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INCANDESCENT CERAMIC ELECTRICAL IGNITER

Filed Nov. 7, 1962

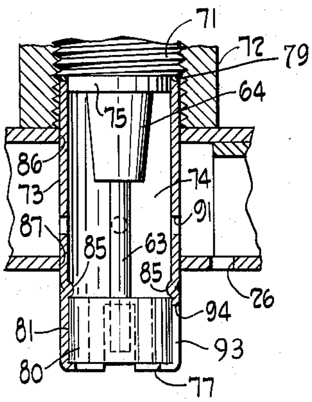

FIG. 2

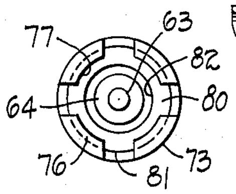

FIG. 3

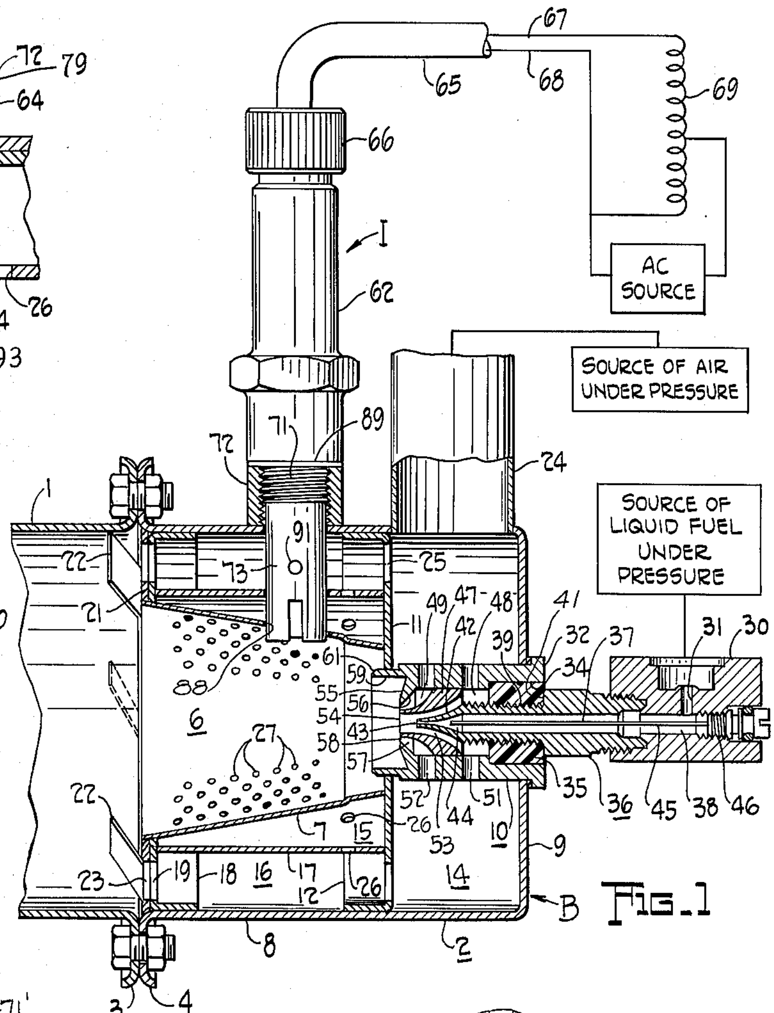

FIG. 1

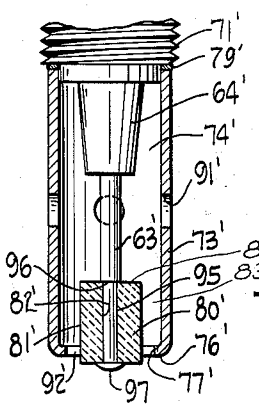

FIG. 5

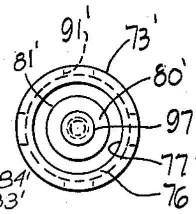

FIG. 6

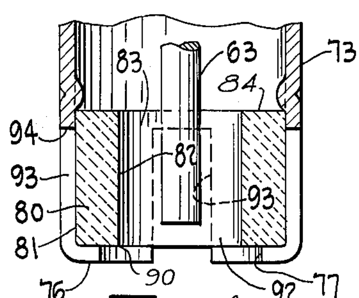

FIG. 4

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INCANDESCENT CERAMIC ELECTRICAL IGNITER

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12 Claims. (Cl. 317—96)

This invention relates to electrical igniters, particularly to spark igniters for oil burners.

