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(54) Amorphous metallic alloy electrical heater system

(57) An electrical heating system uses heating elements made of ribbons of amorphous metallic alloys. The heating elements have a large area using long and wide ribbons, to achieve good heat transfer to the surroundings, that is low thermal resistance. The area of the heating elements and thus the thermal resistance is determined according to the desired thermal power, under the constraint of a low operating temperature, that is a temperature well below the embrittlement temperature of the amorphous alloy used in the heating elements.

The operating temperature is preferably kept low enough so as not to generate benzopyrene or other unhealthy or ecologically unfavorable fumes or gases. The thin ribbons with low thermal resistance also have a fast heating constant, that is the heater reaches its steady state temperature in a short time. The electrical heating system uses low cost insulation and support materials, that is materials intended for use at low temperatures only. Further cost reduction is achieved by making the heating elements of lower cost alloys, that is alloys capable of withstanding oxidation only at low temperatures.

The heating elements undergo treatment using the Manov process of overheating the melted alloy to a precise temperature prior to rapid quenching, to achieve more reliable ribbons with more reproducible characteristics.

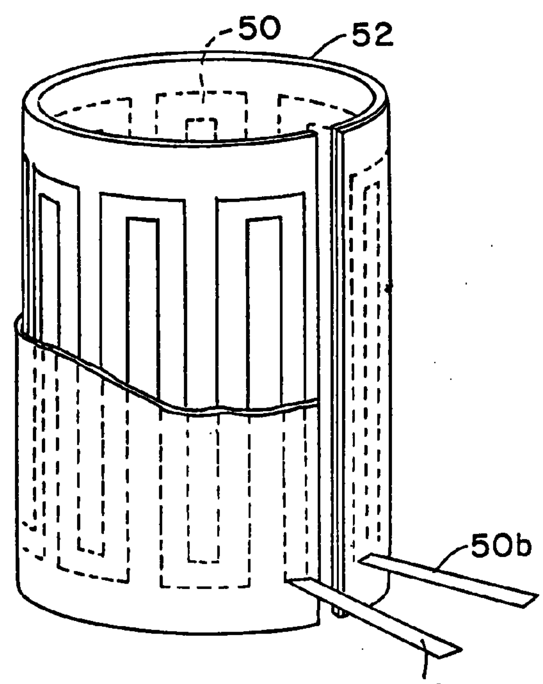

FIG. 2A

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Description

The present invention concerns electrical heater elements and systems. The invention relates in particular to such systems in which the heating elements are thin ribbons made of amorphous metallic alloys having a large area and that are operated at low and moderate temperatures.

At present, electrical heating systems use heating elements made of metallic wire, having a crystalline structure and a small area of contact with the surroundings. To transfer the required heat power to the surroundings, these elements are operated at a high temperature, typically 900-1500°C. This requires a relatively high- cost heater, capable of operation at these high temperatures for prolonged periods, thus having good anticorrosion properties at high temperatures. Commonly used heating elements for high-temperature heaters are made of NiCr alloy, Kanthal and Fechralloy. Other materials, used at lower temperatures in the range of about 800°C, include Manganin and Constantan.

While conventional heating elements can withstand high temperatures, they are expensive. Moreover, because of the high operating temperature, the rest of the heating system is more expensive than it otherwise needs be. For example, the required thermal insulation, heater mechanical supports and other required materials all need be high-grade and expensive to withstand these high temperatures.

The high operating temperatures also create undesirable fumes and odors, for example odors arising from burning the organic dust particles in the air. Formation of benzopyrene, for example, starts at a temperature of about 180°C. These odors have a particularly unhealthy effect while the heaters are used in closed spaces, for example for domestic heating. These heaters are not environment-friendly, and their widespread use creates an ecological problem.

A thin ribbon could be used as a heater and operated at lower temperature because of its larger surface area; unfortunately, the process of making thin ribbons or foils is very expensive, involving etching of a resistive material carried on a substrate, or repeated rolling of a wire. The resulting foil assumes a metallic a crystalline structure.

In recent years, however, attention has been paid to the fabrication of thin amorphous metallic alloy ribbons, primarily for use in magnetic application.

Amorphous ribbons are much cheaper to produce than crystalline ribbons. Usually the process for manufacturing amorphous ribbons involves one-stage melt spinning technology, as detailed for example in Ohno US Patent No. 4,789,022.

Amorphous metallic alloy ribbons are widely used in magnetic applications; these ribbons are not used at present as electrical heaters, although there are indications and comments that such an application may be possible.

For example, Morito Japanese Application No. 63-264213, Disclosure #2-112192 discloses a foil heater made of a thin strip of an amorphous alloy having a specific resistance as detailed, a method for manufacturing the foil heater and materials to be used. The stated goal was to solve the problems of mechanical strength, high cost and stability of electrical resistance.

No details to implement a practical heating system are provided.

It is an object of the present invention to provide a low cost, healthier and environment-friendly heating system.

This object is achieved by an electric heater element as disclosed in claim 1 and by an electrical heating system as disclosed in claim 11.

In accordance with the invention, the object is basically accomplished by providing an electrical heating element made of a ribbon of amorphous metallic alloy, and an electrical heating system including these heating elements. The heating elements are made of an amorphous metallic ribbon.

It is another object of the present invention to provide a heating system which is capable of long-term, reliable operation in the conditions of repetitive mechanical, electrical and temperature loadings.

The heating elements have a new structure and operation: the novel structure includes a large area formed by long and wide ribbons, to achieve good heat transfer to the surroundings, that is lower thermal resistance to surroundings.

The area of the heating elements and thus the thermal resistance is determined according to the desired thermal power, under the constraint of a low operating temperature, that is a temperature well below the embrittlement temperature of the amorphous alloy in use.

Thus new operating conditions are achieved, of low temperature, even for large radiated heat power. An additional novel property: fast heating constant, that is heater reaches its steady state temperature in less time.

The heating element ribbons are manufactured using the process developed by V. Manov et al., that is overheating the melted (liquid) alloy before rapid quenching, to achieve more reliable heater elements with more reproducible properties.

In a preferred embodiment, the structure of the heating elements is such as to keep the operating temperature still lower, so as not to generate benzopyrene or other unhealthy or environment unfriendly fumes or gases.

The heating elements use lower cost alloys, that is alloys capable of withstanding oxidation only at low temperatures.

To achieve a low cost system, the electrical heating system further uses low cost insulation and support materials, that is materials intended for use at low temperatures only.

The invention will now be described by way of example and with reference to the accompanying drawings in which:

Fig. 1A depicts a prior art heating coil element, and Figs. 1B-1D are examples of prior art uses of such a coil, Fig. 1B showing a stove burner, Fig. 1C showing a space heater, and Fig. 1D showing a hair dryer;

Figs. 2A-2C depict an illustrative heating element of our invention, with Fig. 2A being a perspective view, shown partially broken away, Fig. 2B being a similar side view, and Fig. 2C being a top view;

Fig. 3 is a perspective view of a hair dryer, shown partially broken away, made in accordance with the principles of our invention, utilizing the heating element of Figs. 2A-2C;

Figs. 4A-4D depict a space heater constructed in accordance with the principles of our invention, with Fig. 4A being a perspective view of three modules which comprise the heater, Fig. 4B showing the pattern of the ribbon heating element on one of the modules, Fig. 4C being a sectional view through the line 4C-4C of Fig. 4B, and Fig. 4D showing in greater detail a latch mechanism for connecting adjacent panels;

Figs. 5A and 5B depict another form of space heater constructed in accordance with the principles of our invention, with Fig. 5A being a perspective view, shown partially broken away, and Fig. 5B being a cross-sectional view taken along line 5B-5B in Fig. 5A;

Figs. 6A and 6B are two comparable views of an alternative form of a space heater constructed in accordance with the principles of our invention, with Fig. 6A being a perspective view, shown partially broken away, and Fig. 6B being a cross-sectional view taken along line 6B-6B in Fig. 6A;

Fig. 7A depicts a conventional sink with a water heating element 88 constructed in accordance with the principles of our invention, and Fig. 7B is a detailed view of the heating element; and

Figs. 8A and 8B are comparable views of an alternative form of a water heating element constructed in accordance with the principles of our invention.

