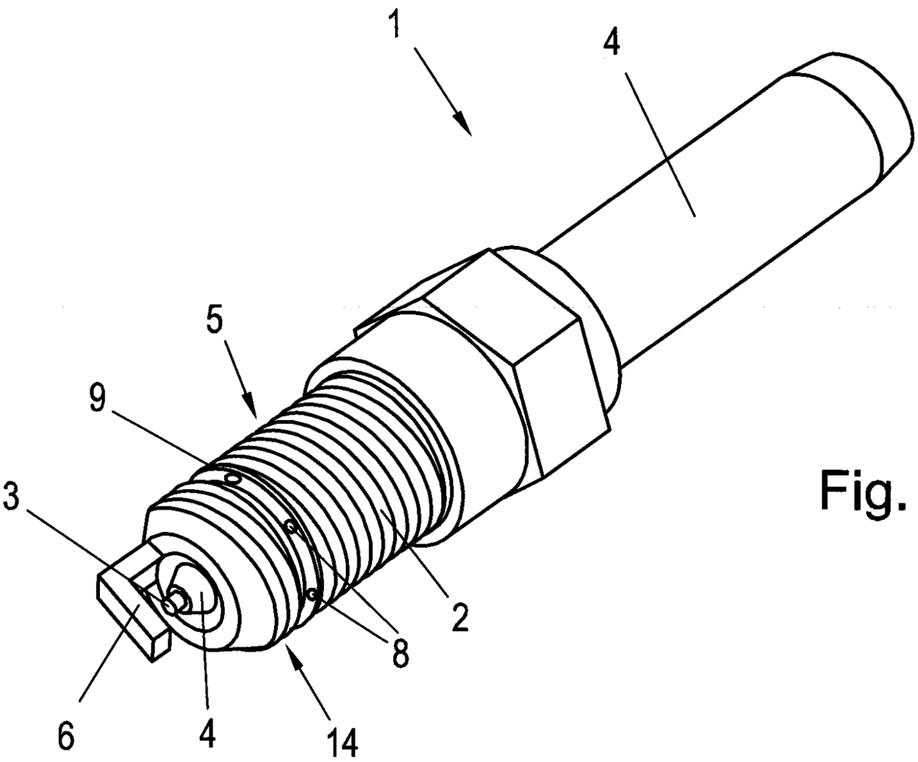

Fig. 1

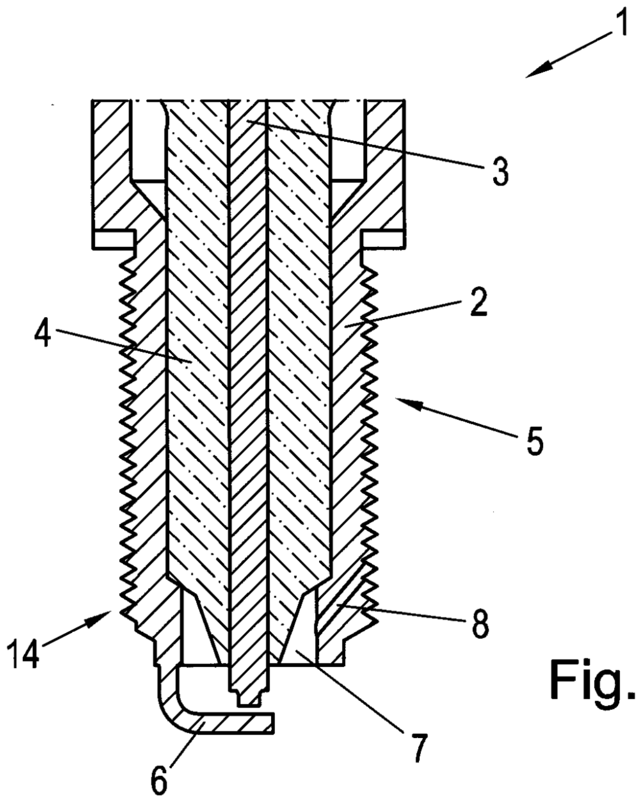

Fig. 2

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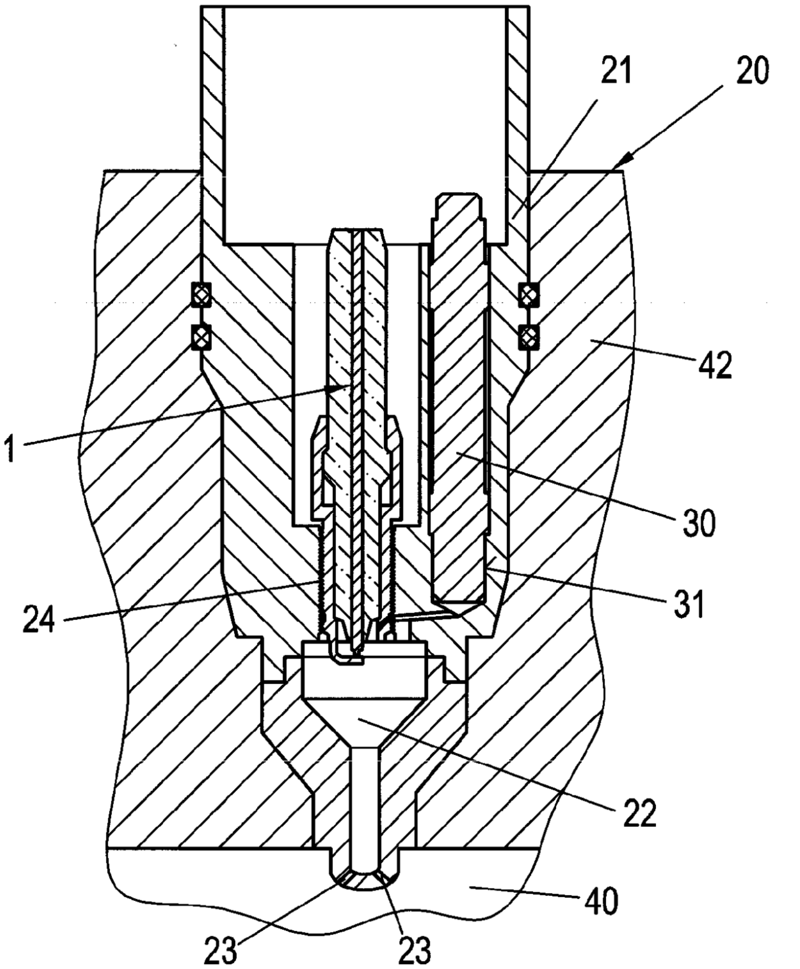
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Fig. 3

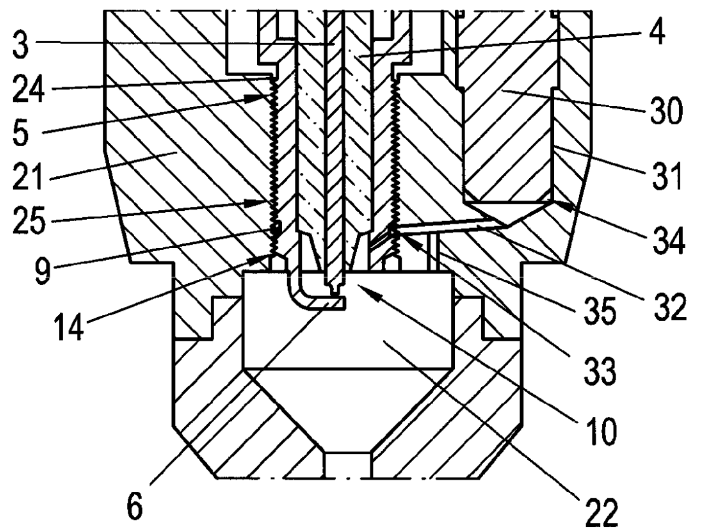
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Fig. 4

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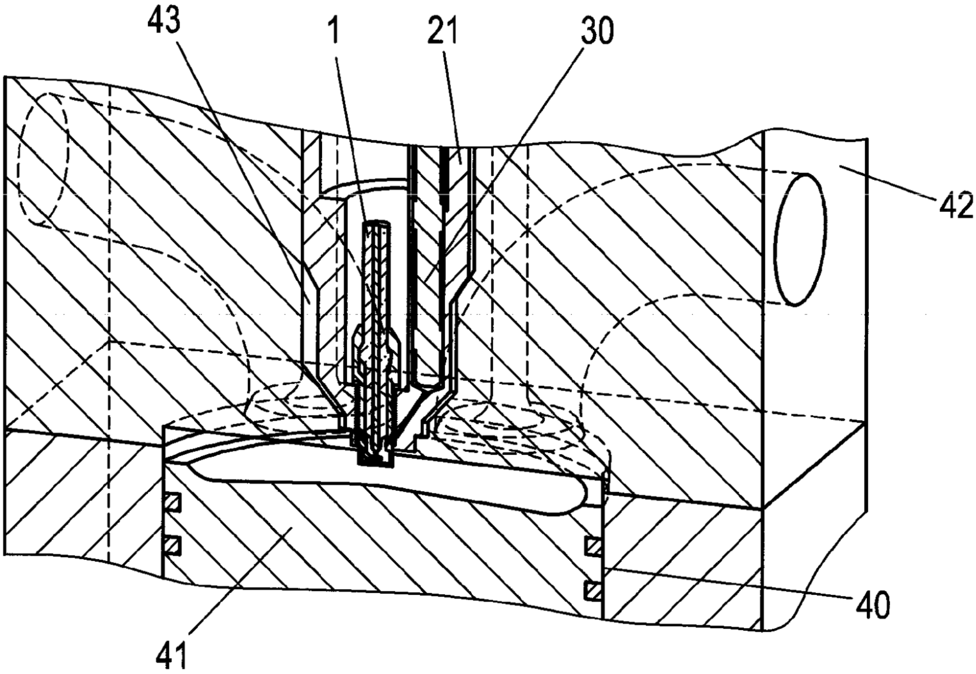

Fig. 5

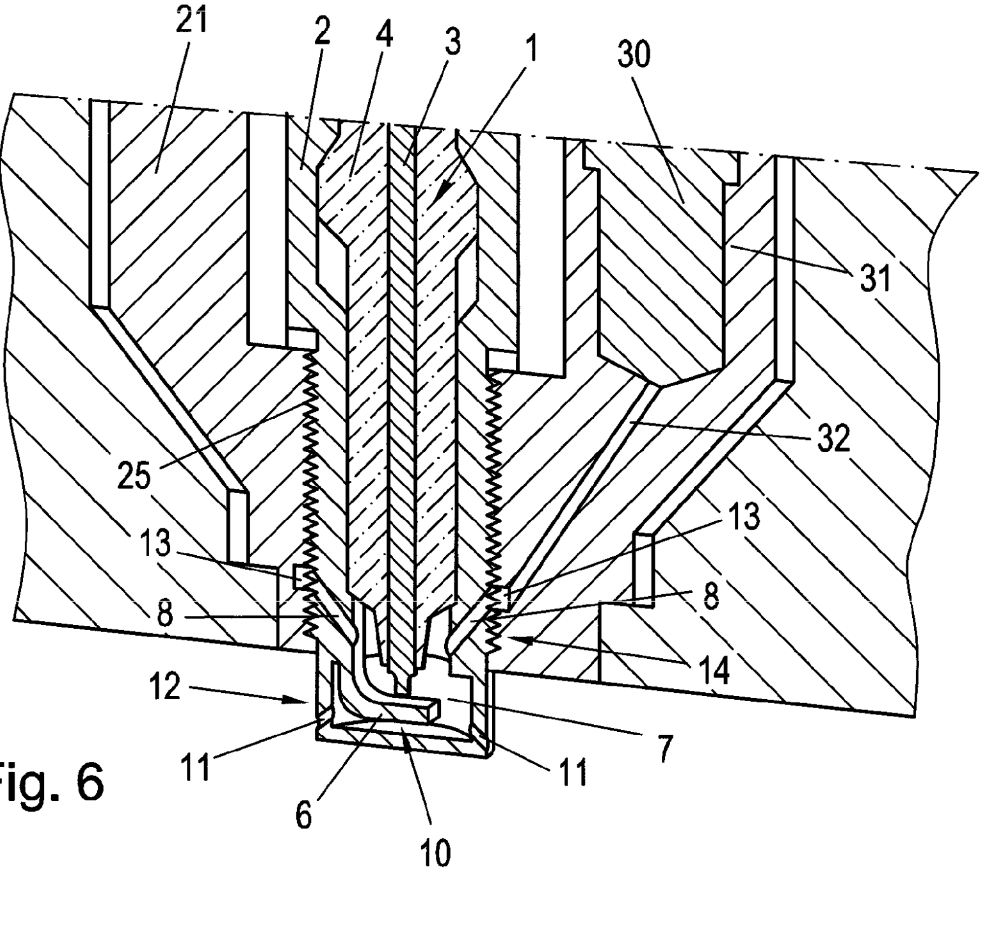

Fig. 6

Description AT517703B1

SPARK PLUG AND GAS ENGINE WITH SPARK PLUG

[0001] The present invention relates to a spark plug with an outer electrode and

a center electrode, which are separated from each other by an insulating body, wherein the outer

outer electrode is designed as an external thread at one axial end of the spark plug and

this axial end between the outer electrode and the center electrode a cavity

is formed, wherein at least one continuous gas channel is provided through the outer electrode

hen, with the gas channel inside the cavity and outside in the area of the external thread

between the outer opening and the axial end of the outer electrode

at least one thread of the external thread is provided. Furthermore, the invention relates

a gas engine with a combustion chamber and a combustion chamber head, which

at least partially, with a threaded opening in the combustion chamber head with a

internal thread is provided, wherein the gas engine is provided with a spark plug according to the invention

is provided.

[0002] Gas engines, which are powered by natural gas or liquefied petroleum gas, for example, have

compared to other combustion engines the advantage of lower emissions, which gas mo-

engines are particularly interesting for large engines, e.g. on ships or in natural gas distribution networks

might.

[0003] The known combustion processes of spark-ignited gas engines are based on the principle

that either combustible mixture is sucked in during the intake stroke, or during

of the compression tract by injection of fuel gas. After compression of the

The mixture is ignited by spark ignition, for example by means of a spark plug.

It is also known to start the gas engine by injecting a small amount of self-igniting

flammable liquid fuel. The ignition can take place directly in the main combustion chamber

(the cylinder) or in a pre-combustion chamber. In the case of a pre-combustion chamber, a

combustible mixture is ignited in the pre-combustion chamber, which produces a

hot gas jet escaping into the main combustion chamber, which ignites the combustible

The combustible mixture in the main combustion chamber

mer is then traversed by generally turbulent flame fronts.

Such a combustion process is described, for example, in DE 10 2014 00 229 A1.

[0004] From the point of view of emissions and consumption, it is desirable to use the gas engine in

Lean operation, i.e. operating with a fuel/air ratio greater than one. However,

Gas engines tend to misfire when the mixture is lean, which in turn leads to

high pollutant emissions, poor efficiency and/or extreme mechanical

Such misfires endanger the safe operation of the gas engine.

and reliable operation of the gas engine. Apart from that, a lean mixture is considerably

significantly more difficult to ignite than a richer mixture. The requirements for the ignition system

of a gas engine, especially a gas engine operating on a lean mixture, are

therefore high.

[0005] To meet these requirements, solutions have already been developed

where fuel is directed specifically towards the spark plug, or at least in its vicinity.

area. This fills the area around the spark plug with fuel.

enriched, creating a richer mixture locally in the area of the spark plug, which is safer

Due to the possible variance caused by different load points

of the gas engine and the local heterogeneous mixture formation, however, a higher

Demand for regulation to maximize the potential for emission reduction and reduction of soot formation

It is advisable to use the fuel directly through the spark plug

to contribute.

[0006] In US 6,481,422 B2, for example, gaseous fuel is used during the

The fuel is fed into the cylinder by the spark plug during the compression stroke and after compression by

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The spark plug is ignited. This is achieved by a special spark plug, which consists of a

Adapter, which simultaneously forms a first pole of the spark plug (grounding), and an inner

electrode part, which forms the second pole of the spark plug. The adapter is inserted into the

Cylinder head provided thread for conventional spark plugs and the inner

The electrode part is screwed into the adapter. In the adapter or between the adapter and the inner electrode

electrode part, a feed channel is provided which is connected to a gas valve and

the gaseous fuel is fed into the cylinder. This arrangement results in

However, the supply channel creates a large dead space, which can be filled with gas during the gas supply.

After the end of the gas supply, the fuel can be

remaining gaseous fuel can flow uncontrollably into the cylinder, which can cause the ignition

Likewise, the flame front in the cylinder after ignition can also extend into the

Since there will be a very rich mixture there, it will

high emissions, which increases the emissions of the gas engine. This also leads to

a strong soot formation, which can contaminate the feed channel. Last but not least,

unburned gaseous fuel flows into the cylinder, which in the exhaust stroke directly

the environment, which is also undesirable. Another problem with this

arrangement is the poor maintainability, since the spark plug is not separated from the gas valve.

Since a spark plug is a service part that needs to be changed regularly

has to be replaced, every replacement of the spark plug is time-consuming.

[0007] US 4,864,989 A shows a spark plug through which gaseous fuel is injected into the space

between the inner and outer electrodes. This space serves as

Pre-combustion chamber, in which the gaseous fuel in the compression tract is combined with the compressed

mixture in the cylinder and forms an ignitable mixture, which is ignited by the spark plug

The escaping flame jet ignites the mixture in the cylinder. On the body of the

A nozzle is arranged in the spark plug and a hole is provided in the body which is connected to the

A similar arrangement is shown in US 4,383,198 A. This means that in the US

4,864,989 A and in US 4,383,198 A essentially the same problems as in US

6,481 ,422 B2.

[0008] From EP 1 143 126 A2 a pre-chamber spark plug is known in which the pre-chamber

mer is firmly connected to the spark plug. Therefore, replacing the spark plug alone is not

possible. The pre-chamber spark plug is inserted into the cylinder head via a thread on the pre-chamber.

head and the fuel is fed into the pre-combustion chamber in an untargeted manner

via an annular groove in the cylinder head and the thread of the pre-chamber spark plug.

Spark plug is located in the upper end of the pre-combustion chamber, which creates a relatively large volume

which must be filled with fuel before it can be ignited.

[0009] US 6,260,546 B1 describes a spark plug which is mounted in the cylinder head.

screwed and which has an opening in the external thread that connects a gas channel with the

Space between the inner electrode of the spark plug and the outer thread.

Fuel can be added through the opening. But this also results in a relatively large volume

which must be filled with fuel until the fuel reaches the ignition zone.

A similar spark plug is shown in JP 2011-222205 A.

[0010] It is therefore an object of the present invention to provide a spark plug

which makes it possible to reduce the above problems.

[0011] This task is solved by the fact that the gas channel inside is directed towards the ignition zone in the

area between the center electrode and the outer electrode of the spark plug.

Because the gas channel is located in the area of the external thread of the spark plug, i.e. in the area

of the axial end of the spark plug, it is possible to reduce the dead volume in the ignition

candle, or the gas supply in general, as far as possible. No long

Gas lines and large additional cavities in the spark plug are necessary to ensure the gas-

Apart from that, this also allows a standard

Spark plug can be used, into which only the gas channel needs to be inserted,

for example, by simply drilling the gas channel. In this way, a conventional

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The spark plug can be easily converted into a spark plug according to the invention.

the alignment of the gas channel inside is aligned with the ignition zone of the spark plug

The gaseous fuel can be introduced specifically where a richer mixture is required.

and at the same time the hot ignition zone is heated by the supplied gaseous

Fuel is optimally cooled. In this way, the risk of unintentional premature

Ignition of the combustible mixture by high temperatures in the area of the ignition zone

ne can be effectively reduced and by lowering the temperature of the ignition bracket of the

outer electrode also increases the lifespan of the spark plug.

[0012] It is advantageous if a plurality of gas channels are provided distributed over the circumference.

This allows the surface area of the gas channels to be increased considerably, which is

the supplied fuel leads to better cooling in the area of the gas channels.

excessive flame propagation from the combustion chamber into the gas ducts can be prevented,

because a flame would be extinguished very quickly and safely on the cool surface.

[0013] It is particularly advantageous if the outer electrode in the area of the outer

wind an outer circumferential groove is provided and the at least one gas channel is in the outer

outer circumferential groove and between the outer circumferential groove and the axial end of the outer electrode

at least one thread is provided. The outer circumferential groove can be used as a simple

Gas distribution ring can be used, which can feed several gas channels, whereby the external

groove only requires a supply of gaseous fuel. Such a spark plug

can therefore also be used easily, since it is irrelevant due to the outer circumferential groove,

in which angular position (relative to a supply of gaseous fuel) the

Spark plug is inserted.

[0014] It is also particularly advantageous if the flow cross-section of the at least

a gas channel is smaller than the flow cross-section of the outer circumferential groove.

In this way, a throttling effect can be achieved through the gas channel, which has several effects

On the one hand, the throttling effect reduces the combustion

and subsequent pressure increase in the combustion chamber, the backflow of exhaust gas into the outside

On the other hand, the throttling effect reduces the flow velocity of the inlet

led gaseous fuel, which increases the penetration depth of the gaseous fuel

in the combustion chamber and also for higher turbulence in the combustion chamber and thus to

better cooling by the gaseous fuel.

[0015] If the cavity is enclosed by the outer electrode and in the outer electrode

rode at least one continuous flame channel is provided in the area of the axial end,

which connects the cavity with the surroundings of the outer electrode can be prevented,

that the injection of gaseous fuel into the ignition zone of the spark plug

is disturbed by turbulence in the combustion chamber. The injected fuel remains in the ignition

zone and effectively greases the ignition zone, ensuring reliable ignition

The cavity thus forms a kind of mini-prechamber.

[0016] Likewise, it is an object of the present invention to provide a gas engine with

of such a spark plug and an ignition method so that a safe ignition

a gas engine becomes possible.

[0017] This task is solved for the gas engine by inserting a threaded opening into a

spark plug is screwed in, and in the combustion chamber head at a distance from the

A valve recess is provided in the threaded opening, the axial end of which is connected via a branch

channel connected to a gas distribution ring between the spark plug and the combustion chamber head

wherein the gas distribution ring is formed by an inner circumferential groove on the internal thread and/or by the

Outer circumferential groove is formed on the spark plug and the at least one gas channel is in the gas

distribution ring, whereby between the gas distribution ring and the axial end of the spark plug

at least one thread of the external and internal thread is provided.

[0018] Due to the spaced arrangement of the gas valve and the spark plug, it is possible

both components separately and independently of each other, whereby the gas engine

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easier to maintain. To service one of the two components, it is no longer necessary to remove both

removed, but only the component that needs to be serviced. Apart from

This allows the ignition system to be easily adapted. For example,

A different spark plug can be easily inserted without replacing the gas valve.

Likewise, a different gas valve can be used without having to change the spark plug

In this way, the gas engine can also be easily installed on different

can be adapted to different requirements.

[0019] The spaced arrangement of the gas valve also allows the gas valve to be positioned as close

as possible on the gas distribution ring. This reduces the length of the branch line and thus

also the dead volume of the gas supply.

[0020] Due to the gas distribution ring, it is irrelevant how the spark plug is inserted into the threaded hole

is screwed in. The gas distribution ring, which is connected to the branch line, is always

ensure that the gas channels are supplied with gaseous fuel.

[0021] The present invention will be described below with reference to Figures 1

to 6 are explained in more detail, which show exemplary, schematic and non-limiting advantageous embodiments

embodiments of the invention.

[0022] Fig.1 a spark plug according to the invention with outer circumferential groove,

[0023] Fig.2 a section through the spark plug according to the invention without external

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[0024] Fig.3 and 4 the arrangement of the spark plug in a pre-chamber as combustion chamber and

[0025] Fig.5 and 6 the arrangement of the spark plug with shielding in a cylinder as combustion

space.

[0026] In Fig. 1 and Fig. 2, a spark plug 1 according to the invention is shown. As in a

conventional spark plug, the spark plug 1 consists of an outer electrode 2, which

at one axial end is designed as an external thread 5. The outer electrode 2 encloses

a center electrode 3, which is separated from the outer electrode 2 by an electrical insulator 4.

From the outer electrode 2, which is normally electrically earthed, there is also

In a known manner, an ignition bracket 6 is electrically connected to the outer electrode 2, which

Formation of the spark gap at the axial end of the spark plug 1 axially opposite the center

ten electrode 3. Between the ignition bracket 6 and the center electrode 3 is created

the ignition spark when a sufficient ignition voltage is applied to the center electrode 3.

At the axial end of the spark plug 1, between the center electrode 3, or the center electrode

rod 3 surrounding insulator 4, and the outer electrode 2 (which also includes the ignition bracket 6)

a cavity 7 is formed.

[0027] In the area of the external thread 5, a first end of a continuous gas

channel 8. The second end of the gas channel 8 opens into the cavity 7. The gas channel 8 goes

through the outer electrode 2 in the area of the external thread 5 and connects

the cavity 7 with the outer peripheral surface of the spark plug 1 in the area of the external thread

of the 5th Through the gas channel 8, a gaseous fuel can be introduced from the outside into the cavity 7

Gaseous fuel also includes an ignitable fuel gas

mixed or a fuel/air mixture. The circumference of the external thread 5

Several gas channels 8 can also be arranged distributed, as shown in Fig.1 by the mouths

indicated.

[0028] Gaseous fuel also includes an ignitable fuel gas mixture or a

Fuel/air mixture. Fuel gases include natural gas, liquefied petroleum gas

or hydrogen. With the inventive spark plug 1, even such

Combustible gases are ignited safely.

[0029] On the outer electrode 2, in the area of the external thread 5, a

circumferential outer circumferential groove 9 (Fig.1, 4) may be provided. Preferably, the outer circumferential

The catch groove 9 is closed over the circumference. In this case, the existing gas channels

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8 on the outside of the spark plug 1 into the outer circumferential groove 9.

[0030] Between the mouths of the existing gas channels 8 and the axial end of the

External thread 5 is provided with at least one sealing thread 14 of the external thread 5.

see.

[0031] In Figs. 3 and 4, the arrangement of a spark plug 1 according to the invention in a

Gas engine 20 is shown, with Fig.4 showing a detailed view of this arrangement. In this

The embodiment is the gas engine 20 with a combustion chamber 22 in the form of a pre-chamber

for ignition and a cylinder 40 in which the main combustion takes place. The

Combustion chamber 22 is connected to cylinder 40 via jet channels 23 in a known manner.

The combustion chamber 22 is closed by a combustion chamber head 21 and the combustion chamber

The cylinder head 21 is arranged in a known manner in a cylinder head 42 of the gas engine 20. lm

A threaded opening 24 with an internal thread 25 is provided in the combustion chamber head 21. The

Spark plug 1 is inserted with its external thread 5 into the internal thread 25 of the threaded opening 24

screwed so that the axial end of the spark plug 1 is aligned with the ignition bracket 6 and the opposite

lying center electrode 3 into the combustion chamber 22. In the area of this axial end,

the ignition zone 10, in which a combustible mixture in the combustion chamber 22 is

Spark ignition is ignited. After ignition, a hot gas jet passes through the jet channels 23

into cylinder 40, which ignites the combustible mixture in cylinder 40. As is known

With such a pre-chamber ignition, the mixture in the cylinder can be

40 will be leaner than with direct ignition in cylinder 40.

[0032] The combustion chamber head 21 is spaced from the threaded opening 24, and thus also

spaced from the spark plug 1, a valve recess 31 is provided in which a gas valve

30 is arranged, with which the gaseous fuel is supplied. The gas valve 30 can be

mechanical valve or as an electronic valve. The valve recess

The connection 31 is connected to a gas distribution ring 33 via a branch channel 32. The branch channel

opens into the valve recess in the area of the axial end of the valve recess 31

31, Preferably between an outlet nozzle 34 of the gas valve 30 and the axial end of the

Valve recess 31. The gas distribution ring 33 is between the combustion chamber head 21 and the

Spark plug 1 is provided, in particular between the external thread 5 of the spark plug 1 and

the internal thread 25 of the threaded opening 24 of the combustion chamber head 21. In the shown

example, the gas distribution ring 33 is inserted through the outer circumferential groove 9 on the external thread 5

of the spark plug 1. Similarly, the gas distribution ring 33 could also be formed by a

inner circumferential groove on the internal thread 25 of the threaded opening 24. Likewise,

an outer circumferential groove 9 and an inner circumferential groove should be provided, which together form the

Gas distribution ring 33. In the case of an inner circumferential groove, the gas channels 8 are in the ignition

candle 1 is arranged so that the gas channels 8 open into the inner circumferential groove.

also in the case of an inner circumferential groove, that between the inner circumferential groove and the

axial end of the internal thread 25 at least one sealing thread 14 remains.

[0033] The gas distribution ring 33 preferably extends over the entire circumference, whereby

The spark plug 1 can be screwed into the internal thread 25 as desired. The gas distribution ring

33 thus distributes the gaseous fuel supplied via the stick channel 32 to the gas

channels 8

[0034] After the gas valve 30 and the spark plug 1 are spaced apart and separated

are arranged in the combustion chamber head 21, these can also be arranged separately and independently of one another.

can be removed and replaced one after the other, which makes maintenance much easier.

[0035] Apart from that, the dead volume of the gas supply can also be reduced, since

the gas valve 30 in the combustion chamber head 21 is arranged very close to the spark plug 1

and no long supply lines (such as branch channel 32) are necessary. The dead volume

men is thus limited to the branch channel 32, the gas distribution ring 33 and the gas channels 8.

[0036] Preferably, several gas channels 8 are distributed over the circumference of the spark plug 1

This allows the entire surface of the gas channels 8 to be used at the same flow

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cross-section can be increased considerably. Since the gaseous fuel is usually cool

(compared to the combustion temperatures in the combustion chamber 22),

This also ensures effective cooling of the spark plug 1 in the area of the gas channels 8 shortly before

Ignition time or flame propagation time is achieved by returning to the gas channels 8. By

The resulting low temperature in the area of the gas channels 8 can reduce the risk of

Flame propagation from the combustion chamber 22 through the gas channels 8 into the gas distribution ring 33

and the branch channel 32 can be effectively reduced, since spreading flames can still be

the gas ducts 8. Such flame spread could lead to heavy soot formation.

contamination and contamination in the gas channels 8, the gas distribution ring 33 and the branch channel 32

what should be avoided.

[0037] Furthermore, a throttling effect can be achieved through the gas channels 8,

if the flow cross-section of the gas channels 8 is smaller than the effective flow cross-section

section of the gas valve or the branch channel 32 or the gas distribution ring 33, which is normally

This is always the case. The throttling reduces the fuel consumption particularly during combustion and

following pressure increase in the combustion chamber 22, the backflow of exhaust gas into the gas

partial ring 33 or the branch channel 32.

[0038] A scavenging channel 35 (Fig.4) can also be provided in the spark plug 1, which

Combustion chamber 22 with the branch channel 32. The cross section of the flushing channel 35 is

designed in such a way that the greatest possible pressure drop is achieved between the flushing channel 35 with

the higher pressure and the gas distribution ring 33. For this purpose, the flushing channel 35 opens into the

Combustion chamber 22 preferably in an area in which a high flow velocity

The pressure must of course remain lower than the pressure of the supplied gaseous

This allows a purge to be carried out during combustion in the combustion chamber 22.

tion of the branch channel 32, the gas distribution ring 33 and the gas channels 8. While

the supply of gaseous fuel via the gas valve 30, a small amount of

gaseous fuel flow through the purge channel 35 into the combustion chamber 22, but this is not

is disturbing.

[0039] The gas channels 8 are preferably aligned so that the supplied gaseous

Fuel onto the ignition zone 10 in the area between the center electrode 3 and the outer

outer electrode 2 (with ignition bracket 6). This ensures that the low temperatures

of the supplied gaseous fuel, the spark plug 1 in the area of the hottest zone

the ignition zone 10 is actively cooled. In conjunction with the previously described throttling effect

Furthermore, a higher penetration depth or higher local flow velocity of the gas-

shaped fuel, so that the jet cone of the fuel injection is directed towards

the ignition zone 10 higher turbulence and consequently more effective cooling in the area of

Ignition zone 10. In this way, the risk of unintentional premature

Ignition of the combustible mixture by high temperatures in the area of the ignition zone

ne 10 can be effectively reduced. In particular, the temperature reduction can also

of the ignition bracket 6 of the outer electrode 2, the service life of the spark plug 1 is significantly increased

become.

[0040] Figures 5 and 6 show a further embodiment of the spark plug 1 according to the invention,

here in connection with the arrangement of the spark plug 1 in the cylinder head 42 of a cylinder

40 of a gas engine 20. In this case, cylinder 40 is the combustion chamber 22. In cylinder 40

A piston 41 is arranged in a known manner. The combustion chamber head 21 closes the combustion

chamber 22 in this design. A combustion chamber head 21 can also be

Cooling jacket 43 through which cooling medium flows is provided in order to actively

The combustion chamber head 21 is essentially as shown in Figures 3

and 4. Of course, it would also be possible to use the spark plug 1 and the

Gas valve 30 directly in the cylinder head 42 of the gas engine 20. In this case, the

Cylinder head 42 is also the combustion chamber head 21.

[0041] In the illustrated embodiment, the spark plug 1 is provided with an outer electrode 2

which defines the cavity 7 at the axial end of the spark plug 1 in the area of the ignition zone.

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ne 10 in the form of a shield 12. Of course,

A spark plug without shielding 12 can also be used. The cavity 7 is thus

the shielding 12 of the outer electrode 2 is delimited to the outside. At the axial end of the outer

outer electrode 2, a number of flame channels 11 are provided, which connect the cavity 7 with

the space surrounding the spark plug 1, the combustion chamber 22. If the cavity

7 a gaseous mixture is ignited, hot gas jets emerge through the flame channels 11,

which ignite the combustible mixture in the combustion chamber 22. Similar to an occurrence

ignition, the mixture in the combustion chamber 22 can be leaner than with a direct

Ignition. By shielding the cavity 7 by the outer electrode 2,

large turbulences in the cavity 7 in the area of the ignition zone 10 are prevented, which ensures safe

Ignition also supported.

[0042] In the embodiment according to Fig.6, the gas distribution ring 33 is designed as an inner circumferential groove 13

in the area of the internal thread 25 in the combustion chamber head 21.

[0043] Between the gas distribution ring 33 and the axial end of the external thread 5 or the

In any case, at least one sealing thread 14 is provided on the internal thread 25, which

prevents an uncontrolled leakage of gaseous

Fuel is fed into the combustion chamber 22 via the thread. Depending on the pressure level of the

The gaseous fuel may also require more than one sealing thread 14.

be possible.

[0044] With a spark plug 1 according to the invention, both the main injection of gas-

shaped fuel, as well as multiple injection of gaseous fuel

become.

[0045] The main injection is particularly interesting when the spark plug 1 is in a

Cylinder 40 is arranged as combustion chamber 22. The combustion chamber for the main combustion

required gaseous fuel is supplied via the spark plug 1. Of course, the

The gaseous fuel required for the main combustion can also be supplied in other ways

be, for example, in the conventional way by suction in the intake stroke of the gas engine

20.

[0046] The spark plug 1 according to the invention is particularly interesting for an ignition

injection. For this purpose, the required amount of gaseous fuel can be injected immediately before ignition.

fuel is fed into the ignition zone 10 via the spark plug 1 in order to ignite the mixture in the

area of the ignition zone 10, which facilitates ignition. This allows

also, to first supply only a small amount of gaseous fuel in a first injection, so that

a mixture so lean that it is not ignitable. Only shortly before ignition is

The mixture is enriched by a second injection in the ignition zone 10. In

In this context, it is also conceivable that a lean mixture in the combustion chamber

22, which would be difficult or impossible to ignite directly by spark ignition.

Such a mixture is, for example, in the compression stroke from the cylinder 40 into a

connected pre-chamber as combustion chamber 22 or from the cylinder 40 into the hollow

space of a spark plug 1 according to Fig.5. Due to the lean mixture, a faulty or

Pre-ignition is prevented. Only shortly before the ignition point is gaseous fuel released via the

Spark plug 1 into the ignition zone 10 of the spark plug 1 in order to ignite the mixture in this

area, which facilitates ignition by spark ignition or even

made possible.

Patent claims

Spark plug with an outer electrode (2) and a center electrode (3) which are connected by a

insulator (4) are separated from each other, wherein the outer electrode (2) is connected to an axial end

de of the spark plug (1) is designed as an external thread (5) and at this axial end

a cavity (7) is formed between the outer electrode (2) and the center electrode (3),

wherein at least one continuous gas channel (8) is provided through the outer electrode (2) hen, wherein the gas channel (8) is inside in the cavity (7) and outside in the area of the outer thread (5), whereby between the outer opening and the axial end of the outer electrode (2) at least one thread (14) of the external thread (5) is provided characterized in that the gas channel (8) is directed internally onto the ignition zone (10) in Area between the center electrode (3) and the outer electrode (2) of the spark plug (1) is aligned.

Spark plug according to claim 1, characterized in that over the circumference of the A plurality of gas channels (8) are provided distributed over the external thread (5).

Spark plug according to claim 1 or 2, characterized in that on the external electrical rode (2) in the area of the external thread (5) an outer circumferential groove (9) is provided and the at least one gas channel (8) opens outwardly into the outer circumferential groove (9) and between Outer circumferential groove (9) and axial end of the outer electrode (2) at least one thread thread (14) of the external thread (5).

Spark plug according to claim 2 and 3, characterized in that the flow cross- cross-section of the at least one gas channel (8) is smaller than the flow cross-section of the Outer circumferential groove (9).

Spark plug according to one of claims 1 to 4, characterized in that the hollow space (7) is enclosed by the outer electrode (2) and in the outer electrode (2) in the at least one continuous flame channel (11) is provided in the region of the axial end, which connects the cavity (7) with the surroundings of the outer electrode (2).

Gas engine with a combustion chamber (22) and a combustion chamber head (21) which chamber (22) at least partially closes, wherein in the combustion chamber head (21) a winning opening (24) with an internal thread (25), characterized in that that a spark plug (1) according to one of claims 1 to 5 with whose external thread (5) is screwed in, and spaced in the combustion chamber head (21) from the threaded opening (24) a valve recess (31) is provided, the axial End via a branch channel (32) with a gas distribution ring (33) between the spark plug (1) and the combustion chamber head (21), wherein the gas distribution ring (33) is connected by a inner circumferential groove (13) on the internal thread (25) and/or through the outer circumferential groove (9) on

the spark plug (1) and that the at least one gas channel (8) is in the gas supply

partial ring (33), whereby between the gas distribution ring (33) and the axial end of the

Spark plug (1) at least one thread (14) of the external and internal thread (5, 25)

is intended.

Gas engine according to claim 6, characterized in that a scavenging channel (35) is provided

which connects the combustion chamber (22) with the branch channel (32).

3 sheets of drawings

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(54) **METHOD AND APPARATUS FOR INCORPORATION OF A FLAME FRONT - TYPE IGNITION SYSTEM INTO AN INTERNAL COMBUSTION ENGINE**

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(22) Filed: **Apr. 25, 2008**

Related U.S. Application Data

(63) Continuation-in-part of application No. 11/622,801, filed on Jan. 12, 2007, now abandoned, Continuation-in-part of application No. 11/689,852, filed on Mar. 22, 2007, now abandoned.