One of the problems encountered in the operation of oil burners, particularly those of the portable type, is the difficulty with which ignition is obtained in a cold environment as in the arctic, especially with liquid hydrocarbon fuels of relatively low vapor pressure, and even in a temperate zone when the weather is unseasonably cold. Conventional spark igniters which may function satisfactorily at temperatures even as low as zero degrees Fahrenheit, frequently fail to achieve ignition of fuel oil when the temperature of the atmosphere in which the burner is to operate is below about —20° F. It has been sought to improve the efficiency of spark igniters by changing the geometry of the electrodes, altering the electrode spacing and providing an electrical current of greater intensity or character. Without in any way intending to detract from the success of such expedients, it is observed that they have not been entirely successful.

It is therefore the principal object of the present invention to provide an improved spark type ignition device for an oil or other liquid fuel burner. More particularly, it is sought to provide an igniter which combines spark ignition and ignition by radiant energy, which vaporizes the fuel and which presents a continuous flow of a highly combustible fuel-air mixture to an ignition spark.

Another object is to provide an electrical igniter of relatively high efficiency capable of successful operation on minimum current consumption.

Another object is to provide an igniter of the character referred to characterized by an element that becomes and remains incandescent in close juxtaposition to a sustained spark discharge; more especially, to provide such an igniter with an element which incandesces in only a localized area to minimize electrical current required and promote wicking of fuel to the ignition zone.

The invention aims to achieve such a result by interposing in the space between metallic ignition electrodes, an igniter body capable of incandescence, such body occupying a fractional portion only of the distance between the electrodes, so that an electrical discharge between the electrodes travels a path through the igniter body and also through the atmosphere of the space between the electrodes. In a preferred version, the igniter body takes the form of a porous ceramic body which is characterized by sharply increased electrical conductivity upon being heated to an elevated critical temperature. By this arrangement and combination the igniter body, heated by spark discharge between the electrodes, becomes increasingly conductive in a localized zone or path and the electrical current then follows such path in preference to an external gaseous path. The persistence of the spark through the ceramic body maintains an incandescent zone and surface spot which vaporizes liquid fuel drawn to it through the porous ceramic by wicking action from cooler portions onto which the fuel is sprayed by the burner nozzle. As a still further refinement, the igniter is arranged to feed a continuous stream of air across the incandescent spot and about the electrical spark, such air mixing with the continuously vaporizing fuel to provide a combustible mixture at such spot and through which the sparking occurs.

Other objects and advantages relate to certain novel

features of construction, combinations and arrangements of parts directed to improved burner and igniter operation and economy and efficiency in manufacture, service and repair, as will become apparent in the following detailed description of preferred embodiments representing the best known mode of practicing the invention. This description is made in connection with the accompanying drawings forming part of the specification.

In the drawings:

FIGURE 1 is a sectional view taken longitudinally through the burner component of a space heater embodying the present invention, showing the structure of and the relationships between the igniter, the primary combustion chamber, the fuel projecting nozzle and the air supply system, this view also showing diagrammatically the sources of fuel, air and electrical ignition current;

FIG. 2 is a fragmentary enlarged sectional detail showing the inner or operating end of the igniter of FIG. 1;

FIG. 3 is an end view of the inner end of the igniter;

FIG. 4 is a fragmentary sectional detail, partly diagrammatic, showing a portion only of the inner end of the igniter, this view corresponding to and being enlarged relative to FIG. 2;

FIG. 5 is a sectional detail similar to FIG. 2 showing a modification of the igniter in which the ceramic ignition body is wholly supported by the center electrode; and

FIG. 6 is an end view of the operating end of the igniter of FIG. 5.

The present invention is concerned with burners of the general type referred to and shown in copending application Serial No. 736,829, filed May 21, 1958, now Patent No. 3,070,150, owned by the assignee of the present application. Thus, in the present description, parts which are the same as or closely similar to corresponding parts of earlier burners and heaters are referred to generally, details being referred to only when necessary to an understanding of the invention or to describe parts that are new or that are in combinations which differ substantially from those known to the art.

The several features of the present invention may be used with or incorporated in various types of conventional and well known heaters. The burner assembly B comprises casing means which includes tubular shell **1** and housing **2**, both hollow circular sectional elements disposed in end to end relation, coaxial and concentric to the longitudinal axis of the burner. The shell and housing are formed with radial flanges **3**, **4**, respectively, located in back to back relation and bolted together. The tubular shell **1** defines the main combustion chamber of the heater, receives combustibles from a primary combustion chamber **6** located in the housing **2** and defined by a frustoconical screen **7** which is conveniently formed as a stamping of stainless steel or similar refractory metal. It is to be understood that the hot gases and products of combustion from the burner component shown in the drawings can be used in different ways: they can be conducted through a suitable heat exchanger to exhaust and thus used to heat air or other substance fed through the exchanger; they can be passed directly into a space to be heated such as a retort or kiln as employed in various processing industries; and they can be discharged from the outlet end (not shown) of the shell **1** into, say, the intake manifold of a diesel or other internal combustion engine. Other applications of the invention will be apparent.

