

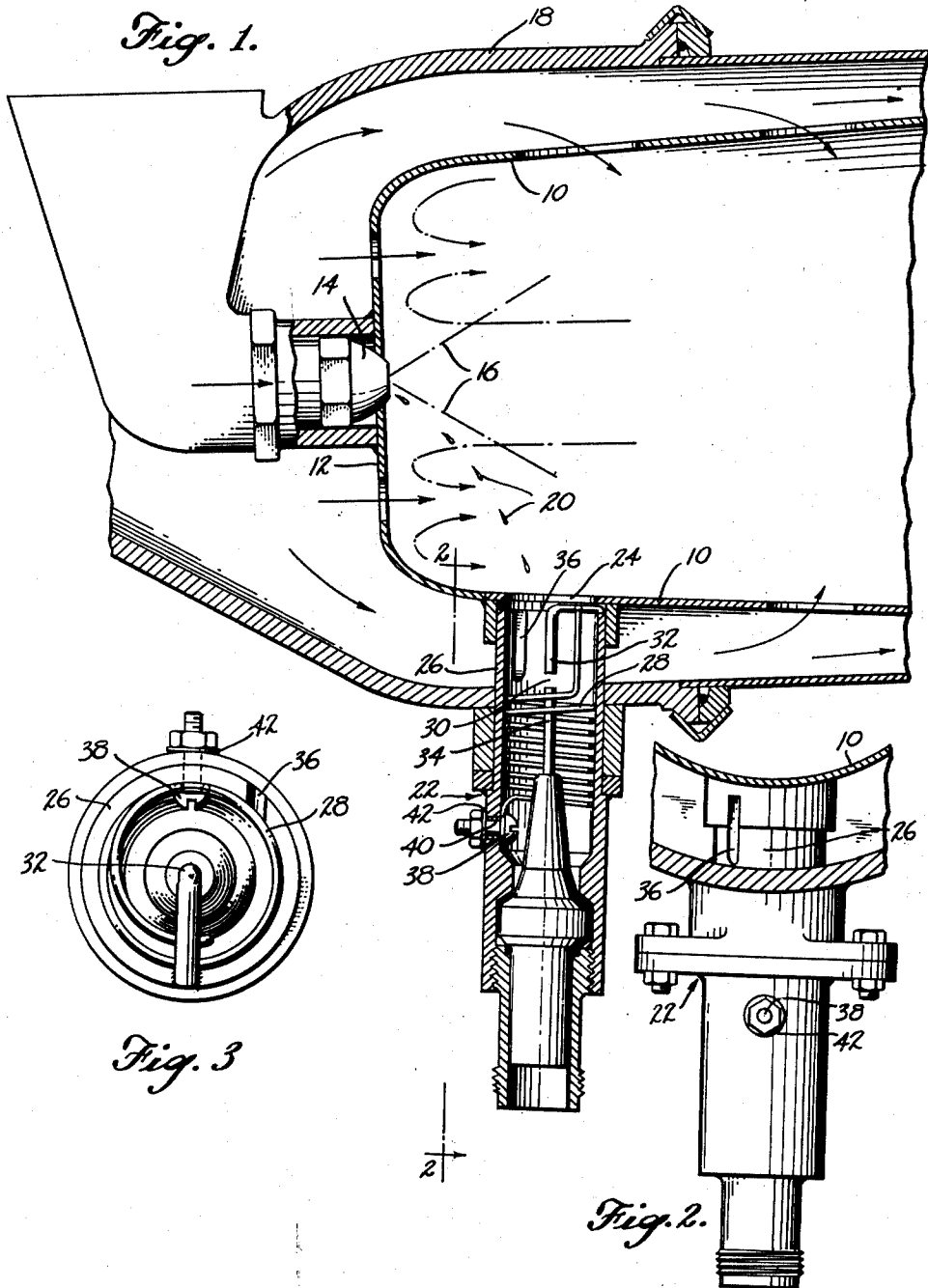
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SPARK PLUG

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## SPARK PLUG

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1

This invention relates to an improved spark plug and spark plug installation for internal combustion apparatus of the liquid fuel burning type and is herein illustratively described by reference to its application in a gas turbine engine of a type intended for use in airplanes. A general object of the invention is to enable such engines to be started reliably at low temperatures, below those at which previous types of spark plugs used in such engines can operate effectively.

A more specific object is a low temperature ignition spark plug installation in which the spark plug is very favorably located for receiving an ignition mixture of fuel injected into the engine combustion chamber to start the engine, and yet the electrodes are protected effectively against fouling and against excessive life-shortening heat resulting from continuous high operating temperature in the adjoining combustion chamber.

