Nov. 16, 1943.

H. K. KING

2,334,204

SPARK PLUG

Filed Feb. 6, 1942

Fig. 1.

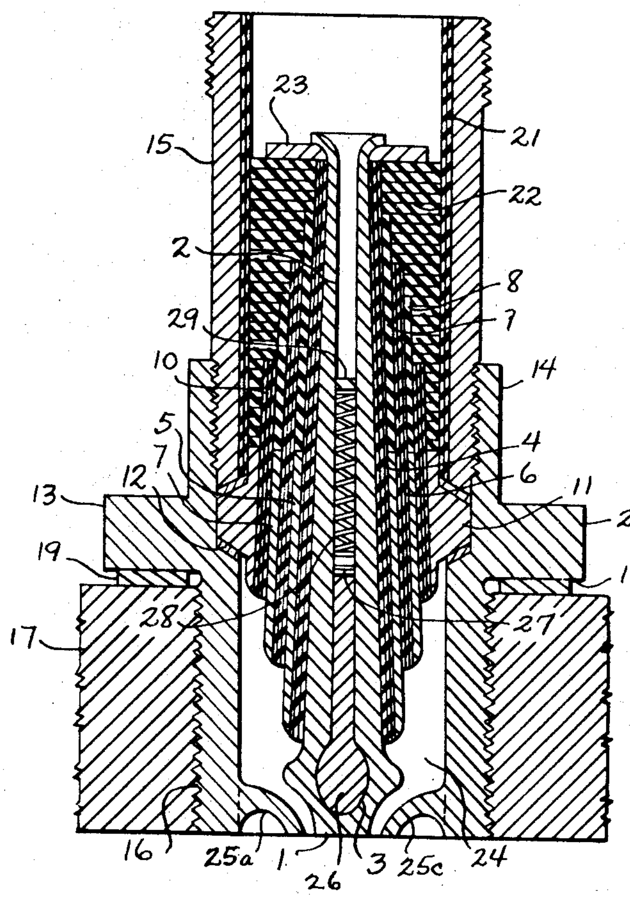
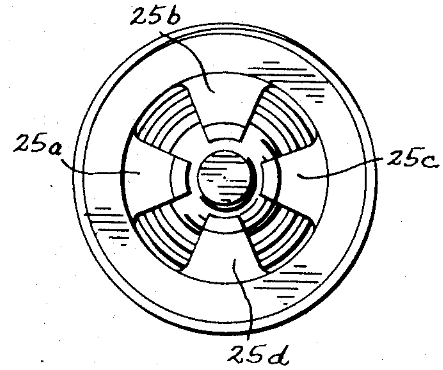


Fig. 2.



INVENTOR
Henry Kendall King
BY
K. C. Dandridge
ATTORNEY

Patented Nov. 16, 1943

2,334,204

UNITED STATES PATENT OFFICE

2,334,204

SPARK PLUG

Henry K. King, Cabin John, Md.

Application February 6, 1942, Serial No. 429,765

13 Claims. (Cl. 123—169)

(Granted under the act of March 3, 1883, as amended April 30, 1928; 370 O. G. 757)

This invention relates in general to spark plugs and in particular to those which at the present time have their principal application in aircraft engines.

It has long been common practice to manufacture different types of plugs for different fields of application. These can be divided in general into two classes. Engines which operate at relatively low temperatures require a "hot" plug, i. e., a plug designed to operate at a high temperature to prevent oil deposit thereon which otherwise would tend to cause the plug to misfire, commonly referred to as "fouling." On the other hand, engines which operate at relatively high temperatures require a "cold" plug, i. e., a plug designed to operate at a low temperature to prevent preignition which otherwise would tend to cause the plug to fire ahead of time.

In modern high powered combustion engines, such as for example those used on aircraft, it has long been a problem to design a spark plug which will give satisfactory performance throughout extremes in operating temperature conditions of the engine. When the engine is operating at full power, its temperature is of course at a maximum and hence there is a tendency towards preignition of the plug, but when the engine is operating at minimum power its temperature is obviously also at a minimum and thus there is a tendency towards fouling.

It is therefore a broad object of my invention to provide an improved spark plug for a combustion engine which is so constructed as to change its overall rate of heat conductivity in accordance with changes in operating temperatures of the combustion engine in which it is installed whereby substantially uniform temperatures may be maintained in the spark plug to thereby prevent "fouling" when the plug is operating at a comparatively low temperature and also to prevent preignition when the plug is operating at comparatively high temperatures.

A specific object of my invention is to provide a spark plug in which an electrode thereof is provided with means for effecting a transfer of heat therethrough by convection.

Another specific object is to provide a spark plug in which an electrode thereof contains a column of matter which is in a liquid state throughout at least a portion of the range of operating temperatures to which the plug may be subjected to thereby effect a transfer of heat through the electrode by convection, which transfer is also made variable by the expansion and contraction of the matter in accordance with changes in operating temperature of the plug.

