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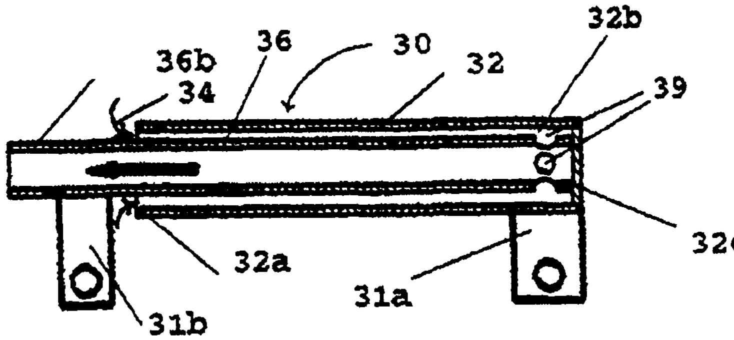
(57) Abstract



An air heater (30) for use with non-combustion vaporizing devices has an electrically heated portion with a large, low-mass, air-heating surface area (36). The low mass allows rapid heat-up and rapid cool-down. The high power allows for rapid heat-up as well as the continuous heating of a continuous air flow (34). The air heater (30) provides electrically heated air instead of by-products of combustion to evaporate the volatile constituents of smoking materials into an airstream that is inhalable. A resistance-heated tube (36) conveys electric power of sufficient magnitude to resistively dissipate between about 10 watts and about 200 watts of thermal energy. The thermal energy is transferred to air that passes by the resistance-heated surfaces of the resistance-heated tube (36). The air heater (30) has an outlet end (36b) into which a cigarette or the tubular end (6a) of a stem (5) can be removably inserted.

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AIR HEATER FOR A NON-COMBUSTION VAPORIZING DEVICE

The present invention is a continuation-in-part of Provisional Patent Application Serial No. 60/094,618, which in turn is a continuation-in-part of Application Serial No. 08/855,440, filed May 13, 1997, the contents of both which are hereby incorporated in their entirety by reference herein and relied upon.

FIELD OF THE INVENTION

The present invention relates to an air heater device preferably for use in connection with non-combustion, forced-convection thermal devices. More specifically, this invention relates an air heater device for use in conjunction with non-combustion vaporizing devices employed in forced-convection heating of volatile-containing substrate materials.

BACKGROUND OF THE INVENTION

The process of smoking, as in the smoking of tobacco, uses thermal energy from the combustion of tobacco to produce hot gases that, when filtered through unburned tobacco, convey thermal energy to unburned tobacco from which the tobacco's volatile constituents, such as nicotine and taste compounds, get evaporated into an inhalable airstream. In other words, the hot gases produced by combustion convey thermal energy to unburned portions of the tobacco and of such other such materials and volatile-containing substrates as described below. The heated combustion gases, when filtered through the tobacco or other volatile-laden substrates, cause the evaporation of such volatile compounds as nicotine and taste chemicals into an airstream that can then be inhaled. The combustion gases get inhaled along with the nicotine and taste or other volatilized compounds.

In such ordinary smoking, the method of heat transfer to the unburned portion of the tobacco is by means of forced convection, i.e., the hot gases produced in the combustion zone are forced, by means of the inhalation of the smoker, to percolate or filter through the unburned tobacco as the smoker inhales the combustion gases through chopped tobacco in such smoking devices as cigarettes, cigars and pipes.

The disadvantage of using combustion gases as the source of heated gases that can evaporate volatile compounds into an inhalable airstream is that the user of such devices as cigarettes and other combustion-based inhalation devices must inhale the toxic combustion gases along with the desired volatile compounds released from the material being heated. The toxic components of combustion by-product gases are described more fully below.

Various non-combustion methods and means have been devised to evaporate compounds from smoking materials such as tobacco and other sources, including porous, medicament-saturated materials such as cotton as well as such herbal compounds and medicaments as are finding increasing use in aroma therapy and other herbal healing substances that are suitable for administration by means of thermal evaportion and subsequent inhalation. Such non-combustion methods for evaporating the volatile constituents from smoking materials eliminate the production and subsequent inhalation of toxic combustion by-products which include carbon monoxide and nitrogen oxides, both of which are deleterious to, respectively, the blood and bronchial tissues of the user. Combustion by-products also include lung-clogging particulate matter and a large class of compounds known collectively as polycyclic aromatic hydrocarbons (PAH), some of which have been correlated with cytotoxic effects, mutagenesis, and even cancer.

Prior art methods of non-combustion heating most often rely upon various methods of conductive transfer of heat into a mass of volatile-containing material or other substrate. Examples of non-combustion heating are disclosed in U.S. Patent Nos. 5,144,962, 5,388,594, 5,269,327, 4,947,875, 5,649,554 and 3,200,819. The heated material accordingly releases its volatile components into an airstream that moves adjacent to the conductively heated material before being inhaled. Such conductive heat transfer methods have, however, a major disadvantage. They require a temperature gradient across the volatile-containing substrate material in order that heat can be conducted into and through the substrate material. The temperature gradient often results in overheating of the portion of the volatile-containing substrate that is closest to the source of heat. In other words, in order to deliver, by thermal conduction methods, sufficient heat to the portions of the substrate that are farthest removed from the source of heat energy, the portions that are closest to the heating source become overheated, resulting in the pyrolytic degradation of certain portions of the substrate. For example, the cellulosic components that make up the substrate of tobacco, when overheated due to being in too close proximity to a heat energy source in a thermal-conduction-type non-combustion inhalation system, undergo thermolytic breakdown and partial oxidation which results in the production of undesirable compounds which are then released in the form of gases and/or particles into the airstream that is to be inhaled.

Furthermore, the conductive heating method, while tending to overheat the portions of the tobacco that are closest to the source of heat, tends also to heat insufficiently those parts of the substrate that are farthest removed from the source of heat. The net effect of such uneven heating of the substate is an inefficient release of volatile compounds into an inhalable airstream and an accompanying production of pyrolytic compounds from those portions of the substrate that get overheated.

Conductive heating of materials such as tobacco has the further disadvantage of only slowly releasing the volatile constituents into the adjacent air that is to be inhaled. In other words, conductive heating methods are rate limited with respect to the amount of energy that can be delivered into the source material (e.g., tobacco, medicament-soaked cotton) from which desired volatile compounds are to be liberated into an inhalable airstream. For example, it is not possible to deliver energy by means of thermal conduction at rates in the range of 10 to 200 watts into several tens of milligrams of tobacco and liberate the volatile constituents without simultaneously causing pyrolytic degradation of the nonvolatile cellulosic substrates. It is, however, possible to deliver such large amounts of energy by means other than conduction.

It should be noted that by and large the prior art noncombustion inhalation systems use the conduction method of delivering heat to the source material (tobacco, etc.).

Specifically, forced convection is a more efficient means of delivering large but controlled amounts of thermal energy, at high rates, to a smoking material such as tobacco. Ordinary smoking has already been cited as an example of such forced-convection heat transfer that can deliver thermal energy uniformly to a mass of volatile-containing substrate or smoking material such as tobacco. The hot gases produced in the combustion zone are drawn through the unburned material from which the volatile compounds are evaporated into a stream of combustion gases that gets inhaled.

An alternative to using combustion and combustion by-product gases as the way to generate heated gases and deliver thermal energy to materials such as tobacco for the purpose of liberating volatile compounds from unburned tobacco-like material can be achieved by using pure air that has been heated by means of contact with a heated surface. In other words, hot gases, and specifically hot air, for use in non-combustion inhaler devices, can be produced by methods that do not involve combustion. The heated air can then be delivered to and filtered through air-porous, volatile-containing material, delivering heat to the material and evaporating the volatile compounds therefrom into the stream of heated air. The volatile-entrained airstream can then be inhaled by the user, who is spared the health risks associated with the inhalation of combustion by-products. It is worth noting that such non-combustion heated air that is used to evaporate volatile compounds from a material becomes cooler when it transfers its thermal energy to the smoking material and induces the process of evaporation. That is to say, the warm air that is ultimately inhaled by the user is at a much lower temperature than the air's maximum temperature prior to being filtered or percolated through the volatile-containing substrate. The process of vaporization requires the endothermic transfer of heat to the volatile components in order to convert them to a gaseous phase. A simple and common example of this cooling process is the cooling of warm, dry air that is passed over a surface that is damp with liquid water. Evaporation of water absorbs about 1,000 Btu per pound of water evaporated from a liquid state into a gaseous state in the warm, dry air.

Such forced-convection methods of delivering thermal energy to chopped or otherwise air-permeable, volatile-containing substrate material requires, of course, that the air must be heated before it transfers its heat to the material. The air can be heated, for example, by allowing it to make intimate contact with an electrically heated surface. The thus heated air can then be filtered through the air-porous substrate material in order to deliver heat energy to the substrate material and thence evaporate the volatile compounds contained therein. The vapor-laden air can then be inhaled.

An example of a forced-convection non-combustion vaporizing inhaler is described in U.S. Patent 4,141,369 ('369), entitled "Noncombustion System for the Utilization of Tobacco and Other Smoking Materials." The heated-air, convection-based system disclosed in the '369 patent uses an ordinary 60-watt electric lamp to heat air inside a plenum chamber. The heated air is then drawn from a plenum and through source material (e.g., tobacco) contained in a stem disposed between the plenum and the user's mouth.

The system disclosed in the '369 patent requires, however, a period of between about 5 minutes and 20 minutes for an initial heat-up during which the air and the adjacent solid plenum and other parts of the device reach the desired operating temperature.

