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Blomgren, Sr. et al.

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[54] COOLING APPARATUS AND METHOD FOR HEAT EXCHANGERS

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[22] Filed: **Aug. 16, 1973**

[21] Appl. No.: **388,829**

Related U.S. Application Data

[62] Division of Ser. No. 132,280, April 8, 1971, Pat. No. 3,794,111.

[52] **U.S. Cl.** **165/1,** 165/96, 165/110
[51] **Int. Cl.** **F28f 13/16**
[58] **Field of Search** 165/110, 1, 96

[56] **References Cited**

UNITED STATES PATENTS

1,835,557	12/1931	Burke	165/1 X
1,980,821	11/1934	Palueff	165/1 X
2,605,377	7/1952	Kaehni et al.	165/1 X
3,056,587	10/1962	Steigerwald	165/1
3,224,497	12/1965	Blomgren, Sr. et al.	165/2
3,370,644	2/1968	Daily et al.	165/1
3,526,268	9/1970	Robinson	165/1

FOREIGN PATENTS OR APPLICATIONS

373,051	4/1923	Germany	165/1

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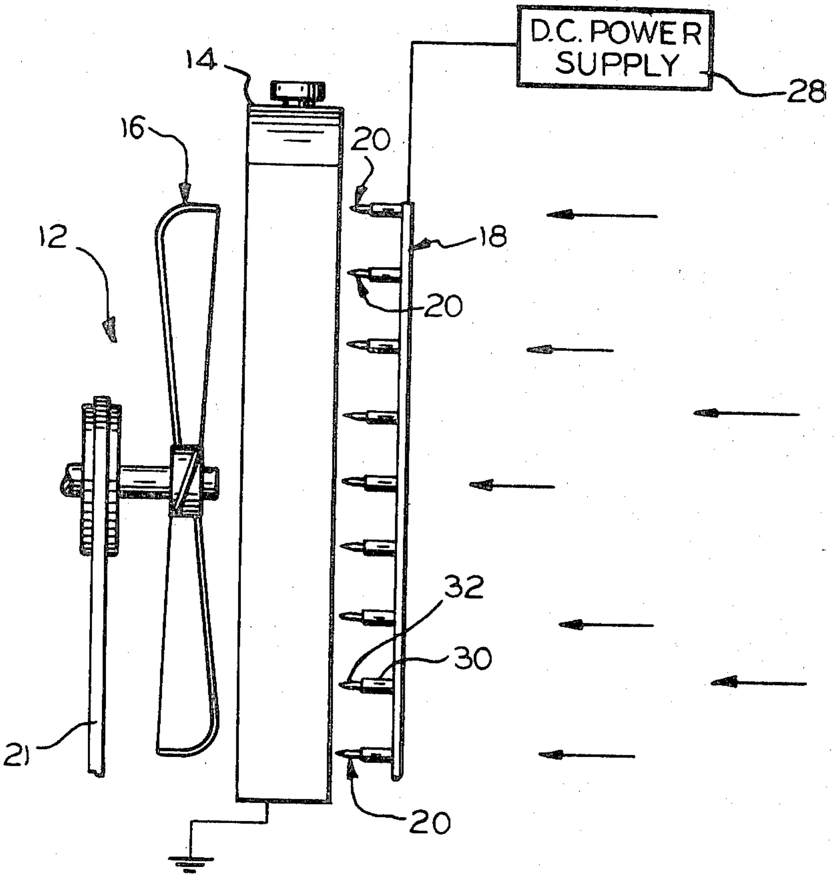
Attorney, Agent, or Firm—Lockwood, Dewey, Zickert & Alex

[57] **ABSTRACT**

To improve the coefficient of heat transfer between the surfaces and the heat exchange media of heat exchangers, such as automobile radiators, steam condensers, and steam boilers. Conductive probes or conductors are energized with a low power, low current high DC potential and spaced from the surfaces a distance slightly greater than the distance at which arcing occurs while the surfaces are grounded to generate an electrostatic field.