Still another object of the invention is the application to best advantage in a gas turbine engine or the like of a fuel preheating type spark plug, and additionally the provision of an improved spark plug construction highly efficient for that purpose, and one which is relatively simple to manufacture and adapted for relatively long life and trouble-free low temperature engine starting operation.

The preheating of liquid fuel in spark plugs has been proposed previously for use in internal combustion engines of the reciprocating type. However, the problem of starting gas turbine engines or the like at very low temperatures has presented special difficulties which are not present in the usual reciprocating engine. For example, the unusually high temperatures developed in gas turbine engines greatly shorten the life of spark plugs unless special protective measures are employed. Furthermore, any expected location of the spark plug electrodes for protection from the high temperature gases in the combustion chamber to prolong their life would seem only to aggravate the already difficult problem of starting the engine at low initial temperatures because of the resulting effective remoteness of the electrodes from the more active zone of the combustion space.

In accordance with the present invention employing an improved fuel preheating type of spark plug, installation of the spark plug is made at the bottom of the combustion liner at a location directly below the discharge stream of the fuel injection nozzle, so that an adequate supply of fuel in the form of drainage from the chamber and droplets falling from the injection nozzle is insured inside the fuel preheating spark plug for starting ignition purposes. Such fuel is heated and vaporized by the heating element inside the spark plug shell and in warm vaporous

2

form saturates the spark gap region in sufficient quantities for reliable starting, even at the lowest engine starting temperatures expected.

In accordance with further features of the invention, the spark plug shell, which opens into the bottom of the combustion liner of the engine, crosses through the air jacket space by which such liner is cooled during operation of the engine. Within such jacket, an opening in the side of the spark plug shell admits air from the jacket space into the spark plug interior and thereby causes agitation and circulation of the fuel droplets therein to insure contact thereof with the heating coil. More specifically, the opening is so arranged and directed that this circulating air enters the spark plug interior generally tangentially. The resulting swirling motion of the fuel droplets inside the spark plug shell carries them outward to the inside wall of the spark plug shell by centrifugal force. The heating coil is advantageously positioned immediately adjacent to such wall and thereby contacts and vaporizes the fuel particles in maximum degree.

Still another feature of the improved spark plug and installation thereof in gas turbine engines, for example, is the arrangement of electrodes protectively within the interior of the spark plug shell away from this intense heat normally present in the engine combustion chamber. Moreover, electrode cooling is afforded by air flow in the engine cooling jacket and around the spark plug shell, and also more directly by the effect of fuel-circulating air entering the spark plug shell itself through the tangential opening therein. In the preferred electrode arrangement, as herein illustrated, the electrode elements are located centrally inside the shell and preferably along its axis to position the spark gap at a region of low velocity of the fuel-circulating air which enters the shell. This arrangement insures a supply of warm fuel-laden air at the spark gap for ready ignition thereof, because the heavier cool air and fuel particles within the shell swirl outward under centrifugal force away from the centrally located spark gap, whereas the warm vapors rise through the gap region as desired.

Preferably the heating coil is placed in direct physical contact with the interior wall of the spark plug shell to provide mechanical support to the coil against turbulence and vibrational forces present in the engine.

These and other features, objects and advantages of the improved spark plug and spark plug installation will become more fully evident from the following detailed description thereof based upon the accompanying drawing, which illustrates the invention in its preferred form and setting.

Figure 1 is a longitudinal vertical sectional view

3  
of the improved spark plug installation in a gas turbine engine combustion apparatus.

Figure 2 is an end view of the spark plug installation looking in the direction of the arrows 2, 2 in Figure 1 to show the tangential location of the side opening in the spark plug shell.

Figure 3 is a top view of the improved spark plug unit installed as in Figure 1.

In starting the usual gas turbine engine the engine rotor shaft is driven by an electric motor or other auxiliary power source to rotate the engine air compressor and operate the fuel pump. As a result fuel and air are forced into the engine combustion chamber in quantities conducive to starting of the engine. The combustion mixture is then ignited by a spark plug and the combustion process thereafter is self-perpetuating. As mentioned above, however, these engines, typical of a class of internal combustion devices, using heavy hydro-carbon fuels and for other reasons, are very difficult to start reliably at low temperatures. Also there is the attendant difficulty of short electrode life due to the extremely high temperatures maintained in the combustion chamber during normal operation of the engine, to which the spark plug, although used primarily only in the starting operation, remains subject.