Publication Classification

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F02B 19/00 (2006.01)

(52) **U.S. Cl.** **123/266**; 29/428

(57) **ABSTRACT**

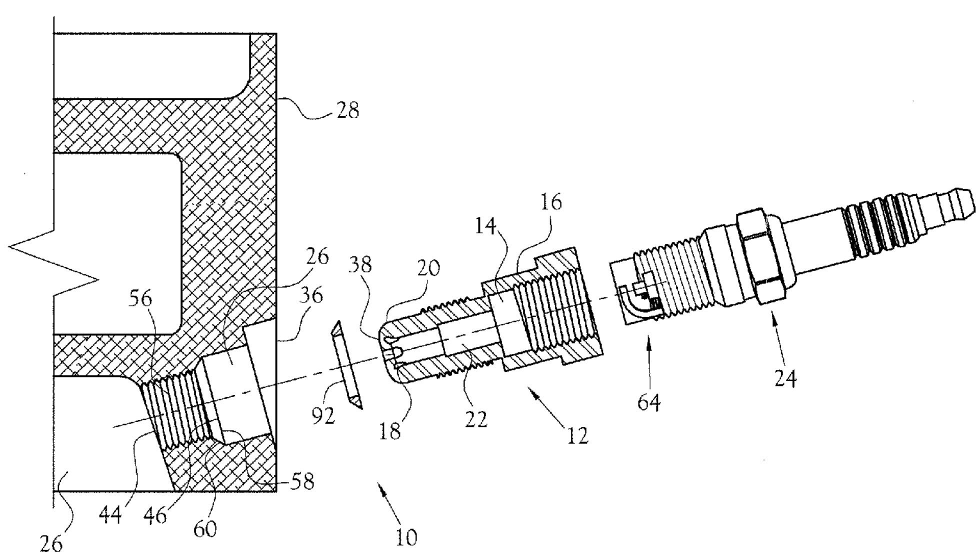
Method for installation and functioning of a flame front type ignition system in the conventional throughbore through the wall of the head of an internal combustion engine. This installation is effected from a location external of the head and while the head is affixed in covering relationship to one or more combustion chambers of the internal combustion engine.

In one embodiment, there is employed a flame cone which is threadably inserted within the throughbore proximate the inboard end of the throughbore. The inboard end of the flame cone is provided with a plurality of exit ports opening from a first central channel within the flame cone thence into the combustion chamber along preselected paths.

The flame cone is provided with one or more alpha letters on the outboard face of the flame cone where they are visible to a person threading the flame cone into the throughbore. Further, a marker (e.g. an arrow) is provided on the outer rim of the throughbore. A datum alpha letter ("A" in the present disclosure) is aligned on the face of the flame cone in a position which, when aligned with the marker on the rim of the throughbore, indicates that the flame cone is at the proper rotational attitude within the throughbore wherein the exit ports in the flame cone are correctly angularly oriented within the throughbore such that flame fronts exiting such ports are also properly aligned relative to those locations within the combustion chamber toward which flame fronts desirably are directed for ignition purposes.

The depth of insertion of the flame cone into the throughbore through the wall of the head of the ICE, is adjustable by means of spacer washers adapted to selectively adjust such depth of sealing insertion of the flame cone within the throughbore as a function of the angular orientation of the exit ports for flame fronts entering the combustion chamber of the ICE.

Apparatus for carrying out the method is disclosed.



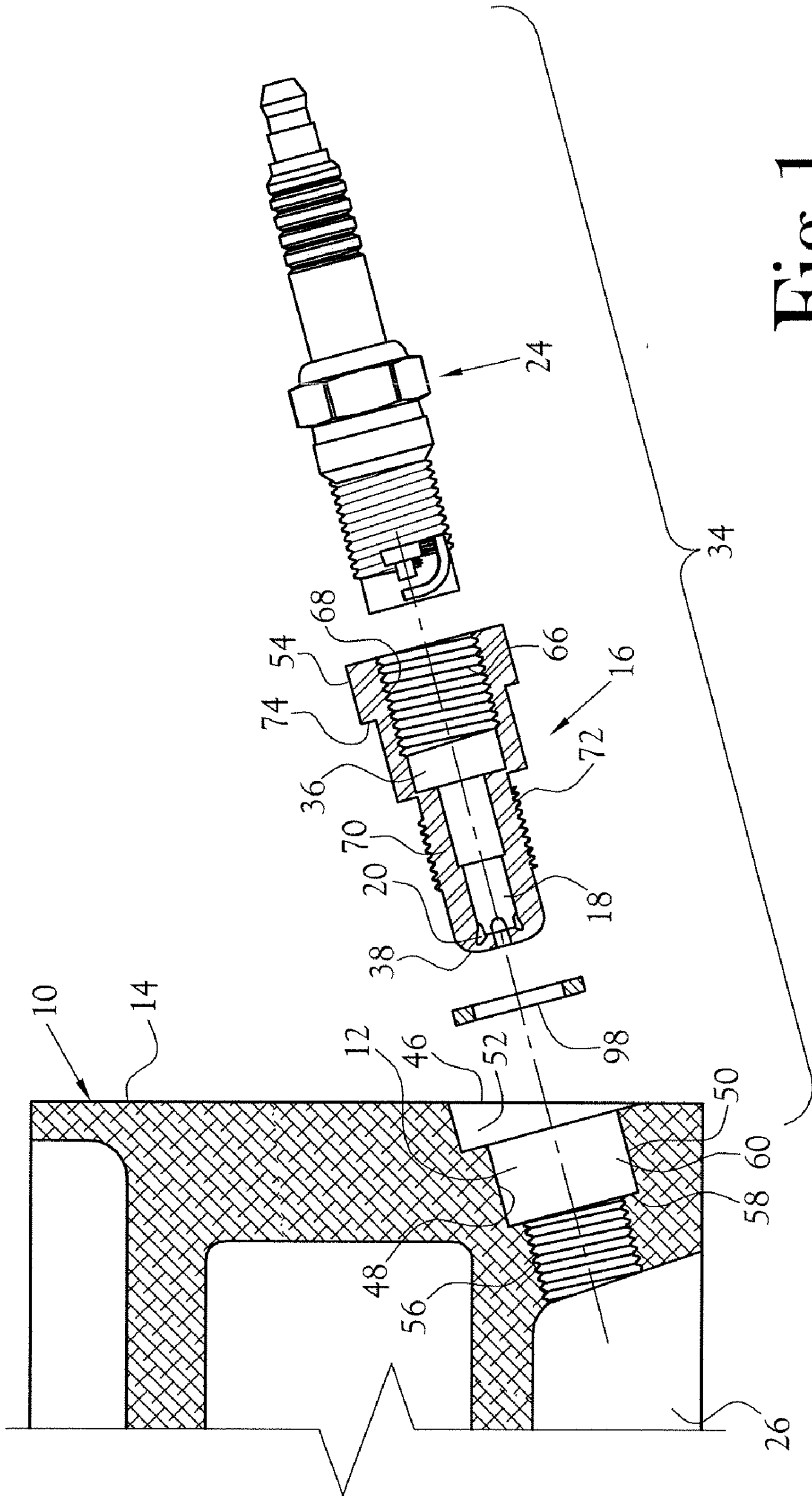

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Fig. 1

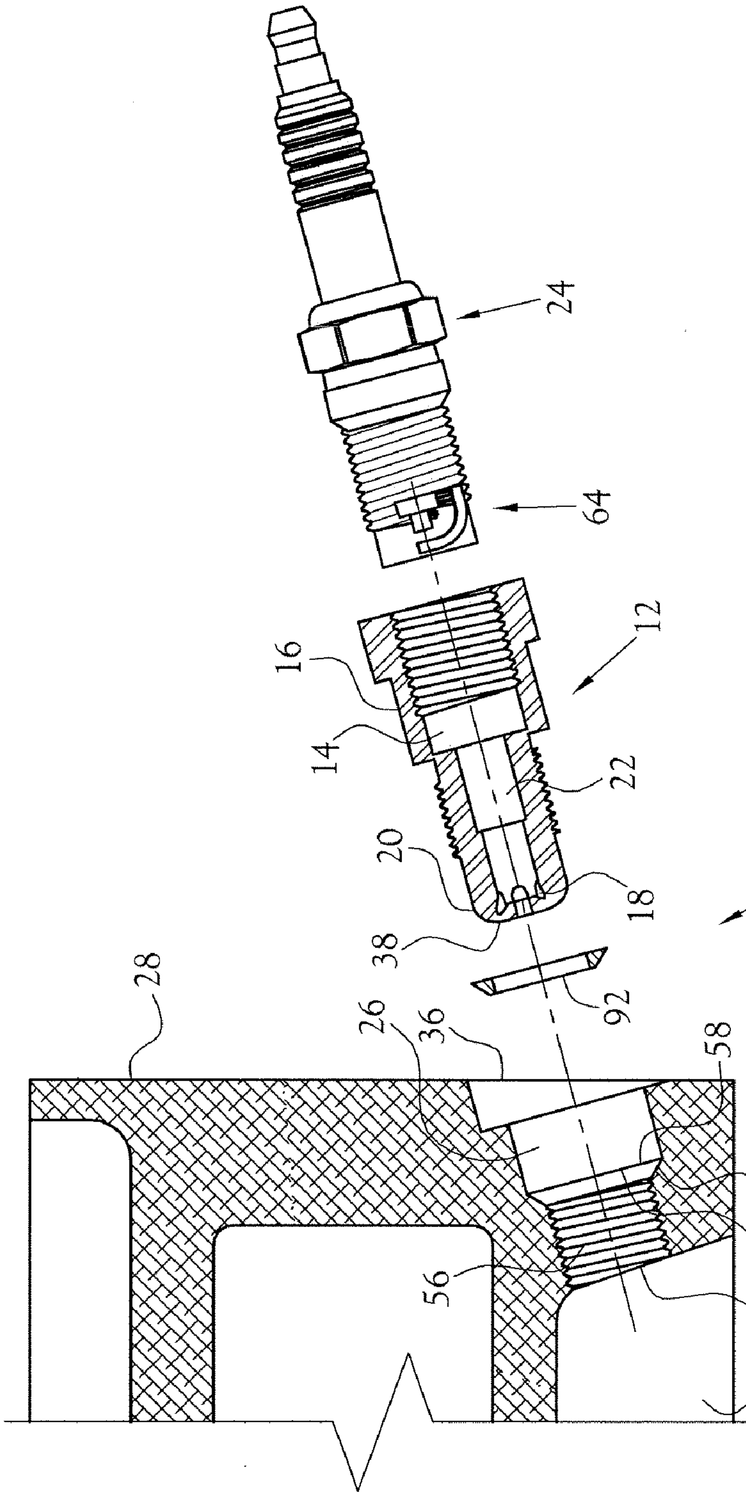

Fig.2

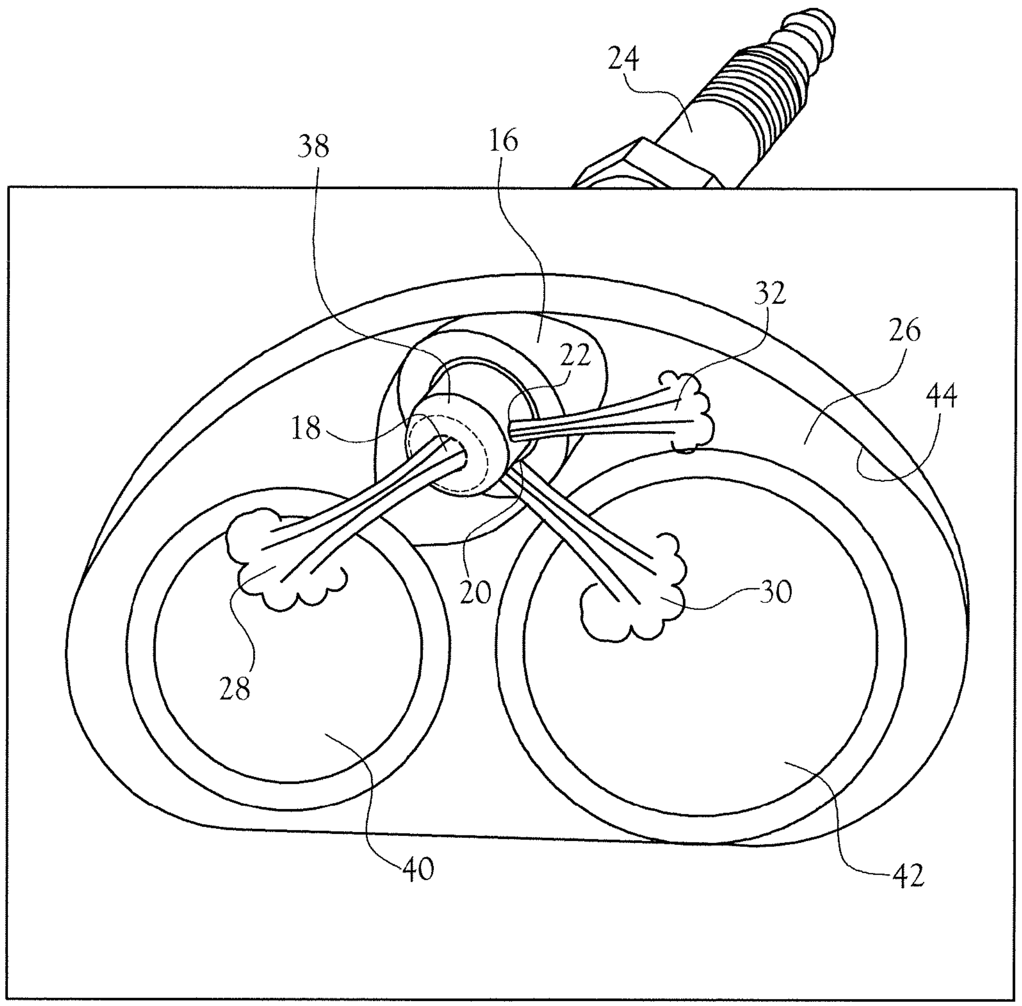

Fig.3

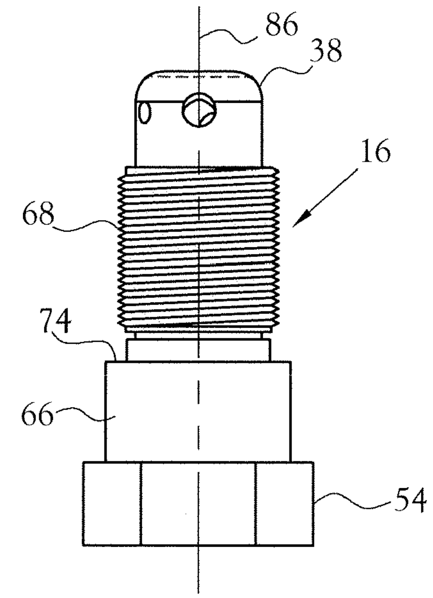

Fig.4

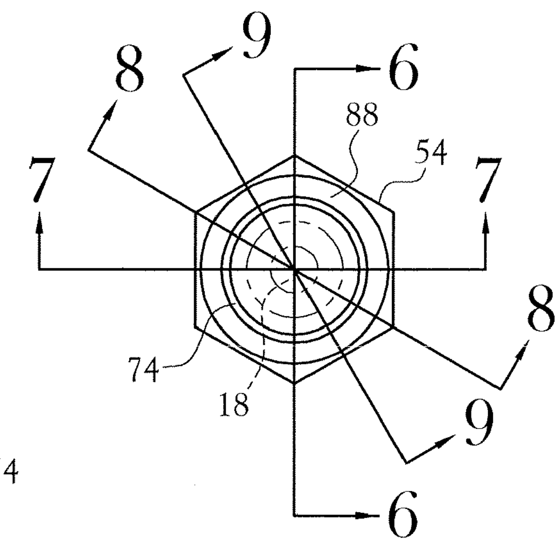

Fig.5

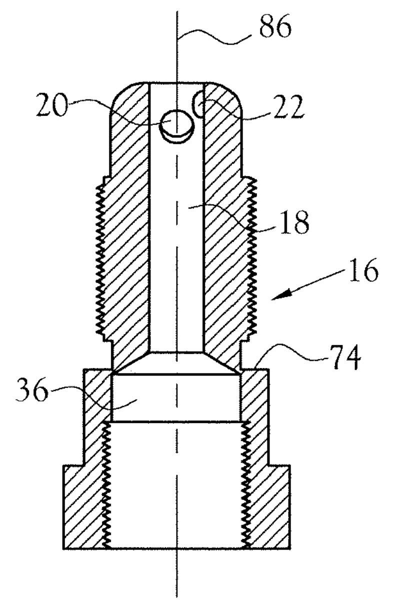

Fig.6

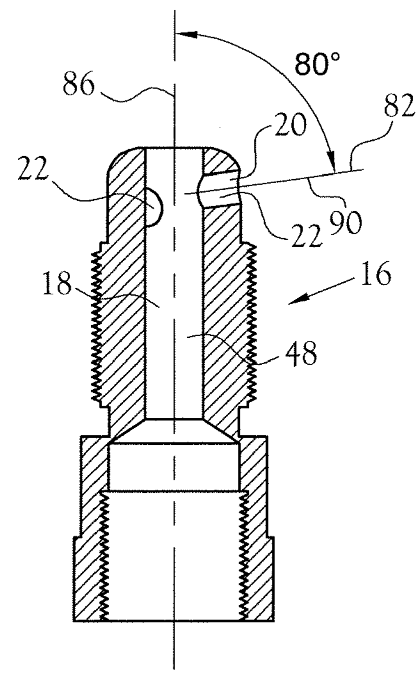

Fig.7

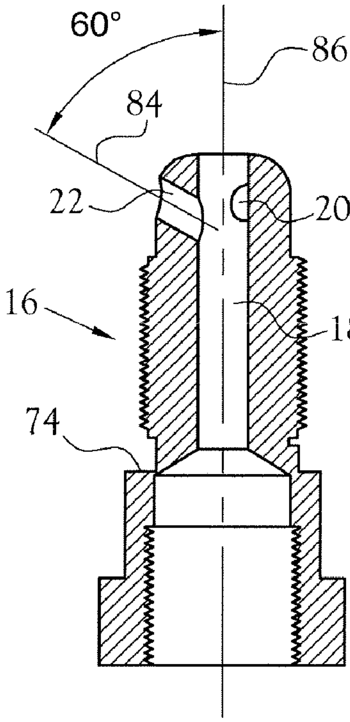

Fig.8

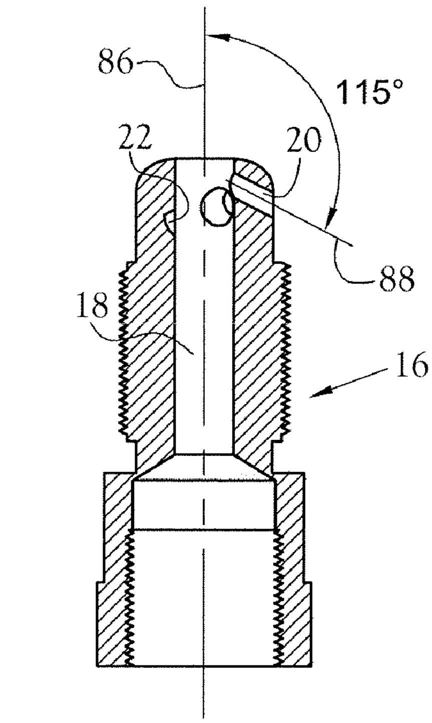

Fig.9

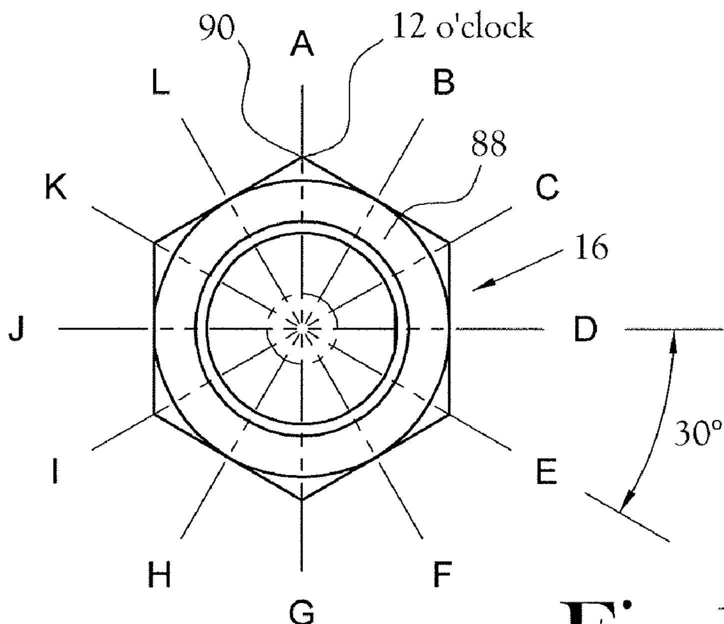

Fig.10

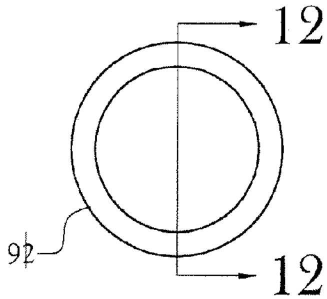

Fig. 11

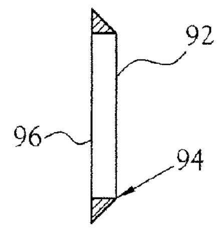

Fig. 12

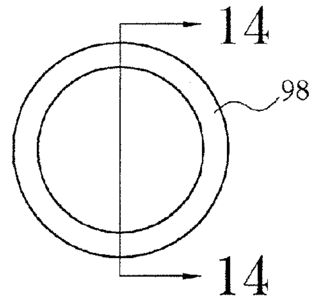

Fig. 13

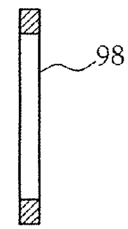

Fig. 14

Letter	Washer Thickness mm
A	none
B	0.104
C	0.208
D	0.312
E	0.416
F	0.520
G	0.624
H	0.728
I	0.832
J	0.936
K	1.040
L	1.144

Fig. 15

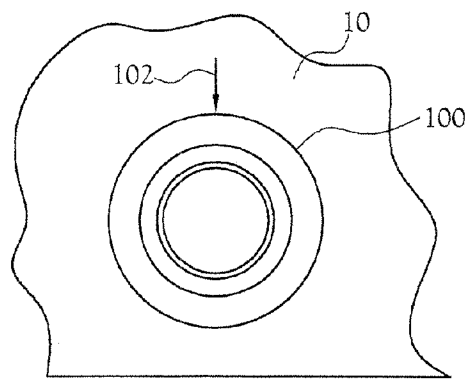

Fig. 16

METHOD AND APPARATUS FOR INCORPORATION OF A FLAME FRONT - TYPE IGNITION SYSTEM INTO AN INTERNAL COMBUSTION ENGINE

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is a continuation-in-part application of co-pending U.S. patent application Ser. No. 11/622,801, filed Jan. 12, 2007, entitled: SPARK IGNITION MODIFIER MODULE AND METHOD, and a continuation-in-part of co-pending U.S. patent application Ser. No. 11/689,852, filed Mar. 22, 2007, entitled: IGNITION SYSTEM FOR INTERNAL COMBUSTION ENGINE, the whole of each of the aforesaid applications being incorporated herein by reference and upon which priority is claimed.

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

[0002] Not Applicable

FIELD OF INVENTION

[0003] This invention relates to ignition systems for internal combustion engines, and more particularly those ignition systems employing multiple flame fronts for gross ignition of a fuel/air mixture contained within a combustion chamber of the engine.

BACKGROUND OF INVENTION

[0004] Relatively recently there have been developed various proposals for ignition systems for internal combustion engines (ICE) wherein a quantity of fuel/air mixture disposed within a combustion chamber of the engine is ignited by means of one or more flame fronts. Such flame fronts are derived from a single flame front which is initiated within an auxiliary pre-combustion chamber which, in turn, is physically separated from the main combustion chamber of the ICE. From this initial ignition point, the flame propagates along a channel leading from the initial ignition point to the combustion chamber. Herein at times, this channel is referred to synonymously as the "first channel" or as the "first central channel". The flame front moving through the first channel is divided into one or more flame fronts, each of which exits separately, from the channel and into the combustion chamber via respective lateral channels. Commonly, a flame front exits into the combustion chamber via the first channel and separate flame fronts exits into the combustion chamber via the one or more lateral channels. Much attention has been paid to the respective directional orientation of the first channel and the lateral channels (and their associated flame fronts) into the combustion chamber, with the desire to maximize the simultaneity and completeness of ignition of the fuel/air mixture disposed within the combustion chamber.

[0005] Of major concern in certain flame front-type ignition systems is how one goes about installation of a flame front ignition system in operative relationship to an existing internal ICE so that the orientation of the flame fronts from the flame cone are directed toward specific locations within the combustion chamber which have been determined to produce maximized simultaneity of ignition and completeness of combustion of the fuel/air mixture disposed within the combustion chamber. This problem is of particular significance when seeking to convert an ICE from a non-flame front ignition system to a flame front ignition system.

[0006] It is to be noted that in all known four-stroke ICEs, there is an internal combustion chamber which is fitted with at least one intake valve, at least one exhaust valve and some means, most commonly at least one spark plug, which serves to ignite a fuel/air mixture drawn into the combustion chamber via the intake valve. In certain of the prior art non-flame front ignition systems the spark plug is threaded into a throughbore provided through the wall thickness of the head of the ICE to the extent that the electrodes of the spark plug are exposed directly within the combustion chamber. Herein, this non-flame cone embodiment is at times referred to as the "standard" system.

[0007] On the other hand, in flame front ignition systems, most commonly, the electrodes of the spark plug are disposed within an auxiliary pre-combustion chamber which is at least semi-isolated from the interior of the combustion chamber. In the compression stroke of the ICE, fuel/air mixture from the combustion chamber is fed into the auxiliary pre-combustion chamber. Thereafter, the firing of the spark plug ignites the fuel/air mixture within the auxiliary pre-combustion chamber and the flame front which is developed propagates along the first channel toward the combustion chamber. In this system, before this flame front exits the first channel, the initial flame front is divided in multiple separate flame fronts as by means of a flame cone. These multiple flame fronts exit the flame cone into the combustion chamber where they ignite the fuel/air mixture disposed with the combustion chamber.

[0008] In one embodiment of a flame front pre-ignition system as described in Applicant's copending application Ser. No. 11/622,801, filed Jan. 12, 2007, entitled SPARK IGNITION MODIFIER MODULE AND METHOD, once the desired orientation of flame fronts exiting a flame cone are determined, a flame cone having such oriented exit channels may be manufactured. One prior art technique for aligning such flame cone within the throughbore, hence the directionality of its exiting flame fronts, includes the use of a flame cone which is insertable into the throughbore from a location internally of the combustion chamber. In this latter technique, the flame cone is threaded into the inboard end of the throughbore until the flame cone is securely, but not necessarily fully, threaded into the throughbore. At this point, the rotation of the flame cone within the throughbore is adjusted such that the directionality of the flame exit ports are in their desired orientation with respect to pertinent ones of the elements disposed within the combustion chamber of the ICE. Thereupon means is required to lock the flame cone in its selected rotational position within the throughbore. Thereafter the spark plug is inserted into the opposite external end of the throughbore and/or the outboard end of the flame cone. This technique requires access to the combustion chamber of the ICE, e.g., removal of the cover of the head of the engine.

[0009] In another technique, described in Applicant's U.S. Pat. No. 7,104,246, entitled SPARK AMPLIFIER, the rotational position of the exit channels of the flame cone are established in the course of manufacturing the flame cone and the flame cone is thereafter inserted into the throughbore starting at the outboard open end of the throughbore (i.e. starting externally of the head). This technique addresses the problem of bottoming out the threading of the flame cone into the throughbore at a location which is inconsistent with the desired rotational orientation of the flame cone, hence the rotational orientation of its exit flame front channels.

[0010] It is recognized that two stroke engines, like in engines for chain saws, etc., do not have valves. Moreover some engines have more than one spark plug per cylinder. One skilled in the art will further recognize the applicability of the present invention to these and/or other internal combustion engines.

BRIEF DESCRIPTION OF THE FIGURES

[0011] FIG. **1** is a schematic representation of a portion of a head of an ICE and depicting a flame cone and spark plug in exploded view and including a flat adjustment spacer washer of the present invention;

[0012] FIG. **2** is a schematic representation of a portion of a head of an ICE as depicted in FIG. **1** and including a conical adjustment spacer washer of the present invention;

[0013] FIG. **3** is a schematic representation of a portion of an ICE combustion chamber and depicting the directionality of various flame fronts entering the combustion chamber;

[0014] FIG. **4** is a side elevation view of a flame cone embodying various of the features of the present invention;

[0015] FIG. **5** is a top end view of the flame cone depicted in FIG. **4**;

[0016] FIG. **6** is a side elevation view, in section, of a flame cone as depicted in FIG. **4** and taken generally along the line **6-6** of FIG. **5**.

[0017] FIG. **7** is a side elevation view, in section, of a flame cone as depicted in FIG. **4** and taken generally along the line **7-7** of FIG. **5**;

[0018] FIG. **8** is a side elevation view, in section of a flame cone as depicted in FIG. **4** and taken generally along the line **8-8** of FIG. **5**;

[0019] FIG. **9** is a side elevation view, in section, of a flame cone as depicted in FIG. **4** and taken generally along the line **9-9** of FIG. **5**;

[0020] FIG. **10** is a top view of the flame cone depicted in FIG. **4** and illustrating the marking of alpha letters on the outer face of the flame cone;

[0021] FIG. **11** is a top view of one embodiment of a conical spacer washer employed in the present invention;

[0022] FIG. **12** is a side view, in section, of the conical spacer washer depicted in FIG. **11**;

[0023] FIG. **13** is a top view of one embodiment of a flat spacer washer employed in the present invention;

[0024] FIG. **14** is a side view, in section, of the flat spacer washer depicted in FIG. **13**;

[0025] FIG. **15** is one embodiment of a lookup table relating the thicknesses of various spacer washers associated with the alpha lettering applied to the outer face of the top end of a flame cone of the present invention; and,

[0026] FIG. **16** is schematic representation of the outer face of a portion of a head wall of an ICE and depicting the outboard open end of a throughbore extending through the thickness of the head wall.

SUMMARY OF INVENTION

[0027] In accordance with one aspect of the present invention there is provided a method and apparatus for installation and functioning of a flame front type ignition system in the conventional throughbore through the wall of the head of an internal combustion engine. This installation is effected from a location external of the head and while the head is affixed in covering relationship to one or more combustion chambers of the internal combustion engine. In one embodiment, there is employed a flame cone which is threadably inserted within the throughbore proximate the inboard end of the throughbore. The inboard end of the flame cone is provided with a plurality of exit ports opening from a first central channel within the flame cone thence into the combustion chamber along preselected paths.

[0028] The flame cone of the present invention is provided with one or more alpha letters on the outboard face of the flame cone where they are visible to a person threading the flame cone into the throughbore. Further, a marker (e.g. an arrow) is provided on the outer rim of the throughbore. A datum alpha letter ("A" in the present disclosure) is aligned on the face of the flame cone in a position which, when aligned with the marker on the rim of the throughbore, indicates that the flame cone is at the proper rotational attitude within the throughbore wherein the exit ports in the flame cone are correctly angularly oriented within the throughbore such that flame fronts exiting such ports are also properly aligned relative to those locations within the combustion chamber toward which flame fronts desirably are directed for ignition purposes.

[0029] The depth of insertion of the flame cone into the throughbore through the wall of the head of the ICE, is adjustable by means of spacer washers adapted to selectively adjust such depth of sealing insertion of the flame cone within the throughbore as a function of the angular orientation of the exit ports for flame fronts entering the combustion chamber of the ICE.

[0030] In one embodiment of the method of the present invention, the flame cone is threadably inserted into the throughbore until the flame cone sealingly seats itself against a circumferential shoulder disposed within the throughbore. The torque employed to sealingly seat the flame cone is established and published by the provider of the engine. Also noted is the alpha letter on the face of the flame cone which is closest to the arrow marker disposed on the outboard rim of the throughbore. Thereupon, the flame cone is withdrawn from the throughbore.

[0031] Using the information obtained with the flame cone, a spacer washer having an alpha letter (representative of the thickness of the spacer washer) corresponding to the alpha number noted to be nearest the marker on the rim of the throughbore, is chosen and inserted within the throughbore in overlying relationship to the circumferential shoulder or, alternatively and preferably, is fitted over the threaded end of the flame cone. Thereupon the flame cone and the washer(s) on the threaded end thereof are sealingly reinserted into the throughbore, employing the same torque (supplied by engine provider as initially noted). This action longitudinally and rotationally spaces and seals the flame cone within the throughbore such that the "A" alpha letter on the flame cone becomes aligned with the marker on the rim of the throughbore, thereby indicating that the exit ports of the flame cone are aligned as desired within the combustion chamber.

DETAILED DESCRIPTION OF THE INVENTION

[0032] In FIG. **1**, there is depicted a partially exploded view of a portion of the head **10** of an ICE, a typical throughbore **12** through the wall **14** of the head, a flame cone **16**, having multiple flame front exit channels **18**, **20** and **22**, threadably insertable into the throughbore, and a conventional spark plug **24** threadably insertable into the flame cone. The general apparatus depicted in FIG. **1** is more fully described in Applicant's copending application Ser. No. 11/689,852, filed Mar.

22, 2007, entitled IGNITION SYSTEM FOR INTERNAL COMBUSTION ENGINE, such description being incorporated herein by reference.

[0033] Referring to FIGS. **1** and **2** of the present application, it will be noted that the desired orientations of the multiple exit channels **18**, **20**, **22** through which multiple flame fronts **28**, **30**, **32** enter the combustion chamber **26** (See FIG. **3**) are determined analytically once the internal geometry of the combustion chamber is known. Determining the internal geometry of the combustion chamber requires access to the design data for the ICE, or it must be determined by examination of the disassembled engine, all as is well known to those skilled in the art. In accordance with one aspect of the present invention, flame fronts **28**, **30**, **32** from respective individual ones of the exit channels **18**, **20**, **22** of the flame cone are directed along predetermined paths selected to maximize the simultaneity and completeness of the ignition of the fuel/air mixture disposed within the combustion chamber. (See embodiments depicted in FIGS. **1**, **2** and **3** of the present application).

[0034] In one embodiment of the present invention, as depicted in FIG. **1**, the pre-combustion system **34** includes a flame cone **16**, a pre-combustion chamber **36** defined in the inboard end **38** of the cone, at least one flame front exit channel **18** defined in the cone and leading from the pre-ignition chamber toward the combustion chamber of the ICE. This first exit channel **18** is directionally oriented to direct its flame front **28** toward the intake valve **40** of the ICE. In the depicted embodiment, there is provided a first lateral channel **20** (See FIGS. **1**, **2** and **3**) whose flame front **30** is directionally oriented toward the exhaust valve **42** and a second lateral channel **22** whose flame front **32** is directionally oriented generally tangentially toward the inner wall **44** of the combustion chamber of the ICE. If desired, one or more lateral channels **23** may be provided whose directional orientation may be chosen to direct a flame front from the cone into the combustion chamber of the ICE toward some further location within the combustion chamber, such as tangentially along the inner wall of the combustion chamber in a direction opposite the direction of the flame front **32** exiting the second lateral channel **22**.

[0035] In the depicted embodiment of FIGS. **1** and **2**, the throughbore **12** through the wall **14** of the head **10** of the ICE includes a first outboard open end portion **46** and an inboard open end portion **56**. The outboard open end portion **46** of the throughbore **12** in the depicted embodiment may have smooth inner **48** and outer **50** surfaces and a diameter which is materially greater that the outer diameter of a conventional spark plug suitable for use in the depicted head of the ICE, thereby defining a void open annular space **52** between the inner surface **48** of the throughbore and the spark plug and the hexagonal head **54** of the flame cone. This annular space is useful for the receipt therein of a torque wrench, for example, for establishing the required depth of insertion of the flame cone into the throughbore.

[0036] The transition between the outboard **46** and inboard end **56** portions of the throughbore defines a circumferential shoulder **58** internally of the throughbore at a location approximately midway between the opposite ends of the throughbore. As depicted in FIG. **1**, this transition includes an inwardly directed flat surface **60**. In the present invention and as depicted in FIG. **2**, for example, it is to be recognized that the circumferential shoulder within the throughbore may define a sloping surface which extends angularly inward of the throughbore, i.e., conical instead of a flat surface as depicted in FIG. **1**.

[0037] In accordance with one aspect of the present invention a plurality of identical flame cones **16**, specific for a given engine type, may be manufactured. Each flame cone includes at least one, and most commonly a plurality of, exit channels which are specifically directionally oriented such that the exit paths of respective ones of flame fronts exiting such channels from the inboard end of the flame cone are directed toward respective specific areas within the combustion chamber of that engine for which the flame cone is designed.

[0038] FIGS. **4-9** depict one embodiment of a flame cone which includes a first central channel **18** and first and second lateral channels **20** and **22**, respectively, in the inboard end **38** of the flame cone, The depicted flame cone is designed for a specific engine type, but the method for manufacture and identification of the depicted flame cone is deemed typical for any other known ICE types.

[0039] With reference initially to FIG. **4**, the depicted embodiment of the flame cone is generally tubular in geometry. The cone includes an outer body portion **66** having internal threads **68** suitable for the threadable insertion of a conventional spark plug therein. The geometry of the first outer body portion **66** of the depicted flame cone includes a hexagonal head **54**. The cone further includes an inboard body portion **70** which is externally threaded **72** to be threadably inserted into the internally threaded inboard end **56** of the throughbore **12** in the wall of the engine of an ICE. A typical throughbore and a flame cone threadably insertable therein may be provided along the length of their respective threaded areas with threads of a known standard type such as M14-1.25 ISO threads.

[0040] The transition between the first and second body portions of the flame cone includes a circumferential shoulder **74** about the outer periphery of the cone, such shoulder including a flat surface **76** which projects substantially perpendicularly away from the cone. The flame cone, therefore, may be threadably inserted into the throughbore to a depth limited by the outer circumferential shoulder of the flame cone sealingly engaging the inner circumferential shoulder **58** of the throughbore, thereby limiting the extent to which a flame cone can be inserted into the throughbore.

[0041] Further, internally of the flame cone there is defined a chamber **78** which ultimately becomes a portion of the pre-combustion chamber **36** of the pre-ignition flame front ignition system **34** for the ICE.

[0042] The first central channel **18** of the depicted flame cone extends in fluid communication from the pre-combustion chamber **36** to the combustion chamber **26** of the ICE. Proximate the inboard end of the first central channel, there are defined first and second separated individual lateral exit channels **20**, **22** which lead, in fluid communication, from the first central channel into the combustion chamber. Each of the channels terminates within the combustion chamber, but proximate to the inner circumferential wall **44** of the combustion chamber such that the directionality of the flame front exiting each channel is not diverted or impeded from its preselected path into the combustion chamber. (See FIGS. **1-3** and **4-10**).

[0043] As noted, the first central channel is in fluid communication between the pre-combustion chamber and the combustion chamber of the ICE. Similarly, each of the first and second lateral channels are in fluid communication from the first channel into the combustion chamber. This arrangement of channels serves to divide a flame front propagating from the pre-combustion chamber through the first central channel into three individual flame fronts. These flame fronts are individually directionally oriented to cause the flame front from the first central channel to be directed toward the intake valve **40** in the combustion chamber and the flame front from the first lateral channel to be directed toward the exhaust valve **42** in the combustion chamber **20**. The flame front from the second lateral channel may be directionally oriented tangentially along the inner wall **44** of the combustion chamber, or toward another location within the combustion chamber. In one embodiment, the internal diameter of the first central channel is chosen to be larger than the internal diameter of one or more of the first and second lateral channels, particularly the internal diameter of the first lateral channel which is directed toward the exhaust valve of the ICE. This geometry causes the flame front exiting the first lateral channel **20** to exhibit a greater velocity of forward movement than the velocity of the flame front exiting the first central channel. By this, or like manipulation of the several flame fronts, ignition of the fuel/air mixture disposed within the combustion chamber may be of enhanced simultaneity, among other advantages.

[0044] FIGS. **6-9** depict various longitudinal sectional views of the flame cone of FIG. **5**. FIG. **6** depicts the lines along which each of the sectional views of FIGS. **6-9** are taken, each line lying along a diameter of the outboard end of the flame cone and all of which intersect one another at the longitudinal centerline **80** of the cone. In each such sectional view, there is depicted an angular relationship of the longitudinal centerline of the depicted embodiment of the flame cone with the respective longitudinal centerline **82**, **84** of the two lateral channels in the depicted cone.

[0045] As depicted in FIG. **7**, the longitudinal centerline **82** of the first central channel may be oriented at an angle of 80 degrees relative to the longitudinal centerline **86** of the cone. This geometry of the first central channel is preferred, but it will be recognized that the placement of the first central channel within the cone may be chosen to be at a location which is not only displaced from the centerline of the cone, but also may be of a less than straight geometry.