2 Claims, 15 Drawing Figures



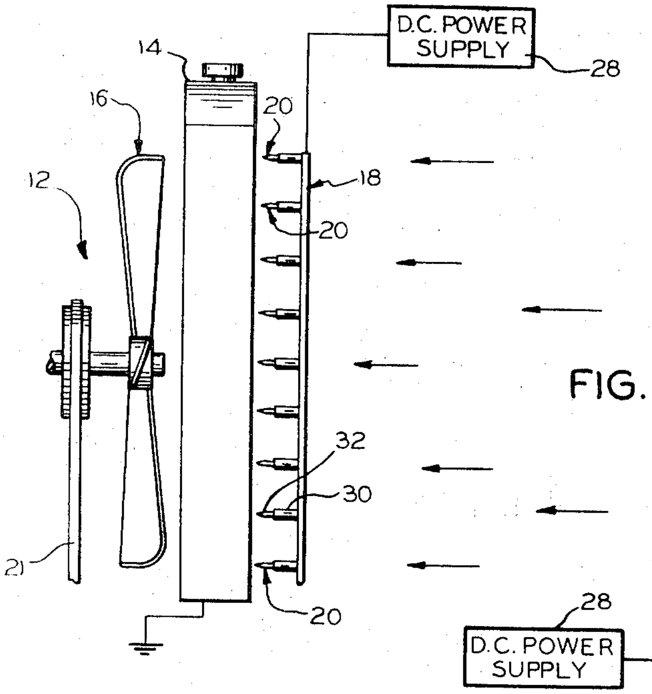


FIG.1

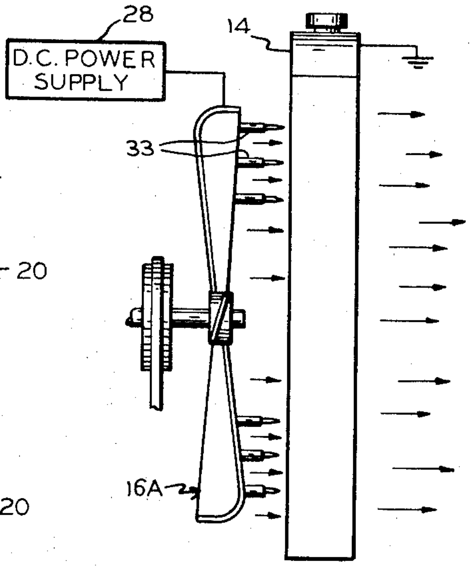


FIG. 2A

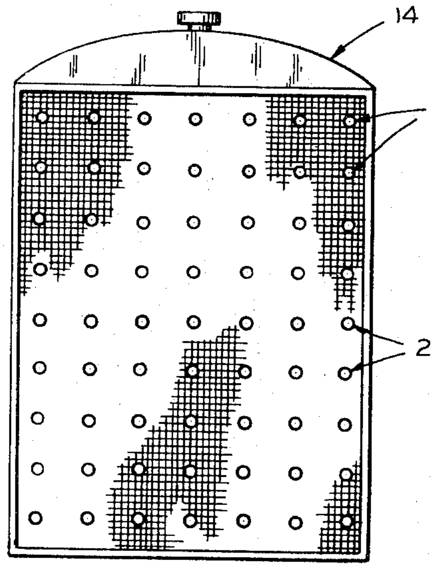


FIG.2

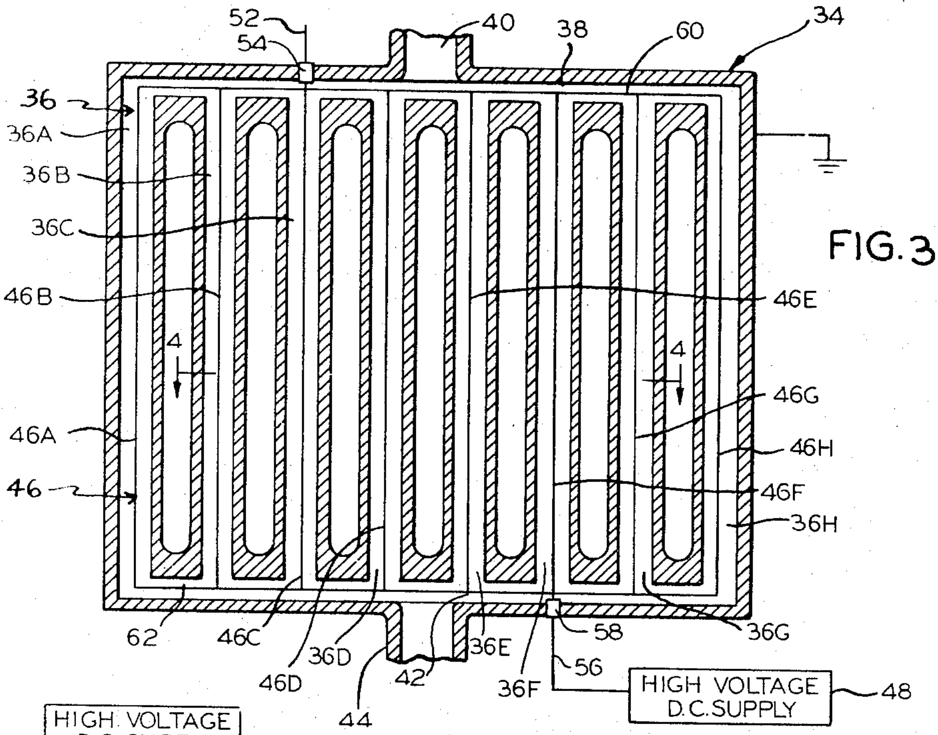


FIG. 3

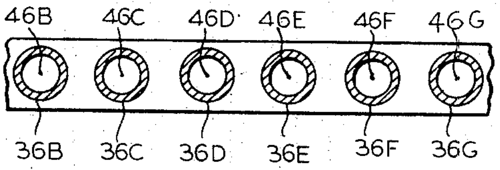


FIG. 4

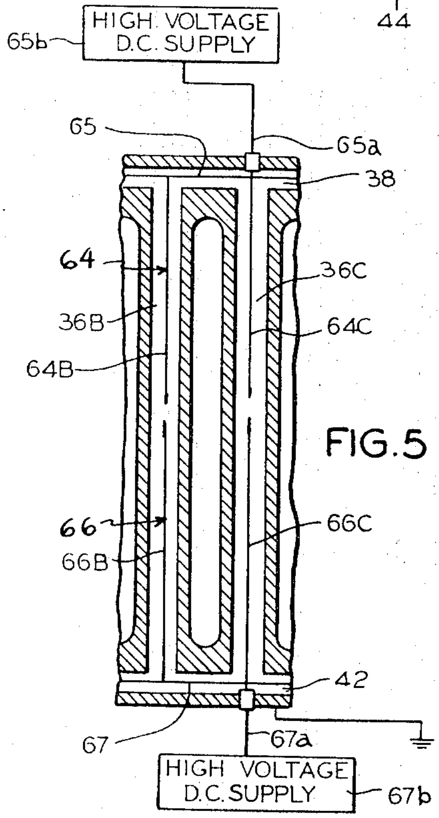


FIG. 5

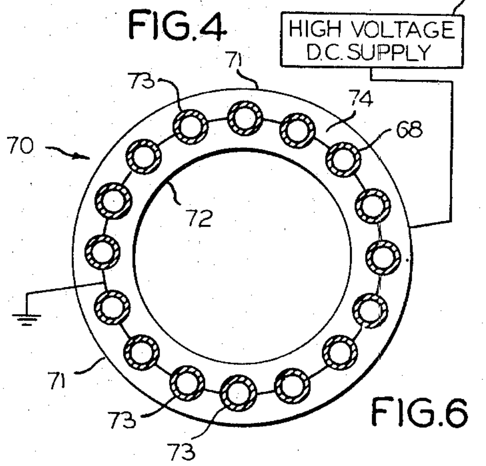


FIG. 6