A shorter heat-up time is of important value. But reduced heat-up time requires a combination of high power and a smaller mass of the air-heating apparatus. With regard to power, the heating of about two liters of air through a temperature change of about 170°C within about 10 seconds requires an energy flow rate (i.e., power) on the order of between about 10 watts and about 200 watts into the air and adjacent structures. In Patent Application Serial No. 08/855,440, the apparatus used to heat the air at such high power, or energy delivery rates, employs the retrieval of stored thermal energy from within a thermally massive piece of thermally conductive metal called a "hot receptacle." The hot receptacle of Patent Application 08/855,440 is made preferably of brass and has passageways through which air is heated as it passes. The massive hot receptacle is itself heated slowly by means of a low-power electrical resistor. For example, a 40-gram hot receptacle might be heated by a 10-watt resistor. The hot receptacle, thus heated by the resistor over a period of between about five minutes and twenty minutes, stores thermal energy which can then be extracted, by the air passing through the hot receptacle, at energy delivery rates of between about 10 watts and about 200 watts, depending on the rate at which the air is drawn through the hot receptacle and thence inhaled.

The disadvantage of using a massive hot receptacle as a means for heating the air is that a substantial period of time is required for the hot receptacle to reach the temperature needed to heat the air passing therethrough to a sufficient temperature. For example, the hot receptacle described in Patent Application Serial No. 08/855,440 takes between about 5 and about 20 minutes to reach its desired operating temperature, after which at least two 2-liter inhalations can be made in rapid succession. That is, two large "puffs" or inhalations can be drawn from the device before the hot receptacle needs to undergo a reheat period. In other words, even though the hot receptacle is heated at, or receives energy at, a rate of about 10 watts, and thermal energy can be delivered to air from the hot receptacle at rates of between about 10 watts and about 200 watts, the initial heat-up time is still on the order of minutes. Thus the device taught in patent application 08/855,440 has the same disadvantage of the device taught in U.S. Patent 4,141,369 described above:

too much time is needed for the initial warm-up period.

Other forced-air convection systems for vaporizing medicaments are disclosed in U.S. 1,485,260 and 1,771,366. These patents incorporate complicated heating systems with resistance heating elements across which air is drawn and heated prior to delivery into the medicaments being vaporized for inhalation by a user..

OBJECTS OF THE INVENTION

It is an object of the present invention to provide an air heater as defined in one or more of the appended claims and, as such, having the capability of being constructed to accomplish one or more of the following subsidiary objects.

One object of the present invention is to provide an air heater having sufficiently low mass and adequate electric power to achieve its operating temperature in fewer than 20 seconds.

Another object of the present invention is to provide an air heater that has a large heated surface area from which to deliver adequate thermal energy to air moving adjacent thereto and corresponding to the maximum air volume through a non-combustion vaporizing device incorporating the air heater.

Another object of the present invention is to provide an air heater that has a large heated surface from which heat can be delivered to air moving adjacent thereto, the heated surface having low mass so as to facilitate rapid heat-up.

Still another object of the present invention is to provide an air heater that can be combined with automatic power cutoffs designed to disconnect the primary source of electrical power to the air heater in the event that the electrically operative parts of a non-combustion, vaporizing device incorporating the air heater become overheated during periods of low air flow through the air heater.

SUMMARY OF THE INVENTION

This invention relates to air heaters adapted for non-combustion, forced-convection vaporizing devices. More specifically, this invention relates to a rapid-heating air heater for use as or in conjunction with non-combustion vaporizing devices employing forced-convection heating of volatile-containing substrate materials. More specifically the invention is directed to an air heater comprising an electrical resistance-heated tube, electric power supply connectors, an air inlet end and and an air outlet end. The air heater has an outer shroud more or less concentric with the electrical-resistance-heated tube, forming an annular air passageway between the electrical resistance-heated tube and the shroud, and one or more connecting passageways communicating between the annular air passageway and the inlet end of the electrical resistance-heated tube. The electrical resistance-heated tube can be made of metal having an electrical resistance of between 0.1 milli-ohm and 10 milli-ohm and is able to dissipate resistance-generated heat at a rate of between 10 watts and 200 watts. The metal electrical resistance heating tube has a mass of less than 4 grams, preferably less than 0.5 gram, and its external surface area is at least about 2 square centimeters, and preferably between about 4 square centimeters and 20 square centimeters. Alternatively, the resistance-heated tube can be made of carbon having an electrical resistance between 50 ohms and 400 ohms, and is able to dissipate resistance-generated heat at a rate of between 10 watts and 200 watts. A stem having a mouthpiece at one end and a tip containing several tens of milligrams of air-porous, volatile-containing source material at the opposite end can be removably inserted into the air outlet end of the air heater, from which heated air can be drawn in order to evaporate volatile compounds into an airstream passing through the stem without the use of combustion.

An alternative embodiment of the air heater invention consists of an air-conveying duct within which resides an electrical resistance heating element. The heating element can be made of metal having an electrical resistance of between 0.1 milli-ohm and 10 milli-ohm and dissipates resistance-generated heat at a rate of between 10 watts and 200 watts. The metal resistance heating element has a mass of less than 4 grams, preferably less than 0.5 gram, and it has a total surface area of at least 2 square centimeters, and preferably between 4 square centimeters and 20 square centimeters. The electrical resistance heating element is corrugated for structural rigidity and to provoke turbulent flow of air flowing adjacent to it. Alternatively, the resistance-heated tube can be made of carbon having an electrical resistance of between 50 ohms and 400 ohms, and is able to dissipate resistance-generated heat at a rate of between 10 watts and 200 watts. The tubular end of a stem containing several tens of milligrams of air-porous, volatile-containing material can be removably inserted into the air outlet end of the air heater, from which heated air can be drawn in order to evaporate volatile compounds into an inhalable airstream without the use of combustion. Alternatively a smoking element, such as a cigarette can be inserted into the air outlet end of the air heater and smoked by a user.

An additional embodiment of the invention is one in which the air heater assembly is contained within a hand-held vaporizer having an outer casing and a receiving hole into which a cigarette or the tip end of a stem can be removably inserted for purposes of non-combustion evaporation of volatile compounds into an inhalable airstream.

DEFINITIONS

"Air heater assembly" refers to the present invention but sometimes, depending on the context, means the same as "air heating tube" or simply "air heater" or "air heater invention."

"Conductive heat transfer" means heat transfer in which thermal energy moves through a substance or material in the direction from the hotter to the cooler regions of the substance or material.

"Convective heat transfer" means heat transfer in which thermal energy is carried in a flow of liquid or gas from one place to another place. "Forced convection" involves the forced movement of the liquid or gas, as might be induced by a fan or a pump, and is distinguished from "natural convection" in which the movement of the gas or liquid is induced to move by the differences in density brought by the acquisition or loss of heat from the gas or liquid.

"Source material" means any air-permeable material such as chopped smoking material such as tobacco or herbs or medicament-laden cotton or fiber glass laden with volatile compounds that can be evaporated into a stream of heated gases. The word "material" is sometimes used to mean source material.

"Substrate material" means the essentially nonvolatile components of a source material, as for example, the cellulosic structure of the smoking material like tobacco leaf.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGURE 1A shows an electrical-resistance heated tube that heats air passing therethrough;

FIGURE 1B shows a stem assembly, with a mouthpiece and a tip as would hold smoking material and be inserted into the tube shown in **FIGURE 1A**;

FIGURE 1C is a cross-sectional view of the elements shown in **FIGURES 1A**

and **1C** in mated relationship;

FIGURE 2 is a cross-sectional view of an electrical-resistance heated air-heating tube incorporating a baffle for inducing turbulent flow;

FIGURE 3A is a cross-sectional view of an electrical-resistance heated air-heating tube having an external shroud for recovering heat from the outer surface of the inner resistance-heated tube;

FIGURE 3B is an orthogonal view of the embodiment shown in **FIGURE 3A**, along with a stem;

FIGURE 4 is a cross-sectional view of an air-heating tube-based apparatus in which an electrical-resistance heated air-heating element is contained within the tube;

FIGURE 5 is a cross-sectional view of an embodiment of the electrical-resistance heated air-heater embodiment incorporating a temperature sensor;

FIGURE 6A is a cross-sectional view of an embodiment of the air-heater invention that can be adapted to an existing high-current electrical appliance;

FIGURE 6B is an oblique view of the embodiment of the air-heater apparatus of **FIGURE 6A** shown with a cigarette disposed for insertion into the air outlet end of the tube through which heated air flows;

FIGURE 7A is an orthogonal view of a first embodiment of a non-combustion vaporizer or vaporizing inhaler incorporating a low-voltage, high-current version of the air-heating assembly;

FIGURE 7B is a cross-sectional schematic view of the hand-held heater portion of the vaporizer shown in **FIGURE 7A**;

FIGURE 8A is an orthogonal view of a second embodiment of a vaporizer incorporating a high-voltage, low-current version of the air-heating assembly;

FIGURE 8B is a cross-sectional schematic view of the hand-held heater portion shown in **FIGURE 8A**;

FIGURE 9A is an orthogonal view of the hand-held portion of a vaporizer system with a cigarette disposed for insertion into the air outlet end; and

FIGURE 9B is a cross-sectional view of a cigarette inserted into the air outlet end of the hand-held air-heating section of the vaporizer system shown in **FIGURE 9A**.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

This invention is directed to a compact, high-powered, rapid-heating air heater preferably intended for use in conjunction with a non-combustion vaporizing system. One aspect of the present invention relates to a way to deliver thermal energy, at high power, to air that is to be filtered or percolated through, and transfer its thermal energy to, source materials such as smoking materials like tobacco and medicament-treated air-permeable substrate material such as cotton or fiber glass. The air-heater of the present invention has sufficient low mass and high power to allow the air-heating apparatus to achieve its desired operating temperature within a period of less than 20 seconds. The mass of the resistance-heated portion of the air heater is less than 4 grams, preferably less than 0.5 gram. Despite the low mass of the air heater of the present invention, it also has a large surface area from which to transfer heat to air moving adjacent the electrical-resistance heated surface. The outer surface area of the resistance-heated portion of the air heater is at least 2 square centimeters, and preferably between 4 square centimeters and 20 square centimeters. The combination of the low-mass and the large air-heating allows for rapid heat up of the resistance-heated portion of the air heater invention prior to use, and rapid cool down after use.

