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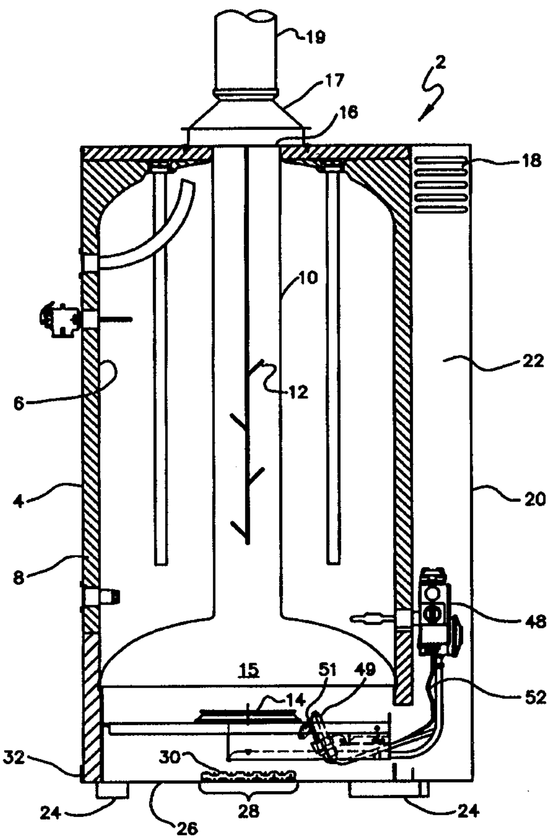
(54) Title: AIR INLETS FOR GAS WATER HEATERS

(57) Abstract

A water heater including a water container; a combustion chamber located adjacent the container, the combustion chamber having a floor portion with an opening; a conduit extending upwardly from and being substantially sealed to the opening; a burner located inside the combustion chamber; and a flame trap positioned across the conduit, the flame trap permitting ingress of air and/or extraneous gases into the combustion chamber and prevent egress of flames from the structure.



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Air Inlets for Gas Water Heaters

Field of the invention

The present invention relates to air inlets gas fired water heaters, particularly to improvements to gas fired water heaters adapted to render them safer for use. The present invention also relates to ignition inhibiting water heaters

Background of the invention

The most commonly used gas-fired water heater is the storage type, generally including an assembly of a water tank, a gas burner to provide heat to the tank, a pilot burner to initiate the main burner on demand, an air inlet adjacent the burner near the base of the jacket, an exhaust flue and a jacket to cover these components. Another type of gas-fired water heater is the instantaneous type which has a water flow path through a heat exchanger heated, again, by a main burner initiated from a pilot burner flame. For convenience, the following description is in terms of storage type water heaters but the invention is not limited to this type. Thus, reference to "water container," "water containment and flow means," "means for storing or containing water" and similar such terms includes water tanks, reservoirs, bladders, bags and the like in gas-fired water heaters of the storage type and water flow paths such as pipes, tubes, conduits, heat exchangers and the like in gas-fired water heaters of the instantaneous type.

A particular difficulty with many locations for water heaters is that the locations are also used for storage of other equipment such as lawn mowers, trimmers, snow blowers and the like. It is common for such machinery to be refuelled in such locations.

There have been a number of reported instances of spilled gasoline and associated extraneous fumes being accidentally ignited. There are many available ignition sources, such as refrigerators, running engines, electric motors, electric light switches and the like.

However, gas water heaters have sometimes been suspected because they often have a pilot flame.

Vapours from spilled or escaping flammable liquid or gaseous substances in a space in which an ignition source is present provides for ignition potential. The expression "fumes," "extraneous gases" or "extraneous fumes" is sometimes hereinafter used to encompass gases, vapours or fumes generated by a wide variety of liquid volatile or semi-volatile substances such as gasoline, kerosene, turpentine, alcohol, insect repellent, weed killer, solvents and the like as well as non-liquid substances such as propane, methane, butane and the like. Many inter-related factors influence whether a particular fuel spillage leads to ignition. These factors include, among other things, the quantity, nature and physical properties of the particular type of spilled liquid fuel. Also influential is whether air currents in the room, either natural or artificially created, are sufficient to accelerate the spread of fumes, both laterally and in height, from the spillage point to an ignition point yet not so strong as to ventilate such fumes harmlessly, that is, such that air to fuel ratio ranges are capable of enabling ignition are not reached given all the surrounding circumstances.

One surrounding circumstance is the relative density of the fumes. When a spilled liquid fuel spreads on a floor, normal evaporation occurs and fumes from the liquid form a mixture with the surrounding air that may, at some time and at some locations, be within the range that will ignite. For example, the range for common gasoline vapour is between about 3% and 8% gasoline with air, for butane between about 1% and 10%. Such mixtures form and spread by a combination of processes including natural diffusion, forced convection due to air current drafts and by gravitationally affected upward displacement of molecules of one less dense gas or vapour by those of another more dense. Most common fuels stored in households are, as used, either gases with densities relatively close to that of air (e.g., propane and butane) or liquids which form fumes having a density close to that of air, (e.g. gasoline, which may contain butane and pentane among other components is very typical of such a liquid fuel).

In reconstructions of accidental ignition situations, and when gas water heaters are sometimes suspected and which involved spilled fuels typically used around households, it is reported that the spillage is sometimes at floor level and it is reasoned that it spreads outwardly from the spill at first close to floor level. Without appreciable forced mixing, the air/fuel mixture would tend to be at its most flammable levels close to floor level for a longer period before it would slowly diffuse towards the ceiling of the room space. The principal reason for this observation is that the density of the fumes typically involved is not greatly dissimilar to that of air. Combined with the tendency of ignitable concentrations of the fumes being at or near floor level is the fact that many gas appliances often have their source of ignition at or near that level.

The invention aims to substantially lower the probability of ignition in typical liquid fuel spillage circumstances. The invention also aims to substantially raise the probability of successful confinement of ignition of spilled flammable substances from typical spillage situations to the inside of the combustion chamber.

Summary of the invention

The present invention provides a water heater including: a water container; a combustion chamber located adjacent said container; a burner located inside said combustion chamber; at least one inlet positioned at an opening in said combustion chamber, said inlet permitting ingress of admit air and extraneous fume species into said combustion chamber and prevent egress of flames from said water heater

The air inlet is or includes a flame arrestor positioned at said opening in said combustion chamber to block ingress of admit air and extraneous fume species when the temperature in said combustion chamber adjacent said flame trap exceeds a predetermined temperature.

A blocking plate can be positioned within said combustion chamber and spaced above said opening.

The water heater can further include a heat sensor positioned within said combustion chamber and adjacent said flame trap and capable of shutting off fuel to said burner when said the temperature in said combustion chamber adjacent said flame trap exceeds said predetermined temperature.

The flame arrestor can also include a blocking plate supported by at least one leg formed from a temperature sensitive fusible material adapted to melt when said predetermined temperature is exceeded, thereby permitting said blocking plate to move toward and over said opening.

Preferably the temperature sensitive fusible material is a thermoplastic, and more specifically low density polyethylene having a melting temperature of about 100 °C to 200 °C.

The air inlet can be formed from a ceramic material having a thickness of about 12 mm or more and having openings of about 36.5 to 73 openings per square centimetre and wherein said openings include about 64% to 80% of the surfaces of said air inlet.

Preferably the openings are square and the ceramic material is extruded.

The air inlet can alternatively be formed from two layers of woven metal mesh arranged to be in contact with each other over substantially all of their respective contacting surfaces and being formed in a non-planar orientation to facilitate substantially even layer contact during expansion and contraction.

The layers of woven metal mesh can be dome-shaped if desired.

The water heater can include a flame arrestor positioned at said opening and adapted to direct a flame extinguishing substance toward a surface of said flame trap in said combustion chamber.

The flame arrestor can include a container having at least one nozzle and contains said flame extinguishing substance. The at least one nozzle can contains a plug made from a fusible material, having material has a melting temperature of about 150 °C to 300°C, that maintains said flame extinguishing substance inside said container unless the temperature in said combustion chamber adjacent said flame trap exceeds a predetermined temperature.

The flame extinguishing substance is selected from the group consisting of sodium bicarbonate and fire blanketing foams mixed with a propellant.

Preferably fire blanketing foams are mixed with a propellant are activated when the temperature adjacent said flame trap is 300 °C -500°C.

The container preferably has two nozzles extending from opposite end portions thereof, each nozzle being directed to opposing edge portions of said at least one inlet.

The at least one inlet can have a plurality of ports, each port having a limiting dimension less than a minimum quenching distance applicable to said extraneous fume species, thereby confining ignition and combustion of said extraneous fume species within said combustion chamber.

Preferably said at least one inlet is constructed such that peak natural frequencies of vibration of said at least one inlet, in combination with said combustion chamber structure, are different from peak frequencies generated by an extraneous fume combustion process on the inlet within the combustion chamber.

During combustion of said extraneous fume species over a prolonged period, a surface of said at least one inlet located outside of said combustion chamber remains sufficiently cool so as to prevent heating the extraneous fume species and air with it before it passes through said at least one inlet to a temperature above an ignition temperature of said extraneous fumes species and air.

The ports of said at least one inlet can be spaced apart on said at least one inlet by a distance which enables the temperature of mixtures of extraneous fume species with air adjacent to the surface of the walls of said ports to remain below the ignition temperature of said mixtures.

The ports of said at lest one inlet can be spaced apart from each other so that a closest point between boundaries of adjacent ports is a distance of no less than about 1.1 mm. The shortest distance between adjacent ports can be substantially the same.

Preferably at least one of said ports of said at least one inlet is adjacent a pilot burner associated with said combustion chamber to ignite said extraneous fume species as the fume species passes into said combustion chamber and before there is a potentially explosive accumulation of fumes in said combustion chamber.

The ports of said at least one inlet include slots and wherein said limiting dimension is the width of said slots.

Preferably said ports include slots which have an L/W ratio of between about 2 to about 15, wherein L is the length of said slots and W is the width of said slots

Preferably said ports of said at least one inlet are arranged in rows. It is preferable that a first port in every alternate row has its location offset with respect to a port of an adjacent row.

Alternatively the ports of said at least one inlet are slots arranged in rows, with at least one peripheral row of said at least one inlet including slots arranged parallel to each other and which have their longitudinal axes at an angle of about 90° the orientation of each of the longitudinal axes of slots in other rows.

Preferably at least one of said rows of ports of said at least one inlet is a peripheral row having a larger interport spacing than others of said rows.

Preferably the at least one inlet is constructed from a sheet material with ports that are elongated and spaced apart, said ports being arranged so that there are at least two regions of ports, an inner region which is included of a group of said ports, and an outer region which is comprised of the remainder of said ports, said outer region having an interport spacing between adjacent ports which is greater than the interport spacing of said ports in said inner region.

Preferably said ports include slots about 0.5 mm in width and if said ports include circular holes, the circular holes are 0.5 mm in diameter.

The water heater can emit an audible signal when said extraneous fumes pass through said at least one inlet and are burning inside said combustion chamber. The audible signal can be produced by the action of the burning of said extraneous fumes near to said at least one inlet, inside of said combustion chamber.

The ports of said alt least one inlet can be formed in a metal plate by photochemical machining.

The water heater combustion chamber can be formed with a surrounding skirt having an end cap joined at one end thereof, with another end of said surrounding skirt being a surface of said combustion chamber. An enclosure can be provided which encloses said container and which also forms both of said surrounding skirt and said end cap. Alternatively said surrounding skirt and said end cap are formed separate from the enclosure which encloses said container and said combustion chamber.

The water heater will include an outlet spaced apart from said at least one inlet allowing products of combustion to exit said combustion chamber.

Thew at least one inlet preferably includes a plate having a plurality of ports. The plate is preferably made of metal.

The at least one inlet can have a heat dissipation region at its periphery. The heat dissipation region can include a metal to metal overlap portion between a peripheral edge of a plate forming said at least one inlet and a peripheral edge of an opening in the combustion chamber.

The plate can include a skirt; while said combustion chamber has an opening which sealingly receives said plate, said opening having a surrounding skirt; and said skirts are sized so that inwardly facing surfaces of said skirt of said plate engage outwardly facing surfaces of said surrounding skirt.

The plate can alternatively include a skirt; while said combustion chamber has an opening which sealingly receives said plate, said opening having a surrounding skirt; and said skirts are sized so that outwardly facing surfaces of said skirt of said plate engage inwardly facing surfaces of said surrounding skirt.

If desired, the heat dissipation region can include an additional surface area in the form of at least one fin extending from the inlet.

The heat dissipation region can include an increased interport spacing adjacent its periphery.

Preferably the plate is a ferrous based material about 0.5 mm thick.

The interport spacing of the ports of said at least one inlet adjacent a peripheral portion of the ports in said plate is in the range of about 2 mm to 4 mm and the interport spacing of remaining ports is in the range of about 1 mm to 1.5 mm.

The plate can be a ceramic plate having a thickness in the range about 9 mm to 12 mm and ports in the range of about 1.1 mm to 1.3 mm diameter.

Flame lift promoters can be provided at edge portions of the ports. The flame lift promoters can be sharp edges at upstream extremities of the ports. Alternatively the flame lift promoters can be undercut cross-sectional profiles wherein the intersection of the ports with at least an inside surface of the plate is an angle of less than 90°. Alternatively the flame lift promoters are interport spacings of at least about 3 mm.

The ports of said at least one inlet can be constructed so that in cross-section, said ports have substantially parallel sides.

The ports can be constructed so that in cross-section said ports have sides which converge. The ports can converge in an upstream direction, and may terminate with substantially parallel sides.

Preferably the ports are slot shaped and not more than about 0.6 mm wide and spaced apart from each other at least about 1.1 mm.

The ports can include peripheral extrusions extending inwardly into the combustion chamber to act as flame lift promoters.

The ports can be formed in a plate in a pattern, said pattern acting as a flame lift promoter.

The ports can be arranged in a pattern comprising solely apertures in the form of an aligned and spaced array of slots.

If desired a first pattern of slots can be located in a centre portion of said inlet and a second pattern of slots at a peripheral portion, with said second pattern comprising a larger interport distance than said first pattern.

The ports can be arranged in a radial pattern or alternatively in a circumferential pattern.

The water heater can include a cooling mechanism in cooperating with said at least one inlet. The cooling mechanism can include a water applicator for said inlet. Preferably the water applicator directs water to a face of the inlet external to the combustion chamber.

The at least one inlet is preferably constructed such that the peak resonant frequencies of said inlet are different from peak resonant frequencies of a combination of said combustion chamber and an exhaust gas flow path when extraneous fumes are being combusted at the inlet.

the heat dissipation region includes an additional surface area in the form of at least one fin extending from the combustion chamber.