[0046] With reference to FIGS. **7** and **9**, there are depicted locations of the first and second lateral channels through which separate flame fronts enter the combustion chamber. In the embodiment of FIG. **7**, the longitudinal centerline **82** of the first lateral channel **20** may be angularly oriented at an angle of 80 degrees relative to the longitudinal centerline **86** of the flame cone when viewed along line **7-7** of FIG. **5**. In similar manner, as seen in FIG. **8**, the longitudinal centerline **84** of the second lateral channel **22** may be oriented at an angle of 60 degrees relative to the longitudinal centerline of the flame cone when viewed along line **8-8** of FIG. **5**. Still further, as seen in FIG. **9**, the longitudinal centerline of the first lateral channel **20** may be oriented at an angle of 115 degrees relative to the longitudinal centerline of the cone when viewed along line **9-9** of FIG. **5**. These angular relationships are chosen to satisfy the requirement that when the flame cone is properly inserted into the throughbore, the flame front from the first central channel be directed toward the intake valve within the combustion chamber, that the flame front from the first lateral channel be directed toward the exhaust valve within the combustion chamber, that the second lateral channel be directed tangentially of the inner wall of the combustion chamber. As noted, these angular relationships may be varied to suit a given geometry within the combustion chamber of known ICE's.

[0047] Referring to FIG. **10**, in particular, the flame cone therein depicted is the same as the flame cone **16** depicted in FIGS. **4-9**. After the flame cone depicted in the several Figures has been formed, including the formation of the channels described hereinabove, the outboard face **88** of the flame cone is marked with alpha letters, e.g. "A" through "L". The "A" letter is assigned to that location on the face of the cone referred to in the Figures as the 12 O'clock position. For convenience, the "A" letter is located at the apex **90** of the angular junction of two adjacent ones of the segments of the hexagonal head **54** of the flame cone **16**. In the depicted embodiment, the lettering of the cone proceeds clockwise about the outer periphery of the face of the cone at intervals of 30 degrees between adjacent letters in the embodiment depicted in FIGS. **11** and **12**.

[0048] As depicted in FIG. **2**, in certain "conical head" ICE's the throughbore is provided with a shoulder which includes an inwardly angled surface **60** extending circumferentially about the inner wall of the throughbore at the transition. Thus, when a flame cone is threaded into the throughbore, without more, the circumferential flat surface **76** defined on the flame cone would engage the angled surface of the circumferential flange defined in the throughbore. This situation is undesirable due to the lack of precision of engagement of these differently configured surfaces and the assurance of sealing therebetween when the flame cone is torqued against the shoulder within the throughbore. To overcome this potential problem, in one aspect of the present invention, the inventor provides a conical shaped washer **92** such as depicted in FIGS. **2**, **11** and **12**. As seen in FIGS. **2** and **12**, such washer includes a first side **94** having a conical-shaped outer perimetral surface. A second, and opposite side **96** of the washer defines a flat surface. The outer diameter of the washer is chosen to permit substantially snug fit of the washer within the throughbore and in overlying relationship to the angled surface circumferential shoulder **58** of the throughbore with the flat side **96** of the conical washer facing away from the shoulder of the throughbore.

[0049] The circumferential shoulder disposed within the throughbore and which slopes inwardly of the throughbore may be referred to as a "conical" head engine (See FIG. **2**). For consistency of effective physical sealing engagement of the "square" shoulder of a flame cone with the conical circumferential shoulder of the throughbore, the present inventor provides a "conical" spacer washer **92** of a thickness suitable to "fill" the conical volume of the circumferential shoulder of the throughbore, thereby redefining this shoulder as a flat shoulder having its exposed surface disposed substantially perpendicular to the longitudinal centerline of the throughbore and facing away from the shoulder of the throughbore. When so employed, this conical spacer washer is retained on the threaded end of the flame cone, along with other flat spacer washers **98** added to adjust the depth of insertion of the flame cone into the throughbore. It will be also recognized that such conical spacer washers are not needed when the circumferential shoulder within the throughbore is a "square" shoulder having a face which is oriented substantially perpendicular to the longitudinal centerline of the throughbore as depicted in FIG. **1**.

[0050] Accordingly, when the flame cone is thereafter threaded into the throughbore, the flat surface of the circumferential shoulder of the flame cone precisely engages the flat surface of the washer, thereby providing for precise depth positioning of the flame cone within the throughbore upon repeated entry and removal of such flame cone with respect to the throughbore. Moreover, such geometrical mating of the flat surfaces of the two circumferential shoulders permits the flame cone to be repeatedly torqued into a specified fluid sealing engagement with the shoulder within the throughbore upon repeated entry and removal events of the flame core into and from the throughbore.

[0051] Referring to FIG. **16**, it will be noted that in accordance with one aspect of the present invention, the outer rim **100** of the throughbore is provided with a marker **102** (e.g. an arrow) which is readily visualized by a person disposed proximate, but externally of, the head **10** of the ICE. The exact location of this marker about the periphery of the rim is not critical, but rather its location must represent the precise threaded depth of the flame cone into the throughbore wherein the datum "A", is aligned with the marker, hence the exit channels in the inboard end of the flame cone are properly aligned such that their respective flame fronts are directionally oriented toward their respective target locations within the combustion chamber. For example, the first lateral exit channel is to be oriented in the direction of the exhaust valve disposed within the combustion chamber.

[0052] Toward this end, the outboard face **88** of the flame cone is divided into spaced apart identified locations about the periphery of the face. Each such location is assigned an alpha letter. As depicted, in a preferred embodiment, these lettered locations proceed alphabetically clockwise, at equally spaced apart distances, about the periphery of the face of the flame cone. More specifically, the letter "A" is assigned to that location on the face of the flame cone wherein the "A" aligns with the marker **102** (arrow) on the rim **100** of the throughbore when the flame cone is threaded into the throughbore, at a given torque, and into fluid sealing engagement of the respective shoulders of the flame cone and the throughbore. By design, this relationship of the flame cone to its depth within the throughbore establishes the proper alignment of the exit channels of the flame cone with their respective targets within the combustion chamber. It is to be noted that if the circumferential shoulder within the throughbore includes an angled surface, an noted above, a conical washer is to be inserted within the throughbore and in overlying relationship to the shoulder within the throughbore thereby defining a continuous flat surface against which the flat face of the circumferential shoulder of the flame cone may sealingly engage when the flame cone is threaded into the throughbore. In those instances where the shoulder within the throughbore exhibits a flat face, no conical washer need be employed.

[0053] For one or more various reasons, the threading of the flame cone into the throughbore may vary between multiple entry and removal events of the flame cone. For example, the torque employed between such events may be such that the depth to which the flame cone enters the throughbore before "bottoming out" against the shoulder within the throughbore at a given torque may vary from event to event. Such variance can result in inaccurate rotational positioning of the exit channels of the flame cone relative to their intended targets within the combustion chamber.

[0054] In the present invention, this and like variances are accommodated. Specifically, in the present invention, a flame cone designed for the ICE in question is initially threaded into a throughbore in the head of the ICE until the respective circumferential shoulders of the throughbore and flame cone engage one another at a preselected torque value. This torque value is selected to produce fluid-tight sealing of the engaged shoulders against fluid flow therepast and is readily established by one skilled in the art.

[0055] When the initial threading of the flame cone into the throughbore is completed, the operator notes whether the "A" letter on the face of the flame cone is aligned with the marker on the rim of the throughbore. If yes, the flame cone, hence its exit channels, are properly aligned with respect to their intended targets within the combustion chamber and no further action need be taken with respect to the installation of the flame cone within the throughbore.

[0056] On the other hand, if the "A" on the flame cone is not aligned with the marker on the rim of the throughbore when the flame cone is fully threaded into the throughbore as described above, the operator notes that alpha letter which is nearest the marker. Thereupon the flame cone is withdrawn from the throughbore and an appropriate spacer washer is fitted onto the threaded end of the flame cone, atop the conical washer, to thereby limit the depth of insertion of the flame cone within the throughbore.

[0057] In one embodiment of the present invention, spacer washers of differing thicknesses are provided. Each spacer washer is identified with an alpha letter which is indicative of the thickness of the washer. In that embodiment where the spatial distance between alpha letters applied to the face of the flame cone and the pitch of threads employed in threading the flame cone into the throughbore, are known, one skilled in the art may readily calculate that thickness of a spacer washer which would limit the depth to which the flame cone would enter the throughbore upon rotation of the flame cone by a rotational distance commensurate with the space between adjacent ones of the alpha letters on the face of the flame cone. Thus, if the initial insertion of the flame cone into the throughbore resulted in the letter "C" being the closest letter to the marker on the rim of the throughbore, then a spacer washer marked "C" would be chosen for installation onto the flame cone and resulting alteration of the depth of the flame cone into the throughbore such that the "A" on the face of the flame cone would come into alignment with the marker on the rim of the throughbore. FIG. **15** is a typical lookup table listing typical thicknesses of spacer washers with their respective alpha identification.

[0058] The flame cone of the present invention is designed initially to ensure that the shoulder on the flame cone will seat with the shoulder on the wall of the throughbore when the "A" indicia is fully aligned with, or just short of alignment with, the marker on the rim of the throughbore. As noted, the spacer washers may affect the depth of insertion of the flame cone by only one revolution (one thread) of the flame cone within the throughbore. For a typical spark plug threads, such depth would be 1.25 mm or 0.05 inch.

[0059] Employing the concept of the present invention, in the method of the present invention, a user selects a flame cone which is designed for the ICE model in question and threadably inserts such flame cone into the throughbore in the wall of the head of the ICE until the circumferential shoulder of the cone sealingly engages the circumferential shoulder of the throughbore. The torque employed to effect such engagement is that torque which is commonly supplied by the engine provider. Further, that indicia which is closest to the arrow marker on the rim of the throughbore is also noted. For example, such closest indicia may be "B".

[0060] Thereupon, the flame cone is withdrawn from the throughbore. Employing the lookup table, the user locates that washer whose thickness carries the "B:" indicia (hence identifies that thickness of spacer washer which, when inserted into the throughbore in overlying relationship to the inner circumferential shoulder of the throughbore, will halt the depth of insertion of the flame cone in question such that the indicia "A" on the flame cone is aligned with the arrow marker on the rim of the throughbore. This chosen spacer washer is then fitted onto the threaded end of the flame cone and the flame cone and its associated washer(s), is again threadably and sealingly inserted into the throughbore, employing the same torque value as observed when the flame cone was initially inserted into the throughbore without the spacer washer being present. Under these conditions, the indica "A" on the face of the flame cone should be in alignment with the arrow marker on the rim of the throughbore. If not, the user notes that indicia which is closest to the arrow marker, the flame cone is withdrawn and the process of selection of a suitable spacer washer and insertion of the flame cone and its associated washer into the throughbore is repeated. Thereupon, the flame cone is again inserted into the throughbore employing the same initially employed torque value. If this further action does not cause the "A" indicia on the flame cone to be aligned with the arrow marker on the rime of the throughbore, the process is repeated until such alignment is accomplished. Upon achieving alignment of the "A" indicia with the arrow marker, the user is assured that the multiple exit channels from the flame cone are directionally aligned properly for their respective flame fronts to be directed toward the intended areas within the combustion chamber. Also, the user is assured that there is a fluid sealed relationship between the cone and the throughbore.

[0061] Should variations in depth occur for any of several reasons, such as change in torque between times of insertion of the flame cone into a throughbore, different starting positions of the flame cone between times of insertion of the flame cone into a throughbore, etc., the present invention accommodates such variations rapidly and accurately by means of the adjustability of the depth of a given flame cone within a given throughbore, irrespective of such variations. This accommodation is made possible by the ready determination of the depth of the flame cone within the throughbore through the means of visual observation of the disposition of alpha letters on the face of the flame cone relative to the fixed arrow marker on the rim of the throughbore and the available choices of adjustment of the depth to which the flame cone can enter into the throughbore. That is, irrespective of what alpha letter (other than "A")) is closest to the rim marker when the flame cone is threaded into the throughbore to an effective sealing position, the present invention provides one or more selectable spacer washers of different thicknesses, which, when inserted within the throughbore, are sufficient in overall thickness to adjust the depth of the flame cone within the throughbore to the extent that the "A" letter is aligned with the arrow marker on the rim of the throughbore upon the flame cone being torqued to that value which ensures suitable fluid sealing of the flame cone within the throughbore. Even if different torque values are employed between the initial and subsequent insertions of the flame cone into the throughbore, so long as the engagement between the circumferential shoulders (with or without spacer washers in the throughbore) effectively creates a fluid-tight seal between the flame cone and the throughbore, selection of one or more spacer washers may be employed to effect the required alignment of the "A" indicia on the face of the flame cone with the arrow marker on the rim of the throughbore, again thereby ensuring proper alignment of the exit channels from the flame cone into the combustion chamber of the ICE. It is to be noted that if the initial insertion of the flame cone into the throughbore results in the "A" indicia being in alignment with the arrow marker on the rim of the throughbore, there is no need for adjustment (s) of the depth of insertion of the flame cone into the throughbore.

[0062] It is to be recognized that, in the art. there commonly are multiple throughbores in a given ICE, i.e., one throughbore for each combustion chamber of the ICE. Thus for a given ICE, all the throughbores thereof are of essentially identical construction, including thread types. Again, irrespective of whether all the throughbores of a given ICE are of truly identical geometry, the present invention provides for adjustability of the depth of insertion of a flame cone in each of the throughbores through the choice of the spacer washers as described hereinabove.

[0063] While the present invention has been illustrated by description of several embodiments and while the illustrative embodiments have been described in considerable detail, it is not the intention of applicant to restrict or in any way limit the scope of the appended claims to such detail. Additional advantages and modifications will readily appear to those skilled in the art. The invention in its broader aspects is therefore not limited to the specific details, representative apparatus and methods, and illustrative examples shown and described. Accordingly departures may be made from such details without departing from the spirit or scope of applicant's general inventive concept.

1. A method for installation of a flame cone of a pre-ignition system for ignition of a fuel/gas mixture within a combustion chamber of an internal combustion engine, comprising the steps of:

(a) from a location external of the head of an internal combustion engine inserting a flame cone having at least one flame front exit channel adapted to direct a flame front from the flame cone into the combustion chamber of the internal combustion engine along a path toward a target location within the combustion chamber of the internal combustion engine, into said throughbore to a first depth,

(b) providing a plurality of indicia on said flame cone which are visible from a location external of the internal combustion engine, a first one of said indicia being indicative of the desired rotational position of said flame cone within said throughbore wherein said at least one exit channel is oriented toward its intended target location within the combustion chamber,

(c) providing a point of reference on said cylinder head proximate said throughbore and which is visible from a location external of the internal combustion engine,

(d) inserting said flame cone into said throughbore to a predetermined depth of sealingly engagement there between,

(e) noting that indicia on said flame cone which is closest to said point of reference on said head when said flame cone achieves said sealingly engagement,

(f) if said indicia on said flame cone which is noted is said first one of said indicia when said flame cone and said throughbore are in sealing engagement with one another, no further action need be taken,

(g) If said indicia on said flame cone which is noted is an indicia other than said first one of said indicia, removing said flame cone from said throughbore;

(h) thereafter, selecting at least one spacer washer having a thickness corresponding with said noted indicia and installing said selected spacer washer onto the flame cone, to be engaged with the sealing surface of the throughbore,

(i) replacing said flame cone into said throughbore in sealing engagement between said selected spacer washer with said throughbore.

2. The method of claim **1** wherein said steps (d) through (i) are repeated until said first one of said indicia on said flame cone is in rotational alignment with said reference point defined on said head when the flame cone and its associated spacer washer are at least one in sealing engagement with the throughbore.

3. The method of claim **1** wherein said indicia on said flame cone are disposed about the outer periphery of said outboard end of said flame cone and spaced apart substantially equidistantly.

4. The method of claim **1** and including the step of providing mating threads on each of said flame cone and said throughbore whereby said flame cone is threadably insertable within said throughbore.

5. The method of claim **4** and including the step of forming said threads of each of said flame cone and said throughbore of substantially like thread classification.

6. A method for installation of a flame cone of a pre-ignition system for ignition of a fuel/gas mixture within a combustion chamber of an internal combustion engine, comprising the steps of:

(a) providing a flame cone having an inboard end and an opposite outboard open end,

(b) defining adjacent said inboard end of said flame cone at least one exit channel adapted to provide fluid communication of a flame front from a location within said flame cone through said exit channel and toward a target location internally of the combustion chamber of the internal combustion engine;

(c) providing a first indicia on said outboard end of said flame cone, said first indicia being visually observable from a location external of the internal combustion engine and further indicative of the physical location and attitude of said at least one exit channel;

(d) providing multiple further indicia on said outboard end of said flame cone at spaced apart locations about the outer periphery of said outboard end of said flame cone and being visible for a location external of the internal combustion engine,

(e) providing a circumferential shoulder about the outer circumference of said flame cone at a location intermediate said inboard and outboard ends of said flame cone, said shoulder extending radially outward of said outer circumference of said flame cone;

(f) defining an elongated throughbore through the head of the internal combustion engine, and throughbore having an open inboard end which opens internally of the combustion chamber of the internal combustion engine and an open outboard end opening to the environmental external of the head, whereby said throughbore defines a passageway between said combustion chamber and the environment external of the head,

(g) defining a circumferential shoulder internally of said throughbore at a location intermediate said inboard and outboard ends of said throughbore, said shoulder extending radially inwardly of said throughbore a distance sufficient to engage and limit the extent of insertion of said flame cone into said throughbore;

(h) providing a reference marker on said head adjacent the outboard open end of said throughbore, said reference marker being visually exposed from a location external of said internal combustion engine;

(i) inserting said flame cone into said throughbore via said outboard open end of said throughbore to the extent that said shoulder of said flame cone sealingly engages said shoulder within said throughbore,

(j) if said first indicia is not aligned with said reference marker upon completion of step (i), removing said flame cone from said throughbore,

(k) altering the depth of which said flame cone will extend into said throughbore and effect a sealing relationship with said throughbore and said first indicia also will be aligned with said reference marker.

7. Apparatus for aligning one or more flame front exit channels of a flame cone within a throughbore having an open inboard end and an open outboard opposite end, defined through the wall of the head of an internal combustion engine, comprising:

(a) flame cone having an open outboard end and an inboard end having one or more flame front exit channels defined therein,

(b) means for adjustably inserting said flame cone within said throughbore via said outboard open end of said throughbore,

(c) a reference marker defined on said head adjacent said outboard open end of said throughbore,

(d) a first indicia defined on said outboard end of said flame cone, said first indicia being indicative of the position and attitude of at least one of said indicia on said outboard end of said flame cone,

(e) a plurality of further indicia defined on said outboard end of said flame cone at spaced apart locations about the outer perimeter of said flame cone,

(f) said reference marker and said indicia being visually observable from a location external of said internal combustion engine,

(g) a plurality of spacer washers of different thickness for selectively adjusting the depth to which said flame cone enters said throughbore and effects a fluid sealing relationship between said flame cone and said throughbore and alignment of said first indicia with said reference marker.

* * * * *

Description **US2008196689A1**

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is a continuation-in-part application of co-pending U.S. patent application Ser. No. 11/622,801, filed Jan. 12, 2007, entitled: SPARK IGNITION MODIFIER MODULE AND METHOD, and a continuation-in-part of co-pending U.S. patent application Ser. No. 11/689,852, filed Mar. 22, 2007, entitled: IGNITION SYSTEM FOR INTERNAL COMBUSTION ENGINE, the whole of each of the aforesaid applications being incorporated herein by reference and upon which priority is claimed.

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

[0002] Not Applicable

FIELD OF INVENTION

[0003] This invention relates to ignition systems for internal combustion engines, and more particularly those ignition systems employing multiple flame fronts for gross ignition of a fuel/air mixture contained within a combustion chamber of the engine.

BACKGROUND OF INVENTION

[0004] Relatively recently there have been developed various proposals for ignition systems for internal combustion engines (ICE) wherein a quantity of fuel/air mixture disposed within a combustion chamber of the engine is ignited by means of one or more flame fronts. Such flame fronts are derived from a single flame front which is initiated within an auxiliary pre-combustion chamber which, in turn, is physically separated from the main combustion chamber of the ICE. From this initial ignition point, the flame propagates along a channel leading from the initial ignition point to the combustion chamber. Herein at times, this channel is referred to synonymously as the "first channel" or as the "first central channel". The flame front moving through the first channel is divided into one or more flame fronts, each of which exits separately, from the channel and into the combustion chamber via respective lateral channels. Commonly, a flame front exits into the combustion chamber via the first channel and separate flame fronts exits into the combustion chamber via the one or more lateral channels. Much attention has been paid to the respective directional orientation of the first channel and the lateral channels (and their associated flame fronts) into the combustion chamber, with the desire to maximize the simultaneity and completeness of ignition of the fuel/air mixture disposed within the combustion chamber.

[0005] Of major concern in certain flame front-type ignition systems is how one goes about installation of a flame front ignition system in operative relationship to an existing internal ICE so that the orientation of the flame fronts from the flame cone are directed toward specific locations within the combustion chamber which have been determined to produce maximized simultaneity of ignition and completeness of combustion of the fuel/air mixture disposed within the combustion chamber. This problem is of particular significance when seeking to convert an ICE from a non-flame front ignition system to a flame front ignition system.

[0006] It is to be noted that in all known four-stroke ICEs, there is an internal combustion chamber which is fitted with at least one intake valve, at least one exhaust valve and some means, most commonly at least one spark plug, which serves to ignite a fuel/air mixture drawn into the combustion chamber via the intake valve. In certain of the prior art non-flame front ignition systems the spark plug is threaded into a throughbore provided through the wall thickness of the head of the ICE to the extent that the electrodes of the spark plug are exposed directly within the combustion chamber. Herein, this non-flame cone embodiment is at times referred to as the "standard" system.

[0007] On the other hand, in flame front ignition systems, most commonly, the electrodes of the spark plug are disposed within an auxiliary pre-combustion chamber which is at least semi-isolated from the interior of the combustion chamber. In the compression stroke of the ICE, fuel/air mixture from the combustion chamber is fed into the auxiliary pre-combustion chamber. Thereafter, the firing of the spark plug ignites the fuel/air mixture within the auxiliary pre-combustion chamber and the flame front which is developed propagates along the first channel toward the combustion chamber. In this system, before this flame front exits the first channel, the initial flame front is divided in multiple separate flame fronts as by means of a flame cone. These multiple flame fronts exit the flame cone into the combustion chamber where they ignite the fuel/air mixture disposed with the combustion chamber.

[0008] In one embodiment of a flame front pre-ignition system as described in Applicant's copending application Ser. No. 11/622,801, filed Jan. 12, 2007, entitled SPARK IGNITION MODIFIER MODULE AND METHOD, once the desired orientation of flame fronts exiting a flame cone are determined, a flame cone having such oriented exit channels may be manufactured. One prior art technique for aligning such flame cone within the throughbore, hence the directionality of its exiting flame fronts, includes the use of a flame cone which is insertable into the throughbore from a location internally of the combustion chamber. In this latter technique, the flame cone is threaded into the inboard end of the throughbore until the flame cone is securely, but not necessarily fully, threaded into the throughbore. At this point, the rotation of the flame cone within the throughbore is adjusted such that the directionality of the flame exit ports are in their desired orientation with respect to pertinent ones of the elements disposed within the combustion chamber of the ICE. Thereupon means is required to lock the flame cone in its selected rotational position within the throughbore. Thereafter the spark plug is inserted into the opposite external end of the throughbore and/or the outboard end of the flame cone. This technique requires access to the combustion chamber of the ICE, e.g., removal of the cover of the head of the engine.

[0009] In another technique, described in Applicant's U.S. Pat. No. 7,104,246, entitled SPARK AMPLIFIER, the rotational position of the exit channels of the flame cone are established in the course of manufacturing the flame cone and the flame cone is thereafter inserted into the throughbore starting at the outboard open end of the throughbore (i.e. starting externally of the head). This technique addresses the problem of bottoming out the threading of the flame cone into the throughbore at a location which is inconsistent with the desired rotational orientation of the flame cone, hence the rotational orientation of its exit flame front channels.

[0010] It is recognized that two stroke engines, like in engines for chain saws, etc., do not have valves. Moreover some engines have more than one spark plug per cylinder. One skilled in the art will further recognize the applicability of the present invention to these and/or other internal combustion engines.

BRIEF DESCRIPTION OF THE FIGURES

[0011] FIG. 1 is a schematic representation of a portion of a head of an ICE and depicting a flame cone and spark plug in exploded view and including a flat adjustment spacer washer of the present invention;

[0012] FIG. 2 is a schematic representation of a portion of a head of an ICE as depicted in FIG. 1 and including a conical adjustment spacer washer of the present invention;

[0013] FIG. 3 is a schematic representation of a portion of an ICE combustion chamber and depicting the directionality of various flame fronts entering the combustion chamber;

[0014] FIG. 4 is a side elevation view of a flame cone embodying various of the features of the present invention;

[0015] FIG. 5 is a top end view of the flame cone depicted in FIG. 4;

[0016] FIG. 6 is a side elevation view, in section, of a flame cone as depicted in FIG. 4 and taken generally along the line 6-6 of FIG. 5.

[0017] FIG. 7 is a side elevation view, in section, of a flame cone as depicted in FIG. 4 and taken generally along the line 7-7 of FIG. 5;

[0018] FIG. 8 is a side elevation view, in section of a flame cone as depicted in FIG. 4 and taken generally along the line 8-8 of FIG. 5;

[0019] FIG. 9 is a side elevation view, in section, of a flame cone as depicted in FIG. 4 and taken generally along the line 9-9 of FIG. 5;

[0020] FIG. 10 is a top view of the flame cone depicted in FIG. 4 and illustrating the marking of alpha letters on the outer face of the flame cone;

[0021] FIG. 11 is a top view of one embodiment of a conical spacer washer employed in the present invention;

[0022] FIG. 12 is a side view, in section, of the conical spacer washer depicted in FIG. 11;

[0023] FIG. 13 is a top view of one embodiment of a flat spacer washer employed in the present invention;

[0024] FIG. 14 is a side view, in section, of the flat spacer washer depicted in FIG. 13;

[0025] FIG. 15 is one embodiment of a lookup table relating the thicknesses of various spacer washers associated with the alpha lettering applied to the outer face of the top end of a flame cone of the present invention; and,

[0026] FIG. 16 is schematic representation of the outer face of a portion of a head wall of an ICE and depicting the outboard open end of a throughbore extending through the thickness of the head wall.

SUMMARY OF INVENTION

[0027] In accordance with one aspect of the present invention there is provided a method and apparatus for installation and functioning of a flame front type ignition system in the conventional throughbore through the wall of the head of an internal combustion engine. This installation is effected from a location external of the head and while the head is affixed in covering relationship to one or more combustion chambers of the internal combustion engine. In one embodiment, there is employed a flame cone which is threadably inserted within the throughbore proximate the inboard end of the throughbore. The inboard end of the flame cone is provided with a plurality of exit ports opening from a first central channel within the flame cone thence into the combustion chamber along preselected paths.

[0028] The flame cone of the present invention is provided with one or more alpha letters on the outboard face of the flame cone where they are visible to a person threading the flame cone into the throughbore. Further, a marker (e.g. an arrow) is provided on the outer rim of the throughbore. A datum alpha letter ("A" in the present disclosure) is aligned on the face of the flame cone in a position which, when aligned with the marker on the rim of the throughbore, indicates that the flame cone is at the proper rotational attitude within the throughbore wherein the exit ports in the flame cone are correctly angularly oriented within the throughbore such that flame fronts exiting such ports are also properly aligned relative to those locations within the combustion chamber toward which flame fronts desirably are directed for ignition purposes.

[0029] The depth of insertion of the flame cone into the throughbore through the wall of the head of the ICE, is adjustable by means of spacer washers adapted to selectively adjust such depth of sealing insertion of the flame cone within the throughbore as a function of the angular orientation of the exit ports for flame fronts entering the combustion chamber of the ICE.

[0030] In one embodiment of the method of the present invention, the flame cone is threadably inserted into the throughbore until the flame cone sealingly seats itself against a circumferential shoulder disposed within the throughbore. The torque employed to sealingly seat the flame cone is established and published by the provider of the engine. Also noted is the alpha letter on the face of the flame cone which is closest to the arrow marker disposed on the outboard rim of the throughbore. Thereupon, the flame cone is withdrawn from the throughbore.

[0031] Using the information obtained with the flame cone, a spacer washer having an alpha letter (representative of the thickness of the spacer washer) corresponding to the alpha number noted to be nearest the marker on the rim of the throughbore, is chosen and inserted within the throughbore in overlying relationship to the circumferential shoulder or, alternatively and preferably, is fitted over the threaded end of the flame cone. Thereupon the flame cone and the washer(s) on the threaded end thereof are sealingly reinserted into the throughbore, employing the same torque (supplied by engine provider as initially noted). This action longitudinally and rotationally spaces and seals the flame cone within the throughbore such that the "A" alpha letter on the flame cone becomes aligned with the marker on the rim of the throughbore, thereby indicating that the exit ports of the flame cone are aligned as desired within the combustion chamber.

DETAILED DESCRIPTION OF THE INVENTION

[0032] In FIG. 1, there is depicted a partially exploded view of a portion of the head 10 of an ICE, a typical throughbore 12 through the wall 14 of the head, a flame cone 16, having multiple flame front exit channels 18, 20 and 22, threadably insertable into the throughbore, and a conventional spark plug 24 threadably insertable into the flame cone. The general apparatus depicted in FIG. 1 is more fully described in Applicant's copending application Ser. No. 11/689,852, filed Mar. 22, 2007, entitled IGNITION SYSTEM FOR INTERNAL COMBUSTION ENGINE, such description being incorporated herein by reference.

[0033] Referring to FIGS. 1 and 2 of the present application, it will be noted that the desired orientations of the multiple exit channels 18, 20, 22 through which multiple flame fronts 28, 30, 32 enter the combustion chamber 26 (See FIG. 3) are determined analytically once the internal geometry of the combustion chamber is known. Determining the internal geometry of the combustion chamber requires access to the design data for the ICE, or it must be determined by examination of the disassembled engine, all as is well known to those skilled in the art. In accordance with one aspect of the present invention, flame fronts 28, 30, 32 from respective individual ones of the exit channels 18, 20, 22 of the flame cone are directed along predetermined paths selected to maximize the simultaneity and completeness of the ignition of the fuel/air mixture disposed within the combustion chamber. (See embodiments depicted in FIGS. 1, 2 and 3 of the present application).

[0034] In one embodiment of the present invention, as depicted in FIG. 1, the pre-combustion system 34 includes a flame cone 16, a pre-combustion chamber 36 defined in the inboard end 38 of the cone, at least one flame front exit channel 18 defined in the cone and leading from the pre-ignition chamber toward the combustion chamber of the ICE. This first exit channel 18 is directionally oriented to direct its flame front 28 toward the intake valve 40 of the ICE. In the depicted embodiment, there is provided a first lateral channel 20 (See FIGS. 1, 2 and 3) whose flame front 30 is directionally oriented toward the exhaust valve 42 and a second lateral channel 22 whose flame front 32 is directionally oriented generally tangentially toward the inner wall 44 of the combustion chamber of the ICE. If desired, one or more lateral channels 23 may be provided whose directional orientation may be chosen to direct a flame front from the cone into the combustion chamber of the ICE toward some further location within the combustion chamber, such as tangentially along the inner wall of the combustion chamber in a direction opposite the direction of the flame front 32 exiting the second lateral channel 22.

[0035] In the depicted embodiment of FIGS. 1 and 2, the throughbore 12 through the wall 14 of the head 10 of the ICE includes a first outboard open end portion 46 and an inboard open end portion 56. The outboard open end portion 46 of the throughbore 12 in the depicted embodiment may have smooth inner 48 and outer 50 surfaces and a diameter which is materially greater that the outer diameter of a conventional spark plug suitable for use in the depicted head of the ICE, thereby defining a void open annular space 52 between the inner surface 48 of the throughbore and the spark plug and the hexagonal head 54 of the flame cone. This annular space is useful for the receipt therein of a torque wrench, for example, for establishing the required depth of insertion of the flame cone into the throughbore.

[0036] The transition between the outboard 46 and inboard end 56 portions of the throughbore defines a circumferential shoulder 58 internally of the throughbore at a location approximately midway between the opposite ends of the throughbore. As depicted in FIG. 1, this transition includes an inwardly directed flat surface 60. In the present invention and as depicted in FIG. 2, for example, it is to be recognized that the circumferential shoulder within the throughbore may define a sloping surface which extends angularly inward of the throughbore, i.e., conical instead of a flat surface as depicted in FIG. 1.

[0037] In accordance with one aspect of the present invention a plurality of identical flame cones 16, specific for a given engine type, may be manufactured. Each flame cone includes at least one, and most commonly a plurality of, exit channels which are specifically directionally oriented such that the exit paths of respective ones of flame fronts exiting such channels from the inboard end of the flame cone are directed toward respective specific areas within the combustion chamber of that engine for which the flame cone is designed.

[0038] FIGS. 4-9 depict one embodiment of a flame cone which includes a first central channel 18 and first and second lateral channels 20 and 22, respectively, in the inboard end 38 of the flame cone, The depicted flame cone is designed for a specific engine type, but the method for manufacture and identification of the depicted flame cone is deemed typical for any other known ICE types.

[0039] With reference initially to FIG. 4, the depicted embodiment of the flame cone is generally tubular in geometry. The cone includes an outer body portion 66 having internal threads 68 suitable for the threadable insertion of a conventional spark plug therein. The geometry of the first outer body portion 66 of the depicted flame cone includes a hexagonal head 54. The cone further includes an inboard body portion 70 which is externally threaded 72 to be threadably inserted into the internally threaded inboard end 56 of the throughbore 12 in the wall of the engine of an ICE. A typical throughbore and a flame cone threadably insertable therein may be provided along the length of their respective threaded areas with threads of a known standard type such as M14-1.25 ISO threads.

[0040] The transition between the first and second body portions of the flame cone includes a circumferential shoulder 74 about the outer periphery of the cone, such shoulder including a flat surface 76 which projects substantially perpendicularly away from the cone. The flame cone, therefore, may be threadably inserted into the throughbore to a depth limited by the outer circumferential shoulder of the flame cone sealingly engaging the inner circumferential shoulder 58 of the throughbore, thereby limiting the extent to which a flame cone can be inserted into the throughbore.

[0041] Further, internally of the flame cone there is defined a chamber 78 which ultimately becomes a portion of the pre-combustion chamber 36 of the pre-ignition flame front ignition system 34 for the ICE.

[0042] The first central channel 18 of the depicted flame cone extends in fluid communication from the pre-combustion chamber 36 to the combustion chamber 26 of the ICE. Proximate the inboard end of the first central channel, there are defined first and second separated individual lateral exit channels 20, 22 which lead, in fluid communication, from the first central channel into the combustion chamber. Each of the channels terminates within the combustion chamber, but proximate to the inner circumferential wall 44 of the combustion chamber such that the directionality of the flame front exiting each channel is not diverted or impeded from its preselected path into the combustion chamber. (See FIGS. 1-3 and 4-10).

[0043] As noted, the first central channel is in fluid communication between the pre-combustion chamber and the combustion chamber of the ICE. Similarly, each of the first and second lateral channels are in fluid communication from the first channel into the combustion chamber. This arrangement of channels serves to divide a flame front propagating from the pre-combustion chamber through the first central channel into three individual flame fronts. These flame fronts are individually directionally oriented to cause the flame front from the first central channel to be directed toward the intake valve 40 in the combustion chamber and the flame front from the first lateral channel to be directed toward the exhaust valve 42 in the combustion chamber 20. The flame front from the second lateral channel may be directionally oriented tangentially along the inner wall 44 of the combustion chamber, or toward another location within the combustion chamber. In one embodiment, the internal diameter of the first central channel is chosen to be larger than the internal diameter of one or more of the first and second lateral channels, particularly the internal diameter of the first lateral channel which is directed toward the exhaust valve of the ICE. This geometry causes the flame front exiting the first lateral channel 20 to exhibit a greater velocity of forward movement than the velocity of the flame front exiting the first central channel. By this, or like manipulation of the several flame fronts, ignition of the fuel/air mixture disposed within the combustion chamber may be of enhanced simultaneity, among other advantages.

[0044] FIGS. 6-9 depict various longitudinal sectional views of the flame cone of FIG. 5. FIG. 6 depicts the lines along which each of the sectional views of FIGS. 6-9 are taken, each line lying along a diameter of the outboard end of the flame cone and all of which intersect one another at the longitudinal centerline 80 of the cone. In each such sectional view, there is depicted an angular relationship of the longitudinal centerline of the depicted embodiment of the flame cone with the respective longitudinal centerline 82, 84 of the two lateral channels in the depicted cone.

[0045] As depicted in FIG. 7, the longitudinal centerline 82 of the first central channel may be oriented at an angle of 80 degrees relative to the longitudinal centerline 86 of the cone. This geometry of the first central channel is preferred, but it will be recognized that the placement of the first central channel within the cone may be chosen to be at a location which is not only displaced from the centerline of the cone, but also may be of a less than straight geometry.

[0046] With reference to FIGS. 7 and 9, there are depicted locations of the first and second lateral channels through which separate flame fronts enter the combustion chamber. In the embodiment of FIG. 7, the longitudinal centerline 82 of the first lateral channel 20 may be angularly oriented at an angle of 80 degrees relative to the longitudinal centerline 86 of the flame cone when viewed along line 7-7 of FIG. 5. In similar manner, as seen in FIG. 8, the longitudinal centerline 84 of the second lateral channel 22 may be oriented at an angle of 60 degrees relative to the longitudinal centerline of the flame cone when viewed along line 8-8 of FIG. 5. Still further, as seen in FIG. 9, the longitudinal centerline of the first lateral channel 20 may be oriented at an angle of 115 degrees relative to the longitudinal centerline of the cone when viewed along line 9-9 of FIG. 5. These angular relationships are chosen to satisfy the requirement that when the flame cone is properly inserted into the throughbore, the flame front from the first central channel be directed toward the intake valve within the combustion chamber, that the flame front from the first lateral channel be directed toward the exhaust valve within the combustion chamber, that the second lateral channel be directed tangentially of the inner wall of the combustion chamber. As noted, these angular relationships may be varied to suit a given geometry within the combustion chamber of known ICE's.

[0047] Referring to FIG. 10, in particular, the flame cone therein depicted is the same as the flame cone 16 depicted in FIGS. 4-9. After the flame cone depicted in the several Figures has been formed, including the formation of the channels described hereinabove, the outboard face 88 of the flame cone is marked with alpha letters, e.g. "A" through "L". The "A" letter is assigned to that location on the face of the cone referred to in the Figures as the 12 O'clock position. For convenience, the "A" letter is located at the apex 90 of the angular junction of two adjacent ones of the segments of the hexagonal head 54 of the flame cone 16. In the depicted embodiment, the lettering of the cone proceeds clockwise about the outer periphery of the face of the cone at intervals of 30 degrees between adjacent letters in the embodiment depicted in FIGS. 11 and 12.

[0048] As depicted in FIG. 2, in certain "conical head" ICE's the throughbore is provided with a shoulder which includes an inwardly angled surface 60 extending circumferentially about the inner wall of the throughbore at the transition. Thus, when a flame cone is threaded into the throughbore, without more, the circumferential flat surface 76 defined on the flame cone would engage the angled surface of the circumferential flange defined in the throughbore. This situation is undesirable due to the lack of precision of engagement of these differently configured surfaces and the assurance of sealing therebetween when the flame cone is torqued against the shoulder within the throughbore. To overcome this potential problem, in one aspect of the present invention, the inventor provides a conical shaped washer 92 such as depicted in FIGS. 2, 11 and 12. As seen in FIGS. 2 and 12, such washer includes a first side 94 having a conical-shaped outer perimetral surface. A second, and opposite side 96 of the washer defines a flat surface. The outer diameter of the washer is chosen to permit substantially snug fit of the washer within the throughbore and in overlying relationship to the angled surface circumferential shoulder 58 of the throughbore with the flat side 96 of the conical washer facing away from the shoulder of the throughbore.

