



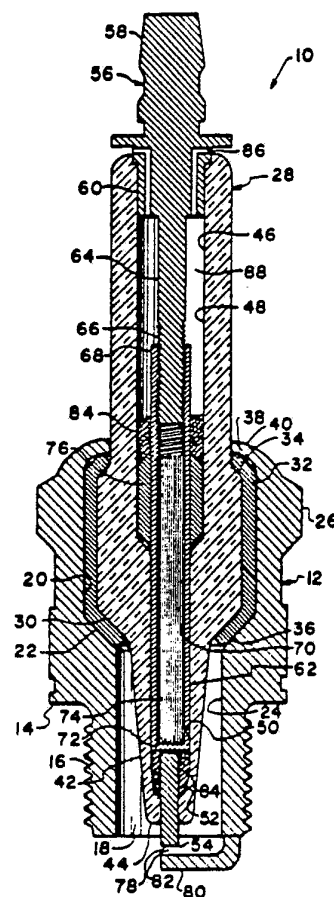
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(54) Title: SPARK PLUG TEMPERATURE CONTROL

(57) Abstract

Spark plugs, particularly those used in high-speed, high-compression engines, are subjected to an extreme range of pressure and temperature conditions. Therefore, it would be desirable for a spark plug to better resist these adverse conditions. In accordance with the invention a spark plug (10) having dynamic heat transfer means such as a heat pipe (62) or reflux condenser incorporated in the center conductor assembly (64) or in the insulator centerbore (46) is provided. The heat transfer means is thermally non-conducting below a design temperature such that the firing end of the spark plug retains heat to burn off fouling deposits. Above the design temperature range, a vaporizable medium in the heat transfer means vaporizes such that its change of state extracts heat from the firing end. The heat transfer means in the insulator (28) controls automatically the operative heat range of the spark plug.



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SPARK PLUG TEMPERATURE CONTROL

Be it known that I, William P. Strumbos, citizen of the United States of America, and resident of Northport, in the county of Suffolk, in the State of New York, am the
5 inventor of the above-entitled invention of which the following is a specification:

Field of the Invention

This invention relates to spark plugs and spark igniters for internal combustion engines and, more
10 particularly, to spark plugs and spark igniters which are provided with dynamic heat transfer means such as a heat pipe or a reflux condenser means to vary the operative heat range of the spark plug automatically.

Background of the Invention

15 Spark plugs, particularly those in high-speed, high-compression engines, are subjected to an extreme range of pressure and temperature conditions. Plug temperatures range from about 200C at low engine speeds and light loads, to as high as 850C under full throttle, full load.
20 Below about 450C, carbon and other products of combustion begin to form on the plug insulator nose. If not removed, those deposits build up until current shorts through the deposits instead of sparking across the electrodes. At normal speeds, enough heat is usually generated to burn
25 those deposits away as quickly as they are formed.

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However, when high speeds or heavy loads raise the plug temperatures above 600C to 700C, deposits that have not been burned away cause misfiring with consequent fuel and power losses. Should plug temperatures become excessive, the plug points themselves become hot enough to ignite the fuel-air mixture in the cylinder. This causes auto-ignition and, if continued, can lead to the destruction of the plug and serious engine damage. Overheated electrodes also cause a condition commonly met in two-stroke engines: the bridging of the electrodes due to the build-up of conducting deposits formed by combustion particles which have melted upon their striking the overheated electrodes. In plug temperatures ranges above 850C, chemical corrosion and spark erosion cause plug failure within a very short time.

It will be seen then, if a hot-type plug is subjected to high compression pressures, temperatures, and loads, electrode burning and auto-ignition will result because of the plug's slow rate of heat transfer. A cold plug, because it will not reach full operating temperature, will not tolerate low-speed, light-load operation for any length of time without becoming fouled with current-conducting deposits causing it to misfire.

It is thus an object of this invention to provide a multiple heat range spark plug whose operating temperature is automatically varied such that the plug runs hot at the lower cylinder temperatures occurring when the engine is idling or at low speeds and loads to thereby inhibit plug

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fouling, and which runs relatively cool at higher temperatures such as those occurring under conditions of high speeds and loads so as to prevent the plug overheating that causes auto-ignition and plug electrode
5 burning.