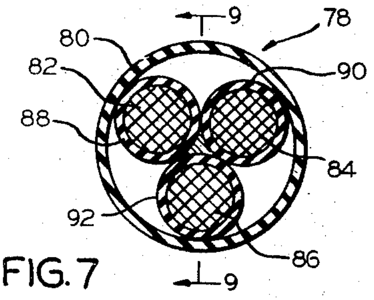


FIG.7

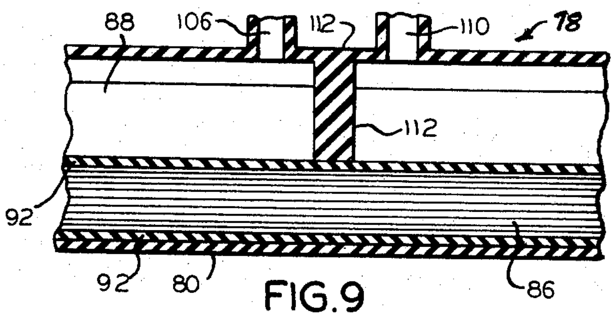


FIG.9

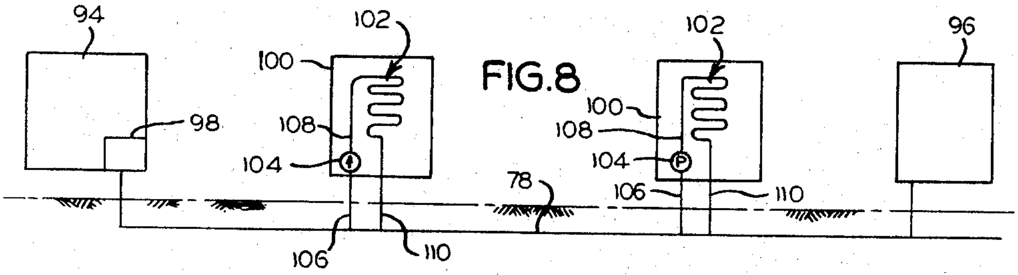


FIG.8

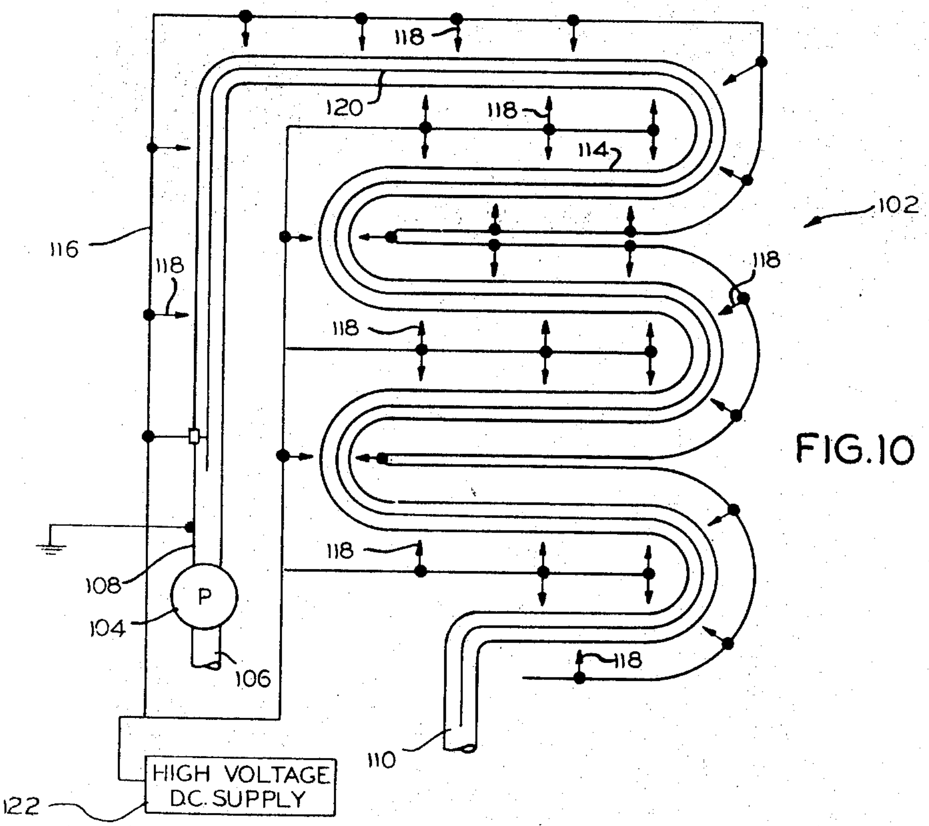
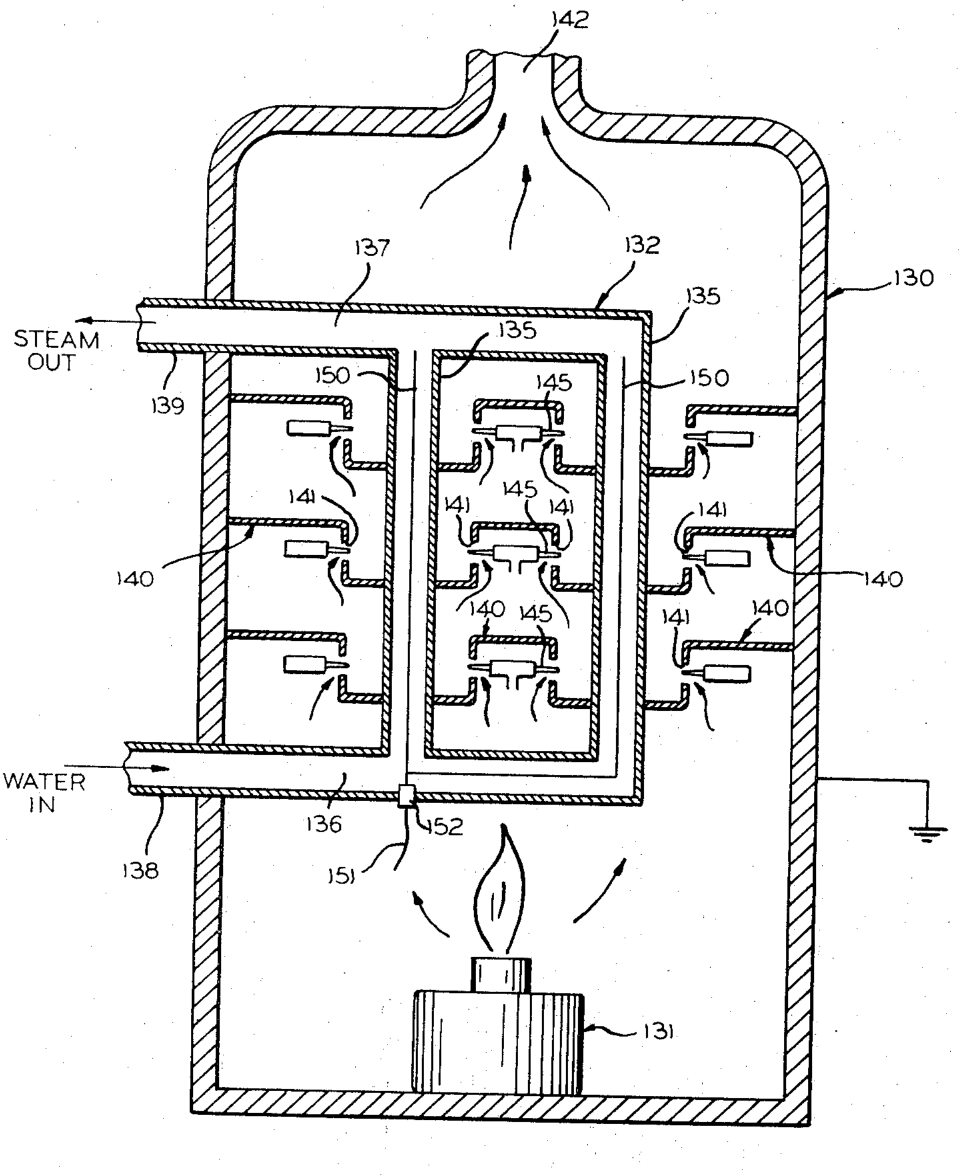


FIG.10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STEAM OUT
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WATER IN
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FIG.11