Still another object of my invention is to provide a spark plug utilizing axially disposed sleeves of insulating material surrounding the inner electrode and sleeves of a highly conductive material overlaying the insulator sleeves to prevent deterioration of the latter, and also to expedite the transfer of heat from the spark path to the exterior of the plug.

These and other objects of my invention will become more apparent from the following detailed description and from the attached drawing.

With respect to the drawing in which like reference numerals indicate like parts;

Fig. 1 is a vertical section of a spark plug illustrating a preferred embodiment of my invention, and

Fig. 2 is a bottom plan view of the plug shown in Fig. 1.

With reference now in particular to Fig. 1, my improved spark plug contains an inner or central metallic electrode **1** which is tapered slightly, and cylindrical in contour. Electrode **1**, which may be made of any suitable material having relatively high heat conductivity and rigidity such as for example, a steel alloy of the "stainless" type, contains a bore **2**, at the bottom of which may be provided a bulbous cavity **3**. Bore **2** and cavity **3** are partially filled with matter **26** (shown in solidified state) which is so selected as to be in a liquid state throughout at least a portion of the range of operating temperature to which the plug will be subjected. In this particular embodiment of my invention I prefer to use a matter which has the following qualities:

(*a*) A low melting point,
(*b*) A low boiling point,
(*c*) A high coefficient of expansion,
(*d*) A high heat conductivity,
(*e*) A high heat of fusion, and
(*f*) A high heat of vaporization.

I have found that both cadmium and zinc exhibit all of these desired properties, the values of which are as follows:

	Melting point	Boiling point	Coef. of exp. per °F.$\times 10^{-6}$	Heat of fusion	Conductivity
	°F.	*°F.*		*Cal./gram*	*Cal./cm.³/°C./sec.*
Cadmium	609.6	1,412.6	16.6	13.17	.217
Zinc	787.0	1,665	[1] 12.8 to 18.0	24.09	.268

[1] Depending upon crystalline structure.

Surrounding electrode **1** are a plurality of tapered sleeves **4**, **6** and **10** which may be made of any suitable insulating material such as, for example, sheet mica, and preformed to size if desired.

Tapered sleeves **5** and **7** are provided and are arranged to overlay insulating sleeves **4** and **6** respectively. Sleeves **5** and **7** are formed from any suitable material having a relatively high conductivity, preferably metallic, which may be of the same composition as electrode 1 and serve a two-fold purpose. First, being overlayed with respect to the mica insulating sleeves, they prevent deterioration of the longitudinal surfaces of the latter which would otherwise take place due to desiccation of the mica. This feature I believe to be novel over the prior art structures which utilize longitudinal and axially disposed sleeves surrounding the inner electrode but which do not afford any protection for the longitudinal surfaces of the sleeves. Secondly, the protective sleeves being made of highly heat conductive material afford a rapid path of heat transfer between the spark path and the exterior of the plug.

It will be noted that these insulating sleeves 4 and 6 and their respective overlaying sleeves 5 and 7 are arranged in pairs which are "stepped," sleeves 4 and 5 being of a smaller diameter than sleeves 6 and 7.

A tapered metallic sleeve member 11 having a frusto-conical portion 12 is provided for holding the alternately arranged metallic and insulating sleeves firmly in position with respect to the central electrode. Being tapered, the sleeves will of course be tightened further upon heating in a manner which is fully described in my prior Patent No. 2,262,769 issued November 18, 1941.

Insulating sleeves 4 and 6 may extend for substantially the entire length of the central electrode 1 to increase the gas sealing qualities of the plug. Sleeves 5 and 7 terminate, however, at a point intermediate the ends of electrode 1, which point is preferably coplanar with the top of member 11. This feature serves to change the flow of heat from axially upward to transversely outward through member 11. To fill the space above sleeves 5 and 7, insulating sleeves 8 and 9, also tapered and preformed if desired, are positioned between insulating sleeves 4 and 6, and 6 and 10 respectively.

A shell 13 is provided for receiving the assembly of the inner electrode and its surrounding sleeves and contains an upper female threaded cylindrical portion 14 for receiving a cylindrical shielding member 15. A lower male threaded base portion 16 provides for screw insertion of the plug through an engine block 17 into a combustion chamber of the latter. Shell 13 is also provided with a horizontal shoulder 18 between which and the wall 17 is inserted the usual gasket member 19 and may also include the usual polygonal surface 20 for receiving a wrench. The inner surface of shell member 15 may be lined with an insulating sleeve 21 and insulating washers 22 which are made from any suitable material such as mica, may be disposed horizontally between sleeve 21 and insulating sleeves 4, 6, 8, 9 and 10 to assist in fixing the electrode 1 and its sleeves in their positions. A cap member 23 may be secured in place between the top of sleeve 4 and an outwardly flared portion formed on the electrode 1.