Description of the Prior Art

In the prior art, J. E. Genn (U. S. patent No. 1,315,298) discloses a spark plug in which an elongated hollow conductor connected with the center electrode
10 contains a small quantity of mercury. In the prior art also, A. A. Kasarjian (U. S. patent No. 2,096,250) discloses a spark plug having a hollow center conductor nearly completely filled with a cooling medium with a small void left to compensate for the thermal expansion of
15 the medium.

There is a teaching in D. Scherenberg et al (U. K. patent No. GB2025525B) in the prior art of an ignition or pre-combustion chamber device which in one embodiment discloses a barrel-shaped hollow center electrode which
20 serves as a heat pipe for dissipation of heat from the electrode lower end to cooling fins at the terminal end of the device.

Summary of the Invention

In this invention, the heat range of the spark plug
25 is varied automatically by a predetermined evaporative cooling of a substance in a hollow chamber which functions

as a dynamic heat transfer means in the insulator bore or in the center electrode of the spark plug. Although the following exposition of the invention will stress the use of a heat pipe as the dynamic heat transfer means, it will be appreciated that other dynamic convective heat transfer means such as, for example, a reflux condenser can be employed if the application permits. The heat transfer substance can be any element or compound that vaporizes at about the design temperature, approximately 500C-900C, of the spark plug.

Description of the Drawings

Fig. 1 is a front elevational view in longitudinal section of an embodiment of the spark plug of the invention;

Fig. 2 is a fragmentary detail of an alternate design of a component of the spark plug of the invention;

Fig. 3 is a front elevational view in longitudinal section of yet another embodiment of the spark plug of the invention in its operating environment in an engine cylinder head;

Fig. 4 is a fragmentary front elevational view in partial longitudinal section of a design of filling means for the heat transfer means embodied in the invention; and

Figs. 5-7 are fragmentary front elevational views in partial longitudinal section of alternate designs of heat pipes embodied in the invention.

Description of the Preferred Embodiments

Referring now to the drawings, the spark plug 10 of the invention embodied in Fig. 1 has a conventional annular metallic shell 12 which has an annular external seat 14 below which is a length of reduced diameter which is externally threaded 16 for installing the spark plug into a threaded bore in the cylinder of an engine with seat 14 in sealing contact on an annular mounting boss on the cylinder head. When so installed, the shell forms an electrical ground. Shell 12 is provided with a bore 18 therethrough with a first section 20 having a shoulder 22 and a second section 24 of reduced diameter. A wrench-engageable head 26 is provided on the shell for threading the spark plug into the engine cylinder head. An elongated electrical insulator 28, which is preferably made of a sintered alumina ceramic is received in the bore of the shell 12. An annular shoulder 30 on the insulator seats it on the shoulder 22 of the shell. An annular sleeve 32 of a relatively soft metal having a high thermal conductivity is interposed between the insulator and the bore of the shell. Sleeve 32 surrounds the insulator in close thermal contact therewith and extends from an insulator upper shoulder 34 to shell shoulder 22 such that the lower end 36 of the sleeve acts to seal the insulator in the shell. Upper end 38 of the sleeve acts to protect the insulator when the upper rim 40 of the shell is turned over to lock the insulator in the shell. Lower length 42 of the insulator is tapered to its firing end 44.

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The insulator has a centerbore 46 having a section 48 of a first diameter and a second section 50 of a reduced diameter which tapers to a section 52 of a further reduced diameter receiving the center electrode 54. Center
5 conductor assembly 56 comprises a terminal 58, a center conductor head 60, a heat pipe 62, and the center electrode 54. Terminal 58 is conventionally configured for connection with the ignition system of the engine in which the spark plug is installed. The terminal can be an
10 integral part of the center conductor head which has a conductor shank 64 whose end portion 66 can be threaded for engagement with an interior threaded section 68 in the upper end of the heat pipe 62. The heat pipe is an elongated cylindrical chamber having a side wall 70 and a
15 lower end wall 72. Longitudinal capillary grooves 74 or other suitable wicking means are provided on the side wall. A vaporizable heat pipe medium is placed in the heat pipe, normally in an amount slightly in excess to that required to wet completely the capillary means, and
20 the heat pipe is hermetically sealed by installing an upper end wall or by threading end portion 66 of the center conductor shank into the heat pipe upper end. If a threaded closure is used, the interior volume of the heat pipe can be adjusted selectively by screwing the shank end
25 portion inwardly or outwardly. As is known, an inert non-condensable gas can be introduced into the heat pipe to vary its thermal characteristics. The lower end of the heat pipe at the firing end of the spark plug forms the