The main housing **2** comprises a cylindrical wall **8** of stainless steel or other suitable heat resistant metal and, at the rear end of the latter, an end closure wall **9** which is normal to the burner axis and is formed with a central opening through which is snugly received a nozzle structure **10**. A specialized internal partitioning arrangement is provided within the housing **2** for controlling the air supply. A partition 11 comprising a circular disc of similar sheet metal has an integral peripheral flange 12 press fitted into the housing and brazed or welded in place. This partition divides the interior of the housing into a forward chamber and a receiving chamber 14 located between the partition and the rear wall 9. The forward chamber is divided by a cylindrical metal partition member 17 coaxial with the burner axis into an annular outer portion 16 and an inner portion which, in turn, is divided by the screen 7 into the primary combustion chamber 6 and an annular air distribution chamber 15 which surrounds the screen. The cylindrical partition member 17, at its rear end, is abutted against and preferably welded to the circular partition 11, the forward end of the cylindrical partition being secured as by welding to the inner periphery of a flanged ring 18 secured as by welding or press fitting in the opening at the front end of the housing. The radial portion of the ring 18 is formed with a multiplicity of circumferentially spaced circular openings 19 through which secondary air exits the chamber portion 16 and is projected into the main combustion chamber defined by the tubular shell 1.

Fixed to the larger diameter outer end of the screen 7 is a circular ring 21 formed with a multiplicity of angularly disposed struck-out tabs or vanes 22 equal in number to the apertures 19 of the ring 18. The ring is suitably secured to the housing and retains the screen in place; openings 23 formed by striking the vanes 22 from the ring 21 register with the openings 19 of the ring 18, the vanes 22 overlying the openings to impart a spiral or swirling motion to the secondary air released therethrough into the combustion chamber.

Air under pressure is supplied to the housing 2 as from a blower or other source, the air entering the rear chamber 14 tangentially through a delivery pipe 24. Openings 25, a number of which are located adjacent and distributed about the outer periphery of the partition 11, allow the pressurized air in the rear chamber 14 to enter the outer chamber portion 16 in the forward part of the housing. A multiplicity of radial openings 26 in the cylindrical partition member 17 communicate the outer chamber portion 16 with the air distribution chamber portion 15 so as to feed pressurized air to the outside of the screen 7, such air entering the primary combustion chamber 6 through distributed openings 27 in the screen.

Liquid fuel such as gasoline, diesel engine fuel or fuel oil is supplied to the nozzle structure 10 from a suitable source through a supply conduit, not shown. This supply conduit is connected to and discharges the fuel into receiving passage 31 of the terminal block 30. The nozzle 10 may be of the type shown in copending application for Patent Serial No. 99,191, filed March 29, 1961, or, as shown, may comprise a body member 32 of circular section turned from brass, bronze or similar metal. A stepped diameter axial bore is formed in the nozzle body and a large diameter portion 34 at the rear end of the body receives a press fitted annulus 35 of heat resistant plastic insulating material such as polytetrafluoroethylene. A fuel feed tube 36 is supported coaxially in the insulating annulus 35 and, in turn, supports the terminal block 30; the outer end of the fuel tube is threaded into a socket in the terminal block and an axial passage 37 in the fuel tube is continuous with an axial passage 38 in the terminal block which communicates with the radial fuel receiving passage 31. A reduced diameter portion 39 of the fuel tube is formed with external threads and is screwed through the bore of the insulating annulus which has matching threads, radial shoulder 41 of the fuel tube being thus drawn and held against the outside end face of the insulating annulus. At its extreme forward end the fuel tube 36 is formed with a tapered portion 42 concentric about the axis of the nozzle. An axial orifice 43 on the end of the tapered portion 42 is connected by a tapered internal passage 44 with the fuel passage 37 so as to be supplied with fuel delivered under pressure from the source through the passages 31 and 38 in the terminal block. Suitable provision is made for regulation of the rate of fuel flow as by means of a needle 45 carried by an adjusting plug 46 screwed into the threaded portion of a stepped diameter counterbore in the terminal block passage 38. The needle extends axially through the passages 38 and 37 into the tapered passage 44, the forward end of the needle coacting with the tapered wall of the passage in metering the fuel flow.

The main portion of the bore in the nozzle body 32 is divided by a turned brass press fitted partition plug 47 into first and second air chambers 48, 49. These tandem chambers receive pressurized air from the housing chamber 14 which surrounds them through a plurality of tangential passages 51, 52, respectively, drilled through the wall of the nozzle body 32. The drill holes 51, 52, of which there are several of each in a circular series, are inclined in the same direction and in the same direction as the air delivery tube 24 so that the air entering the chambers 48, 49 swirls or rotates in the same direction and in the same direction as the pressurized air in the housing chamber 14. The plug 47 has a recessed convexly curved rear surface which defines a first tapered passage 53 into which projects the tapered end 42 of the fuel tube, the fuel tube projecting axially through the major portion of the length of the passage 53. Air advancing through the passage 53 is accelerated and continues to rotate, picking up fuel oil released from the orifice 43 and exiting through an orifice 54 at the extreme forward end of the plug 47.