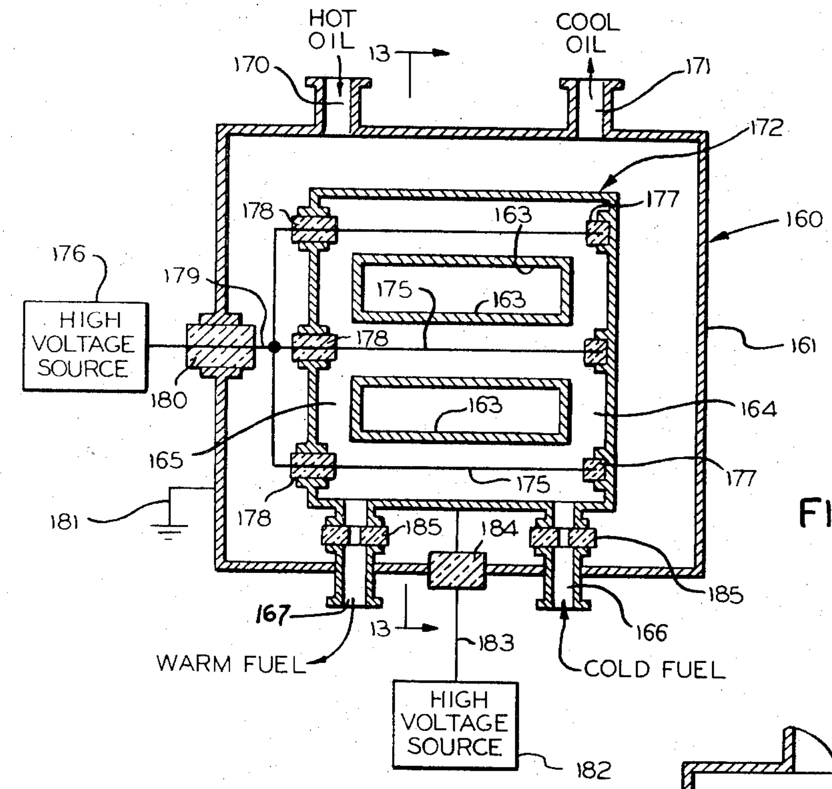

FIG.12

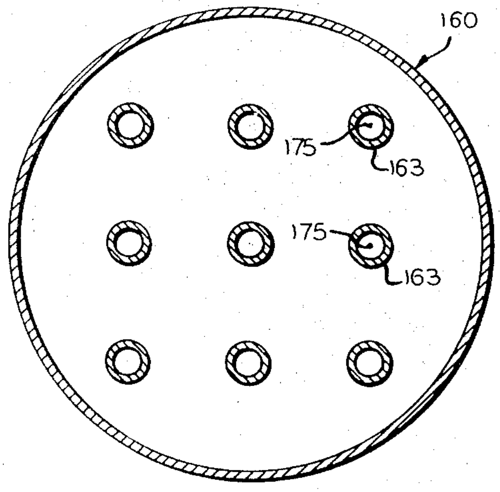

FIG.13

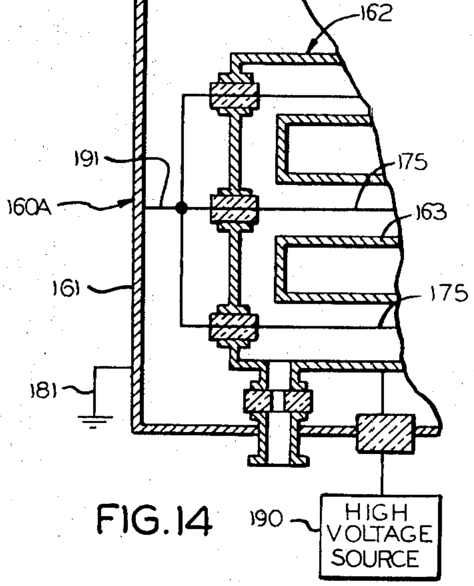

FIG.14

COOLING APPARATUS AND METHOD FOR HEAT EXCHANGERS

This is a division of application Ser. No. 132,280, filed Apr. 8, 1971, now U.S. Pat. No. 3,794,111, granted Feb. 26, 1974.

This invention relates in general to heat exchange methods and apparatuses, and more particularly to methods and apparatuses for increasing the coefficient of heat transfer between a solid surface and a heat transfer medium or between a heat transfer medium and a solid surface, or of increasing the coefficient of heat transfer of both surfaces of a heat exchange conduit or tube, one surface of which contacts a heat transfer medium of one temperature and the other of which contacts a heat transfer medium of another temperature.

The heat exchange apparatus of this invention includes a surface through which heat is to be transferred and conductors or probes that have a high voltage low current DC potential with respect to the surface and are spaced a distance from the surface such as to prevent arcing at a given potential while creating a strong electrostatic field between the surface and the conductors. A voltage source of 30 to 60 kilovolts produces the potential difference between the conductors or probes and the surfaces treated where a small ionic current in the low microampere range results in treating the surface with a low power economically. This arrangement results in a greatly increased rate of heat transfer through the surface by the electrostatic field surface bombardment.

When the invention is included in a heat exchanger of the type in which a heated fluid is pumped through cooling tubes that remove heat from the fluid, the energized conductors may be inside, outside or both inside and outside of the tube to aid in transferring heat into, from or both into and from the walls of the tube.

A further feature of the invention is to combine jet impingement of a heat transfer media and an electrostatic field to a surface for increasing the rate of heat transfer.

In the method of this invention the application of a high voltage DC potential to the conductors near the surface creates a strong electrostatic field that aids in the transfer of heat through the surface without requiring further apparatuses. For example, when conductors along the central axis of a condenser tube of a steam condenser or along the central axes of the cooling tubes of a radiator are energized with a high voltage DC potential while the walls of the tubes are grounded, heat is transferred from the steam to the walls of the condenser tube and from the coolant to the walls of the cooling tubes at a greater rate than before the conductors were energized. Similarly, when probes spaced outside the cooling tubes are energized with a high voltage DC potential, heat is transferred from the walls to the surrounding air at a greater rate than before the probes were energized.

It is therefore an object of the invention to provide a novel heat exchange method and apparatus.

Another object of the invention is the provision of a heat exchange apparatus and method that operates electrically and does not have moving parts.

Still another object of the invention is the provision of a method and apparatus for economically cooling without the use of a coolant such as water, or where a minimum of coolant is used, and with low power requirements.

A further object of the invention is the provision of a method and apparatus for improving the efficiency of conventional heat exchangers.

A still further object of the invention is the provision of a heat exchanger that is constructed economically of inexpensive, reliable parts that are assembled without high cost.

A still further object of the invention is the provision of a heat exchanger that is usable where there is insufficient room for other conventional heat exchangers.

Other objects, features and advantages of the invention will be apparent from the following detailed disclosure, taken in conjunction with the accompanying sheets of drawings, wherein like reference numerals refer to like parts, in which:

FIG. **1** is a diagrammatic view of a radiator and fan for a cooling system illustrating an embodiment of the invention;

FIG. **2** is a front elevational view of the embodiment of FIG. **1**;

FIG. **2A** is a diagrammatic view similar to FIG. **1**, illustrating a radiator and fan for a cooling system and a modification of the invention;

FIG. **3** is a diagrammatic, fragmentary, sectional view of a heat exchanger such as a steam condenser that illustrates another embodiment of the invention;

FIG. **4** is a sectional view of the embodiment of FIG. **3**, taken through lines **4—4** of FIG. **3**;

FIG. **5** is a diagrammatic, fragmentary, sectional view of another embodiment of a heat exchanger in accordance with the invention;

FIG. **6** is a diagrammatic sectional view of still another embodiment of a heat exchanger in accordance with the invention;

FIG. **7** is a transverse sectional view of a high voltage transmission line with which an embodiment of the invention may be used;

FIG. **8** is a diagrammatic view of a high voltage transmission system illustrating another embodiment of the invention;

FIG. **9** is a longitudinal, sectional view of the transmission line of FIG. **7**;

FIG. **10** is a diagrammatic view of a heat exchanger that is usable in the embodiment of FIGS. **7–9**;

FIG. **11** is a somewhat diagrammatic vertical sectional view taken through a unit having a heat exchanger and illustrating another embodiment of the invention;

FIG. **12** is a diagrammatic and party schematic view of a heat exchanger embodying another modification of the invention, wherein the heat exchanger transfers heat between two liquids;

FIG. **13** is a transverse sectional view taken substantially along line **13—13** of FIG. **12**; and

FIG. **14** is a fragmentary, diagrammatic and partly sectional view of a heat exchanger, similar to FIG. **12**, but illustrating a further modification of the invention, and in particular a modification of the embodiment of FIG. **12**.

There are many different types of heat exchangers. The structural design of a type of heat exchanger is governed by the problem that is to be solved by the heat exchanger so that a steam-to-air heat exchanger in a steam condenser, for example, has a different design than a water-to-air heat exchanger in the radiator of an automobile.