The inventive features, which are most specifically related to the high-power, low-mass, large-surface-area air heater apparatus, will become evident upon contemplation of the drawings and the accompanying text.

The Basic Air Heater Apparatus

Referring to **FIGURE 1A**, there is shown an air heater or air-heating device **2** comprising an electrically conductive tube **3** having an air inlet end **3a** and an air outlet end **3b**. The end sections of the tube **3** have electrical lugs or connectors **4a,4b** each have holes **8** for making connection to an electrical power source. Lugs **4a,4b** convey electrical energy to the respective ends **3a,3b** of the tube **3**. The tube **3** is made of an electrically conductive material, preferably metal or carbon. Such materials have low electrical resistance, but sufficient resistance for producing heat when large electrical currents are flowing in the axial direction along the walls of the tube. Among the metals that could be used in the construction of the tube **3**, the most preferably ones are of the class that includes brass, iron, steel, stainless steel, copper and combinations thereof. The tube **3** is between about 0.5 inch and about 3 inches in length in the region between the electric power lugs **4a,4b**. The tube **3** has an outside diameter of about 5/16 inch and an inside diameter of about 9/32 inch with a wall thickness of between about 0.005 inch and about 0.015 inch.

If the tube **3** is made of metal, then the source of the electric power delivers electrical energy at high current and low voltage. However, if the tube **3** is made of a material such as carbon, which has much higher electrical resistance than metal, the voltage of the electric power source can be much higher than if the tube is made of a low resistance metal. The most preferred materials for the tube **3** are alloys of copper, iron or nickel. The most preferred electric power source is a low-voltage alternating current electrical transformer that is able to maintain a voltage of between 200 millivolts and 1,000 millivolts across the two lugs **4a,4b** while delivering a current of between 100 amperes and 750 amperes through the tube **3**. In the preferred embodiment, the tube **3** is made of metal and the electrical resistance of the portion of the tube between the lugs **4** is between 0.1 milli-ohms and 10 milli-ohms. The resistively-generated heat that is dissipated by the portion of the tube **3** between the lugs **4a,4b** is preferably in the range of between 10 watts and 200 watts. If the tube **3** is made of a higher resistance material such as carbon, then the voltages can be higher and the current lower in order to dissipate resistively-generated heat at a rate of between 10 watts and 200 watts of electric power from the portion of the tube **3** between the lugs **4a,4b**. The corresponding electrical resistance of such a carbon tube **3** would be between 50 ohms and 400 ohms.

FIGURE 1B shows an oblique view of the external part of stem **5**. **FIGURE 1C** is a cross-sectional view of stem **5** shown inserted in the air outlet end **3a** of tube **3** of the electrical-resistance air heating assembly **2**. The stem **5** comprises a cylindrical outer body **14** having a mouthpiece end **7** and a tubular inner body **6** with a tubular end **6a** projecting outward from the outer body **14** in a direction opposite from the mouth piece end **7**. The outer body **14** is made of wood or plastic or similar thermally and electrically nonconductive material. Overall length of the stem **5** is typically between about 2 inches and about 3 inches, and the overall diameter is typically between about 1/2 inch and about 5/8 inch. The tubular inner body **6** is made of metal, such as thin-walled brass, that is fitted inside of the outer body **14**. Air-porous source material **10**, such as chopped smoking material like tobacco, is held in the tubular end **6a** of the inner body **6** of stem **5**.

A screen **12** fitted into the tubular end **6a**, as shown in **FIGURE 1C**, keeps the source material **10** from being carried along with the air that passes through stem **5** from the direction of the tubular end **6a** to the mouthpiece end **7**. The tube **6** has an outside diameter that corresponds to the inside diameter of the outlet end **3b** of resistance heating tube **3** of the resistance air-heater assembly **2**, allowing a snug but non-forced fit with the air heating tube **3** as shown in **FIGURE 1C**. The tube **6** has an inside diameter of about 1/4 inch and an outside diameter of about 9/32 inch, though such specific dimensions are not listed here in a way intended to be limiting. Moreover, it is within the terms of the invention to provide an end **6a** with a larger cross section as long as the section of end **6a** that fits within outlet end **3b** forms a snug but non-forced fit.

Referring to **FIGURE 1C**, when the user of a vaporizing device incorporating the air-heater of the present invention places their mouth on the mouthpiece end **7** of the stem **5** and inhales air through the resistance-heated air heater assembly **2** and thence through the substrate material **10**, the air becomes heated because of the intimate contact it makes with the inside surface of the air heating tube **3** as it flows from the air inlet **3a** to the air outlet **3b**. The heated air thence moves through the source material **10**, transferring heat energy to the material and thereby evaporating and liberating from the substrate material the volatile constituents contained therein. The liberated volatile compounds join with the moving airstream (indicated by the arrows **9**) which moves through the stem **5** and into the mouth of the user. The air that is heated in the air-heating assembly **2** is cooled by the energy required to evaporate the volatile constituents from the material **10**, i.e., by the heat of vaporization of the volatile constituents. The screen **12** retains the material **10** in place so that it does not get carried along with the flow of air and into the mouth of the user.

The tube **3** of the air heating device **2**, as shown schematically in **FIGURES 1A** and **1C**, has two disadvantages with respect to the efficiency of the transfer of heat into the air **9** as the air moves through the tube. One disadvantage is that the air **9**, which enters at the air inlet end **3a** of the tube **3**, is initially at room temperature, which imparts to the air a degree of viscosity sufficient as to invoke laminar flow within the tube **3**. In other words, the air that enters the tube **3** at the air inlet end **3a** flows in such a way that non-turbulent flow takes place inside the tube **3**. Such non-turbulent flow inhibits the transfer of heat to the air from the inner walls of tube **3**.

FIGURE 2 shows a cross-sectional view of another embodiment of an air-heating assembly **20** comprising a tube **22** with an air inlet **22a**, an air outlet **22b** and a turbulence-inducing baffle **24** disposed in the air inlet **22a**. Baffle **24** includes a plurality of openings or holes **24a** through which the air, shown by arrows **25**, must pass to enter the tube **22**. The holes **24a** of the baffle **24** are essentially small holes that are drilled in an otherwise closed air inlet end **22a** of the tube **22**. Alternatively, the baffle can be a screen made of a heat-resistant material such as metal or ceramic. Such a baffle **24** initiates turbulence in flow of the air that moves through tube **22**, thereby increasing the coefficient of convective heat transfer between the inside surface of tube **22** and the air moving through the tube.

The second disadvantage of the air-heating assembly **2** illustrated in **FIGURES 1A** and **1C** relates to the inefficiency resulting from heat being radiated radially outward from the outer surface of the tube **3**. Also, in additional to radiative heat losses from the outer surfaces of the tube **3**, losses of heat to the ambient air, due to natural convection, also take place, thereby resulting in losses of thermal energy that could otherwise heat the air that is to be used for vaporization and inhalation. Accordingly, **FIGURE 3A** shows, in cross-sectional schematic form, an air-heating assembly **30** having an outer tube or shroud **32** for directing the incoming air, shown by arrows **34**, along the outer surface of the resistance-heated tube **36** in a direction opposite to the flow of air through the tube **36**. The outer tube **32** has an open inlet end **32a** and an opposite closed end section **32b** having an end cap **32c**. The outer tube **32** is disposed more or less concentric relationship with the electrically heated air-heating tube **36** so that the air inlet end **36a** is secured to the interior surface of end cap **32c**. The opposite air outlet end **36b** of tube **36** projects outward from inlet end **32a** of tube **32**. The width of the annulus **38** (in **FIGURE 3B**) between the inner diameter of the tube **32** and the outer diameter of the tube **36** is between about 1/32 inch and about 1/4 inch. The electrically energized resistance-heating tube **36** has an outside diameter of about 5/16 inch and an inside diameter of about 9/32 inch and a length of between about 0.5 inch and about 3 inches between the locations where electric current is conveyed into and out of the resistance-heating tube component of the air heating assembly **30**. The air that enters the air-heater assembly **30** at the circular annulus **38**, as shown in the orthogonal view of **FIGURE 3B**, progresses between the concentric tubes **32,36** to the holes **39** (**FIGURE 3A**), through which the air passes into the inner portion of the electrically heated tube **36**. Thus the air is preheated as it passes along the outer surface of the tube **36**, and then the air is heated further as it passes through the holes **39**, which also induce turbulent flow, and then passes into and through the central regions of the innermost tube **36** where it is heated further before progressing to the stem **5** which can be removably inserted into the tube **36** at the tip end **37**. (The tip end **37** can also receive the tip end of a cigarette.) Thus the heat that otherwise would be lost to ambient air from the outer surface of the tube **36** is captured in such a way as to preheat the air that is heated yet more during its movement through the center of the resistance-heated tube **36** of the assembly **30**. In summary, **FIGURE 3A** shows a cross-sectional view of circularly cylindrical and concentric tubes **32,36** of the air heating assembly **30** in which the innermost tube **36** is heated by electrical resistance and the heat energy is recovered from both the outer portion and the inner portion of the tube **36**. The holes **39** allow the air to move from the outside of the tube **36** to the inside while also inducing turbulence into the flow of air moving through the air-heating assembly. In net effect, the concentric tubes **32,26** of the air-heating assembly **30** shown in schematic cross-section in **FIGURE 3A**, present a large surface area to the air that is being heated, thereby ensuring efficient capture of the thermal energy that is released by the resistance-heating of tube **36**. Furthermore, the thin-wall design of the resistance-heated tube **36** ensures the desirable low mass that yields a fast heat-up time for the electrical-resistance-heated tube **36**.