Fig. 1A illustrates prior art heating element 12 made of a coiled nichrome wire. The wire has a crystalline structure; this is the normal state of a metal which is allowed to solidify gradually. Fig. 1B shows a stove burner with heating coils 12 and 18. The two coils are embedded in ceramic plate 14, with electrical connections (not shown) to apply electric power to the heating coils.

Fig. 1C shows another well-known use of prior art crystalline coils for heating purpose. The space heater includes case 22, two heating coils 24, 26 two reflectors 23, 25 and power switch 27.

Fig. 1D shows yet another prior art crystalline metallic wire for heating purposes, a hair dryer. Case 32 and handle 34 are usually an integral plastic molded piece. Power is extended from line cord 48, through contacts on switch 38, to wire 42 which is wound around mica frame 40. The frame, which must withstand high temperatures, simply serves to support the wire heating element. The heating unit is contained within mica insulating sleeve 44. A fan 36 at the rear of the heating element is turned by a motor (not shown) when switch 38 is turned on. A good part of the cost of a conventional hair drier is attributable to the heating element 42.

The remaining drawings illustrate the use of amorphous ribbons as heating elements according to our invention. The present invention details a new structure and operation of electrical heating systems, with heating elements which are thin ribbons made of amorphous metallic alloys having a large area and that are operated at low and moderate temperatures.

Fig. 2A is a perspective view, shown partially broken away, of a heating element constructed in accordance with the principles of our invention; Fig. 2B is a side view of the heating element, also shown partially broken away, and Fig. 2C is a top view. The heating element consists of an amorphous metallic alloy ribbon 50 mounted between two (in this case, cylindrically-shaped) plastic sheets glued, laminated or otherwise joined together as a unit 52. Suitable plastics for use with the heating element of Figs. 2A-2C are polystyrene and polyamide. In general, the material encasing the ribbon should have good heat conductivity and poor electrical conductivity. The ends 50a, 50b of the ribbon as shown may be attached to terminal lugs. These heating elements are made of amorphous metallic alloys.

Most metals and metallic alloys assume a crystalline form. In recent years, however, attention has been paid to the fabrication of thin amorphous metallic alloy ribbons, primarily for use in magnetic applications.

Amorphous ribbons have very good mechanical properties (e.g., hardness, flexibility and tensile strength), they are much cheaper to produce than crystalline ribbons, and they are easier to work with.

An example of a process for making an amorphous ribbon is disclosed in Ohno US Patent No. 4,789,022. Most often amorphous ribbons are produced using one-stage melt spinning technology. A ribbon is formed from a melt which is rapidly quenched so as to "freeze" the metal atoms before they can arrange themselves in a crystalline structure. Amorphous ribbons can be made in a wide range of widths thicknesses. Typical widths are 1 - 100 mm, and typical thicknesses are 20-35 microns. Such amorphous ribbons have electrical resistivities which can go as high as 20E-6 ohm*m, although typically their resistivities are in the range of 1.5E-6 ohm*m, still equal to or higher than the resistivities of crystalline ribbons.

Despite all of the activity in amorphous metallic ribbons, such materials have just not been used as heating elements. It is believed that there are two reasons for this: the reproductivity of amorphous ribbons, and the low permitted operating temperature.

The first reason is that the properties of amorphous metallic ribbons are not generally reproducible in the sense that the material characteristics are not consistent from one batch to the next, and even from the start of any single ribbon to its end. Different resistivity results in different emitted heat power and is not tolerable in a standard heater for consumer use; moreover, different parts of the heater may heat to different temperatures, which may result in heater destruction and thus lower reliability of the heater system.

A surprising discovery that we have made is that there appears to be no degradation in the ribbon material characteristics over long periods of operation. This is contrary to every expectation since amorphous metallic materials are just not acknowledged to be of practical use as heating elements. In one experiment we constructed a space heater whose amorphous metallic ribbon was operated at 150 °C for over a year, and there was absolutely no difference in operating characteristics from beginning to end.

The present invention proposes the use of the Manov overheating process to achieve amorphous ribbons with reproducible characteristics. In an article by Manov et al., entitled "The influence of quenching temperature on the structure and properties of amorphous alloys" published in Materials Science and Engineering, A133 (1991), 535-540, an "overheating" technique was disclosed, that is that is overheating the melted (liquid) alloy to a precise temperature prior to rapid quenching, to achieve more reliable heater elements with more reproducible properties.

Although the abovementioned Manov et al. article details the overheating process of the liquid melt and some resulting properties of ribbons thereby formed, that is of higher and more stable resistivity, these properties have no value for electric heaters. Accordingly, there is no mention in the article of any application of this process for electric heater production.

However, the Manov process has additional benefits, in that it also achieves ribbons having a new, different structure and a composition distribution which is significantly more uniform, both in the volume and on the surface. This results in fewer local micro-defects in the ribbon. These micro-defects are the main cause of the cracks propagation as the electrical current passes through the ribbon, which cracks in the end result in the heating element failure. So, the ribbons are more reliable in the sense that heating elements made therefrom are capable of operation for prolonged periods. It is these findings, hitherto unpublished, which justify the use of the Manov process for producing ribbons for heating elements.

Thus, the use of the Manov process is a novel process used in the present invention in conjunction with heaters made of amorphous metallic alloys, and solves a long felt problem which prevented widespread, practical use of these alloys as heater elements.

A second reason that amorphous alloys were not used as heating elements, is the low permitted operating temperature. The required resistance of a heating element is readily determined. The power input is equal to the square of the voltage across the heating element, divided by the resistance of the element. Since the full line voltage is usually applied across the heating element and the desired power is known (limited by the maximum current which can be drawn), the required resistance can be calculated. Heaters known in the art are operated at a high temperature, between 900-1500°C, offering the benefit of small size, since a small heater can provide much heat and transfer it to the surroundings.

The heaters in the present invention, however, are designed to be operated at a much lower temperature, about 50-300°C, with a preferred range of 50-200°C. The low operating temperature was determined according to several considerations: the amorphous alloy ribbons become brittle at about 250-300°C (the "embrittlement" temperature), and become crystalline at a slightly higher temperature, about 350-400°C. The temperature should therefore be kept below these values. Moreover, according to the present invention, the structure of the heating elements is such as to keep the operating temperature still lower, so as not to generate benzopyrene or other unhealthy or ecologically unfavorable fumes or gases.

According to the present invention, the heating elements have a new structure and operation: the novel structure includes a large area formed by long and wide ribbons, to achieve good heat transfer to the surroundings, that is lower thermal resistance to surroundings.

The area of the heating elements and thus the thermal resistance is determined according to the desired thermal power, under the constraint of a low operating temperature, that is a temperature well below the embrittlement temperature of the amorphous alloy in use as detailed above.

Thus, the lower operating temperature results in less heat transfer to the surroundings, since the quantity of heat transferred is proportional to the temperature difference; to compensate for that and to achieve good transfer of all the heat power as desired, a large surface heater element is used.

Regarding the heat transfer performance, the amorphous ribbon heating element is much more effective than the crystalline wire heating element because of the much larger heat transfer area. For the same steady state heating element temperature, much more heat is transferred to the surrounding air by a ribbon than a wire whose masses are the same. Mass is a very important consideration, because it directly affects cost. Were a crystalline ribbon to be substituted for the wire, the heat transfer characteristics would be more comparable because of the larger area of the crystalline ribbon. However, a crystalline ribbon costs much more than a comparable amorphous ribbon.