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vaporization zone of the heat pipe and its upper end proximate the center conductor head forms the condensation zone with an adiabatic zone between the two. An annular metallic ring 76 having high thermal conductivity surrounds the heat pipe in intimate thermal contact therewith and the centerbore of the insulator proximate the condensation zone of the heat pipe. The center electrode 54 is positioned in the insulator centerbore section 52 with the firing tip 78 protruding from the firing end 44 of the insulator. A ground electrode 80 welded on the lower rim of the shell is positioned with respect to the center electrode firing tip such that a spark gap 82 is formed therebetween. The center electrode and the lower end of the heat pipe and, if required, its upper end, are embedded in a suitable known fused conductive ceramic or glass seal 84 such that electrical and thermal continuity therebetween is assured.

In operation, except for the thermal control provided by the heat pipe, spark plug 10 performs in a conventional manner to ignite the fuel/air mixture in the engine cylinder. When operating below some specific design temperature, the heat pipe is non-conducting such that the spark plug acts as a conventional "hot" plug with heat from the firing end being required to pass up the lower end of the insulator and, by means of the lower end 36 of the sleeve 32, travel through the shell and thence to the cylinder head of the engine to be dissipated into the cooling system thereof. Because of this relative long

heat path, some of it through materials having rather poor thermal conductivity, heat is transferred slowly from the firing end such the plug runs at a temperature which is high enough to burn off fouling deposits even during
5 prolonged periods of idling or low-speed operation. This may be considered to be the "hot" range of the spark plug.

When the operating temperature in the engine cylinder rises above the design point, heat from the firing ends of the center electrode and the insulator supplies heat of
10 vaporization to the heat pipe medium in the vaporizing zone to vaporize it such that the change of state extracts heat from the firing end of the spark end. The vapor pressure of the vaporization zone increases with vaporization causing vapor to flow to the lower pressure
15 adiabatic zone and thence to the condensation zone. There the vapor is cooled and condenses to give off heat of liquefaction. The condensed medium returns to the vaporization zone by the capillary action of the capillary means such that a circulation that transfers heat from the
20 firing end to the condensation zone is established. As is known, the temperature gradient is very small over the entire length of a heat pipe and a large amount of heat is transferred. Heat from the condensation region of the heat pipe passes through ring 76, then through the
25 insulator wall and by means of the annular sleeve 32 the heat passes to the shell shoulder and thence into the cylinder head of the engine for dissipation therein. Because of the high thermal conductivity of the heat pipe,

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heat is transferred rapidly from the firing end such that the temperatures of the spark plug remain relatively low to thereby avoid self-ignition, preignition, and thermal erosion problems. This may be considered to be the "cold" range of the spark plug. Should operating conditions
5 cause engine cylinder temperatures to drop such that the firing end temperatures fall below the design range, the heat pipe will automatically cease to conduct heat. With the heat pipe becoming non-conducting, the spark plug will
10 revert to its "hot" range.

To avoid fouling which occurs at spark plug temperatures below about 450°C, the heat pipe should be designed to become effective at about that temperature, preferably somewhere in the range between 450°C and 600°C,
15 and the working medium and other design parameters should be chosen accordingly.

A further embodiment of the invention is the spark plug 110 shown in Fig. 3. Spark plug 110 has an insulator 128 that differs from the Fig. 1 embodiment. As is known,
20 the alumina or other ceramic used in the construction of insulator 128 is an excellent electrical insulator but its thermal conductivity is low. To improve the heat dissipation properties of the construction, an annular section 186 in the waist of the insulator proximate the
25 condensation zone of the heat pipe is reduced in diameter such that the thickness of the insulator wall in that region is reduced to a minimum consistent with the electrical insulation requirements of the insulator. The

necked-in annular section 186 is filled in with a suitable material 190 having the requisite strength properties and a high thermal conductivity.

