This invention relates to improved spark plugs and spark plug installations of a type primarily intended for the high-temperature operation of certain internal combustion engines, such as various gas turbine types currently being used in propulsion of aircraft. A general object is to achieve a spark plug having prolonged life even under the destructive high temperature conditions characteristic of these engines, achieving this purpose through more effective cooling of the electrodes and insulating element of the spark plug.

A certain amount of spark plug cooling naturally results from direct conduction of heat to the surrounding cooling jacket of the engine, and to other parts through the electrical connections. However, these sources of cooling are insufficient protection at the extremely high operating temperatures of a gas turbine engine, for example. In that instance conventional spark plug electrodes burn off or erode so quickly that replacement becomes a burdensome maintenance problem.

Cracking of the ceramic insulating bushing through thermal expansion and contraction, and the depositing of carbon on the insulating bushing and adjoining internal surfaces of the spark plug, causing ignition inefficiencies, are still other problems which the present invention solves.

In order to greatly retard destruction of the spark plug electrodes, this invention provides a spark plug having one or both electrodes of tubular form, and arranged for blowing cooling air through them. Preferably, one hollow electrode discharges its cooling air stream directly against the other electrode to afford further cooling thereof in the vicinity of the spark gap.

Additional spark plug protection through cooling is obtained by directing flow of cooling air also through the end-opening annular insulation cavity which surrounds the central electrode and insulating bushing within the spark plug casing. This flow of cooling air not only affords direct and uniform cooling of the ceramic insulation bushing, but also impinges upon the external surfaces of the internally cooled tubular electrodes, and cools them still further. Apart from its cooling aspect, this axial flow of air through the spark plug cavity into the combustion chamber carries with it any fuel-laden air tending to penetrate the cavity from the combustion chamber of the engine, and by so doing greatly diminishes deleterious deposits of carbon which would create short circuits and cause interior arcing to reduce the efficiency of the spark plug for ignition purposes.

A further and related feature of the invention resides in the combination of a wall-aperature spark plug directly intercepting already available cooling air from the engine's cooling jacket, to be forced through the spark plug's various cooling passages. By this simple arrangement, which differs from a conventional spark plug installation in that conventionally no effective utilization is made of jacket air-flow for direct cooling of the spark plug electrodes and insulating bushing, greatly prolonged spark plug life, and increased dependability and operating efficiency are obtained without necessity for any modification of the engine itself. The improved spark plug itself is not appreciably more expensive than the conventional types and may largely comprise basic standard parts modified in the manner to be described.

These and other features, objects and advantages of the invention, including various details of construction of a preferred form, will become evident from the following description based upon the accompanying drawing.

Figure 1 is a longitudinal section of a typical installation of my improved spark plug mounted in a gas turbine engine only a fragmentary portion of which appears in the figure, with parts of the spark plug broken away to reveal interior details.

Figure 2 is a transverse section of the spark plug taken on line 2-2 of Figure 1.

Figure 3 is a transverse section of the same taken on line 3-3 of Figure 1.

In its basic construction the present improved spark plug, as herein illustrated, may be generally similar to a standard type widely used in aircraft gas turbine engines, for example. It comprises an annular body portion or casing 16 threaded internally at its base end to receive the end of sleeve extension 12. The opposite end of the extension in turn is externally threaded for connection to the coupler of an electrical conductor (not shown). Such a conductor is conventionally engaged with the terminal 14 of a central electrode 18 mounted axially within the body portion 16.

A collar mounting plate 22 encircles, and is welded at 22', to the opposite or base end of the cylindrical casing 10. Extending through aligned apertures 25 in the engine's double wall, the spark plug is mounted in place by bolts 26 passed through collar plate apertures 24 and threaded into projections outside combustion chamber.
outer wall 30. Spaced inward from the wall 30 is a combustion liner wall 32, which, together with the outer wall 30, forms a cooling air duct or jacket 35 outside the combustion space 34 of the engine. The internally projecting length of casing 16 is preferably no greater than necessary to locate its inner or electrode end even with liner wall 32 or projecting just inside the combustion space 34.