The resistance of the heating element is calculated using methods well known in the art, from the desired electrical power and the applied voltage.

"Thermal resistance" is the term used in the art to define the heat transfer property of a material or between a body and the ambient; it is defined as the temperature difference resulting from the flow of 1 Watt of thermal power.
A lower thermal resistance is achieved by increasing the area of the heating elements. Thus, increasing the area of the heating elements results in a capability to transfer a desired thermal power to the surroundings, while the heating element is kept at a lower temperature.

It is well known that the electrical resistance is proportional to the length of a wire or ribbon, and inversely proportional to its cross-sectional area. Thus, for a ribbon of constant thickness, the same electrical resistance can be achieved by using either a short and narrow ribbon, or a wide and long ribbon.

Ribbons known in the art for use in heating elements use a thin and short ribbon; for example, JP-112192 repeatedly describes a 10 mm wide ribbon; our use of a 200 mm wide ribbon results in a 20 times increase in width with a 20 times required increase in length to achieve the same resistance; thus the area increases 400 times, dramatically decreasing the thermal resistance to ambient, and an about 400 times reduction in the operating temperature. This is an illustration of an extremely wide element, to be used for very high power or very low operating temperatures according to the present invention; more practical values for the element width are about 30 mm to 100 mm. However, the illustration serves to demonstrate the great flexibility of the novel approach in the present invention, in which precise control of the heater area determines the operation temperature, setting it at a low value beneficial from several aspects as detailed here.

Thus new operating conditions are achieved, of low temperature, even for large radiated heat power. An additional novel property and benefit: a fast heating constant is achieved, that is the heater reaches its steady state temperature in less time. This is beneficial to the user, since the room is heated faster; this results in lower electrical power consumption, and also increases the reliability of the heater since there is less mechanical stress because of high temperature differentials and high temperatures inside the heater, which are not allowed because of the amorphous alloy limitations.

It is well known in the art that the higher the temperature of a material, the more is that material susceptible to oxidation. In practical use, oxidation results in rust formation and degradation of the heating elements. To allow operation at high temperatures, the heating elements have to be made of expensive metals, capable of withstanding oxidation at high temperatures.

In the heater structure and operation described in the present invention, however, the heating elements use lower cost alloys, that is alloys capable of withstanding oxidation only at low temperatures, since the heating element operates only at low temperatures. Accordingly, the whole electrical heating system is cheaper to produce since it further uses low cost insulation and support materials, that is materials intended for use at low temperatures only.

The ribbon supporting structures in heaters of our invention may be made of Teflon, silicone, rubber, RTV, Kapton and like materials.
To increase the reliability of the amorphous ribbon operation as a heating element, a variant of the present embodiment is provided where the ribbon is produced in a perforated form with the sizes, positions and quantity of the orifices being determined by the conditions of preventing the propagation of a crack which may appear due to any reason during the heating element operation. The holes are such sized and located that any crack propagating in a straight line will meet a hole after a short distance of propagation, and stop there.

For the best practice of our invention, the heating element ribbon should be no thicker than 100 microns. In many cases, however, it can be thick enough to require no supporting substrate (while still being under 100 microns). In all cases, the ribbon thickness should be as uniform as possible.

Preferred alloys include one or more of iron, nickel and cobalt in the range 65-88 molar percent, one or more of boron, silicon and phosphorus in the range 12-28 molar percent, and chromium in the range 0-11 molar percent. For such alloys, the ribbon thickness is preferably below 45 microns. Alloys used in our invention have electrical resistivities in the range 1E-6 to 1E-5 ohm*m, and preferably in the range 1-5*E-6 ohm*m.

Following is a list of amorphous alloys known in the art which can be used to produce the heater elements described in the present invention:

$$Fe_{80}B_{20}$$

$$Fe_{40}Ni_{40}B_{15}C_1Si_4$$

$$Ni_{70}Si_{15}B_{15}$$

$$Fe_{85}B_{15}$$

$$Fe_{76}B_{24}$$

$$Fe_{78}B_{18}Si_4$$

$$Fe_{74}Co_{2.5}Cr_{7.5}B_{16}$$

$$Ti_{48.5}Cu_{45}Ni_5Si_{1.5}$$

$$Al_{65}Co_{10}Ge_{25}$$

One use for the heating element of Figs. 2A-2C is depicted in Fig. 3, a hair dryer. Case 56 and handle 58 comprise an integral molded piece, with power switch 62 in the handle controlling the flow of current from line cord 66. Switch 62 controls both the heating ribbon and the motor which drives fan 60. The heating element is placed within case 56. There is no need for high-temperature mica supports or high-temperature insulation as in the prior art hair dryer of Fig. 1D. In order to compare the new hair dryer with prior art, only the heating element was substituted. Prior art dryer used a heating element made of crystalline Kanthal wire of 0.4 mm diameter, with a length of 486 cm. The device operated at 920 watts, with a wire temperature of approximately 600 °C.

The new heater was made of Fe80B20 material, also operated at 920 watts. The ribbon thickness was 20 microns, its width was 5 mm, and its length was 388 cm. The operating temperature of the ribbon heating element was measured at 100 °C, that is six times less than the operating temperature

of the commercial hair dryer heating element. The cost of the amorphous ribbon used was approximately one-half that of the wire used in the commercially available product. It will be understood that because of the lower operating temperature, it is possible to reduce the overall cost of the device still further, because there is no longer necessary to use expensive, high temperature insulating materials.

The space heater of Fig. 4A consists of multiple modules 64. The pattern of the heating ribbon 70 is shown most clearly in Fig. 4B. The ribbon terminates at two ends 70a, 70b. Only one intermediate module is shown in Fig. 4A.

The leftmost module includes a control knob 72 for controlling the power delivered to the heater as known in the art, as well as a line cord, as shown.
In order to connect the several modules or panels to each other, they are provided with hooks 66, as shown most clearly in Fig. 4D. When a button 68 is depressed, the hooks separate to allow their insertion into notches (not shown) of an adjacent module; when the button is released, the hooks grab corresponding pins (not shown) so that the connection remains secure. Other similar connection means may be used.

Fig. 4C depicts the cross-section of a panel. The rear of the heater panel consist of cover 76; ribbon 70 can be attached to the cover 76 if the cover is made of an insulating material. The front of the module consists of an aluminum cover 73 secured to the ribbon with a layer of silicone glue 74. A heater of the type shown in Figs. 4A-4D, but with only a single panel, was made using an amorphous alloy of Fe78B18Si4 material. The ribbon had a thickness of 20 micron, a width of 1 cm, and a length of 10.15 m. It was attached to the aluminum plate which had an area of 0.3 m2. when operating at a power of about 500 watts, the temperature of the heating element was only 150 °C.

Figs. 5A and 5B depict a space heater in which the amorphous metallic ribbon is not supported by a substrate. The heater consists of base 84, top cover 81 which has holes 81a, and a radiating case 78 which surrounds the heating element but includes notches 78a at the bottom. Notches 78a and holes 81a allow air to flow up, thus carrying heat by convection.

The heating element comprises vertically oriented insulating rods 79, around which is wound a long amorphous ribbon 80. The ribbon 80 is preferably fixed by silicone glue to the rods. The base includes a regulating knob 82 and line cord socket 83 of conventional design.

Ribbon 80 was constructed of $Fe_{78}B_{18}Si_4$ material, had a thickness of 20 micron, a width of 2 cm, and a length of 8 m. When operated at a power of about 1300 watts, the temperature of the ribbon surface did not exceed 130 °C.
This heater, and the 500-watt heater discussed immediately above, were operated for over 1,000 hours. In each case the amorphous ribbon was checked by X-ray diffraction, and no changes in ribbon structure were found.