If desired the ports can be formed with cross-sections which, within a single port, both converge and diverge.

The said at least one inlet can be formed from a metal plate which is deformed from a flat form to include stiffening members extending across at least a portion containing said plurality of ports. Preferably said stiffening members intersect with ports. Alternatively stiffening members are provided extending across unported portions which subdivide said plurality of ports into an integral number of sub-portions

The invention also provides a control valve for supplying fuel to a water heater containing a main burner and a pilot burner including: a fuel inlet adapted to connect to a supply of fuel; at least one fuel outlet adapted to connect to the main burner; a conduit for fuel flow between the inlet and outlet; a closure associated with the conduit to control flow of fuel from the inlet to the outlet; a circuit associated with the valve and including a thermally actuated device associated with the closure, said device, when heated by the pilot burner providing a signal to the closure to open or close the closure; and a combustion sensitive fuse connected to the circuit and positioned to be exposed to extraneous sources of flame and/or heat external to and adjacent the control valve.

The control valve can further include an externally accessible socket in the circuit into which the fuse is removably insertable. Alternatively the socket is adapted to receive the fuse independently separate from the thermally actuated device. Preferably the socket is accessible from an underside of the valve, while the fuse is positioned at an underside of the valve.

The closure of the control valve includes a member located in a portion of the conduit and is normally resiliently biased in a closed position.

Preferably the circuit further includes a solenoid associated with the closure, the solenoid being capable of receiving an electrical signal from the thermally actuated device and opening said closure in response.

Preferably the fuse is temperature sensitive and the circuit further includes an over temperature energy cut out switch associated with a temperature sensitive thermostat probe, said energy cut out switch being capable of interrupting gas flow through said control valve to the main burner and the pilot burner.

Preferably the thermally actuated device is a thermocouple.

The circuit can further include a manual switch connected to the thermally actuated device and having on, off and pilot positions, said pilot position causing the closure to open until such time as the thermally actuated device is capable of providing a signal to open the closure.

The closure can include a member located in a portion of the conduit and which is normally resiliently biased in a closed position.

Preferably said circuit associated with the valve includes a solenoid associated with the closure, the solenoid being capable of receiving output from the thermocouple and maintaining open said closure in response to output indicative of a flame at said pilot burner.

The control valve can include an energy cut out switch associated with a temperature sensitive thermostat, the energy cut out switch being associated with a temperature sensitive thermostat probe, said energy cut out switch being capable of interrupting gas flow through said control valve to the main burner and the pilot burner.

Preferably the control valve includes a combustion sensitive fuse connected to the control valve circuit and positioned to be exposed to extraneous sources of flame and/or heat external to and adjacent the control valve.

The invention further provides a water heater as described above having a control valve as also described above.

Said at least one inlet can be positioned below and adjacent said pilot burner and with said water heater further including a venturi extending into said combustion chamber to supply combustion air to said main burner.

Preferably the water heater further includes a lint trap positioned exteriorly of said at least one inlet and across said opening.

The invention provides a gas water heater including a water container adapted to be heated by a gas burner. An enclosure surrounds the burner and the water container. The water heater has at least one opening adapted to allow air for combustion or extraneous fumes to enter the enclosure without igniting flammable extraneous fumes outside of the enclosure.

In another aspect the invention encompasses a water heater including a water container and a combustion chamber located adjacent the container. The combustion chamber has a floor portion with an opening. An upwardly extending conduit is substantially air tightly sealed to the edge of the opening. A burner is located inside the combustion chamber and a flame trap is positioned across the conduit, the flame trap permitting ingress of air and extraneous gases, if present, into the combustion chamber and prevent egress of flames from the structure. A flame arrestor is positioned at the opening and is actuated when the temperature in the combustion chamber adjacent the flame trap exceeds a predetermined temperature.

In other embodiments, the water heater includes specially constructed flame traps. One is a ceramic material having a thickness of about 12 mm or more and having openings of about 36.6 to 73 openings per square centimetre (openings/$cm^{2)}$ and wherein the openings are about 64% to 80% of the surface of the flame trap. Another has two layers of woven mesh arranged to be in contact with each other over substantially all of their respective contacting surfaces and in formed in a non-planar orientation to facilitate substantially even layer contact during expansion and contraction.

The invention also provides a water heater including a water container, adjacent which is, a combustion chamber having one or more inlets to admit air and any extraneous flammable fume species which may have escaped in the vicinity of the water heater into its combustion chamber. In one particularly preferred form, an inlet comprises a metal plate of thickness about 0.4 to 0.6 millimetres and through which pass many ports, each of which has a quenching distance as will be defined within 10% of the thickness of the plate. Because of choice of the quenching distance appropriate to several types of inlet plate the water heater is able to confine ignition and combustion of extraneous fume species within the combustion chamber; despite the presence of a burner(s) in the combustion chamber to combust fuel to heat the water in container.

In an alternative form the inlet can take the form of a ceramic plate having a thickness in the range about 9 mm to 12 mm through which passes many ports each having a quenching distance of 1.1 to 1.3mm, which can likewise confine ignition and combustion of extraneous fumes to the combustion chamber.

Brief description of the drawings

Selected embodiments of the invention will now be described, by way of example only, by reference to the accompanying drawings in which:

Figure 1 is a schematic partial cross-sectional view of a gas water heater embodying aspects of the invention.

Figure 2 is a schematic partial cross-sectional view of a gas water heater similar to Figure 1, with additional safety features.

Figure 3 is a cross-sectional view of the water heater of Figure 2 taken through the line III-III.

Figure 3A is a cross-sectional view of the base region of the water heater of Figure 1.

Figure 4 is a schematic partial cross-sectional view of a gas water heater similar to that of Figure 2.

Figure 5 is a cross-sectional view of the water heater of Figure 4 taken through line V-V.

Figure 6 is a schematic partial cross-sectional view of a gas water heater with a safety feature in accordance with aspects of the invention.

Figure 7 is a schematic partial cross-sectional view of a gas water heater of another embodiment of the invention.

Figure 8 is a schematic partial cross-sectional view of a gas water heater of yet another embodiment of the invention.

Figure 9 is a schematic partial cross-sectional view of still another embodiment of the invention.

Figure 10 is a cross-sectional view of the water heater of Figure 9 taken through the line X-X.

Figure 11 is an upright elevational view taken from the rear of a gas valve according to the aspects of invention.

Figure 12 is an upright elevational showing the left side of the gas valve shown in Figure 11.

Figure 13 is an upright perspective view of the valve of Figure 11 and Figure 12.

Figure 14 is a schematic partial cross-sectional view of a water heater with the gas valve as shown in Figure 11 to

Figure 13.

Figure 15 is an electrical circuit embodied in the gas valve shown in Figure 11 to Figure 13.

Figure 16 is a cross-sectional view of the gas valve shown in Figure 11 to Figure 13.

Figure 17 is a schematic elevation, taken partly in section, of a portion of the bottom end of a water heater of the type shown in Figure 14 including further means for dampening combustion.

Figure 18 show the first extinguishing means of Figure 17 following actuation in the event of combustion on the flame trap illustrated.

Figure 19 is a further embodiment of a means for extinguishing fire similar to that shown in Figure 17.

Figure 20 shows the first extinguishing means of Figure 19 following actuation in the event of combustion on the flame trap.

Figure 21 is a detailed schematic elevation, taken partly in section, of a bottom end portion of a water heater of the type shown in Figure 14 substituting a different type of flame trap.

Figure 22 is a detailed schematic elevation, taken partly in section, including a heat actuated chemical fire extinguishing means operative with the flame trap.

Figure 23 is a detailed schematic elevation, taken in section and similar to Figure 22, including an embodiment of flame trap material arranged in two contacting layers.

Figure 24 is a schematic partial cross-sectional view of a gas-fuelled water heater having a single large air inlet according to the invention..

Figure 25 is a cross-sectional view of a water heater of Figure 24 taken through the line II-II in Figure 24.

Figure 26 is a schematic plan view depicting a portion of the base of a combustion chamber of a water heater including an air inlet.

Figure 27 is a schematic plan view of an air inlet according to the invention of a type which could be included in the Figure 26. arrangement.

Figure 28 is a schematic plan view depicting a portion of the base of a combustion chamber of a water heater substituting an air inlet of different shape and hole pattern.

Figure 29 is a schematic plan view of an air inlet according to the invention of a type which could be included in the Figure 28 arrangement.

Figure 30 is a plan view of an inlet plate showing a hole pattern applicable to an air inlet of the type shown in Figure 29.

Figure 31 is a plan view of an inlet plate showing a further hole pattern applicable to an air inlet of the type shown in Figure 29.

Figure 32 is a plan view of ports on an inlet plate according to the invention of the embodiment shown in Figure 26.

Figure 33 to Figure 41 are each a further plan view of additional alternative patterns of ports on an inlet plate according to the invention of the embodiment shown in Figure 26.

Figure 42 illustrates a plan view of a single port as shown in Figure 33 to Figure 41.

Figure 43 and Figure 44 are each a detail view of the spacing of part of the arrangement of ports on the inlet plate of Figure 33 and Figure 34 respectively.

Figure 45 is a cross-section of an embodiment of a port in an air inlet according to the invention.

Figure 46 is a schematic cross-section of a water heater having a ported inlet connected to a remotely positioned clean-in-place lint filter, according to the invention.

Figure 47 and Figure 48 illustrate alternative forms of attachments according to the invention of two shapes of inlet to a wall of a combustion chamber of a water heater.

Figure 49 a plan view of one version of an air inlet plate and its attachment to a combustion chamber.

Figure 50 is a side view of the air inlet plate of Figure 49.

Figure 51 is a partial cross of the air inlet plate of Figure 49 at the lines LI-LI.

Figure 52 is an attachment detail cross section of the air inlet plate of Figure 49 and its attachment to a combustion chamber.

Figure 53 is a perspective view of a version of an embodiment of an air inlet plate.

Figure 54 is a perspective view of a version of another embodiment of an air inlet plate.

Figure 55 is a cross-sectional view of the version of air inlet plate shown in Figure 54.

Figure 33 to Figure 35 are schematic cross-section views of three embodiments of water heaters showing relative positions of air inlet plates to other components including the combustion chamber walls.

Figure 59 is a detail of an inlet in cross section.

Figure 60 is a perspective view of one port in the inlet as shown in Fig 36.

Figure 61 is a perspective view of one port of an inlet with an adjacent bead of solder.

Figure 62 is a cross section of an air inlet plate coated with an intumescent coating.

Figure 63 is a cross section identical with Figure 62 with the addition of combustion of extraneous fumes on one surface.

Figure 64 is a cross section showing the aftermath of the combustion shown in Figure 63.

Figure 65 is a perspective schematic view of an inlet plate with a sliding mechanism to occlude ports in an inlet plate.

Figure 66 is a cross section along the line A-A through the arrangement of Figure 65 with ports aligned.

Figure 67 is the same cross section of Figure 65 when the ports are occluded.

Figure 68 is a perspective schematic view of an inlet plate with a rotary mechanism to occlude ports in an inlet plate.

Figure 69 is a cross section along the line B-B through the arrangement of Figure 68 with ports aligned.

Figure 70 is the same cross section of Figure 68 when the ports are occluded.

Figure 71 is a partial cross section of the lower portion of a water heater with a spray nozzle at an air inlet according to the invention and including an audible alarm.

Figure 72 to Figure 75 are partial cross-sections of ports in inlet plates.

Figure 76 is a plan view of an air inlet plate stiffened by cross-broken diagonal folds.

Figure 77 is front elevation of the air inlet plate of Figure 76.

Figure 78 is a side elevation of the air inlet plate of Figure 76.

Figure 79 is a plan view of an air inlet plate stiffened and divided into separate perforated portions with stiffening formations between those separate portions.

Figure 80 is a front elevation of the air inlet plate of Figure 79.

Figure 81 is a side elevation of the air inlet plate of Figure 79.

Figure 82 is a schematic elevation of a bottom half of a water heater with an inlet plate mounted in the base of the combustion chamber, the base being dampened by contact with resilient damping materials sandwiched between the external surface of the combustion chamber and a pan forming the base of the water heater's protective jacket.

Figure 83 is a plan view of an air inlet in the base of a water heater enclosure.

Figure 84 is a side view of the base of Figure 83.

Figure 85 is a detail cross sectional view of a portion of Figure 84.

Detailed description of the embodiments

It will be understood that the invention disclosed and defined herein extends to all alternative combinations of two or more of the individual features mentioned or evident from the text or drawings. All of these different combinations constitute various alternative aspects of the invention.

It will be appreciated that the following description is intended to refer to the specific embodiments of the invention selected for illustration in the drawings and is not intended to define or limit the invention other than in the appended claims.

Figure 1 illustrates a storage type gas water heater 2 including jacket 4 which surrounds a water tank 6, a main burner 14 in a combustion chamber 15. Water tank 6 is preferably of mains pressure capability and capable of holding heated water. Water tank 6 is preferably insulated by foam insulation 8. Alternative insulation may include fibreglass or other types of fibrous insulation and the like.

Located underneath water tank 6 is main burner 14 which preferably uses natural gas or other gases such as LPG, for example. Main burner 14 combusts a gas and air mixture and the hot products of combustion resulting rise up through flue 10. Flue 10, in this instance, contains a series of baffles 12 to better transfer heat generated by main burner 14. Near pilot burner 49 is a sheath 52, preferably made of copper, containing wires from a flame detecting thermocouple 51 which is a known safety measure to ensure that in the absence of a flame at pilot burner 49 the gas control valve 48 shuts off the gas supply.

The products of combustion pass upwardly and out the top of jacket 4 via flue outlet 16 after heat has been transferred from the products of combustion. Flue outlet 16 discharges conventionally into a draught diverter 17 which in turn connects to an exhaust duct 19 leading outdoors.

Close to the height of the top of jacket 4 and flue outlet 16 is an air inlet 18 through which air is drawn down duct 22 to main burner 14. Duct 22 is preferably constructed from sheet metal 20. In a non-illustrated alternative construction, a part or all of duct 22 may be inside the external cylindrical envelope of jacket 4.

Water heater 2 is preferably mounted on legs 24 to raise the base 26 off the floor. In base 26 is an aperture 28 which is closed, but not gas tightly, by a flame trap device 30 which operates on a flame quenching principle.

Flame trap 30 is preferably made from two substantially parallel sheets of mesh each about 0.010 inch diameter metal wire strands woven into mesh having about 30 to 40 strands per inch. Alternatively, inlet could be a woven metal mesh having transverse wires of thickness about 0.2 to 0.5 millimetres defining a plurality of ports, so that each port has a quenching distance equal to the greater of the side lengths of four-sided open areas between the woven wires and in a range of about 0.3 to 0.5 mm, being thereby able to confine ignition and combustion of said extraneous fume species within said combustion chamber. Mild steel or stainless steel wire are suitable.