The lower cylindrical screw portion 16 of shell 13 receives the assembly of electrode 1 and its surrounding sleeves and is spaced from the outer surfaces of said sleeves to form a chamber 24 therebetween. Because of the stepped arrangement of the pairs of sleeves, chamber 24 has a considerable volume wherein gases of combustion may circulate to render the spark gap self-cleaning. Outer electrodes 25a to 25d may be formed adjacent the bottom of base member 14 to provide a spark path.

If the spark plug is to be utilized in the so-called radial type of combustion engine wherein the plug may be operated with its base upward, it will be necessary to provide means for confining the matter 26 within the bore 2 when the former is in a liquid state. The particular means provided in the present embodiment comprise a piston 27 which operates reciprocally within bore 2. A spring member 28 inserted between piston 27 and stop member 29 serves to keep the top of piston 27 yieldingly pressed against the matter 26.

While the plug herein described is not in use, the column of matter 26, if cadmium is utilized, will be in a solidified state since its melting point is 609.6° F. Likewise, when the combustion engine is operating at minimum power the probability is that the temperature generated will be insufficient to melt the cadmium. As the cadmium heats up with an increase of temperature which accompanies increased power demand, it will expand considerably due to its relatively high coefficient of expansion. Because of the small cross-sectional area of bore 2 as compared with reservoir 3, such expansion will cause the cadmium column to rise considerably within bore 2.

The rate of heat transfer from the spark gap upwardly through electrode 1 is, of course, proportional to the cross-sectional area thereof. Consequently, as the cadmium column rises with an increased operating temperature of the engine the rate of heat transfer will also increase.

As the power demand from the engine further increases and approaches the melting point of the cadmium, the heat of fusion, i. e., the heat which must be furnished to convert the cadmium from a solid to a liquid state at its melting temperature, will serve to further increase the rate of heat transfer from the area adjacent the spark gap axially upward through the inner electrode assembly.

Should now the temperature of the engine increase further, the cadmium now in liquid form will act to convey heat away from the spark area by principles of convection. Furthermore, the level of the column of liquid cadmium will be raised with such increase in temperature which will further increase the rate of heat transfer upwardly through the inner electrode assembly.

Should the operating temperature of the engine increase to such an extent that the boiling point of the cadmium is approached, the heat of vaporization, i. e., the heat which must be furnished to convert the cadmium from a liquid state to a gaseous state at its boiling temperature, will further increase the rate of transfer of heat from the area of the electrode 1 adjacent the spark gap axially upward through electrode 1.

Conversely, as the operating temperature to which the spark plug is subjected decreases, the column of cadmium will obviously undergo a reverse change of state, that is, it will pass from a gaseous to a liquid state, thence to a solid state. Such changes in state give off heat which is effective to reduce the rate of heat transfer from the spark area upwardly through the inner electrode assembly.

It will be evident from the foregoing description that the increase or decrease of the heat conductive characteristic of the inner electrode structure which takes place as the temperature to which the spark plug is subjected increases or decreases respectively may be utilized to maintain substantially uniform temperature of the inner electrode structure, thereby preventing fouling at low temperatures as well as preignition at high temperatures.

In conclusion, I desire it to be understood that the scope of the claims appended hereto is not to be construed to be limited to the use of either cadmium or zinc as the "matter" to be contained within the bore of the central electrode, as it will be evident that my invention may be carried out by the use of other types of "matter" which shall be effective to vary the rate of heat transfer from the area of the central electrode adjacent the spark gap upwardly therethrough in accordance with changes in operating temperature. For example, suitable metallic alloys having certain of the desired properties hereinbefore described as well as liquids may be utilized. It will also be evident that various other changes may be made in the form, details of construction and arrangement of parts without departing from the spirit and scope of my invention.

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

Having now fully described my invention, what I claim is:

1. A spark plug comprising inner and outer electrodes insulated from each other and providing a spark gap therebetween, said inner electrode having a bore therein containing cadmium.

2. A spark plug comprising inner and outer electrodes insulated from each other and providing a spark gap, said inner electrode including a bore containing therein a column of cadmium, said cadmium being in a liquid state throughout at least a portion of the range in temperature to which said inner electrode may be subjected whereby a transfer of heat therethrough may be effected by convection and which transfer is made variable in rate in accordance with changes in level of said column of cadmium as the latter expands or contracts.

3. A spark plug comprising inner and outer electrodes insulated from each other and providing a spark gap therebetween, said inner electrode having a bore therein containing zinc.