The space heater of Figs. 6A and 6B is similar to that of Figs. 5A and 5B with one major difference. This tower-shaped heater includes the same cover 81 with holes 81a, radiating cover 78 and base 84 with knob 82 and plug socket 83. But instead of an amorphous metallic ribbon being wound around insulating rods, here a heating element of the type shown in Figs. 2A-2C is used, although the heating element used for a space heater would be larger than that used for the hair dryer of Fig. 3. Ribbon 50, supported on a single plastic sheet 83, is shown in Fig. 6B, with the two ends 50a, 50b of the ribbon terminating in a central block 85.

Fig. 7A depicts the use of the invention for heating water in a conventional sink 87, with part of the hot water pipe being replaced by heating element 88, shown in detail in Fig. 7B.

The heating element consists of a copper pipe 89 through which cold water flow from the bottom and hot water exit from the top, an about 0.3 mm thick layer of silicon insulation 52, a ribbon layer 50 mounted on a plastic carrier 91 glued to layer 52, and an about 2.4 mm thick layer of mineral thermal insulation 90. In one embodiment of the invention, the water flow rate was 2kg/min, the input temperature of the water was 10-20 °C, and the output temperature at the top of the pipe, was 96-98 °C . The pipe 89 had an inner diameter of 8 mm, an outer diameter of 10 mm, and a length of 0.5 m. Three ribbons were connected in parallel and wound around the pipe.

Each ribbon was 25 micron thick, 1 cm wide, and 3 m long, for a total mass of 14.5 gram. The ribbon material was Fe78B18Si4 . The total power was 11 kilowatts. The measured temperature of the ribbon was 180 °C. The hot water heater was operated for 200 hours with no complications.

Figs. 8A and 8B are similar to Figs. 7A and 7B and depict an alternative mechanism for heating water as it flows through a conventional pipe. Heating element laminate 94 is shown in Fig. 8B, and is of the type depicted in Figs. 2A-2C. Heating element 94 is placed inside pipe 89, and water flows around it as shown by arrow 95 in Fig. 8A. Here the heating element heats the water directly.

Although the invention has been described with reference to particular embodiments, it is to be understood that these embodiments are merely illustrative of the application of the principles of the invention. Numerous modifications may be made therein and other arrangements may be devised without departing from the spirit and scope of the invention.

Claims

1. An electric heater element made of an amorphous metallic alloy ribbon, said ribbon having an electrical resistance according to the desired electrical power to be converted into heat power, and said ribbon further having a shape and size such as to achieve the thermal resistance required to deliver said heat power to the surroundings with said element being at a desired operating temperature, wherein said temperature is below the embrittlement temperature of said alloy, and wherein said ribbon is manufactured according to the Manov process of overheating the melted alloy to a precise temperature prior to rapid quenching.

2. An electric heater element as claimed in Claim 1, wherein said operating temperature is below the temperature of formation of benzopyrene or other unhealthy or ecologically unfavorable fumes or gases.

3. An electric heater element as claimed in Claim 1, wherein said operating temperature is in the range 50 - 200 degrees Celsius.

4. An electric heater element as claimed in Claim 1, wherein said shape and size of said ribbon consist in a generally planar ribbon having a thickness of less than 100 micron and the length and width of said ribbon being such as to achieve said electrical resistance and said thermal resistance.

5. An electric heater element as claimed in Claim 1, wherein said ribbon is made of an alloy of $Fe_{78}B_{18}Si_4$ or $Fe_{13}Ni_{60}Cr_5Si_{10}B_{12}$ or $Fe_{74}Co_{25}Cr_{75}B_{16}$ or $Al_{65}Co_{10}Ge_{25}$.

6. An electric heater element as claimed in Claim 1, wherein said ribbon is made of an alloy having one or more of iron, nickel and cobalt in the range 65-88 molar percent, one or more of boron, silicon and phosphorus in the range 12-28 molar percent, and chromium in the range 0-11 molar percent.

7. An electrical heating system comprising:

(A) One or more electric heater elements made of an amorphous metallic alloy ribbon, each of said ribbons having an electrical resistance according to the desired electrical power to be converted into heat power, and said ribbon further having a shape and size such as to achieve the thermal resistance required to deliver said heat power with said element being at a desired operating temperature, wherein said temperature is below the embrittlement temperature of said alloy;

(B) Electrical insulation means for covering said ribbons to prevent electrical shock while transferring said heat power, wherein said insulation is made of materials only capable of operation at low temperatures in the range of said operating temperature; and

(C) Support means for mechanically holding said ribbons in said heating system, wherein said support means are made of materials only capable of operation at low temperatures in the range of said operating temperature.

8. An electrical heating system as claimed in Claim 7, wherein said insulation includes a plastic laminate covering said ribbon.

9. An electrical heating system as claimed in Claim 8, wherein said plastic laminate is made of polystyrene or polyamide or silicon.