At the forward end of the nozzle body 32 an inwardly directed frusto conical circular flange 55 has an internal tapered wall surface 56 which defines the forward end of the nozzle chamber 49, the flange 55 constituting the end wall of the nozzle body. A tapered protruding convex surface on the front side of the partition plug 47 together with the internal surface 56 of the flange define a second tapering passage 57 which receives air from the second swirl chamber 49. Air thus advanced through the passage 57 is accelerated and exits through an annular orifice 58 coplanar with and in surrounding coaxial relation to the orifice 54.

Fuel oil, sprayed from the orifice 43 is first entrained in the rotating air traveling through the terminal portion of the passage 53 ahead of the orifice 54 and, upon passing through the latter, is surrounded by a sheath of air concurrently discharged from the annular orifice 58. The central fuel rich cone of spirally advancing air discharged from the orifice 54 rotates in the same direction as the spirally advancing surrounding sheath of air from the orifice 58, the two spirally advancing air masses commingling, first in a shallow circular chamber 59 at the forward end of the nozzle and then in the primary combustion chamber 6. The chamber 59 is defined as by an integral annular flange 61 formed on the nozzle body 32 in concentric relation to the nozzle axis.

The fuel-air mixture projected into the combustion chamber 6 is ignited by an electrical sparking device I embodying the features which characterize the present invention. Such features are concerned only with the working end of the igniter at which the sparking occurs, being the end which is exposed in the combustion chamber. Accordingly, it is satisfactory and convenient to produce the present igniter by modifying a conventional igniter of the type comprising a tubular metal body 62, an electrode rod 63 extending through and coaxial to the tubular body, and an insulator 64 of porcelain or other suitable ceramic material. The insulator is molded to fit and be held captive in the body 62 and the electrode 63, received through, electrically insulated from the body 62 and supported by the insulator, is suitably secured therein against axial shifting. High frequency electrical current is supplied to the igniter I through a two conductor flexible cable 65 secured to the outer end of the igniter body 62 as by a screw cap or fitting 66. The cable conductors, indicated at **67**, **68** are connected to the metal body **62** and the center electrode **63** and to the high potential output terminals of a suitable ignition system such as an auto transformer **69**, the input terminals of the ignition system being connected to a suitable A.C. source, as shown.

At the operating end of the igniter I, the body **62** is formed with a reduced diameter threaded portion **71** by means of which the igniter is made fast to the burner B, the housing **2** being provided with a suitable internally threaded access boss **72** into which the threaded end **71** of the igniter body is screwed. A cylindrical metal tube **73** surrounds the projecting electrode **63** in coaxial relation and with an intervening annular insulating dielectric space **74**. The tube **73**, made of stainless steel or other heat and corrosion resistant electrically conductive material, has a relatively thin wall, of the order of from about .025 inch, to about .05 inch, desirably and preferentially, about .04 inch. The inner or base end of the tube **73** is received over a reduced diameter cylindrically surfaced portion **75** on the extreme end of the igniter body **62**, adjacent the threaded portion **71**. The tube is abutted against a radial shoulder provided at the juncture of the cylindrical portion **75** and the threaded portion **71** and is brazed or otherwise suitably secured in place. At its distal or outer end the tube **73** is formed with integral inturned flange means **76** having arcuately curved inner peripheries **77** concentric to the longitudinal axis of the igniter and to the center electrode **63**, the flange means being at or slightly beyond the end of the center electrode.

Received within the metal tube **73** and against the flange means **76** is a porous ceramic igniter body **80**. This igniter body is in the form of an annulus or sleeve with an outer cylindrical surface **81** having an easy sliding fit in the metal tube **73** and an inner cylindrical surface **82** separated from the center electrode **63** by an annular clearance **83**. The end flanges **76** of the tube retain captive the igniter body **80**, the tube **73** being deformed inwardly of inner end face **84** of the body as by prick punching from outside in the provision of internal protuberances **85** which engage and prevent objectionable shifting of the igniter body **80** away from the end flange means **76**.

The mounting boss **72** is over and the opening through it is aligned with an opening **86** in the cylindrical wall **8** of the housing, with other aligned openings **87** in the cylindrical partition member **17** and **88** in the frusto conical screen **7**. The igniter tube **73** has easy running fits in the openings **86**, **87** and **88** for easy removal and replacement. The joint between the igniter I and the mounting boss **72** is sealed as by a gasket **89**.