FIGURE 4 shows another method by which to capture heat from a large-surface-area, low-mass heating element. The air-heating assembly **40** shown in **FIGURE 4** comprises a thin-walled outer tube or duct **42** and a large-surface-area electrical resistance heating element **44** contained wholly within the outer duct **42**. The heating element **44** is preferably made of metal that conveys a large electrical current at a low voltage and has a large surface area. For example, if the outer duct **42** has an inside diameter of about 9/32 inch, then the heating element would have a width corrugated or otherwise shaped so as to induce and maintain turbulence in the flow of the air passing near it as well as to give the heating element a degree of structural rigidity. The arrows **46** show air entering the air inlet **42a** of duct **42**. The air flows through the air-heating assembly **40**, and out of outlet end **42b** into a stem (not shown) or cigarette (not shown) that would be removably inserted into the outlet end of the duct **42**. The mass of the heating element **44** is less than about 4 grams, and preferably less than 0.5 gram, and the total surface area is at least 2 square centimeters and preferably between about 4 square centimeters and 20 square centimeters. The inventor recognizes that the large-surface-area resistance heating element **44** could also be made of a high-resistance material such as carbon, and that the corresponding electric power source could supply electrical current at voltages as high as 240 volts to enable the resistive dissipation of between 10 watts and 200 watts from the heating element **44**. The corresponding electrical resistance of such a carbon heating element would be between about 50 ohms and about 400 ohms.

FIGURE 5 shows, in schematic cross-sectional view, an air heating assembly **50** comprising concentric outer and inner circular tubes **52,54**, respectively, electrical connectors **51a,51b** which convey electric power to the resistance-heated inner tube **54**, a temperature sensor **55** in the inlet and a flow restrictor **57** located downstream of the temperature sensor. Air, shown by arrows **51**, enters the annular space **59** between the outer tube **52** and the inner tube **54** and progresses through the annulus in such a way as to capture heat that is released by the outer portion of the resistance-heating tube **54**. The air thence moves through the holes **58** to the inside of the tube **54** before being conveyed to the stem and the source material such as tobacco (neither of which is shown in **FIGURE 5**). The temperature sensor **55** is connected to an electrical control circuit (not shown) which allows automatic, on-demand energizing of the air-heating assembly **50**. That is to say, the electrical power that heats the resistance-heating tube **54** is conceived by the inventor to be controllable in an automatic way. More specifically, when the user is not drawing air through the air-heating assembly **50**, the temperature sensor **55**, becoming hot, sends a signal to an electrical power control circuit that shuts off the electric power to the resistance heating tube **54**. When the user inhales air through the stem (not shown) and through the air-heating assembly **50**, a small portion of the initially cool air passes adjacent the sensor **55**, cooling it sufficiently to cause the power control circuit to turn on the electric power. The flow restrictor **57** minimizes the portion of the total airflow that bypasses the annulus between the innermost tube **54** and the outermost tube **52**. The flow restrictor **57** allows, however, enough air to flow past the sensor **55** to make it undergo rapid cooling upon inhalation by the user, for the purpose of a rapid-response automatic control of the electric power that is conducted through and delivers energy to the inner resistance heating tube **54**. It should be apparent, upon contemplation of **FIGURE 5**, that most of the air heated by the assembly **50** receives its heat from the outer surface of the inner tube **54**. Accordingly, the outside diameter of the tube **54** must be large enough to efficiently transfer heat, by means of forced convection, to the air that passes through the annulus **59** between the innermost tube **54** and the outermost tube **52**, but not so large as to increase the mass of the tube **54** in ways that will adversely affect the heat-up period, i.e., lengthen the heat-up time. Typical length of the electrically energized and heated portion of the tube **54** would be between about 1 inch and about 3 inches. The outside diameter of the tube **54** would be between about 1/4 inch and 1/2 inch. The inventor recognizes that such temperature sensors and automatic power controls could also be integrated with other embodiments of the air-heating assemblies described herein.

FIGURE 6A shows, once again in cross-sectional schematic format, an embodiment of the air-heating assembly portion **60** that is designed so as to be attachable to the power output posts of a high-current electrical appliance such as a soldering gun containing a low-voltage transformer. Power lugs **4** with holes **8** allow attachment to a soldering gun. The outer circular tube **62** has sufficiently low resistance, due to intrinsic low resistance of a material such as copper and also due to a greater wall thickness than in the embodiments described above, so as to minimize the proportion of resistance heating that takes place in the outer tube as it conveys electric power to the innermost resistance heating tube **64**. In this embodiment, air, shown by arrows **65** enters the annulus **66** (between the innermost tube **64** and the outermost tube **62**) and progresses along the outside of the innermost resistance-heating tube **64** to the slits **67** (which could as well be circular holes) and thence in the reverse direction on the inside of the tube **64**, acquiring additional thermal energy before being drawn into the stem (not shown) and into the mouth of the user of the vaporizer. **FIGURE 6B** shows an oblique view of the external surface of the same air-heating assembly **60** depicted **FIGURE 6A**. The tip **61** of a cigarette **68** is shown being inserted into the tip **69** of the innermost tube **64** in such a way that a person could inhale heated air through the cigarette and induce the vaporization, without combustion, of the volatile constituents of the tobacco in the cigarette's tobacco. The inventor recognizes, through experimentation, that the use of the various embodiments of the compact, rapid-heating air-heating assemby described herein in conjunction with ordinary cigarettes is one way to use ordinary cigarettes to inhale the desired constituents of tobacco without requiring the use of combustion of the tobacco in the cigarette which would expose the user to inhaled combustion by-products.

Vaporizer Embodiments

FIGURE 7A shows in oblique view the external surfaces of the stem **5** and a hand-held power/heater assembly **70** of an embodiment of a complete vaporizer assembly. The hand-held power/heater assembly **70** comprises an outer cover or housing **72** inside of which is a low-voltage transformer **76** that supplies between about 100 amps and about 800 amps of electrical current to an air heater assembly **75** of the kinds shown schematically in the **FIGURES 2, 3A** and **4. FIGURE 7B** shows the hand-held power/heater assembly **70** in schematic cross section, revealing the approximate locations of the air-heating assembly **75** and the low-voltage transformer **76** inside the housing **72.**

During use of such a vaporizing inhaler, the end **6a** of the stem **5**, after being loaded with an amount of source material (shown as **10** in **FIGURE 1C**), is inserted by the user into the receptacle **74** which communicates with the resistance air heating assembly **75** (of the types described above) contained inside the housing **72** of the hand-held power/heater assembly **70**. Electrical power at 120 volts AC or 240 volts AC is delivered to the low-voltage transformer inside of the hand-held portion **70** by means of electrical cord 77. Electrical power is activated by power button **78**. Indicator light **79** indicates that electrical power is turned ON and is inducing the resistance heating of the air-heating assembly contained inside the housing **72**. As the user inhales air through the mouthpiece end 7 of the stem **5** and the air-heating assembly **75** inside the housing **72**, air is heated by the air-heater assembly and thence moves through the air-porous material held in the end **6a** of the stem **5**. The volatile components contained in or absorbed upon the source material are thereby heated and evaporated into the airstream which is thence inhaled by the user whose mouth (not shown) is on the mouth piece 7 of the stem **5**.

The inventor anticipates that the hand-held power/heater assembly **70** would contain automatic thermostatic controls designed to shut off electric power and thus limit overheating of the low voltage transformer and other parts contained within the housing **72**. Automatic, "on-demand," power controls could also be incorporated in accordance with the description given in relation to **FIGURE 5**.

The push-button switch **78** is of the "push-on" type that makes electrical connection only while being pushed. Such a switch ensures that power is not delivered when the device is not in use. The switch **78** additionally is recessed so as to minimize the chance of inadvertently causing the device to become energized due to the weight of the hand-held power/heater resting on the switch. The inventor recognizes that the incorporation of two such recessed switches (not shown), requiring the pressure force of two separate fingers, can further increase the safety of the vaporizer.

FIGURE 8A shows another embodiment of the invention comprising a stem **5** and a hand-held power/heater assembly **80**. The hand-held power/heater assembly **80** comprises an outer cover or housing **82** inside of which is a high-electrical-resistance air heating assembly of the kinds shown schematically in the **FIGURES 2**, **3A** and **4**. **FIGURE 8B** shows the hand-held power/heater assembly **80** in schematic cross section, showing the approximate location of the air-heating assembly **85** inside the housing **82**. In contrast to the embodiment depicted in **FIGURES 7A** and **7B**, the hand-held power/heater assembly **80** contains an air-heater assembly **85**, the electrically heated portions of which are made of high resistance material such as carbon. Since such a high-resistance heater material as carbon can operate at higher voltages than metal-based heating assemblies herein described, the use of a low-voltage transformer is obviated.