[0049] The circumferential shoulder disposed within the throughbore and which slopes inwardly of the throughbore may be referred to as a "conical" head engine (See FIG. 2). For consistency of effective physical sealing engagement of the "square" shoulder of a flame cone with the conical circumferential shoulder of the throughbore, the present inventor provides a "conical" spacer washer 92 of a thickness suitable to "fill" the conical volume of the circumferential shoulder of the throughbore, thereby redefining this shoulder as a flat shoulder having its exposed surface disposed substantially perpendicular to the longitudinal centerline of the throughbore and facing away from the shoulder of the throughbore. When so employed, this conical spacer washer is retained on the threaded end of the flame cone, along with other flat spacer washers 98 added to adjust the depth of insertion of the flame cone into the throughbore. It will be also recognized that such conical spacer washers are not needed when the circumferential shoulder within the throughbore is a "square" shoulder having a face which is oriented substantially perpendicular to the longitudinal centerline of the throughbore as depicted in FIG. 1.

[0050] Accordingly, when the flame cone is thereafter threaded into the throughbore, the flat surface of the circumferential shoulder of the flame cone precisely engages the flat surface of the washer, thereby providing for precise depth positioning of the flame cone within the throughbore upon repeated entry and removal of such flame cone with respect to the throughbore. Moreover, such geometrical mating of the flat surfaces of the two circumferential shoulders permits the flame cone to be repeatedly torqued into a specified fluid sealing engagement with the shoulder within the throughbore upon repeated entry and removal events of the flame core into and from the throughbore.

[0051] Referring to FIG. 16, it will be noted that in accordance with one aspect of the present invention, the outer rim 100 of the throughbore is provided with a marker 102 (e.g. an arrow) which is readily visualized by a person disposed proximate, but externally of, the head 10 of the ICE. The exact location of this marker about the periphery of the rim is not critical, but rather its location must represent the precise threaded depth of the flame cone into the throughbore wherein the datum "A", is aligned with the marker, hence the exit channels in the inboard end of the flame cone are properly aligned such that their respective flame fronts are directionally oriented toward their respective target locations within the combustion chamber. For example, the first lateral exit channel is to be oriented in the direction of the exhaust valve disposed within the combustion chamber.

[0052] Toward this end, the outboard face 88of the flame cone is divided into spaced apart identified locations about the periphery of the face. Each such location is assigned an alpha letter. As depicted, in a preferred embodiment, these lettered locations proceed alphabetically clockwise, at equally spaced apart distances, about the periphery of the face of the flame cone. More specifically, the letter "A" is assigned to that location on the face of the flame cone wherein the "A" aligns with the marker 102 (arrow) on the rim 100 of the throughbore when the flame cone is threaded into the throughbore, at a given torque, and into fluid sealing engagement of the respective shoulders of the flame cone and the throughbore. By design, this relationship of the flame cone to its depth within the throughbore establishes the proper alignment of the exit channels of the flame cone with their respective targets within the combustion chamber. It is to be noted that if the circumferential shoulder within the throughbore includes an angled surface, an noted above, a conical washer is to be inserted within the throughbore and in overlying relationship to the shoulder within the throughbore thereby defining a continuous flat surface against which the flat face of the circumferential shoulder of the flame cone may sealingly engage when the flame cone is threaded into the throughbore. In those instances where the shoulder within the throughbore exhibits a flat face, no conical washer need be employed.

[0053] For one or more various reasons, the threading of the flame cone into the throughbore may vary between multiple entry and removal events of the flame cone. For example, the torque employed between such events may be such that the depth to which the flame cone enters the throughbore before "bottoming out" against the shoulder within the throughbore at a given torque may vary from event to event. Such variance can result in inaccurate rotational positioning of the exit channels of the flame cone relative to their intended targets within the combustion chamber.

[0054] In the present invention, this and like variances are accommodated. Specifically, in the present invention, a flame cone designed for the ICE in question is initially threaded into a throughbore in the head of the ICE until the respective circumferential shoulders of the throughbore and flame cone engage one another at a preselected torque value. This torque value is selected to produce fluid-tight sealing of the engaged shoulders against fluid flow therepast and is readily established by one skilled in the art.

[0055] When the initial threading of the flame cone into the throughbore is completed, the operator notes whether the "A" letter on the face of the flame cone is aligned with the marker on the rim of the throughbore. If yes, the flame cone, hence its exit channels, are properly aligned with respect to their intended targets within the combustion chamber and no further action need be taken with respect to the installation of the flame cone within the throughbore.

[0056] On the other hand, if the "A" on the flame cone is not aligned with the marker on the rim of the throughbore when the flame cone is fully threaded into the throughbore as described above, the operator notes that alpha letter which is nearest the marker. Thereupon the flame cone is withdrawn from the throughbore and an appropriate spacer washer is fitted onto the threaded end of the flame cone, atop the conical washer, to thereby limit the depth of insertion of the flame cone within the throughbore.

[0057] In one embodiment of the present invention, spacer washers of differing thicknesses are provided. Each spacer washer is identified with an alpha letter which is indicative of the thickness of the washer. In that embodiment where the spatial distance between alpha letters applied to the face of the flame cone and the pitch of threads employed in threading the flame cone into the throughbore, are known, one skilled in the art may readily calculate that thickness of a spacer washer which would limit the depth to which the flame cone would enter the throughbore upon rotation of the flame cone by a rotational distance commensurate with the space between adjacent ones of the alpha letters on the face of the flame cone. Thus, if the initial insertion of the flame cone into the throughbore resulted in the letter "C" being the closest letter to the marker on the rim of the throughbore, then a spacer washer marked "C" would be chosen for installation onto the flame cone and resulting alteration of the depth of the flame cone into the throughbore such that the "A" on the face of the flame cone would come into alignment with the marker on the rim of the throughbore. FIG. 15 is a typical lookup table listing typical thicknesses of spacer washers with their respective alpha identification.

[0058] The flame cone of the present invention is designed initially to ensure that the shoulder on the flame cone will seat with the shoulder on the wall of the throughbore when the "A" indicia is fully aligned with, or just short of alignment with, the marker on the rim of the throughbore. As noted, the spacer washers may affect the depth of insertion of the flame cone by only one revolution (one thread) of the flame cone within the throughbore. For a typical spark plug threads, such depth would be 1.25 mm or 0.05 inch.

[0059] Employing the concept of the present invention, in the method of the present invention, a user selects a flame cone which is designed for the ICE model in question and threadably inserts such flame cone into the throughbore in the wall of the head of the ICE until the circumferential shoulder of the cone sealingly engages the circumferential shoulder of the throughbore. The torque employed to effect such engagement is that torque which is commonly supplied by the engine provider. Further, that indicia which is closest to the arrow marker on the rim of the throughbore is also noted. For example, such closest indicia may be "B".

[0060] Thereupon, the flame cone is withdrawn from the throughbore. Employing the lookup table, the user locates that washer whose thickness carries the "B:" indicia (hence identifies that thickness of spacer washer which, when inserted into the throughbore in overlying relationship to the inner circumferential shoulder of the throughbore, will halt the depth of insertion of the flame cone in question such that the indicia "A" on the flame cone is aligned with the arrow marker on the rim of the throughbore. This chosen spacer washer is then fitted onto the threaded end of the flame cone and the flame cone and its associated washer(s), is again threadably and sealingly inserted into the throughbore, employing the same torque value as observed when the flame cone was initially inserted into the throughbore without the spacer washer being present. Under these conditions, the indica "A" on the face of the flame cone should be in alignment with the arrow marker on the rim of the throughbore. If not, the user notes that indicia which is closest to the arrow marker, the flame cone is withdrawn and the process of selection of a suitable spacer washer and insertion of the flame cone and its associated washer into the throughbore is repeated. Thereupon, the flame cone is again inserted into the throughbore employing the same initially employed torque value. If this further action does not cause the "A" indicia on the flame cone to be aligned with the arrow marker on the rime of the throughbore, the process is repeated until such alignment is accomplished. Upon achieving alignment of the "A" indicia with the arrow marker, the user is assured that the multiple exit channels from the flame cone are directionally aligned properly for their respective flame fronts to be directed toward the intended areas within the combustion chamber. Also, the user is assured that there is a fluid sealed relationship between the cone and the throughbore.

[0061] Should variations in depth occur for any of several reasons, such as change in torque between times of insertion of the flame cone into a throughbore, different starting positions of the flame cone between times of insertion of the flame cone into a throughbore, etc., the present invention accommodates such variations rapidly and accurately by means of the adjustability of the depth of a given flame cone within a given throughbore, irrespective of such variations. This accommodation is made possible by the ready determination of the depth of the flame cone within the throughbore through the means of visual observation of the disposition of alpha letters on the face of the flame cone relative to the fixed arrow marker on the rim of the throughbore and the available choices of adjustment of the depth to which the flame cone can enter into the throughbore. That is, irrespective of what alpha letter (other than "A")) is closest to the rim marker when the flame cone is threaded into the throughbore to an effective sealing position, the present invention provides one or more selectable spacer washers of different thicknesses, which, when inserted within the throughbore, are sufficient in overall thickness to adjust the depth of the flame cone within the throughbore to the extent that the "A" letter is aligned with the arrow marker on the rim of the throughbore upon the flame cone being torqued to that value which ensures suitable fluid sealing of the flame cone within the throughbore. Even if different torque values are employed between the initial and subsequent insertions of the flame cone into the throughbore, so long as the engagement between the circumferential shoulders (with or without spacer washers in the throughbore) effectively creates a fluid-tight seal between the flame cone and the throughbore, selection of one or more spacer washers may be employed to effect the required alignment of the "A" indicia on the face of the flame cone with the arrow marker on the rim of the throughbore, again thereby ensuring proper alignment of the exit channels from the flame cone into the combustion chamber of the ICE. It is to be noted that if the initial insertion of the flame cone into the throughbore results in the "A" indicia being in alignment with the arrow marker on the rim of the throughbore, there is no need for adjustment(s) of the depth of insertion of the flame cone into the throughbore.

[0062] It is to be recognized that, in the art. there commonly are multiple throughbores in a given ICE, i.e., one throughbore for each combustion chamber of the ICE. Thus for a given ICE, all the throughbores thereof are of essentially identical construction, including thread types. Again, irrespective of whether all the throughbores of a given ICE are of truly identical geometry, the present invention provides for adjustability of the depth of insertion of a flame cone in each of the throughbores through the choice of the spacer washers as described hereinabove.

[0063] While the present invention has been illustrated by description of several embodiments and while the illustrative embodiments have been described in considerable detail, it is not the intention of applicant to restrict or in any way limit the scope of the appended claims to such detail. Additional advantages and modifications will readily appear to those skilled in the art. The invention in its broader aspects is therefore not limited to the specific details, representative apparatus and methods, and illustrative examples shown and described. Accordingly departures may be made from such details without departing from the spirit or scope of applicant's general inventive concept.

Claims:

1. A method for installation of a flame cone of a pre-ignition system for ignition of a fuel/gas mixture within a combustion chamber of an internal combustion engine, comprising the steps of:

(a) from a location external of the head of an internal combustion engine inserting a flame cone having at least one flame front exit channel adapted to direct a flame front from the flame cone into the combustion chamber of the internal combustion engine along a path toward a target location within the combustion chamber of the internal combustion engine, into said throughbore to a first depth,

(b) providing a plurality of indicia on said flame cone which are visible from a location external of the internal combustion engine, a first one of said indicia being indicative of the desired rotational position of said flame cone within said throughbore wherein said at least one exit channel is oriented toward its intended target location within the combustion chamber,

(c) providing a point of reference on said cylinder head proximate said throughbore and which is visible from a location external of the internal combustion engine,

(d) inserting said flame cone into said throughbore to a predetermined depth of sealingly engagement there between,

(e) noting that indicia on said flame cone which is closest to said point of reference on said head when said flame cone achieves said sealingly engagement,

(f) if said indicia on said flame cone which is noted is said first one of said indicia when said flame cone and said throughbore are in sealing engagement with one another, no further action need be taken,

(g) If said indicia on said flame cone which is noted is an indicia other than said first one of said indicia, removing said flame cone from said throughbore;

(h) thereafter, selecting at least one spacer washer having a thickness corresponding with said noted indicia and installing said selected spacer washer onto the flame cone, to be engaged with the sealing surface of the throughbore,

(i) replacing said flame cone into said throughbore in sealing engagement between said selected spacer washer with said throughbore.

2. The method of claim 1 wherein said steps (d) through (i) are repeated until said first one of said indicia on said flame cone is in rotational alignment with said reference point defined on said head when the flame cone and its associated spacer washer are at least one in sealing engagement with the throughbore.

3. The method of claim 1 wherein said indicia on said flame cone are disposed about the outer periphery of said outboard end of said flame cone and spaced apart substantially equidistantly.

4. The method of claim 1 and including the step of providing mating threads on each of said flame cone and said throughbore whereby said flame cone is threadably insertable within said throughbore.

5. The method of claim 4 and including the step of forming said threads of each of said flame cone and said throughbore of substantially like thread classification.

6. A method for installation of a flame cone of a pre-ignition system for ignition of a fuel/gas mixture within a combustion chamber of an internal combustion engine, comprising the steps of:

(a) providing a flame cone having an inboard end and an opposite outboard open end,

(b) defining adjacent said inboard end of said flame cone at least one exit channel adapted to provide fluid communication of a flame front from a location within said flame cone through said exit channel and toward a target location internally of the combustion chamber of the internal combustion engine;

(c) providing a first indicia on said outboard end of said flame cone, said first indicia being visually observable from a location external of the internal combustion engine and further indicative of the physical location and attitude of said at least one exit channel;

(d) providing multiple further indicia on said outboard end of said flame cone at spaced apart locations about the outer periphery of said outboard end of said flame cone and being visible for a location external of the internal combustion engine,

(e) providing a circumferential shoulder about the outer circumference of said flame cone at a location intermediate said inboard and outboard ends of said flame cone, said shoulder extending radially outward of said outer circumference of said flame cone;

(f) defining an elongated throughbore through the head of the internal combustion engine, and throughbore having an open inboard end which opens internally of the combustion chamber of the internal combustion engine and an open outboard end opening to the environmental external of the head, whereby said throughbore defines a passageway between said combustion chamber and the environment external of the head,

(g) defining a circumferential shoulder internally of said throughbore at a location intermediate said inboard and outboard ends of said throughbore, said shoulder extending radially inwardly of said throughbore a distance sufficient to engage and limit the extent of insertion of said flame cone into said throughbore;

(h) providing a reference marker on said head adjacent the outboard open end of said throughbore, said reference marker being visually exposed from a location external of said internal combustion engine;

(i) inserting said flame cone into said throughbore via said outboard open end of said throughbore to the extent that said shoulder of said flame cone sealingly engages said shoulder within said throughbore,

(j) if said first indicia is not aligned with said reference marker upon completion of step (i), removing said flame cone from said throughbore,

(k) altering the depth of which said flame cone will extend into said throughbore and effect a sealing relationship with said throughbore and said first indicia also will be aligned with said reference marker.

7. Apparatus for aligning one or more flame front exit channels of a flame cone within a throughbore having an open inboard end and an open outboard opposite end, defined through the wall of the head of an internal combustion engine, comprising:

(a) flame cone having an open outboard end and an inboard end having one or more flame front exit channels defined therein,

(b) means for adjustably inserting said flame cone within said throughbore via said outboard open end of said throughbore,

(c) a reference marker defined on said head adjacent said outboard open end of said throughbore,

(d) a first indicia defined on said outboard end of said flame cone, said first indicia being indicative of the position and attitude of at least one of said indicia on said outboard end of said flame cone,

(e) a plurality of further indicia defined on said outboard end of said flame cone at spaced apart locations about the outer perimeter of said flame cone,

(f) said reference marker and said indicia being visually observable from a location external of said internal combustion engine,

(g) a plurality of spacer washers of different thickness for selectively adjusting the depth to which said flame cone enters said throughbore and effects a fluid sealing relationship between said flame cone and said throughbore and alignment of said first indicia with said reference marker.

United States Patent [19]

Linder

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[45] **Date of Patent:** **Apr. 12, 1988**

[54] **COMBUSTION CONTROL SYSTEM FOR INTERNAL COMBUSTION ENGINES**

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[22] Filed: **Mar. 19, 1987**

[51] **Int. Cl.**[4] **F02B 19/10**

[52] **U.S. Cl.** **123/267**; 123/297; 123/525; 123/557; 313/120; 313/143

[58] **Field of Search** .... 123/266, 267, 169 V, 123/297, 557, 525, 522; 313/120, 143

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Attorney, Agent, or Firm—H. Albert Richardson, Jr.

[57] **ABSTRACT**

A combustion control system for internal combustion engines which includes a novel spark plug having a precombustion chamber in which a butane/air mixture injected through the plug is ignited in order to initiate and manage combustion wave propagation within the engine cylinder. The system also includes a fuel system to provide gasoline at an elevated pressure to the fuel metering system of the engine and a gaseous air/butane mixture under pressure to the spark plugs.

14 Claims, 3 Drawing Sheets

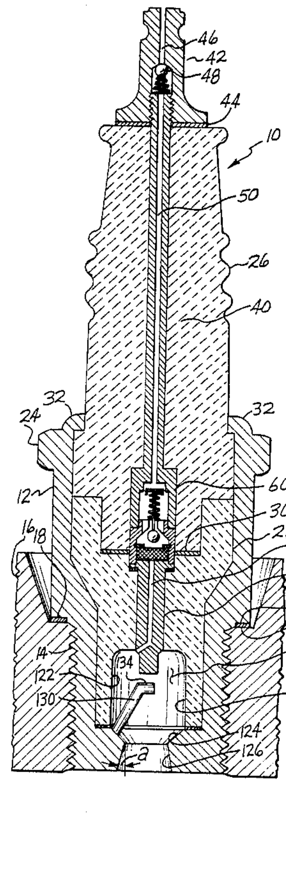


Fig. 1

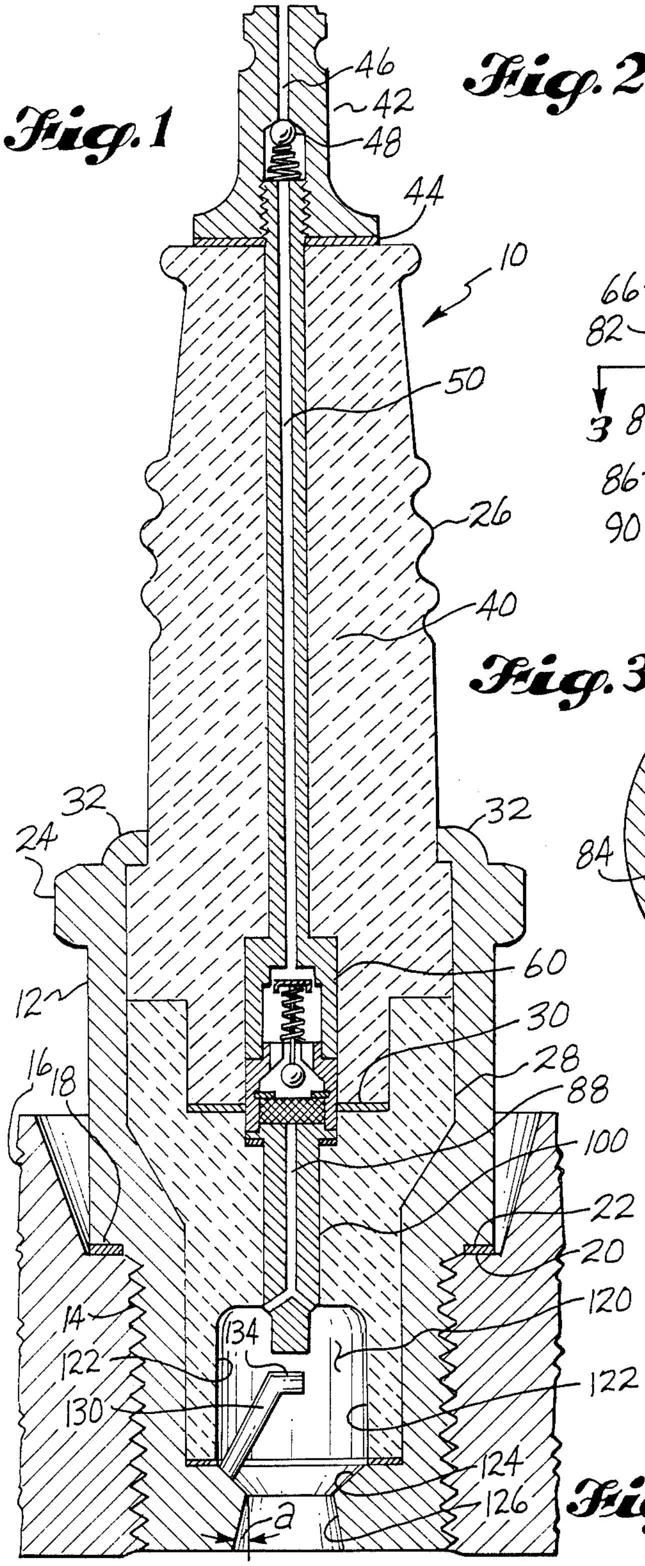


Fig. 2

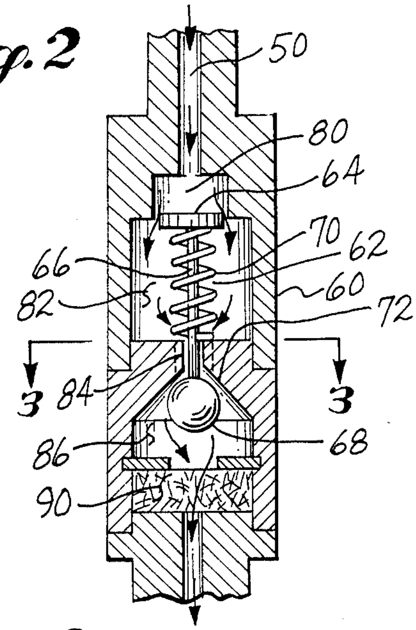
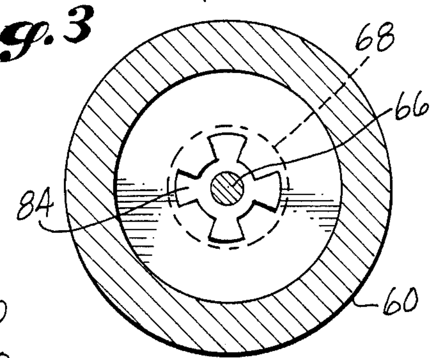


Fig. 3



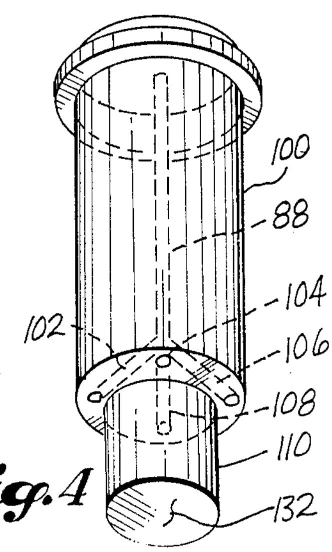


Fig. 4

Fig. 5

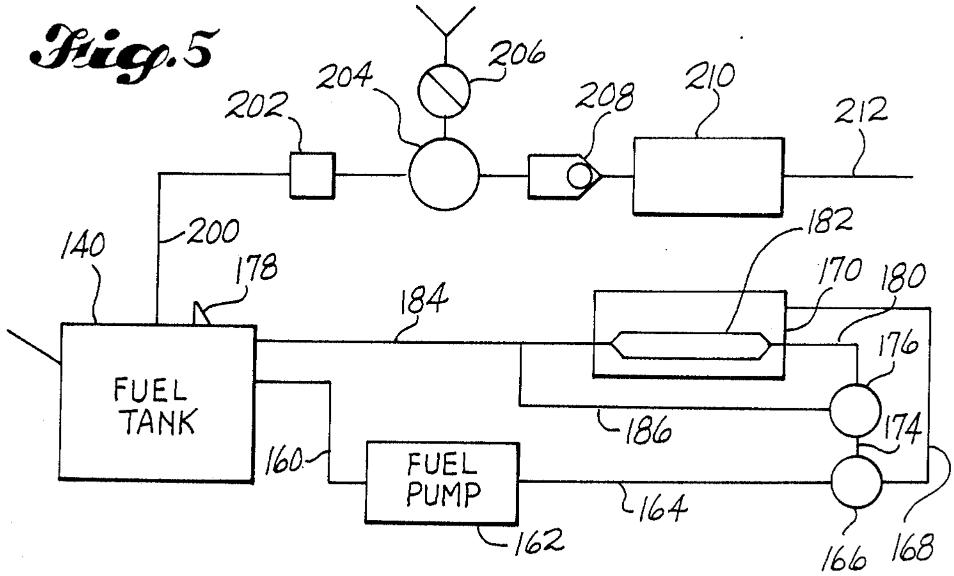


Fig. 6

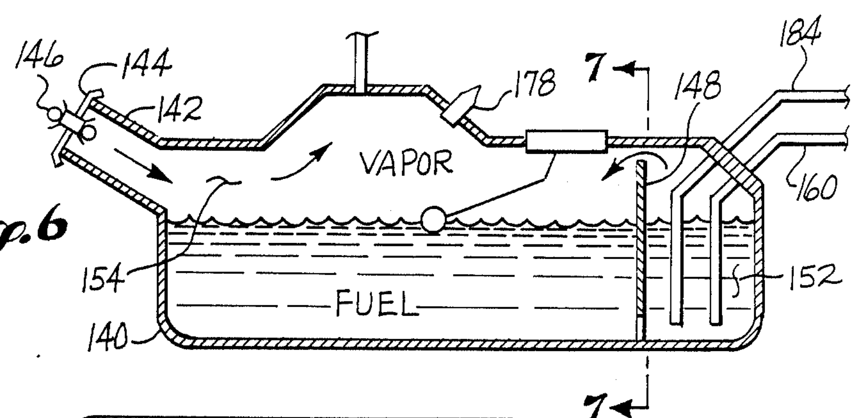
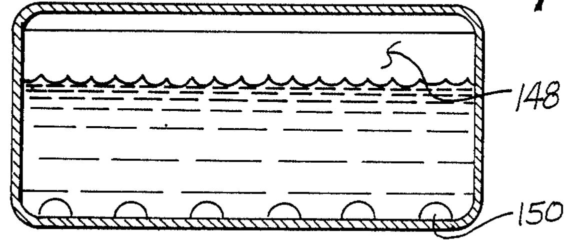


Fig. 7



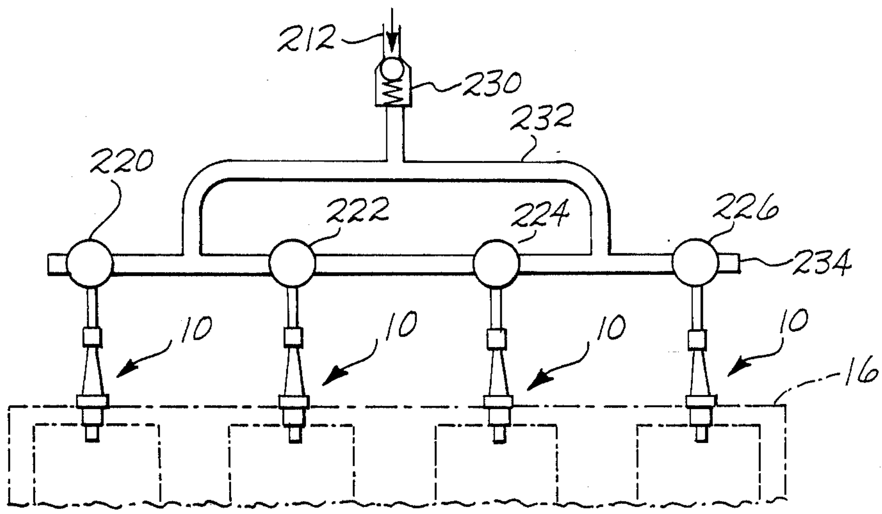


Fig. 8

COMBUSTION CONTROL SYSTEM FOR INTERNAL COMBUSTION ENGINES

BACKGROUND OF THE INVENTION

This invention generally relates to internal combustion engines and more particularly to a combustion control system for such engines.

In recent years, much effort in the automobile and petroleum industries has been directed toward controlling the manner in which ignition, flame propagation, and combustion take place within each cylinder. For example, the use of tetraethyl lead additives to suppress detonation, combustion chamber design changes, swirl charges, automatic ignition timing controls, and high-energy spark devices, have all contributed to the control of combustion.

One of the most important recent changes in fuel composition has been the removal of lead-based anti-knock compounds to eliminate lead oxide emissions from the exhaust. Effective non-polluting substitutes for the lead compounds have not been found so the octane ratings of presently available "unleaded" fuels have been significantly reduced.

Cylinder detonation or "knock" has been a most difficult problem to deal with. When a fuel/air mixture in an engine cylinder is ignited by a spark plug, there is approximately a five and one-half (5½) millisecond delay before a flame front is established. Thereafter the combustion wave front expands in a relatively uniform manner. Shortly, however, as heat and pressure increase and before the wave front reaches the opposite side of the cylinder wall, the unburned fuel ahead of the front suddenly explodes, creating sound waves that hammer against the cylinder and piston resulting in vibrations which are heard as "engine knock". The reason that the unburned fuel prematurely explodes is because it was raised to its ignition threshold by the elevated heat and pressure in advance of the combustion wave front. As engine load increases, the tendency of the fuel/air mixture to detonate also increases.

Detonation is a serious problem because it results in loss of engine power, a reduction in efficiency and an increase in engine operating temperature. If allowed to persist, it will ultimately damage or destroy the engine. The detonation problem was substantially solved in the 1930s by the discovery that the addition of certain lead compounds to gasoline materially reduced the tendency of certain radical molecules to prematurely explode. A radical molecule, such as hydroperoxide (HO2), is formed by the partial breakdown of larger molecules in the presence of air. Given enough time during flame propagation, these radicals congregate just ahead of the wave front and somewhere in the second half of the flame travel, become a direct cause of autoignition of the remaining unburned portion of the cylinder charge, resulting in detonation. The tetraethyl lead compounds previously contained in gasoline, would turn to lead oxide in the cylinder and act as a radical "trap". The combined effect of the removal of those lead compounds from modern fuels, and the use of higher air-to-fuel ratios has resurrected the problem.

One solution commonly employed in currently available engines, is to reduce the compression ratio. That solution is not satisfactory because it does not entirely solve the problem and reduces engine efficiency.

Another solution which has been suggested to produce more uniform and complete combustion of rarified fuel mixtures, involves the use of a so-called "stratified" charge in the combustion chamber. The cylinder of an engine designed to operate with a stratified charge normally includes a main cylinder in which the piston reciprocates and a smaller auxiliary chamber in communication with the upper portion of the main cylinder. In operation, a small quantity of relatively rich fuel mixture is placed in the auxiliary chamber near the time of ignition and is ignited by a spark plug located in the auxiliary chamber. The combustion wave front originates in the auxiliary chamber and spreads into the main chamber, causing a multipoint ignition of the leaner main fuel charge. While engines of this design have enjoyed limited success, they have not seen wide-spread commercial use because of their limited effectiveness.

A third solution has been the use of high-energy ignition (HEI) which is designed to "force" a high voltage current to cross the gap of the spark plug electrodes while the spark plug is operating in leaner fuel/air mixtures. Although successful to date, it does require the ignition system to operate within rather critical parameters.

Accordingly, it is an object of this invention to provide for a combustion control system which will significantly reduce the problem of detonation in engines operating with lower octane, lead-free fuels, and do it without any modification of engine designs.

Recent research has shown that octane, a gasoline fraction twice as large as butane, breaks in half to form additional butane during the combustion process. With an overabundance of butanes (with their fast flame speed) in the second half of the engine combustion cycle as a contributing factor in the cause of detonation, it becomes an object of this invention to "shift" most of the butanes contained in gasoline, using them to not only initiate combustion, but also to increase the flame propagation speed so that a normal flame front will reach the opposite side of the combustion chamber before detonation can "set up".

It is yet another object of this invention to provide for a combustion control system in which normally wasted engine heat is used to remove most of the butanes from the gasoline fuel supply just prior to its use in the engine.

Finally, it is a further object of this invention to provide for a combustion control system which includes a combined spark plug and precombustion chamber into which a butane/air mixture is injected and ignited in order to initiate and manage combustion wave propagation within the engine cylinder.

SUMMARY OF THE INVENTION

This invention can be most broadly summarized as a combustion control system for an internal combustion engine which includes a modified spark plug having a base and an insulator disposed within the base. The insulator has a precombustion chamber formed in it. The plug also includes a central electrode which passes through the base, extends into the precombustion chamber and defines a passageway in communication with the chamber for the transmission of a gaseous fuel/air mixture.

The system also includes a temperature control device for heating by-pass fuel to a predetermined temperature for the production of fuel vapors. It further includes means for transmitting the fuel vapors to the modified spark plug.

A BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a cross-section of the disclosed modified spark plug.

FIG. 2 is a more detailed view of the check valve and flame arrester section of FIG. 1.

FIG. 3 is a cross-section of the check valve taken at 3—3 of FIG. 2.

FIG. 4 is an isometric view of the lower end of the center electrode.

FIG. 5 is a schematic view of the disclosed air/butane vapor generating system.

FIG. 6 is a sectional view of the fuel tank of FIG. 5.

FIG. 7 is a sectional view showing the fuel tank baffle taken at 7—7 of FIG. 6.

FIG. 8 is a schematic view of the air/butane vapor manifold assembly.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The novel features to be characteristic of this invention are set forth in the appended claims. The invention itself, however, may be best understood and its various objects and advantages best appreciated by reference to the detailed description below in connection with the accompanying drawings.

In FIGS. 1 through 4 a modified spark plug constructed in accordance with the teachings of this invention is illustrated and generally designated by the numeral 10. The primary purpose of the disclosed modified plug is to permit engines to operate at higher air-to-fuel mixture ratios while substantially reducing the detonation problems found in current engines. When conventional spark plugs are used as an ignition source, certain chemical reactions must take place at the point of ignition before the combustion wave front is established. That delay permits the unburned fuel mixture ahead of the wave front to "set up" for detonation. When the disclosed modified plug is used, the combustion wave is established almost instantly in the main chamber, followed by an increase in flame propagation speed, substantially reducing the likelihood of detonation or "knock".

Referring to FIG. 1, it can be seen that the plug includes a base 12 which is generally cylindrical in shape and has a threaded lower portion 14 which cooperates with a threaded bore in cylinder head 16 to retain the plug in the cylinder head. A seal is achieved between the plug base and the cylinder head by annular gasket 18 which is compressed between shoulder 20 on the cylinder head and shoulder 22 on the plug base when the plug is in position. As with conventional plugs, upper portion 24 of the base, has a series of flats adapted to be engaged by a conventional socket for installation and removal of the plug.

The plug also includes upper and lower insulators 26 and 28, each of which is preferably made of sintered ceramic material having a high dielectric constant and which is able to withstand thermal shock. The two insulators are separated by seal 30 and are held in position in the base by bead 32 which is formed after the insulators are installed in the base during assembly.

Extending downward along the axis of each insulator is center electrode 40 which has two important functions. It conducts electrical current under high voltage from the ignition wire (not shown) and also transmits butane/air vapors into the precombustion chamber within the plug as described below. Vapors are supplied to the plug by a supply line (not shown in this view) which is attached to the top of connector 42 by a quick-release fitting (also not shown). In addition to providing a point of connection for the vapor supply line, the cap functions as a connection for the ignition lead (also not shown) to the center electrode. The cap is threaded onto the top of the center electrode as shown and is spaced from the upper surface of insulator 26 by gasket 44.

The injection system will provide controlled period injection of vapors into the plug and will provide longer periods of injection for starting and under load conditions that would tend to cause detonation. Longer injection periods during high engine load conditions will not only fill the precombustion chamber of the plug, but will place a butane/air mixture in front of the plug to assist in accelerating the combustion wave front across the combustion chamber of the cylinder.

When gasoline is used as fuel for the engine, normal butane and isobutane removed from the gasoline are injected into the plug. They are convenient to use because they are the only components of the gasoline that will remain in the gaseous state at normal temperatures and pressures after removal from the gasoline. Also, unlike most of the more complex molecules found in gasoline, they are resistant to thermal breakdown with associated deposits of carbon at the operating temperatures found in the precombustion chamber of the plug.

The timing and rate of flow of butane/air vapors into the plug are controlled electronically by means well known to those of ordinary skill in the art and described below in greater detail. The vapors enter the plug through the cap through passageway 46, forcing open ball check valve 48. After passing the valve they continue downward through central passageway 50 and enter checkvalve section 60 in the center electrode which is shown in greater detail in FIG. 2. Located within section 60 is valve assembly 62 which includes valve actuator 64, valve stem 66, ball valve 68 and valve spring 70 which biases the valve upward toward a closed position and against seat 72. Vapors entering the valve section from passageway 50 enter chamber 80 and force the actuator 64 downward, compressing spring 70 and opening valve 68. After passing around the sides of the actuator the vapors continue downward through chamber 82, passageways 84, around valve 68, through chambers 86 and into flame arrestor 90. Preferably the flame arrester is made of an appropriate porous ceramic material. Passageways 84 are shown in greater detail in sectional view in FIG. 3.

After leaving the flame arrester the vapors continue downward through passageway 88 which is centrally disposed in lower portion 100 of the center electrode. The lower portion is shown in greater detail in FIG. 4. In that view it can be seen that passageway 88 branches into four exit segments 102, 104, 106, and 108. It is important that these passageways be relatively small in diameter to minimize the possibility of a flashback from the combustion chamber. The lower end of the electrode is reduced in diameter to form electrode tip 110 which protrudes downward into precombustion chamber 120.

The precombustion chamber is semi-enclosed in design and is formed in the lower portion of lower insulator 28. It is bounded by wall 122 of the insulator and surfaces 124 and 126 formed in base 12. The angle "a" of surface 126 with respect to the central axis of the plug should not exceed twelve degrees in order that gasses exiting the precombustion chamber will continue to follow the surface and keep it free of carbon deposits. Ground electrode **130** protrudes upward and radially inward from surface **124** and is positioned to form a gap of a predetermined distance between surfaces **132** and **134**.

Because the lower insulator is extended downward to form the precombustion chamber, heat generated in the chamber is directed inward and away from the metal base of the plug. Another advantage of this design is that it prevents the spark from tracking along the relatively short horizontal distance from the center electrode to ground on the plug base.

When technology permits, it may be possible to make the entire lower portion of the plug of a sintered ceramic. In that case it would also be necessary to provide a means for grounding and supporting the center electrode such as an integrally mounted band or ring.

This new plug is designed to operate only with gaseous fuel/air mixtures. As stated, a butane mixture is preferred, but other fuels such as propane, methane and natural gas may be used. In extremely cold climates, natural gas would be ideal.

FIG. **5** is a schematic diagram of a modified fuel system which is preferred for use with an automobile engine equipped with the modified plug described above. The purpose of the system is to provide gasoline under pressure for use in the primary combustion chamber of the engine and a gaseous butane/air mixture under pressure to the modified plugs described above. Gasoline is stored in a specially designed fuel tank **140** which is illustrated in greater detail in the sectional views of FIGS. **6** and **7**. Referring to FIG. **6** it can be seen that fuel is added to the tank through filler neck **142** which is closed by pressure cap **144**. The cap contains valve **146** which will retain a small positive or negative pressure differential with the tank. Baffle **148** is transversely mounted in the forward portion of the tank. Openings **150** spaced along the bottom of the baffle permit the flow of fuel between tank compartments **152** and **154**. Because the baffle does not extend entirely to the top of the tank, vapors may flow across the top of the baffle between the compartments as shown.