Alternatively, a ported ceramic tile of the SCHWANK® type (registered trade mark) can be utilised although the recognised flame quenching ability of metallic woven or knitted mesh together with its robustness and ease of forming generally commends its use. A ported ceramic tile functions as a flame quenching trap as long as the porosity is suitable. If a ported ceramic tile is used, preferably it has a thickness in the range about 9 mm to 12 mm and having openings of about 36.5 to 73 openings per square centimetre. Preferably the openings include about 64% to 80% of the surfaces of the tile or aperture which the tile will cover. Preferably the tile is made of extruded ceramic material and can have openings which are square, or alternatively the openings can be slots having an length to width ratio (L/W) of between about 3 to about 20. Circular holes could also be used but preferably these will have a quenching distance which is a diameter of about 1.1 mm to 1.3mm.

A single layer of mesh or a porous ceramic tile may be susceptible to clogging by lint or other "blocking" materials such as dust or the like. Lint caught in the openings of a single mesh or a tile might act as a wick which may allow flame, which would not otherwise pass through the flame trap, to do so. In this situation the flame trap device would tend not to function as efficiently. To prevent this tendency, the flame trap is preferably constructed with either two layers of mesh or a layer of mesh and a tile. The mesh layers are most preferably in contact with one another. In this way the layer of mesh further from the source of fumes acts as a flame trap and the layer closer to the source of fumes acts as a lint trap.

Where base 26 meets jacket 4, mating surfaces 32 (made up from surfaces of base 26 and jacket 4) can be sealed thoroughly to prevent ingress of air or flammable gas or vapour. In Figure 1, mating surfaces 32 extend upwardly from base 26 around jacket 4. The cylindrical wall of jacket 4 (the majority of gas water heaters are cylindrical; however, a cubic or other shaped jacket 4 may be utilised) can be sealed gas tightly so no openings or breaks remain upon assembly and installation. In particular, gas, water, electrical, control or other connections, fittings or plumbing, wherever they pass through jacket 4 or base 26 to jacket 4 and all service entries or exits to jacket 4 or duct 22 need not be sealed airtight providing they are designed and constructed to have only minor surface to surface clearances or gaps, each of which is capable of acting as flame quenching traps. The structure of such service entries or exits are known in the art and not described herein. It is preferred, however, that the space around the burner be substantially air/gas tight except for means to supply combustion air.

Pilot flame establishment can be achieved by a piezoelectric igniter. A pilot flame observation window sealed to the jacket 4 can be provided. Alternatively, if the pilot 49 is to be lit by removing or opening an access, safety interlocks (not illustrated) are included to ensure complete closure against unprotected fume access during water heater operation.

During normal operation, water heater 2 operates in the same fashion as conventional water heaters except that most air for combustion enters at air inlet 18 and a small proportion through flame trap 30. However, if spilt fuel is in the vicinity of water heater 2 then some gas or vapour from the spilled fuel may be drawn through flame trap 30 before it builds up to a level to enter via air inlet 18. Flame trap 30 allows the combustible gas or vapour and air to enter but prevents flame escaping jacket 4 or duct 22. The spilled fuel is burned within combustion chamber 15 and exhausted either through flue 10 via outlet 16 and duct 19 or through duct 22 and inlet 18 (which in this case will act as an outlet). Because flame is restricted from passing outwardly through flame trap 30, spilled fuel external to water heater 2 will not be ignited.

If desired, the embodiment of illustrated could, as in Figure 3A, include a flame sensitive switch 50A located near to the flame trap 30 so that it can detect the existence of flame on the flame trap 30 and subsequently close valve 48 to shut down the gas supply to the burner 14 and pilot 49. If desired, the flame sensitive switch 50A may be substituted by a light detector or a heat detector, or a gas, fume or vapour detection switch, or an oxygen depletion sensor, so as to close off gas control valve 48 when either a flammable fume or a flame is detected.

Figure 2 and Figure 3 show an embodiment similar to that of Figure 1. Like parts use the same reference numbers as those of Figure 1. In Figure 2, there is adjacent gas control valve 48, a flame sensitive switch 50 which may be inserted in the same circuit as pilot flame detecting thermocouple 51 and located close thereto.

With reference to the cross section depicted in Figure 3, duct 22 contains gas control valve 48 and flame trap 30 is shown forming a bottom end of the duct 22. In fact, flame trap 30 can be arranged and installed spanning the bottom end of duct 22 and an adjacent portion of base 26. An advantage from such a positioning of flame trap 30, including that shown in Figure 2 and Figure 3, by comparison with the centre position of base 26 shown in Figure 1, is that it permits positioning of flame sensitive switch 50 (Figure 2) directly below gas control valve 48 which is also an ideal position to detect flame spillage from combustion chamber 15 which can occur if, for example, flue 16, or exhaust duct becomes blocked. Similarly, it is ideally positioned to detect flame spillage such as would occur due to air starvation if inlet 18 were inadvertently blocked.

As shown in Figure 2 and Figure 3, opening 28 and flame trap 30 (including a lint trap device as mentioned above) are at the base of duct 22 below gas control valve 48 and flame detecting switch 51 (see Figure 2). In this way, should fumes which enter through flame trap 30 be ignited, a flame forms and burns on the inside surface of the flame trap and flame detecting switch 50 actuates the gas control valve 48 to shut off the gas supply, thus removing it as a continuing source of ignition. After the pilot and main flames have been extinguished, any vapours of spilled fuel continuing to enter through flame trap 30 may continue to burn because of the initial ignition and resulting suction of air (which may also be due to how water in tank 6) and may continue to burn until there is insufficient flammable vapour remaining to be drawn in from the vicinity of water heater 2.

By providing an air inlet 18 at a high position above the base 26, for the more commonplace liquid fuels there will be a lesser likelihood of flammable gases and vapours being available for ignition by burner or pilot flame.

In the water heater 2 of Figure 4 and Figure 5, the path for air entry to main burner 14 is provided by a combined air inlet and duct 54 fabricated of metallic mesh 21. This arrangement provides that combustion air passes through the air inlet which is constructed from a flame quenching surface 21 and the height of duct 54 need not be as high as jacket 4 nor need it necessarily extend upwardly. As evident in Figure 5, it is preferably composed of separated layers 21a and 21b of metallic mesh. This two layer construction avoids a layer of lint, deposited externally, providing a possible combustion path through the mesh, as previously explained.

Lint deposition in the openings of the mesh may be a cause of gradual blockage. In due course such linting may cause starvation of combustion air. Therefore, an extended surface area (along the full height of water heater 2 as depicted for instance) of the combined air inlet and air duct 54 may be of advantage for prolonging the time taken for duct 54 to become occluded with lint and for providing an adequate path for free induction of the air normally required for combustion.

The gas valve 48 is illustrated in its preferred position outside of duct 54 as shown in Figure 5. The entry of the gas pipe and thermocouple sheath into duct 54 is effected so that if a hole is left it is small enough either to be totally sealed or to act as a flame quenching trap.

The preference for gas valve 48 outside duct 54 is that it provides one way of providing user access to the control knob and any buttons on gas control valve 48. It would be equally applicable in cases where duct 22 is made of imperforate sheet metal 20 as shown in Figure 1 and Figure 2.

For ease of construction one option is that the gas pipe and thermocouple sheath can enter water heater 2 via an opening in jacket 4, completely bypassing duct 54. This opening can then be sealed or if a gap is left, the gap is sized to act as a flame trap. However, whichever way the thermocouple sheath passes to enter the combustion chamber, if it includes a flame sensitive switch 50 or other equivalent sensor (eg item 50A from figure 3A), then it is greatly preferred that the flame sensitive switch 50 or other sensor is located in relation to the position of flame trap 30 so that the relative positions co-operate in the event that a flame from spilled fuel forms on the flame trap.

Illustrated in Figure 6 is another embodiment of the present invention, similar to that of Figure 1, with like parts like numbered. This embodiment includes an anchor 34 which anchors a nylon line 36 which is a heat sensitive frangible member. The nylon line 36 passes close to the upper surface of flame trap 30 and around a lower pulley 38 then continues on to an upper pulley 40 around which it passes though 180 degrees, to make connection with a flap 42. Flap 42 is connected by hinge 44 either to the inside of passage 22 or to a flange 46.

Flange 46, if it is utilised, can have a sealing medium (not illustrated) around it so that when flap 42 makes contact with it, an air tight seal or a flame trap is formed. If flange 46 is not utilised, flap 42 can carry a seal so that, when released to move to a closed position, it will seal the inside of duct 22 to air tight quality, or, in the alternative to form a flame trap. Flap 42 can be biased towards the closed position by a spring, which is a preferred method, or alternatively the biasing can be by other means. If desired, flap 42 can be constructed from mesh, as described above to act as a flame trap.

In the embodiment of Figure 6, when fumes from spilled fuel passing through the flame trap 30 are ignited, the heat of ignition breaks nylon line 36, which is heat sensitive and frangible, thereby causing flap 42 to move to a closed position, shutting off the air supply to main burner 14. This leaves no path down duct 22 for air or combustible fumes which may have built up around water heater 2 to sufficiently gain access to main burner 14 and so pilot burner 49 and main burner 14 may not have enough air available through flame trap 30 to continue burning in which case flame detection thermocouple 50 will cut off the gas supply until manual intervention can restore it when a safe atmosphere is restored.

In Figure 7 and Figure 8 are illustrated a gas water heater 2 constructed similarly to that illustrated in Figure 1, and illustrated with like parts being numbered. Water heater 2 includes a base 26 and jacket 4 which are either completely sealed (not illustrated) to air tight and flammable gas or vapour tight quality or, alternatively, unsealed gas paths are fine (small) enough to act as flame traps. In this instance, when completely sealed, air for combustion is drawn in from the air inlet 18, and there is no means present to ignite spilled fuel at the lower portions of water heater 2.

The embodiments shown in Figure 7 and Figure 8 have no flame trap 30 or opening 28. However, an appreciable time delay will occur before gases or vapours from spilled fuel rise to the elevated level of air inlet 18. Only once the gases or vapours from spilled fuel rise to the level of air inlet 18 could the gases or vapours be drawn down passage 22 to main burner 14. Many spillages, nevertheless are quite minor in terms of volume of liquid spilled and in such cases the embodiment of Figure 7 would tend to provide an adequate level of protection and that of Figure 8 even more so. The air inlet 18, if it does not include a flame trap 30, should be at least about 500 millimetres (20 inches) from base 26 (if base 26 is near to the ground), in the presence of gasoline fumes (a different height may be required for other fumes). However, for added protection a greater distance is preferred.

The more frequently used typical flammable fumes of spilled liquid fuels are far less likely to be available to a gas water heater flame by providing an air inlet 18 at a high position above base 26.

If base 26 and jacket 4 has small gaps or openings limited in their size to act as flame traps, then its operation will be similar to the embodiment of Figure 1. The features of Figure 6 can be incorporated also with the embodiments described in Figure 7 and Figure 8 when base 26 and jacket 4 are sealed. In this instance, because the water heater now includes a heat sensitive frangible member 36 located in an air passage in the vicinity of the main burner 14, if gases or vapours ignite having flowed down the passage 22 (which would indicate that the volume of gases or fumes had risen to the level of air entry of the air inlet 18), the resulting flame would melt a frangible member such as nylon line 36 in the vicinity of main burner 14. Nylon line 36 can be connected in turn to a non-flammable and non-frangible section which in turn makes connection with a spring biased flap similar to flap 42 capable of sealing passage 22. The distance between nylon line 36 and flap 42 is sufficiently long to close passage 22 before a flame travelling back up passage 22 reaches flap 42. If flap 42 is hinged so that its closing motion is in the direction that flame would have to travel to exit passage 22, the hinging arrangement may be aided in closing by the movement of flame in a closing direction.

A further improvement to the above embodiments shown in Figure 1 to Figure 6 is to provide a snorkel 60 as shown in Figure 8 extending the air inlet upwardly. Snorkel 600 allows air to be drawn to main burner 14 but, by taking air from a height above the top of jacket 4, will further reduce the risk of water heater 2 being an ignition source of flammable gases or vapours from spilled fuel. If the height of jacket 4 is not greater than about 500 millimetres (20 inches) above base 26, snorkel 60 can be used to draw combustion air from a more appropriate height, depending upon the spillage which may occur.

In conjunction with any form of the invention as shown in Figure 1 to Figure 6, a gas shut down facility similar to the above mentioned gas shut down ability can be provided. In another form, the gas shut down facility can be initiated by a flame sensitive switch 50 or thermocouple 51. Such a thermocouple is preferably located just inside of the flame trap 30 where ever it appears. Flame sensitive switches may also be used in circuit with the thermocouple (e.g., thermocouple 51 of Figure 1) provided for confirming the establishment and retention of a pilot flame by raising an electric current flow to a level capable of keeping open a gas supply to the pilot burner.

Flame sensitive switches may also be used to reduce fire hazards in circumstances where flame of the burner can "spill" through an air access opening adjacent the main and pilot burners. In known flame sensitive switches, the heat sensor is externally positioned and in some embodiments of the invention a flame sensitive switch is positioned above flame trap 30 to sense flame heat input resulting from spilled flammable vapour burning on the inside of flame trap 30 after having entered the combustion chamber through a possible entry path. In the embodiment of Figure 3A, the preferred position of the flame sensitive switch 50A is immediately above the flame trap and it is preferred that a small heat shield (not shown) be placed above the flame sensitive switch to shield it from the normal radiant heat associated with the main burner 14. In Figure 2, the flame sensitive switch 50 is positioned a short way above flame trap 30.

An additional level of safety is provided by the addition of an oxygen depletion sensor in conjunction with pilot burner 49. This makes available the entire air requirement for the pilot flame to the pilot burner only through a pilot air duct (not illustrated), gas tightly separate from air supply duct 22 and combustion chamber 15. The pilot air duct has an air intake external to the remainder of the water heater assembly, preferably low to floor level where water heaters are generally installed, standing upright on a floor. At any convenient location in the pilot air duct between the air intake end and the pilot burner is a flame quenching insert, composed of one or more of a variety of high thermal capacity gas porous heat resistant materials such as described in relation to flame trap 30. Locating the flame quenching insert at or near the air intake end is advantageous to make it accessible for cleaning of lint or dust that may accumulate in it. An element sensitive to oxygen depletion is also located in the pilot air duct.