4. A spark plug comprising inner and outer electrodes insulated from each other and providing a spark gap, said inner electrode including a bore therein containing a column of zinc, said zinc being in a liquid state throughout at least a portion of the range in temperature to which said inner electrode may be subjected whereby a transfer of heat therethrough may be effected by convection and which transfer is made variable in rate in accordance with changes in level of said column of zinc as the latter expands or contracts.

5. A spark plug comprising inner and outer electrodes insulated from each other and providing a spark gap, said inner electrode including a bore therein containing a column of matter for conducting heat therethrough and which has a melting temperature between 600° F. and 800° F.

6. In a spark plug a hollow base member forming an outer electrode and a central electrode assembly extending within said base member, said assembly comprising a tapered central electrode including a bore containing therein a column of matter which is in a liquid state throughout at least a portion of the range in temperature to which said inner electrode may be subjected whereby a transfer of heat therethrough may be effected by convection and which transfer is made variable in rate in accordance with changes in level of said column of matter as the latter expands or contracts, and a plurality of stepped pairs of metallic and insulating sleeves disposed coaxially with said inner electrode, each of said metallic sleeves overlaying the insulating sleeve paired therewith to prevent deterioration thereof and said metallic sleeves being spaced from the inner surface of said base member to form a chamber therebetween for the circulation of gases of combustion.

7. The combination set forth in claim 6 including means providing a reservoir for matter at the base of the bore provided in said central electrode whereby the level of the column of matter will be changed substantially in response to relatively minor changes in operating temperature.

8. In a spark plug a hollow base member forming an outer electrode and a central electrode assembly extending within said base member, said assembly comprising a tapered central electrode including a bore therein containing a column of cadmium and a plurality of stepped pairs of tapered insulating and metallic sleeves disposed coaxially with said inner electrode, each of said metallic sleeves overlaying the insulating sleeve paired therewith to prevent deterioration thereof, and being spaced from the inner surface of said base member to form a chamber therebetween for the circulation of gases of combustion.

9. The invention as set forth in claim 8 including means providing a bulbous reservoir for cadmium at the base of the bore provided in the central electrode whereby the level of the column of cadmium will be changed substantially in response to relatively minor changes in operating temperature.

10. In a spark plug a hollow base member forming an outer electrode and a central electrode assembly extending within said base member, said assembly comprising a tapered central electrode including liquifiable means for effecting a transfer of heat internally therethrough by convection and a plurality of stepped pairs of tapered insulating and metallic sleeves disposed coaxially with said inner electrode, each of said metallic sleeves terminating substantially in the area defining the primary path of heat flow transversely from said central electrode to the cylinder block, each of said metallic sleeves overlaying the insulating sleeve paired therewith to prevent deterioration thereof and serving to expedite the transfer of heat axially away from the spark gap formed between said inner and outer electrodes, and each of said metallic sleeves being spaced from the inner surface of said base member to form a chamber therebetween for the circulation of gases of combustion.

11. In a spark plug a hollow base member forming an outer electrode and a central electrode assembly extending within said base member, said assembly comprising a tapered central electrode including a bore therein containing a column of zinc, and a plurality of stepped pairs of tapered insulating and metallic sleeves disposed coaxially with said inner electrode, each of said metallic sleeves overlaying the insulating sleeve paired therewith to prevent deterioration thereof and being spaced from the inner surface of said base member to form a chamber therebetween for the circulation of gases of combustion.

12. In a spark plug, a cylindrical metallic base

member, electrode means disposed at the bottom of said base member, a metallic ring member, the outer wall of said ring member being in surface contact with the inner wall of said base member, and a central electrode assembly held by and extending through said ring member into said base member, said assembly comprising a central electrode and a plurality of stepped pairs of insulating and metallic sleeves overlying said central electrode, each of said metallic sleeves overlying the insulating sleeve paired therewith, said metallic sleeves being spaced from said base member to form a chamber therebetween for the circulation of gases of combustion, and the upper ends of said metallic sleeves being terminated at the level of said ring member whereby the heat path for the greater portion of heat conducted axially upward through said central electrode and metallic sleeves will be transversely outward to said base member at the level of said ring member.

13. In a spark plug, a cylindrical metallic base member, electrode means disposed at the bottom of said base member, a metallic ring member, the inner wall of which is tapered and the outer wall of which is in surface contact with the inner wall of said base member, and a central electrode assembly held by and extending through said ring member into said base member, said assembly comprising a tapered central electrode and a plurality of stepped pairs of insulating and metallic sleeves overlying said central electrode, each of said metallic sleeves overlying the insulating sleeve paired therewith, said metallic sleeves being spaced from said base member to form a chamber therebetween for the circulation of gases of combustion, and the upper ends of said metallic sleeves being terminated at the level of said ring member whereby the heat path for the greater portion of heat conducted axially upward through said central electrode and metallic sleeves will be transversely outward to said base member at the level of said ring member.

HENRY K. KING.