Several different types of heat exchangers that are embodiments of the invention are described hereinafter and other types of heat exchangers that include the invention but are not specifically described herein can be understood by analogy to those embodiments of the invention which are specifically described.

In FIGS. **1** and **2**, there is shown a portion of an automobile or engine cooling system in accordance with the invention, having a fan **12** with a fan blade **16.** A conventional radiator or heat exchanger **14** having a suitable thin walled conduit system of tubes through which coolant is pumped is positioned in front of the fan blade **16,** and a bank **18** of probes **20** is positioned in front of the radiator **14** in the air stream.

To draw cool air over the cooling tubes of the radiator **14,** the fan blade **16** of the fan **12** is rotated by a motor (not shown) through the fan belt **21.** The blade **16** of the fan **12** is constructed to draw air through the bank of probes **20** and over the cooling tubes of the radiator. The probes **20** form a matrix of rows and columns of probes across the radiator, with each row of probes being suitably supported. The band or grid **18** of probes **20** is electrically connected to a high voltage DC power supply **28** and is insulated from the radiator **14,** which remains at ground level potential with respect to the probes **20.** The power supply **28** has an output potential of between 10 and 60 KV (kilovolts). An ionic current in the low microampere range results in low power requirements. For example, a voltage of 30,000 volts draws a current in the range of 200 microamps resulting in a power requirement of 6 watts.

The probes **20** each include a tubular insulative base **30** and a pointed conductive electrode **32.** The insulative base **30** of each of the probes **20** extends toward the radiator **14** and each of the electrodes **32** passes through the longitudinal axis of a different base **30,** being electrically connected at one end to the high voltage power supply **28.** The tips of the electrodes **32** are spaced from the radiator **14** a distance slightly in excess of the distance at which arcing occurs.

In the operation of the embodiment of FIGS. **1** and **2,** heat is removed by the heat exchanger from a coolant flowing in the cooling tubes of the radiator **14.** The fan **12** and the bank **18** of probes **20** of the heat exchanger cooperate in removing the heat from the cooling tubes of the radiator **14.**

The belt **21** of the fan **12** is driven by a motor (not shown) and rotates the fan blade **16,** which draws air through the bank **18** of probes **20** and through the radiator **14.** As the air flows through the radiator **14,** it removes heat from the outer surfaces of the cooling tubes of the radiator **14** to enable more heat to be conducted from the liquid in the radiator through the walls of the cooling tubes.

At the same time that air is being drawn over the cooling tubes of the radiator **14,** the electrodes **32** of the bank **18** of probes **20** are energized by the high voltage DC power supply **28** establishing a potential gradient between the probes and radiator. The electrodes are preferably connected to the negative side of the power supply with the other side grounded or connected to the radiator, although the electrodes may be connected to the positive side with the negative side grounded or connected to the radiator.

The electrodes **32** create an electrostatic field between the cooling tubes of the radiator **14** and the tips of the electrodes **32,** which electrostatic field has a high intensity at all points between the tips of the electrodes and the cooling tubes of the radiator **14** but has an especially high intensity adjacent to the tips of the electrodes. This electrostatic field dramatically reduces the temperature of the walls of the cooling tubes by rapidly removing heat from them.

The mechanism that enables the electrostatic field to cool a surface is not fully understood, but it is believed that the electrostatic field breaks the skin of insulating molecules that normally adheres to the surface of the cooling tubes. This skin of molecules is not normally removed by the flow of air drawn to the fan **12,** and when present, reduces the transfer of heat away from the tube walls.

The high intensity electrostatic field near the tips of the electrodes **32** creates corona, which ionizes some of the molecules in the air. Ions and electrons are accelerated toward the cooling tubes. The bombarding ions disturb or condition the boundary layer to increase materially the coefficient of heat transfer.

Although a portion of the cooling system of an automobile engine or other engine has been illustrated and described to explain an embodiment of the invention, it can be understood that the principles of the invention as taught in this description can be easily applied to other similar heat exchangers, such as for example, to air conditioners.

Moreover, the probes may be mounted at many different locations such as at the side of the cooling tubes, or in the case of cooling tubes through which a fan blows air rather than drawing air therethrough, FIG. **2A,** the probes **33** are mounted on the fan blade **16A** and the fan blade is suitably insulated from the motor driving the fan. Power supply **28** is diagrammatically shown as connected to fan **16A,** but it will be appreciated it will be connected mechanically thereto in any suitable manner. Accordingly, the embodiment of FIG. **2A** illustrates a moving probe or electrode instead of the fixed probe arrangement of FIG. **1,** wherein a single probe can then electrostatically treat a larger area. It should be appreciated that other means may be provided to impart movement to a movable probe such as to cause oscillation of a probe in a rectilinear or orbital path, and in the latter arrangement the means mounting the movable probe need not also pump air. It should also be appreciated that the present invention in the form of a radiator for an engine cooling system increases the cooling capacity, thereby enabling the use of a radiator or smaller heat exchanger for a given cooling capacity.

In the embodiment illustrated in FIGS. **3** and **4,** an electrostatic field aids in the transfer of heat in a manner similar to that of the embodiment of FIGS. **1** and **2,** and further aids in transferring heat from steam within the heat exchanger **34** to the walls of the exchanger tubes **36A–36H** rather than from the walls of cooling tubes to air.

The heat exchanger **34** could serve any desired purpose, but will be described as a steam condenser which includes an upper manifold **38** for receiving low pressure steam through the inlet **40** and a lower manifold **42** for supplying low pressure condensate to the outlet **44,** with the upper manifold **38** communicating with the lower manifold **42** through the eight parallel, vertical condenser tubes **36A–36H**. A different one of the eight insulated conductors **46A–46H**, each of which is a conductive wire, extends axially through each of the tubes **36A–36H**. The conductors are suitably held in place and insulated from the tubes and manifolds.

To energize the conductors **46A–46H** with a high DC potential, a high voltage terminal of a high voltage power supply **48** is connected to either a first lead **52** and/or a second lead **56**. The first lead **52** extends through a first ceramic feed-through bushing **54** in the walls of the upper manifold **38** and the second lead **56** extends through a second ceramic feed-through bushing **58** in the walls of the lower manifold **42**, with either one of the leads **52** or **56** being electrically connected at one end outside of the steam condenser **34** to a high voltage terminal of the high voltage power supply **48** and at its other end to the conductors **46A–46H** inside of the heat exchanger **34** through buses **60** and **62**. Negative or positive potential may be applied to the conductors, but the negative potential is preferred. The other side of the power supply is connected to ground potential or the condenser.

In the operation of the embodiment of FIGS. **3** and **4**, low pressure steam flows into the upper manifold **38** through the inlet **40**. The steam flows from the upper manifold **38** through the condenser tubes **36A–36H** and into the lower manifold **42**, which communicates with the outlet **44**. The exterior surfaces of the tubes are exposed to atmosphere and may have air blown thereover if desired, or any other cooling media may be used to take heat away from the condenser.

As the steam is flowing through the condenser, the walls of the condenser tubes **36** are held at ground potential and the conductors **46** are energized with a potential with respect to the walls of the condenser tubes of between 10 and 60 KV by the application of this potential to the conductor **56** and/or the conductor **52**. The difference in the potentials of the conductors **46A–46H** and the walls of the condenser tubes **36A–36H** results in an electrostatic field inside of each tube, and treating of the tube surface to enhance the coefficient of heat transfer.