A number of radial apertures **91** are formed in that portion of the igniter tube **73** which is disposed in the outer portion **16** of the forward air chamber, pressurized air in such chamber entering the annular space **74** through such apertures and flowing axially through the igniter tube **73** including the annular space **83** defined by the ceramic igniter body **80**, and discharging through an annular orifice **92** defined by the center electrode **63** and the ceramic igniter body **80**.

In the embodiment shown, wherein the igniter tube **73** has an inside diameter of about .43 inch, the ceramic body **80** has an outside diameter of about .415 inch, an axial length of from about ¼ inch to about 7/16 inch, and an internal diameter of about .235 inch. Variation of internal and external diameters of the ceramic body **80** of as much as about .01 inch is satisfactory in this particular embodiment. The center electrode **63** has a diameter of from about 5/64 inch to about 3/32 inch. A number of axial slots **93** are formed in the outer or distal end of the igniter tube **73**, these slots being continuous through the flange means, dividing the latter into a plurality of individual coplanar flanges arranged in a circle concentric to the center electrode. The slots **93** are of less axial length than the ceramic body **80**, slot ends **94** being short of or spaced toward the outlet end of the igniter tube from the inner end face **84** of the ceramic body so that the ceramic seals the slots, preventing air escape and constraining air flow to the annular passage **83** which surrounds the center electrode **63**.

Suitable materials out of which the igniter body **80** may be formed are sintered ceramics, particularly and preferably the semi-conductors, characterized by increased electrical conductivity upon temperature increase. For example, the oxides of silicon and zirconium, known as silicon dioxide (SiO_2) or silica and zirconium oxide or zirconia (ZrO_2) are suitable when stabilized and modified by an alkaline earth compound such as calcium oxide, present in small but substantial proportion such as at least about five percent (5%) by weight, preferably about eight percent (8%) but satisfactory in the range of from about five percent (5%) to about fifteen percent (15%).

In lieu of the lime (calcium oxide) there may be substituted magnesium oxide or itrium oxide in equivalent amount, or an equivalent amount of a mixture of these oxides.

The stabilized zirconia semi-conductor contemplated for the present invention is characterized by high thermal shock tolerance; its crystal structure is predominantly cubic in form as distinguished from the mono-clinic. In order to obtain the necessary wicking effect, the igniter ceramic body **80** has a porosity in the range of from about at least five percent (5%) to about fifteen percent (15%), preferably about nine percent (9%).

The porosity referred to is measured by the percentage of total weight represented by water absorbed by the ceramic when the latter is immersed in boiling water for about one (1) hour at sea level.

With less than five percent porosity the igniter body lacks the capillary characteristics necessary for wicking or carrying fuel oil received on its surface to the zone of the incandescent path for heating and vaporization. With greater than about fifteen percent porosity the igniter body lacks the necessary mechanical strength to stand up in service; moreover, the larger pore size reduces the capillary effects and lowers the effectiveness of the ceramic in conducting fuel oil toward the vaporizing zone surrounding the incandescent path.

In making the body **80** with the physical and electrical characteristics referred to it is feasible to employ the conventional practices and techniques of the ceramic art. Thus, in making the stabilized zirconia-calcium oxide body described, the zirconia (ZrO_2) and the calcium oxide (CaO or an equivalent amount of calcium carbonate, $CaCO_3$) are ground to a fineness such that the materials substantially all pass through a twenty-eight mesh (−28) screen and are substantially all retained on a forty-eight mesh (+48) screen. The screened material, generally uniformly graded between the limits mentioned are compacted and formed to the desired shape in a Stokes or equivalent pill press, desirably with the preliminary addition of a suitable binder. Upon removal from the press the formed green body is sintered as in a gas fired oven at a temperature of from about 2900° F. to about 2980° F. for a period of about one-half (½) hour to about one and one-half (1½) hours, the higher temperatures requiring less time than the lower temperatures.

The stabilized sintered zirconia body so made is characterized by inversion of its property as an insulator; over a relatively short temperature range wholly above the non-visible heat spectrum and starting at about 1800° F. the zirconia rapidly increases in electrical conductivity.

In accordance with the foregoing considerations, the following composition is satisfactory for use in making the igniter body **80** using the procedure described:

Example 1

	Percent
ZrO_2 (zirconia)	94
CaO (calcium oxide)	6

Another test for porosity of the igniter body **80** is based on fuel oil absorption characteristics. To perform this test the specimen is first dried as by heating in an oven at from about 300° F. to about 400° F. for about one-half hour. It is then weighed in air and immersed in No. 2 fuel oil at about 70° F. for one hour. Upon removal from the fuel oil the specimen is drained on blotting paper for five minutes and weighed. Absorption is then determined according to the formula:

$$\frac{B-A}{A}100=\text{percent absorbtion} \qquad \text{(I)}$$

where:

A=original weight of specimen
B=weight of specimen after oil immersion

In accordance with this test procedure Example (1) above was found to have an oil absorption of about 7%.