During use, the end **6a** of the stem **5**, after being loaded with an amount of material (shown as **10** in **FIGURE 1C**) is inserted by the user into the receptacle **84** which communicates with the resistance air heating assembly **85** (of the kinds described above) contained inside the outer housing **82** of the hand-held power/heater assembly **80**. Electrical power at 120 volts AC or 240 volts AC is delivered to the hand-held portion **80** by means of electrical cord **87**. Electrical power is activated by recessed power button **88**. Indicator light **89** indicates that electrical power is turned ON and is inducing the resistance heating of the air-heating assembly **85** contained inside the housing **82**. As the user inhales air through the stem **5** and the air-heating assembly inside the housing **82**, air is heated by the air-heating assembly **85** and thence moves through the material held in the tip **6** of the stem **5**. The volatile components contained in or absorbed upon the air-porous source material are thereby heated and evaporated into the airstream which is thence inhaled by the user whose mouth (not shown) is on the mouth piece **7** of the stem **5**.

The inventor anticipates that the hand-held power/heater assembly **80** would employ automatic thermostatic controls designed to shut off electric power and thus limit overheating of the resistance heated air-heating assembly **85** contained within the housing **82**.

The push-button switch **88** is of the "push-on" type that makes electrical connection only when pushed. The incorporation of such a switch ensures that power is not delivered when the vaporizer is not in use. The switch **88** is recessed to minimize the chance of inadvertently causing the device to become energized due to the weight of the hand-held power/heater resting upon the switch. The inventor recognizes further, that the incorporation of two such recessed switches (not shown), requiring the pressure force of two separate fingers, can further increase the safety of the vaporizer.

FIGURE 9A shows in oblique view an embodiment of the hand-held portion of a vaporizer **90** incorporating a high-power air-heating assembly **95**, the latter being shown in the cross-sectional view of **FIGURE 9B**. The hand-held portion **90** has mounted in its outer casing **92** an indicator lamp **99**, a recessed push-button electrical switch **98**, and a receptacle **94** into which a cigarette **91** can be inserted. Electrical power is supplied by way of electrical cord **97**. The air-heater assembly, depicted as **95** in **FIGURE 9B**, can be of the low-voltage metal-resistor type or the high-voltage carbon-resistor type. The high-power nature of the air-heater assembly **95** which is described in various air-heater embodiments elsewhere in this disclosure, is such as to allow the heating of a continuous inhalation of air to a sufficiently high temperature to make possible a large inhalation of air sufficient to convey adequate thermal energy to and through a cigarette **91** so as to simulate the effect of an ignited cigarette tip. That is to say, the amount and rate of delivery of air-borne thermal energy delivered to the tobacco in the cigarette would be equivalent to the combustion-gas-borne energy produced by the combustion of a cigarette's tip during ordinary smoking. In yet other words, the hand-held heater portion, shown as **90** in **FIGURES 9A** and **9B**, and containing the high-power air-heating assembly **95** which is able to heat air at an energy input rate corresponding to between about 10 watts and about 200 watts, is able to supply approximately the amount of energy produced per unit of time in the hot tip of a burning cigarette. The inventor accordingly envisions an embodiment of a vaporizer **90** incorporating the present air-heater invention

95. Such an embodiment would be able to receive a cigarette **91** as shown in **FIGURE 9A** and **9B**. **FIGURE 9B** is a cross-sectional view of the vaporizer system **90**, containing air-heating assembly **95**, with an ordinary cigarette **91** shown inserted into the portion of the air-heating assembly which, in **FIGURES 1C**, **7A**, and **8A**, is shown receiving the end **6a** of the stem **5**. Thus a user of this invention would be able to use the air-heating portion, shown as **90** in **FIGURES 9A** and **9B**, of a vaporizing inhaler incorporating the present air-heater invention without using the intermediary component that is the stem **5** (shown in **FIGURES 1B**, **1C**, **7A** and **8A**) within which the source or source material is envisioned as being held.

Summary of Design-and-Use Features

1. The various embodiments of the air-heating assembly described herein have in common a low mass (and heat capacity) such that, in conjunction with the delivery of large amounts of electrical power, e.g., between about 10 watts and about 200 watts, the various embodiments can reach full operating temperature within a period of between about 1 second and about 10 seconds.

2. The resistance-heated surfaces of the air-heating assemblies described herein are sufficiently large to provide efficient forced-convection transfer of heat from the electrical resistance heated surface to the air that is being heated.

3. The low mass of the resistance-heated air-heating surface area allows for rapid cool down of the operating elements immediately after each successive use.

4. The present invention can be used in conjunction with the low-voltage transformers of existing appliances, such as an electric, hand-held soldering gun or, when the air heater assembly is made of high resistance material such as carbon, it can be powered at the higher voltages of the kinds used in residences in North America and Europe.

5. The present air-heater invention allows the use of sufficient power, on the order of 10 to 200 watts, to heat air in such a way that a user of a vaporizer incorporating this air-heater invention may insert a cigarette directly into a vaporizing inhaler and thereby receive, without the deleterious effects of having to inhale combustion by-products, the full taste and other desired effects associated with the inhalation of the tobacco's volatile constituents.

6. The use of one or more recessed power control buttons minimizes the potential for inadvertent or accidental turning on of the electric power to this present air heating invention.

7. One or more indicator lamps show when the electrically active parts of the invention are receiving electric power.

8. Automatic thermostatic power controls can be used to limit the temperatures of the electrically active portions of the invention.

While the present invention has been described in connection with what is considered to be the most practical and preferred embodiments, it is to be understood that the invention is not limited to the disclosed embodiments, but on the contrary is intended to cover various modifications and equivalent arrangements included within the spirit and scope of the appended claims.

Thus, it is to be understood that variations in the present invention can be made without departing from the novel aspects of this invention as defined in the claims. All patents and patent applications cited herein are incorporated in their entirety by reference hereto and relied upon.

What is claimed:

1. An air heater characterized by:

an electrical resistance-heated tube having an air inlet end and an air outlet end;

an outer shroud having an inlet end and a closed opposite end disposed concentric with the electrical resistance-heated tube;

an annular air inletbetween the electrical-resistance-heated tube and the shroud; and

one or more connecting passageways communicating between the annular air passageway and the inside of the electrical-resistance-heated tube.

2. The air-heater of claim 1 characterized in that the electrical resistance-heated tube is made of metal and has an electrical resistance of between 0.1 milli-ohm and 10 milli-ohm.

3. The air heater of claim 2 characterized in that the electrical-resistance-heated tube dissipates electrical resistance-generated heat at a rate of between about 10 watts and about 200 watts.

4. The air heater of claim 2 characterized in that the electrical-resistance-heated tube has a mass of less than about 4 grams, preferably less than 0.5 gram.

5. The air heater of claim 2 characterized in that the electrical resistance-heated tube has an outer surface area of at least 2 square centimeters, and preferably between 4 square centimeters and 20 square centimeters.

6. The air heater of claim 1 characterized in that the electrical resistance-heated tube is made of carbon and has an electrical resistance of between 50 ohms and 400 ohms.

7. The air heater of claim 6 characterized in that the electrical resistance-heated tube dissipates resistance-generated heat at a rate of between 10 watts and 200 watts.