Fuel is drawn from the tank through line **160** by the fuel pump **162** which transmits the fuel through line **164** to pressure regulator **166**. Line **168** transmits fuel at standard pressures to the fuel metering system of the engine. Line **174** transmits by-pass fuel at reduced pressure to two-way valve **176** which is controlled by vapor sensor **178** mounted near the top of fuel tank **140**. If the vapor sensor indicates that there is an inadequate amount of butane vapor in the tank, valve **176** is positioned to direct the by-pass fuel through line **180** into a special augered or spiraled section **182** of temperature control unit **170** where the fuel is heated to remove butanes. Butane vapors and the remaining liquid fuel are then returned to fuel tank **140** through line **184**. If sensor **178** indicates that sufficient vapors are present in the tank, it positions valve **176** so as to direct by-pass fuel around the temperature control unit through line **186** and into line **184** where it is returned to the fuel tank.

Temperature control unit **170** is a device described in U.S. Pat. No. 4,044,742 issued to the Applicant on Aug. 13, 1977, which utilized hot water from the engine cooling system and cold water which is made cold by passing engine hot water through a heat exchanger mounted in the engine intake air stream.

The upper portion of the gas tank will act as a condensing area for the separated gasoline fractions leaving the temperature control **170** since any fractions heavier than the butanes that do not remain in air suspension at normal ambient temperatures and pressures will return to the liquid state.

Butane vapors to be used in the plugs are drawn from the fuel tank through line **200** by pressure pump **204**. It is necessary that the butanes be mixed in proper proportion with air for use in the plugs so a butane/air ratio sensor **202** is positioned in line **200** just upstream of pump **204** to sense this ratio. If additional air is necessary, it can be drawn through check valve **206** which is controlled by sensor **202**. Vapors leaving the pump are passed through one-way check valve **208** and into storage tank **210**.

FIG. **8** schematically illustrates the manifold system by which butane/air vapors are distributed to the plug. Flow into each plug **10** is controlled by an associated solenoid valve **220, 222, 224, 226**, etc., which are each in turn controlled electronically by means well known to those of ordinary skill in the art. Upon the opening of one or more of the solenoid valves, butane/air vapors under pressure are passed from storage tank **210** through line **212** and check valve **230** and pass onward through distribution rails **232** and **234** to the solenoids.

The construction of the modified spark plug is such that if the butane/air system supplying the modified plug fails, the engine could continue to operate with the plugs functioning as standard spark plugs.

There are a number of additional benefits to be gained from the use of this combustion control system. Stratification of the engine cylinder will allow leaner fuel/air mixtures in the main cylinder especially during cruise conditions with associated fuel savings, along with lower exhaust emissions including nitrous oxide. The modified spark plug will provide for good ignition under all operating conditions because of the richer fuel/air mixtures in the precombustion chamber. Since the butanes are the most temperature-stable of all the gasoline fractions, they will not deposit carbon inside the plug precombustion chamber. For cold starting, automatic lengthening of the plug injection "on" time will be ideal. Because the butanes have an octane rating of approximately 92, a lengthened plug injection "on" time during heavy engine load conditions will raise the octane rating of the overall cylinder charge and thus help suppress detonation. With sufficient stored vapors, the engine can idle on plug injection alone.

A particular hurdle to overcome in this type of fuel system is carbon accumulation in any area that operates in excess of 1020 degrees Fahrenheit. The first gasoline fractions to "crack" or thermally break down and deposit carbon are the heaviest ones, starting with Xylene which begins to break down at about 1022 degrees Fahrenheit. At the other end of the spectrum the lightest gasoline fractions, namely the butanes, are the most temperature-stable and do not begin to break down until the temperature reaches approximately 1300 degrees Fahrenheit. Even then, that temperature would have to be sustained for a full minute in order to obtain seventy-five percent decomposition. Because the precombustion chamber of the instant plug operates at temperatures below 1300 degrees Fahrenheit, there should be no carbon deposits as long as a temperature-stable fuel such as butane is used.

To be the most effective, this combustion control system should be electronically coordinated with standard electronic fuel injection in the primary portion of the fuel system. In that way, there would be automatic enrichment injection at the plugs for cold starting and automatic leaning of the primary injection system during idle, cruise, and light engine load conditions.

Considering the amount of butanes contained in "summer" blended gasolines, and the preferred volume of the instant plug precombustion chamber, it is estimated by the inventor that only about 1/7th of that amount would be needed for the plugs to provide engine stratification, leaving the remainder available for starting, combustion wave and detonation control, and idle mixtures.

Thus it could be seen that the present invention provides for a combustion control system which incorporates many novel features and offers significant advantages over the prior art. Although only one embodiment of this invention has been illustrated and described, it is to be understood that obvious modifications can be made of it without departing from the true scope and spirit of the invention.

I claim:

1. modified spark plug for internal combustion engines comprising:

- a base made of an electrically conductive material and adapted to be installed in the engine;
- an insulator disposed within the base and having a precombustion chamber formed therein;
- a central electrode passing through the insulator, extending into the precombustion chamber and defining a passageway in communication with the precombustion chamber for the transmission of a gaseous fuel/air mixture; and,
- a spring operated check valve assembly for controlling the flow of said fuel/air mixture through said passageway, said assembly being disposed within said insulator and spaced from said precombustion chamber.

2. The modified spark plug of claim **1** wherein said check valve assembly further includes an actuator, a valve, a valve stem interconnecting the actuator and the stem; and means for biasing the valve toward a closed position.

3. The modified spark plug of claim **1** wherein said base includes a lower portion defining a nozzle for gasses leaving the precombustion chamber.

4. The modified spark plug of claim **1** wherein said base includes a lower portion defining a nozzle for flame leaving the precombustion chamber.

5. A fuel system for providing a gaseous butane/air mixture and liquid gasoline for an internal combustion engine comprising:

- a tank for storing gasoline;
- temperature control means in communication with the tank for heating gasoline to a predetermined temperature to produce butane vapor and for delivering the vapor to the tank;
- means for controllably mixing air with the butane vapor; and,
- means in communication with said tank for transmitting the butane/air mixture and gasoline to the engine.

6. The fuel system of claim **5** further including means for storing butane vapor, means associated with said butane vapor storing means for sensing the quantity of butane stored therein, and means responsive to said quantity sensing means for controlling the production of butane vapor by said temperature control means.

7. The fuel system of claim **5** wherein said mixing means includes means for sensing the ratio of butane vapor to air at a preselected location in the system and means responsive thereto for mixing air with the butane vapor.

8. The fuel system of claim **5** further including means associated with said means for transmitting for increasing the pressure of the butane vapor and electronic means for controllably injecting the vapor into the engine.

9. A combustion control system for an internal combustion engine comprising:

- a modified spark plug including a base made of an electrically conductive material, an insulator disposed within the base and having a precombustion chamber formed therein and a central electrode passing through the insulator, extending into the precombustion chamber and defining a passageway in communication with the precombustion chamber for the transmission of a gaseous fuel/air mixture;
- a tank for storing fuel;
- temperature control means in communication with the tank for controllably producing fuel vapor;
- means for storing fuel vapor, means associated therewith for sensing the quantity of stored vapor and means responsive to said quantity sensing means for controlling the production of fuel vapor by the temperature control means; and,
- means in communication with the tank for transmitting fuel to the engine and fuel vapor to the modified spark plug.

10. The combination control system of claim **9** wherein the modified spark plug further includes a spring operated check valve assembly for controlling the flow of said fuel/air mixture through said passageway, said assembly being disposed within said insulator, spaced from said precombustion chamber and including a flame arrester.

11. The combustion control system of claim **9** wherein said check valve assembly further includes means for biasing the valve toward a closed position.

12. The combustion control system of claim **9** further including means in communication with said vapor storing means for sensing the ratio of fuel vapor to air at a preselected location in the system and means responsive thereto for mixing air with the fuel vapor.

13. The combustion control system of claim **9** further including means associated with the means for transmitting for increasing the pressure of the fuel vapor and electronic means for controllably injecting the vapor into the modified spark plug.

14. A combustion control system for an internal combustion engine comprising:

- a modified spark plug including a base made of an electrically conductive material, an insulator disposed within the base and having a precombustion chamber formed therein and a central electrode passing through the insulator, extending into the precombustion chamber and defining a passageway in communication with the precombustion chamber for the transmission of a gaseous fuel/air mixture;
- a tank for storing liquid gasoline;
- temperature control means in communication with the tank for heating gasoline to a predetermined temperature to produce butane vapor and for delivering the vapor to the tank;

means for storing the butane vapor, means associated therewith for sensing the quantity of stored vapor and means responsive to said quantity sensing means for controlling the production of butane vapor by the temperature control means;

means in communication with said vapor storing means for sensing the ratio of butane vapor to air at a preselected location in the system and means responsive thereto for mixing air with the vapor;

means in communication with the tank for transmitting fuel to the engine and butane vapor to the modified spark plug; and,

means associated with the means for transmitting for increasing the pressure of the butane vapor and electronic means for controllably injecting the vapor into the modified spark plug.

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Procédé de travail et dispositif pour faire fonctionner des moteurs à combustion interne.

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La présente invention a pour objet un nouveau procédé de travail pour moteurs à combustion interne et un dispositif pour la mise en œuvre de ce procédé. Le procédé consiste en ce qu'on provoque une pulvérisation interne instantanée du combustible, avec formation d'un mélange de combustible et d'air, et l'allumage de ce mélange par l'effet des étincelles de décharges instantanées d'un courant électrique de haute tension sur un combustible liquide.

L'importance du nouveau procédé pour le fonctionnement de moteurs à combustion interne réside dans l'exclusion totale de toute la catégorie des combustibles, en majeure partie des hydrocarbures, dont le pouvoir antidétonant a été augmenté par addition de produits chimiques tels que l'éthyle de plomb, les dérivés du brome, etc., ou par hydrogénation.

D'autre part, le nouveau procédé entraîne une modification considérable du principe de fonctionnement des moteurs à deux temps. Ce procédé permet l'emploi de pressions d'alimentation quelconques et empêche parfaitement toute perte de combustible par l'orifice d'échappement de moteurs à deux temps à carburateur, de sorte qu'un moteur à deux temps suivant l'invention constitue un moteur thermique de la plus haute perfection.

Le procédé de fonctionnement suivant l'invention rend le fonctionnement d'un moteur — même s'il travaille avec une pression d'alimentation extrêmement élevée, qu'il soit à deux ou à quatre temps — totalement indépendant du pouvoir antidétonant du combustible utilisé. Pour ce moteur, on ne sert que de combustibles à faible degré octane, dont le prix de revient est bien inférieur à celui des combustibles à pouvoir antidétonant élevé, augmenté artificiellement.

La formation du mélange inflammable de combustible et d'air est possible à toutes les pressions d'alimentation, aussi bien dans les moteurs à deux que dans ceux à quatre temps, c'est-à-dire même aux degrés de compression, dont les températures finales se trouvent situées au-dessus du point d'inflammation du combustible utilisé, sans qu'il se produise des détonations. Grâce à l'augmentation de la pression d'alimentation, un moteur fonctionnant d'après le procédé suivant l'invention travaille avec un rendement maximum.

Du reste, le nouveau procédé offre, par rapport au procédé à injection, l'avantage considérable d'une vitesse de rotation bien

Prix du fascicule : 15 francs.

plus élevée des moteurs auxquels il est appliqué.

L'allumage du mélange combustible étant effectué par des étincelles électriques, il est dans beaucoup de cas souhaitable, même aux dépens de l'économie, de maintenir la compression inférieure à celle des moteurs à injection, le moteur tournant alors avec une plus grande douceur et avec moins de bruit. Dans les moteurs de véhicules automobiles, par exemple, on choisira la pression d'alimentation de façon à éviter précisément la marche désagréablement dure et bruyante des moteurs à injection. Cependant, la pression d'alimentation est bien plus élevée que dans les moteurs Otto, même lorsque ces derniers sont alimentés avec des combustibles antidétonants; en conséquence, le rendement d'un moteur fonctionnant d'après le nouveau procédé est bien supérieur au rendement d'un moteur Otto.

Avec le nouveau procédé, on peut utiliser sans artifice non seulement des combustibles à point d'ébullition bas, mais également ceux à point d'ébullition élevé, et même ceux dont la nature se rapproche de celle des huiles de graissage, la force disruptive d'une décharge instantanée dans un intervalle d'éclatement, placé par exemple dans un bain d'huile de transformateur, étant suffisamment puissante pour pulvériser et enflammer même des combustibles à point d'ébullition élevé et de viscosité relativement élevée.

Pendant le processus d'admission, le combustible est amené sans interruption, avec une pression de quelques atmosphères seulement, dans la chambre de pulvérisation du moteur. Pendant le passage du courant, il s'y produit une pulvérisation et un allumage instantanés du combustible; dans certains cas, on peut compléter cet allumage par un intervalle d'éclatement complémentaire.

La pulvérisation instantanée du combustible dans un moteur à combustion interne reproduit les phénomènes, ou des phénomènes analogues à ceux qui conduisent à l'explosion des commutateurs à bain d'huile.

Un appareillage permettant de constater ces phénomènes a été constitué par l'inventeur de la façon suivante :

Dans un tube en papier dur placé verticalement et fermé en bas, ayant un diamètre intérieur de 25 mm. et un diamètre extérieur de 40, on constitue une colonne d'huile de transformateur d'une longueur de 100 mm. environ, dans la partie inférieure de laquelle on ménage un intervalle d'éclatement. L'une des électrodes est mise à la terre, tandis que l'autre est connectée à un transformateur d'usine électrique par l'intermédiaire d'une capacité.

La décharge instantanée d'une capacité électrique d'environ 1 MF, à une tension de 150 KV, produit instantanément dans l'huile, principalement par la pression et la chaleur de l'étincelle, une bulle ou un piston de gaz qui, grâce à sa haute pression, pulvérise l'huile avec une forte détonation et la réduit en un brouillard de la plus grande finesse en la projetant à une hauteur d'environ 20 mètres, en déchirant le tube en papier dur et en allumant l'huile finement pulvérisée.

Lorsqu'il s'agit d'employer la pulvérisation du combustible par exemple dans un moteur à deux temps de véhicule automobile d'une puissance de 100 CV, il faut tenir compte du fait qu'un moteur à deux temps de 100 CV à quatre cylindres, tournant à 300 tours par minute et consommant 200 g. de combustible par CV/heure, consomme à chaque cycle de travail environ 28 mg. ou 35 mm^3 de combustible dans chaque cylindre, et que cette quantité de combustible doit être pulvérisée par une impulsion de courant dans un intervalle de temps d'environ 1/500 de seconde ou moins.

Pour pulvériser environ 30 mg. de combustible 200 fois par seconde, chaque fois en 1/500 à 1/1000 de seconde, il faut pour chaque pulvérisation une quantité d'énergie d'environ 0,3 watt/seconde, c'est-à-dire une puissance continue de $200 \times 0,3 = 60$ watts. Quoiqu'il soit nécessaire, par suite d'un mauvais coefficient de rendement, d'envisager des quantités de courant plus élevées, les appareils électriques nécessaires à la production des impulsions de courant ne prennent en aucun cas des dimensions encombrantes, même pour les moteurs de puissance relativement élevée.

Le courant est pris sur une batterie ou produit par voie électromagnétique. Dans un allumage par batterie, les impulsions de courant, produites par un trembleur dans le circuit primaire, sont transformées par induction avec une tension élevée dans le circuit secondaire, et appliquées aux intervalles d'éclatement par addition de capacités secondaires.

La pulvérisation et l'allumage d'un combustible liquide par une décharge instantanée sont également possibles à l'aide d'un condensateur de grande capacité, chargé par l'intermédiaire d'un redresseur et connecté en parallèle avec l'intervalle d'éclatement.

Pour la pulvérisation du combustible, on se sert d'un dispositif ayant la constitution d'une bougie d'allumage et que l'on appellera « bougie de pulvérisation ».

Lorsqu'il s'agit, à l'aide de bougies de pulvérisation, de produire à l'intérieur d'un moteur à combustion interne une charge inflammable, on remplit d'abord de combustible la chambre de pulvérisation, on pulvérise le combustible à l'aide d'une ou de plusieurs impulsions ou de décharges instantanées et on allume le mélange de charge après formation de celui-ci.

Dans les moteurs Diesel, l'allumage du combustible finement pulvérisé se produit automatiquement sous l'action de la température de compression élevée. Dans les moteurs, où la température de compression est inférieure à la température d'inflammation du combustible utilisé, le combustible peut être allumé, après sa pulvérisation, à l'aide d'une bougie d'allumage ou d'une série de bougies d'allumage, le plus souvent indépendantes de l'intervalle d'éclatement et de pulvérisation.

Le dessin montre des exemples d'exécution :

La fig. 1 est une coupe et

La fig. 2 une élévation d'un premier mode d'exécution d'une bougie de pulvérisation;

Les fig. 3 à 5 sont des coupes longitudinales à travers quatre variantes de bougies de pulvérisation.

La bougie de pulvérisation suivant les fig. 1 et 2 comporte à son extrémité supérieure une tubulure 1 destinée à l'introduction du combustible amené par pompage, ainsi qu'une cosse de connexion 2 pour l'arrivée du courant électrique. Au-dessous de la tubulure 1 est prévu un clapet de retenue du combustible 3, suivi du tube 4. L'extrémité inférieure de ce tube 4, effilée en forme de cône et se terminant par une pointe hémisphérique, pénètre à l'intérieur de la chambre 5 de pulvérisation du combustible. Dans cette extrémité sont ménagées des fentes 6, à travers lesquelles le combustible peut s'écouler dans la chambre 5. L'espace 5 formé entre l'extrémité du tube 4 et la paroi interne d'un corps annulaire 12, a une largeur en tous points égale. Les dimensions de cet espace sont choisies de façon que le combustible soit retenu par l'effet de la capillarité à l'encontre de l'effet de la pesanteur, même lorsque la bougie occupe une position inclinée. Pendant le remplissage, le combustible y est maintenu sans être projeté.

La tubulure 1, le clapet de retenue 3 et le chapeau 7, prolongé par une jupe filetée, sont isolés électriquement par un isolateur 8, à travers lequel passe le tube central 4.

Le corps annulaire 12 est fait d'une matière à haute résistance mécanique, résistant également à de fortes variations de température. La chambre de pulvérisation du combustible 5 est fermée en bas à l'aide d'un capuchon métallique 13, dont le fond constitue la contre-électrode d'un intervalle d'éclatement 10. Ce capuchon métallique 13 est évasé en forme de cône vers le haut et perforé de grands trous 14. Son bord supérieur est replié vers l'intérieur et s'engage et s'accroche dans une gorge périphérique de l'isolateur 8.

Un intervalle d'éclatement 15 est ménagé dans la partie inférieure du bouchon de fixation 11; cet intervalle est formé par les électrodes 16, tandis que les contre-électrodes sont constituées par les bords des trous 14 ménagés dans le capuchon métallique 13.

Lors des décharges électriques le combustible est d'abord traversé, fortement échauffé, dissocié et ionisé par le courant dans le voisinage de l'intervalle 10, sous l'action de la pression de l'étincelle, avec production d'ondes de pression violentes. Sous l'action des masses de gaz et de vapeur de forte tension, produites par la température élevée et d'autres forces disruptives, telles que les oscillations, le combustible est pulvérisé et fortement ionisé ce qui est de la plus grande importance pour son allumage rapide et sa combustion totale. Le combustible ainsi pulvérisé est ensuite expulsé vers le haut, hors de la chambre annulaire 5 étroite, comme sous l'effet d'une explosion. Par suite du choc contre la face inférieure de l'isolateur 8 en matière très résistante, le combustible est davantage pulvérisé et divisé de façon à former un brouillard de la plus grande finesse. La pulvérisation explosive du combustible est tellement violente que tous les résidus sont expulsés de la chambre de pulvérisation et que celle-ci reste par conséquent toujours propre.

Le combustible pulvérisé et fortement ionisé pénètre par les trous 14 du capuchon 13 dans la chambre de combustion du moteur, où il se mélange avec l'air déjà présent pour former un mélange facilement inflammable et qui s'allume dans le premier, mais sûrement dans le deuxième intervalle d'éclatement 15.

La vitesse, avec laquelle une particule de combustible du mélange ainsi obtenu est projetée du centre jusqu'à la paroi du cylindre moteur d'un diamètre d'environ 10 cm., n'atteint que 25 m./sec. pendant une période de pulvérisation de 1/500 de sec.

Pour les moteurs de grandes dimensions, tournant lentement et ayant des cylindres placés verticalement, la chambre de pulvérisation 5, pour avoir une grande contenance, pourrait recevoir de grandes dimensions aux dépens de la retenue capillaire du combustible, afin que le combustible puisse être projeté hors de la chambre de pulvérisation sous l'action de fortes impulsions de courant.

La fig. 3 montre une autre variante de la bougie de pulvérisation. Dans la partie inférieure du tube central 4, qui forme tube capillaire, le plus souvent avec un diamètre intérieur de 3,5 mm., se trouve l'intervalle d'éclatement et de pulvérisation 10. Cet intervalle est formé par le fait que la partie inférieure, épanouie, du tube central 4 est séparée par un isolateur annulaire 17 d'une tubulure 18 ajoutée au bas de cet isolateur. Cette tubulure, solidement reliée à l'isolateur 8, porte à son extrémité inférieure une rondelle circulaire de fermeture 19 à laquelle est fixé par des nervures un déflecteur 20 qui constitue la fermeture inférieure de la bougie de pulvérisation.

Au lieu de ne prévoir qu'un seul intervalle d'éclatement et de pulvérisation 10 on peut également, comme le montre la fig. 4, ménager toute une rangée d'intervalles d'éclatement 21 disposés en série ce qui n'empêche pas l'utilisation de deux intervalles d'éclatement seulement.

Dans le voisinage de la rondelle de fermeture 19 sont placées les électrodes 16 qui forment avec cette rondelle l'intervalle d'éclatement 15 pour l'étincelle d'allumage.

La bougie de pulvérisation d'après les fig. 3 et 4 fonctionne de la manière suivante :

A l'aide d'une pompe, le tube 4 est rempli de combustible jusqu'au niveau des intervalles d'éclatement et de pulvérisation 10 et 21; l'égouttement de ce combustible hors du tube 4 est empêché par la capillarité.

Sous l'action de l'étincelle traversant le combustible, le combustible se trouvant dans et au-dessous de l'intervalle d'éclatement est pulvérisé et comme le clapet de retenue 3 est fermé, ce combustible est projeté hors du tube 4 sur le déflecteur 20 et pulvérisé de façon à former un brouillard d'une extrême finesse; il est ensuite mélangé avec de l'air et allumé dans l'intervalle d'éclatement de l'étincelle d'allumage 15.

Le déflecteur n'est pas seulement destiné à parfaire la pulvérisation du combustible. Grâce à sa forme, les particules ricochantes du combustible sont correctement réparties à l'intérieur de la chambre de combustion ce qui conduit à une combustion intégrale et rapide de la charge. Cependant on peut également supprimer le déflecteur et, dans ce cas, son office est rempli par le fond du piston.

La bougie de pulvérisation que montre la fig. 5 comporte un intervalle d'éclatement et de pulvérisation 10 concentrique au tube 4 et à travers lequel le courant passe sur l'électrode 22 du déflecteur 20. Ce déflecteur est fixé dans la partie inférieure de l'isolateur 8 par des nervures 21 évasées en haut en forme de couronne. Le combustible est retenu par capillarité dans les cavités formées entre les nervures; il est finement pulvérisé sur le déflecteur et allumé dans l'intervalle d'éclatement de l'étincelle d'allumage 15.

La chambre de pulvérisation peut également recevoir une autre conformation; par exemple, le combustible peut être retenu par capillarité dans une fente étroite entre deux plaquettes parallèles et y être pulvérisé par l'effet de décharges électriques.

Pour amener le combustible dans la chambre de pulvérisation en quantités exactement dosées, on se sert d'une pompe, par exemple d'une pompe à engrenages actionnée par le moteur et qui refoule le combustible en quantité réglable et sous pression de quelques atmosphères. A travers un système de tuyauteries, dans lesquelles règne une pression statique, le combustible atteint toutes les bougies de pulvérisation en quantités égales à travers des tuyères parfaitement identiques.

Après l'échappement, pendant la période de charge suivante du moteur, la pression du combustible à l'intérieur de la tuyauterie d'arrivée est au début très supérieure à la pression de balayage à l'intérieur des cylindres ce qui occasionne le refoulement du combustible dans la chambre de pulvérisation 5; suivant le dosage contrôlé par un régulateur, celle-ci est alors plus ou moins remplie. Si, pendant la période de compression, la pression monte dans le cylindre moteur pour devenir supérieure à la pression de pompage, l'arrivée du combustible s'arrête et, si la pression de compression continue à monter, le clapet de retenue 3 se ferme. Vers la fin de la course de compression se produit alors le passage du courant dans les intervalles d'éclatement 10 et 21, avec pulvérisation du combustible et allumage ultérieur du mélange dans les intervalles d'éclatement 15.

A la fin de la course de travail, après échappement des gaz de combustion, un nouveau cycle recommence avec l'entrée de l'air dans le cylindre moteur et du combustible dans la chambre de pulvérisation.

Le processus de travail peut également être constitué de façon que la pulvérisation du combustible soit produite dès le début de la course de remplissage par une ou plusieurs décharges sans allumage. Le combustible pulvérisé peut alors se mélanger avec l'air comburant pour former une charge inflammable. L'allumage ne se produit que vers la fin de la course. On dispose alors pour la formation du mélange inflammable d'un laps de temps plus long; par contre, pour les pressions de charge élevées, il est nécessaire d'employer un combustible antidétonant.

Afin de produire des éclatements capables d'effectuer la pulvérisation de chaque dose de combustible dans le laps de temps prescrit, il est nécessaire d'employer des impulsions de courant puissantes, ayant généralement une énergie de quelques dixièmes de watt/sec. On l'obtient en donnant à la capacité du bobinage secondaire, soit par une capacité propre, soit par une capacité extérieure suffisantes, une capacité suffisamment élevée, en montant un condensateur en parallèle avec l'intervalle d'éclatement.

En général on peut dire ceci : Une impulsion d'une bobine d'allumage ordinaire produit une étincelle électrique composée d'une décharge capacitaire d'une durée d'environ 1/100.000 de seconde et d'une décharge inductive consécutive de 1/1000 de seconde et plus. Par suite de l'utilisation d'une capacité l'énergie de la décharge capacitaire est augmentée aux dépens de la décharge inductive, et la décharge, sous l'action d'une impulsion de courant, se transforme en une décharge instantanée.

Une décharge par étincelle, sous l'action d'une impulsion de courant, ne se produit donc que sous l'action de la capacité propre du système, tandis qu'une décharge instantanée ne se produit que sous l'action de la capacité propre plus une capacité extérieure, le plus souvent un condensateur.

Les essais avec une bougie de pulvérisation suivant les fig. 3 et 4 ont été effectués avec des quantités de courant de quelques dixièmes de watt/seconde avec des capacités différetes de 0,006 à 1,0 MF et des tensions de 5-30.000 volts. Les résultats ont montré que le passage de la décharge, sous l'action d'une impulsion de courant, à la décharge instantanée proprement dite, produit déjà une pulvérisation du combustible. La vitesse de la pulvérisation et son intensité augmentent avec l'augmentation de l'énergie électrique employée et on obtient en même temps une augmentation de la longueur des intervalles d'éclatement.

Les essais avec une décharge isolée, et non pas avec un train d'éclatements, dans un intervalle d'éclatement d'un tube de pulvérisation d'un diamètre intérieur d'environ 3,0 mm., d'après la fig. 3, ont donné les résultats suivants :

Avec une décharge instantanée isolée d'un courant de 10-30.000 volts, d'une capacité de 0,1-1 0 MF et d'une puissance d'environ 0,3 watt/sec., on a pulvérisé dans un intervalle d'éclatement environ 30 mg. d'essence, de pétrole, d'huile à moteur Diesel, d'huile de goudron de lignite et même d'une huile de graissage, et on a obtenu un nuage de la plus grande finesse ayant une hauteur de 70-80 cm. et un diamètre d'environ 30 cm., et ce, en un laps de temps de 1/100 ou même de 1/1000 de seconde. Malgré la décharge unique et la présence d'une seule bougie d'allumage, le combustible a été chaque fois enflammé.

Lorsque l'on applique des impulsions de courant d'une intensité, tension et capacité suffisantes, on n'emploie que des bougies d'allumage n'ayant qu'un seul intervalle d'éclatement et dans lesquelles on produit la pulvérisation et même l'allumage de ce combustible.

Dans le cas d'une tension et d'une intensité suffisamment élevées, et si la longueur de l'intervalle d'éclatement est suffisamment grande, la capacité propre de la bobine d'induction suffit à elle seule pour pulvériser et allumer le combustible dans un seul intervalle d'éclatement; cependant, l'effet de la pulvérisation et de l'allumage est augmenté par l'addition d'une capacité extérieure, sous forme d'un condensateur.

RÉSUMÉ :

1° Ce procédé de travail pour faire fonctionne des moteurs à combustion interne consiste à provoquer une pulvérisation instantanée du combustible, avec formation d'un mélange inflammable, et son allumage, par l'action sur le combustible liquide, d'étincelles provenant de la décharge d'impulsions de courant et de décharges instantanées d'un courant éleectrique de haute tension;

2° L'application de ce procédé, pour faire fonctionner des moteurs à combustion interne, exclut l'utilisation de combustibles à pouvoir antidétonant élevé produits intentionnellement, et dans les moteurs travaillant d'après ce procédé, ces combustibles sont remplacés par des combustibles ordinaires, c'est-à-dire des combustibles dont le pouvoir antidétonant n'a pas été augmenté artificiellement, même dans le cas d'une compression de charge maxima;

3° Les moteurs à deux temps travaillant d'après ce procédé deviennent des moteurs à deux temps nouveaux, avec formation sans perte du mélange de charge et utilisation d'une compression quelconque;

4° Le combustible est pulvérisé et enflammé par une décharge unique d'un courant électrique de haute tension, sous forme d'une étincelle, dans un ou plusieurs intervalles d'éclatement;

5° On produit et accumule une capacité de courant de haute tension telle que l'énergie d'impulsion ou de décharge instantanée soit suffisante pour pulvériser le combustible nécessaire à un cycle dans un ou plusieurs intervalles d'éclatement en série et pour allumer le mélange combustible ainsi formé;

6° On produit un train rapide de grandes capacités d'un courant électrique de haute tension et on pulvérise et allume le combustible en une suite rapide d'impulsions et de décharges instantanées séparées, pendant un cycle de travail et dans un ou plusieurs intervalles d'éclatement;

7° Lorsqu'on emploie un ou plusieurs intervalles d'éclatement en série, on n'en recouvre qu'une partie de combustible, tandis que l'autre partie reste dégagée du combustible et se trouve dans la zone d'action de l'air de combustion;

8° L'étincelle ne sert qu'à pulvériser le combustible, tandis que son inflammation est produite par d'autres moyens, par exemple à l'aide d'une charge d'air de combustion, chauffée au-dessus de la température d'inflammation, par des bougies d'allumage prévues en dehors de l'intervalle d'éclatement;

9° L'impulsion de courant et la décharge instantanée d'un courant électrique de haute tension sont produites dans deux ou plu-

sieurs intervalles d'éclatement montés en série, le ou les premiers intervalles d'éclatement servant à la pulvérisation du combustible et le deuxième ou dernier intervalle d'éclatement étant destiné à l'allumage du mélange combustible;

10° On produit successivement deux ou plusieurs impulsions de courant ou décharges instantanées dans des laps de temps tels que la dernière décharge ne se produise que lorsque le combustible est déjà pulvérisé et mélangé avec de l'air sous l'action de la première et, éventuellement, les décharges suivantes et la dernière décharge allume le mélange combustible ainsi formé;

11° Les laps de temps entre les différentes décharges sont réglés de façon que le combustible soit pulvérisé au début de la course d'aspiration du moteur et qu'il ne soit allumé qu'à la fin de cette course;

12° Le combustible est refoulé à travers la tuyauterie d'alimentation par une pompe à débit réglable de façon que le combustible soit amené dans la chambre de pulvérisation au début de la période de charge et que son retour soit empêché pendant la course de compression et de travail;

13° On emploie des hydrocarbures à point d'ébullition élevé et d'autres combustibles liquides difficiles à évaporer et ayant un faible pouvoir antidétonant;

14° Le dispositif pour la mise en œuvre de ce procédé consiste en une bobine de secondaire à haute tension produisant les décharges instantanées dans les laps de temps désirés avec une tension et une capacité suffisantes, grâce au fait que la bobine a une capacité propre telle (qui est complétée par un condensateur additionnel si elle est insuffisante) que la capacité totale soit suffisante pour que le courant induit dans la bobine secondaire soit accumulé en une quantité telle qu'il soit évacué sous forme d'impulsion ou de décharge instantanée d'une intensité suffisamment grande pour pulvériser le combustible nécessaire à chaque cycle de travail et pour allumer le mélange combustible ainsi produit;

15° Pour produire une grande capacité électrique pour charger le condensateur, on prévoit un redresseur;

16° Pour amener le combustible et le courant électrique dans la chambre de combustion du cylindre moteur, pour le pulvériser et pour l'allumer, on prévoit une bougie de pulvérisation;

17° La bougie de pulvérisation et d'allumage comporte un tube axial logé dans un isolateur électrique et destiné à l'admission du combustible et à l'introduction du courant électrique et ce tube contient un clapet de retenue et, à son extrémité inférieure, une chambre de pulvérisation avec un intervalle d'éclatement prévu dans cette chambre;

18° Cette bougie de pulvérisation et d'almage comporte deux ou plusieurs intervalles d'éclatement disposés en série;

19° La chambre de pulvérisation, conformée par exemple en tube d'admission pour le combustible, est assez étroite pour que le combustible y soit retenu par l'effet de la capillarité;

20° La chambre de pulvérisation est ouverte en direction de l'intérieur du cylindre de façon que le combustible, sous l'action de la décharge instantanée, soit expulsé de la chambre de pulvérisation sous une forme finement pulvérisée;

21° Le tube central est interrompu par une ou plusieurs couches isolantes, constituant un ou plusieurs intervalles d'éclatement;

22° Les électrodes de l'intervalle d'éclatement se trouvent disposées dans l'axe longitudinal du tube d'amenée du combustible et sont maintenues par des nervures longitudinales, le combustible étant retenu par capillarité entre ces nervures;

23° A l'extrémité inférieure de la bougie de pulvérisation et d'allumage est disposé un déflecteur contre lequel est projeté le combustible expulsé de la chambre de pulvérisation et sur lequel ce combustible subit une deuxième pulvérisation, ce déflecteur produisant, par ricochet du combustible pulvérisé, une répartition correcte dans la chambre de combustion et une combustion complète;

24° Ce déflecteur constitue l'une des électrodes du deuxième intervalle d'éclatement.

Hubert JEZLER.

Par procuration :

Blétry.

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Fig. 1

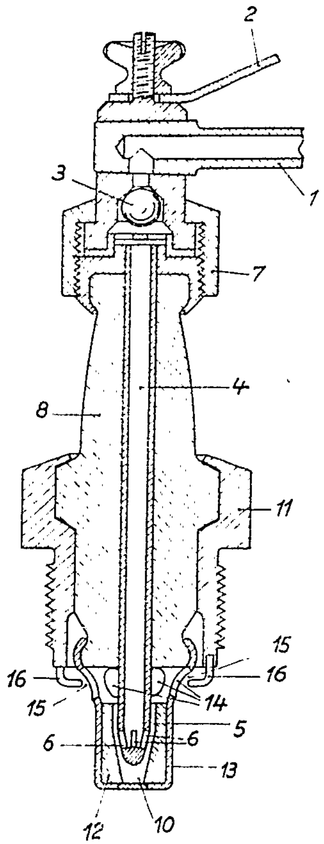


Fig. 2

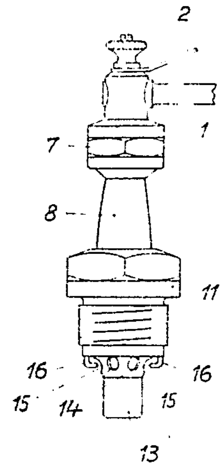


Fig. 3

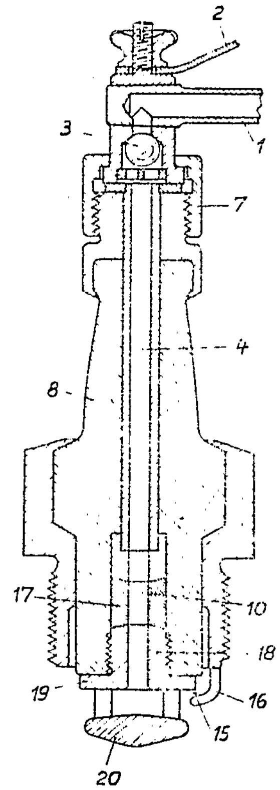


Fig. 5

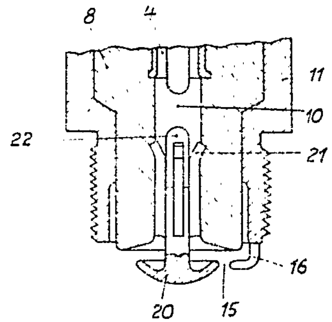
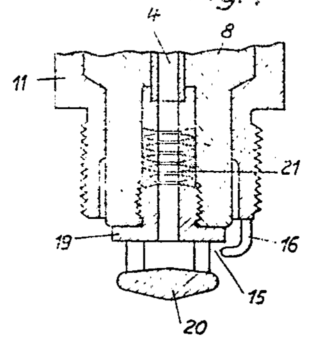


Fig. 4



N° 900.408

Fig.1

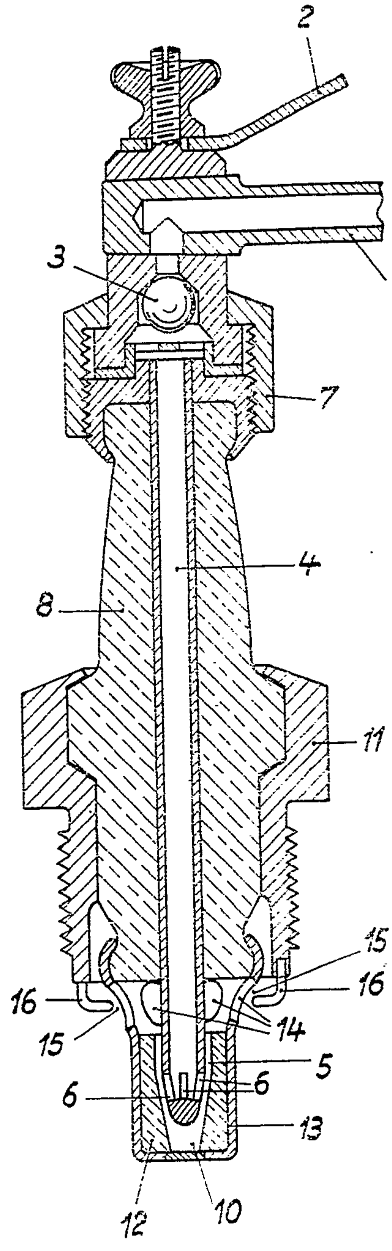
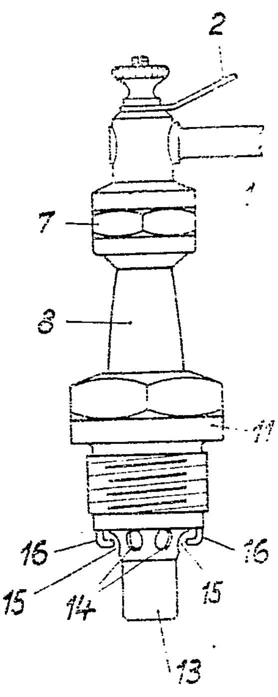


Fig.2



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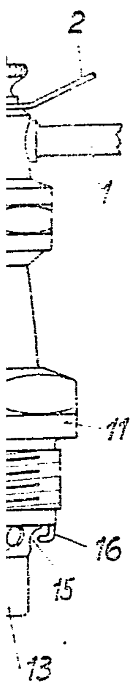


Fig.3

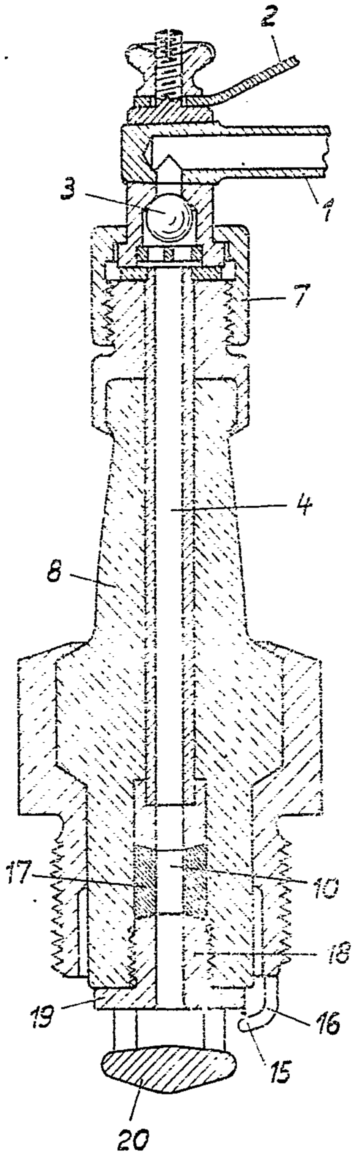


Fig.5

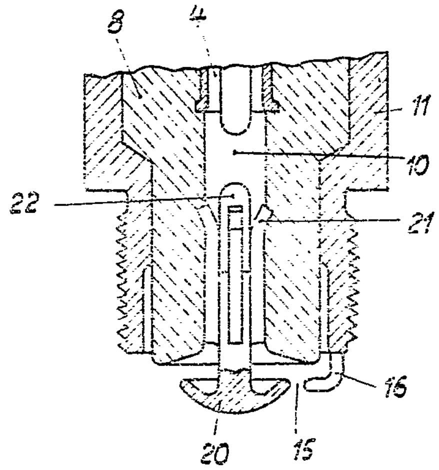
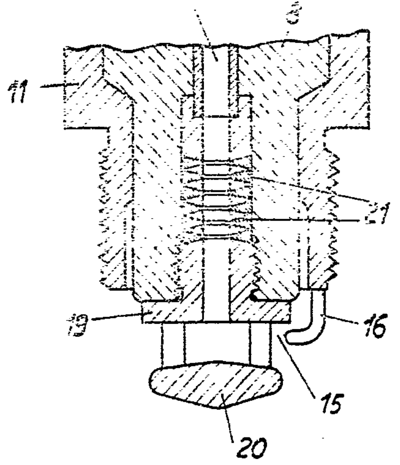


Fig.4



Notice

DESCRIPTION FR900408A

10 Working method and device for operating internal combustion engines

[0001]

14 —Working method and device for operating internal combustion engines. Mr. Hubert JEZLER residing in Switzerland. Requested on December 7, 1943, at 2:15 p.m., in Paris. Issued October 1944. — Published June 28, 1945. (Patent application filed in Switzerland on November 19, 1996. — Declaration of the applicant.) The present invention relates to a new working method for internal combustion engines and a device for implementing this method. Method B consists of causing an instantaneous internal pulverization of the fuel, with the formation of a mixture of fuel and air, and the ignition of this mixture by the effect of sparks from instantaneous discharges of a high voltage electric current on a liquid fuel. The importance of the new process for the operation of internal combustion engines lies in the total exclusion of the entire category of fuels, mainly hydrocarbons, whose anti-knock power has been increased by the addition of chemicals such as ethyl lead, bromine derivatives, etc., or by hydrogenation.

