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[54] **PLASMA HEATING TORCH**

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[52] **U.S. Cl.** ....**219/121 P,** 219/10.51, 219/10.79, 219/75, 313/231

[51] **Int. Cl.** **B23k 9/04**

[58] **Field of Search**..........219/10.49, 10.51, 219/10.79, 121 P, 75, 76, 69; 313/231; 310/11

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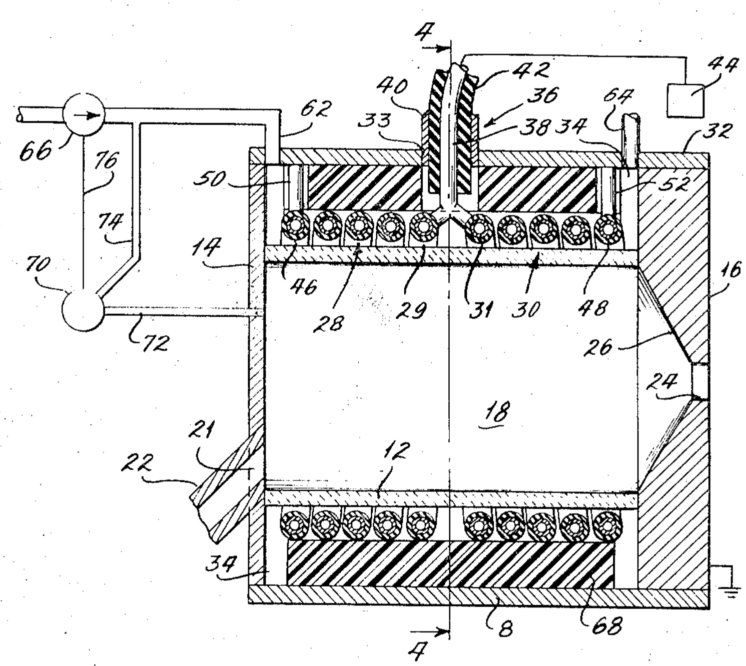
[57] **ABSTRACT**

A high pressure plasma heating torch comprising a hollow dielectric cylinder and a pair of electrically conductive end plates which form a plasma chamber in the cylinder and where the end plates are respectively provided with gas inlet and discharge ports. A pair of aligned, electrically conductive heating coils are concentrically disposed about the cylinder and in this arrangement extend along the cylinder for substantially the entire length thereof. The coils are connected together at a central location and are fed energy from a relatively high voltage, high frequency electrical source and the outer or opposite ends of the coils are grounded or connected to a low potential location through the end plates so that a plasma introduced into the chamber is subjected to a relatively high energy field which extends between the two end plates, but which is developed by a source which has its highest potential near the center of the device thereby reducing the potential required and the possibility of high frequency sputtering and arcing. A cooling jacket surrounds the dielectric cylinder and forms a cooling chamber with the other parts including the parts that house the heating coils, and this cooling chamber receives a suitable coolant which is used to remove excess heat generated during operation of the device. Provision can also be made to make the coils of tubular material and to pass coolant through the coils, if desired. In a preferred embodiment of the invention, means are also provided for sensing pressure changes in the plasma chamber and in the coolant chamber to control the introducing of coolant under pressure into the cooling chamber and to thereby also maintain substantially uniform and/or equal pressure conditions in both chambers.