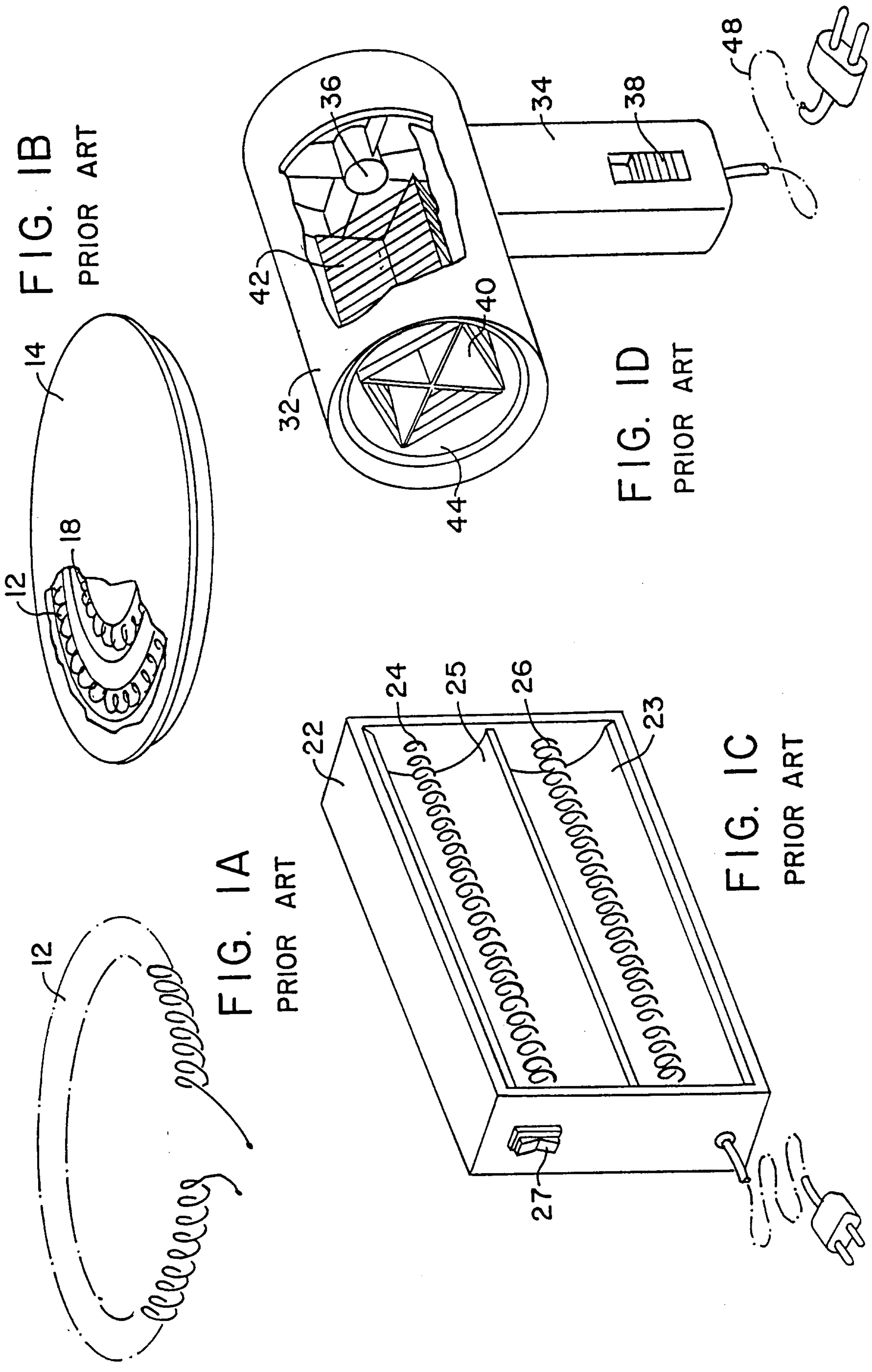


FIG. 1A
PRIOR ART

FIG. 1B
PRIOR ART

FIG. 1C
PRIOR ART

FIG. 1D
PRIOR ART

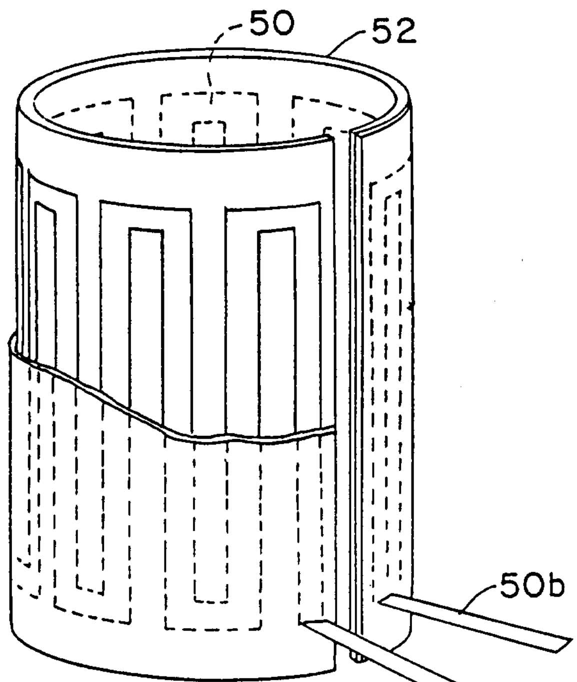


FIG. 2A

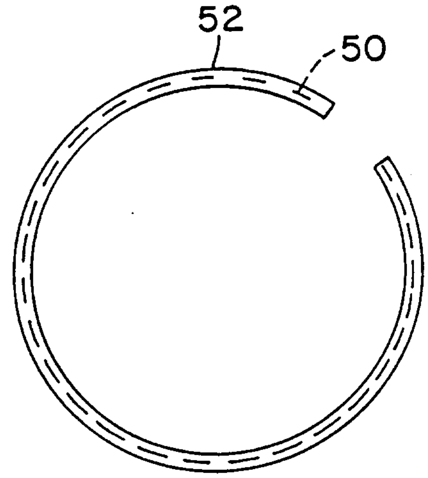
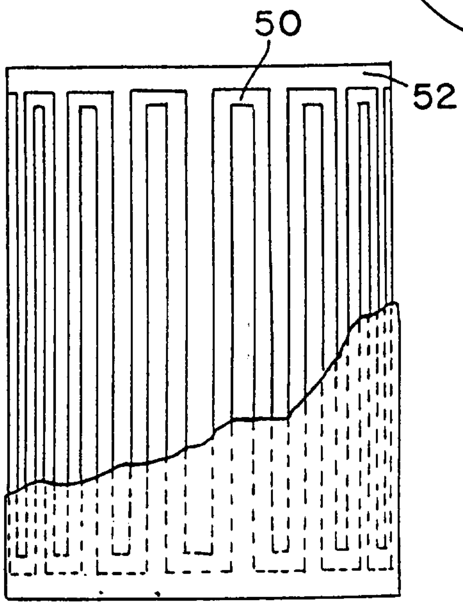