With these features added to the embodiments of Figure 1 to Figure 7, use of the oxygen depletion sensor reduces the risk of ignition of flammable vapour in particular when pilot burner 49 is alight but main burner 14 is not, by sensing oxygen depletion in the incoming pilot air supply if a flammable component ignites in which case it would cause a gas control valve 48 of the type referred to in Figures 1 to Figure 7 to shut down gas flow to the pilot burner. The shut down provides a time period for flammable vapour to safely ventilate. Resumption of normal operation of the water heater requires human intervention but, even if done ill-advisedly, in any event the oxygen depletion sensor would continue to deny pilot burner 49 of gas and the arrangement would behave safely even with extraneous flammable fumes remaining near water heater 2. An oxygen depletion sensor can be used alternatively in place of or in conjunction with the previously described flame sensitive switch 50, and can be located similarly.

The invention thus far described can function at three levels of safety. The first level is illustrated in relation to Figure 7 and Figure 8, wherein there is added height and distance so that fumes from spilled fuel must travel to reach main burner 14 or pilot burner 49.

The second level, as illustrated in Figure 1, Figure 2, Figure 3 and Figure 6, adds not only height and distance but also allows some, and advantageously all, the extraneous fumes to enter the base of water heater 2 and be consumed safely, conceivably until all residual risk of fire and explosion is avoided by dissipation of the spillage.

The third level, as illustrated in Figure 4 and Figure 5, adds a further level of confidence by protecting all air entry with a flame arrestor, recognising that high levels of airborne lint or other dust may tend to block the air intake and starve the burner of air for combustion if the air entry were not periodically cleared of that lint or other dust. The embodiment of Figure 4 and Figure 5 can be constructed to protect against ignition of flammable gases and vapours outside of the enclosure or jacket regardless of the density of those gases and vapours relative to air.

In a preferred form the water heater 2 contains at least some of the following features: the opening includes an aperture which is covered by a flame trap, which prevents the burner from igniting extraneous fumes outside of the enclosure, and an air inlet through which air for combustion purposes is drawn; the opening is remote from the burner and includes a duct for passage of air to the burner; the opening and the aperture are collocated or are a single item; the at least one opening is covered by a flame trap; the aperture is in the enclosure; the aperture is positioned close to a lower end of the enclosure; the aperture is positioned in a lower end of the enclosure; the aperture is positioned below the burner; the aperture is positioned to allow air and fumes outside of the water heater to enter into an air passage leading to the burner; the aperture is positioned to allow air and fumes outside of the water heater to enter into an air passage leading to the burner; the aperture allows air and fumes to enter the lowest point of the air passage; one of or a combination of: a light detection or sensitive device; a flame detecting or sensitive device; a temperature sensitive or detecting device; a heat detecting or sensitive device; and an oxygen depletion sensitive or detection device, is located in the water heater to detect flame from the fumes if they have been ignited inside the enclosure; the opening includes an air inlet which is not covered by a flame trap, the air inlet having its lowest opening at a height of not less than about 500 millimetres or about 20 inches or more from the bottom of the enclosure; the opening is located at or adjacent to the highest point of the enclosure, if the enclosure has a height of about 500 millimetres (mm) or greater, from the bottom of the enclosure; a snorkel device is provided to extend the at least one opening at a height above the highest point of the enclosure; the flame trap includes a heat resistant permeable material having high thermal capacity; the flame trap includes a screen selected from either woven or knitted mesh; the flame trap is made of metal; the flame trap is made from a metal selected from the group consisting of: steel, stainless steel, copper and aluminium; a lint trap is included to wholly cover the aperture and the flame trap; the lint trap is formed by mesh placed in the path of lint or dust travelling to the flame trap means; the water heater includes a gas shut off means which shuts off the gas supply to the burner and or a pilot burner if the air and fumes are ignited after entering the enclosure; the gas shut off means includes a heat sensitive means; the gas shut off means includes a flame sensitive switch; the gas shut off means includes an oxygen depletion sensitive means; the enclosure includes a separable jacket and base; the flame trap is provided at or as part of the construction of joining areas of the base to the jacket, or the jacket to other component or the base to other component or at any location where the fumes could enter the enclosure; the flame trap is inherent in or is formed by the joining areas including either only gaps or apertures of a size small enough to act as a flame trap; the flame trap has been added to the joining area or is deliberately incorporated as part of the joining area; the flame trap is a layer of metallic mesh cooperating with the joining area to achieve the flame quenching or arresting function; the flame trap is inside of the water heater; and the gas shut off means includes a light detection means.

One advantage provided by the invention is the provision of a barrier to unprotected entry, at the lower end of the jacket or enclosure, of flammable extraneous fumes. In alternative embodiments it provides a protected entry means for such fumes near or at the base of the enclosure in which case these extraneous fumes are consumed in a controlled manner. The protected entry is, in the most preferred form, an air inlet or a flame trap preventing ignition of the remaining fumes in the surrounding atmosphere or of any liquid remaining nearby.

An advantage of locating the air intake for combustion purposes above the midpoint of the gas water system is that it reduces the chance of extraneous fumes entering the heater via the air intake because generally such flammables are heavier than air, which in the main do not attain dangerous levels at the air intake level.

The use of air close-off means and gas shut-off means activated by a trigger provides the advantage of suffocating any flame in the heater, or switching off the gas supply, or preventing uncontrolled or undirected ignition of gases or vapours from exiting the heater environment.

By providing an extended air intake, the risk of lint or dust affecting the efficiency of the water heater is reduced.

Still further advantages of the invention are provided by the structure shown in Figure 9 and Figure 10. Figure 9 and Figure 10 show water heater 2 wherein aperture 28 having flame trap 30 across its mouth and positioned below pilot burner 49, pilot burner 49 being located adjacent one edge of main burner 14. Aperture 28 is positioned immediately underneath pilot burner 49, preferably the closer the better to assist in achieving smooth and or early ignition. Aperture 28 is connected to the lower end of the enclosure by an upwardly extending tube 70, the upwardly extending portion of tube 70 being preferably impermeable to air, gas or fumes. Tube 70 is preferably constructed of sheet metal, although other suitable materials may be substituted. It is also possible that tube 70 as shown in Figure 9 can be made either partially or completely from flame trap materials, especially the upper portion.

Locating flame trap 30 above base 26 minimises the possibility of water condensate occluding the pores or openings in flame trap 30 or water splashing from, for example, hosing the floor near base 26 of water heater 2. Thus,, the length of tube 70 is not especially critical so long as it performs the function of preventing pore or port occlusion. In Figure 9 a horizontal blocking plate 74 is located above flame trap 28 to prevent water condensate or particulate matter such as steel scale flakes falling on the flame trap, thereby reducing the chance of occluding it.

It has also been discovered that a two layer construction of flame trap 30 with a lint filter is highly advantageous. Figure 9 illustrates a lint filter 72 in addition to a double layer flame trap 30. Filter 72 may be a different material from flame trap 30. The potential for accumulation of lint over time has been a concern. However, it has been unexpectedly discovered that structure such as that shown in Figure 9 and Figure 10 is surprisingly free of lint accumulation problems. It is believed that the horizontal and very close positioning of flame trap 30 to main burner

14 results in small pressure pulses associated with main burner 14 igniting on each occasion. Apparently, the pulses blow away any lint from the face of flame trap 30. This appears to provide a repeating self-cleaning effect.

Another significant advantage can be provided to the water heaters described above by providing an improved gas control valve which is better illustrated in figures 11 to 16. In conventional gas valves, the thermocouple and over-temperature fuse have been inconveniently located in an integrated structure sheathed in a copper capillary tube with significant thermal inertia. If either the thermocouple or the temperature fuse require replacement then it is not immediately apparent which one has failed and, because both are replaced as an integrated unit, unnecessary cost is involved. The thermal fuse is a relatively low cost item compared to the entire integrated structure and, therefore, it is advantageous to be able to test the circuit by merely removing the suspect fuse and replacing it. This test does not involve removal of the thermocouple which requires awkward access into the water heater combustion chamber. Thus, there can be a considerable reduction in the time a water heater service person needs to identify and correct a problem in the many cases where an open circuit is related to the fuse rather than the thermocouple. Therefore, the reason for replacement being necessary can be ascertained more directly and, thus, safe operation resumed more certainly.

Figure 11 to Figure 14 show a gas control valve 48 supplying main burner 14 having an adjacent pilot burner 49 in water heater 2 with combustion chamber 15 The valve 48, illustrated in figure 11 to 16 include a gas inlet 120 for connection to a supply (not shown) of combustible gas. Valve 48 has a gas outlet 124 for connection to a conduit (not shown) leading to main burner 14 and an outlet 126 to connect to pilot burner 49. Internal components of the valve include an orifice or conduit 127 for gas flow between the inlet 120 and outlet 124 and a closure 154 normally resiliently biased to close the orifice to prevent or permit flow of gas from the inlet 120 to the outlet 124 as required.

Incorporated in valve 48 is an electrical circuit 128 such as shown in Figure 15 and 16, including thermocouple 51 connected to a solenoid 132. Thermocouple 51 provides an electrical potential, sometimes hereinafter referred to as "signal", when heated by a flame established at pilot burner 49, typically 12 to 15 mV, to solenoid 132 which is sufficient to maintain solenoid 132 open against the normally closing bias of a spring 156 associated with closure 154. Specifically, the electrical potential is provided to solenoid 32, creating a magnetic force which, via an armature connected to closure 154, maintains closure 154 open. It should be noted that the electrical potential is not sufficient to open closure 154 from its closed position except when valve passage 127 is first opened by manual switch 142 being manually position in the "pilot" or "on" positions and the potential is adequate to maintain closure 154 in its open position.

When a flame is absent at pilot burner 49, valve 48 remains shut except during a start up procedure. The circuit has a manual switch 142 with three positions, "off", "pilot" and "on". In the "pilot" position the switch may be depressed to hold open valve 48 while thermocouple 51 heats sufficiently to power circuit 128. Manual switch 142 is depressed in the "pilot" and "on" positions to lift closure 154 off its seat against the closing bias force of spring 156. In the open position, an electrical current passing through the coil of solenoid 158 generated by the thermocouple 51 when heated by the flame of the pilot burner 49 (Figure 4) is adequate to maintain closure 154 in the open position during normal use of water heater 2. Normal use of water heater 2 involves pilot burner 49 being alight at all times.

An over-temperature energy cut out 144 is installed inside a temperature sensitive thermostat probe 146 (shown in Figure 12) which interrupts all gas flow through the valve in the event that an unsafe temperature develops inside the tank.

As best seen in Figure 11 and Figure 15, valve 48 has a fuse 134 connected in electrical circuit 128 and exposed at the bottom surface of valve 48 to be sensitive to extraneous sources of flame and heat external to and in the region of the valve, particularly underneath it.

Valve 48 features an externally accessible socket 136 in electrical circuit 128 in which thermal fuse 134 is removably inserted. Socket 136 is positioned to receive thermal fuse 134 independently and separate from thermocouple 51.

Socket 136 and fuse 134 are accessible from the underside of valve 48 as shown in Figure 11 and Figure 14 wherein valve 48 is mounted on an external vertical wall of water heater 2. This leads to the advantage of rapid response time since the underside is more likely to be impinged upon by extraneous flame because valve 48 is also vertically above access point 138 to main burner 14 and pilot burner 49 such as for lighting, inspection and combustion air entry. Extraneous flame and heat within water heater 2 may result from accidental combustion of a flammable substance near water heater 2, the flame being likely to establish itself firstly adjacent to access point 138.

Another advantage of mounting fuse 134 to be accessible at a downward facing surface of valve 48 is that fuse 134 would not be as noticeable upon a casual inspection of water heater 2 and valve 48 and, therefore, not so likely to invite removal by personnel unaware of its safety-motivated purpose. Water heater 2 will not continue to function if it were removed and not replaced.

Despite the preferred downward facing position of fuse 134, positions on other faces of valve 48 are possible. Fuse 134 has minimal thermal inertia and to that end involves minimal mass and is not enclosed in a copper or similar sheath. A preferred fuse 134 is one encapsulated only in a small quantity of organic polymer resin. One presently preferred form of thermal fuse 134 is manufactured by Therm-O-Dis, Inc., Mansfield, Ohio, USA. The radial lead type is the most suitable for insertion into a socket 136 and a model available with a maximum rated opening temperature of 102 °C has a suitably rapid response time.

Further advantageous embodiments of the invention are described below in relation to Figure 17 to and those following. The embodiments in Figure 17 to Figure 23 are particularly advantageous in situations where it is desired that water heaters embodying to the invention do not function to consume substantial quantities of spilled fuel but rather to prevent all combustion of extraneous fumes around a water heater, leaving spilled flammable vapours or fumes to be dispersed by ventilation rather than controlled combustion in the combustion chamber.

One important reason why this may be a preferred option is that if a considerable amount of spilled flammable vapour is available to be consumed, then the flame established on the flame trap or air inlet porous surface inside the combustion chamber of the water heater could last long enough to substantially heat the conductive flame trap material so that the side of it exposed to the source of flammable vapours ("upstream" side) may become sufficiently heated to reach the auto-ignition temperature of the particular spilled vapour such that the vapour could be ignited outside the water heater without actual transference of the flame through the flame trap. The embodiments shown in Figure 17 to Figure 23 address this unlikely but potential difficulty according to several broad strategies.

The first such strategy involves mechanical devices triggered to operate by the heat of the flame burning on the face of the flame trap in the combustion chamber. The devices operate to starve flames of air for continuing combustion which flames are established on the flame trap surface.

The second strategy is to extinguish flames established on the flame trap quickly by a combined chemical and physical reaction to the heat o the flame trap by generating, releasing and propelling a flame extinguishment substance into the intake of the flame upstream of the flame trap.

The third strategy involves selecting specific flame trap materials and coating them with an ablative or intumescent substance that, when subjected to heat of combustion of split flammable vapours on the "downstream" surface of the flame trap, expands to occlude the pores of the flames trap thereby extinguishing the flame.

The fourth strategy is to select a thick, low heat conductive flame trap material such that heating at the downstream surface of the flame trap results in a much longer or infinite period before the temperature on the upstream face of the flame trap could reach a temperature able to cause ignition of the spilled vapours upstream of the flame trap entry.

With reference to Figure 17, base 226 of the water heater has an aperture to which an upstanding tube 270 is joined, the tube terminating approximately 5 cms above the base 270 to create a hole spanned by a flame trap 229. Above tube 270 and flame trap 229 is a substantially horizontal blocking plate 274 adjacent combustion chamber 2B which may be conical or curved so as to be able to deflect any condensation water falling upon its upper surface outwardly beyond the flame trap area. Fixed to the underside of horizontal blocking plate 274 is a temperature sensitive fuse 234 connected to the gas valve 48 (see, for example Figure 1) arranged to enable flow of gas through the gas valve to be shut off in the event of fuse 234 being open circuited by formation of a flame on the upper surface of the flame trap. A drop tube 302 is provided to create a smooth sliding fit inside the tube 270. Drop tube 302 is held in the upward position illustrated in Figure 17 by a ring of fusible sealant 304 which acts as a hot melt adhesive to support tube 302 for normal operation in an upward position. Fusible sealant 304 most preferably has a melting temperature of about 100 °C to 200 °C.