There are sufficient ions in steam so that it is not necessary to create ions at the conductors. It is only necessary to create an electrostatic field. The conductors are insulated to prevent a direct short across the steam to the tube walls. In a heat exchanger where the fluid flowing through the tubes is a dielectric, the conductors need not be insulated, and would not be insulated in order to create an ionic current flow.

The embodiment of the steam condenser of FIGS. **3** and **4** has the advantage of being smaller in size than other conventional steam condensers of the same capacity and therefore being less expensive. The steam condenser may be smaller in size because it has a high coefficient of heat transfer on the steam side of the condensing tubes. With the increased coefficient of heat transfer provided by this heat exchanger, more heat is removed from steam through the same area of condenser tubes than with condensers that do not have an electrostatic field in the interior of the condenser tubes.

In FIG. **5**, a fragmentary view of a modification is shown that is the same as the steam condenser shown in FIGS. 3 and 4 except for the application of the electrostatic field, wherein it is applied at various levels of intensity in accordance with the heat transfer rate needed. The parts of the embodiment of FIG. **5** that are identical to the parts of the embodiment of FIGS. **3** and **4** are indicated by the same reference numerals.

In the embodiment of FIG. **5**, eight condenser tubes **36A–36H** are provided, with two of the condenser tubes **36B** and **36C** being shown in FIG. **5**. Each of the condenser tubes **36A–36H** have a corresponding one of eight insulated conductors **64A–64H** (only **64B** and **64C** shown) extending from the upper manifold **38** and a corresponding one of eight insulated conductors **66A–66H** (only **66B** and **66C** shown) extending from the lower manifold **42**, with both conductors in each tube extending less than half the length of the tube along its longitudinal axis. The conductors are suitably supported in the upper and lower manifolds and respectively connected to buses or commons **65** and **67**.

The bus **65** is electrically connected to a source of high voltage DC potential through the lead **65A** at the upper manifold and the bus **67** is electrically connected to a source of high voltage DC potential through lead **67A** at the lower manifold, lower than that for the lead **65A**. Suitable ceramic insulators insulate the leads **65A** and **67A** from the condenser. Lead **65A** is connected to a high voltage DC supply **65B**, while lead **67A** is connected to a high voltage DC supply **67B**,

The potentials applied to the conductors **64** and **66** are each slightly less than the minimum potential that causes arcing. Since the steam at the top of the condenser tubes is drier and more gaseous than the steam and condensate near the bottom of the tubes, its minimum arcing potential is higher than the minimum arcing potential of the steam near the bottom of the tubes. Accordingly, the potential applied to the conductors **64A–64H** is higher than the potential applied to the conductors **66A–66H**. With this arrangement, the electrostatic field is at the most effective value permitted by the steam in the condenser tube at both the top and bottom of the tube. Moreover, a high rate of heat transfer is needed and provided where the heat level is the highest.

Although the embodiment of FIG. **5** includes only two separate conductors in each condenser tube to create two different intensity electrostatic fields, it can be understood from this description that more than two conductors or probes may be included in each condenser tube and connected to different potentials through connecting conductors that pass through the walls of the manifolds or condenser tubes to provide gradients in the electrostatic field so that the field is the maximum possible without arcing. Moreover, the conductors may have shapes different from those shown in FIG. **5**. By increasing the number of conductors and selecting their shapes, an electrostatic field can be formed that has the greatest intensity permitted by the quality of the steam at each location in the condenser tube.

Another application for the present invention is shown in FIG. **6** in connection with a heat exchanger or steam condenser **70**, which includes a tubular shell having inner and outer walls **71** and **72** of electrically conductive material. A plurality of circumferentially arranged tubes **73** are positioned in the tubular shell chamber **74** which functions as a condensing shell. Steam is introduced into one end of the tubular shell and condensate is taken from the other end.

The outer and inner tubular walls **71** and **72** have a high voltage DC potential **75** of between 10 and 60 KV applied to them and each have their surface that contacts the steam in the space **74** covered with electrical insulation. Alternately, the outside of the tubes **73** may be covered with electrical insulation. The cooling tubes **73** are grounded and/or connected to the ground side of the source of potential and circulate a cooling liquid or gas that removes heat from the steam in the chamber **74** of the condenser shell **70.**

In the operation of the embodiment of steam condenser shown in FIG. **6,** ions bombard the outer surfaces of the cooling tubes **73** to condition the boundary layers on the surface and increase the transfer of heat from the steam in the space **74** to the walls of the cooling tubes **73** by the same process that increases the removal of heat from the steam in the steam condensers of FIGS. **3, 4,** and **5.** However, the embodiment of FIG. **6** is arranged to have an increased turbulence or effect created in the insulating skin or boundary layer of the cooling surfaces and therey an increased coefficient of heat transfer of the cooling surfaces in the embodiments of FIGS. **3, 4,** and **5.**

Although the embodiments of FIGS. **3, 4, 5,** and **6** are all described as steam condensers, it can easily be understood that the principles of the invention can be applied to other similar types of heat exchangers. For example, the principles of the invention can be applied to heat exchangers that contain gases or liquids other than steam such as Freon used in refrigeration and air conditioning equipment and the principles of the invention can be applied to other types of steam heat exchangers, such as to boilers or steam generators. Of course, certain modifications are necessary or permissible when applying the principles to other types of heat exchangers, such as for example, the insulation would not be included on the wires **46A–46H** of the embodiment of FIGS. **3** and **4** if Freon, which is a dielectric, were used rather than steam. In a boiler, where the heat transfer rate is increased for the tubes, a given output capacity can be obtained with a smaller boiler.

In the embodiments of FIGS. **1–6,** an electrostatic field is applied from one side of a wall to increase the transfer of heat into the wall in some embodiments, and from the other side of the wall to increase the transfer of heat from the wall in other embodiments. In FIGS. **7, 8, 9** and **10,** a heat exchanger embodiment is shown in which one electrostatic field increases the transfer of heat into one side of a wall and another electrostatic field increases the transfer of heat from the opposite side of the wall.

In FIG. 7, a high voltage transmission line **78** is shown having a cylindrical outer casing **80** surrounding three conductors **82, 84** and **86,** each of which is covered by a respective one of the three tubular electrical insulators **88, 90** and **92.** A liquid coolant circulates around the insulated conductors within the casing **80.**

As shown in FIG. **8,** the transmission line **78** may conduct a high voltage such as 325 KV from a power plant **94** to a distribution station **96,** with the transmission line **78** extending beneath the surface of the ground. As power is transmitted through the conductors **82, 84** and **86** of the transmission line **78,** heat is generated. To remove this heat, a pump **98** in the power station **94** pumps a liquid coolant through the transmission line **78** and around the insulated conductors **82, 84,** and **86** within the outer casing **80.**

Because the temperature of the coolant is increased as it flows through the transmission line and receives heat from the conductors therein, cooling stations **100** are located above ground along the route of the transmission line **78** to remove the coolant from the transmission line **78,** cool the coolant, and pump it back into the transmission line. Each cooling station **100** includes: (1) a heat exchanger **102** to cool the coolant; (2) a pump **104** communicating with the transmission line **78** through a conduit **106** and communicating with the heat exchanger **102** through a conduit **108;** and (3) a conduit **110** communicating with the heat exchanger **102** and the transmission line **78** to return the coolant to the transmission line after heat been removed from it.