8. The air heater of claim 1 characterized in that the tip end can removably receive the tubular end of a stem.

9. The air heater of claim 1 characterized in that the tip end can removably receive the tip end of a cigarette.

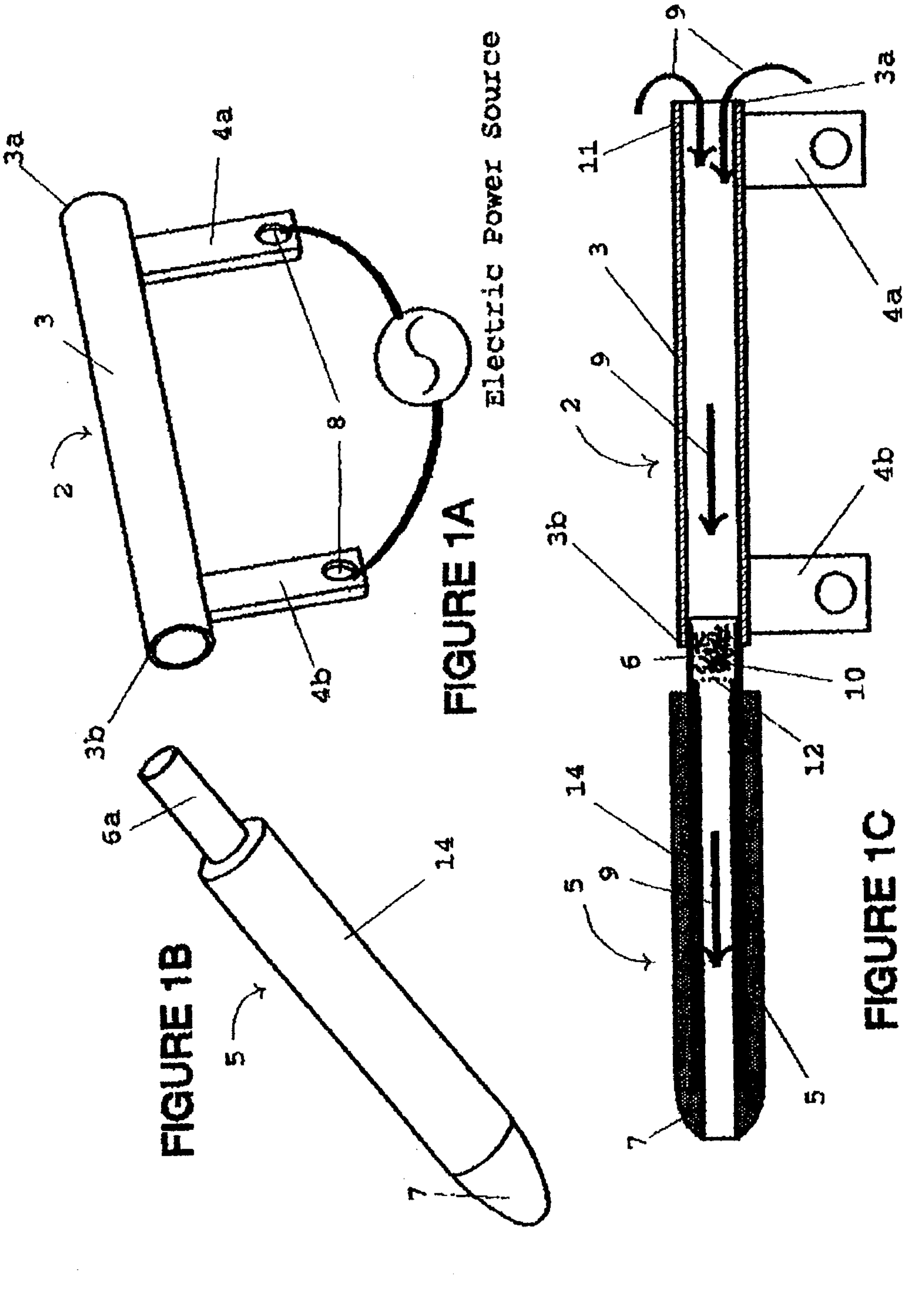

FIGURE 1A

FIGURE 1B

FIGURE 1C

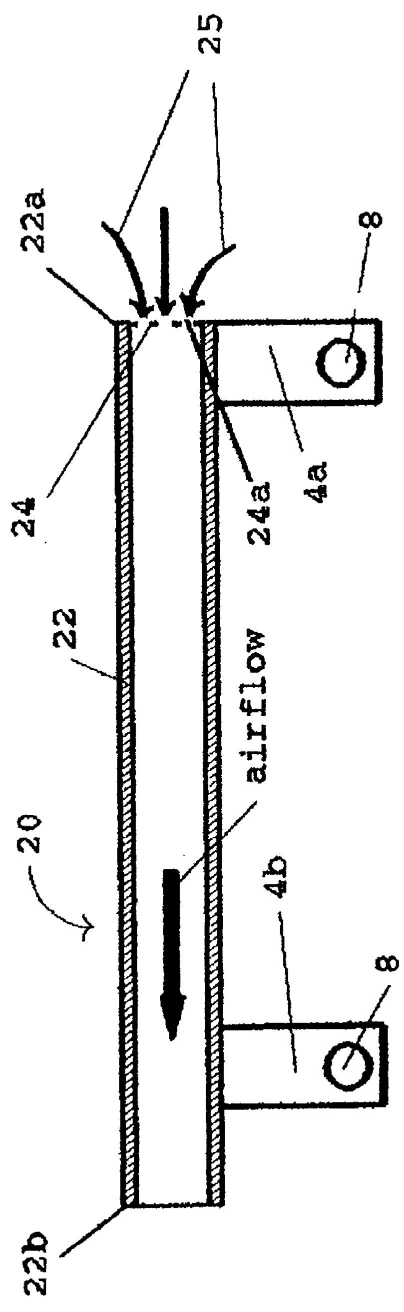

FIGURE 2

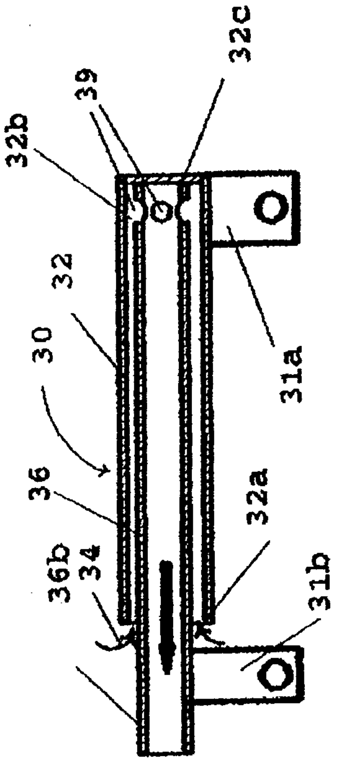

FIGURE 3A

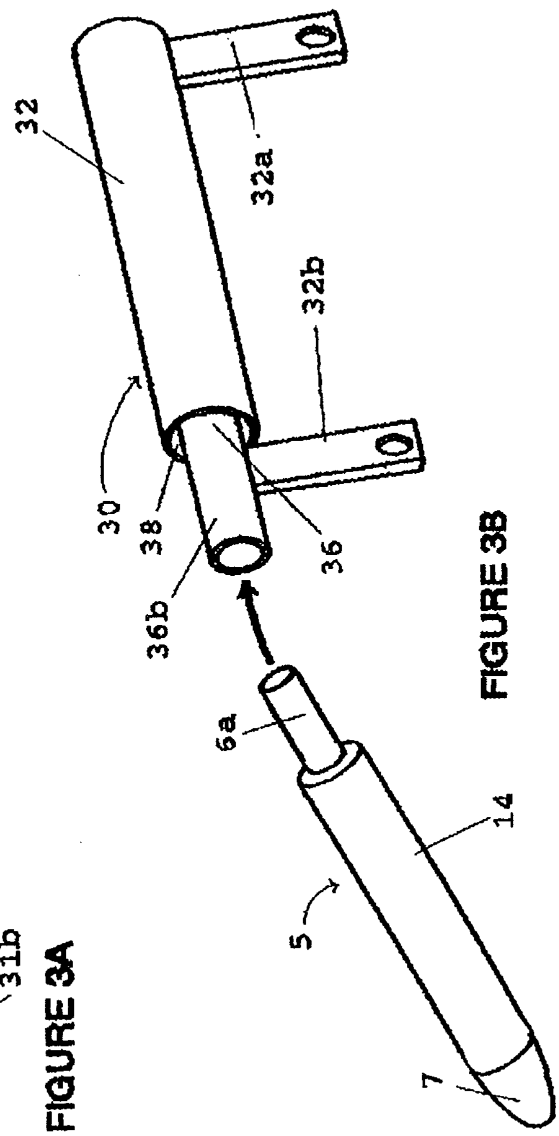

FIGURE 3B

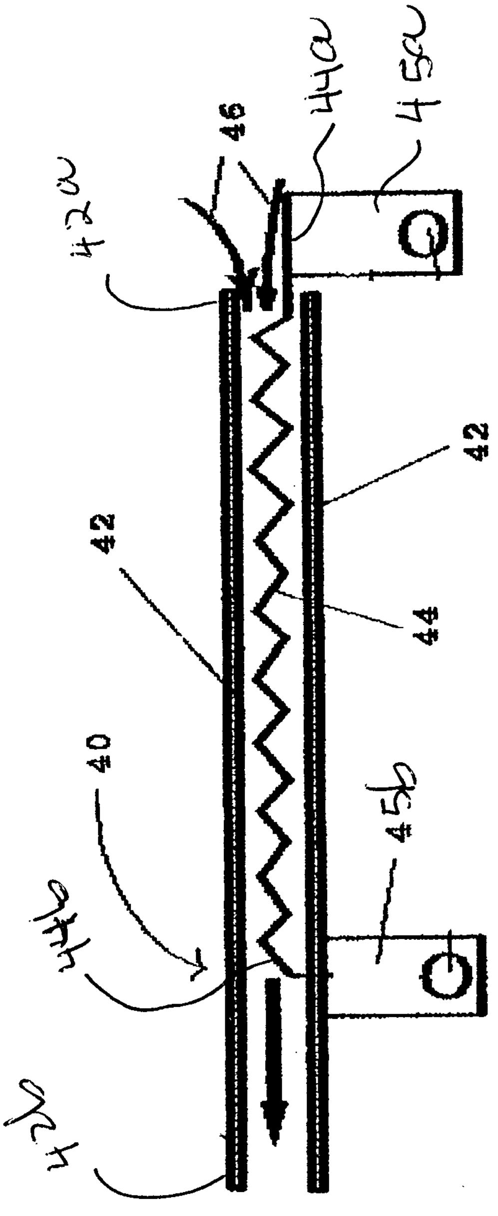

FIGURE 4

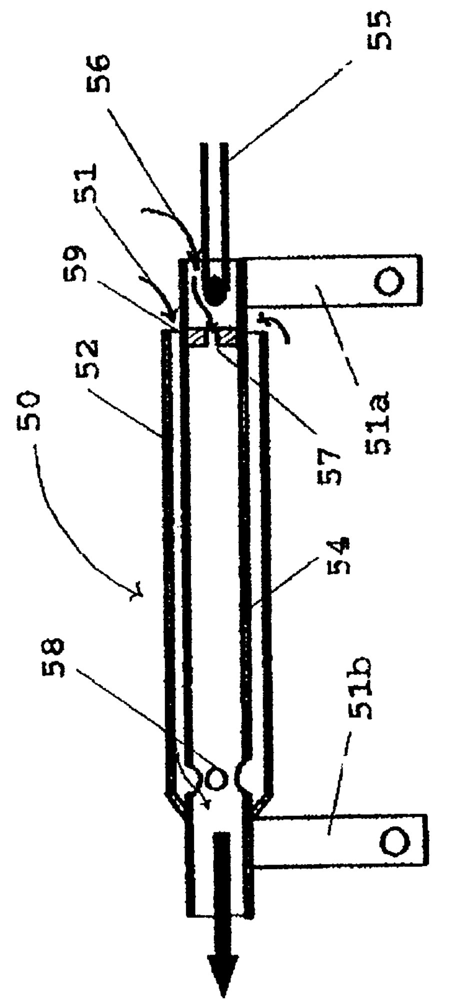

FIGURE 5

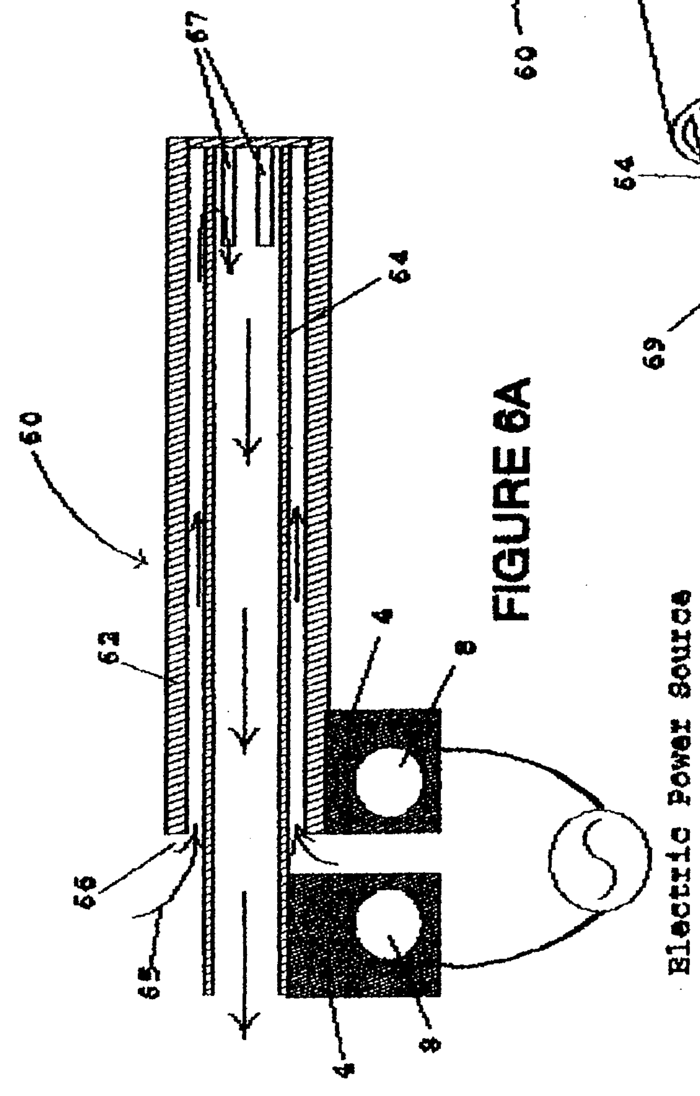