Figure 4 illustrates the upper portion of a spark plug 210 of the invention showing means that can be provided to fill the dynamic convective heat transfer means which can be a heat pipe or a reflux condenser with the vaporizable medium and, if such is used, an inert non-condensable gas. The conductor shank 264 in this design is tubular with a centerbore 265 extending along its length and has a soft metal filling tube 267 received in the centerbore with its upper end 269 extending therefrom. The bore 271 of filling tube 267 can be of a size fitting a suitable heat pipe filling means (not shown). To fill the heat pipe, the heat pipe filling means injects a charge of the required heat pipe constituents into the filling tube where it passes through centerbore 265 and into the heat pipe. Following the charging of the heat pipe, the end of the filling tube is pinched or crimped securely closed and may be soldered as is the usual practice. Centerbore 265 can be of a suitable size to serve as a partial reservoir for the inert, non-condensable gas, if such is used in the heat pipe.

Figure 5 illustrates another embodiment 310 of the spark plug of the invention. It differs in that the lower section 348 of insulator centerbore 346 forms the chamber of the heat pipe 362. Thus, the tubular conductor shank

364 of the center conductor assembly has a circular transverse end flange 369 which forms the upper end wall of the heat pipe 362. Centerbore 365 of the center conductor shank serves as the filling aperture of the heat pipe. A lower end wall (not shown) can be provided for the heat pipe should the requirements so dictate. The walls of the insulator centerbore lower section which form the heat pipe side walls are provided with electrically conducting capillary wicking means 374. In operation, spark plug 310 of this embodiment operates identically with the previously described embodiments with the exception that condensation in the heat pipe takes place directly on the insulator centerbore wall such that the heat transfer characteristics of the device are improved.

Yet another embodiment 410 of the spark plug of the invention is illustrated in Fig. 6. In this embodiment, the conductor shank 464 of the center conductor assembly extends through the heat pipe chamber and has a circular transverse end flange 471 which forms the lower end wall of the heat pipe and an upper circular transverse flange 469 which forms the upper end wall of the heat pipe. Centerbore 465 of the center conductor and a transverse passage 466 serve as the filling means for the heat pipe. The characteristics of spark plug 410 are identical to the Fig. 5 embodiment except that non-electrically conducting wicking means 474 can be employed because the center conductor shank provides an electrical current path to the center electrode.

A further embodiment 510 of the spark plug of the invention is shown in Fig. 7. Instead of a wall wick, however, capillary grooves 574 or other suitable wicking means are provided on the peripheral surface of the center conductor lower shank 564 and the under surface 567 of flange 569 which acts as the upper end wall of the heat pipe has a suitable thickness of wicking means 575.

In this exposition, emphasis has been placed on the use of the heat pipe for the dynamic heat transfer means; however, as has been pointed previously herein, a reflux condenser type convective heat transfer means can be employed in applications where the sparking device is mounted vertically in an upright orientation such that gravity will return the condensate to the evaporation zone at the firing end whose operating temperature is being maintained. In such design when the design temperature is exceeded, the working medium at the firing end vaporizes such that its change of state extracts heat therefrom. The vapor moves by vapor pressure to a region of lower temperature where it condenses on the wall bounding that region to release its heat by a change of state. The condensate flows back by gravity to the vaporization zone where the cycle is repeated as long as the design temperature is exceeded. It will be recognized that, inasmuch as gravity is depended upon to return the condensate to the vaporization zone, it is not required to provide capillary wicking to perform that function. Thus, as illustrated in Fig. 4, the walls of the insulator

centerbore 246 need not be provided with capillary wicking means if the design employs a reflux condenser as the heat transfer means. The same condition applies if the bore of the center conductor rather than the insulator centerbore is utilized as the dynamic heat transfer means.