FIG. 2C

FIG. 2B



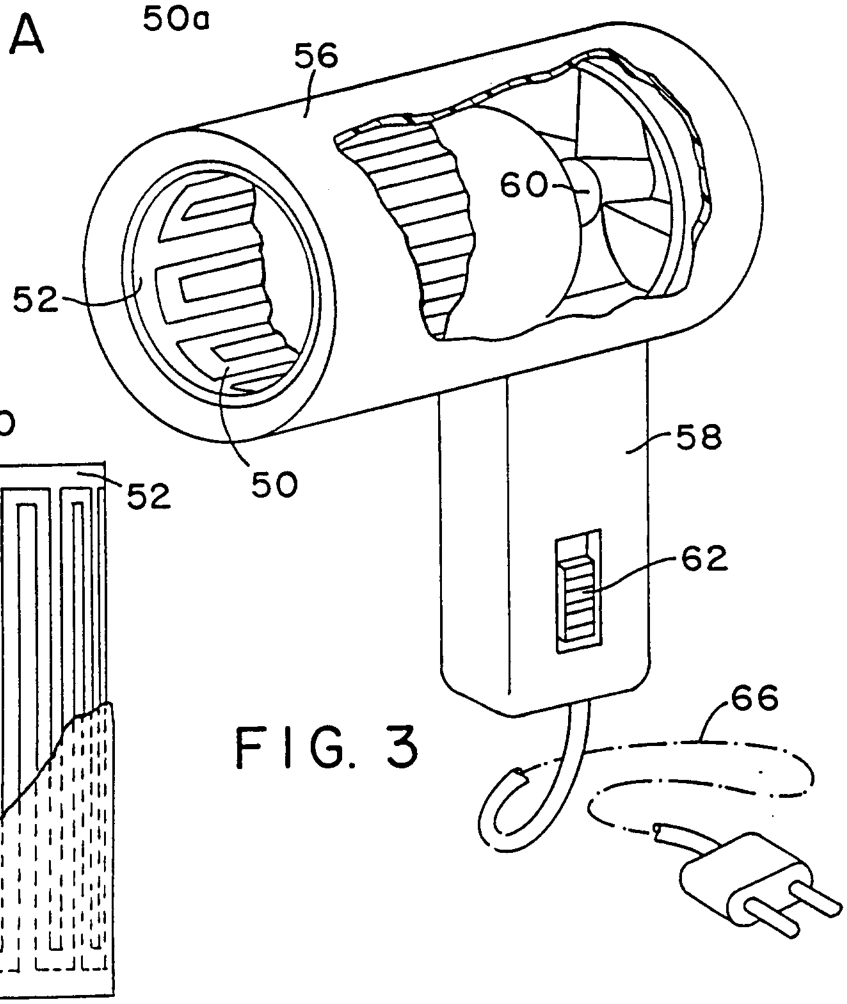


FIG. 3

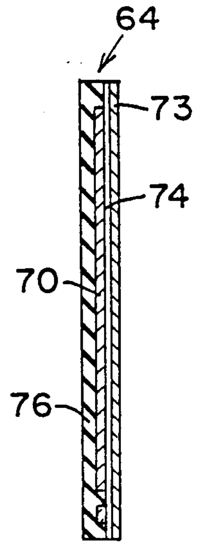


FIG. 4C

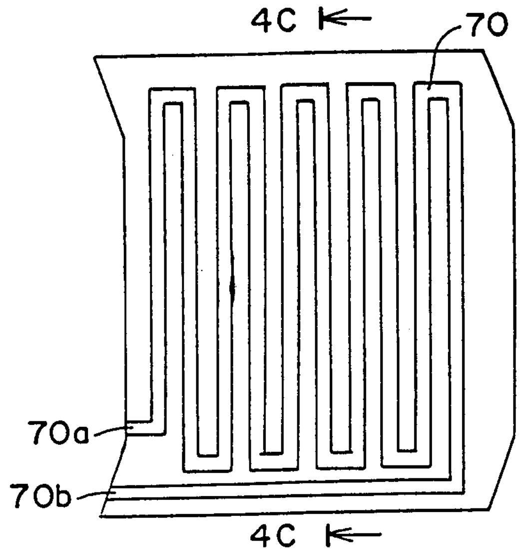


FIG. 4B

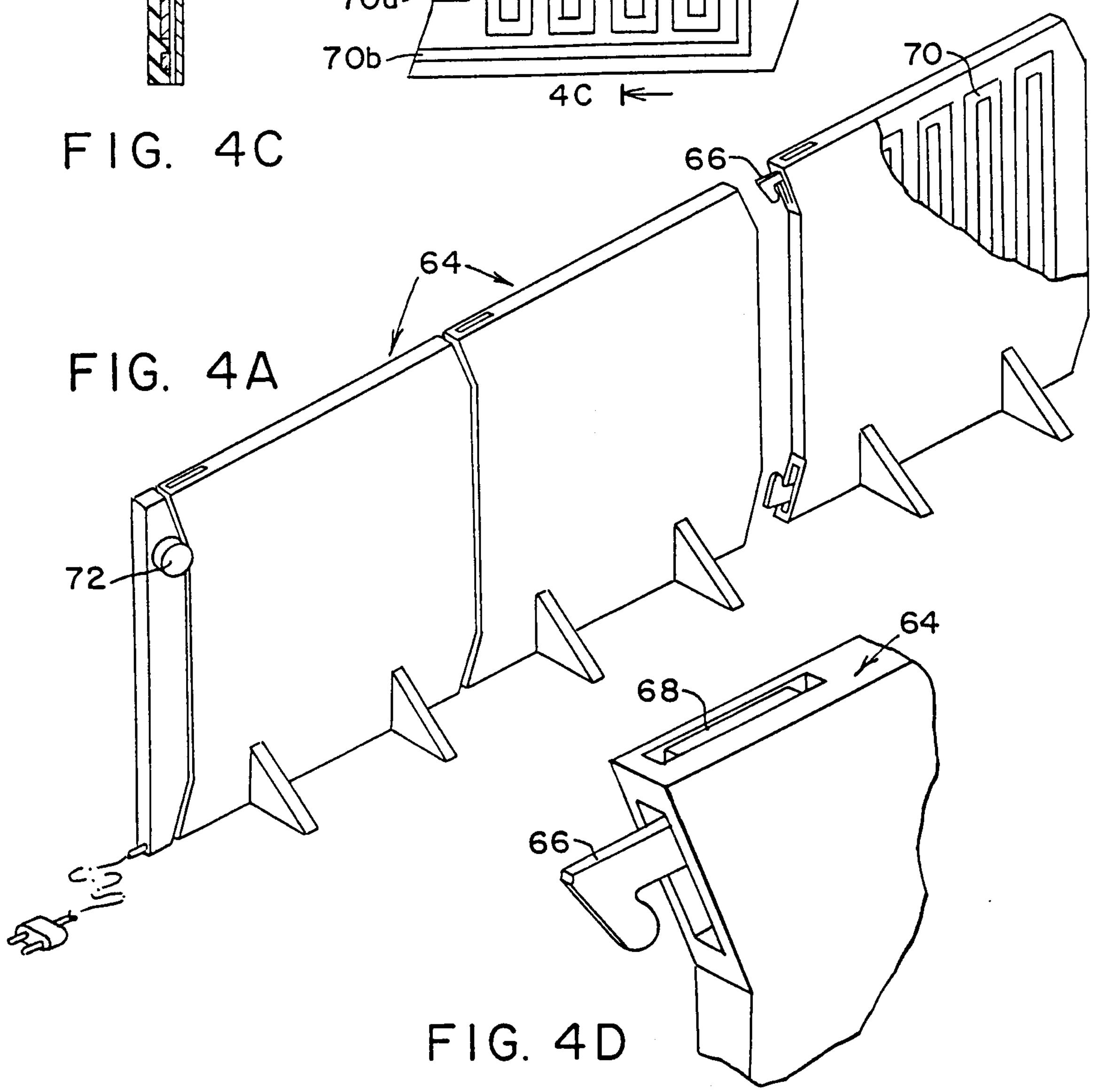


FIG. 4A

FIG. 4D

FIG. 5A

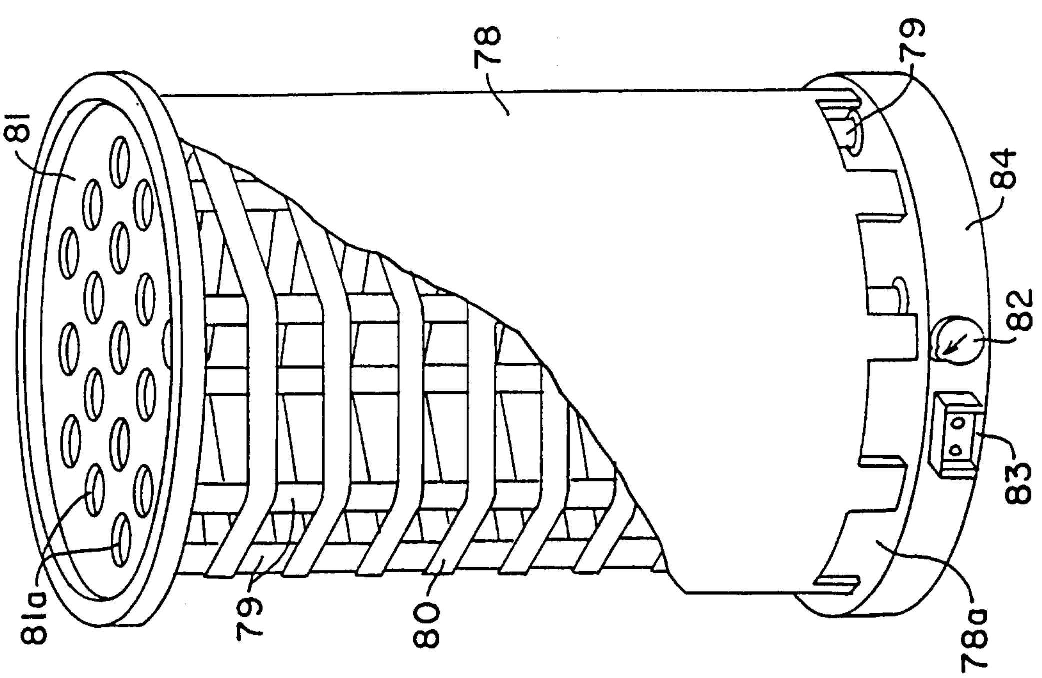