22 Claims, 4 Drawing Figures



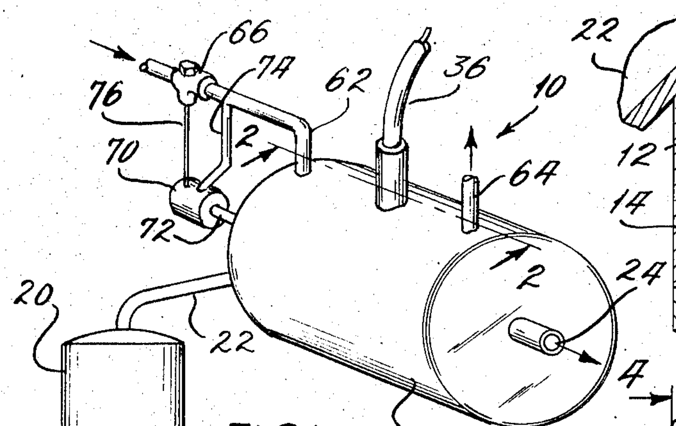


FIG. 1

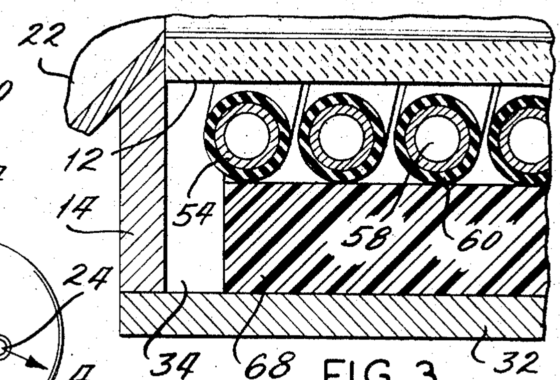


FIG. 3

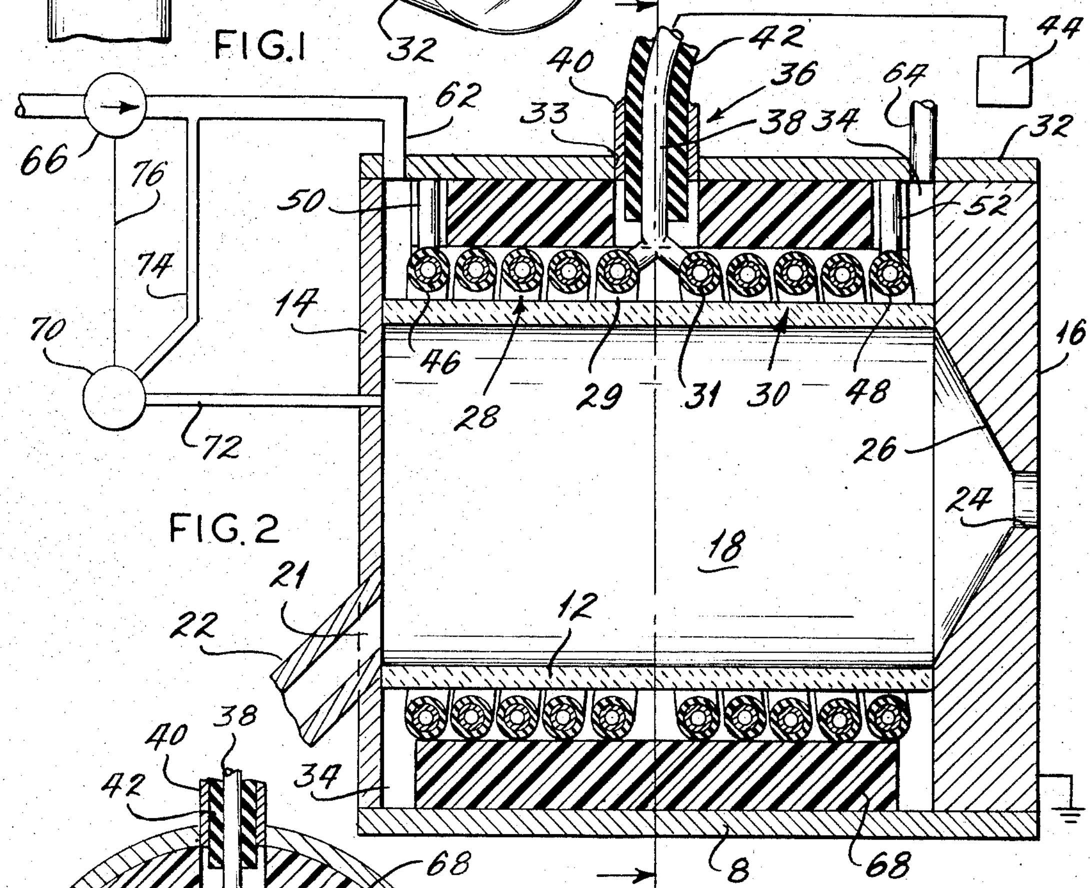


FIG. 2

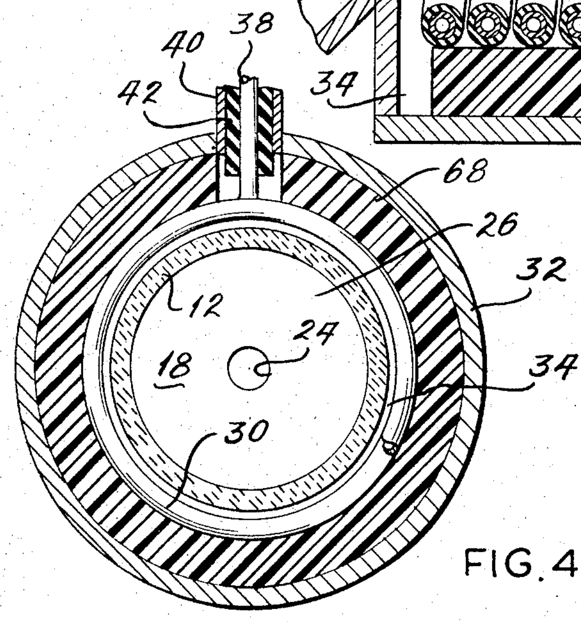


FIG. 4

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PLASMA HEATING TORCH

This invention relates in general to certain new and useful improvements in heating torches, and more particularly to a plasma heating torch construction which is capable of operating effectively and safety even at relatively high temperature and pressure conditions.