FIGURE 6A

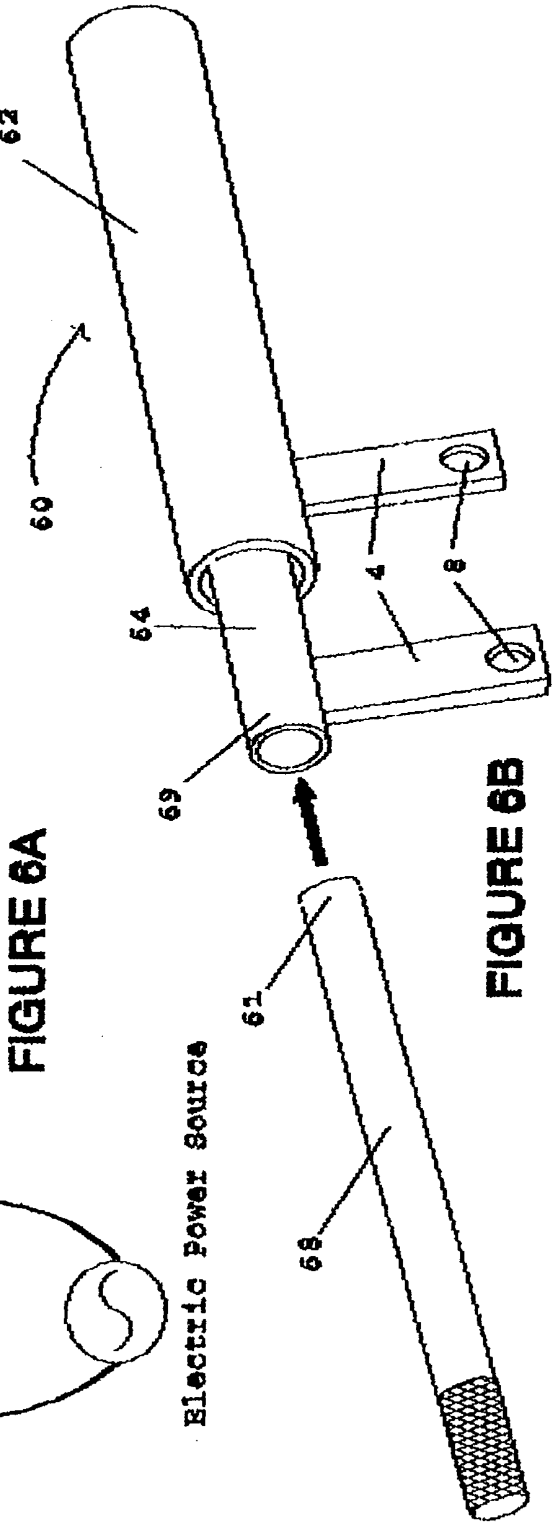

FIGURE 6B

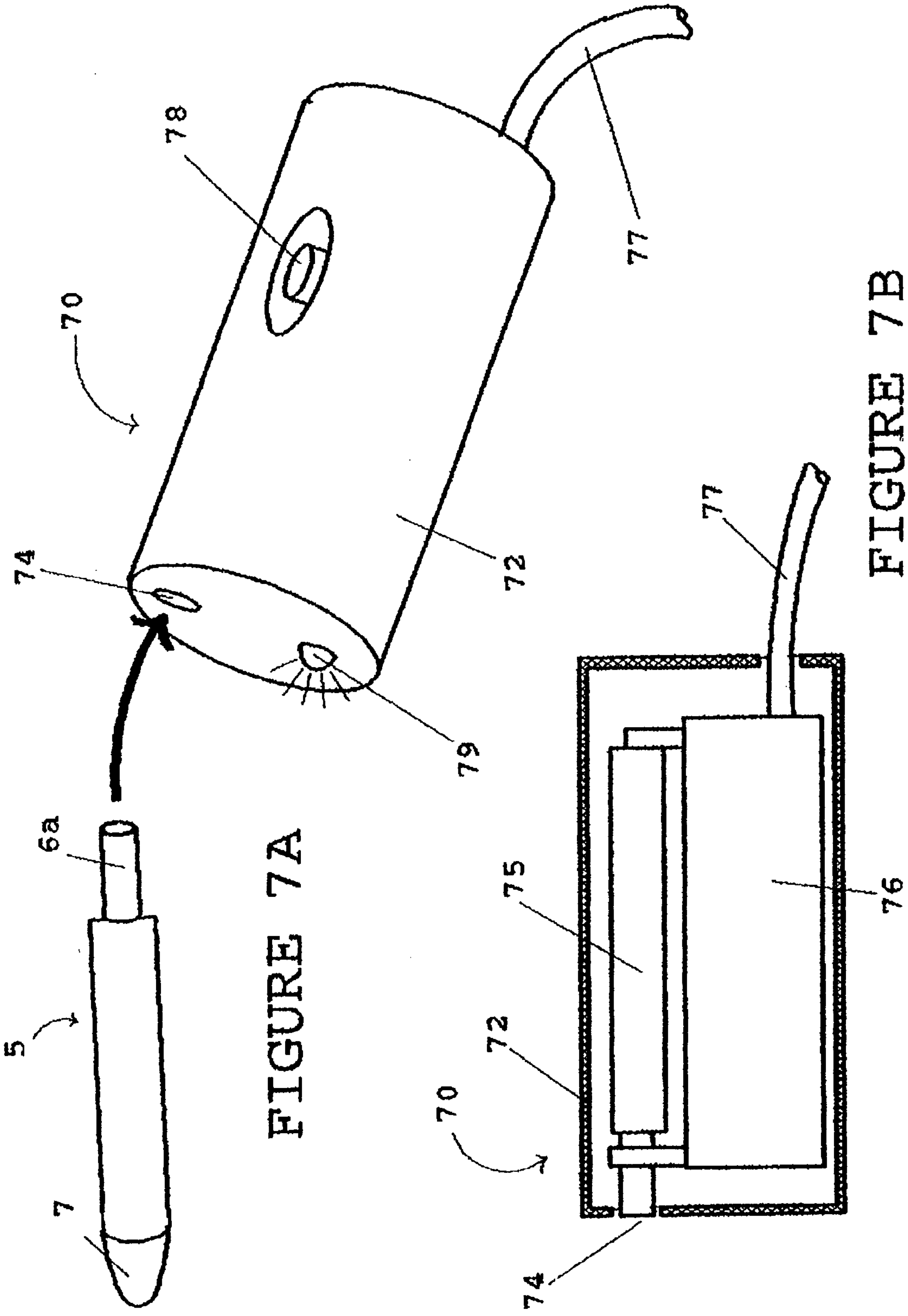

FIGURE 7A

FIGURE 7B

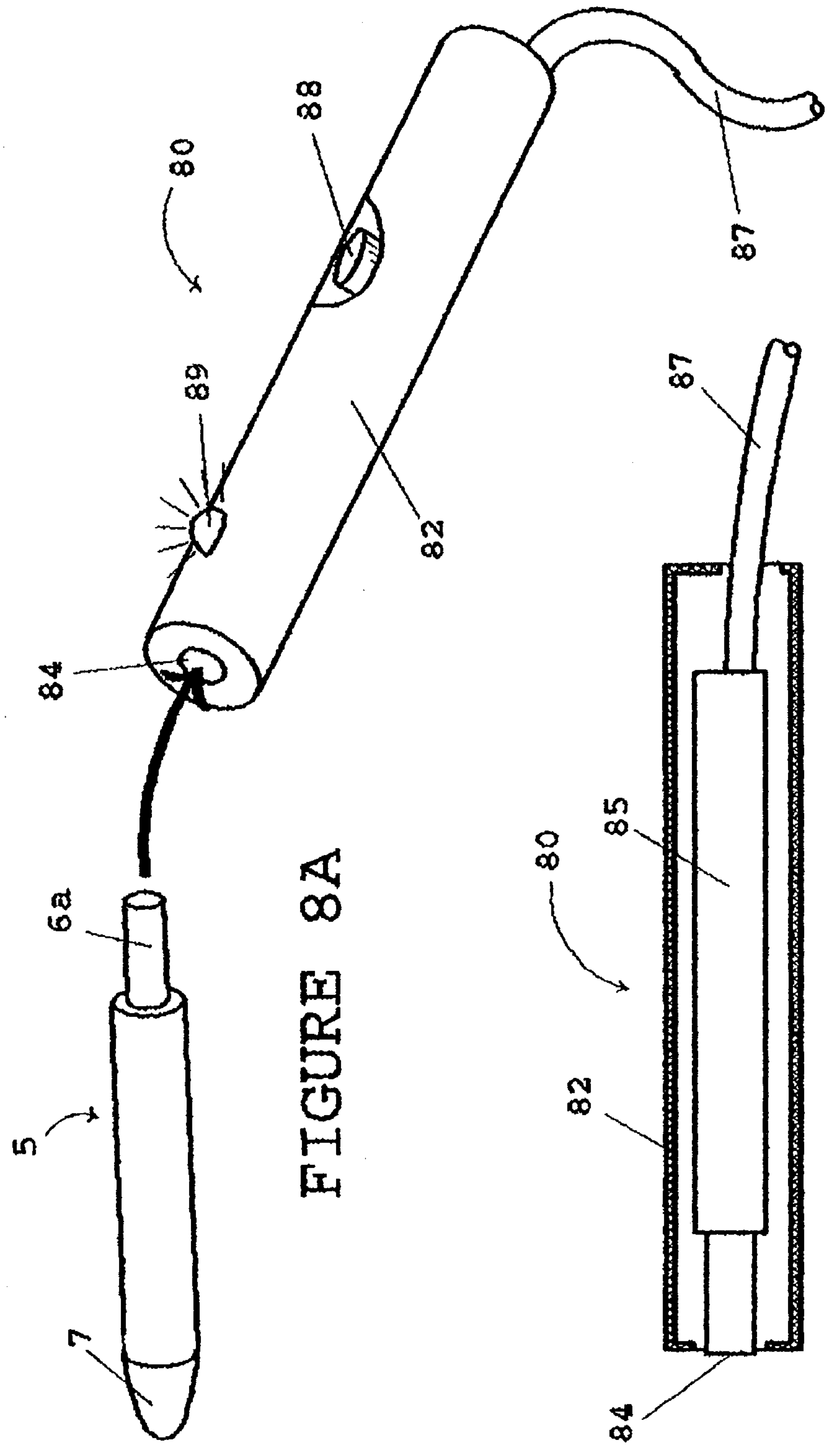

FIGURE 8A

FIGURE 8B

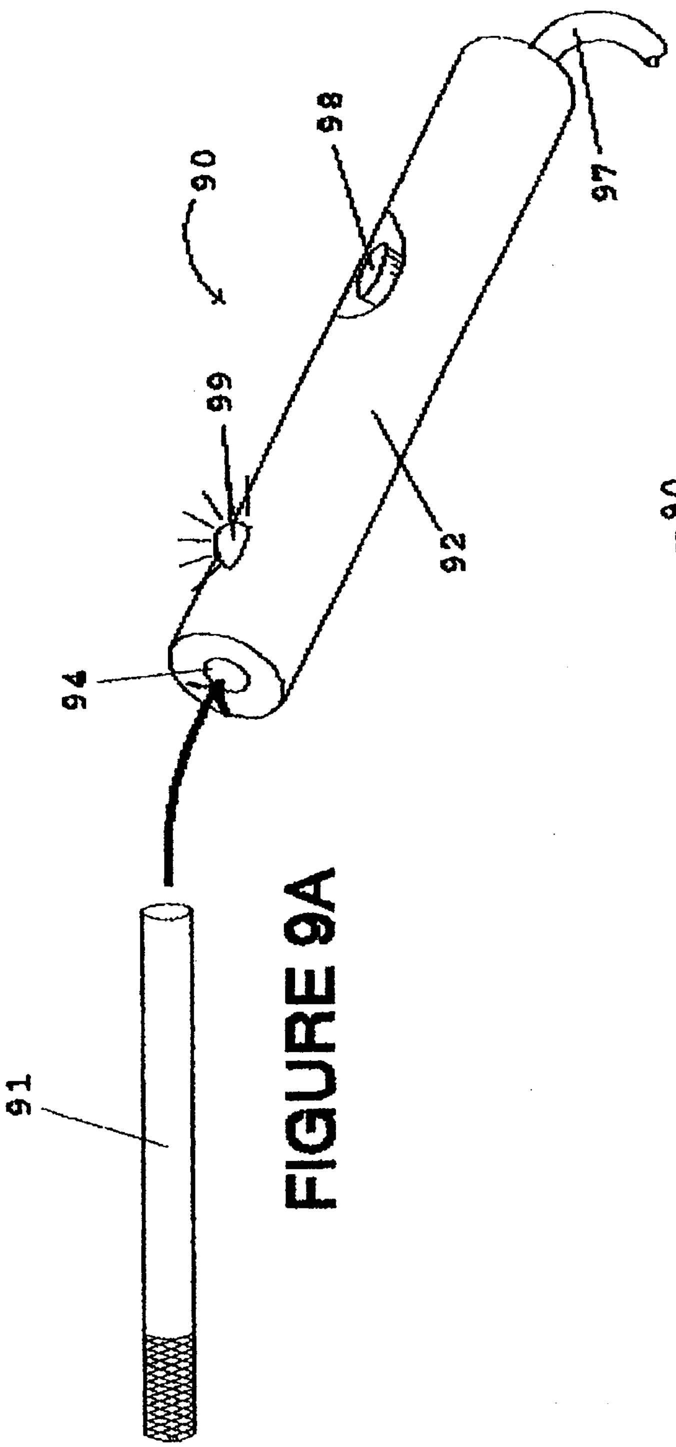

FIGURE 9A

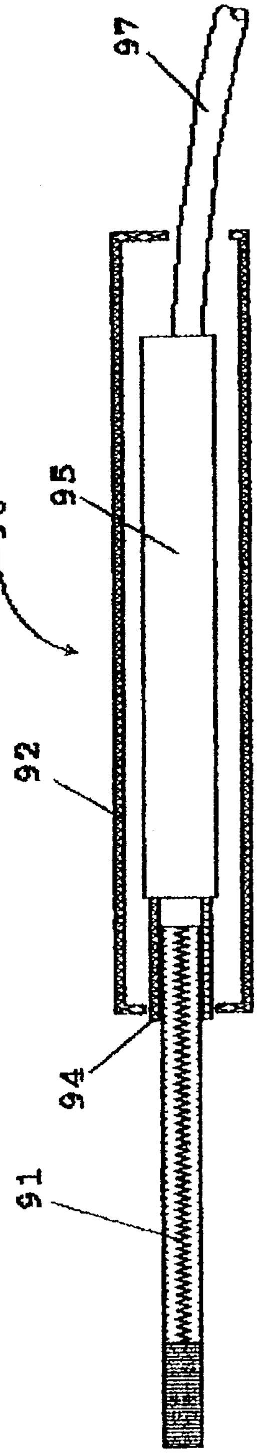

FIGURE 9B

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US99/17287

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :A24F 1/10
US CL : 131/330,329,194
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 131/330,329,194; 128/202.21,204.17,204.18,204.21,203.26,203.27,204.13

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X ---- Y	US 1,485,260 A (ERNST) 26 February 1924, col. 1, lines 29-38; col. 2, lines 62-66, 76-89	1 ---- 2-9
Y	US 1,771,366 A (WYSS et al) 22 July 1930, col. 2, lines 68-82; col. 3, lines 4-15; col. 4, lines 1-2, 119-125.	1-9

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
18 OCTOBER 1999	09 NOV 1999

Name and mailing address of the ISA/US	Authorized officer
Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231	DIONNE A. WALLS
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Form PCT/ISA/210 (second sheet)(July 1992)★