Opening 271 in the drop tube 302 may be spanned by a lint filter 272 if desired. As shown in Figure 18 in the event of a flame forming on flame trap 229 the fusible sealant 304 melts allowing drop tube 302 to fall until it reaches a flat surface such as a floor or mating stop 303 upon which the heater is installed. The distance between the floor 303 and the base 226 of the heater must be not more than the vertical height of drop tube 302 so that, as illustrated, there is no space for sufficient air to enter the tube 270 to enable combustion on the upper surface of the flame trap. Such combustion effectively triggers the falling of drop tube 302, which substantially closes opening 271 and thereby starves the flame of any further vapour or fumes and air and extinguishing it.

A different arrangement performing a similar function to that shown in Figure 17 and Figure 18 is provided in Figure 19 and Figure 20. In this case a horizontal blocking plate 274 is supported above flame trap 229 (Figure 19) by three legs 320 made from readily fusible material, preferably a thermoplastic material such as low density polyethylene. The readily fusible material most preferably has a melting temperature of 100 °C to 200 °C. Of course, other readily fusible materials may be substituted. With this arrangement, in the event that combustion of spilled flammable vapour or fumes occurs on the flame trap 229, legs 320 melt as shown in Figure 20 so that horizontal blocking plate 274 falls onto the top of tube 270, thus blocking the flow of further vapour or fumes and air to continue combustion, thereby extinguishing combustion.

With reference to Figure 21, an alternative type of flame trap material 329 is illustrated. The flame trap 329 may be in a number of forms, the common feature of which is a much greater dimension in the direction of through flow of air or fumes than previously disclosed in the illustrated embodiments. The main purpose of the thicker flame trap material 329 is to delay and/or reduce the conduction of heat from the top surface of flame trap 329 to the underside of flame trap 329 in the event of combustion being established due to flammable fumes and vapour igniting on the upper surface of flame trap 329. One type of flame trap is constructed of stainless steel foil, which is corrugated and joined to an uncorrugated strip of stainless steel foil of similar thickness and the first and second tapes joined together and spirally wound as disclosed in Hayakawa et al. U.S. Patent 5,588,822. Then, the time taken for the inlet side of the flame trap to become heated to a temperature sufficient to ignite flammable vapours external to the water heater is considerably increased. This configuration can be rearranged if the overall shape of the flame trap is other than circular.

Even longer delay times are provided when the flame trap material 329 is constructed of ceramic materials such as Celcor (registered trade mark of Corning Incorporated of Houghton Part, Corning, NY 14831) extruded ceramic having a thickness of about 12 mm or greater being preferred. It is preferably provided with an open frontal area between about 64% and 80% and with between about 36.6square openings/cm^2 and 73 square openings/cm^2. Flame trap 329 may be in any desired shape and may be built up to a total required area by using smaller modules of the ceramic material. Adjacent modules of ceramic can be sealed to each other using a flexible sealant 330 or the like as required.

With reference to Figure 22, an alternative means of extinguishing flames on flame trap 229 is shown. Upstanding tube 270, water heater base 226 and optional lint filter 272 are as previously illustrated as in Figure 23. Flame trap 229 may be made from any of the materials as herein mentioned. Additional structure in Figure 22 includes a container 306 charged with a substance capable of extinguishant flame which is restrained from leakage by fusible plugs 310 inserted in one or more outlets 308 to the container. Ends of the tubes 308 distant from the attachment to the container 306 may terminate in nozzles 312 to increase the mixing of flame extinguishant from the nozzles. Flame extinguishing in container 306 may include one or more of many known substances decomposable under the effect of elevated temperature occasioned by the formation of flames on the flame trap 229 including, for example sodium bicarbonate. Sodium bicarbonate decomposes under the effect of elevated temperature to give off carbon dioxide gas which when mixed into the air stream, including flammable vapour entering the open end of tube 270, is able to extinguish flames on the upper (or inside) surface of the flame trap 229. Whilst the fusible plug or plugs 310 closing container 306 may have quite a wide range of suitable fusing temperatures, it is preferred that the range be sufficiently high so that fuse 234 is more likely to open the circuit and, therefore, shut off the gas flow before fusible plug(s) 310 melt. Accordingly, a preferred melting temperature of the fusible plug(s) is in the range of about 150 °C to 300 °C.

Thermal fuse 234 is positioned in such a way that the presence of container 306 does not impede the fuse's function of shutting down supply of fuel gas to the main and pilot burners as elsewhere illustrated. The flame extinguishant encapsulated in container 306 may include fire blanketing foams together with a propellant which, under the effect of a temperature attained (typically in the range of 300 °C to 500 °C) just above the flame trap when a flame is burning thereon, would create high vapour pressure to propel the flame suppressant foam out through the nozzles 312 and into the fume/air intake travelling upwardly through tube 270.

With reference to Figure 23, an alternatively shaped flame trap 332 is shown. Support tube 270, water heater base 226 and optional lint filter 272 are as previously illustrated, for example as in Figure 23. With reference to the flame trap material 332, this includes a double layer of woven metal mesh as previously described except that in Figure 23 the two component layers are formed in a non-planar upwardly domed shape (for a circular aperture tube or an upwardly corrugated shape for a square or rectangular aperture at the top of tube 270). The advantage of the flame trap 332 over flat woven mesh constructions is that the two layers can be reliably manufactured substantially in contact and will remain substantially in contact because of the way they expand when so curved and do not form localised areas of contact between the two layers of mesh. A disadvantage obtained with localised contact is that hot spots form quickly at such areas of contact and these might initiate ignition of unburned flammable fuels on the outside of the flame trap structure. Thus, the flame trap illustrated in Figure 23 can sustain combustion on its upper surface for a greater length of time than a similar flat structure without causing ignition on the lower or outward side of the flame trap.

Whilst the above embodiments are directed to room or indoor installed gas water heaters, the improvements described will function in an outdoor environment, if spillages occur nearby and fumes enter the gas water heater.

If desired the flame trap or air inlet may be located at various positions other than those shown in the drawings and described above. One alternative position is in the side of the combustion chamber opposite the gas supply. In such a construction the flame trap or air inlet would be located in an opening in the skirt below the water tank and extending through the corresponding portion of insulation.

In a further option the flame trap is positioned above the height of entry to the combustion chamber and a flame sensitive switch is positioned above that height of entry in the flow path of combustion air toward the burner. The aperture covered by the flame trap is in radiant heat communication with a flame sensitive switch also positioned to be sensitive to flame roll out from flue blockage or combustion air starvation.

Further, the flame trap may be made from a variety of materials such as those described above, but can be fabricated from others not specifically identified so long as they permit passage of air and fumes in one direction but prevent flames from travelling in the opposite direction.

Suitable flame trap materials include those being porous, gas permeable and possessing sufficiently high thermal capacity to quench flame under typical conditions of use. Metallic structures having holes of sizes described below, made from, for example, mild steel, stainless steel, copper or aluminium as described below are suitable and porous ceramics including glass or mineral wool woven or non-woven constructions are also suitable. Fibre matrix ceramic is suitable as is flexible or rigid constructions.

Also, the air passage for combustion air, such as in the structure labelled 22 in Figure 1, can be located between water tank 6 and jacket 4. The passageway can be of a variety of shapes and sizes and can be formed in and bounded by the insulation or can be formed by tubes, pipes conduits and the like.

It should also be understood that utilisation of the flame sensitive switch or similar devices may be used with all types of gas fired water heaters, including those not equipped with flame traps. Further, devices other than thermocouples 51 providing electrical potentials may be employed so long as they are capable of converting heat energy to assist in actuating closure 154. Heat to mechanical, heat to optical, heat to magnetic and the like types of conversions are all within the scope of the invention. Accordingly, "signal" as used in the claims refers not only to "electrical potential" but to any means whereby closure 154 is actuated/deactuated as a result of detection of heat energy.

Main burner 14 and combustion chamber 15 can have different constructions such as those described in U.S. patents 4,924,816; 5,240,411; 4,355,841, for example, the subject matter of which is incorporated herein by reference.

Duct 270 may be made from a number of heat and corrosion resistant materials, may be shaped and sized in different configurations, and can have flame trap 229 placed in any number of relative position, including horizontal, vertical and at various angles.

Finally, it is possible that container 306 shown in Figure 22 may be located in alternative positions within combustion chamber 215 or even exteriorly of the water heater so long as fusible material 310 and nozzles 312 are located adjacent flame trap 229, either above or below it.

Moving now to the description of figures 24 to 85

Conventional water heaters typically have their source(s) of ignition at a low level. They also have their combustion air inlets at or near floor level. In the course of attempting to develop appliance combustion chambers capable of confining flame inside appliances, we discovered that a type of air inlet constructed by forming holes in sheet metal in a particular way has particular advantages in damage resistance when located at the bottom of a heavy appliance such as a water heater which stands on a floor. We further discovered that providing holes having well defined and controlled geometry assists reliability of the air intake and flame confining functions in a wide variety of circumstances.

A thin sheet metallic plate having many ports of closely specified size formed, cut, punched, perforated, etched, punctured and/or deformed through it at a specific spacing provides an excellent balance of performance, reliability and ease of accurate manufacture. In addition, the plate provides damage resistance prior to sale and delivery of a fuel burning appliance such as a water heater having such an air intake and during any subsequent installation of the appliance in a user's premises.

On the other hand, both ceramic plaque tiles (such as SCHWANK® tiles) and certain less robust types of woven metal mesh have the disadvantage of being easily damaged. Moreover, ceramic plaque tiles are typically 20 to 25 times thicker than thin metallic plates or metal mesh and, therefore, have the disadvantage of creates a greater flow resistance per unit of area of air intake.

In the disclosure relating to figures 1 to 23 above we addressed the question of reliability by disclosing certain arrangements applicable to water heaters whereby an incidence of combustion of flammable fumes (arising from a nearby spill) confined safely to the side of the air intake facing the inside of the combustion chamber, can be quickly extinguished by several arrangements which result in the air and flammable fume entry to the combustion chamber of a water heater being blocked by a variety of means triggered by one or more effects of combustion, such as temperature rise. This blocking was directed to a desire to extinguish all flame sources within the combustion chamber within a matter of minutes, or less, of such a combustion incident commencing. While this structure will be successful in seeking to ensure maximum reliability, we subjected that structure to exhaustive testing in the absence of provision of an entry blocking means involving prolonged combustion of one US gallon (3.79 litres) of gasoline which, in 30 or 40 US gallon domestic sized water heaters tested of nominal 30,000 or 45,000 BTU/hour heating capacity requires more than one hour to completely combust.

In experiments conducted with air intakes in general having a variety of port shapes and patterns formed through a thin metal plate, it was observed that some variants were more effective than others in flame confinement function. We noted that certain ones enabled a flame to burn in close contact with the inside surface of air inlet plate, thereby leading to substantial temperature rise of the plate on its outside surface, by heat conduction. In some instances, this was observed to involve a pulsating combustion phenomenon which enhanced heat release in the combustion chamber.

An excessive rising temperature of the perforated plate in contact with the flame can transfer heat by conduction through the relatively thin metal plate to the extent that it can reach a sufficiently high temperature (of the order of 1250°F or 675°C) such that a failure might possibly occur under some conditions caused by hot surface ignition of the spilled fumes on the outside of the combustion chamber.

During experimentation, which was designed to create potential ignition conditions not likely to occur under normal operating conditions and, with a video camera filming the inside of the combustion chamber, a potential mode of failure was observed in some instances to involve flame retention more closely to the periphery of the inlet plate than in the centre. Where the flames are closely retained the inlet plate becomes visibly hotter such as by becoming red, which indicates a temperature in excess of 1250°F and which was confirmed by thermocouple based temperature measurement.

The embodiments attempt to address ways of meeting extreme conditions and keeping the overall temperature of the inlet plate to a level that will not encourage external ignition by excessive heating of any portion of the inlet plate. The invention also addresses ways of avoiding detonation wave type ignition that we discovered propagates from the inside to the outside of the combustion chamber through the inlet plate under certain circumstances, by minimising the amount of flammable fumes which may enter the combustion chamber before initial ignition inside the combustion chamber occurs; and, also, during prolonged combustion incidents, in controlling thermally induced resonance within the combustion chamber.

Working from the basis that a burner designed to heat the contents of a water heater of a given capacity in a satisfactorily short time requires a particular air flow rate for proper combustion of the gaseous fuel, the inventors found that the shape and the pattern of the ports in an air intake plate having the required air flow rate can be surprisingly significant in preventing detonation ignition and delaying or preventing temperature rise of the plate during prolonged combustion testing resulting from a spill. Furthermore, the inter-port spacing in the plate can be specified to minimise flash-through ignition, all other parameters being in a satisfactory range.

Turning now to the drawings in general and Figure 24 and Figure 25 in particular, there is illustrated a storage type gas water heater 462 including jacket 464 which surrounds a water tank 466 and a main burner 474 in an enclosed chamber 475. Water tank 466 is preferably capable of holding heated water at mains pressure and is insulated preferably by foam insulation 468. Alternative insulation may include fibreglass or other types of fibrous insulation and the like. Fibreglass insulation surrounds chamber 475 at the lowermost portion of water tank 466. It is possible that heat resistant foam insulation can be used if desired. A foam dam 465 separates foam insulation 468 and the fibreglass insulation.

Located underneath water tank 466 is a pilot burner 473 and main burner 474 which preferably use natural gas as their fuel or other gases such as LPG, for example. Other suitable fuels may be substituted. Burners 473 and 474 combust gas admixed with air and the hot products of combustion resulting rise up through flue 470 possibly with heated air creating a suction that draws ambient air into the combustion chamber 475, as will be further described below. Water tank 466 is lined with a glass coating for corrosion resistance. The thickness of the coating on the exterior surface of water tank 466 is about one half of the thickness of the interior facing surface to minimise "fish scaling". Also, the lower portion of flue 470 is coated inside to prevent eventual formation of scale that could detach as flakes of rust due to prolonged effects of acidic condensate. Such flakes could fall into chamber 475 possibly blocking off or reducing air flow by lodging on the air inlet plate 490.