When tested in accordance with the procedure related to Equation (I), the igniter body **80** should be capable of absorbing from 5% to 15% of its own weight of No. 2 fuel oil.

For some applications it is satisfactory to modify the igniter body material such as zirconium oxide, silicon dioxide or other such semi-conductor material having the characteristic of rapid increase in electrical conductivity over a short high temperature (incandescent) range by the addition of a small percentage of an electrical modifier which has higher electrical conductivity at low temperatures than does the principal ceramic base material. For example, suitable materials which may be added or which may be allowed to remain in the material when occurring incidentally as impurities include the alkali and alkaline earth compounds such as sodium silicate, sodium zirconate, calcium zirconate, and metals and metallic oxides such as powdered nickel and nickel oxide which are not lost at the incandescent operating temperatures. These electrical modifiers are satisfactory when added in only small amounts such as up to about 5% by weight. It is believed that the presence of one or more of these modifiers increases the electrical conductivity of the ceramic body at low or starting temperatures, aiding in establishing an initial path in or along the ceramic for the electrical discharge and carrying the electrical current until the temperature of the ceramic base material is raised to the point at which its resistance drops sharply and the electrical current is then carried substantially wholly by the ceramic base material. Thus, the following compositions have also been found to be satisfactory for use as the material of the igniter body **80**:

Example 2

Zirconium oxide, stabilized, with the addition of 5% calcium in the form of calcium oxide or calcium carbonate and 2% commercial nickel powder, silicon 1%, present as silicon dioxide and with traces of iron, aluminum and magnesium. The mixture is ground, pressed, and sintered as described above to obtain the desired porosity giving fuel oil absorption calculated by Formula (I) of about 6%.

Example 3

Zirconium oxide, stabilized, with the addition of 5% calcium in the form of calcium oxide or calcium carbonate, 2% silicon as silicon dioxide and with traces of sodium, aluminum, iron and magnesium. The mixture is ground, pressed, and sintered as above. Fuel oil absorption of this material, calculated in accordance with Formula (I) is 7.3%.

To operate the burner and ignition system of the present invention, the fuel, air and electrical sources are energized, operated or released, preferably simultaneously, so that the desired fuel-air mixture is projected into the initial combustion or ignition chamber **6** from the nozzle **10** and a high tension spark is produced between the center electrode and the flange means **76** of the igniter I. The burner and igniter described are designed for use with an ignition system which supplies a 60 cycle alternating electrical current at an initial potential of from about 4,000 to about 5,000 volts. With the alternating current potential referred to impressed across the metal electrodes of the igniter I, a visible spark is produced between such electrodes. If the fuel being used has a high vapor pressure and if the ambient temperature is sufficiently high, ignition is obtained instantaneously or substantially so because of the existence of the ignitable mixture in the path of the spark across the igniter electrodes. However, if a fuel of low volatility is used, or if the temperature of the environment is low, ignition may not occur instantaneously because of the absence from the vicinity of the spark of gas phase fuel. Moreover, the electric spark discharge has poor thermal coupling to the fuel so that volatilization and ignition of the fuel is objectionably slow and may not occur at all, this being one of the faults of conventional spark igniters. Because of the placement and geometry of the igniter body **80**, the flange means **76** of the electrode tube being further from the center electrode **63** than the ceramic igniter body (FIG. 4), the electric arc is maintained in close proximity to the surface of the igniter body, particularly at edge corner **90** defined by the intersection of its end face and its inner cylindrical surface **82**; it skirts the ceramic body which latter is thereby heated along a localized path. Thus, the ceramic body does not interfere objectionably with the sparking between the metal electrodes; the ceramic is merely located in juxtaposition to the sparking zone so as to be heated thereby. It is also significant, as will appear, that the ceramic body **80** occupies a fractional portion only (about half) of the space between the metal electrodes to insure that, regardless of the conductivity of the ceramic body, a portion of the electrical arc necessarily travels an air or gas gap of substantial length between the metallic electrodes.

Because of the relatively low thermal conductivity of the ceramic body **80**, the latter is rapidly heated adjacent the path of the electric arc, and reaches the critical temperature at which its electrical conductivity begins to increase sharply, about 1800° F. in the case of the stabilized zirconia used in the example. This increased conductivity of the ceramic body adjacent the path of the arc shorts out a part of the running arc. Thus is initiated an avalanche effect which heats the ceramic along a progressively greater portion of the length of the arc. As conductance through the ceramic igniter body occurs, the ceramic is heated by the resistance effect, I^2R, the heat being conducted at but a low rate from the thin path of the electric current to the ceramic body at large. Thus the electric current is concentrated in the hot, relatively low resistance part of the ceramic, resulting in a filamentary line or path of conductive ceramic.