FIG. 5B

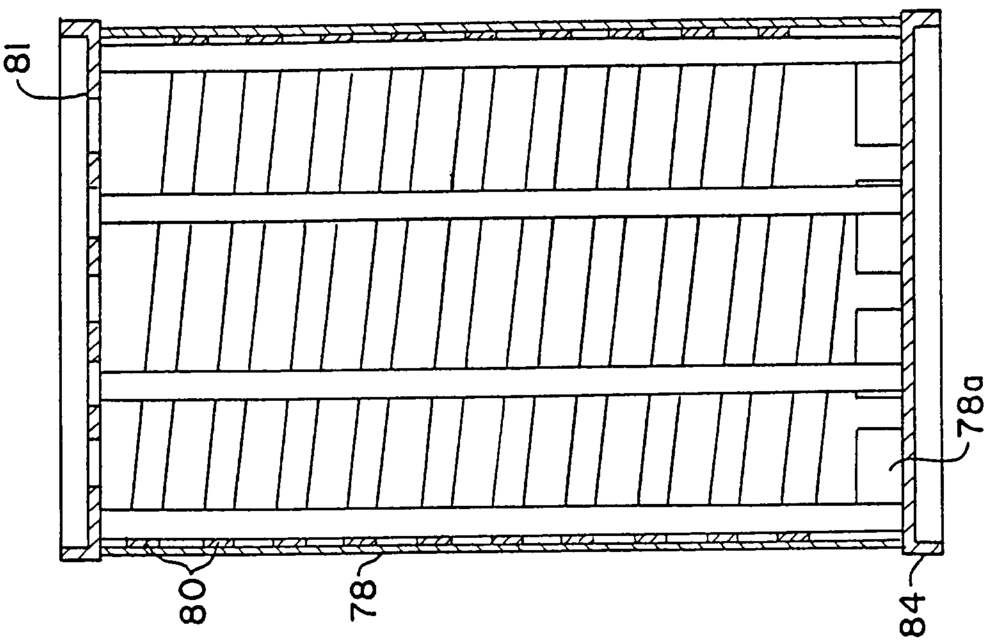


FIG. 6A

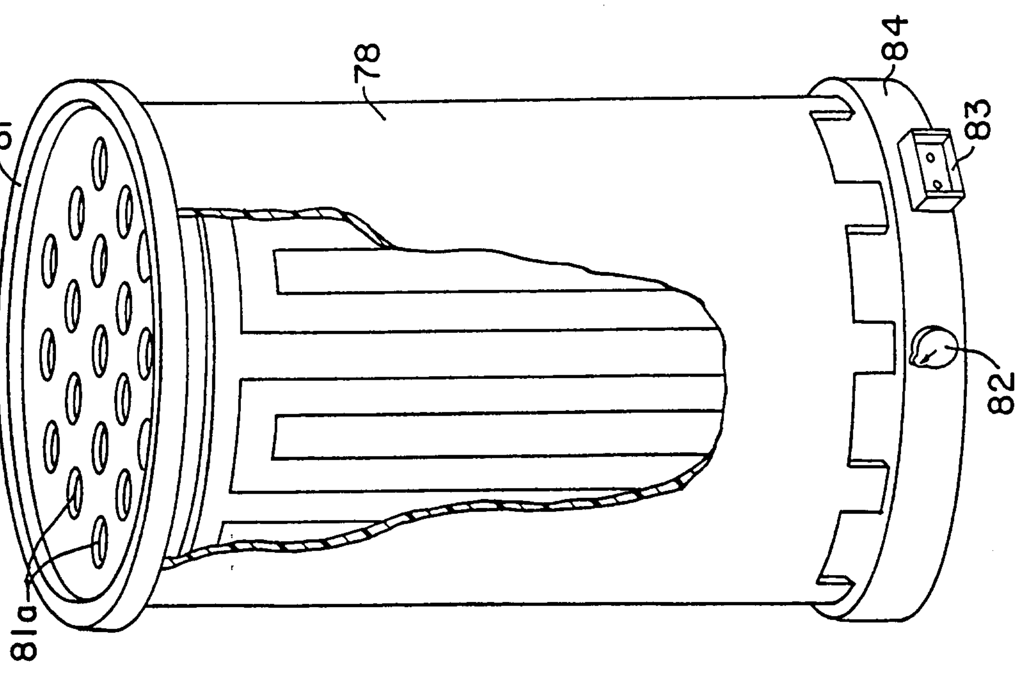


FIG. 6B

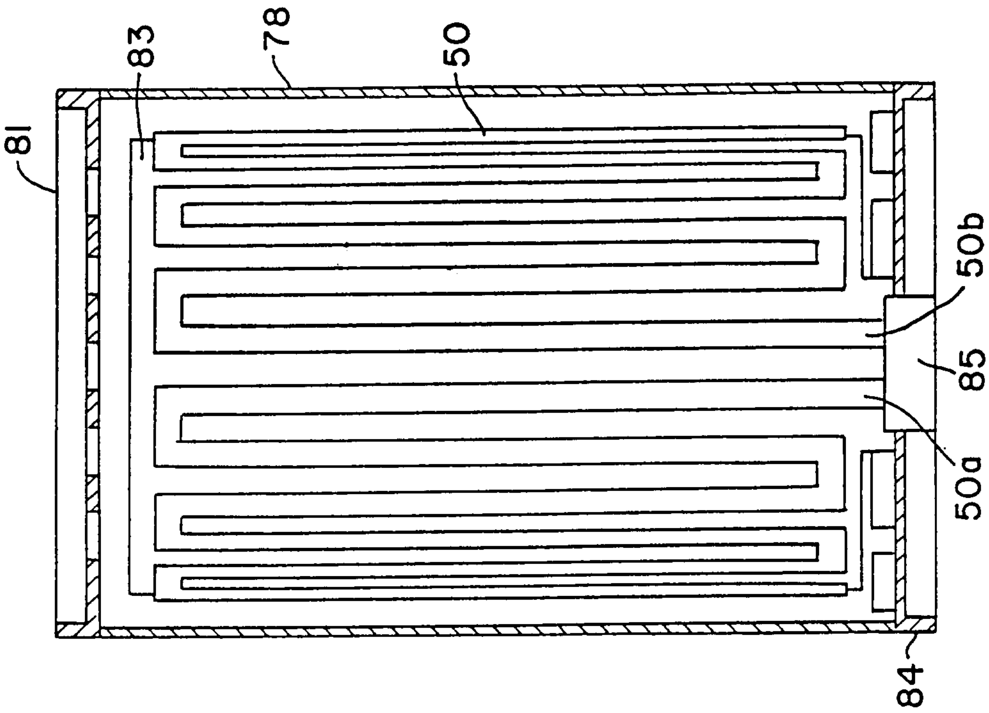


FIG. 7B

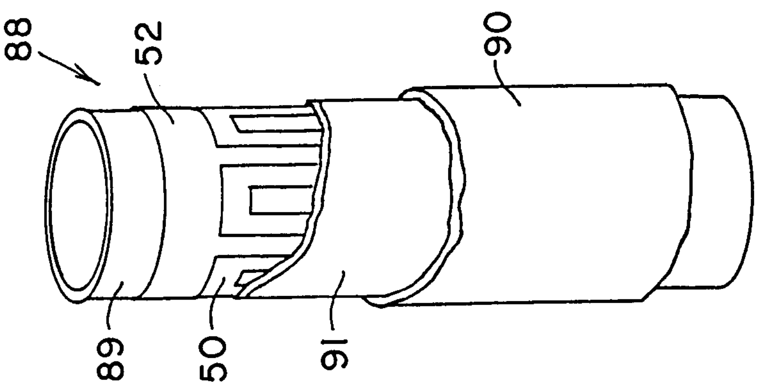
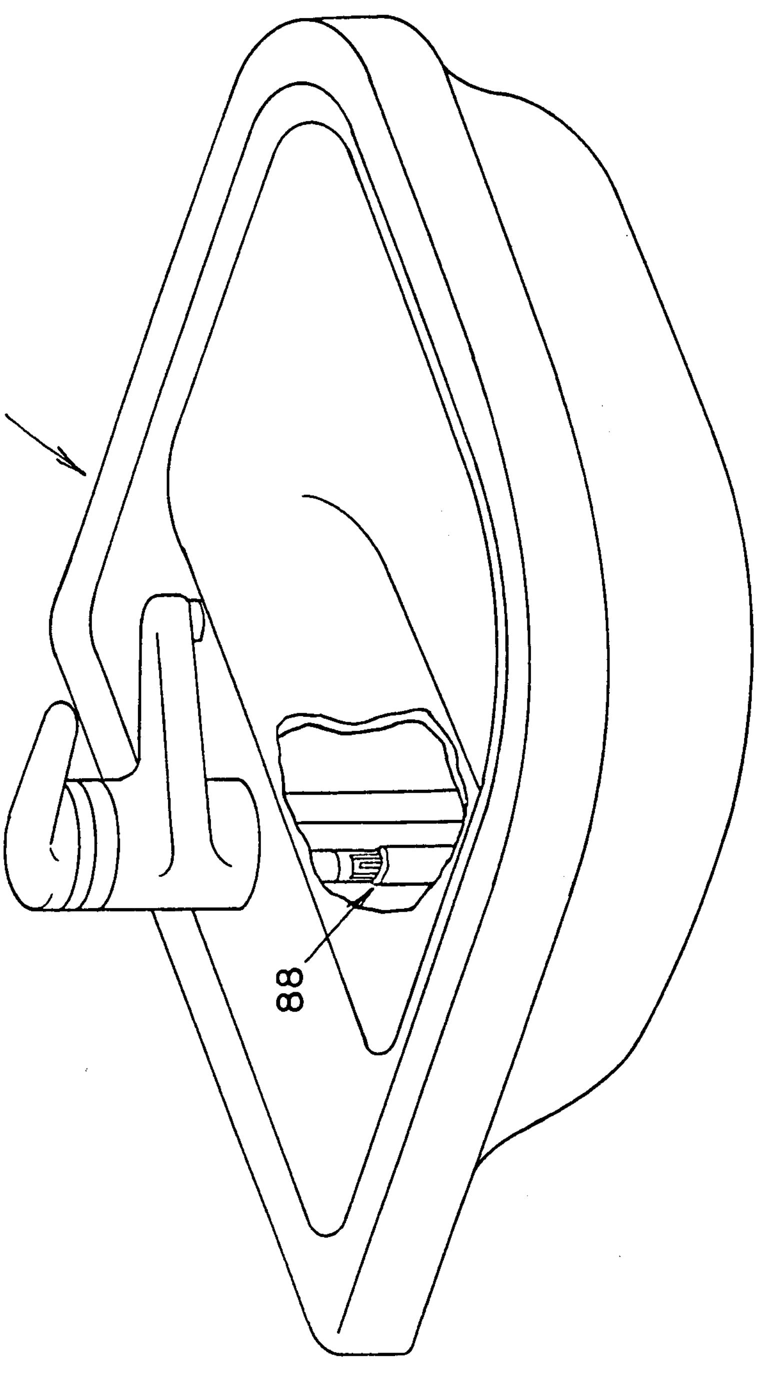