In Figure 1 the illustrated portion of the gas turbine engine comprises the forward end section of the annular combustion liner 10 having an end wall 12, in which the fuel injection nozzle 14 is mounted to direct a spray of liquid fuel into the combustion chamber defined by such liner. The broken lines 16 represent the conical pattern outline of the fuel sprayed into the chamber. A cooling jacket 18 surrounding the combustion liner 10 provides an annular space around such liner through which air is forced under pressure created by the engine compressor (not shown), the general flow of air being indicated by arrows. Some of this air enters the combustion chamber within the liner 10 through wall openings in the latter as indicated, to provide a supply of oxygen for combustion of the fuel. The details of the combustion chamber and cooling jacket and also the arrangement and construction of the fuel injection nozzle 14 and suitable supply conduits connected to the nozzle are in themselves no part of the present invention and are described at no greater length herein for that reason.

It will be observed in Figure 1 that some of the fuel sprayed into the combustion chamber by the nozzle 14 until combustion takes place will fall to the bottom of the combustion chamber. This is indicated symbolically by the falling droplets 20 represented in the figure. In accordance with one phase of the present invention, advantage is taken of the inherent tendency for some of the fuel to fall from the discharge stream of the injection nozzle 14 and to collect in the bottom of the combustion chamber, as a means of priming a fuel preheating spark plug unit installed in a fuel receiving location in the bottom wall of such combustion chamber. For this purpose the spark plug unit 22 is mounted in depending position in the bottom wall of combustion liner 10 in registry with a drainage aperture 24 in such wall, through which the fuel droplets fall into the interior of the spark plug shell 26. Such fuel particles entering the spark plug interior come into contact with the heating element 28 therein and are thereby converted into warm vaporous form conducive to ready ignition in the spark gap 30 between electrodes 32 and 34. Because of the special location of the fuel preheating spark plug unit 22 in the

bottom of the combustion liner below the discharge location of the fuel injection nozzle and in registry with the drainage hole 24, there is always ample assurance that an adequate supply of liquid fuel will drain or drop into the spark plug interior for engine starting purposes.

Additional features of the invention reside in the construction of the spark plug unit itself and also in its arrangement with relation to the fuel chamber and cooling jacket for obtaining most efficient low temperature starting of the engine and also maximum protection of the spark plug electrodes against extreme heat from the combustion chamber.

As shown, the spark plug unit depending from the bottom wall of the combustion liner 10 extends across the lower portion of the cooling jacket space hence lies in the path of flow of cooling air passing through the jacket in the direction of the arrows. A side opening 36 facing against the cooling air stream is formed in the spark plug shell 26 to admit air from the jacket space into the spark plug interior. The air thus admitted not only facilitates cooling of the spark plug electrodes 32 and 34 mounted in the shell 26, but agitates and circulates fuel particles around inside the interior of the spark plug, so that in large degree they come into contact with the heating element 28, as desired. Preferably the side opening 36, facing against the air stream in the cooling jacket space is directed generally tangential with relation to the interior of the shell 26, as shown in Figures 2 and 3, so that the admitted air will move circumferentially within the spark plug and create a swirl of airborne fuel particles therein. As these particles swirl around inside the spark plug shell, they spiral outward under centrifugal force and tend to concentrate in the annular region immediately adjacent to the interior wall of the shell as they settle slowly by gravity toward the bottom of the spark plug interior.

By employing a spiral coil heating element 28 or the like, which lies immediately adjacent to the inside wall of the shell 26 in and along the path of the swirling particles of fuel, the latter are converted with maximum efficiency into the desired warm vaporous form by contact or proximity with the heating element surfaces. Preferably, and as shown in Figures 1 and 3, the heating element 28 comprises an electric heating coil placed in direct physical contact with the inside wall of the shell 26, such coil extending over a substantial portion of the length of the spark plug shell and lying generally below the air inlet opening 36. The lower end of the coil is secured physically and electrically to the insulated binding post comprising the machine screw 38 passing through an opening in the lower side portion of the shell 26 and insulated therefrom by a nonmetallic grommet 40 and washer 42 in the manner shown. The upper end of the heating coil 28 is welded or otherwise permanently bonded to the grounded electrode 32 fixed upon the upper end portion of the shell 26. The heating coil is suitably coated with baked enamel or other thin temperature-resistant insulating material permitting direct physical contact of the coil with the grounded shell of the spark plug without electrically shorting the coil turns. When the coil is installed inside the shell 26, it is expanded somewhat by twisting in order to insure firm engagement thereof with the wall of the shell so that maximum mechanical support to the coil is afforded against vibrational forces.