The central electrode 16 is supported in axial position within casing 16 by a ceramic insulating block 15, which supports it from the surrounding interior wall of both casing 16 and extension 12. This bushing, the illustrated manner in which it is held within casing 16, and the materials used are conventional, and so will require no further detailed description herein.

A second electrode 20, anchored in the lower or inner, engine end of spark plug casing 10, projects axially therewith generally parallel to electrode 16 and to a point approximately even with the endwise location of the tip of electrode 16, where it is bent radially inward to intersect the spark plug's central axis and underlie such tip.

As an important part of my invention the spark plug is so arranged and constructed as to cooperate in novel manner with the engine jacket 35 for maximum utilization of cooling air flowing therein, as a means of cooling the spark plug parts effectively during operation of the engine. In a conventional gas turbine engine the pressure head of this air stream in the jacket is normally one or more pounds per square inch above the gas pressure in the combustion space 34. The hot gases produced in the latter flow through the engine in a direction generally parallel to the flow of air in jacket 35, as shown by the arrows in Figure 1.

In general terms, the wall-apertured spark plug intercepts some of this cooling air, and part is forced through the electrodes while the remainder intercepted passes through the insulating cavity 38 in the plug between bushing 18 and casing 10. Cooling of the electrodes in this manner is enabled by making them hollow or tubular over at least a part of their lengths. Cooling of ceramic bushing 18 by air flow through the spark plug cavity is accomplished without any modification other than that necessary to admit air from the cooling jacket into the base of the cavity. At the same time any fuel-laden air in the cavity 38 is blown out into combustion space 34 where its burning will not result in appreciable carbon deposits inside the spark plug.

Flow of cooling air through the tubular passage in central electrode 16 is established by admission through aperture 40 in casing 10 and an aligned, though preferably somewhat smaller, aperture 42 formed through insulating bushing 18 and the underlying tubular wall of this electrode. When the spark plug is installed these apertures are preferably located on the side which faces against the stream of cooling air flowing into the cooling jacket 35, so that the amount of cooling air forced through central electrode 16 by reason of the differential pressure between the jacket and combustion space is materially augmented by the ram effect resulting from the velocity head of the jacket's air stream between.

A substantial fraction of the air which passes through the somewhat larger aperture 40 never enters the aligned aperture 42 to enter the central electrode passage. Instead it flows through the spark plug and into the combustion space 34 by an alternate cooling path including the annular end-opening cavity 39 defined between the bushing and housing walls. In so doing it flows around the inner wall of the casing 16 for cooling purposes. At the same time this air stream carries with it any fuel-laden air which may have entered the cavity, so that the burning of fuel will not take place appreciably inside the spark plug and cause deposits of carbon lengthwise to discharge its cooling or the inner wall of the casing to produce short circuiting or mislocated sparking. This axially flowing air, as it discharges from cavity 39, also cools the electrodes to an extent.

A certain definite cooling of outer electrode 20 additionally results from the location of its tip in the axial discharge stream from electrode 16. Preferably, however, electrode 20 is also made tubular and is cooled internally by flow of cooling air through it from jacket 35. For this purpose, communicating with this tubular air passage, a duct 44 is formed in casing 10, which also opens into the jacket air-stream to intercept cooling air for admission to the electrode passage. By directing the tip end of electrode 20 in the direction of flow of hot gases in combustion space 34, as shown, a maximum utilization of both pressure differential and the ram effect of air entering the electrode passage through duct 44 is obtained to achieve maximum flow of cooling air through this electrode also.

It is obvious that the electrode 20 could be shortened in length to discharge its cooling air stream against central electrode 16 instead of the reverse being true as in the illustrated case. It should also be evident that the particular arrangement or location of cooling-air entrances to the spark plug may be varied without departing from the principles herein described by reference to the preferred form.

Actual tests prove a manifold increase in the useful life of spark plugs when constructed and installed according to this invention, while the cost of so doing is only slightly increased by the somewhat greater expense of manufacturing spark plugs in the illustrated manner. Under gas turbine engine testing conditions, whereas a conventional electrode would be good for perhaps only three or four engine starts, this improved air-cooled electrode lasted for well over a hundred starts, other conditions being the same in both tests, yet suffered no noticeable deterioration.