The fuel gas is supplied to both burners (473,474) through a gas valve 469. Flue 470 in this instance, contains a series of baffles 472 to better transfer heat generated by main burner 474 to water within tank 466. Near pilot burner 473 is a flame detecting thermocouple 480 which is a known safety measure to ensure that in the absence of a flame at pilot burner 473 the gas control valve 469 shuts off the gas supply. The water temperature sensor 467, preferably located inside the tank 466, co-operates also with the gas control valve 469 to supply gas to the main burner 474 on demand.

The products of combustion pass by natural convection upwardly and out the top of jacket 464 via flue outlet 476 after heat has been transferred from the products of combustion. Flue outlet 476 discharges conventionally into a draught diverter 477 which in turn connects to an exhaust duct 478 leading outdoors.

Water heater 462 is mounted preferably on legs 484 to raise the base 486 of the combustion chamber 475 off the floor. In base 486 is an aperture 487 which is closed gas tightly by an air inlet plate 490 which admits all required air for the combustion of the fuel gas combusted through the main burner 474 and pilot burner 473, regardless of the relative proportions of primary and secondary combustion air used by each burner.

Air inlet plate 490 is preferably made from a thin metallic perforated sheet of stainless steel. Copper or brass sheet metal can be used to take advantage of its superior heat conducting properties. Stainless steel when used may be surface treated by dipping in molten sodium and/or potassium dichromate, to blacken it and raise its emissivity. Preferably the metal plate has a thickness of about 0.4mm to 1 mm Alternatively, a ported ceramic tile of the SCHWANK® type (registered trade mark) can be utilised although the robustness of thin perforated metal when compared to its good flow capacity commends its use. The ceramic tile type functions adequately as long as the porosity is suitable and it does not become damaged during assembly, transit, installation or use.

Where base 486 meets the vertical combustion chamber walls 479, adjoining surfaces can be either one piece or alternatively sealed thoroughly to prevent ingress of air or flammable extraneous fumes. Gas, water, electrical, control or other connections, fittings or plumbing, wherever they pass through combustion chamber wall 479 are sealed.

The combustion chamber 475 is air/gas tight except for means to supply combustion air and to exhaust combustion products through flue 470. Some alternative structure of the combustion chamber is shown schematically in Figure 56 to Figure 58, which is discussed later.

Pilot flame establishment can be achieved by a piezoelectric igniter. A pilot flame observation window can be provided which is sealed. Cold water is introduced at a low level of the tank 466 and withdrawn from a high level in any manner as already well known.

During normal operation, water heater 462 operates in substantially the same fashion as conventional water heaters except that all air for combustion enters through air inlet plate 490. However, if spilled fuel or other flammable fluid is in the vicinity of water heater 462 then some extraneous fumes from the spilled substance may be drawn through plate 490 by virtue of the natural draught characteristic of such water heaters. Air inlet 490 allows the combustible extraneous fumes and air to enter but confines combustion inside the combustion chamber 475.

The spilled substance is burned within combustion chamber 475 and exhausted through flue 470 via outlet 476 and duct 479. Because flame is confined by the air inlet plate 490 within the combustion chamber, flammable substance external to water heater 462 will not be ignited.

We define the "quenching distance" of a port in an inlet plate in a combustion chamber of a water heater or similar appliance to account for a wide variety of suitable shape of port. The quenching distance in this context is that distance measured in the plane of the port area below which a flame formed by a combustible mixture of a fume species and air passing or having passed through the port in a forward direction will not propagate through the port in a reverse direction, whether as a result of detonation or deflagration type initiation of combustion or as a result of prolonged steady combustion at the inlet plate within the combustion chamber.

For shapes of ports such as may be categorised as geometrically regular such as circular holes or straight slots or irregular, such as curved or wavy slots, we define the quenching distance of such a port by first defining an axis of the open area of that port as the longer or longest line, which may be straight or curved, which divides that open area in half exactly or approximately. The quenching distance of that port, is then the length of the longest straight line which passes perpendicularly through the defined axis to meet the boundary of the open area. Thus the quenching distance according to this definition for a straight slot is its width and, for a circle, its diameter.

For both geometrically regular and irregular shapes of port, complex patterns may be formed by superimposing shapes where axes may cross or intersect, in many ways, one example being wavy slots intersecting perpendicularly.

Preferably, the blocking plate 492 if used is the same or slightly larger size and shape as the inlet plate and has the purpose of stopping condensate or scaly particulate matter falling from above and occluding the openings of the air inlet plate 490.

As best seen in Figure 25, the inlet plate has mounted on or adjacent its upward facing surface a thermally sensitive fuse 494 in series in an electrical circuit with pilot flame proving thermocouple 480 and a solenoid coil in gas valve 469.

With reference to Fig 1, the size of air inlet plate 90 is dependent upon the air consumption requirement for proper combustion to meet mandated specifications to ensure low pollution burning of the gas fuel. Merely by way of general indication, the air inlet plate of Fig 1 should be conveniently about 3700 square mm in perforated area when fitted to a water heater having between 35,000 and 50,000 BTU/hr (approximate) energy consumption rating to meet US requirements for overload combustion.

Figure 26 shows schematically an air inlet 490 to a sealed combustion chamber including an aperture 487 in a portion of the lower wall 486 of the combustion chamber and, overlapping the aperture 487, a thin sheet metal air inlet plate 490 having a perforated area 500 and an unperforated border 501.

Holes in the perforated area 500 of plate 490 can be circular or other shape although slotted holes have certain advantages as will be explained, the following description generally referring to slots.

Figure 27 to Figure 41 show in each case an air inlet plate 490 of various configurations as will be described to admit air to the combustion chamber 475. The air inlet plate 490 is a thin sheet metal plate having many small slots 504 passing through it. The metal may be stainless steel having a nominal thickness of about 0.5 mm although other metals such as copper, brass, mild steel and aluminium and a thickness in the range about 0.3 mm to about 1 mm as an indication, are suitable. Depending on the metal and its mechanical properties, the thickness can be adjusted within the suggested range. Grade 409, 430 and 316 stainless steel, having a thickness of 0.45 mm to 0.55 mm are preferred.

Figure 27 is a plan view of an air inlet plate 490 having a series of ports in the shape of slots 504 aligned in rows. All such slots 504 have their longitudinal axes parallel. The ports are arranged in a rectangular pattern formed by the aligned rows. The plate is about 0.5 millimetres thick. This provides inlet plate 490 with adequate damage resistance and, in all other respects, operates effectively. The total cross-sectional area of the slots 504 is selected on the basis of the flow rate of air required to pass through the inlet plate 490 during normal combustion. For example, a gas fired water heater rated at 50,000 BTU/hour requires at least 3,500 to 4,000 square millimetres of port space in plates of nominal thickness of approximately 0.5 mm.

Figure 4 to Figure 41, and Figure 45, Figure 47, Figure 48 and Figure 49 show numerous variations in the pattern of slots 504 in the perforated area 500, each variation representing one of many patterns which is suitable in the practice of this invention. In each illustration of a plate 490, a pattern of slots 504 and the size and shape of them constitutes an important consideration for optimum function in the event that extraneous flammable fumes accidentally enter with the air entering the combustion chamber 475, thereby creating a risk of accidental and dangerous ignition of a substantial or significant quantity of such spilled flammable volatile substance, such as gasoline, external to the combustion chamber.

Figure 33 shows one particularly suitable pattern with longitudinal axes of the edge slots 507 at right angles to those of the ports 504 in the remaining perforated area 505.

The slots 504 are provided to allow sufficient combustion air through the inlet plate 490 and there is no exact restriction on the total number of slots 504 or total area of the plate, both of which are determined by the capacity of a chosen gas (or fuel) burner to generate heat by combustion of a suitable quantity of gas with the required quantity of air to ensure complete combustion in the combustion chamber and the size and spacing of the slots 504. The air for combustion passes through the slots 504 and not through any larger inlet air passage or passages to the combustion chamber, no such larger inlet or air inlet being provided.

While Figure 27 to Figure 45 and Figure 54 illustrate ports which are elongated in shape, the present invention is applicable to inlet plates formed with circular shaped ports as is illustrated in Figure 53, or alternatively the slot ports of the other figures can be replaced by circular ports preferably no bigger than 0.5 mm or 0.6 mm.

To form the slots 504 or other form of port 502 one of several manufacturing operations are appropriate. Such operations include laser cutting, etching, photochemical machining, stamping, punching, blanking or piercing. A process of piercing and bending, sometimes referred to as lancing, can be used to produce a slot formed as shown in cross section in Figure 45. In the process a tool punctures a line in a plate and a portion of the plate to one side of the line is then displaced laterally to create a slot of desired length and width W as shown.

We find the pattern of Fig 34 to have an advantage of good rigidity, favoured by the off-set arrangement of adjacent rows of slots 1 to 4.

Figure 42 shows a single slot 504 having a length L, width W and curved ends. To confine any incident of the abovementioned accidental dangerous ignition inside the combustion chamber 475, the slots 504 are formed having at least about three times the length L as the width W and are preferably at least about twelve times as wide. Length to width (L/W) ratios outside these limits are also effective. We found that slots are more effective in controlling accidental detonation wave ignition than circular holes although beneficial effect can be observed with L/W ratios in slots as low as about 3. Above L/W ratios of about 15 there can be a disadvantage in that in a plate 490 of thin flexible metal possible distortion of one or more slots 504 may be possible as would tend to allow opening at the centre of the slots creating a loss of dimensional control of the width W. However, if temperature and distortion can be controlled then longer slots can be useful; reinforcement of a thin inlet plate by some form of stiffening, such as cross-breaking, can assist adoption of greater L/W ratios. L/W ratios greater than about 15 are otherwise useful to maximise air flow rates and use of a thicker plate material than about 0.5 mm or a more highly tempered grade of steel, stainless steel or other chosen metal, can be expected to favour a choice of a ratio of about 20 to 30. Also the slot pattern shown in Figure 34 favours a choice of a relatively high L/W ratio.

To perform their ignition confinement function, it is important that the slots 504 perform in respect of any species of extraneous flammable fumes which may reasonably be expected to be involved in a possible spillage external to the combustion chamber 475 of which the air inlet plate 490 of the invention forms an integral part or an appendage.

In combustion science and engineering literature quenching diameters for circular tubes for various gas species at a pressure of one atmosphere and a temperature of 20°C in a mixture with air have been determined and are tabulated below: (Reference: Jones, H.R.N. "The Application of Combustion Principles to Domestic Gas Burner Design", British Gas plc, 1989, p57, quoting Harris, J. A. & South, R, *Gas Engineering Management* **18**, 153 (1978))

Gas	Quenching Diameter, mm
Methane	3.5
Ethylene	1.8
Ethane	2.5
Propane	2.9
Butane	3.0
Natural Gas	2.7

(For butane, an alternative source, quotes 0.12 inches or 3.0 mm which is consistent but also lists an absolute minimum quenching distance of 1.78 mm which is not consistent with other data in Jones indicating that for methane, another hydrocarbon in the same family as butane, the minimum quenching distance is experienced with mixtures close to the stoichiometric ratio. See "Basic considerations in the combustion of hydrocarbon fuels with air" Barnett, H. C. & Hibbard, Robert R., eds., Report 1300 of The National Advisory Committee for Aeronautics, by Propulsion Chemistry Division, Lewis Flight Propulsion Laboratory, 1957.)

We find that a quenching distance for either holes or slots in a thick metal plate is not more than about 0.6 mm. We have discovered the following factors account for the quenching distance that we prefer is reduced substantially in relation to the above tabulated values by reason of several variables.

Increase in temperature of a plate 490 and its immediate surroundings preheats the unburned gas/air mixture, which increases its burning velocity and reduces the quenching distance. Also it has been discovered by other workers that preheating widens the flammability limits of a given gas species mixed with air. For example, in methane/air mixtures, at 200°C a primary aeration as low as 55% is flammable but at 20° C mixtures below 65% are not flammable.. Other flammable substance/air mixtures show the same phenomenon as methane..

The quenching distance adopted for the slots 504 or other port 502 needs to be modified downwards to allow for preheating of the unburnt extraneous fume/air mixture which inevitably obtains, although its intensity is variable depending on specific water heater design parameters and other variables associated with particular incidents. We recognise that flame speed increases with preheat of the unburnt mixture and have read that for a mixture of butane (as a convenient example of an extraneous fume species) with air that the maximum flame temperature achievable occurs with a slightly lean mix (about 103% air) and is about1900°C. In our tests we measured typical air inlet plate temperatures at 675°C maximum. Computer modelling of unburnt gas passing through our highly preferred 0.5mm by 6mm long slots indicated a temperature of the unburnt gases reaching 375°C.. Our belief is that preheating causes the flame temperature (1900°C) to be increased by about the same amount as the preheat temperature, i.e., to about 2275°C. Using relationships familiar to those skilled in combustion engineering principles it would be estimated that for paraffins such as propane or butane a reduction in quenching distance of about 30% is expected as a result of this amount of preheat. This must be emphasised as an estimate only and assumes for example that the temperature of the wall of the slot is the same as the temperature of the unburnt fume/air mixture passing through. However, we found this not to be true due to natural draft "pulling" the mixture through the plate 490 a heat transfer effect occurs but not to the extent that it reaches anywhere near the red heat observable on the combustion chamber side of the plate 490. Such temperatures would be well in excess of the hot surface ignition temperature of the extraneous fume species/ air mixture. Since combustion has been reliably observed to be confined within the combustion chamber the hot surface ignition temperature is not attained in practise. A further assumption made in estimating the 30% reduction in quenching distance is that the fume/air mixture is at the stoichiometric ratio. In the situations addressed by the present invention there is no way of controlling the air/extraneous fume ratio over a prolonged period of combustion given the random nature of accidental spillage situations wherein many different species of combustible extraneous fumes and arrival of potentially significant quantities of any or each at the inlet 490 to a fuel burning appliance desired to be rendered more safe, are random and unpredictable quantities spread over wide limits. Given the random nature of variations in these species and events and the possibility of pre-heat effects, we determined that literature based estimates of a quenching distance to adopt were insufficient to give the improved safety of the water heaters of the invention and we determined that a quenching distance not more than about 0.6mm in a thin metal plate of about 0.5 mm thickness is preferred and these we have a further preference for slots with an L/W ratio of at least 3 but more preferably about 12 but can in appropriate patterns be as high as about 20.