In recent years plasma heating torches have been used in a large number of diverse applications, including welding and other like applications as well as in the reduction of metallic ores, spheridizing of particles, crystal growing, and in other areas where a high temperature moving plasma is required. Generally, the known heating torches have been constructed using hollow dielectric cylinders having dielectric end plates disposed over their transverse ends, and the plasma is normally introduced into and exhausted from the cylinder through one or more ports formed in the end plates. A high energy electrical heating coil or other heating mechanism has also been circumferentially disposed about the cylinder for heating the moving plasma as it passes through the cylinder. A wide variety of these heating torches are commercially available and some are relatively complicated and bulky and have required substantial insulation to protect against arcing and sputtering especially where the applied voltage are substantial. For these and other reasons, the available torches have enjoyed limited usefulness, have been relatively expensive and unsafe to use and have enjoyed limited efficiency in that severe constraints are placed upon their maximum temperature and pressure levels. Usually, the cooling systems associated with these torches are also not particularly effective, and if the generated heat exceeds the heat dissipation or heat removal, the components of the torch will fatigue and/or melt and break down. In addition, the temperature levels which can be withstood by known torches are limited by their ability to operate at high voltages without encountering voltage breakdown problems.

In order to increase the temperature generated in many of the known torches, the voltage applied across the heating coil is increased, but if the applied voltage exceeds the voltage handling capabilities of the coil, and the breakdown point of the insulation associated therewith, a capacitive discharge results causing arcing between the coil and the plasma in the chamber, or between adjacent convolutions in the heating coil, and oftentimes also between the heating coil and the end plates of the torch. Such excessive voltage levels can result in sputtering, similar to a corona discharge, which not only damages the torch through localized heating and devitrification, but contaminates the plasma or other gaseous composition that is in the torch. Thus, the known heating torches may be relatively effective but inefficient when operating at lower voltage potentials, they may also encounter serious problems when operating at substantially higher voltage levels. For these and other reasons, many of the commercially available heating torches must be operated while isolated from the operating personnel since the arcing and sputtering and the associated radio frequency leakage which is encountered especially at the high voltage levels creates serious safety hazards to operating personnel. In an effort to overcome these and other problems and shortcomings of the known torches, the users of such torches have generally been constrained to operate them at relatively low temperature, pressure and voltage levels, and accordingly, they are not effective for use in many applications.

It is, therefore, the primary object of the present invention to provide a high frequency plasma heating torch which can be operated at relatively high temperature and pressure levels and without much risk of encountering arching, sputtering radio frequency leakage, and other similar problems.

It is another object of the present invention to provide a high frequency plasma heating torch of the type stated which employs a pair of electrically conductive heating coils arranged about a plasma chamber in such a manner that currents passing through these coils will generate additive magnetic fields.

It is a further object of the present invention to produce a relatively high frequency plasma heating torch which obviates voltage breakdown and current discharge problems by employing minimum electrical potential differences between the ends of a plasma cylinder and between the heating coils associated therewith.

It is also an object to provide a high frequency plasma heating torch capable of being operated at relatively high pressure levels and which has pressure equalizing means associated therewith.

It is an additional object of the present invention to provide a high frequency plasma heating torch which is highly efficient even when operating at relatively high operating temperature and pressure levels and which is relatively safe to use.

Another object is to teach the construction and operation of a relatively simple, versatile, efficient and inexpensive plasma torch.

Another object is to increase the effective operating potential of a plasma torch by center feeding the applied electric energy.

Another object is to minimize the amount of insulation required in plasma heating torches capable of operating under relatively high voltage conditions, and thereby reduce the size and weight of these plasma heating torches.

These and other objects and advantages of the present plasma heating torch will become apparent after considering this application which describes preferred embodiments in conjunction with the accompanying drawings, wherein;

FIG. 1 is a perspective view of a high frequency plasma heating torch constructed in accordance with and embodying the teachings of the present invention;

FIG. 2 is a vertical cross-sectional view taken along line 2—2 of FIG. 1 and showing the electrical and fluid connections to the heating torch;

FIG. 3 is an enlarged fragmentary sectional view showing more in detail the construction of the heating coils used in the subject heating torch; and

FIG. 4 is a cross-sectional view taken along line 4—4 of FIG. 2.

Referring now in more detail and by reference characters to the drawing which illustrates a practical embodiment of the present invention, number **10** designates a high frequency plasma heating torch constructed according to a preferred form of the present invention. The torch **10** comprises a hollow dielectric cylinder **12** provided with spaced attached end plates **14** and **16** which together form a plasma chamber **18**.

The cylinder 12 is preferably made as a relatively thin-walled structure to increase its heat transfer efficiency and to reduce the possibility of fracturing due to thermal shock or like conditions.