Therefore, where a reflux condenser means of heat transfer is used in a design such as, for example, the embodiment 310 of the spark plug of the invention shown in Fig. 5 wherein electrical continuity from the terminal to the center electrode is ensured by the use of an electrically conductive capillary wicking 374, the capillary wicking is not required and the wall of the insulator centerbore 346 will be furnished with a conductive coating of metal or the like to provide electrical continuity for the sparking current between the terminal and the center electrode.

CLAIMS

1. An internal combustion engine spark plug embodying dynamic convective heat transfer means for automatically varying its operative heat range according to changes in the combustion temperatures within the engine, said spark plug having a terminal end and an inner firing end and comprising an annular metal shell carrying a ground electrode and having external threads for installing said spark plug for operation in an engine, an electrical insulator received in said shell with the insulator inner end nose portion being tapered and in a radially spaced relationship with the bore of said shell, a center conductor assembly received in a centerbore in said insulator, said center conductor assembly having at least said electrical terminal, a center conductor shank, said heat transfer means, means for filling said heat transfer means, and a center electrode having a firing end positioned with respect to said ground electrode such that a spark gap is formed therebetween, said heat transfer means being hermetically sealed and containing a vaporizable heat transfer means medium and having a vaporization zone and a condensation zone with an adiabatic zone therebetween, heat conducting means in thermal contact with said condensation zone for extracting heat therefrom for dissipation substantially into said engine, said heat transfer means being thermally non-conducting below a design temperature such that said spark plug firing end runs hot to burn off fouling deposits

settling thereon, and said vaporizable medium in said heat transfer means vaporizing above said design temperature such that its change of state extracts heat from said firing end, said vapor moving by vapor pressure to said condensation zone and condensing to release its heat by a change of state, the condensed medium subsequently returning to said vaporization zone, such that a circulation that transfers heat from said firing end is established when spark plug temperatures exceed said design temperature such that the overheating thereof is avoided, said circulation ceasing below said design temperature to render the heat transfer means thermally non-conducting, whereby said heat transfer means controls the operative heat range of said spark plug automatically.

2. The spark plug defined in claim 1 wherein the walls of the insulator centerbore form the side walls of the heat transfer means, means defining upper and lower walls of said heat transfer means and means providing electrical continuity between the terminal end and firing end of said spark plug.

3. The spark plug defined in claim 1 or 2 wherein the heat transfer means is a heat pipe.

4. The spark plug defined in claim 1 or 2 wherein the heat transfer means is a reflux condenser.

5. The spark plug defined in claim 1 or 2 wherein the center conductor shank has an axial bore in fluid communication with the heat transfer means and wherein

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filling means associated with said axial bore are provided for filling said heat transfer means.

6. The spark plug defined in claim 1 or 2 wherein the cylinder head of the engine is furnished with cooling means providing a heat sink for said spark plug and the heat transferring means comprises a tubular sleeve of high thermal conductivity enclosing said insulator in intimate thermal contact therewith, said sleeve extending from the region of said insulator proximate said heat pipe condensation zone to the bore of said shell proximate the region of said shell seating on said cylinder head whereby a thermal path of high conductivity from said heat pipe to said heat sink is provided.

7. The spark plug defined in claim 1 or 2 wherein the electrical insulator is a relatively poor thermal conductor and has an annular necked-in region proximate said heat pipe condensation zone to reduce the thickness of relatively poor thermal conducting material in the path of heat dissipation from said heat pipe, said necked-in region being built up with a relatively good thermally conducting material.

8. The spark plug defined in claim 1 or 2 wherein means are provided for varying selectively the volume of the heat transfer means such that its thermal characteristics can be varied.

9. The spark plug defined in claim 8 wherein the elongated center conductor has a lower heat transfer means end and an upper terminal end and wherein the means for

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varying selectively the volume of the heat pipe are a threaded portion in the bore of the upper condenser end of said heat transfer means and a threaded portion in the lower end of said upper terminal end, said lower end of said upper terminal end being threaded into said upper condenser end such that said terminal end can be screwed inwardly or outwardly to thereby vary the volume of said heat transfer means.

10. The spark plug defined in claim 3 wherein the heat pipe has capillary means extending from its condensation zone to its vaporization zone and wherein the upper and lower wall means and the capillary means are electrically conducting and wherein the capillary means are on the walls of the heat pipe.