We found published literature ultimately gave little practical guidance. A quenching distance can best be determined with the assistance of some experimental observations for a given design of air inlet plate 490 in a water heater 462 having a combustion chamber 475. Our defined quenching distance is affected by one or more of the following factors: the incoming air and extraneous fume temperature, as affected by preheating; the ratio between extraneous fumes and air; the nature of the extraneous fumes in relation to its flame speed and flammability limits in combination with air as an oxidant; appliance design related variables, including flue length and therefore the velocity of input air and extraneous fume mixtures and pressure difference across the air inlet plate 490; the depth and shape of the chosen air inlet ports 502; internal construction of combustion chamber 475 relative to the main burner 474 positioning and the air inlet plate 490 positioning including effects of back radiation from the burner to the air inlet plate4 90 and any other internal or external restrictions to air flow through the air inlet plate 490; the material of the flame trap including its thermal conductivity, the emissivity of its surface and the effect of any catalytic substance having combustion influence applied to its surface; and the effect of any combustion driven oscillation of the system as a whole; this can be a factor depending on the natural frequency of the structure as constructed by comparison with the natural frequency and amplitude of any combustion process occurring inside the combustion chamber 475.

Figure 42 to Figure 44 show slot and inter-port spacing dimensions adopted in the embodiments depicted in Figure 27 to Figure 41 generally, Figure 43 and Figure 44 particularly referring to Figure 33 and Figure 34. The dimensions of the ports are equal and have a length L of 6 mm and a width W of 0.5 mm. The ends of each slot are semicircular but more squarely ended slots are suitable. The chosen manufacturing process can influence the actual plan view shape of the slot. However, metal blanking such large numbers of holes can be difficult as regards maintaining good condition of such small punches if the corner radii are not rounded. The photochemical machining process of manufacture of plates 490 with slots 504 is adapted to also produce radiused cornered slots.

The discussion has so far assumed ports 502 that are either circular 503 or slot shaped 504. There is no reason that the invention be restricted to such shapes. Slots 504 may in fact, be formed as lines which can be curved or wavy. The quenching distance of such non straight lines fits our definition and thus is independent of length L so long as L>3W. For squares, pentagons, hexagons or other polygons, the quenching distance as we define it also applies.

The interport spacing illustrated in Figure 43 and Figure 44 performs the required confinement function in the previously described situation. The dimensions indicated in the Figure 43 and Figure 44 were as follows:

C, 4.5 mm; E, 3.7 mm; J, 1.85 mm; K, 1.6 mm; M, 1.4 mm and P, 3.7 mm.

As one example, the inlet plate 490 having the dimensions and spacing of slots 504 as indicated above and the pattern shown in Fig 33, during one testing procedure, allowed passage of fumes of spilled gasoline through the inlet plate 490 where they ignited inside the combustion chamber 475 and burned until 1 U.S. gallon was consumed. This was done without the outside surface temperature of the inlet plate 490 increasing at any point such as to ignite fumes which had not yet passed through the inlet plate, the test concluding when no more gasoline remained to be consumed after more than one hour of continuous burning on the plate 490.

We found by conducting experiments that interport spacing differences of 1.1 mm, 1.6 mm and 2.6 mm each gave satisfactory results. Our experiments led us to believe that interport spacings greater than 6 mm would be equally successful. However, close interport distances are preferred because the perforated area expressed as a percentage of the total area of an air inlet plate 490 is greater for closer interport distances, for example, with the slot dimensions already given of 0.5 mm wide by 6 mm long perforated area percentages are as follows:

Interport Distance mm	1	2	3	4
Perforated Area %	29	15.5	9.8	6.9

We found interport spacings of 0.5 mm having slot dimensions 0.5 mm x 6 mm to the Fig 4 pattern in 0.5 mm thickness plates 90 not to be as versatile to all possible situations.

Figure 46 depicts schematically an outline of a lower portion of a water heater 462 having an air inlet leading to a combustion chamber 475 including a plate 490 of the type or similar to those depicted in Figure 27 to Figure 41. Because of the small size of the ports 502 in plate 490 they could, in certain circumstances, be prone to block up or become clogged with lint or other foreign materials. Furthermore, being at a relatively inaccessible part of a water heater 462, an accumulation of lint may not be noticed since water heaters in general are usually not serviced regularly.

Accordingly, it can be desirable to provide an accessible, more noticeable lint filter 512 as now described. The inlet plate 490 is connected to an air entry duct 510 which turns at right angles and extends substantially horizontally to the front of a water heater 462 whereupon it again turns at right angles to extend upwardly to terminate any convenient distance above the floor level, about 60 cm to 100 cm or higher being suitable. Higher levels are preferred because generally airborne lint levels decrease with increasing height above floor level. The air entry duct 510 is nominally gas-tight (this term is amplified below) where it is terminated by the inlet plate 490 at one end portion and by a non-removable lint filter 512 facing the front of the heater 462 at an accessible height above floor level.

The lint filter 512 has many accessible small holes which can be circular, slotted or other shape, with no hole individually substantially larger in dimensions than the limiting distance as above defined of the ports (502,504) chosen in the particular air inlet plate 490 adopted. The total open area must at least exceed the total open area of the air inlet plate 490 so as not to add greater restriction to air flow than the inlet plate 490 itself. To this end, it is better if the lint filtering holes have in total a very much greater area for air flow than the ports (502, 504) in the air inlet plate 490 so that the total resistance to flow is minimised and, furthermore, the available area for lint interception is maximised. Most of the lint filtering holes are positioned ideally as far above the floor as possible to face the front of the heater so as to be accessible for cleaning routinely, ideally with a vacuum cleaner. A safety maintenance notice to occupiers of premises in which such water heaters or other gas consuming appliances benefiting from equivalent protection are installed, is ideally fixed adjacent to the face of the lint filter 512 to remind of the need for regular intervention to remove any apparent lint build-up.

The duct 110 was above described as nominally gas tight - it is not required to be fully gas tightly sealed, so long as its connection to the combustion chamber wall 86 meets the criterion of having no gap or crack exceeding the defined quenching distance for any feasible extraneous fume species (entering the air inlet) which is desired to be confined if ignited, within the combustion chamber 75.

Fig 29 shows in schematic cross-section one suitable connection between an air inlet plate 90 and lower wall 86 of a combustion chamber 75. We observed that prolonged combustion of a relatively large quantity of extraneous fumes on the inside surface of the plate 90 (e.g. such as would vaporise from the spill of one US gallon of gasoline), leads to intermittent heating to incandescence at various points around the inside surfaces various plates 90 tested. We observed as expected that heating to maximum incandescence of the plates 90 particularly correlates to extraneous fumes to air ratios close to the stoichiometric value for the particular extraneous fumes. The air inlet plate 90 in such circumstances acts like some types of perforated metal gas burners which function at red heat such as for broiling or grilling but, unlike any such burner of that type, the air inlet plate in this invention must be able to provide reliable confinement operation despite an uncontrollable and uncontrolled spectrum of flow rates of flammable fumes relative concentration in a mixture of air and the flammable fumes. With our air inlet plate 90, any pre-mixing of the air and extraneous fumes is incidental and random, unlike the uniform pre-mixing of air and fuel in a normally designed gas burner.

The form of construction shown in Figure 47 and Figure 48 shows two variants in which separated from its assembled position, an inlet plate 490 which has an unperforated border 501 which is assembled downwardly (as indicated by the dashed lines) in highly thermally conductive contact with a combustion chamber opening 487 formed, such as by piercing and extruding, a flanged border 514 defining an inwardly opening hole 487 into the combustion chamber 475. The compressive contact, can be achieved by metal to metal frictional contact involving mating flanges 514 and 501 or may include some form of gasket between the contacting faces of those flanges. Figure 47 shows a circular plate 490 which fits tightly inside the flanged border 514 around the extruded hole 487 in the combustion chamber wall 486. Figure 48 shows a rectangular plate 490 which fits tightly on the outside of the flanged border 514 around the mating hole 487 in the combustion chamber wall 486. It is optional whether either the circular or the four-sided variant mates inside or outside the flanged border.

While Figure 47 and Figure 48 show one method of affixing the air inlet plate 490 to the combustion chamber wall 486, a second method is illustrated in Figure 83, Figure 84 and Figure 85 which show another arrangement to suitably fix or seal the two components. It is intended that the air inlet 490 be substantially sealed against combustion chamber wall 486 to prevent air and or extraneous fumes passing between the surfaces of air inlet 490 and combustion chamber wall 486. Air inlet plate 490 has an outer flange 601 that extends beyond the edge of the opening in combustion chamber wall 486. periodically, along flange 601, mechanical crimps 602 are pressed into flange 601 and corresponding portion of combustion chamber wall 486. Such crimps 603 are well known in the sheet metal art as TOG-L-LOC® being a particular preferred example. Other means of securing or fixing air inlet plate 490 to combustion chamber wall 486 are possible, spot welding being one of them.

Figure 49 to Figure 52 illustrate a rectangular inlet plate 490 including a perforated central portion 505 bounded by a non-perforated portion 501 which is formed to include a peripheral channel 516. The peripheral channel 516 is shaped to enable the inlet plate 490 tightly engage, or otherwise to snap into a mating connection 518 (Figure 52) formed around an opening 487 in the base 486 of the combustion chamber 475. The combustion chamber 475 with inlet plate 490 fitted is enclosed at the top by a mating connection to or adjacent the outside periphery of the curved base of the tank 466 of a water heater 462 and so forms a closed combustion chamber 475. Those potential sources of ignition of extraneous fumes forming part of a water heater burners 473 and 474 are enclosed by location in the combustion chamber 475. The combustion chamber walls 479 support the mass of a water tank 466. The peripheral channel 516 in the inlet plate 490 and the mating peripheral groove 518 surrounding the opening 487 in the base of the combustion chamber 475 frictionally engage to nominally sealed standard as explained above. The groove 518 can function as a dam to exclude condensed moisture accumulating on the base 486 of the combustion chamber 475 from spreading across the perforated areas 505 of the plate 490.

Figure 53 to Figure 55 schematically show alternative forms of profiled ports on a portion of air inlet plate. The ports (slots in Figure 54) can provide a more streamlined flow profile through them and can provide a convenient "valley" matrix in which to position viscous form(s) of intumescent swellable coating 536. The application of intumescent swellable coating 536 to this invention will be described subsequently in relation to Figure 62 to Figure 64.

In relation to all the forms of inlet plate 490 so far illustrated, it is of concern that an initial ignition of flammable extraneous fumes inside the combustion chamber 475 as a sudden energetic detonation be minimised. Otherwise, there might theoretically be a risk of blowing a flame front back through the ports 502, 504 of the inlet plate 490. Forms of water heater 462 shown schematically in Figure 56 to Figure 58 particularly address this concern.

In Figure 56, the entire base 486 of the combustion chamber is positioned at the top of a drawn wall 525 of the combustion chamber 475, the lowest perimeter of the combustion chamber providing a support which rests on a support pan 528 which in turn is supported above floor level on feet 484. The base 486 of the combustion chamber 475 and the inlet plate 490 are co-planar or approximately so and, by virtue of the described structure position the inlet plate 490 as close as possible to the burners 473, 474.

In Figure 57, the main burner 474 is conventionally positioned but the pilot burner 473 is positioned immediately above the inlet plate 490 upper surface. This provides opportunity for a more immediate ignition of extraneous fumes entering the combustion chamber 475 through the inlet plate ports 502, 504 and, thereby, substantially increases the probability that only a very small quantity of extraneous fumes would be in the combustion chamber 475 when ignition first occurs. Such a small volume of extraneous fumes, if ignited, is likely to burn with a relatively low energy of initial ignition prior to establishment of a continuous flame upon the upper surface of the inlet plate 490. In order to ensure reliable ignition of the main burner 474 of a water heater during normal operation, when the pilot burner is positioned particularly closely adjacent to the inlet plate as shown in Figure 58, a flash tube 530 is provided leading from the pilot burner 473 up to the level of emission of the gaseous fuel from the main burner 474 to facilitate the frequent re-ignition of the main burner 474 from the pilot burner 473 during normal use of a water heater 462.

In order to avoid the development of high sound pressures various predeterminable design parameters can be chosen or operating conditions influenced to minimise undesirable effects. If a design is prone to excessive sound level generation, then changes to that design to lessen the tendency include the reduction of temperature of the plate 490, changes to the length of the flue pipe 470, the spacing of ports 502 and the thickness of the air inlet plate 490, embossments to stiffen the air inlet plate 490 and gasket placement between the plate 90 and combustion chamber lower wall 486, as will be described.

Figure 59 to Figure 61 show arrangements to terminate prolonged combustion on a plate 490 for use in those instances in which it is desirable to extinguish that combustion quickly rather than allow it to draw remaining spilled extraneous fumes to consume them by combustion. Figure 59 depicts a portion of air inlet plate 490 covered by a thin layer 532 of solder which has matching ports 533 to those in the plate 490. When this layer 532 is heated by extraneous fumes burning on the inside of the combustion chamber 475, the heated solder layer 532 liquefies and spreads to block or tend to block the adjacent slot or slots 504. The plate 490 may be also formed with surfaces converging toward each slot 504, allowing the liquefied solder to more readily block each slot.

Because of the small dimensions of the slots 504 the solder bridges them by capillary action by virtue of its surface tension,. so occluding them fully or, at least partially. Partial occlusion is desirable even if full occlusion is not achieved since any reduction of port cross-section area under the circumstances tends to destabilise the flames, thereby increasing the probability of extinguishing them quickly. To further assist the flow of solder 532 the surface of the plate 490 can be pre-treated with a fluxing agent such as widely known in soldering techniques.

At times when the inlet plate 490 admits a near stoichiometric mixture of air and extraneous fumes, particularly over a prolonged period, then the temperature of the inlet plate 490 caused by combustion of that mixture inevitably increases. We discovered that upon a sufficient increase in the temperature of the inlet, a harmonic resonant sound may be generated by various complex thermal effects including that known as the Rijke tube effect. In certain embodiments of the invention, we discovered that these effects cause energetic sound waves to be produced in the combustion chamber 475, most noticeable when combusting at around 100% aeration. This can build to sound at a high level at a frequency or frequencies, usually in a frequency range about 80-250 Hz during operation, continuing until such time as the gas to air mixture changes sufficiently away from the stoichiometric value or burning conditions otherwise change.

With reference to Figure 62 to Figure 64 a portion of inlet plate 490 is shown in cross-section having a solid matrix separated by ports 102. Closely positioned above the upper surface of the inlet plate 490 is a sensor 494 applicable to all variants of the present invention, being adapted to shut off the gas supply to the main burner 474 and pilot burner 473 if a flame becomes established on the upper surface of the inlet plate 490. In the inlet plate 490 shown in Figure to Figure 64 an intumescent ablative coating 536 has been applied to cover the solid matrix of the inlet plate, leaving (in Figure 62) the ports 502 unobstructed. As shown in Figure 63, if extraneous fumes enter through the ports 490, and form a combustible mixture in the combustion chamber 475, the main burner 474 or pilot burner 473 (as shown in Figure 24, positioned typically 5 - 10 cm above the inlet plate) would establish ignition of the extraneous fumes as flames 537 on the upper surface of the inlet plate 490. The sensor 494 then reacts quickly to cause shut-off of gas to the main and pilot burners (474, 473).