The cylinder 12 is preferably formed of a non-metallic refractory material such as one of the fused silicas, a vitrified clay product such as fused quartz, fused silicon dioxide or one of the various lime-silica slags, or of some other similar refractory material. For most applications, materials such as Pyrex and saphire are preferred refractory materials used in the construction of the dielectric cylinder 12. In some cases, the cylinder 12 may also be formed of various metal type refractory materials including metal compounds such as boron nitride or of some of the high alumina refractories, including mullite, and the like. The end plates 14 and 16 are preferably formed of a conductive material such as copper, although other high temperature resistant electrically conductive materials particularly those which can be water cooled may be used, and include for example, the various carbon and tungsten steels, as well as various metal alloys including the well known copper alloys.

A gas such as nitrogen, argon, hydrogen, or the like, from a suitable source 20 (schematically illustrated in FIG. 1) is introduced into the plasma chamber 18 through an inlet port 21 shown formed in the end plate 14, which inlet port is communicated with the source 20 through a conduit or duct 22. The gas introduced into the chamber 18 is ionized therein by means of eddy currents created by the electrical energy supplied to the heating coils and the plasma thus produced passes through the chamber 18 and is exhausted from a discharge aperture 24 formed in the other opposite end plate 16. The discharge aperture 24 is located substantially at the center of the end plate 16 and is also shown located on the axis of the cylindrical chamber 18, and is at the center of an annular tapered surface 26 on the end plate 16. This is done as a means to help direct and shape the plasma as it moves through and is discharged from the chamber. The inlet port 21, on the other hand, is preferably offset with respect to the axis of the chamber 18 to intentionally prevent coaxial alignment of the inlet and outlets ports 21 and 24, in order to avoid as much as possible any straight throughflow of the plasma. In some cases it may even be desirable to provide a plurality of inlet ports spaced at different locations on the inlet end plate 14, and these may be connected to the same or to different gas sources as required. The outlet end plate 16 may also be provided with a plurality of spaced discharge apertures in which case they would be located off the axis of the device and either in or out of alignment with any one or more of the inlet ports. Generally speaking, it is also desirable to orient the inlet duct 22 and the orifice 21 so that it communicates with the inlet end plate 14 at some angle such as an angle of from about 30° to about 60° relative to the plane of the inlet end plate 14 so that the entering gas stream will be made to follow a somewhat helical path as it passes through the chamber 18 from the inlet to the outlet ends thereof.

The term "plasma" as used herein usually refers to a gaseous substance produced by a gaseous discharge where the resultant substance is electrically neutral and has an equal number of positive ions and negative electrons. The subject torch can be operated with a number of different plasmas in various atomic states including plasmas formed of the inert or monatomic gases such as argon, neon and helium; the diatomic gases such as hydrogen, carbon monoxide, nitrogen and oxygen as well as certain of the triatomic gases such as carbon dioxide and the like and other polyatomic gases. As a general rule however, higher field strengths are required when using diatomic and polyatomic gaseous plasmas than for the others due to the higher ionization potentials for these gases. Other plasmas including air, and even the so-called "exotic" gases which include gases such as uranium hexafluoride and the like may be used in the subject heating torch. The selection of the plasma will depend on the use to which the torch is to be used and the desired operating conditions required.

The gas that passes through the chamber 18 is heated and ionized by a pair of electrically excited conductive heating coils 28 and 30 which are circumferentially disposed about and slightly spaced outwardly from the outer surface of the dielectric cylinder 12. This construction, as will be explained, enables a cooling fluid to be circulated around the exterior surfaces of the coils 28 and 30 to prevent them from overheating and to provide some temperature control for the torch. The coils 28 and 30 are preferably formed of the same electrically conductive material and are positioned or wound about the cylinder 12 with each having the same number of convolutions or windings so that each of the coils will also have the same overall impedance and electrical conductivity characteristics to provide substantially equivalent heat generating properties. The convolutions which form the coils 28 and 30 extend along the dielectric cylinder 12 for the greater portion of the axial length thereof so that the heat generated thereby will be relatively uniformly distributed along the length of the chamber 18.

A cylindrical cooling jacket 32 is concentrically disposed about the hollow dielectric cylinder 12 in radially spaced relationship outwardly therefrom and outwardly from the windings 28 and 30, being secured to the outer annular peripheral surfaces of the end plates 14 and 16. The members 12, 14, 16 and 32 therefore form a substantially enclosed cooling chamber 34 which surrounds and encloses the coils 28 and 30. The cooling jacket 32 is also preferably formed of the same or of a similar electrically conductive material used in the construction of the end plates 14 and 16, though any conductive material capable of withstanding high temperature environments without breakdown can be used. The important thing is that the wall 32 establishes electrical continuity between the end plates 14 and 16 for reasons which will be explained. In an alternative construction, the cylindrical cooling jacket 32 can also be formed of a dielectric material such as any of the aforementioned refractory materials for temperature protection and then provided with an electrically conductive outer lining disposed in electrical contact with the end plates 14 and 16. In like manner, the end plates 14 and 16 may be fabricated from a dielectric material similar to that used for the dielectric cylinder 12, in which case they must also be provided with electrically conductive outer layers disposed in electrical contact with the cooling jacket 32.