I claim as my invention:

1. In combination with an internal combustion engine of the continuous combustion type having a cooling air duct adjacent to its combustion chamber for passage of a stream of cooling air along the outside of such chamber to remove heat therefrom, a spark plug having an annular body portion mounted extending at least partly through said cooling air duct in transverse relation thereto, to project the electrode end of the spark plug into the combustion space, said spark plug having a tubular central electrode, an insulating bushing surrounding said central electrode and, over a portion of its length, spaced radially inward from said annular body portion to define an annular cavity therebetween, opening into the combustion space, said body portion having an aperture of facing against the airstream in said duct, and being closed on its opposite side, for entrance of
cooling air by ram effect from said air duct into said cavity for cooling of said insulating bushing, and said insulating bushing and said central electrode having registered apertures located generally in alignment with the aperture in said annular body for direct entrance of cooling air by ram effect into said central electrode, the ignition end of such central electrode being open for flow of cooling air through such electrode and into the combustion space.

2. The combination defined in claim 1 wherein the spark plug further comprises a tubular outer electrode mounted on the inner end of the body portion and projecting into cooperative relation with the central electrode, the body portion of the spark plug further having a cooling air inlet on the same side thereof as the said aperture, opening directly against the airstream in the cooling duct to admit cooling air by ram effect from said duct for flow through such outer electrode and into the combustion space.

3. The combination defined in claim 2, wherein the outer electrode projects axially of the spark plug generally parallel to the central electrode and is bent inward directly across the path of discharge of cooling air from the open end of the central electrode for increasing the cooling of such outer electrode by its interception of cooling air discharged from the former.

4. For an internal combustion engine of the continuous combustion type having a cooling air duct adjacent to its combustion chamber for passage of a stream of cooling air along the outside of such chamber to remove heat therefrom, a spark plug having an annular body portion mounted extending at least partly through said cooling air duct in transverse relation thereto, to project the electrode end of the spark plug into the combustion space, said spark plug having a tubular central electrode, an insulating bushing surrounding said central electrode and, over a portion of its length, spaced radially inward from said annular body portion to define an annular cavity therebetween opening into the combustion space, said body portion having an aperture in the side thereof facing against the airstream in said duct, and being closed on its opposite side, for entrance of cooling air by ram effect from said air duct into said cavity for cooling of said insulating bushing, and said central electrode having an aperture located generally in alignment with the aperture in said annular body portion for direct entrance of cooling air by ram effect into said central electrode, the ignition end of such central electrode being open for flow of cooling air through such electrode and into the combustion space.

5. The spark plug defined in claim 4 wherein the spark plug further comprises a tubular outer electrode mounted on the inner end of the body portion and projecting into cooperative relation with the central electrode, the body portion of the spark plug further having a cooling air inlet on the same side thereof as the said aperture, opening directly against the airstream in the cooling duct to admit cooling air by ram effect from said duct for flow through such outer electrode and into the combustion space.

6. The spark plug defined in claim 5, wherein the outer electrode projects axially of the spark plug generally parallel to the central electrode and is bent inward directly across the path of discharge of cooling air from the open end of the central electrode for increasing the cooling of such outer electrode by its interception of cooling air discharged from the former.

7. In combination with an internal combustion engine of the continuous combustion type having a cooling air duct adjacent to its combustion chamber for passage of a stream of cooling air along the outside of such chamber to remove heat therefrom, a spark plug having an annular body portion mounted extending at least partly through said cooling air duct in transverse relation thereto, to project the electrode end of the spark plug into the combustion space, said spark plug having a tubular central electrode, an insulating bushing surrounding said central electrode and, over a portion of its length, spaced radially inward from said annular body portion to define an annular cavity therebetween opening into the combustion space, said body portion having an aperture in the side thereof facing against the airstream in said duct, and being closed on its opposite side, for entrance of cooling air by ram effect from said air duct into said cavity for cooling of said insulating bushing, and said central electrode having an aperture located generally in alignment with the aperture in said annular body for direct entrance of cooling air by ram effect into said central electrode, the ignition end of such central electrode being open for flow of cooling air through such electrode and into the combustion space.

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