25 On the other hand, the new process involves a considerable modification of the operating principle of two-stroke engines. This method allows the use of any supply pressures and completely prevents any loss of fuel through the exhaust port of two-stroke carburetor engines, so that a two-stroke engine according to the invention constitutes a thermal engine of the highest perfection. ^ The operating method according to the invention makes the operation of an engine - even if it works with an extremely high supply pressure, whether it is two-stroke or four-stroke - completely independent of the anti-knock power of the fuel used. For this engine, only low octane fuels are used, the cost of which is much lower than that of fuels with high anti-knock power, which is artificially increased.

34 The formation of the flammable mixture of fuel and air is possible at all supply pressures, both in two-stroke and four-stroke engines, that is, even at compression degrees whose final temperatures are above the ignition point of the fuel used, without detonations occurring. Thanks to the increase in supply pressure, an engine operating according to the method according to the invention works with maximum efficiency.

[0002]

46 Moreover, the new process offers, compared to the injection process, the considerable advantage of a much[900.508]—higher rotation speed of the engines to which it is applied.

48 Since the ignition of the combustible mixture is effected by electric sparks, it is in many cases desirable, even at the expense of economy, to keep the compression lower than that of injection engines, the engine running more smoothly and with less noise.

[0003]

54 and closed at the bottom, having an internal diameter of 25 mm. and an external diameter of 40, a transformer oil column 55 of a length of approximately 100 mm is formed, in the lower part of which a bursting point is provided.

57 One of the electrodes is grounded, while the other is connected to a 6o electrical plant transformer through a capacitor. The instantaneous discharge of an electrical capacity of about 1 MF, at a voltage of 150 XY, instantly produces in the oil, 65 mainly by the pressure and heat of the spark, a bubble or a gas pistou which, thanks to its high pressure, atomizes the oil with a strong detonation and reduces it to a mist of the greatest 70 fineness by projecting it to a height of about 20 meters, tearing the hard paper tube and igniting the finely pulverized oil. When it comes to using fuel atomization, for example, in a two-stroke motor vehicle engine with a power of 100 hp, it must be taken into account that a four-cylinder, 100 hp two-stroke engine, rotating at 80,300 revolutions per minute and consuming 200 g of fuel per hp/hour, consumes in each working cycle about 28 mg or 35 mm of fuel in each cylinder, and that this quantity of fuel must be atomized by a current pulse in a time interval of about 1/500 of a second or less.

68 To spray about 30 mg of fuel 200 times per second, each time in 1/500 to 1/1000 of a second, an amount of energy of about 0.3 watts/wave is required for each spray, i.e. a continuous power of 200 X 0.3 = 60 watts. Although it is necessary, due to a poor efficiency coefficient, to consider higher current quantities, the electrical devices necessary for the production of current pulses do not in any case take on bulky dimensions, even for relatively high power motors. The current is taken from a battery or produced electromagnetically. In automotive engines, for example, the feed pressure will be chosen to precisely avoid the unpleasantly harsh and noisy running of injection engines. However, the feed pressure is much higher than in Otto engines, even when the latter are fueled with anti-knock fuels; consequently, the efficiency of an engine operating according to the new process is much higher than the efficiency of an Otto engine.

78 With the new process, not only low-boiling fuels, but also high-boiling fuels, and even those similar in nature to lubricating oils, can be used without any aid, the disruptive force of an instantaneous discharge in a discharge gap, placed for example in a transformer oil bath, being sufficiently powerful to pulverize and ignite even high-boiling fuels of relatively high viscosity. }5 During the intake process, the fuel is fed continuously, with a pressure of only a few atmospheres, into the spray chamber of the engine. During the passage of the current, there is

produced a spraying and an instantaneous ignition of the fuel; in certain cases, this ignition can be completed by an additional burst interval. The instantaneous spraying of combustible fuel in an internal combustion engine reproduces the phenomena, or phenomena analogous to those which lead to the explosion of oil bath reactors.

90 An apparatus enabling these phenomena to be observed has been constituted by the inventor in the following manner: In a hard paper tube placed vertically, the impulses produced by a tremor in the primary circuit are transformed by induction with a high voltage in the secondary circuit, and amplified at the intervals of e-elation by the addition of secondary capacitances. The priming and ignition of liquid fuel by an instantaneous discharge is always possible using a high-capacity fuse, charged via a rectifier and connected in parallel with the burst interval. To spray the camkustible, a device is used which resembles a spark plug and which is called a "spray plug". When it is a question of producing an inflammable charge inside an internal combustion engine using atomizing candles, the atomizing chamber is first filled with fuel, the fuel is atomized using one or more impulses or instantaneous discharges and the charge mixture is ignited after its formation.

105 In diesel engines, ignition of the finely pulverized fuel occurs automatically under the influence of the high compression temperature. In engines where the compression temperature is lower than the ignition temperature of the fuel used, the fuel may be ignited, after atomization, by means of a spark plug or a series of spark plugs, most often independent of the burst and atomization interval. The drawing shows examples of execution: Fig. 1 is a section and Fig. 2 an elevation of a first mode of execution of a spray candle; /i 5 Figs. 3 to 5 are longitudinal sections through four variants of spray candles. The spray candle according to figs. 1 and 2 has at its upper end a tube 1 intended for the introduction of the fuel brought by pumping, as well as a connection point 2 for the arrival of the electric current.

114 Below the tube 1 is provided a fuel check valve 3, followed by the tube 4. The lower end of this tube 4, tapered in the shape of a cone and ending in a hemispherical point, penetrates inside the fuel atomization chamber 5. In this end are provided slots 6o, through which the fuel can flow into the chamber 5. The space 5 formed between the end of the tube 4 and the internal wall of an annular body 12 has an equal width at all points. The dimensions 65 of this space are chosen so that the fuel is retained by the effect of capillarity at ! against the effect of gravity, even when the candle is in an inclined position. During filling, the fuel is held there without being projected. The pipe, the check valve 3 and the cap 7, extended by a threaded skirt, are electrically insulated by an insulator 7 5 8, through which the central tube 4 passes.

123 The annular body 12 is made of a material with high mechanical resistance, also resistant to strong temperature variations. The fuel spray chamber 5 is closed at the bottom by means of a metal cap 13, the bottom of which constitutes the counter electrode of a burst gap 10. This 13 metal cap is flared in a cone shape towards the top and per- 8!) drilled large holes 14. Its upper edge is folded inwards and engages and hooks into a peripheral groove of the insulator 8. A burst gap 15 is provided in the lower part of the fixing plug 11; this gap is formed by the electrodes 16, while the counter-electrodes are formed by the edges of the holes 14 provided in the metal cap 13. During electrical discharges, the fuel is first passed through, strongly heated, dissociated and ionized by the current in the vicinity of the gap 10, under the action of the pressure of the spark, with the production of violent pressure waves.

141 Under the action of the high-tension gas and vapor masses produced by the high temperature and other disruptive forces, such as os- [900.408]—ections, the fuel is pulverized and highly ionized, which is of the greatest importance for its rapid ignition and complete combustion. The fuel thus pulverized is then expelled upwards, out of the narrow annular chamber 5, as if by an explosion. As a result of the impact against the underside of the insulator 8 made of very resistant material, the fuel 10 is further pulverized and divided so as to form a very fine mist. The explosive atomization of the fuel is so violent that all residues are expelled from the atomization chamber and it therefore always remains clean. The pulverized and highly ionized fuel enters through the holes 14 of the cap 13 into the combustion chamber of the engine. 20 where it mixes with the air already present to form an easily flammable mixture which ignites in the first, but surely in the second burst interval 15. aB The speed, with which a fuel particle of the mixture thus obtained is projected from the center to the wall of the engine cylinder with a diameter of about 10 cm., reaches only 25 m./sec. during a period 3o of spraying of 1/o 00 of sec.

156 For large engines, rotating slowly and having vertically placed cylinders, the spray chamber 5, in order to have a large capacity, could be given large dimensions at the expense of the capillary retention of the fuel, so that the fuel can be projected out of the spray chamber under the action of strong current pulses. Fig. 3 shows another variation of the spray candle. In the lower part of the central tube 4, which forms a capillary tube, most often with an inner diameter AB of 3.5 mm, there is the bursting and spraying gap 10. This gap is formed by the fact that the lower, flared part of the central tube 4 is separated by an annular insulator 17 from a tube 18 added to the bottom of this insulator. This tube, firmly connected to the insulator 8, carries at its lower end a circular closing washer 19 to which is fixed by ribs a deflector 20 which constitutes the lower closure of the spray candle.

166 Instead of providing only one bursting and spraying interval 10, it is also possible, as shown in Fig. 4, to provide a whole row of bursting intervals 21 arranged in series, which does not prevent the use of only two bursting intervals. In the vicinity of the closing washer 19 are placed the electrodes 16 which 65 form with this washer the burst gap 15 for the ignition spark. The spray candle according to Figs. 3 and 4 works as follows: By means of a pump, the tube 4 is filled with fuel up to the level of the bursting and spraying intervals 10 and 21; dripping of this fuel out of the tube 4 is prevented by capillarity. Under the action of the spark passing through the fuel 76, the fuel located in and above the burst gap is atomized and as the check valve 3 is closed, this fuel is projected out of the tube 4 onto the deflector 20 and atomized so as to form a mist of extreme fineness; it is then mixed with air and ignited in the burst gap of the ignition spark 15.

177 The deflector is not only intended to perfect the atomization of the fuel. Thanks to its shape, the ricocheting fuel particles are correctly distributed inside the combustion chamber, which leads to complete and rapid combustion of the charge. However, the deflector can also be removed and, in this case, its function is fulfilled by the bottom of the piston. The spray candle shown in 9 to 5 has a bursting and spraying gap 10 concentric with the tube 4 and through which the current passes to the electrode 22 of the deflector 20. This deflector is fixed in the lower part of

the insulator 100 8 by ribs 21 flared at the top in the shape of a crown. The fuel is retained by capillarity in the cavities formed between the ribs; it is finely sprayed — 5 — [900.408] onto the deflector and ignited within the ignition spark burst interval 15.

189 The spray chamber can also be given another shape; for example, the fuel can be retained by capillarity in a narrow slot between two parallel plates and sprayed there by the effect of electric discharges. To bring the fuel into the spray chamber in precisely metered quantities, a pump is used, for example a gear pump driven by the engine and which delivers the fuel in adjustable quantities and under a pressure of several atmospheres. Through a system of pipes, in which static pressure prevails, the fuel reaches all the atomizing candles in equal quantities through perfectly identical nozzles. After exhaust, during the following engine charging period, the fuel pressure inside the inlet pipe is initially much higher than the scavenging pressure inside the cylinders, which causes the fuel to be forced back into the spray chamber 5; depending on the dosage controlled by a regulator, the latter is then more or less filled.

203 If, during the compression period, the pressure rises in the engine cylinder to become greater than the pumping pressure, the fuel supply stops and, if the compression pressure continues to rise, the non-return valve 3 closes. At the end of the compression stroke, the current then passes into the burst intervals 10 and 21, with atomization of the fuel and subsequent ignition of the mixture in the burst intervals 15. At the end of the working stroke, after the combustion gases have escaped, a new cycle begins with the entry of air 45 into the engine cylinder and fuel into the spray chamber. The working process can also be constituted in such a way that the atomization of the fuel is produced from the beginning 5o of the filling stroke by one or more discharges without ignition. The pulverized fuel can then mix with the combustion air to form a flammable charge.

213 Ignition only occurs towards the end of the stroke. A longer time is then available for the formation of the flammable mixture; however, for high charge pressures, it is necessary to use an anti-knock fuel.6 o In order to produce bursts capable of atomizing each dose of fuel within the prescribed time, it is necessary to use powerful current pulses, generally having an energy of a few tenths of a watt/sec. It is obtained by giving the capacity of the secondary winding, either by its own capacity or by a sufficient external capacity, a sufficiently high capacity, by mounting a capacitor in parallel with the bursting interval. In general we can say this: An impulse from an ordinary ignition coil produces an electric spark consisting of a capacitive discharge lasting about 1/100,000 of a second and a subsequent induced discharge lasting 1/1000 of a second or more.

223 As a result of the use of an eapaeity the energy of the capacitive discharge is increased at the expense of the inductive discharge, and the discharge, under the action of a current pulse, transforms into an instantaneous discharge. A spark discharge, under the action of a current pulse, therefore only occurs under the action of the system's own capacitance, while an instantaneous discharge only occurs under the action of the system's own capacitance plus an external capacitance. 9most often a capacitor. The tests with a spray candle according to Figs. 3 and 4 were carried out with current quantities of a few tenths of a watt/second with 9 5 diflerted capacities of 0.006 to 1.0 MF and voltages of 5-30,000 volts. The results showed that the transition from discharge, under the action of a current pulse, to the actual instantaneous discharge, already produces 100% fuel pulverization.

239 The speed of the spraying and its intensity increase with the increase in the electrical energy used and at the same time an increase in the length of the bursting intervals is obtained. Tests with an isolated discharge, not with a burst train, in a burst interval of a spray tube with an internal diameter of about 3.0 mm, according to Fig. 3, gave the following results: With an isolated instantaneous discharge with a current of 10-30,000 volts, a capacity of 0.1-10 MF and a power of about 0.3 watts/sec, about 30% of gasoline, petroleum, diesel engine oil, lignite tar oil and even a lubricating oil were sprayed in a burst interval, and a cloud of the greatest fineness with a height of 70-80 cm was obtained. and a diameter of about 30 cm, and this in a time span of 1/100 or even 1/1000 of a second.

250 Despite the single discharge and the presence of a single spark plug, the fuel was ignited each time. When applying current pulses of sufficient intensity, voltage and capacity, only spark plugs with only one burst interval are used, in which the atomization and even the ignition of this fuel are produced. In the case of a sufficiently high voltage and current, and if the length of the burst interval is sufficiently large, the self-capacitance of the induction coil alone is sufficient to atomize and ignite the fuel in a single burst interval; however, the effect of atomization and ignition is increased by the addition of an external capacitance, in the form of a capacitor. HESDMADE!

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261 ° This working method for operating internal combustion engines consists in causing an instantaneous pulverization of the fuel, with the formation of an inflammable mixture, and its ignition, by the action on the liquid fuel, of sparks originating from the discharge of current pulses and instantaneous discharges of a high voltage electric current; 2° The application of this method, for operating internal combustion engines, excludes the use of intentionally produced fuels with high anti-knock power, and in engines operating according to this method, these fuels are replaced by ordinary fuels, that is to say fuels whose anti-knock power has not been artificially increased, even in the case of a compression of 6o maximum load; 3° Two-stroke engines operating according to this process become new two-stroke engines, with lossless formation of the charge mixture and use 65 of any compression; 4° The fuel is atomized and ignited by a single discharge of a high-voltage electric current, in the form of a spark, in one or more burst intervals 70; 5° A high-voltage current capacity is produced and accumulated such that the instantaneous pulse or discharge energy is sufficient to atomize the fuel 7 5 required for a cycle in one or more burst intervals in series and to ignite the combustible mixture thus formed; 6° A rapid train of high-capacity high-voltage electric current is produced and the fuel is pulverized and ignited in a rapid succession of separate instantaneous pulses and discharges during a working cycle and in one or more burst intervals;85 7° When one or more burst intervals are used in series, only part of them is covered with fuel, while the other part remains clear of fuel and is in the zone of action of the combustion air; 8° The spark serves only to pulverize the fuel, while its ignition is produced by

other means, for example by means of a charge of combustion air, heated above the ignition temperature, by spark plugs provided outside the burst interval; 9° The current pulse and the instantaneous discharge of a high-voltage electric current are produced in two or more electric currents in the combustion chamber of the engine cylinder, to atomize and ignite it, a 55 atomization spark plug is provided; 17° The atomization and ignition spark plug comprises an axial tube housed in an electrical insulator and intended for the admission of fuel and the introduction of the electric current and this tube contains a non-return valve and, at its lower end, a atomization chamber with a burst gap provided in this chamber; 18° This atomization and ignition spark plug comprises two or more burst gaps arranged in series; 19° The atomization chamber, shaped for example as an admission tube for the fuel, is narrow enough for the fuel to be retained therein by the effect of capillarity; 20° The spray chamber is open towards the inside of the cylinder 76 so that the fuel, under the action of the instantaneous discharge, is expelled from the spray chamber in a finely pulverized form; 21° The central tube is interrupted by one or more insulating layers, constituting one or more bursting gaps; 22° The electrodes of the bursting gap are arranged in the longitudinal axis of the fuel supply tube and are held by longitudinal ribs, the fuel being retained by capillarity between these ribs; 23° At the lower end of the atomization and ignition spark plug 00 is arranged a deflector against which the fuel expelled from the atomization chamber is projected and on which this fuel undergoes a second atomization, this deflector producing, by ricochet of the atomized fuel, a correct distribution in the combustion chamber and a complete combustion; 24° This deflector constitutes one of the electrodes of the second burst interval.

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326 several bursting intervals connected in series, the first bursting interval(s) being used for pulverizing the fuel and the second or last bursting interval(s) being intended for igniting the combustible mixture; 10° Two or more current impulses or instantaneous discharges are produced successively in such time periods that the last discharge only occurs when the fuel is already pulverized and mixed with air under the action of the first and, possibly, the following discharges and the last discharge ignites the combustible mixture thus formed; The time intervals between the different discharges are adjusted so that the fuel is atomized at the beginning of the engine's suction stroke and is not ignited until the end of this stroke; 12° The fuel is forced through the feed pipe by a pump with an adjustable flow rate so that the fuel is brought into the atomization chamber at 5 at the beginning of the load period and its return is prevented during the compression and working stroke; 13° High boiling point hydrocarbons and other fuels are used which are difficult to evaporate and have low anti-knock properties; 14° The device for implementing this process consists of a high-voltage secondary coil producing the discharges, instantaneous in the desired time intervals with sufficient voltage and capacity, thanks to the fact that the coil has such an inherent capacity (which is supplemented by an additional capacitor if it Ao is insufficient) that the total capacity is sufficient for the current induced in the secondary coil to be accumulated in such a quantity that it is discharged in the form of a pulse or instantaneous discharge of an intensity sufficiently great to pulverize the fuel necessary for each working cycle and to ignite the combustible mixture thus produced; 15° To produce a large electrical capacity to charge the capacitor, a rectifier is provided; 16° To supply the fuel and the current. For the washing of the booklets, contact the Impeimeeie Nationale, 27, me de la Convention, Paris (IS-).

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SNAMPROGETTI S.p.A., Mailand / Italien

Zuführ- und Zündanlage für Brennkraftmaschinen zum Betrieb bei sehr mageren Luft-Kraftstoff-Gemischen

Die Erfindung betrifft eine Zuführ- und Zündanlage für Brennkraftmaschinen, die für einen Betrieb der Brennkraftmaschine bei mageren Luft-Kraftstoff-Gemischen bestimmt ist.

Bekannt sind Brennkraftmaschinen, die als sogenannte Vorkammer-Kraftmaschinen bezeichnet werden. Das Vorkammersystem stellt eine Weiterentwicklung des Verbrennungsprinzips der bekannten Kraftmaschinen dar. Oder anders ausgedrückt kann mit Hilfe der Vorkammer eine Kraftmaschine mit einem mageren Gemisch gleichmäßig und kontinuierlich betrieben werden, d.h. ein solches Gemisch, das mengenmäßig einen relativ geringen Benzinanteil im Vergleich zur angesaugten Luft aufweist.

Im Aufbau stimmt eine Vorkammer-Kraftmaschine mit jenem einer bekannten Kraftmaschine überein, jedoch ist eine kleine Vorverbrennungskammer vorgesehen, in die eine Zündkerze eingesetzt ist. In dieser Kammer befindet sich auch ein Hilfsansaugventil für jeden Zylinder. Das normalerweise vorhandene Ansaugventil fördert hierbei eine große Menge des mageren Gemisches zu der Brennkraftmaschine, während das Hilfsventil eine geringe Menge eines sehr fetten oder reichen Gemisches in der Umgebung der Zündkerze erzeugt. Am Ende der Kompressionsphase wird der Zylinder auf die folgende Art und Weise gefüllt. In der kleinen Vorkammer in der Umgebung der Zündkerze befindet sich ein reiches Gemisch, während sich in der Brennkammer ein mageres Gemisch bildet.

Die Erfindung befaßt sich mit einer Zuführ- und Zündanlage für Brennkraftmaschinen, die die folgenden Merkmale aufweist:

a) die Zuführung zur Brennkraftmaschine erfolgt in zwei Phasen, wobei die erste eine flüssige (oder gasförmige) Phase darstellt, die mit einem Vergaser, der für magere Gemische bestimmt ist, durchgeführt wird, und wobei die zweite Phase eine gasförmige Phase darstellt, für die eine entsprechend abgewandelte Zündkerze vorgesehen ist;

b) der Zylinderkopf und das Oberteil der Brennkraftmaschine bleiben insgesamt unverändert und

c) in der Zündkerze sind ein oder mehrere Kanäle für die Zufuhr einer gasförmigen Substanz vorgesehen (z.B. Methan und ähnliches, die gegebenenfalls mit Luft gemischt sind).

Die Zündkerze wirkt hierbei als ein intermittierender Brenner, dessen Flammenfront sich bis in die Brennkammer ausbreitet, die kritischsten Punkte erreicht und Turbulenzen verursacht.

Die gemäß der Erfindung abgewandelte Zündkerze bildet die Vorbrennkammer einer Vorkammer-Kraftmaschine , so daß die Auslegung und die Geometrie der Brennkraftmaschine nicht verändert werden muß, so daß beträchtliche Herstellungskosten sowie Material eingespart werden können.

Ein weiterer Vorteil der Erfindung liegt darin, daß die Flamme, die durch die Zündung infolge der Zündkerze der gasförmigen Substanz auftritt, eine Fläche überstreicht, die durch die Menge, den Druck und die Geschwindigkeit der zugeführten gasförmigen Substanz regelbar ist.

Ferner wird mit der Zuführ- und Zündanlage gemäß der Erfindung im Vergleich zu bekannten derartigen Anlagen der Kraftstoffverbrauch, die Menge der Stickstoffoxide, Kohlenwasserstoffe und abgegebener Kohlenmoxide reduziert.

Die Erfindung wird nachstehend anhand der beigefügten Zeichnung an Ausführungsbeispielen näher erläutert.

Fig. 1 zeigt in einer Querschnittsansicht schematisch einen Zylinder und einen Zylinderkopf einer bekannten Vorkammer-Kraftmaschine;

Fig. 2 zeigt in einer Vertikalschnittansicht eine Zündkerze, an der die Zuführ- und Zündanlage vorgesehen ist;

Fig. 3 zeigt eine Vertikalschnittansicht einer weiteren bevorzugten Ausführungsform gemäß der Erfindung, bei der zwei oder mehrere Masseelektroden vorgesehen sind und einen sogenannten Halbflächenentladungstyp darstellt.

Unter Bezugnahme auf Fig. 1 ist mit der Bezugsziffer 1 ein Ventil zur Zuführung des mageren Gemisches, mit 2 ein Ventil zur Zuführung des fetten Gemisches, mit 3 das Auslaßventil, mit 4 die Vorbrennkammer bezeichnet, die über das Ventil 2 das fette Gemisch aufnimmt. Mit der Bezugsziffer 5 ist eine Zündkerze bezeichnet, die in der Vorbrennkammer 4 angeordnet ist.

Die fette Mischung, die durch die Zündkerze 5 gezündet wurde, verursacht die Zündung der mageren Mischung in der Brennkammer 6.

Unter Bezugnahme auf Fig. 2 ist eine Zündkerze 7, eine Mittelelektrode 8, eine Masseelektrode 9, ein Zündbereich 10, der die Vorbrennkammer bildet,ein Einlaßkanal 11 (der entsprechend isoliert ist) für Methan oder ähnliche Kohlenwasserstoffe und ein Rückschlagventil 12 für den Einlaßkanal 11 vorgesehen.

In Fig. 3 ist eine Zündkerze 7', die zwei oder mehrere Elektroden aufweist und ein sogenannter Oberflächenentladungstyp ist, eine Mittelelektrode 8' so vorgesehen, daß sie einen Einlaßkanal 11' (entsprechend isoliert) für Methan oder ähnliche Kohlenwasserstoffe bildet. Mit 9' sind eine oder mehrere Vorelektroden und mit 10' die Zündzone bezeichnet, die die brennkammer darstellt. Die Abmessung der Vorbrennkammer kann durch entsprechende Variation der Abmessungen der Zündkerze variieren.

Der Einlaßkanal für Methan oder ähnliche Kohlenwasserstoffe kann beispielsweise in einem entsprechenden Dichtungskragen angeordnet sein (dies ist in Fig. 2 beispielsweise mit der Bezugsziffer 13 bezeichnet). Die Zündung des mageren Gemisches in der Brennkammer erfolgt folgendermaßen: aus einem Behälter, der beispielsweise Methan (nicht gezeigt) enthält,und über ein bekanntes Reduktionssystem strömt das Methan mit regulierbarem Druck und regulierbarer Geschwindigkeit durch die Kanäle 11 oder 8' oder 13. Daraufhin gelangt das Methan in die Kammer 10 oder 10', wo es durch den Funken, der zwischen den Elektroden der Zündkerze auftritt, gezündet wird.

Diese Flamme, deren Größe und Temperatur wesentlich höher als jene des Funkens ist, zündet seinerseits das magere Gemischt, das die Brennkammer ausfüllt, wobei die Zündung vollständiger und schneller erfolgt, da durch die Flamme in dem fetten Gemisch Turbulenzbewegungen verursacht werden.

Zur Zuführung des Methans zu der Vorbrennkammer können beispielsweise mechanische und/oder elektrische Einrichtungen vorgesehen sein, die über die Antriebswelle, die Verteilerwelle oder über die elektrische Anlage betrieben werden, die die Zündung steuern (Zündspule, Batterie und dergl.).

Hierbei tritt der Vorteil auf, daß, da die Flammentemperatur in der Zone, die die Elektroden umgibt, sehr hoch ist, nahezu alle Ablagerungen auf den Elektroden beseitigt sind.

P a t e n t a n s p r ü c h e

1. Zuführ- und Zündanlage für Brennkraftmaschinen beim Betrieb mit sehr mageren Luft-Kraftstoffgemischen, d a d u r c h g e k e n n z e i c h n e t, daß in einer Zündkerze Zuführungen für ein gasförmiges, reiches Luft-Kohlenwasserstoff-Gemisch vorgesehen sind, die eine Verbrennungszone für das Gemisch in der Umgebung der Zündelektroden bilden.

2. Anlage nach Anspruch 1, dadurch gekennzeichnet, daß ein oder mehrere Kanäle in der Zündkerze für die Zuführung eines gasförmigen Luft-Methan-Gemisches von einem Behälter, der außerhalb der Zündkerze angeordnet ist, zu einer innerhalb der Zündkerze liegenden Verbrennungszone vorgesehen ist, die zu den Elektroden benachbart liegt.

3. Anlage nach Anspruch 1, dadurch gekennzeichnet, daß ein Kanal in der Mittelelektrode der Zündkerze zur Zuführung eines gasförmigen Luft-Methan-Gemisches von einem Behälter, der außerhalb der Zündkerze angeordnet ist, zu einer innerhalb der Zündkerze liegenden Verbrennungszone vorgesehen ist, die den Elektroden benachbart liegt.

4. Anlage nach Anspruch 1, dadurch gekennzeichnet, daß eine oder mehrere Kanäle in der Zündkerze vorgesehen sind, die durch einen Dichtungskragen mit einer kreisförmigen Ausnehmung und einer Öffnung führen, die zur Zuführung eines gasförmigen Luft-Methan-Gemisches von einem Behälter, der außerhalb der Zündkerze angeordnet ist, zu einer innerhalb der Zündkerze liegenden Verbrennungszone in Verbindung stehen, die den Elektroden benachbart liegt.

5. Anlage nach Anspruch 1, dadurch gekennzeichnet, daß die Zündzone in der Umgebung der Elektroden, die die Vorbrennkammer bilden, durch eine zylindrische Wand begrenzt ist, die ein Einschraubgewinde für die Zündkerze aufweist.

6. Anlage nach Anspruch 5, dadurch gekennzeichnet, daß sich die mit einem Einschraubgewinde versehene zylindrische Wand zur Begrenzung der Vorbrennkammer durch Rückversetzung des Keramikkörpers und der Mittelelektrode der Zündkerze bildet.

7. Anlage nach einem der vorhergehenden Ansprüche, dadurch gekennzeichnet, daß Regeleinrichtungen für den Druck des gasförmigen Luft-Methan-Gemisches durch die in der Zündkerze vorgesehenen Kanäle vorgesehen sind, die in der Nähe der Elektroden der Zündkerze münden.

8. Anlage nach Anspruch 1 und 7, dadurch gekennzeichnet, daß elektrische und/oder pneumatische Synchronisationseinrichtungen zur Synchronisation der Zuführung des gasförmigen Luft-Methan-Gemisches in die die Elektroden umgebende Zone mit der Zündung der Zündkerze vorgesehen sind.

9. Anlage nach Anspruch 8, dadurch gekennzeichnet, daß die Synchronisationseinrichtung über die Antriebswelle, die Verteilerwelle oder die Zündspule betätigbar ist.

8

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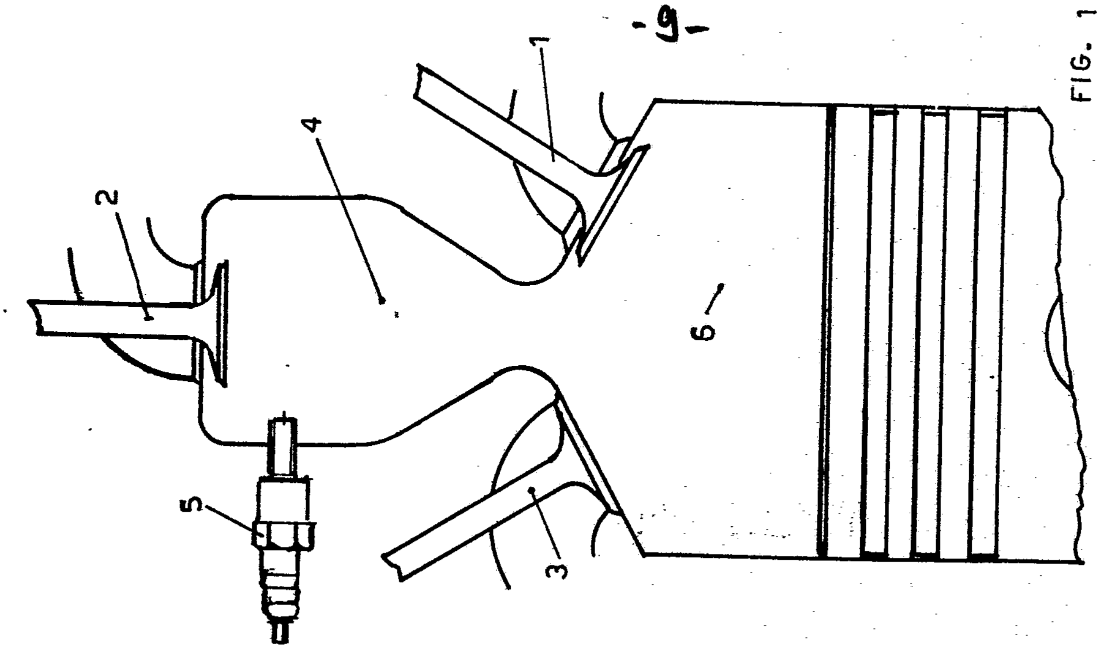

FIG. 1

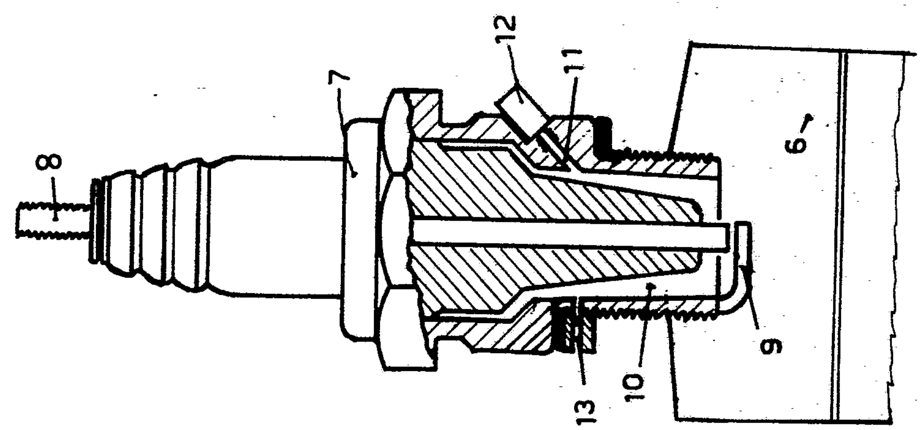

FIG. 2

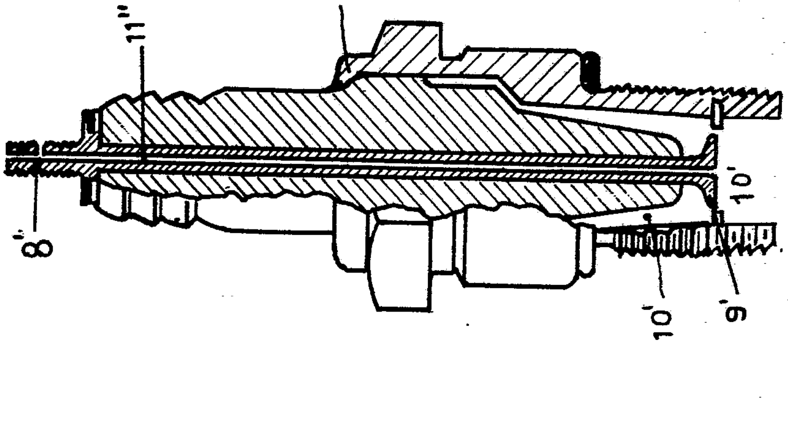

FIG. 3

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Supply and ignition system for internal combustion engines for operation with very lean air-fuel mixtures

Classifications

- F02B19/1004 Engines characterised by precombustion chambers with fuel introduced partly into pre-combustion chamber, and partly into cylinder details of combustion chamber, e.g. mounting arrangements
- F02M57/06 Fuel-injectors combined or associated with other devices the devices being sparking plugs
- *Y02T10/12* Improving ICE efficiencies

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Other languages: English

Inventor: Vincent Liguori, Mauro Dr Maestrelli

Current Assignee : SnamProgetti SpA

Worldwide applications

1974 IT 1975 FR *LU BE NL* OF JP

Application DE19752503983 events

1975-01-31	Application filed by SnamProgetti SpA
1975-08-14	Publication of DE2503983A1
Status	Pending

Info: Cited by (10), Similar documents, Priority and Related Applications

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Claims (8)

Hide Dependent

1. Patent claims

   Supply and ignition system for internal combustion engines; when operating with very lean air-fuel mixtures, characterized in that inlets for a gaseous, rich air-hydrocarbon mixture are provided in a spark plug, which form a combustion zone for the mixture in the vicinity of the ignition electrodes.

2. 2. Installation according to claim 1, characterized in that one or more channels are provided in the spark plug for supplying a gaseous air-methane mixture from a container arranged outside the spark plug to a combustion zone located inside the spark plug and adjacent to the electrodes.

3. 3. Installation according to claim 1, characterized in that a channel is provided in the central electrode of the spark plug for supplying a gaseous air-methane mixture from a container **arranged** outside the spark plug to a combustion zone located inside the spark plug and adjacent to the electrodes.

4. 4. Installation according to claim 1, characterized in that one **or** more channels are provided in the spark plug, which lead through a sealing collar with a circular recess and an opening, which communicate for the supply of a gaseous air-methane mixture from a container arranged outside the spark plug to a combustion zone located inside **the** spark plug and adjacent to the electrodes.

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5. 5. Installation according to claim 1, characterized in that the ignition zone in the vicinity of the electrodes forming the pre-combustion chamber is delimited by a cylindrical wall having a screw thread for the spark plug.

6. 6. System according to claim 5» characterized in that the cylindrical wall provided with a screw thread for defining the pre-combustion chamber is formed by setting back the ceramic body and the center electrode of the spark plug.

7. 7. Installation according to one of the preceding claims, characterized in that control devices for the pressure of the gaseous air-methane mixture are provided through the channels provided in the spark plug, which open near the electrodes of the spark plug.

8. 8. Plant according to claims 1 and 7, characterized in that electrical and/or pneumatic synchronization devices are provided for synchronizing the supply of the gaseous air-methane mixture into the zone surrounding the electrodes with the ignition of the spark plug*

•9. System according to claim 8, characterized in that the synchronization device can be actuated via the drive shaft, the distributor shaft or the ignition coil.