The cooling jacket **32** is provided with an aperture **33** located at an intermediate location along the length thereof between the end plates **14** and **16** to receive a high energy electrical means for connection to the adjacent innermost end windings **29** and **31** of the coils **28** and **30** respectively. The electrical connection means are shown as being coaxial cable **36** which includes a central current carrying conductor **38** which is connected to the inner windings of the coils **28** and **30**, an outer tabular conductor **40** connected to the conductive portion of the member **32** which is also connected to the end plates and is usually grounded for safety reasons, and a tubular layer of insulating material **42** between the inner and outer conductors **38** and **40**. The opposite end of the cable **36** is connected to a suitable source of high frequency electrical current, such as a source **44** of radio frequency electrical current schematically illustrated in FIG. **2**. The opposite or outermost end windings **46** and **48** of the coils **28** and **30** respectively are connected through return leads **50** and **52** to the electrically conductive portion of the cooling chamber **34** including the cooling jacket **32** and the end plates **14** and **16** so that the end windings **46** and **48** are all held at approximately the same electrical potential and preferably are grounded. The outer cable conductor **40** is also connected to the cooling jacket **32** and the end plates **14** and **16** and is preferably grounded as aforesaid. This type of electrical connection is highly desirable for several reasons including making the subject torch relatively safe to handle and operate because most of the exposed parts are grounded, providing a relatively uniform field distribution from end to end of the device, and most of all the center-fed construction of the present torch enables it to operate at much higher input potentials and with much less possibility for arcing, sputtering and breakdown.

Each of the coils **28** and **30** preferably comprises a similar tubular conductive element **54** (FIG. **3**) having their adjacent end loops connected to the input current carrying conductor **38** and also connected to each other, and each of the coil conductive elements **54** has a flow passage **58** therethrough and through which a coolant can be circulated during operation of the torch. An outer protective coating layer **60** formed of a suitable heat shrinkable material such as Teflon, polyethylene, polyvinylchloride, or the like, is applied to the outer surfaces of the windings of the coils **28** and **30** for protection from the coolant that circulates in the chamber **34** and around the outer surfaces of the coils. The coating layer **60** should be as thin as possible so that adjacent convolutions of the coils can be as close together as possible. By further reference to FIGS. **2** and **3**, it can be observed that the various convolutions of the coils **28** and **30** extend axially from their input ends which are at the center of the device to their outermost end windings **46** and **48** located in closely spaced relationship to the respective end plates **14** and **16**. Also, the coils **28** and **30** are wound in such a manner that when current is applied to the coils, the magnetic field established by each of the coils **28** and **30** will be additive so that there will be a relatively uniform high strength field established in the plasma chamber from end to end. This means that with the present construction, it is possible to obtain a relatively strong field with a relatively low input voltage, and therefore with even less chance for arcing than would be the case if the input were applied to one end of a single coil as in the prior art constructions. With the present construction, therefore it is possible to operate effectively at voltages as low as 500 volts, or even less as required depending on the particular application, as well as at voltages as high as five thousand volts or higher without running much risk of producing voltage breakdown problems. Voltages in this range can also be used over a wide range of operating current levels. The input source **44** would normally be a radio frequency source preferably operating in the very high frequency (VHF) or ultra high frequency (UHF) ranges. The construction of the torch is such that it will function as a shield to the high frequency voltage applied to the coils, and therefore, little or no radio frequency transmission is likely. Consequently, the torch can be operated at virtually any frequency within the desired range without producing undesirable radio frequency interference.

While the present disclosure describes and illustrates the device as having a pair of axial aligned heating coils **28** and **30**, it is also possible to construct it to using a single electrically conductive heating coil similarly located but centerfed and provided with a pair of return leads at its opposite ends for connection to the end plates. However, care must be taken when using a single coil to be sure that it is constructed so that when current is applied the magnetic fields generated are additive. The present invention also contemplates use of more than two individual coils extending longitudinally along and about the dielectric cylinder **12** in endwise axially aligned relationship in which case care must be used in connecting the inputs and outputs.

It should be understood that while radio frequency heating has been found to be highly effective and is the preferred form of heating, other high energy heating systems could be used as well. For example, and without substantially changing the nature of the invention, any heating means which generates inductive magnetic fields and produces heat by establishing eddy currents in a plasma could be used and are contemplated for some applitions. The precise length of the heating coils and the number of windings in each is not critical, though the total number of windings in all of the coils should be sufficient to produce the desired field strength and field strength distribution to generate the desired amount of heat.