As shown in FIG. **9,** the transmission line **78** includes a transverse partition or wall **112** in the casing **80** and around the insulated conductors to block the flow of the coolant, with the conduits **106** and **110** each communicating with the interior of the casing **80** of the transmission line on opposite sides of the partition **112.** The heated coolant is removed from one side of the partition **112** through the conduit **106,** pumped through the heat exchanger **102** by the pump **104** and returned to the transmission line on the opposite side of the partition **112.** The heated coolant is removed from one side of the partition **112** through the conduit **106,** pumped through the heat exchanger **102** by the pump **104** and returned to the transmission line on the opposite side of the partition **112** at a lower temperature.

To remove heat from the coolant, the heat exchanger **102,** as best shown in FIG. **10,** includes a tubular conduit or coil **114** formed into a conventional flat heat exchange coil that communicates at one end with the upper end of the conduit **108** to receive warm coolant and communicates at its other end with the upper end of the conduit **110** to return coolant to the transmission line after removing some of the heat from it. A first conductor **116** electrically connects a plurality of probes **118** that are spaced at intervals outside of the coil **114** and a second conductor **120** extends along the interior of the coil **114,** with both first and second conductors **116** and **120** being electrically connected to the high voltage terminal of a supply of DC potential **122.** The conductor **120** is insulated if the coolant is an electrolyte and uninsulated if the coolant is a dielectric.

The source of DC potential **122** is slightly lower than the potential that would cause arcing between the conductor **120** and the interior of the wall of the coil **114,** and the points of the probes **118** are spaced from the wall of the coil **114** a distance slightly greater then the distance at which arcing occurs to the walls. The walls of the coil **114** are grounded and/or connected to the grounded side of the supply **122.**

In operation, a coolant is pumped through the transmission line **78** by the pump **98** (FIG. **8**) in the power plant **94** as high voltage power is transmitted along the conductors **82, 84** and **86** (FIG. **7**) of the transmission line **78** between the power plant **94** and the distribution station **96.** As the power is transmitted along the transmission line **78,** heat is generated in the conductors and received by the coolant to increase the temperature of the coolant so that the coolant is at a higher temperature some distance from the point it enters the transmission line than it was when it entered the transmission line.

After the coolant has increased substantially in temperature, it reaches one of the cooling stations **100,** where it is removed from the transmission line **78** through the conduit **106** (FIGS. **9** and **10**) and pumped by the pump **104** through the conduit **108** to the top of the heat exchange coil **114**. The coolant then flows through the heat exchange coil **114** into the conduit **110** which returns it to the transmission line **78** (FIG. **8**).

As the coolant flows through the conduit **114** of the heat exchanger **102**, its temperature is lowered, with heat being conducted from the coolant into the walls of the coil **114**, aided by the energized conductor **120** and being transferred from the walls of the coil **114** to the surrounding air aided by the energized probes **118**.

To aid in the transfer of heat from the coolant to the walls of the coil **114** of the heat exchanger **102**, the conductor **120** is energized with a high voltage DC potential (either negative or positive although negative is preferred) which creates an electrostatic field in the interior of the conduit. This electrostatic field increases the coefficient of heat transfer from the coolant to the walls of the coil **114** in the manner explained in connection with the embodiment of FIGS. **3** and **4**.

To aid in the transfer of heat from the walls of the coil **114** to the surrounding air, the conductor **116** and the probes **118** are energized with the same potential which creates an electrostatic field on the outside of the walls of the coil **114**. This electrostatic field increases the coefficient of heat transfer from the walls of the coil **114** in a manner similar to that explained in connection with the embodiment of FIGS. **1** and **2**, except that normally an air blower is not included in the cooling stations **100**. Even without the blower, the electrostatic field created by the energized probes **118** removes sufficient heat from the walls of the coil **114** to substantially lower the temperature of the coolant in the conduit.

The heat exchanger **102** has several advantages over conventional air cooled heat exchangers in lowering the temperature of the coolant in a transmission line such as: (1) it is smaller in size because of its increased efficiency; (2) it is less expensive because of its reduced size and low cost component parts; (3) it requires less maintenance because it does not require moving parts; and (4) it is silent in operation.

The heat exchanger **102** has several advantages over conventional water cooled heat exchangers, which are: (1) it may be used where water of adequate pressure is not available; (2) it is less expensive to install; (3) the conduits of the heat exchanger may be constructed of inexpensive materials such as carbon steel rather than of stainless steel which is generally required for conventional water cooled heat exchangers; and (4) there is no thermal pollution of natural bodies of water in the vicinity.

Referring now to the embodiment of FIG. **11**, the invention is illustrated as applied to a steam boiler or generator wherein the rate of heat transfer is increased materially by the use of jet impingement of one of the heat transfer media against the boiler tubes and the establishment of electrostatic fields at the inner and outer walls of the tubes.

The steam boiler includes generally an outer shell **130** having arranged therein a burner **131** for producing hot combustion gases, and a heat exchanger **132** for taking the heat from the combustion gases and transferring it to water that is turned into steam. Thus, one of the heat transfer medias is hot combustion gases, while the other of the heat transfer media is water and steam.

The heat exchanger includes a plurality of tubes **135** connected at their lower end by a water intake manifold **136** and at their upper end by a steam discharge manifold **137**. Water is introduced into the lower manifold **136** at the water inlet **138**, while steam is discharged from the upper mainfold **137** through a steam outlet **139**.

A baffle arrangement **140** defining a plurality of orifices or nozzles **141** is arranged within the shell **130** to direct the hot combustion gases in jets against the exterior walls of the tubes **135**. Additional pumping means may be provided to pressurize the combustion gases to establish the jet impingement of combustion gases against the exterior walls of the tubes. The spent gases are exited through the discharge flue **142**.

The high velocity of the combustion gases against the exterior surfaces of the tubes **135** disturb the laminar boundary layer to enhance the rate of heat transfer between the gases and the tube walls. Additionally, a plurality of probes **145** are arranged with sharp pointed terminal ends within the orifices **141**, and charged with a high voltage DC potential that establishes an electrostatic field between the probes and the tubes at the exterior walls which further disturbs the laminar boundary layer to increase the rate of heat transfer between the combustion gases and the walls. Thus, the jet impingement coacts with the electrostatic field to affect the laminar boundary layer at the exterior walls of the tubes to enhance the rate of heat transfer between the combustion gases and the tube walls. The magnitude of the high voltage potential applied to the probes **145** is such as to be slightly less than that which would cause arcing between the probes and the tube walls. It is understood that the shell and tube walls would be at ground potential. Further, the probes may be otherwise positioned than at the central area of the orifices **141**, it being appreciated that the electrostatic field generated by the probes is to coact with the jet impingement of the combustion gas media to enhance the rate of heat transfer.