Electric current to heat the coil 23 is supplied from a suitable source (not shown) connected to the binding post screw 38 and to the grounded shell of the spark plug to complete a heating circuit.

In their preferred form as shown in the drawing, the spark plug electrodes are arranged to provide a spark gap located in the central region of the spark plug interior. This places the spark gap 30 in a low velocity region of air moving around inside the spark plug cavity. As a result the warm fuel vapors conducive to ready ignition, being relatively light tend to gather in the central region occupied by the spark gap whereas the heavier liquid fuel particles borne by cooler air swirl outward and away from the spark gap under centrifugal force entailed by circulation of air admitted through the shell opening 36, as previously explained. As these liquid particles come into contact with the annular heating coil 23, however, and are converted into warm vaporous form they are displaced generally inward toward the central portion of the spark plug and rise into and through the region of the spark gap in a continuous process.

In the illustrated case the lower electrode 34 extends straight upward along the axis of the spark plug and terminates just above the upper end of the heating coil body portion, while the upper electrode 32 extends downward along the same axis to its terminal spaced just above the electrode 34, to define the spark gap 30. The upper end portion of the electrode 32 is turned at right angles to its axial portion for connection to the upper edge of the shell 25.

By locating the spark plug electrodes thus protectively within the shell 25 and removed from the more intense heat of the combustion chamber of the engine, greatly increased spark plug life is thereby achieved. The added cooling effect of air admitted through opening 36 and also general cooling of the spark plug shell 25 by virtue of its location in the cooling jacket space further increase the life of such spark plugs.

Because other details of construction of the spark plug and the way in which the same is attached to the engine combustion structure may vary considerably, no detailed explanation of the remaining portions of the illustrated spark plug structure is made, the drawing generally illustrating a typical arrangement of the parts involved. It will be appreciated that these and the parts specifically described may vary somewhat as to form and arrangement without departing from the essentials of the invention in its various aspects.

I claim as my invention:

1. In internal combustion apparatus having a combustion chamber and a fuel injection nozzle mounted in one wall thereof above its bottom, the spark plug installation comprising an open-ended spark plug shell depending from the bottom wall of the combustion chamber, such bottom wall having a fuel drainage aperture therein so disposed in relation to said nozzle and to the contours of said bottom as to function as an outlet passage for liquid fuel dropping to or collecting on the bottom of said combustion chamber, and said open-ended spark plug shell being mounted, open end up, in fuel receiving position thereunder, coaxing spark plug electrode elements carried by and within said shell substantially wholly below said drainage aperture, and fuel preheating means mounted within said shell and comprising a heating element arranged to heat

fuel within said shell to a more readily ignitable condition for ready starting of the combustion apparatus.

2. In a gas turbine engine or the like having a combustion chamber, a fuel injection nozzle mounted in one wall thereof above its bottom and cooling duct means extending along the bottom outside wall of said combustion chamber to receive and guide a stream of cooling air therealong, the spark plug installation comprising an open-ended spark plug shell depending from the bottom wall of the combustion chamber and extending through the cooling duct thereunder, such bottom wall having a fuel drainage aperture therein so disposed in relation to said nozzle and to the contours of said bottom as to function as an outlet passage for liquid fuel dropping to or collecting on the bottom of said combustion chamber, and said open-ended spark plug shell being mounted, open end up, in fuel receiving position thereunder, coaxing spark plug electrode elements carried by and within said shell substantially wholly below said drainage aperture, and fuel preheating means mounted within said shell and comprising a heating element arranged to heat fuel within said shell to a more readily ignitable condition for ready starting of the gas turbine engine, said shell having a side opening therein admitting air from the cooling air stream into the shell interior for circulation of such air and fuel particles therein to effect maximum contact of such fuel with said heating element.

3. The spark plug installation defined in claim 2, wherein the spark plug shell is generally cylindrical and the side opening therein is generally tangential with relation thereto causing circumferential flow of air around the interior of such shell.

4. The spark plug installation defined in claim 2, wherein the spark plug shell is generally cylindrical and the side opening therein is generally tangential with relation thereto causing circumferential flow of air around the interior of such shell, the heating element being of cylindrical form adjoining the inside wall of the shell and extending below such opening for maximum heating contact with such coil of circulating fuel particles falling in the shell and spiraling outward under centrifugal force.

5. The spark plug installation defined in claim 4, wherein the spark plug electrodes are mounted within the spark plug shell in relative positions defining a spark gap which is generally central and is thereby located in a region of relatively low velocity of circulating air, inside the spark plug shell.

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