A suitable coolant is circulated through the cooling chamber **34** between a coolant inlet line **62**, (FIG. **2**) and a coolant discharge line **64**. A coolant pump **66** may be located in the coolant inlet line **62** for pumping the coolant into the chamber **34** under pressure, and heat exchanger means may be provided if the same coolant is to be continuously recirculated. The coolant may be an electrically non-conductive liquid or a gas, though a liquid with a high heat capacity is generally used since such liquids are far more effective and efficient in removing and carrying away the substantial amounts of heat that will be generated in the torch. Water is an excellent choice as a coolant, though other electrically non-conductive liquids including a number of the glycols such as ethylene glycol, and liquified gases such as liquid nitrogen may be used. It is usually more efficient to discharge or exhaust the spent coolant to a sewer or other disposal systems, though with some of the more expensive coolants the discharge line **64** may be connected to a suitable evaporator or other heat exchanger for reconditioning and recycling as stated.

A cylindrical plug **68** is concentrically disposed within the cooling chamber **34** and is constructed to have sufficient thickness in its radial dimension to reduce overall coolant chamber fluid volume and thereby increase the speed of movement of coolant as it passes through the chamber **34**. The plug **68** may also be constructed of any of a number of thermoplastic materials and have some beneficial insulating characteristics as well.

In operation, the coils **28** and **30** are energized by a high frequency electrical input such as the radio frequency input while a plasma gas is introduced into the chamber **18** through the one or more inlet ports **21**. The gas is preferably introduced into the chamber **18** at an angle with respect to the axial centerline of the chamber **18** so that as it travels through the chamber **18** it moves along a somewhat helical path until it finally exhausts out of the discharge aperture **24**. At low pressures the plasma flow is diffused and at high pressures the plasma assumes a shape somewhat similar to a teardrop. This helical movement of the plasma tends to more uniformly force the moving plasma into the teardrop shape with the more pointed end of the teardrop generally directed toward the discharge aperture **24**. The plasma is introduced into the chamber **18** at flow rates which are sufficient to generate the desired pressure levels, and during its movement the plasma undergoes rapid heating to a temperature sufficient to perform the desired work by its exposure to the field generated by the radio frequency energy applied to the windings **28** and **30**.

Since the current carrying conductor **38** of the input cable **36** is connected to the two adjacent and centrally located end windings **29** and **31**, as aforesaid, the fields produced by the two windings will be approximately the same. In addition, since the opposite end windings **46** and **48** are connected to ground or to some other relatively low potential, the possibility of arcing between the windings **46** and **48** and the respective end walls **14** and **16** has been virtually eliminated since most of the high voltage is centrally located between the windings. Accordingly, the problems of voltage breakdowns, sputtering and arcing which normally arise where a single full length winding is used and where the input is applied to one end are virtually eliminated. Furthermore, the various windings in the coils **28** and **30** are preferably closely spaced and are electrically insulated from each other thereby increasing the total number of possible windings for a given length of the cylinder **12**. Consequently, the voltage drop between two adjacent coil windings is relatively small and therefore the possibility of arcing between any two adjacent windings is also substantially reduced.

In many cases where high pressure heating operations are required, it is usually desirable to achieve pressure equalization between the pressure in the plasma chamber **18** and the pressure in the cooling chamber **34**. To accomplish this, means **70** which respond to the pressure in the chamber **18** are provided to control the operations of the coolant pump **66** and/or of valve means associated therewith. The means **70** in this case are connected to the chamber **18** through a pressure tap **72** that communicates with an opening in the inlet end plate **14**. The means **70** may be pressure sensor, preferably or a type which senses the absolute pressure of the gas or plasma contained in the chamber **18** and generates an output signal which is used to control the pump **66** in direct proportion to the pressure sensed in the chamber **18**. The pressure in the coolant inlet line **62** between the pump **66** and the cooling chamber **34** may also be sensed by some type of sensor means through another connection **74** in the manner as illustrated in FIGS. **1** and **2**. In this case, a comparison of the pressures in the fluid inlet line **62** and in the plasma chamber **18** is performed by the sensor **70** which in this case is a simple differential pressure device, and includes means responsive to the pressure differential to operate the pump **66** by means of an actuator **76** so as to introduce coolant into the chamber **34** at a rate which is sufficient to maintain approximate equality between the pressures in the plasma chamber **18** and in the cooling chamber **34**. The dielectric cylinder **12** may also be made of a relatively fragile material incapable of withstanding high pressures in which case pressure control in the coolant chamber becomes even more important to prevent damage to the device.

When using the pressure equalizing system described above, the cooling medium should preferably be a non-conductive fluid though in some cases any of the aforementioned liquids could also be used. Some of the preferred gases which can be used as a cooling medium include freon, sulfur hexafluoride, some of the fluorinated ethers, carbon dioxide and similar electrically non-conductive gases to name a few.