The conductive ceramic filament is heated by resistance loss throughout its length and electric arc heating is present at its ends; accordingly, the conductive filament progressively lengthens until it shorts out as large a portion of the arc length as possible, limited by the geometry of the metallic electrodes and the relative position of the ceramic ignition body. The tendency of the electrical discharge to shorten its path has the effect of pulling the filamentary low resistance path into the interior of the ceramic body. The electrical discharge, when established along a filamentary path extending radially through the ceramic igniter body, has a terminal point on the surface **82** at which the arc or visible portion of the discharge contacts or enters the ceramic body. This ignition spot is maintained incandescent; in the Example 1 described it has a diameter of about 1/32 inch to about 1/16 inch. The only part of the electrical discharge which remains visible is that which exists between the center electrode **63** and a hot spot or ignition point on the inside cylindrical surface **82** of the igniter body.

In order to achieve the desired concentration of electrical current flow in a filamentary path through the ceramic igniter body, it is necessary that the material of such igniter body be characterized by low heat conductivity over the entire operating range of the igniter and by rapid or sharp increase in electrical conductivity over a short elevated temperature range; that is, over a relatively short portion of the visible heat range of an optical pyrometer. Although the stabilized zirconia used in the preferred embodiment loses its character as an electrical insulator and becomes a conductor in the range of from about 1800° F. to about 2700° F. and in this respect is referred to as a semi-conductor, it must be recognized that a ceramic which becomes rapidly more conductive at a lower temperature, such as about 1200° F., would be useful for an igniter body in certain applications. A ceramic exhibiting the semi-conductor characteristic referred to, that is, a sharply breaking curve of electrical conductivity showing a rapid increase starting at a temperature as high as 2000° F. or above would be useful in other applications. The lower the temperature at which the ceramic exhibits the sharp increase in electrical conductivity, its semi-conductor characteristic, the more general is the heating of the ceramic in operation, and the lower is the temperature of the ignition or hot spot on the surface of the ceramic igniter body. Conversely, the higher the temperature at which the ceramic becomes conductive, the higher is the temperature of the ignition or hot spot on the surface and the more concentrated is the path of the electrical discharge through the ceramic. However, ceramics which do not begin to increase in electrical conductivity until elevated to a temperature above about 2000° F. are not practical for most igniter applications because of the difficulty of achieving such a high temperature in the ceramic using the electrical current sources presently available in ignition systems. Thus, the critical temperature at which the ceramic igniter body begins to exhibit the sharp increase in electrical conductivity desired occurs from about 1200° F. to about 2000° F. The stabilized zirconia of Example 1 having its critical temperature range starting at about 1800° F. is a preferred material since the electrical current is confined to a fine, filamentary path of small cross section, the steady temperature of the ignition or hot spot is relatively high, and the spark discharge is maintained with relatively low current.

When the spark discharge reaches a steady state with the electrical current maintained through the ceramic body, there is a substantial decrease in the voltage drop across the electrodes. In the Example 1 described, the decrease is from the initial 5000 volts to about 500 volts, 60 cycle A.C., which is sufficient to maintain the sparking.

The fuel oil sprayed from the nozzle **10** impinges on and is absorbed by the igniter body **80**. By capillary action or wicking effect, the ceramic carries the absorbed liquid fuel to or toward the conductive high temperature path of the electrical discharge where the fuel oil, or a portion of it, is vaporized and released or forced by its expansion into the annular passage **83** between the ceramic body and the center electrode **63**. Such fuel vapor commingles with air flowing through the igniter I from the air supply chamber **16** of the burner assembly, the combustible mixture thus formed being carried across the path of the visible portion of the spark. Ignition of the mixture results from the electrical spark or the heat from the hot point, or by a combination of the hot point heat and the visible spark.

The heat of the filamentary conductance path through the porous ceramic is sufficient to crack or fractionate hydrocarbon fuel oils to a high vapor pressure form so as to provide within the igniter passage **83** the desired vapor phase fuel which is readily ignited when mixed with the oxygen of the air concurrently supplied to the igniter through the passage. The ignited mixture is carried out the orifice **92** at the discharge end of the igniter I in the form of a torch-like flame which ignites the main fuel-air spray being projected from the nozzle **10**.

The filamentary conductance path migrates through the ceramic body **80** in accordance with variations in the electrical conductivity of those portions of the ceramic body which, from time to time, adjoin the conductance path. Hydrocarbon fuel oil in the ceramic may deposit carbon which increases the electrical conductivity, the presence of such carbon resulting in a localized increase in conductivity of the ceramic body with resultant migration of the conductance path into that portion of the body having or containing the carbon. However, the high temperature of the electrical discharge and of the filamentary conductance path results in the carbon being consumed and released as carbon dioxide.