11. The spark plug defined in claim 3 wherein the heat pipe has capillary means extending from its condensation zone to its vaporization zone and wherein the center conductor shank extends through the heat pipe to provide electrical continuity between the terminal end and the firing end and wherein the capillary means are on the walls of the heat pipe.

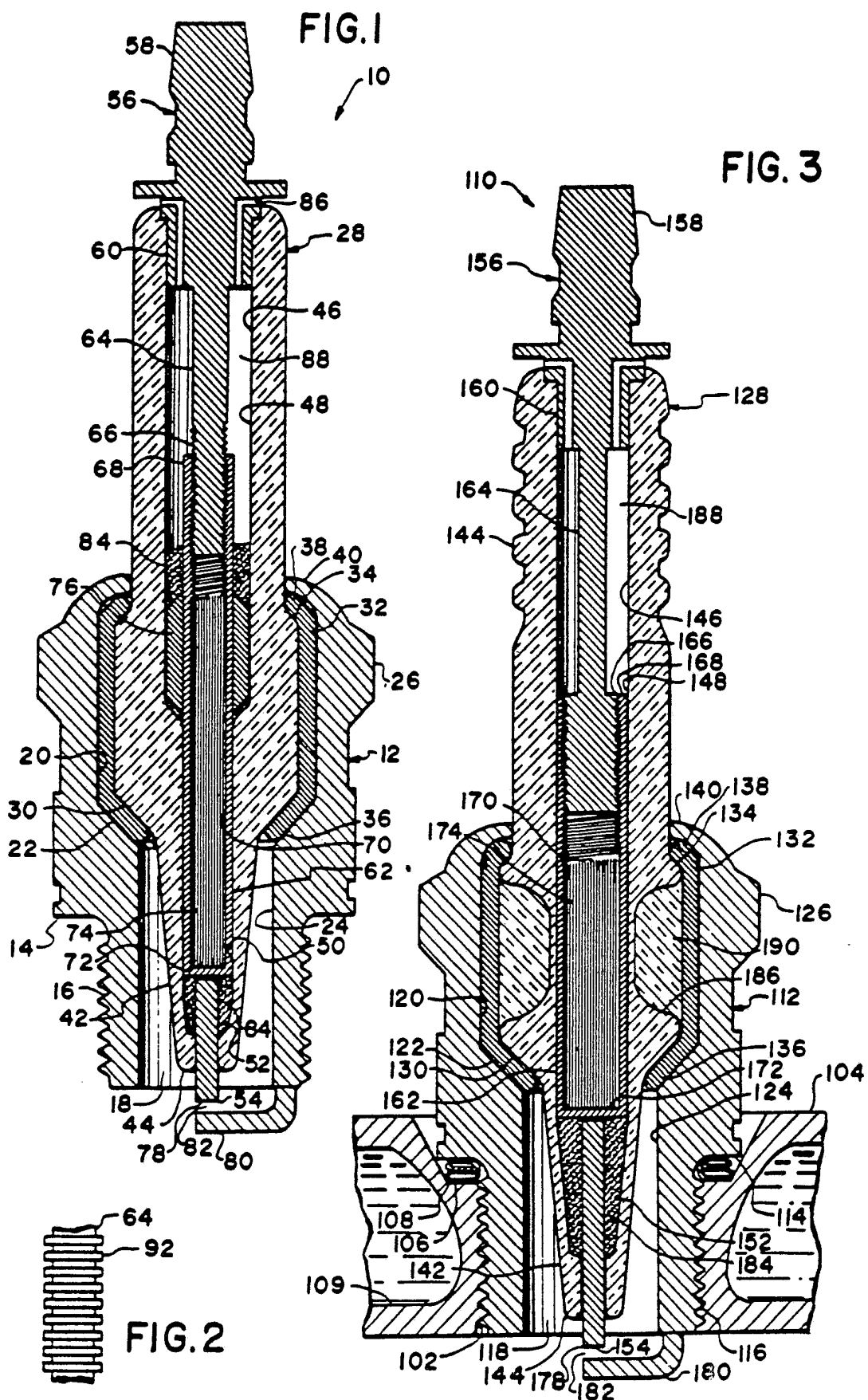
12. The spark plug defined in claim 3 wherein the heat pipe has capillary means extending from its condensation zone to its vaporization zone and wherein the center conductor shank extends through the heat pipe to provide electrical continuity between the terminal end and the firing end and wherein the capillary means are on said

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center conductor shank and at least on the inside surface
of the upper wall of said heat pipe.