The plasma heating torches of the present invention are capable of being used in widely varying high temperature operations including use as a welding tool, a cutting tool, a brazing tool, as well as in many other similar high temperature applications. The subject torch construction is also capable of being used in the spheridizing of particles in which particles of a substance such as carbon in particulate form which are first pulverized are introduced along with the plasma into the chamber **18** where they are spheridized and are then exhausted with the escaping plasma. The apparatus for such an application would normally be constructed so that the plasma chamber **18** has a greater overall length than the aforesaid devices which length may be as long as twenty feet or more, in order to provide sufficient cooling in a free fall region. In this case, the apparatus would probably also be oriented vertically to take advantage of gravity. The substantial heat and pressure maintained in such an embodiment will cause the free falling carbon or other particles to melt, and thereafter to be cooled while in their free falling condition which will cause the particles to become spheridized. The structure and operation of such a device may be very similar to the torch described above.

Due to the high temperature and high pressure levels which may be employed in the chamber **18**, the torch can also be effectively employed to reduce many metallic ores. For example, platinum and zirconium can be separated in this way from other naturally occurring metal complexes or metal mixtures of components such as are usually present with these materials. In this case the plasma torch would again preferably be vertically disposed and would also have a length sufficient to accomplish the reduction operation.

The subject plasma heating torch can also be used in various vapor disposition operations and in the growing of various crystal structures such as the growing of semi-conductor crystals. In the production of crystal structures, a highly particulate powder or a gas in the form of a plasma stream can be introduced into the chamber **18** and deposited and caused to vaporize on relatively cold projections located in the chamber **18** in order to generate the growth of a desired crystalline structure. The introduced plasma would normally contain an active component which is capable of being deposited on either a cold projection or on substrates rendered cold by supportive engagement on the projection means. In vapor deposition operations of this type, the torch **10** would be typically oriented in a vertical position and would be constructed with a fairly short overall length typically a length in the range from about six inches to two feet, though other lengths may also be used in some cases. The subject torch has also been found to be useful in various high temperature chemical studies, such as in electrical attachment experiments, chemical conversion, chemical bond breaking, and the like. Furthermore, the subject torch **10** may be useful in conducting other high temperature experimentation, including uranium fission and rocket propulsion.

It can now be seen that the subject device is capable of receiving a plasma stream and subjecting the same to relatively high temperature and pressure conditions in the presence of a high energy field in order to produce a desired result. These conditions are achievable without encountering undue current leakage, voltage breakdown, R.F. sputtering, arcing or other damaging or dangerous conditions during operation, and hence, with greatly reduced possibility for potential damage to the equipment and to personnel. The reduced electrical potentials required as compared to known torches also reduces the potential hazards to operating personnel. Also, by employing a pressure controllable cooling system as explained, high pressure operation can be achieved without much risk of damage to the equipment. While the subject device has been described in connection with particular preferred embodiments, and in conjunction with a plasma stream, it is apparent that the subject device can be used to operate with other fluid media as well.

Thus, there has been shown and described novel embodiments of a plasma heating torch which fulfill all of the objects and advantage sought therefor. Many changes, modifications, variations, and other uses and applications of the subject device, will, however, become apparent to those skilled in the art after considering this specification and the accompanying drawing. All such changes, modifications, variations, and other uses and applications which do not depart from the spirit and scope of the invention are deemed to be covered by the invention which is limited only by the claims which follow.

What is claimed is:

1. Means for generating a source of high temperature plasma comprising means forming a chamber including a pair of spaced electrically conductive chamber end walls and a closure wall extending therebetween, means for grounding said end walls, means including an orifice in one of the spaced end walls for operative connection to a source of gas under pressure permitting introduction of gas from said source into the chamber, an outlet opening in the other of said spaced end walls through which a plasma produced in the chamber can escape, and means subjecting the plasma as it moves through the chamber to a high energy field, said last named means including an electrically conductive coil positioned around the chamber closure wall and extending substantially the full length thereof between the spaced chamber end walls, said coil having a center connector location and a pair of end connector locations, said end connector locations being located respectively adjacent to the chamber end walls, said coil having first and second coil portions extending respectively between said center connector location and the respective end connector locations, means for connecting a relatively high voltage radio frequency energy source to the center connector location of said coil, said first and second coil portions being constructed to generate in-phase components of said high energy field in the chamber, and other means connecting the end connector locations electrically to the said respective grounded end walls.

2. The means defined in claim **1** wherein the electrically conductive coil is formed by a tubular conductor member, and means for passing a coolant substance through the said tubular conductor member during operation of the subject means.

3. The means defined in claim **1** including means forming a cooling chamber surrounding the conductive coil, and means feeding a coolant through the said cooling chamber and around the coil positioned therein.