Operation of the igniter, with the electrical discharge following the filamentary path of small cross sectional area through the ceramic igniter body, does not result in appreciable deterioration of the ceramic, no chemical decomposition occurs. The ceramic is not pierced or destroyed to achieve electrical conductance or to provide a path for the electrical discharge. The ceramic remains unchanged, the electrical path being provided by the change in electrical characteristics resulting from the increase in temperature. The dimensions of the thermally stressed ceramic constituting the electrical path are so small, relative to the entire mass of the ceramic igniter body, that thermal shock does not appear to cause objectionable deterioration or destruction of the ceramic.

FIGS. 5 and 6 illustrate a modification in which a porous ceramic igniter body **80'**, corresponding to the igniter body **80**, is carried by a center electrode **63'**, corresponding to the center electrode **63**. In this modification an unslotted igniter tube **73'** is used in lieu of the slotted tube **73** of the preceding figures, the tube **73'** having an annular gap and discharge outlet **92'** corresponding to the outlet **92**. This outlet is defined by an inturned circular radial flange **76'** formed on the distal or outer end of the igniter tube **73'**, circular inner periphery **77'** of such flange being equi-distant from cylindrical surface **81'** of ceramic body **80'** which it faces. Bore **82'** of the igniter body **80'** is received over a reduced diameter portion **95** of the center electrode **63'**, the ceramic igniter body being located between shoulder **96** of the center electrode which is at the juncture of the main portion of the electrode and the reduced portion **95**, and an upset or peened over end portion **97**. Other parts of the modification correspond to parts described in connection with the preceding figures and are identified by corresponding primed numerals. The operation is similar, with the vapor-air passage surrounding instead of being surrounded by the ceramic ignition body.

In accordance with the patent statutes the principles of the present invention may be utilized in various ways, numerous modifications and alterations being contemplated, substitution of parts and changes in construction being resorted to as desired, it being understood that the embodiments shown in the drawings and described above and the particular method set forth are given merely for purposes of explanation and illustration without intending to limit the scope of the claims to the specific details disclosed.

What is claimed and desired to be secured by Letters Patent of the United States is:

1. An ignition device comprising a pair of electrodes, means mounting the electrodes in spaced insulated relation to one another,

said electrodes having spaced sparking ends and being adapted for connection to a high tension electrical source to produce an arc between said ends across said space,

and an ignition body interposed between the electrodes adjacent said ends in position to be heated by such an arc,

said body being characterized by low heat conductivity and having a porosity such that it absorbs about 5% to about 15% of its weight of No. 2 fuel oil when immersed therein for one hour at 70° F., and

said body comprising a ceramic material which is essentially an electrical insulator at all temperatures below the visible heat spectrum and which has the characteristic of inverting to the status of an electrical conductor over a relatively short temperature range wholly within the visible heat spectrum.

2. An ignition device as in claim **1** in which the inversion to the conductive state of the ceramic material occurs in the range of from about 1800° F. to about 2700° F.

3. An ignition device as in claim **1** in which the ceramic material of the ignition body is essentially stabilized zirconia.

4. An ignition device as in claim **1** in which the material of the ignition body is a semi-conductor ceramic.

5. An ignition device as in claim **1** in which the ignition body comprises zirconium oxide and inverts to the electrically conductive state over a temperature range wholly above 1800° F.

6. An ignition device comprising an inner rod electrode and an outer tubular electrode,

means mounting the electrodes in coaxial, insulated relation with an annular dielectric space between them,

an ignition body surrounding the rod electrode in said space,

said body comprising a porous ceramic material having low electrical conductivity at all temperatures below the visible heat spectrum and having electrical conductivity that increases rapidly over a transition temperature range wholly within the visible heat spectrum,

said body, throughout its axial length, being separated from one of the electrodes by a sparking space, one of the electrodes having an element projecting toward the other electrode and separated therefrom by a sparking gap,

said gap being so located relative to the ceramic body that a portion of the latter is heated to said transition temperature by an electrical spark across the gap whereby the electrical current of the spark is carried by the ceramic body and the spark is maintained across the sparking space between the ceramic body and the electrode from which the latter is separated.

7. An ignition device as in claim **6** in which the ceramic body has substantially cylindrical inner and outer coaxial surfaces one of which is in engagement with one of the electrodes.

8. An ignition device as in claim **6** in which the ceramic ignition body comprises a sleeve carried by the tubular electrode and throughout its length is separated from the inner electrode by an annular sparking space.

9. An ignition device as in claim **6** in which the outer electrode is formed with an axial slot and the ceramic body bridges the slot as a closure.

10. An ignition device as in claim **6** in which the outer electrode has, remote from the mounting means, a sparking end formed with inturned radial flange means, the flange means being of less radial dimension than the ceramic body.

11. An ignition device as in claim **10** in which the ceramic body is abutted against the flange means.

12. An ignition device as in claim **10** in which the outer electrode is formed with a slot continuous through the flange means and the ceramic body bridges the slot as a closure.

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