FIG. 7A



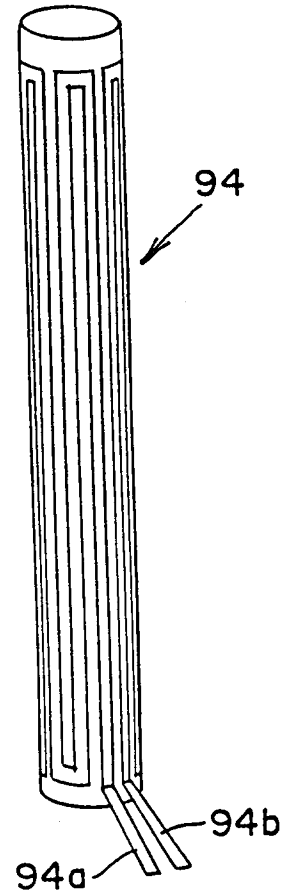


FIG. 8B

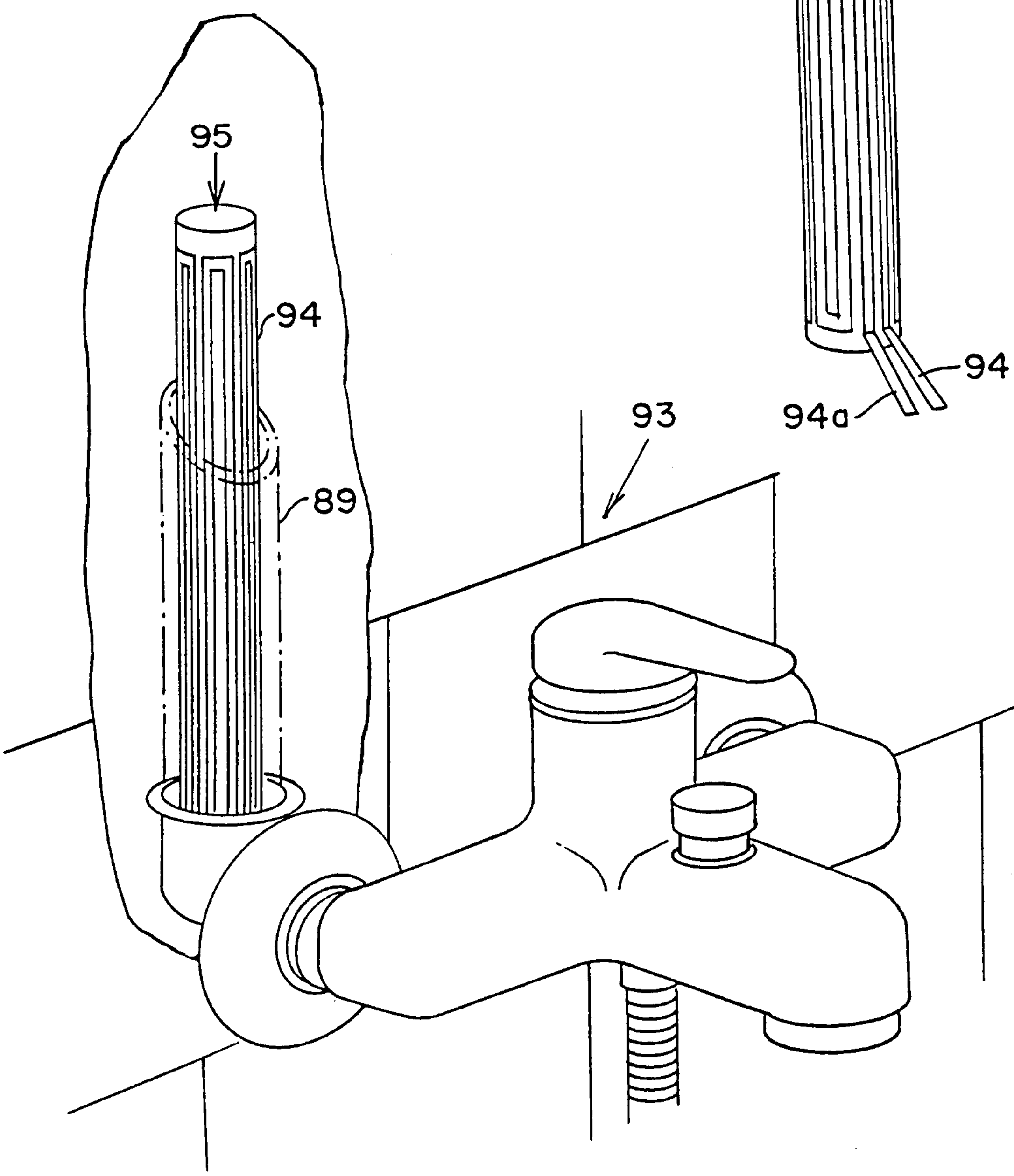


FIG. 8A

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 96 10 7892

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
A	PATENT ABSTRACTS OF JAPAN vol. 008, no. 098 (C-221), 9 May 1984 & JP-A-59 013051 (MATSUSHITA DENKI SANGYO KK), 23 January 1984, * abstract *	1	H05B3/10 H05B3/36
A	EP-A-0 295 351 (BEAUFEREY JEAN FRANCOIS) 21 December 1988		
A	EP-A-0 177 669 (ALLIED CORP) 16 April 1986		
A	PLASTVERARBEITER, vol. 34, no. 9, 1983, SPEYER/RHEIN; DE, pages 827-828, XP002016682 "MIT POLYIMID ISOLIERTE FOLIEN-HEIZELMENTE"		

TECHNICAL FIELDS SEARCHED (Int.Cl.6)
H05B
C22C

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	23 October 1996	De Smet, F

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