4. The means defined in claim **1** including means associated with the orifice in said one end wall to direct the gas into the chamber so that the plasma produced therein will follow a non-linear path between the spaced end walls.

5. The means defined in claim **1** including means to control the temperature of the conductive coil including means to pass a coolant adjacent thereto.

6. The means defined in claim **5** including means to control the pressure of coolant flow adjacent to the coil, said control means including means responsive to the pressure of the plasma in the chamber.

7. Apparatus for raising the temperature of fluid comprising means forming a chamber receiving said fluid, said means including a pair of end walls and an enclosing side wall extending therebetween forming said chamber, one of said end walls having orifice means therein permitting passage of a fluid from a fluid source into said chamber and the other of said end walls having orifice means permitting discharge of the fluid from said chamber, high frequency electrical heating means located in heat transfer relationship to said chamber for heating the fluid therein, said heating means having first and second coil portions with first and second opposed terminal portions connected respectively to said end walls, means grounding said end walls, and means for introducing high frequency electrical energy to said heating means at an intermediate location thereon located between said first and second terminal portions, said first and second coil portions being constructed to produce in-phase fields in the chamber when said high frequency electrical energy is introduced.

8. The apparatus of claim **7** further characterized in that said first and second coil portions of the heating means are arranged in such manner that electrical current applied across said heating means is capable of generating a continuous radio frequency magnetic field in the chamber, said first coil portion extending between the intermediate location and one of said terminal portions, and the second coil portion extending between said intermediate location and the other of said terminal portions.

9. The apparatus of claim **7** further characterized in that said intermediate location is located approximately midway between said terminal portions.

10. The apparatus of claim **7** further characterized in that said heating means comprises a multi-turn coil disposed about said side wall and extending therealong for substantially the entire length thereof.

11. The apparatus of claim **7** further characterized in that said heating means comprises a plurality of coils disposed about said side wall in approximate axial alignment and extending therealong for substantially the entire length thereof.

12. The apparatus of claim **7** further characterized in that a cylindrical member is concentrically disposed around and spaced outwardly from said side wall, said cylindrical member engaging said end walls and forming an annular space with said side and end walls, and means in fluid communication with said annular space and with said chamber including means to maintain substantially equal pressure conditions in said chamber and in the annular space.

13. In a heating torch having a pair of spaced apart conductive end walls and an enclosing side wall which form a fluid chamber for receiving a supply of fluid under pressure; a pair of similar high frequency electrical heating coils disposed about and extending along said side wall in heat transfer relationship to said fluid chamber, each of said heating coils having opposed first end windings which are located respectively in closely spaced relationship to each of said respective end walls and which are operatively connected to a common electrically conductive element which includes at least one of said end walls in said torch, each of said coils having second end windings, the said second end windings of said coils being located in closely spaced relationship to each other, and means connecting a common source high frequency electrical energy to each of said second end windings of said heating coils, said coils of said pair being constructed to generate electric fields in the fluid chamber that are in-phase with each other.

14. The heating torch of claim **13** further characterized in that the high frequency energy source is a radio frequency energy source.

15. The heating torch of claim **13** further characterized in that the coils are arranged about said chamber forming means in such flows that the current that flows through each of said coils flows in a direction to generate field which are additive.

16. The heating torch of claim **13** further characterized in that each of said coils comprises an electrically conductive member having a coating of electrical insulating material thereon.

17. The heating torch of claim **16** further characterized in that adjacent convolutions of said coils are relatively closely spaced to each other and to the chamber forming means.

18. Apparatus for raising the temperature and pressure of a fluid comprising means forming a fluid chamber capable of receiving a fluid, high frequency electrical heating means including a coil disposed in heat transfer relationship to said chamber for heating the fluid contained therein, said coil having an intermediate connection to a source of high frequency voltage and a pair of spaced low potential end connections, means forming a cooling chamber in heat transfer relationship to the electrical heating means, and means for circulating a coolant through said cooling chamber, said circulating means including means to establish a pressure of coolant in the cooling chamber that depends at least in part on the pressure of the fluid in said fluid chamber.

19. The apparatus of claim **18** further characterized in that said means forming a fluid chamber includes a cylindrical wall, said cooling chamber surrounding at least a portion of said cylindrical wall.

20. The apparatus of claim **18** including pressure responsive control means operatively associated with the means for feeding the coolant to maintain a predetermined pressure of said coolant in said cooling chamber, said pressure responsive means including means responsive to the pressure in the fluid chamber and to the pressure in the cooling chamber.

21. The apparatus of claim **18** including pressure responsive control means operatively associated with the means for feeding the coolant, said pressure responsive means including means to control the means for feeding coolant to maintain the pressure in the cooling chamber approximately equal to the pressure in the fluid chamber.

22. The apparatus of claim **18** further characterized in that the apparatus is a heating torch and the fluid is a plasma.

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