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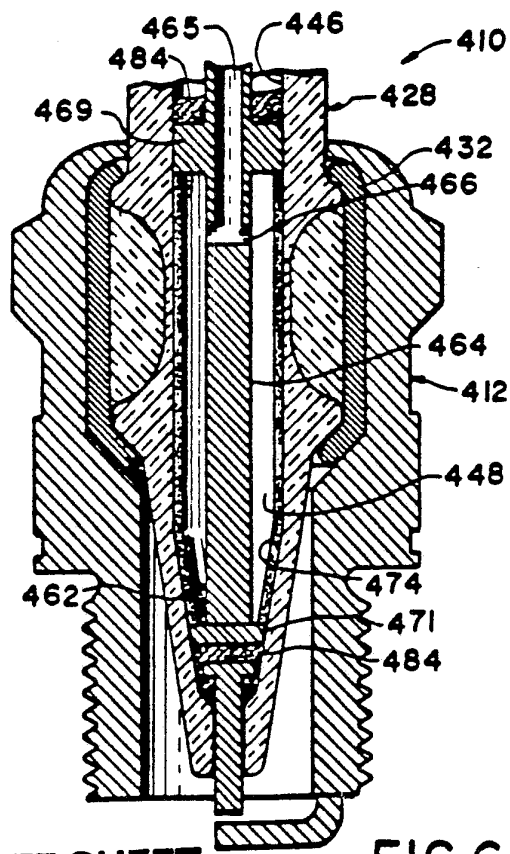
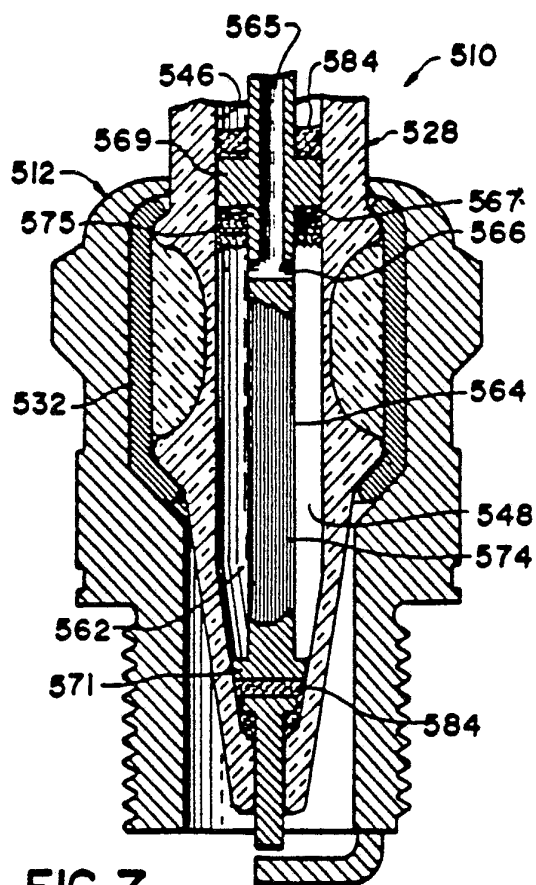
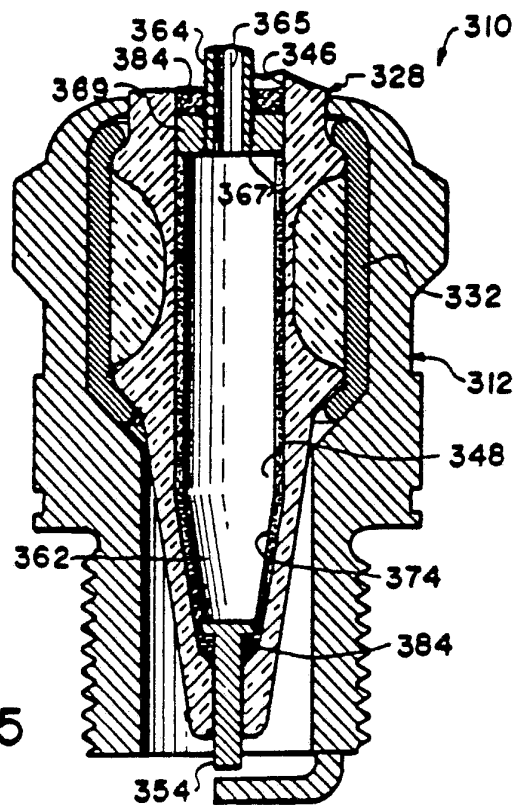
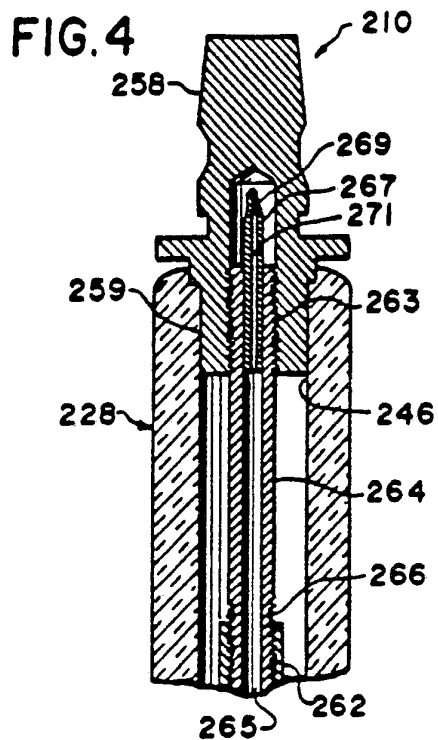