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Description

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SNAMPROGETTI SpA, Switzerland / Italy

Supply and ignition system for internal combustion engines for operation with very lean air-fuel mixtures

The invention relates to a supply and ignition system for internal combustion engines, which is intended for operation of the internal combustion engine with lean air-fuel mixtures.

Internal combustion engines known as pre-chamber engines are well known. The pre-chamber system represents a further development of the combustion principle of conventional engines. In other words, with the help of the pre-chamber, an engine can be operated evenly and continuously with a lean mixture, ie, a mixture which has a relatively small proportion of gasoline compared to the intake air.

The design of a pre-chamber engine is similar to that of a conventional engine, but with a small pre-combustion chamber in which a spark plug is inserted. This chamber also contains an auxiliary

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Intake valve for each cylinder. The normally present intake valve delivers a large amount of the lean mixture to the engine, while the auxiliary valve creates a small amount of a very rich or rich mixture in the area around the spark plug. At the end of the compression phase, the cylinder is filled in the following way: A rich mixture is present in the small prechamber near the spark plug, while a lean mixture forms in the combustion chamber.

The invention relates to a supply and ignition system for internal combustion engines, which has the following features:

a) the supply to the internal combustion engine takes place in two phases, the first being a liquid (or gaseous) phase, which is carried out by means of a carburettor designed for lean mixtures, and the second being a gaseous phase, for which a suitably modified spark plug is provided;

b) the cylinder head and the upper part of the internal combustion engine remain unchanged and

c) one or more channels are provided in the spark plug for the supply of a gaseous substance (e.g. methane and the like, possibly mixed with air).

The spark plug acts as an intermittent burner, whose flame front spreads into the combustion chamber, reaching the most critical points and causing turbulence.

The spark plug modified according to the invention forms the pre-combustion chamber of a pre-chamber engine, so that the design and geometry of the internal combustion engine do not have to be changed, so that considerable manufacturing costs and material can be saved.

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A further advantage of the invention is that the flame which occurs as a result of the ignition of the gaseous substance by the spark plug covers an area which can be regulated by the quantity, pressure and speed of the supplied gaseous substance.

Furthermore, the supply and ignition system according to the invention reduces fuel consumption, the amount of nitrogen oxides, hydrocarbons and carbon dioxide emitted, compared to known systems of this type.

The invention is explained in more detail below with reference to exemplary embodiments in the accompanying drawings.

Fig. 1 shows a cross-sectional view schematically of a cylinder and a cylinder head of a known pre-chamber engine;

Fig. 2 shows a vertical sectional view of a spark plug on which the supply and ignition system is provided;

Fig. 3 shows a vertical sectional view of another preferred embodiment according to the invention, in which two or more ground electrodes are provided and represents a so-called half-area discharge type.

With reference to Fig. 1, reference numeral 1 denotes a valve for supplying the lean mixture, 2 a valve for supplying the rich mixture, 3 the exhaust valve, 4 the pre-combustion chamber, which receives the rich mixture via the valve 2. Reference numeral 5 denotes a spark plug arranged in the pre-combustion chamber 4.

The rich mixture ignited by the spark plug 5 causes the ignition of the lean mixture in the combustion chamber

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Referring to Fig. 2, a spark plug 7, a center electrode 8, a ground electrode 9, an ignition region 10 forming the pre-combustion chamber, an inlet port 11 (which is suitably insulated) for methane or similar hydrocarbons and a check valve 12 for the inlet port 11 are provided.

In Fig. 3, a spark plug 7' having two or more electrodes and being of a so-called surface discharge type, a center electrode 8' is provided so as to form an inlet channel 11f (suitably insulated) for methane or similar hydrocarbons. 9' denotes one or more pre-electrodes, and 10' the ignition zone, which constitutes the combustion chamber. The dimensions of the pre-combustion chamber can be varied by appropriately varying the dimensions of the spark plug.

The intake port for methane or similar hydrocarbons can, for example, be arranged in a corresponding sealing collar (this is designated, for example, by reference numeral 13 in Fig. 2). Ignition of the lean mixture in the combustion chamber occurs as follows: from a container containing, for example, methane (not shown), and via a known reduction system, the methane flows at an adjustable pressure and speed through the channels 11 or 81 or 13. The methane then enters the chamber 10 or 10', where it is ignited by the spark that occurs between the electrodes of the spark plug.

This flame, whose size and temperature are much higher than that of the spark, in turn ignites the lean mixture that fills the combustion chamber, with ignition being more complete and faster because the flame causes turbulence in the rich mixture.

To supply the methane to the pre-combustion chamber,

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For example, mechanical and/or electrical devices may be provided that are operated via the drive shaft, the distributor shaft or via the electrical system that controls the ignition (ignition coil, battery, etc.)

The advantage here is that, since the flame temperature in the zone surrounding the electrodes is very high, almost all deposits on the electrodes are removed.

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US4105010A *	1976-01-02	1978-08-08	Rand Jr Earl W	Fuel saving apparatus for multiple cylinder internal combustion engines
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JP5437136B2 *	2010-04-07	2014-03-12	Japan Auto Parts Research Institute Co., Ltd.	Spark plugs for internal combustion engines
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* Cited by examiner, † Cited by third party, ‡ Family to family citation

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DE2452951A1	1976-05-13	internal combustion engine
DE2950830A1	1981-06-25	Spark-ignition internal combustion engine operated with stratified charge
DE102022103532B4	2023-09-14	Method for operating an internal combustion engine and corresponding internal combustion engine
DE704893C	1941-04-09	Working procedures for spark-ignited two-stroke internal combustion engines in which fuel is injected
DE2217873A1	1972-10-26	Device for supplying fuel to an internal combustion engine
DE2425503A1	1975-01-02	Method and device for operating a spark-ignition internal combustion engine

Priority And Related Applications

Applications Claiming Priority (1)

Application	Filing date	Title
IT20076/74A	1974-02-01	Power supply and ignition system for internal combustion engines designed to allow their operation in the range of extremely lean air-fuel mixtures

US 20040149256A1

(19) **United States**

(12) **Patent Application Publication** (10) **Pub. No.: US 2004/0149256 A1**

Dye et al. (43) **Pub. Date: Aug. 5, 2004**

(54) **FUEL INJECTION ASSEMBLY**

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Publication Classification

(51) **Int. Cl.**^{7} **F02M 57/06**

(52) **U.S. Cl.** **123/297**; 313/120

(57) **ABSTRACT**

A fuel injection assembly comprising a main structure **(101)** for mounting on an internal combustion engine, the main structure having one or more orifices **(115)** for injecting fuel directly into the combustion chamber of the internal combustion engine, and the main structure also having mounted thereon charge electrodes **(105, 118)** positioned to provide an electric field which passes through the flow of fuel, for charging fuel particles to improve atomisation. The main structure also has mounted thereon a spark electrode **(104)** adapted to provide a fuel ignition spark for the internal combustion engine. The main structure of the assembly is adapted for removable mounting, having a threaded portion **(102)** adapted to co-operate with a threaded aperture in the internal combustion engine, normally adapted to receive a convention spark plug.

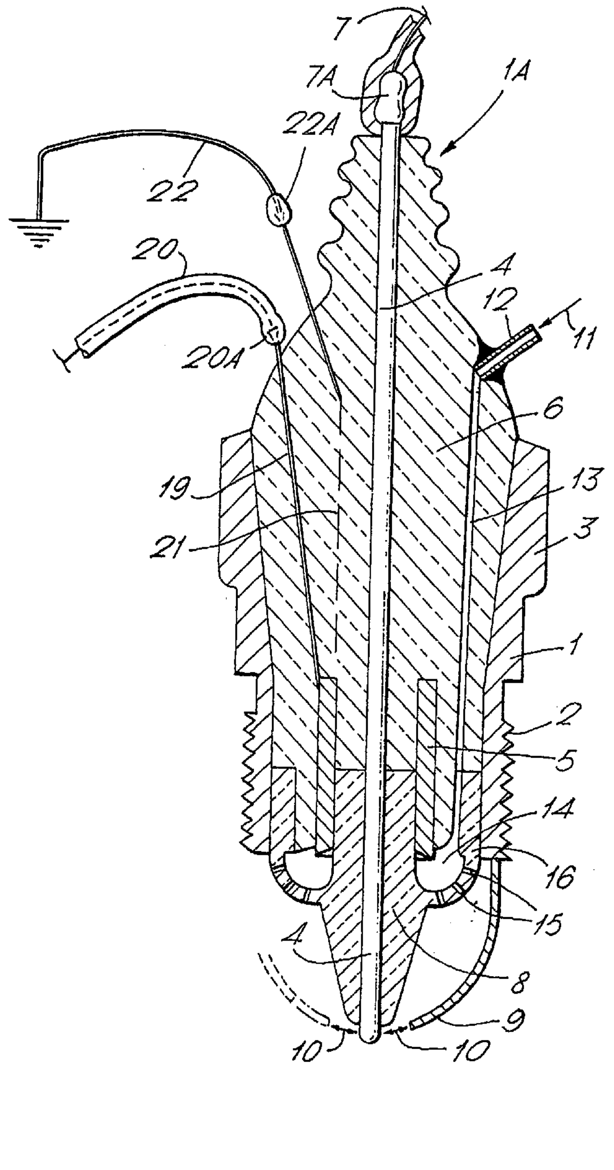
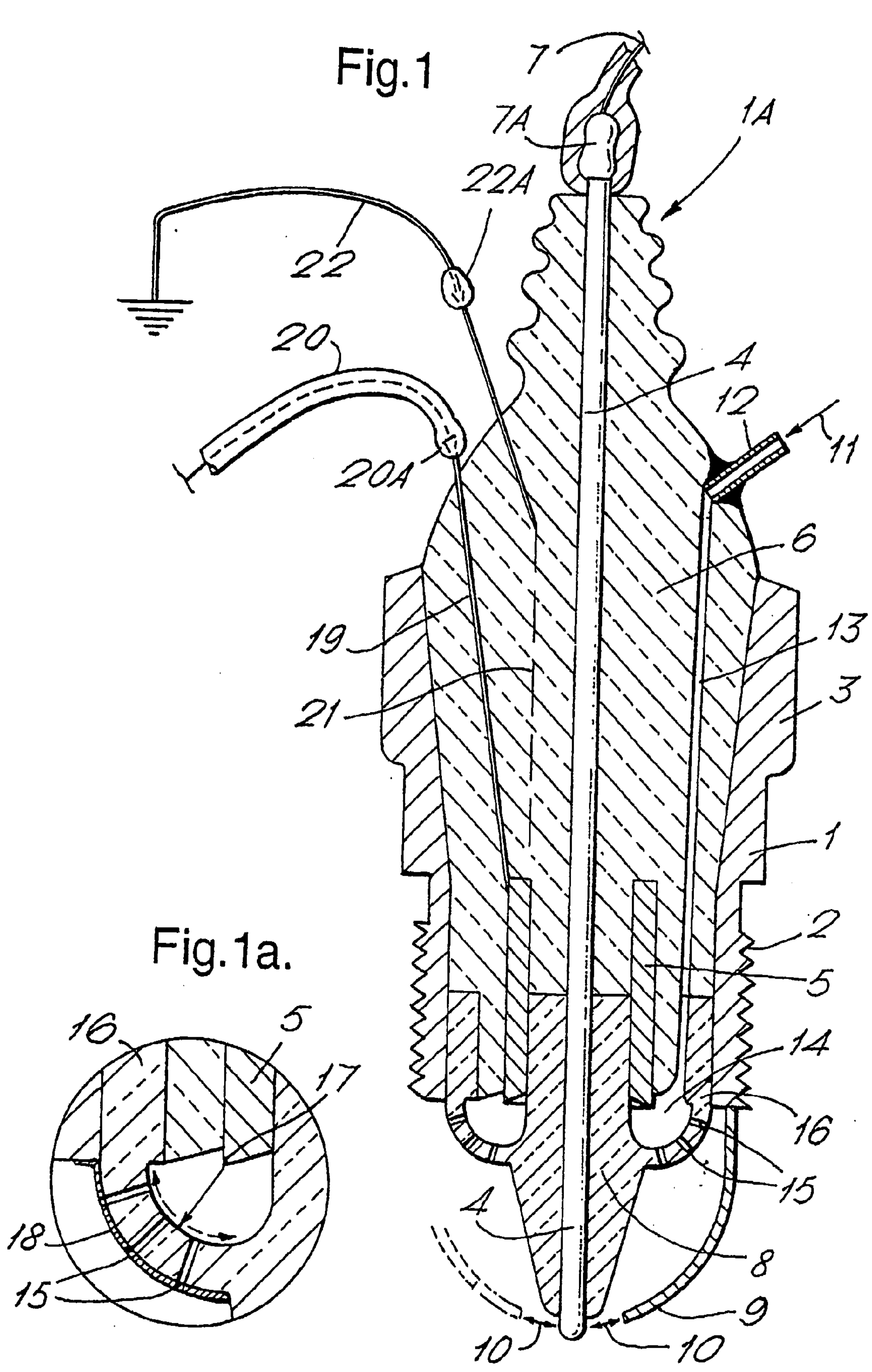


Fig. 1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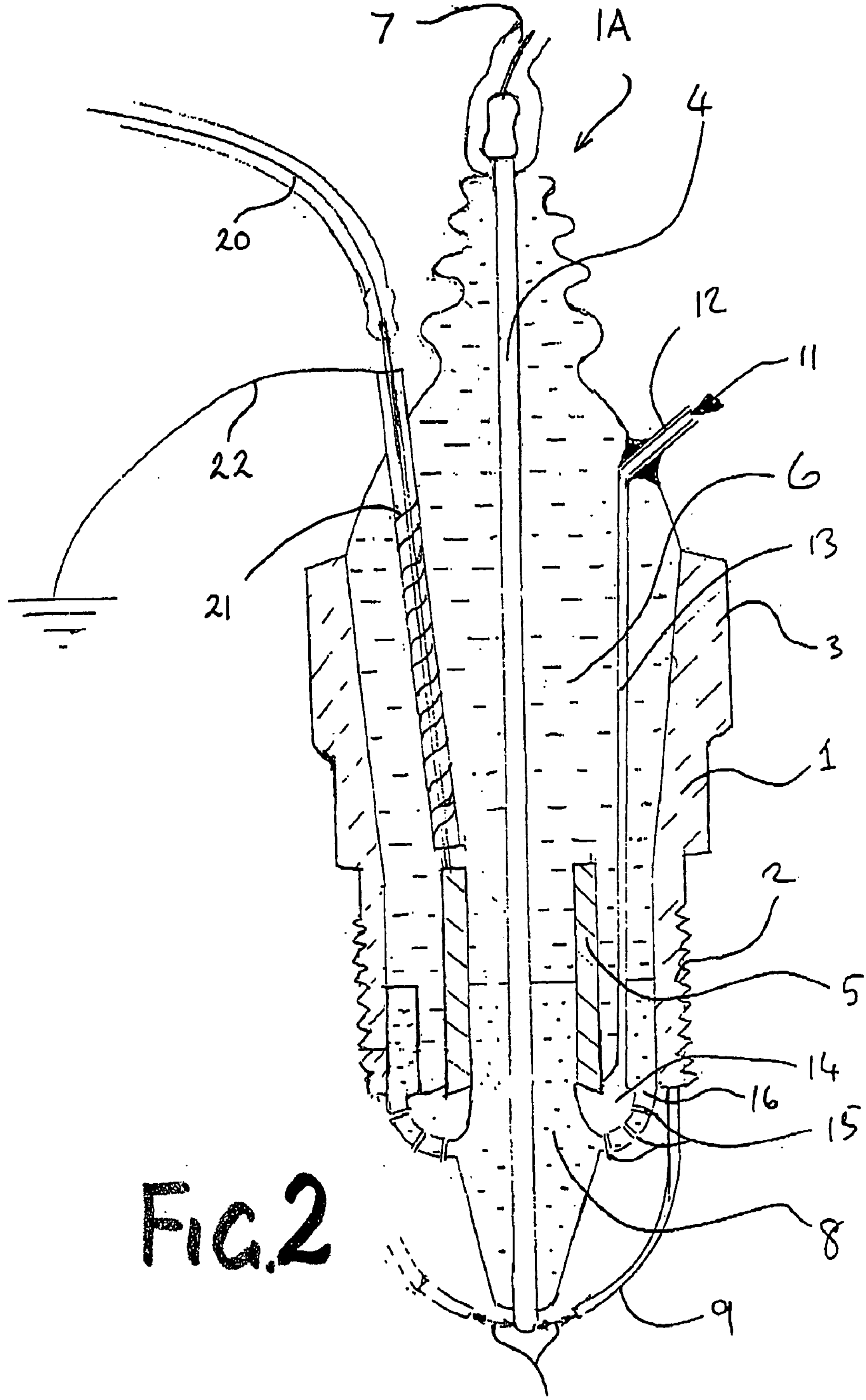

FIG. 2

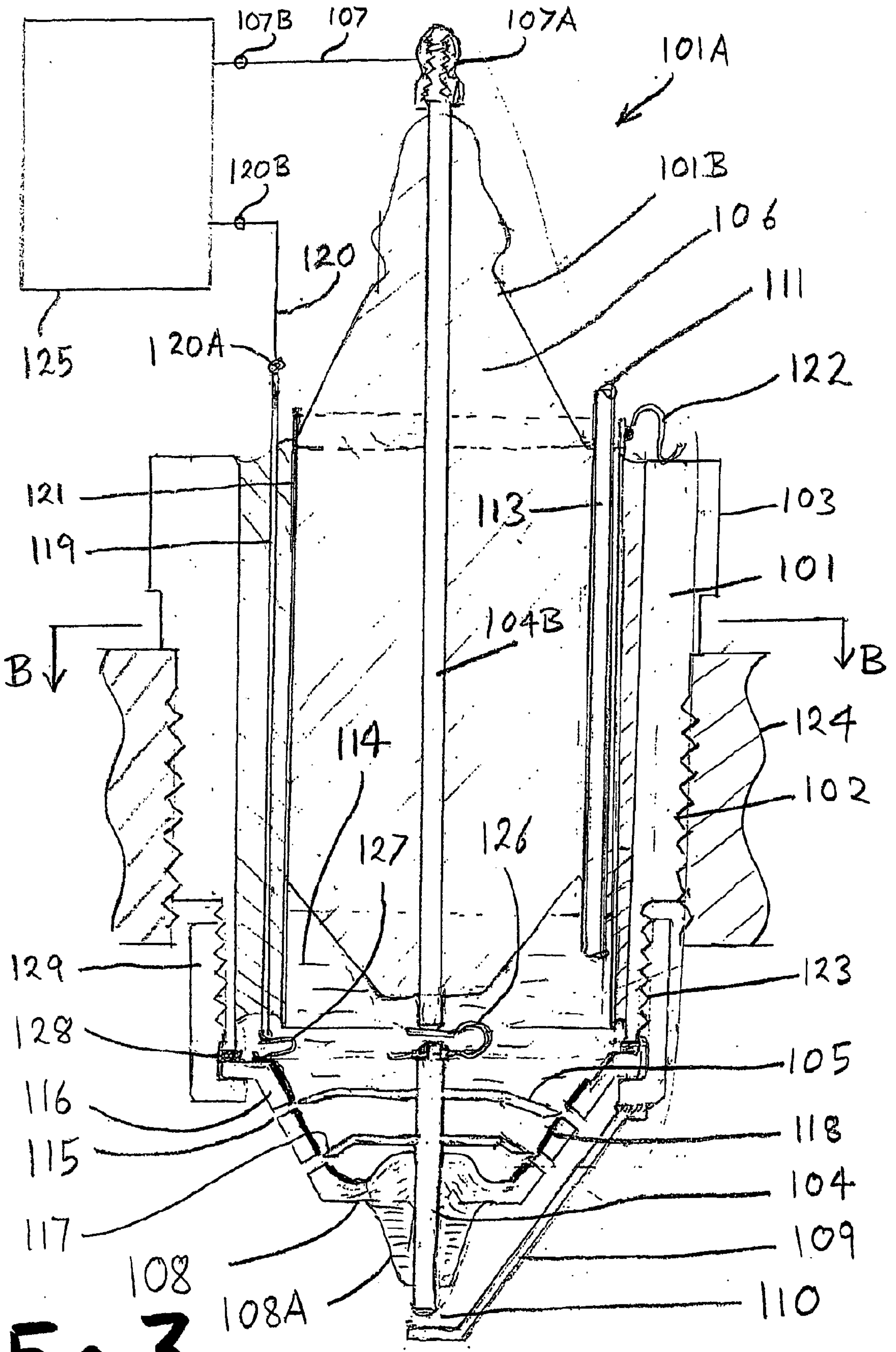
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FIG.3

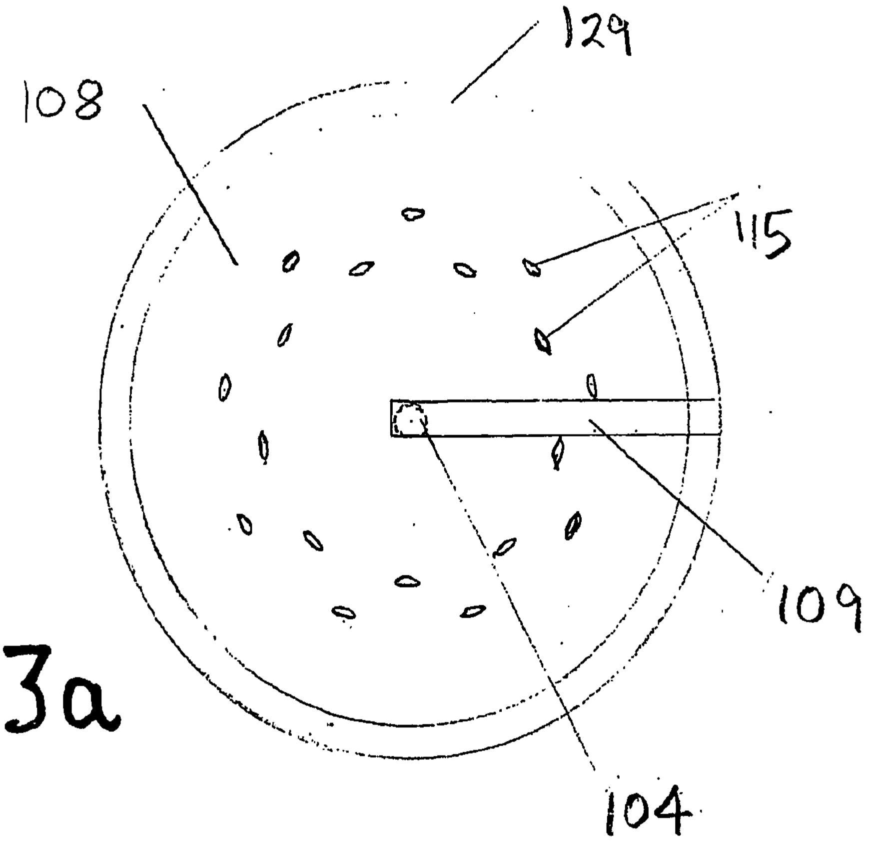


FIG. 3a

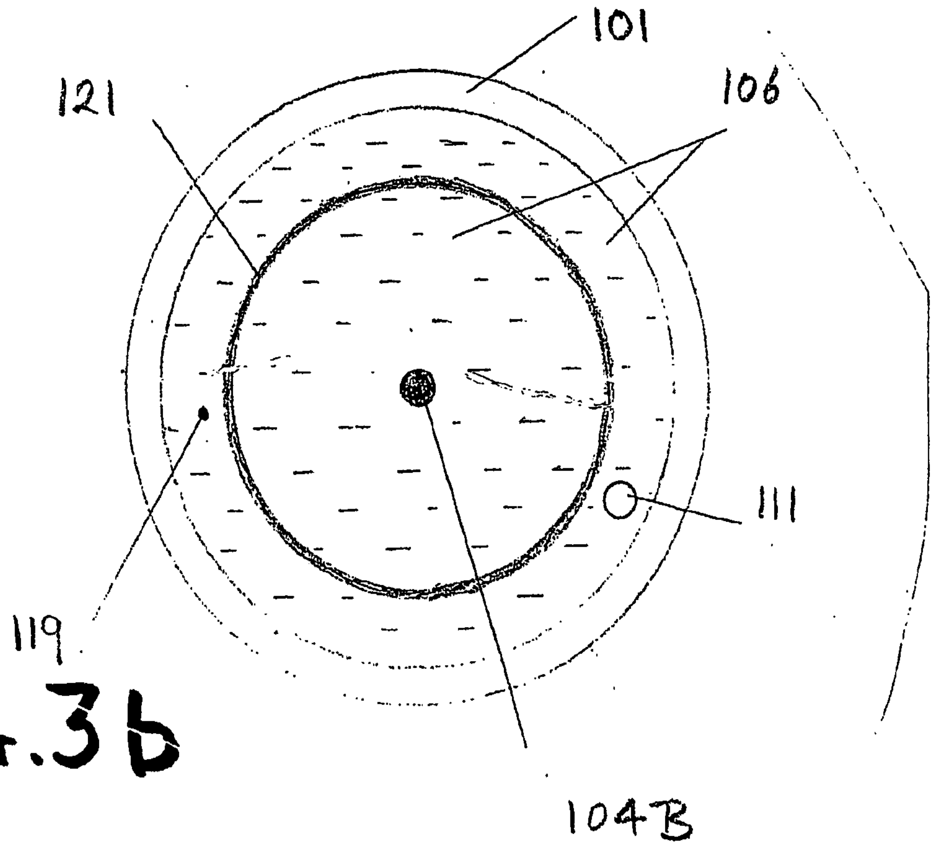


FIG. 3b

Fig.4.

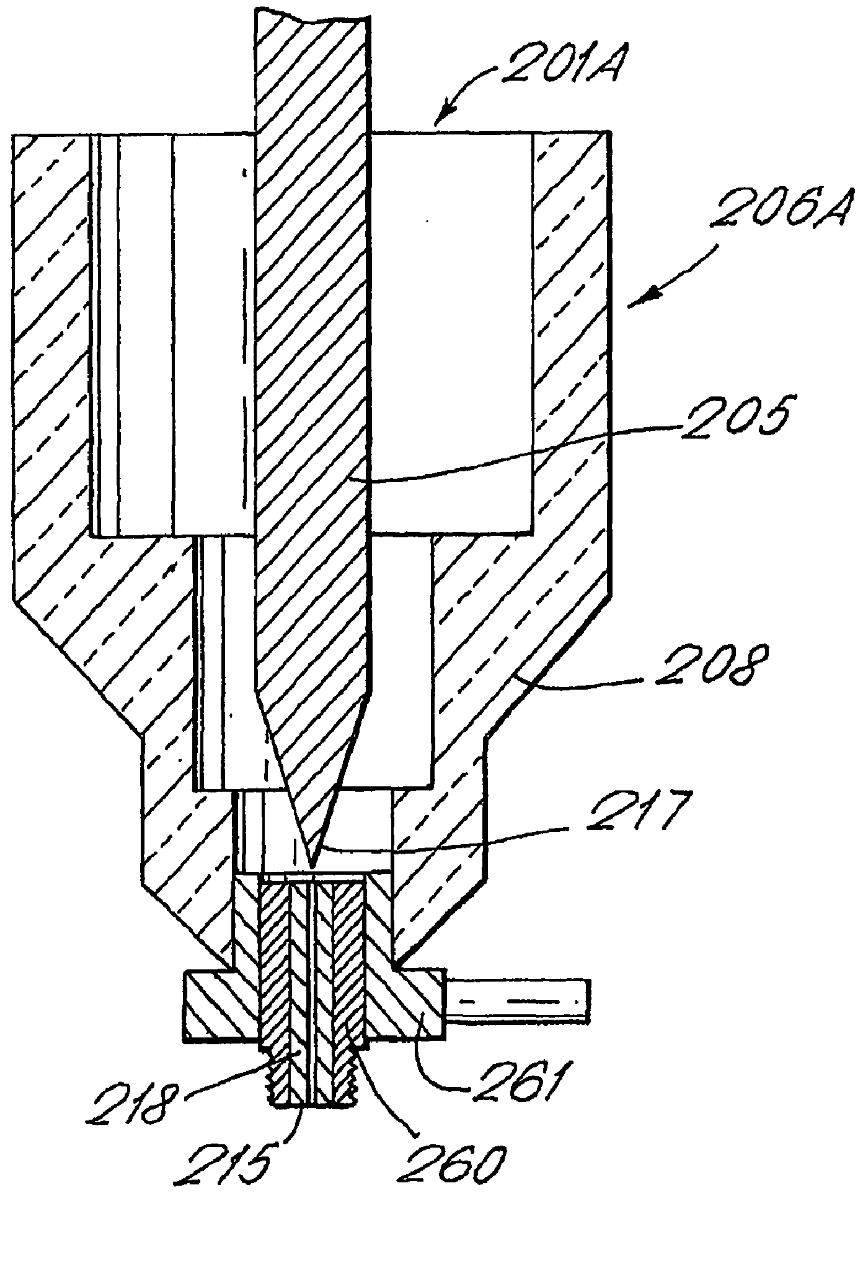


Fig.4b.

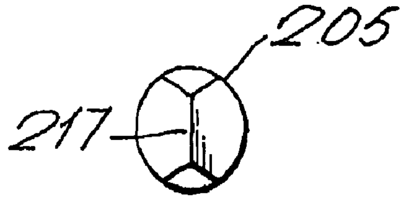
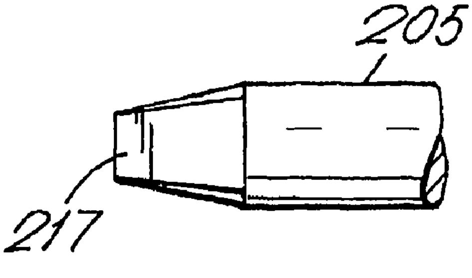


Fig.4a.



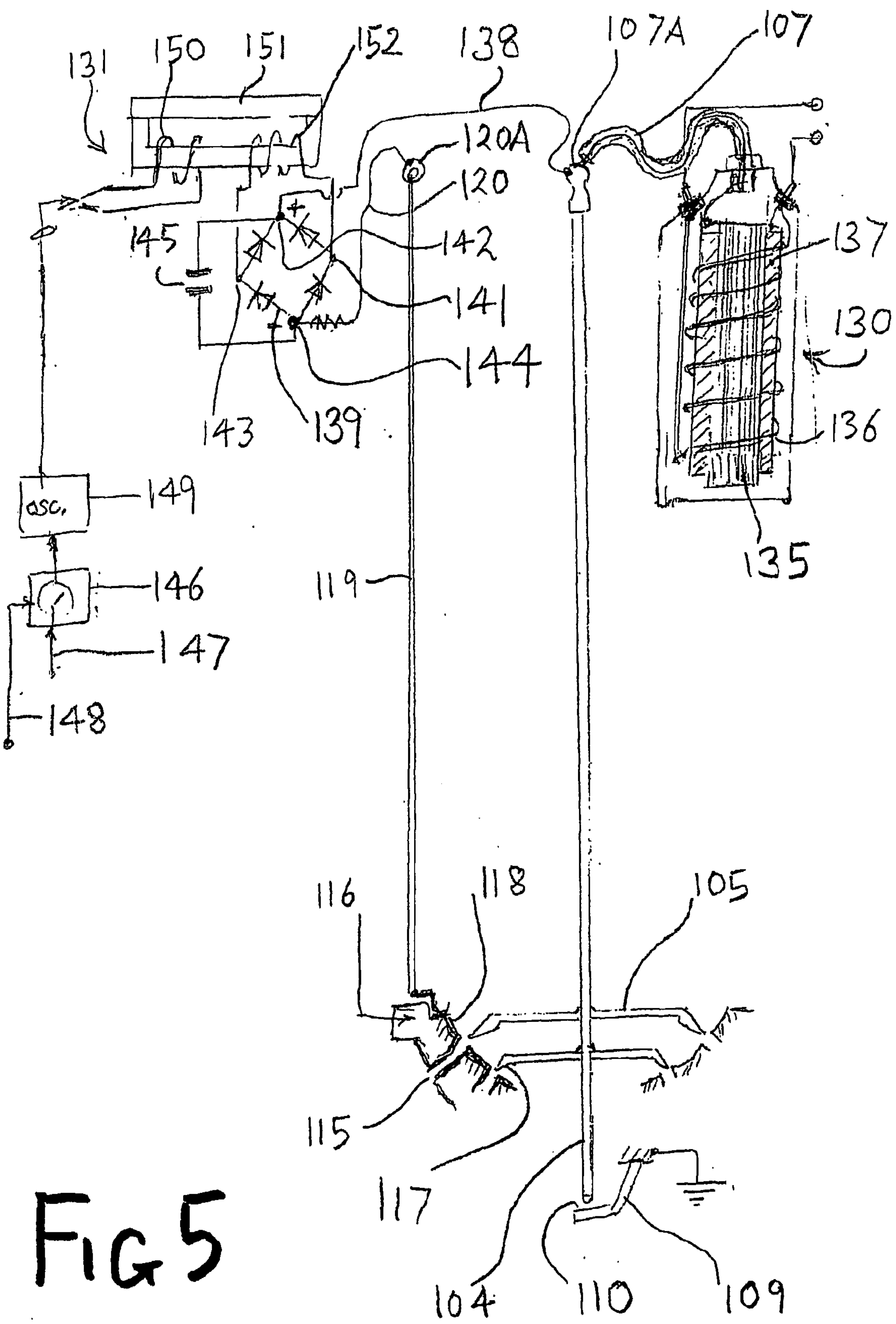

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FIG 5

FUEL INJECTION ASSEMBLY

[0001] The present invention relates to a fuel injection assembly.

[0002] It is known to provide, for example as disclosed in U.S. Pat. No. 5,234,170, means for achieving finely divided atomisation of fuel from an injector into the cylinder of an internal combustion engine, known as the charged injection process. The means consists essentially of a pair of electrodes situated on either side of the delivery orifice of a fuel injector. These electrodes supply a high voltage, low current charge to the fuel stream as it passes through the orifice. This causes the behaviour of the fuel stream as it leaves the orifice to change very substantially when compared with its behaviour in the absence of the electrostatic charge. In the absence of electrostatic charge, the concentrated fuel stream proceeds some distance from the injector before beginning to break up into sub-streams and eventually droplets. It is found that the electrostatic charge causes the stream to break up close to the orifice and form small droplets, which are charged and which therefore repel each other and scatter rapidly to form a mist or aerosol extending widely into the confined volume of the cylinder. It is also disclosed that this process of greatly enhanced atomisation of the fuel stream occurs effectively with much reduced delivery pressure compared with those pressures conventionally used in direct injection fuel injectors.

[0003] In DE-A-19629171 there is disclosed a known juxtaposition of a fuel atomisation device and a spark plug in the cylinder head of an internal combustion engine. The ignition system has a system for producing a fuel cloud in a combustion chamber and a spark plug projecting in the combustion chamber. The system for producing the fuel cloud includes an ionising electrode for the electrical charging of the fuel cloud. The spark plug has no earth electrode. The system for producing the fuel cloud may have an injection valve, or can be a carburettor. The system for electrically charging the fuel cloud may have a laser. The spark plug and the electrical charging device are mounted separately in the cylinder head of the engine.

[0004] In recent years, a new genus of spark ignition, gasoline fuelled internal combustion engine has grown which is known as the Gasoline Direct Injection (GDI) Engine. These engines are characterised by having the gasoline fuel injected directly into the cylinder via an injector the delivery orifices of which are located in the combustion chamber. In such engines, the fuel is delivered either all in one pulse or in a number of pulses phased through the period of the induction and compression strokes or, in the case of 2-stroke GDI versions, through the compression phase only. In all cases, there is less time for full atomisation of the fuel to take place than is the situation in previous forms of spark ignition gasoline engines where the air/fuel mixture has been prepared externally from the cylinder. It has therefore been a feature of the art in GDI engines to locate the injector in the most favourable position and to use the spray pattern most effectively so as to achieve the most rapid vaporisation of the fuel which is possible within the limitations which are imposed by the requirement to deliver the fuel directly into the cylinder. This means that the most favoured location for the injector nozzle is central within the combustion chamber. This is also the most favoured location of the spark plug.

[0005] In FR-A-900408 (Jezler) there is disclosed a fuel injection assembly for mounting on an internal combustion engine. A combined spark plug and fuel atomiser is provided in which fuel passes through a spark plug to a fuel atomisation chamber in an inner end of the spark plug. The dimensions of the chamber are selected so that the fuel is retained by the effect of capillarity. A high tension spark voltage is applied across the fuel atomisation chamber. The effect of this voltage pulse across the stationary fuel in the atomisation chamber is that the fuel is strongly heated, dissociated and ionised by the current, producing an explosive action by which the fuel is expelled out of the chamber into the combustion chamber of the engine. The device is connected externally by two electrical connectors comprising a conventional HT terminal and a conventional threaded earth connection into the cylinder block of the engine. A single potential difference is provided for both atomising and igniting the fuel.

[0006] It is an object of the present invention to provide a fuel injection assembly which allows the favourable positioning of various components necessary to the operation of an internal combustion engine, in the most favourable locations in the combustion chamber.

[0007] According to the present invention there is provided a fuel injection assembly comprising a main structure for mounting on an internal combustion engine, the main structure having an array of orifices for injecting fuel directly into the combustion chamber of the internal combustion engine, the main structure also having mounted thereon an electrode structure for atomising and igniting the fuel including a spark electrode adapted to provide a fuel ignition spark for the internal combustion engine, in which the electrode structure includes charge electrodes positioned to provide an electric field which passes through a flow of fuel for charging fuel particles in the flow to improve atomisation, and the main structure has three electrical connectors adapted to be connected externally to three different potentials, and being connected to said electrodes to allow provision of a relatively low potential difference for atomising the fuel and a relatively high potential difference for igniting the fuel.

[0008] Preferably the main structure is adapted for removable mounting on an internal combustion engine so as to protrude into the combustion chamber of the engine. Conveniently the main structure has a threaded portion adapted to co-operate with a threaded aperture in an internal combustion engine adapted to receive a conventional spark plug. Also conveniently the main structure has an inner portion of insulating material and an outer portion of conducting material adapted to be secured to the main casing of an internal combustion engine.

[0009] Normally in embodiments of the invention it will be arranged that the main structure has an internal region adapted to be positioned in communication with the interior of a combustion chamber when the structure is mounted on an internal combustion engine, and an external region adapted to be external to the combustion chamber when the main structure is mounted on the engine. Conveniently the assembly includes a fuel supply passage passing through the main structure from a fuel supply inlet positioned at the external region of the main structure, to the said fuel injection orifice or orifices, which are positioned at the said internal region of the main structure.

[0010] Conveniently the spark electrode is exposed from the main structure at the said internal region thereof, and passes through the main structure to an electrical connector means at the external region of the main structure, for connection to a high tension voltage lead.

[0011] In one particularly preferred form the said spark electrode is electrically connected to a first of the said charge electrodes. Preferably the spark electrode is connected to the first charge electrode by a connection positioned within the main body. In a particularly preferred form according to the invention, it is arranged that the assembly includes a voltage supply unit arranged to supply varying potentials to the spark electrode and to a second of the charge electrodes, the voltage supply unit being arranged to vary the potentials supplied during a firing cycle of an internal combustion engine so as to maintain a potential difference between the first charge electrode and the second charge electrode at a first, constant, value for atomisation of fuel, and to provide a potential at the spark electrode which varies between a first preselected value sufficiently small to avoid generation of an ignition spark, and a second preselected value sufficiently large to provide an ignition spark.

[0012] In preferred arrangements according to the invention, the said spark electrode is a primary spark electrode, and there is provided on the main structure at least one secondary spark electrode spaced apart from the primary spark electrode to provide a fuel ignition spark for the internal combustion engine; the said charge electrodes comprising at least one primary charge electrode and at least one secondary charge electrode, spaced apart across a fuel flow path of the assembly. It is to be appreciated that there may be provided more than one primary spark electrode, but it is conveniently found that a single primary spark electrode is sufficient.