In order to further increase the heat transfer between the inner walls of the tubes **135** and the media being pumped therethrough, in this case water which is turned into steam, conductors **150** are positioned axially within the tubes, and supported in any suitable manner, and supplied with a source of high voltage DC potential through a lead **151** that connects to the conductors through the walls of the manifold **138**. An insulating member **152** insulates the lead **151** and the conductors **150** from the heat exchanger. Inasmuch as the heat exchanger and the shell are at ground potential, an electrostatic field is generated between the conductors **150** and the inner walls of the tubes **135** which, through ionic bombardment of the inner walls, disrupts the laminar boundary layer, thereby increasing the rate of heat transfer between the tubes and the media pumped therethrough. The level of potential for the conductors **150** is slightly less than that which would cause arcing between the conductors and the tubes. Inasmuch as the media is essentially an electrolyte, the conductors **150** are coated with a suitable insulation to prevent a short circuit across the media to the tubes. In a situation where the media within the tubes is a dielectric, conductors may be uninsulated.

A typical voltage for the probes **145** would be 30–60 kilovolts DC, while a typical voltage for the conductors

150 would be about 4.5 kilovolts/CM. As in the other embodiments already described, a low current in the microamp range would result in low power requirements.

While the embodiment of FIG. 11 has been described as a steam generator, it should be appreciated that the heat exchanger 132 may be employed to remove heat from the media pumped therethrough, and in this case, a cooling media is passed through the shell 130 in place of the hot combustion gases. In either case, the electrostatic fields and the jet impingement coact to increase the rate of heat transfer between the medias and the heat exchanger tubes. Accordingly, it can be appreciated that the heat exchanger 132, according to the invention, for a given capacity, would be smaller than heretofore known heat exchangers.

Another embodiment of the invention is shown in FIGS. 12 and 13 in the form of a heat exchanger 160 of a type capable of transmitting heat from one liquid medium to another liquid medium. The heat exchanger includes an outer shell 161 having mounted therein a tube assembly 162 defined by a plurality of tubes 163 connected at their opposite ends by inlet and outlet manifolds 164 and 165. An inlet 166 extends from the inlet manifold 164 out through the outer shell 160, while an outlet 167 extends from the outlet manifold 165 through the outer shell 160. Accordingly, liquid may be circulated through the tube assembly 162 by connecting the inlet 166 and outlet 167 to a suitable liquid circuit. Another liquid circuit in connection with the heat exchanger is connected to a shell 161, inlet 170 and a shell outlet 171 so that a second liquid can be circulated about the tube assembly 162 within the shell 161.

As an example of usage, the heat exchanger 160 may be employed in connection with the operation of an engine, wherein the engine utilizes a supply of oil for lubrication that must be cooled, and a supply of fuel for combustion that preferably is heated prior to combustion. Accordingly, hot oil may be introduced into shell inlet 170, reduced in temperature and discharged from the shell outlet 171 at a cooler temperature, while cool fuel may be introduced into the tube assembly inlet 166 and discharged at a warmer temperature through the tube assembly outlet 167. Thus, the fuel will be raised in temperature to enhance combustion, while the oil will be reduced in temperature to render it more effective for lubrication and enhance its life.

Application of the present invention to the heat exchanger increases the coefficient of heat transfer at the inner and outer surfaces of the tube 163 of the tube assembly 162 by conditioning the boundary layers on the inner and outer surfaces of the tubes. Conditioning of the boundary layers is accomplished by establishing a potential gradient or difference between the surfaces of the tubes and a reference. This potential gradient is established by use of a small power resulting from a high voltage DC source and a very low current. For example, the high voltage source may be in the neighborhood of 30,000 volts, while the current would be on the order of 200 microamps.

To establish the potential gradient at the inner surface of the tubes 163, insulated conductors 175 are mounted along the longitudinal axes of the tubes and connected to a high voltage source 176 of a given capacity. The conductors are coated with an electrical insulation and may be mounted in any suitable way, such as anchoring the conductors in high voltage ceramic end pieces 177 and extending them through high voltage ceramic feed-throughs 178. The ceramic end pieces and ceramic feed-throughs electrically insulate the conductors from the tube assembly 172 and the feed-throughs further seal against liquid leakage. The conductors 175 are connected to a common feed conductors 179 which extends through a ceramic feed-through 180 in the outer shell 161. The feed-in wire 179 is connected to the high voltage source 176. The outer shell is connected to ground potential at 181, while the tube assembly 162 is connected to a high voltage source 182 through a feed conductor 183 extending through a ceramic feed-through 184 in the outer shell 161. Ceramic washers 185 are provided to electrically insulate the tube assembly 162 from the inlet and outlet fittings which extend through the outer shell 161.

The high voltage source 182 is at a given level, such as 30,000 volts, thereby establishing a potential gradient between the outer surfaces of the tubes 163 and the outer shell 161 which is at ground potential, while the high voltage source 176 is at a substantially higher level, such as 60,000 volts to establish a potential gradient between the conductors 175 and the inner surfaces of the tubes 163. Accordingly, the boundary layers at the inner and outer layers of the tubes 163 are conditioned by the electrostatic fields established to subtantially increase the coefficients of heat transfer therefor so that the heat transfer between the liquids, such as oil and fuel, is increased to such an extent that a smaller heat exchanger than heretofore possible can be employed to perform the heat transfer work. It will be understood that the voltage sources will be such that arcing between the high and low voltage references will not occur, and since the current draws of the high voltage sources will be in the low microampere range, the power requirements to produce the desired effect will be low.

A modification of the embodiments of FIGS. 12 and 13 is shown in FIG. 14, wherein the heat exchanger is identified as 160A, and parts that are identical are designated with the same numerals. In this embodiment, only a single high voltage source 190 is employed, and the conductors 175 mounted within the tubes 163 are connected to ground potential by connection of the feed-in wire 191 to the outer shell 161. Accordingly, a potential gradient is established between the inner surfaces of the tubes 163 and the conductors 175, and the outer surfaces of the tubes 163 and outer shell 161. As in the embodiment of FIGS. 12 and 13, the potential gradient conditions the boundary layers to increase the coefficients of heat transfer so that heat is transferred between the liquid medias at a faster rate.

It will be understood that modifications and variations may be effected without departing from the scope of the novel concepts of the present invention, but it is understood that this application is to be limited only by the scope of the appended claims.

The invention is hereby claimed as follows:

1. A method of changing the heat content of a fluid comprising the steps of pumping steam through a plurality of condenser tubes of a steam condenser, positioning a first elongated electrical conductor of a first plurality of elongated electrical conductors inside each tube of said plurality of condenser tubes of the steam condenser near the steam inlet to the condenser, positioning a second elongated electrical conductor of a

second plurality of elongated electrical conductors inside each tube of said plurality of condenser tubes of the steam condenser at another location in the condenser tube, connecting the tubes to ground potential, and applying a high voltage DC electrical potential slightly less than that at which arcing to the tube walls occurs to each of said first plurality of elongated conductors and applying a lower high voltage DC electrical potential to each of said second plurality of elongated electrical conductors, whereby the rate of transfer of heat through the walls of the tubes is increased.

2. A steam condenser comprising a plurality of steam condenser tubes, inlet and outlet manifolds for the tubes at opposite ends thereof, a first set of elongated

electrical conductors one each inside each of the condenser tubes adjacent the inlet manifold, a second set of elongated electrical conductors one each inside each tube and adjacent the outlet manifold, said conductors being spaced a short distance from the tube walls and extending along the longitudinal axis of each tube, means connecting the tubes to ground potential, means applying a first high voltage DC electrical potential to the first set of conductors slightly less than that at which arcing to the tube walls would occur, and means applying a second high voltage DC electrical potential to the second set of conductors which is lower than the potential applied to the first set of conductors.

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