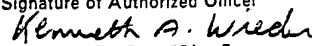
FIG. 7

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FIG. 6

INTERNATIONAL SEARCH REPORT

International Application No. PCT/US89/00503

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) ⁶		
According to International Patent Classification (IPC) or to both National Classification and IPC		
INT. Cl. ⁴ H01T 13/16		
U.S. Cl. 313/11.5, 313/136, 313/143, 123/169C		
II. FIELDS SEARCHED		
Minimum Documentation Searched ⁷		
Classification System	Classification Symbols	
U.S.	313/11.5, 313/34, 313/118, 313/136, 313/143, 313/145 123/169R, 123/169C, 123/169EL	
Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched ⁸		
III. DOCUMENTS CONSIDERED TO BE RELEVANT ⁹		
Category *	Citation of Document, ¹¹ with indication, where appropriate, of the relevant passages ¹²	Relevant to Claim No. ¹³
A	US, A, 2,096,250 (KASARJIAN) 19 October 1937	1-12
A	US, A, 4,361,122 (LATSCH) 30 November 1982	1-12
A	US, A, 4,394,855 (LATSCH ET AL.) 26 July 1983	1-12
A	US, A, 4,416,228 (BENEDIKT ET AL.) 22 November 1983	1-12
A	US, A, 4,491,101 (STRUMBOS) 01 January 1985	1-12
A	US, A, 4,514,656 (DAMSON ET AL.) 30 April 1985	1-12
<div style="display: flex; justify-content: space-between;"> <div style="width: 45%;"> <p>* Special categories of cited documents: ¹⁰</p> <p>"A" document defining the general state of the art which is not considered to be of particular relevance</p> <p>"E" earlier document but published on or after the international filing date</p> <p>"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)</p> <p>"O" document referring to an oral disclosure, use, exhibition or other means</p> <p>"P" document published prior to the international filing date but later than the priority date claimed</p> </div> <div style="width: 45%;"> <p>"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention</p> <p>"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step</p> <p>"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.</p> <p>"&" document member of the same patent family</p> </div> </div>		
IV. CERTIFICATION		
Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report	
07 June 1989	11 JUL 1989	
International Searching Authority	Signature of Authorized Officer	
ISA/US	 Kenneth A. Wieder	