[0013] Preferably the spacing between a primary charge electrode and an associated secondary charge electrode is a distance in the range 25 microns to 500 microns, most preferably in the range 125 microns to 200 microns. In one preferred form the spacing is 150 microns.

[0014] Conveniently the primary spark electrode is electrically connected to an ignition source connector mounted on the main body and adapted to be connected to a source of ignition potential to provide a fuel ignition spark for the internal combustion engine. Conveniently the ignition source connector may comprise a conventional high tension terminal as found on a conventional spark plug. Also conveniently it is provided that the said at least one secondary spark electrode is connected to an earth portion of the assembly adapted to be earthed to a casing of an internal combustion engine.

[0015] In one form of the invention it may be arranged that the said at least one secondary charge electrode is connected to an earth portion of the assembly adapted to be earthed to a casing of an internal combustion engine, and the said at least one primary charge electrode is connected to a charge source connector mounted on the main body and adapted to be connected to a source of potential for providing the said atomisation of fuel. However this form is not preferred. In a preferred form according to the invention the said at least one primary charge electrode is electrically connected to the said primary spark electrode, and the said at least one secondary charge electrode is connected to a charge source connector mounted on the main body and adapted to be connected to a source of potential for providing the said atomisation of fuel. Preferably the said at least one primary charge electrode is connected to the said primary spark electrode by a connection positioned within the main body.

[0016] In operation, it will conveniently be arranged that primary spark electrode is electrically connected to a source of ignition potential to provide a fuel ignition spark for the internal combustion engine, and that the said at least one secondary spark electrode is connected to an earth portion of the assembly adapted to be earthed to a casing of an internal combustion engine. In a particularly preferred form according to the invention the assembly includes a voltage supply unit arranged to supply varying potentials to the primary spark electrode and to the secondary charge electrode, the voltage supply unit being arranged to vary the potentials supplied during a firing cycle of an internal combustion engine so as to maintain a potential difference between the primary charge electrode and the secondary charge electrode at a first, constant, value for atomisation of fuel, and to provide a potential difference between the primary spark electrode and the said at least one secondary spark electrode which varies between a first preselected value sufficiently small to avoid generation of an ignition spark, and a second preselected value sufficiently large to provide an ignition spark.

[0017] Preferably the said first value lies in the range 2 to 14 kV, most preferably in the range 5 to 8, and preferably the second value lies in the range 10 to 50, most preferably in the range 35 to 45 kV.

[0018] In a particularly preferred form, the main structure includes an annular distribution gallery positioned around a central axis of the main structure, the said at least one primary charge electrode providing an annular edge facing into the distribution gallery and the said at least one secondary charge electrode being positioned in an annular configuration around the distribution gallery on a surface of a wall thereof. Preferably the said injection orifices are directed outwardly from the annular distribution gallery.

[0019] It is also preferred that the said primary spark electrode is aligned along a central longitudinal axis of the main structure. Conveniently the said primary spark electrode produces the ignition spark of the internal combustion engine in co-operation with a plurality of secondary spark electrodes distributed around the said main longitudinal axis.

[0020] It may occur that there is difficulty in electrical leakage in the main structure of the assembly, between the spark electrode, and conductors leading to the charge electrode. To avoid this, it is preferred the said main structure includes within the interior of the structure an electrostatic shield member extending between the said spark electrode and electrical conductors leading to the said charge electrode.

[0021] It is to be appreciated that where features according to the invention have been set out herein with reference to a fuel injection assembly, these features may also be provided in accordance with a method of injecting and igniting the fuel in an internal combustion engine, and vice versa. In particular there may be provided in accordance with another aspect of the invention a method of injecting and igniting the fuel in an internal combustion engine comprising the steps of injecting fuel directly into the combustion chamber of the internal combustion engine through an array of orifices positioned in a main structure of a fuel injection assembly mounted on the internal combustion engine; and supplying current to an electrode structure mounted on the main structure for atomising and igniting the fuel, including supplying a pulsed potential to a spark electrode of the electrode structure to provide a fuel ignition spark for the internal combustion engine; the method including supplying a potential difference across charge electrodes of the electrode structure positioned to provide an electric field which passes through a flow of fuel for charging fuel particles in the flow to improve atomisation; and the method including supplying a relatively low potential difference for charging the fuel particles to improve atomisation and a relatively high potential difference to provide the fuel ignition spark.

[0022] In a preferred form of the method according to the invention, it may be provided that the spark electrode is electrically connected to a first of the charge electrodes, and that the method includes supplying varying potentials to the spark electrode and to a second of the charge electrodes, varying the potentials supplied during a firing cycle of the internal combustion engine so as to maintain a potential difference between the first charge electrode and the second charge electrode at a first, constant, value for atomisation of fuel, and so as to provide a potential at the spark electrode which varies between a first preselected value sufficiently small to avoid generation of an ignition spark, and a second preselected value sufficiently large to provide an ignition spark.

[0023] Embodiments of the invention may provide an application of the enhanced atomisation and vaporisation capability of the charged injection process encapsulated within a single unit which also acts as a conventional spark plug. Thus, the two functions of fuel delivery with atomisation, and spark ignition, can be performed from a single unit which can be screwed into a standard spark plug orifice in the location in the combustion chamber which is most favourable for both of these functions.

[0024] Embodiments of the invention will now be described by way of example with reference to the accompanying drawings in which:

[0025] **FIG. 1** is a cross-section along a longitudinal axis through a fuel injection assembly constituting a first embodiment of the invention;

[0026] FIG, 1*a* is an enlargement of the cross-section in the region where the precise location of fuel delivery orifices in relation to the active tip of the charge electrode is shown;

[0027] **FIG. 2** is a cross-section through a second embodiment of the invention;

[0028] **FIG. 3** is a cross-section along a longitudinal axis through a further fuel injection assembly which shows modifications from the assembly of **FIG. 1**, and which is a preferred embodiment of the invention;

[0029] **FIG. 3*a*** is a plan view from below of the fuel injection assembly shown in **FIG. 3**, and **FIG. 3*b*** is a cross-section on the lines B-B in **FIG. 3**;

[0030] **FIG. 4** is a cross-section along a longitudinal axis through a test rig utilised in determining the spacing of various electrodes shown in the embodiment of **FIG. 3**, **FIG. 4*a*** shows a side view of a tip of an electrode shown in **FIG. 4**, and **FIG. 4*b*** shows an end view of the electrode tip; and

[0031] **FIG. 5** is a diagrammatic circuit diagram of one form of voltage supply assembly which may be utilised in association with the fuel injection assembly of **FIG. 3** embodying the invention;

[0032] A first embodiment shown in cross-section in **FIG. 1** consists of a combined spark ignition and fuel atomisation device constituted by a main structure indicated generally at 1A. An inner insulating portion **6** is contained by a metal outer casing **1** having a standard spark plug thread **2** and hexagonal periphery at **3** enabling the device to be screwed into a spark plug hole provided in the combustion chamber (not shown). A spark electrode **4**, constituting a primary spark electrode, and a cylindrical electrostatic discharge electrode **5**, constituting a primary charge electrode, are supported concentrically within the main ceramic insulator **6** which fills most of the space contained within the outer casing **1**.

[0033] The spark electrode **4** is connected externally to a conventional HT (high tension) ignition lead having a capacity typically of approximately 40 kV. At the inner tip of the device, the spark electrode **4** is protected by the ceramic insulation material which forms a removable dual function cap **8** of the device. A small number, preferably not less than three, earth electrode extensions **9**, are equally spaced around the inner end of the device and constitute secondary spark electrodes. Each of the spark gaps **10** is initially set to be of equal length. This provides spark gaps with a length which will tend to remain substantially constant over the life of the device because any tendency for the spark to persistently occur via one only of the earth electrode extensions **9**, will result in erosion of that electrode which will cause an increase in its spark gap. This gives a consequent increase in resistance to the earth path which it affords, which will then favour one or other of the alternative earth paths afforded by the other earth electrode extensions **9**.

[0034] A petrol fuel supply **11** is routed through the device via a metal ripple **12** leading to a cored hole **13** which is formed through the ceramic insulator **6** prior to the firing stage of manufacture. The cored hole **13** conducts the fuel into an annular distribution gallery **14** in the dual function cap **8**. Numerous orifices **15** perforate an outer wall **16** of the distribution gallery **14**. The positions of the orifices **15** are such that the fuel streams to which they give rise during the periods of delivery pas between the earth electrode extensions **9**. The arrangement of the orifices **15** in relation to an annular active edge **17** of the primary charge electrode **5** is shown in greater detail in **FIG. 1*a***. The orifices are arranged in an arc such that fuel is distributed through a wide field in the cylinder downwards toward the piston. The inner and outer surfaces of the distribution gallery **14** are concentric with the active edge **17** of the primary charge electrode **5** to within a tightly limited tolerance. The outer surface of the distribution gallery **14** is coated with a conductive metallised skin **18** which is permanently attached to the ceramic surface via a molecular bond. This metallised skin extends to the end of the threaded part of the outer casing **1** thus providing a ground return for the electrostatic charge. The metallised skin **18** constitutes a secondary charge electrode for producing, with the primary charge electrode **5**, the electrostatic discharge for producing atomisation of fuel.

[0035] The electrostatic discharge is effected from the active edge **17** of the charge electrode **5** by means of an electric pulse excitation along a lead **20** in the order of 10 kV which is delivered to the charge electrode **5** via a conductor **19** through the ceramic insulator **6** from an oscillator (not shown). The lead **20** is connected to the conductor **19** at an electrical connector **20**A in the form of a conventional electrical terminal. In general the arrangement and operation of the charge electrodes **5**, **18** may be as set out in U.S. Pat. No. 5,234,170. The charge electrode **5** is protected from inadvertent excitation which might otherwise arise as a result of leakage through the ceramic insulator, by means of an electrostatic shield **21** which consists of a strip of copper of approximately 25 microns thickness located within the ceramic insulator **6**. The shield **21** extends from a position close to the top of the charge electrode **5** to a point in the upper part of the ceramic insulator **6** where the conductor **19** is so distant from the spark electrode **4** as to provide no further risk of HT ignition voltage leakage. The upper end of the electrostatic shield **21** is connected via an earth lead **22** and external connector **22**A to a convenient earth point.

[0036] During operation of the device, fuel is supplied from a delivery system (not shown) which incorporates a standard means of supply of fuel at a pressure within the range 2 to 10 Bar, via a metering control of standard type (also not shown) which can typically be operated by a solenoid control valve with electronic means of control providing a variable period of opening according to the fuelling regime required by the particular engine in which the device is installed. Switching of an excitation pulse to initiate or terminate charge delivery from the charge electrode **5** can also be controlled electronically, preferably via a sensor signal from a pressure transducer (not shown) which is able to detect the existence of sufficient pressure in the fuel delivery supply **11** to cause fuel flow through the device. In this way, the electrostatic charge delivery only takes place when a flow of fuel is established through the orifices **15**. At all other times, activation of discharge from the charge electrode **5** is protected by means of the electrostatic shield **21**. Thus any inadvertent sparking which might initiate a combustion event as a result of HT activity is effectively prevented.

[0037] **FIG. 2** shows a further preferred embodiment of the invention in which the electrostatic shield **21** is formed as a helical earth shield around the conductor **19**. This extends for a substantial portion of the conductor length, over which exists the risk of leakage from the HT ignition source. The helical shield **21** extends to a point close to the lower end of the conductor **19** where it will continue to afford protection from HT leakage while maintaining an adequate insulating distance from the charge electrode **5** and the conductor **19**.

[0038] **FIGS. 3**, **3***a* and **3***b*, show a further, and preferred, embodiment of the present invention incorporating modifications of the embodiment shown in **FIG. 1**. Where components in **FIG. 3** correspond generally to components in **FIG. 1**, these are indicated by like reference numerals but starting at a base of **100**. It is particularly to be noted that **FIG. 3***c* is not drawn to scale. The diameters of the cylindrical components are exaggerated by a multiple of approximately 2.5 compared with axial parameters of the assembly.

[0039] Referring firstly to **FIG. 3, a** fuel injection assembly embodying the invention has a main structure **101**A consisting of an upper structure **101**B and a lower cap **108**, the two being joined together in use at a threaded junction **123**. The upper structure **101**B has an inner insulating portion **106** contained by a metal outer casing **101** having a standard spark plug thread **102** and hexagonal periphery at **103** enabling the device to be screwed into a spark plug hole provided in the cylinder head wall **124** of an internal combustion engine.

[0040] The main structure **101**A has an array of orifices **115** in the lower cap portion **108** for injecting fuel directly into the combustion chamber. The main structure **101**A also has mounted thereon primary charge electrodes **105** and secondary charge electrodes **118** positioned to provide an electric field which passes through the flow of fuel for charging fuel particles passing through the perforations **115** to improve atomisation. The main structure **101**A also has mounted thereon a primary spark electrode **104** and secondary spark electrode **109**, adapted to provide a fuel ignition spark for the internal combustion engine.

[0041] The primary spark electrode **104** is connected internally through the main structure **101**A to an ignition source connector **107**A which may be a conventional electrical terminal of the kind used on a conventional spark plug. The primary charge electrodes **105** are connected internally within the main structure **101**A to the primary spark electrode **104**. The secondary charge electrodes **118** consisting of the conductive skin, are connected by way of a conductor **119** through the main structure **101**A to a charge source connector **120**A which again may be a conventional electrical terminal.

[0042] The secondary spark electrode **109** is connected directly to the metal outer casing **101**, and is earthed through the connection of the casing **101** to the cylinder head block **124** by the thread **123**. The spark gap between the primary spark electrode **104** and secondary spark electrode **109** is indicated at **110**. To prevent leakage between the primary spark electrode **104** and the conductor **119** there is provided an electrostatic shield member **121**. The electrostatic shield member **121** is connected to earth by an electrical connection known as a pigtail, indicated at **122**.

[0043] A petrol fuel supply is fed along a fuel feed line **111** leading through a cored hole **113** which is formed through the ceramic insulator **106** prior to the firing stage of manufacture. The fuel supply hole **113** leads to an annular distribution gallery **114** from which the orifices **115** lead outwardly through an outer wall **116** of the distribution gallery **114**. The potentials required for the primary spark electrode **104** and secondary charge electrodes **118**, are provided respectively along an HT lead **107** leading to the terminal **107**A, and along an electrical lead **120** leading to the terminal **120**A. The leads **107** and **120** are connected to output terminals **107**B and **120**B of a voltage supply assembly **125**, to be described in more detail hereinafter.

[0044] The required electrical connections between components in the upper supporting structure **101**B and the cap **108** are made by spring metal strips which make electrical contact when the cap **108** is screwed onto the upper supporting structure **101**B. The primary spark electrode **104** has at its upper end a U-shaped spring strip **126** secured thereto which is biased openly in the upward direction so as to make good electrical contact with an HT conducting rod **104**B which passes through the inner insulating portion **106** of the upper supporting structure **101**B and leads to the terminal **107**A. Similarly a spring strip **127** is fixed to an upper region of the metallic layer **118** which constitutes the secondary charge electrode. The spring strip **127** is similarly a U-shaped spring strip biased openly and upwardly so as to bear against the conductor **119** when the upper supporting structure **101**B and cap **108** are screwed together. A sealing ring **128** is provided between the lower end of the metal casing **101** and the upper end of the wall **116** of the distribution gallery **114**, to provide a seal against leakage of fuel in the gallery **114**.

[0045] There is substantial advantage in manufacturing the assembly in two separable parts. The upper main supporting structure **101**B contains the central conducting element **104**B which carries the high voltage power to the electrodes. The conductor **104**B is surrounded by the ceramic insulation material **106** contained within the outer metallic cylindrical wall **101**. This wall is externally threaded at its lower end **123** to enable attachment of the lower section, which is formed as the separate cap assembly **108**. The cap contains the electrodes for both spark ignition of the fuel/air mixture in the combustion chamber and for electrostatic charging of the fuel prior to its delivery into the combustion chamber. The cap is fabricated in ceramic material **116**, **108**A which supports the electrodes **105**, **104** in correct position. The ceramic portion is attached to an internally threaded cylindrical metal support **129** which enables it to be screwed into position where the components of the cap can communicate with the services provided in the upper structure **101**B.

[0046] **FIG. 3***a* is an axial view from the combustion chamber end, of the lower cap part **108** of the injector/atomiser. It shows a cup-shaped ceramic part **108**A, which is perforated by two rings of orifices **115** and supported by an internally threaded metal cylindrical outer part **129**. Eighteen orifices **115** are shown, equally spaced peripherally and so that the fuel jets which are emitted do not interfere with the earth electrode **109** for the ignition spark system.

[0047] **FIG. 3***b* is an axial section at lines B-B through the upper main supporting structure of the injector/atomiser. It shows the ceramic insulating material **106**, which fills most of the volume contained by the outer metallic cylindrical wall **101** and supports in position the following components, namely: the central high voltage power conductor **104**B, the electrostatic shield tube **121**, the polarising voltage conductor **119**, and the fuel feed line **111**.

[0048] The positions of the central high voltage power conductor **104**B and the electrostatic shield tube **121** are axi-symmetrical but the positions of the polarising voltage conductor **119** and the fuel feed line **113** do not require to be precisely determined. Thus, during the compression and firing phases of manufacturing the assembly, the positions of the latter two components may move slightly without harming the efficacy of the whole assembly.

[0049] The upper main structure **101**B has the second external thread **102** applied on its outer wall **101**. This must be above, and at a larger radius than that of the outside of the lower cap section **129**. Thus, the whole assembly **101**A may be screwed into the threaded orifice commonly provided in the cylinder heads of spark ignited engines, for the spark plug.

[0050] Returning to consideration of the secondary charge electrodes **118**, the metallising surface conductor **118** on the lower ceramic cap **108**, which connects with the polarising voltage conductor **119** in the upper structure **101**B, is confined to the inner surface only of the ceramic cap, where it forms the secondary electrode for the electrostatic ionising system. The gap between the ionising power supply electrode **105** and the secondary electrode **118** is thus seen clearly as the gap between the tip **117** of the primary electrode and the inner surface **118** of the ceramic wall **116** where it surrounds an orifice **115**. This gap must be substantially equal for all of the orifices.

[0051] The main modification shown in **FIG. 3** compared with **FIG. 1**, is that the fuel atomisation elements and the ignition spark generation elements share a common electrode. The additional secondary electrode **118** is provided for the fuel atomisation elements, whilst the secondary electrode **109** for the spark ignition remains as previous disclosed in **FIG. 1**, in the form of a protrusion **109** from the outer casing **101** of the assembly, thus providing an earth electrode.

[0052] It is commonly understood, that at a certain point in the engine cycle of a typical spark-ignited engine, when the piston is just about to reach TDC (top dead centre), a spark plug is activated. A potential difference of approximately ±40 kV (ranging from 10 kV to 50 kV depending on the individual device) is applied between the electrode of the spark plug and its earth casing. This causes an electrical break-down, in the form of a visible arc or spark, in the engine cylinder, across the fuel air mix, which results in ignition of the fuel. Thus, throughout the engine cycle, a conventional spark plug electrode is held at OV then pulsed to approximately ±40 kV at the ignition point, and returned to OV after the spark discharge. The secondary electrode consists of the earthed casing of the plug, which is always maintained at OV.

[0053] In the device illustrated in **FIG. 3**, the single shared electrode system **104** and **105** will be maintained at −7 kV throughout the majority of the engine cycle, pulsed to −40 kV at the ignition point and returned to −7 kV after the spark discharge takes place. The secondary electrode **109** for spark ignition, connected to the metallic outer casing **101**, will be maintained earthed throughout the cycle. The application of a 7 kV potential across the spark plug electrodes **104**, **109** will not impair the performance of the spark plug and will be insufficient to cause sparking.

[0054] Also in the proposed device, a potential difference of approximately 7 kV (in the range 2 kV to 14 kV) is maintained, consistently, between the shared electrode system **104**, **105** and the secondary atomiser electrode **118**. The shared electrode system **104**, **105** can be held at a negative or positive potential with respect to the secondary atomiser electrode **118**, but preferably is held negative. The 7 kV potential causes a corona discharge from the sharp edge **117** of the electrodes **105**, which charges the fuel passing between the atomiser electrodes **118**.

[0055] The shared electrode system **104**, **105** will alternate between −7 kV and 40 kV, depending on the point in the engine cycle. In order for a 7 kV potential difference to be maintained between the atomiser electrodes **105** and **118**, the voltage of the secondary atomiser electrode **118** will have to be varied and synchronised with the shared electrode system

104, 105, alternating between 0 kV and −33 kV. An electronic control unit for providing the −40 kV pulse, timed as required to achieve effective combustion of fuel, is shown at **125** and is essentially common to those widely employed in current spark ignition using a coil with a large number of windings on the secondary circuit. Means for providing the voltage differential of −7 kV at all times are illustrated in **FIG. 5**. **FIG. 5** also shows a linking bridge **139** between the two sources of high voltage potential, i.e. a source **130** supplying energy for the ignition spark and the source **131** supplying the energy source for the atomiser. This linking bridge **139** sustains the differential of −7 kV between the primary and secondary electrodes **105, 118** of the atomiser at all times. Thus at the time when voltage in the ignition conductor **104** rises to −40 kV, the voltage in the atomiser conductor **119** simultaneously rises to −33 kV.

[**0056**] Referring now to **FIG. 5**, the source of ignition potential for the primary spark electrode **104** is indicated at **130**. This comprises a conventional ignition coil comprising an iron core **135**, a primary coil **136** and a secondary coil **137**. The HT lead **107** is connected to the terminal **107**A. A further lead **138** connects the ignition voltage source **130** to the linking bridge **139** formed of four diodes arranged to provide four connection points **141, 142, 143** and **144**. The lead **138** is connected to the connection point **142** and the charge voltage lead **120** is connected to the connection point **144**. A capacitor **145** is connected across the connection points **142** and **144**.

[**0057**] The source **131** for the polarising or charge voltage for producing atomisation is driven by DC power supplied to a fast switch **146** at an input terminal **147**. A timing pulse is supplied to a further terminal **148** of the fast switch **146**, and is driven in synchronisation with the conventional timing circuit for triggering the ignition coil **130**. The output of the fast switch **146** is fed to an oscillator **149** the output of which is fed through a primary coil **150** of a polarising transformer **151**. A secondary coil **152** of the transformer **151** is connected across the connection points **141, 143** of the bridge **139**.

[**0058**] Reference will now be made to **FIGS. 4, 4***a* and **4***b*, which show in axial section a design rig used to determine certain parameters of the fuel injection assembly embodying the invention shown in **FIG. 3**. **FIG. 4** shows a single orifice fuel atomiser rig **260**, in which the distance between an end tip **217** of a power supply (high voltage) electrode **205** and an earth electrode **218** can be varied. An end cap **208** of the atomiser rig is illustrated to show details of the mounting defining an orifice **215** in order to indicate the variable position which the orifice **215** can occupy in relation to the tip **217** of the electrode **205**.

[**0059**] It will be seen that the orifice **215** is defined by a steel tube (forming the earth electrode **218**) with a through hole **215** along its axis. The bore of the hole is 80 microns (0.080 mm). This orifice tube **218** is pressed into a steel probe carrier **260** of the same axial length (2.82 mm). The tube **218** fits sufficiently tightly within the carrier **260** so as not to be dislodged by the pressure of the fuel when fuel is flowing through the atomiser. The steel probe carrier **260** fits within a brass bush **261** which is firmly fixed into the ceramic end of the atomiser cap **208**. The brass bush **261** also provides a conductive path to earth. The precision fit of the steel probe **260** within the brass bush **261** is such as to prevent inadvertent movement due to pressure of the flowing fuel but it is capable of sliding movement inwards, i.e., towards the power supply electrode **205** which movement can be controllably provided by a micrometer (not shown). The steel probe **260** also has a short external thread at its outer end, by means of which it can be withdrawn away from the power supply electrode **205**.

[**0060**] When used to determine electrode spacing for the embodiment of **FIG. 3**, the rig of **FIG. 4** is mounted vertically with the orifice **215** directed downwards to produce a jet of fuel which can be clearly observed. Standard fuel is supplied to the atomiser at a pressure of 5 Bar and the jet can be seen as a clear, needle shaped stream issuing into the receptacle below without breaking up into droplets. When progressively increasing negative voltage is applied to the electrode **205**, a change in the form of the jet is visible. When the voltage reaches approximately 3 kV, the form of the jet can be seen to begin to break up before reaching the receptacle, i.e. a distance of approximately 500 mm from the orifice. This effect becomes progressively more extreme until the voltage reaches 5 to 8 kV, when shattering of the jet stream is evident from approximately 10 mm distance from the orifice. Further increase in applied voltage produces no greater effect above approximately 8 kV, until the limit of the insulation at the external terminal of the electrode is reached at about 11 kV.

[**0061**] A series of tests was carried out with this apparatus in order to determine variations in the atomising performance with varying the critical distance between the tip of the electrode and the inner end of the orifice. The critical distance illustrated in **FIG. 4** is 150 microns (0.150 mm). The objective of investigating this variable is in order to observe the variation in the strength of the electric field in the region between the tip of the power supply electrode **205** and the nearest earth point which is formed by the inner end of the orifice tube **218**.

[**0062**] The maximum critical distance at which some atomising effect was visible as a result of voltage applied to the power supply electrode **205** was approximately 500 microns (0.500 mm). However, visible improvement in atomisation was apparent as the critical distance was reduced from this value. Best atomising performance was apparent at about 150 microns. Performance with critical distance below 100 microns became intermittent rather than smoothly consistent, although atomisation was still apparent at a critical distance as small as 25 microns.

[**0063**] From this experiment, it can be concluded that the preferred range for the critical distance is from 25 microns to 500 microns. Within this range the highly preferred range is 125 to 200 microns. The fuel flow rate was measured at the supply pressure of 5 Bar which was used throughout the test series. It was found to be 26.1 ml per minute. No significant effects due to variation of the applied voltage were found over the range of critical distance observed i.e. the optimum effect remained within the range approximately 5-8 kV.

[**0064**] Returning now to consideration of **FIGS. 3 and 5**, an objective of the design is to prevent the rapid voltage change for igniting the fuel/air mixture from seriously influencing the electrical charge imparted to the fuel droplets. The various electrical circuits should be designed to have high immunity to mutual disturbance by adherence to the principles of electromagnetic compatibility. The fuel charge is injected into the combustion area by pulsed timing of the injection pressure, and is charged with a particular polarity by imposing a strong potential gradient. The object is to make the charged droplets repel one another after emerging from the nozzle apertures.

[0065] The spark-plug voltage-time wave can be produced as the result of contacts interrupting a flow of 2 amps through the primary of an ignition coil. The energy of the collapsing magnetic field is released into a capacitor, resulting in a damped oscillation estimated at about 3 kHz. Typically the secondary winding steps up the output to 40 kV peak, which is enough to jump a gap of 0.030" (0.75 mm) at 10 bar pressure. Variants (such as electronic ignition) may deliver the energy stored in a capacitor charged to 250 V, into the primary of a similar coil used as a step-up transformer. The resulting oscillatory waveform is similar.

[0066] The engine rotation can be used to control the timing of all events. A toothed wheel and magnetic transducer can subdivide 180 teeth at 2 degrees with a precision of about 0.1 deg. Alternatively a quartz clock and suitable dividers can perform the function.

[0067] The voltages used are important. The ionising potential preferably needs to be held stable within 10 percent. The supply at 3 to 7 kV feeds a full-wave bridge rectifier with good regulation. The incoming a.c. voltage is generated by a four-element switching-transistor bridge fed into a coil on a transformer-core which is physically separated by a polythene disk distant enough from the secondary to resist sparks jumping across the windings. Energy content (expressed to joules) and air/fuel ratio determine ignition success.

[0068] The injector chamber **114** is built as a bowl-shaped assembly with the copper ring-seal **128** allowing the atomiser assembly **108** to be aligned before closing the end of the unit with the upper portion **101**B. The nozzle apertures **115** are metallised at **118** and connected to the voltage source via the thin rod **119**. The ioniser coronet shaped electrodes **105** can be electron-beam welded in place on the spark-plug core rod **104** before final assembly. The electrical potential gradient across the electrodes **105** to **118** is held substantially constant by a capacitor of low impedance connected between the ioniser electrode **105** and the metallised aperture electrode array **118**.

[0069] Alternative arrangements are feasible in principle. It can be arranged to carry the electrode system **105** of the polariser up and down in potential by a negative swing of 40 kilovolts, because it forms part of the same metal structure as the ignitor electrode **104**. Also it can be arranged as far as possible, to keep the polarising circuit **105**, **118** and ignitor circuit **104**, **109** electrically independent of each other. This requires the polarising circuit to act as a unit having low impedance at high rates of change of voltage. The electrical path from the polariser crown electrode **105** to the perforated electrode **118** should preferably be capacitive. The pigtail connection **122** is needed to ground the shield tube **121** to the housing **101**. The simple electrostatic shield **121** for the connection to the polariser, reduces capacitance from the ignitor impulse rod **104**B to downlead **119**.

1. A fuel injection assembly comprising a main structure (1A, **101**A) for mounting on an internal combustion engine, the main structure having an array of orifices (**15**, **115**) for injecting fuel directly into the combustion chamber of the internal combustion engine, the main structure (1A, **101**A) also having mounted thereon an electrode structure for atomising and igniting the fuel including a spark electrode (**4**, **104**) adapted to provide a fuel ignition spark for the internal combustion engine;

characterised in that the electrode structure includes charge electrodes (**5**, **18**; **105**, **118**) positioned to provide an electric field which passes through a flow of fuel for charging fuel particles in the flow to improve atomisation; and

the main structure has three electrical connectors (**20**A, **120**A; **7**A, **107**A; and **2**, **102**) adapted to be connected externally to three different potentials, and being connected to said electrodes to allow provision of a relatively low potential difference for atomising the fuel and a relatively high potential difference for igniting the fuel.

2. An assembly according to claim 1 in which the main structure (1A, **101**A) is adapted for removable mounting on an internal combustion engine so as to protrude into the combustion chamber of the engine.

3. An assembly according to claim 2 in which the main structure has a threaded portion (**2**, **102**) adapted to cooperate with a threaded aperture in an internal combustion engine adapted to receive a conventional spark plug.

4. An assembly according to any preceding claim in which the main structure has an inner portion (**6**, **106**) of insulating material and an outer portion (**1**, **111**) of conducting material adapted to be secured to the main casing of an internal combustion engine.

5. An assembly according to any preceding claim in which the main structure (1A, **101**A) has an internal region adapted to be positioned in communication with the interior of a combustion chamber when the structure is mounted on an internal combustion engine, and an external region adapted to be external to the combustion chamber when the main structure is mounted on the engine.

6. An assembly according to claim 5 including a fuel supply passage (**3**, **113**) passing through the main structure from a fuel supply inlet (**12**, **112**) positioned at the external region of the main structure, to the said fuel injection orifice (**15**, **115**) or orifices, which are positioned at the said internal region of the main structure.

7. An assembly according to any preceding claim in which the said spark electrode (**4**, **104**) is a primary spark electrode (**4**, **104**), and said electrode structure includes at least one secondary spark electrode (**9**, **109**) spaced apart from the primary spark electrode (**4**, **104**) to provide a fuel ignition spark for the internal combustion engine; the said charge electrodes comprising at least one primary charge electrode (**5**, **105**) and at least one secondary charge electrode (**18**, **118**), spaced apart across a fuel flow path of the assembly.

8. An assembly according to claim 7, in which the spacing between a primary charge electrode (**5**, **105**) and an associated secondary charge electrode (**18**, **118**) is a distance in the range 25 microns to 500 microns.

9. An assembly according to claim 8, in which the said range is 125 microns to 200 microns.

10. An assembly according to any of claims 7 to 9, in which the primary spark electrode (**4**, **104**) is electrically connected to one of said connectors which is an ignition source connector (**7A**, **107A**) adapted to be connected to a source of ignition potential to provide a fuel ignition spark for the internal combustion engine.

11. An assembly according to claim 10, in which the said at least one secondary spark electrode (**9**, **109**) is connected to one of said connectors which is an earth connector (**1**, **101**) adapted to be earthed to a casing (**124**) of an internal combustion engine.

12. An assembly according to claim 11, in which the said at least one secondary charge electrode (**18**) is connected to said earth connector (**1**), and the said at least one primary charge electrode (**5**) is connected to one of said connectors which is a charge source connector (**19A**) mounted on the main body (**1A**) and adapted to be connected to a source of potential for providing the said atomisation of fuel.

13. An assembly according to claim 11, in which the said at least one primary charge electrode (**105**) is electrically connected to the said primary spark electrode (**104**), and the said at least one secondary charge electrode (**118**) is connected to one of said connectors which is a charge source connector (**119A**) adapted to be connected to a source of potential for providing the said atomisation of fuel.

14. An assembly according to claim 13, in which the said at least one primary charge electrode (**105**) is connected to the said primary spark electrode (**104**) by a connection positioned within the main structure (**101A**).

15. An assembly according to claim 13 or **14**, including a voltage supply assembly (**125**) arranged to supply varying potentials to the primary spark electrode (**104**) and to the secondary charge electrode (**118**), the voltage supply assembly being arranged to vary the potentials supplied during a firing cycle of an internal combustion engine so as to maintain a potential difference between the primary charge electrode (**105**) and the secondary charge electrode (**118**) at a first, constant, value for atomisation of fuel, and to provide a potential difference between the primary spark electrode (**104**) and the said at least one secondary spark electrode (**109**) which varies between a first preselected value sufficiently small to avoid generation of an ignition spark, and a second preselected value sufficiently large to provide an ignition spark.

16. An assembly according to any of claims 1 to 6 in which the said spark electrode (**104**) is electrically connected to a first (**105**) of the said charge electrodes (**105**, **118**).

17. An assembly according to claim 16 in which the spark electrode (**104**) is connected to the first charge electrode (**105**) by a connection positioned within the main structure (**101A**).

18. An assembly according to claim 16 or **17**, including a voltage supply assembly (**125**) arranged to supply varying potentials to the spark electrode (**104**) and to a second (**118**) of the charge electrodes (**105**, **118**), the voltage supply assembly being arranged to vary the potentials supplied during a firing cycle of an internal combustion engine so as to maintain a potential difference between the first charge electrode (**105**) and the second charge electrode (**118**) at a first, constant, value for atomisation of fuel, and to provide a potential at the spark electrode (**104**) which varies between a first preselected value such as to avoid generation of an ignition spark, and a second preselected value such as to provide an ignition spark.

19. An assembly according to claim 15 or **18**, in which the first value lies in the range 2 to 14 kV.

20. An assembly according to claim 19, in which the first value lies in the range 5 to 8 kV.

21. An assembly according to any of claims **15**, **18**, **19** or **20**, in which the second value lies in the range 10 to 50 kV.

22. An assembly according to claim 21, in which the second value lies in the range 35 to 45 kV.

23. An assembly according to any preceding claim in which the main structure includes an annular distribution gallery (**14**, **114**) positioned around a central axis of the main structure, at least one charge electrode (**5**, **105**) providing an annular edge (**17**, **117**) facing into the distribution gallery and at least one charge electrode (**18**, **118**) being positioned in an annular configuration around the distribution gallery on a surface of a wall (**16**, **116**) thereof.

24. An assembly according to claim 23 including the said injection orifices (**15**, **115**) are directed outwardly from the annular distribution gallery (**14**, **114**).

25. An assembly according to any preceding claim in which the said spark electrode (**4**, **104**), or where provided the said primary spark electrode (**4**, **104**), is aligned along a central longitudinal axis of the main structure (**14**, **114**).

26. An assembly according to any preceding claim in which the said main structure (**1A**, **101A**) includes within the interior of the structure an electrostatic shield member (**21**, **121**) extending between the said spark electrode (**4**, **104**) and electrical conductors leading to the said charge electrode (**5**, **105**).

27. An internal combustion engine having mounted thereon a fuel injection assembly according to any preceding claim.

28. An engine according to claim 27 in which the fuel injection assembly is positioned centrally on an axis of the combustion chamber aligned along the axis of a piston reciprocating in the combustion chamber.

29. A method of injecting and igniting the fuel in an internal combustion engine comprising the steps of

injecting fuel directly into the combustion chamber of the internal combustion engine through an array of orifices (**15**, **115**) positioned in a main structure (**1**, **101**) of a fuel injection assembly mounted on the internal combustion engine; and

supplying current to an electrode structure mounted on the main structure (**1**, **101**) for atomising and igniting the fuel, including supplying a pulsed potential to a spark electrode (**4**, **104**) of the electrode structure to provide a fuel ignition spark for the internal combustion engine;

characterised by supplying a potential difference across charge electrodes (**5**, **18**; **105**, **118**) of the electrode structure positioned to provide an electric field which passes through a flow of fuel for charging fuel particles in the flow to improve atomisation;

the method including supplying a relatively low potential difference for charging the fuel particles to improve atomisation and a relatively high potential difference to provide the fuel ignition spark.

30. A method according to claim 29, in which the said spark electrode (**104**) is electrically connected to a first (**105**) of said charge electrodes, and in which the method includes:

supplying varying potentials to the spark electrode (**104**) and to a second (**118**) of the charge electrodes, varying the potentials supplied during a firing cycle of the internal combustion engine so as to maintain a potential difference between the first charge electrode (**105**) and the second charge electrode (**118**) at a first, constant, value for atomisation of fuel, and so as to provide a potential at the spark electrode (**114**) which varies between a first preselected value sufficiently small to avoid generation of an ignition spark, and a second preselected value sufficiently large to provide an ignition spark.

31. A method according to claim 29 or **30**, in which the said spark electrode (**4, 104**) is a primary spark electrode (**4, 104**), and said electrode structure includes at least one secondary spark electrode (**9, 109**) spaced apart from the primary spark electrode (**4, 104**), the said charge electrodes comprising at least one primary charge electrode (**5, 105**) and at least one secondary charge electrode (**18, 118**), spaced apart across a fuel flow path of the assembly;

the method including providing a fuel ignition spark for the internal combustion engine, across the gap between the primary spark electrode and the said at least one secondary spark electrode.

32. A method according to claim 31 in which the said at least one primary charge electrode (**105**) is electrically connected to the said primary spark electrode (**104**), and the method includes:

supplying to the primary spark electrode (**4, 104**) an ignition potential to provide a fuel ignition spark for the internal combustion engine;

earthing the said at least one secondary spark electrode (**9, 109**) to a casing (**124**) of an internal combustion engine; and

supplying to the said at least one secondary charge electrode (**118**) a potential for providing the said atomisation of fuel.

33. A method according to claim 32 including supplying varying potentials to the primary spark electrode (**104**) and to the secondary charge electrode (**118**), and varying the potentials supplied during a firing cycle of an internal combustion engine so as to maintain a potential difference between the primary charge electrode (**105**) and the secondary charge electrode (**118**) at a first, constant, value for atomisation of fuel, and to provide a potential difference between the primary spark electrode (**104**) and the said at least one secondary spark electrode (**109**) which varies between a first preselected value sufficiently small to avoid generation of an ignition spark, and a second preselected value sufficiently large to provide an ignition spark.

34. A method according to claim 29 or **30** in which the said spark electrode (**104**) is electrically connected to a first (**105**) of the said charge electrodes (**105**, **118**); and the method includes supplying varying potentials to the spark electrode (**104**) and to a second (**118**) of the charge electrodes (**105, 118**), and varying the potentials supplied during a firing cycle of an internal combustion engine so as to maintain a potential difference between the first charge electrode (**105**) and the second charge electrode (**118**) at a first, constant, value for atomisation of fuel, and to provide a potential at the spark electrode (**104**) which varies between a first preselected value such as to avoid generation of an ignition spark, and a second preselected value such as to provide an ignition spark.

35. A method according to claim 33 or **34**, in which the first value lies in the range 2 to 14 kV.

36. A method according to claim 35, in which the first value lies in the range 5 to 8 kV.

37. A method according to any of claims **33**, **34**, **35** or **36**, in which the second value lies in the range 10 to 50 kV.

38. A method according to claim 37, in which the second value lies in the range 35 to 45 kV.

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