Combustion on the plate 490 most likely continues and the flames 537 cause the temperature of the inlet plate 490 as a whole to rise and at a temperature appropriate to the intumescent coating selected, the coating 536 softens and reacts, to swell to numerous times its original volume (Figure 64), thereby occluding the ports 502 of the inlet plate 490. Such occlusion has the effect of excluding the extraneous fumes and air so combustion on the inlet plate 300 quickly ceases. No further possibility then exists of igniting extraneous fumes inside or outside the combustion chamber 475 without replacing the plate 490. Suitable intumescent/ablative coatings include "FIRETEX" "M70/71" (basecoat/top seal intumescent fire retardant coating, manufactured by Fyreguard); and "FIREDAM 2000" intumescent coating supplied by 3M. A coating thickness of about 200µm on a SCHWANK® tile or plate of the types shown in Figure 55, Figure 54 and Figure 55, is suitable and a lesser thickness about 100µm, is more appropriate for a flat or substantially flat perforated metal sheet type inlet plate 490 as illustrated in Figure 62 to Figure 64.

Figure 65 to Figure 70 show a series of devices in which a prolonged combustion incident inside a combustion chamber 475 can be more quickly extinguished. Mounted to the inlet plate 540 is a sliding plate 541 which has ports 502 of corresponding size, patterns and orientation to the ports 502 in the fixed inlet plate 540. Figure 66 shows alignment of the ports 502 to provide a through passage for air and extraneous fumes to pass. The sliding plate 541 is biased to the position shown in Figure 66 by one or more spring(s) 543, which as depicted in Figure 65 can be tension spring(s) 543. The sliding plate 541 is locked into one location by a solder or thermoplastics pin 544, tension being applied to the spring 543. The sliding plate 541 can move by sliding relative to the fixed plate 540, guided in a restricted path by sealed rivets 542 which are secured leak tightly to the fixed plate 540 and which are a sliding fit into a pair of guide slots in the sliding plate 541.

In the event that extraneous fumes pass through the fixed inlet plate 540 and sliding plate 541, the extraneous fumes with an appropriate air mixture would be ignited by either the pilot 473 or main burner 474 of the water heater 462. Following a short period of burning, the sliding plate 541 would heat to a temperature sufficient to melt the solder or thermoplastics pin 544 whereupon the force applied by the spring 543 would move the sliding plate 541 in the direction of the arrow. The guide slot(s) can only be long enough to allow unperforated parts of sliding plate 541 to align with the ports 502 in fixed plate 540 or, as an alternative, the slots 502 can be longer but two stops 146 can be provided to limit the travel of the sliding plate 541 over the fixed plate 540 and, either way, as shown in Figure 67, result in the closure of all the ports 502 thus extinguishing any further combustion.

To reopen the combustion chamber 475 after an episode of ignition of extraneous fumes, the sliding plate 541 is held against the bias provided by the spring 543 while placing a replacement solder or thermoplastics pin 544 into the aligned holes provided for the purpose through the plates 540, 541. The air inlet 490 would then be functional again to allow normal combustion air flow but to cut off air and extraneous fumes if needed.

In a suggested variation of the inlet cut-off of Figure 65 to Figure 67, the solder or thermoplastics pin can be replaced by a thin layer of solder between the plates. This layer of solder creates a laminate of the two metal plates sandwiching the solder, being also provided with ports aligned initially through all three layers of the laminate. Connection of the sliding plate to a spring could be provided as shown in Figure 65 or equivalent. This variation has advantages including that the solder facilitates relative sliding between the plates once the solder liquefies due to heat input. Moreover, its ability to exclude extraneous fumes from finding a leakage access between the plates is an advantage. The sliding plates shown in Figure 65 to Figure 67 could be susceptible to seizure in their open position in the likely event of only extremely rarely being activated and, to move, any friction between them must be overcome. This suggested variation having a laminate of solder between slidable plates will not seize and once the solder liquefies, will slide freely.

Figure 68 to Figure 70 show a similar occluding mechanism to those of Figure 65 to Figure 67, although in this case the cut-off of air entry is by relative rotation between the plates rather than linear movement.

Figure 68 shows a circular inlet plate like that illustrated in Figure 25. Overlying the fixed plate 540 is a rotary plate 541 with ports 545 aligning with ports 502 in fixed plate during normal use, as shown in the cross section of Figure 69. Secured to the fixed plate 540 is one end of a spindle 149, which carries, at its other end, one end of a bimetallic torsion spring 548 which in turn, at its other end, is attached to the rotary plate, by a pin 550. Upon heating of the bimetallic torsion spring 548 by the burning of extraneous fumes at the ports 545 the bimetallic torsion spring 548 rotates the rotating plate 541 relative to the fixed plate 540. Appropriate stops between the two plates 540, 541, are provided to enable the respective ports 502 and 547 to remain out of mutual alignment, as shown in Figure 70.

Upon cooling of the bimetallic torsion spring 548, the rotating plate 541 returns to its original position bringing the ports 502, 545 in both plates into alignment again, ready to allow air to pass through to enable combustion and to allow extraneous fumes if present, to pass through.

Figure 68 to Figure 70 features can be combined, such as the bimetallic torsion spring 548 being replaced by a coil spring or other spring, and the plates 540, 541 being held in register (to allow air to pass) by a solder or thermoplastics plug 544 or a layer of solder between them, in each case relying on heat to melt the solder or thermoplastics, so allowing the spring force to rotate the rotating plate 541 relative to the fixed plate 540 to shut off combustion of extraneous fumes in the combustion chamber 475.

Inlet plates of the invention which have ports solely in the shape of slots 504 allow flames burning extraneous fumes inside the combustion chamber 475 to lift further off the air inlet plate 490 and thereby reduce the operating temperature of the air inlet plate 490 as compared to a plate of the same material and thickness having circular holes 503. Therefore, a plate 490 with slots 504 can consume more spilled substance over a longer combustion period, than can a plate 490 with holes 503 having an equivalent Quenching distance. Also, slots 104 enable lint passage more readily than holes of equivalent quenching distance.

Figure 71 shows two additional provisions possible to incorporate, so enhancing the likelihood of a safe outcome following a flammable substance spillage incident near a gas water heater having an air inlet 490 according to the invention. Either provision may be included separately or together.

The first provision is an audible alarm 558 which operates in the event of a flame becoming established in the combustion chamber 475 at or adjacent the inside surface of the air inlet plate 490. The alarm 558 can be actuated by a number of energy sources, one being an enclosed metallic bulb 555 containing a volatile substance which expands when heated, the bulb 555 being connected to the alarm by a small bore tube. The tube is sealed by a frangible diaphragm that bursts to vent the volatile substance through a whistle or similar audible device included in the alarm 558.

The second provision is a cooling device including a spray nozzle 556 positioned and aligned capable of directing a fine spray of water 557 at the perforated area of the air inlet plate 490. The water 557 is sourced from the mains pressurised cold water supplied to the tank through a pipe 551, diverted therefrom by a branch pipe 552 through a valve 553, the outlet of which is connected to the spray nozzle 556. The valve 553 is biased in a normally closed position and is opened to allow passage of water through the valve by lateral admission of a pressurised fluid via a small bore tube 154. The pressurised fluid is in turn sourced from the temperature sensitive element 555 on any such occasion that it is heated by flame arising from combustion of extraneous fumes on the inside surface of the air inlet plate 490. Other flame extinguishing substances such as compressed carbon dioxide may be suitable and can be released using generated heat to similarly open an appropriate escape path.

Figure 73 to Figure 75 shows the possibility of forming the ports 502 in plates 490 of the invention having not only a parallel sided cross-section, as shown in Figure 72, which can be readily formed by any of the processes previously mentioned. Ports 502 can be used, which in cross-section have both convergent and divergent shapes. The photochemical machining process lends itself to forming holes with convergent or divergent shapes as illustrated in Figure 473, Figure 74 and Figure 75.

Figure 73 shows a hole 563 or slot 565 which converges from a larger dimension at the upstream face (i.e. the lower side, as illustrated) of the air inlet plate 490. Air and, if present, extraneous fumes, passes through the tapering hole 563 or tapering slot 565 in a downstream direction indicated by the two vertical arrows into the combustion chamber 475. The hole 563 or slot 565 as illustrated in Figure 73 converges in an upstream direction firstly but then terminates with substantially parallel sides

Figure 74 shows a tapered hole 567 or tapered slot 569 which converges to a throat of minimum cross-sectional area between the upstream and downstream faces of the air inlet plate 490 which tends to provide minimum drag for a given limiting dimension of the port 567, 569. By this technique the air inlet plate 490 can provide an optimised combination of maintaining restriction to air flow within workable bounds with ability to confine combustion inside the combustion chamber 475 for as long a time as necessary.

Figure 75 shows a tapering hole 571 or tapering slot 573 in which air for combustion passing through the air inlet plate 490 in the direction of the vertical arrows into the combustion chamber 475 first passes through a divergent portion which then converges such that the intersection of the port 571, 573 intersects with the inside (upper) surface of the plate 490 at an angle somewhat less than 490°. The very sharp edged orifice so formed at the inside surface of the air inlet plate 490 may function as a flame lift promoter so that combustion of extraneous fumes occurring near the inside surface of the plate 490 is encouraged to lift flames away from that surface, with the effect of causing the plate to remain cooler during prolonged burning or, even more preferably, to cause the flame to lift-off entirely and extinguish. The tapered ports of Figure 73, Figure 74 or Figure 75 can be formed by applying higher concentration of etchant solution to one side of the metal sheet from which the air inlet plate 490 is constructed, until the ports are perforated to the required shape.

With reference to Figure 77, the air inlet plate 490 with perforations 504 is provided with diagonal cross-breaking lines 580 which can provide the plate 490 with additional stiffness in order to change the natural frequency of the combination of the combustion chamber 475 and connected air inlet plate 490 to move that natural frequency away from a frequency of combustion process which may occur if extraneous fumes entering the air inlet chamber become ignited inside the combustion chamber 475. Depending on the frequency of combustion encountered for a particular design of water heater, the stiffened structure shown in Figure 77 may be even more efficient than a corresponding flat air inlet plate 490 as illustrated in Figure 58.

In Figure 81 an air inlet plate 490 having slots 504 is shown having stiffening members extending at 90° to each edge of the plate 490. In the case of Figure 51, the central perforated area as shown in Fig 35 is altered by deleting a suitable number of rows of slots followed by the forming of one or more rounded channels 582 extending in one or more directions across the unperforated portions of the perforated area 500 of the plate 490. The stiffening of the plate 490 and the dividing of it into a number of smaller separated perforated areas by the rounded channels 582 causes both a change in the natural frequency of mechanical vibration of the structure of the combustion chamber in a particular water heater 462 with the air inlet plate 490 fitted and also changes the acoustic frequency of any combustion process that occurs at the air inlet plate 490 as a result of extraneous fumes entering the combustion chamber 475 and igniting. Thus the incorporation of a perforated plate 490 as illustrated in Fig 81 can be beneficial in providing an increased level of safety for a water heater of this invention. Any troublesome resonance during combustion can be reduced or prevented by stressing the base 486 of the combustion chamber 475 to change the natural frequency of the structure as a whole. One approach to make the structure effectively immune to troublesome acoustic related problems is as shown in Fig 82, in which the air inlet plate 490 mounted to the base 486 of the combustion chamber is separated from the support pan 528 by compressing a batt 584 of fibrous heat insulation such as, KAOWOOL (registered trade mark) and, adjacent the perimeter of the air inlet plate 490, a loop or, alternatively, for a rectangular shaped air inlet plate 490, two to four lengths, of fibreglass rope 586 under additional compression. This is one alternative form of rigidising and muffling which particularly effectively enables damping of combustion induced oscillation from exciting vibration of the water heater structure, further enhancing effectiveness.

It is to be understood that the invention disclosed and defined herein extends to all alternative combinations of two or more of the individual features mentioned or evident from the text or drawings. All of these different combinations constitute various alternative aspects of the invention.

The foregoing describes embodiments of the present invention and modifications, obvious to those skilled in the art, can be made to them without departing from the scope of the present invention.

Claims

1. A water heater including:

(a) a water container;

(b) a combustion chamber located adjacent said container;

(c) a burner located inside said combustion chamber;

(d) at least one inlet positioned at an opening in said combustion chamber, said inlet permitting ingress of admit air and extraneous fume species into said combustion chamber and prevent egress of flames from said water heater

2. A water heater as claimed in claim 1 wherein said air inlet is or includes a flame arrestor positioned at said opening in said combustion chamber to block ingress of admit air and extraneous fume species when the temperature in said combustion chamber adjacent said flame trap exceeds a predetermined temperature.

3. A water heater as claimed in claim 1 or 2 further including a blocking plate positioned within said combustion chamber and spaced above said opening.

4. A water heater as claimed in any one of claims 1 to 3 further including a heat sensor positioned within said combustion chamber and adjacent said flame trap and capable of shutting off fuel to said burner when said the temperature in said combustion chamber adjacent said flame trap exceeds said predetermined temperature.

5. A water heater as claimed in claim 2, wherein said flame arrestor includes a blocking plate supported by at least one leg formed from a temperature sensitive fusible material adapted to melt when said predetermined temperature is exceeded, thereby permitting said blocking plate to move toward and over said opening.

6. A water heater as claimed in claim 5, wherein said temperature sensitive fusible material is a thermoplastic.

7. A water heater as claimed in claim 6, wherein said thermoplastic is low density polyethylene.

8. A water heater as claimed in any one of claims 5 to 7, wherein said fusible material has a melting temperature of about 100 °C to 200 °C.

9. A water heater as claimed in any one of claims 1 to 8, wherein said water heater includes a flame arrestor positioned at said opening and adapted to direct a flame extinguishing substance toward a surface of said flame trap in said combustion chamber.

10. A water heater as claimed in claim 9, wherein said flame arrestor includes a container having at least one nozzle and contains said flame extinguishing substance.

11. A water heater as claimed in claim 10, wherein said at least one nozzle contains a plug made from a fusible material that maintains said flame extinguishing substance inside said container unless the temperature in said combustion chamber adjacent said flame trap exceeds a predetermined temperature.

12. A water heater as claimed in claim 11, wherein said fusible material has a melting temperature of about 150°C to 300°C.

13. A water heater as claimed in any one of claims 9 to 12, wherein said flame extinguishing substance is selected from the group consisting of sodium bicarbonate and fire blanketing foams mixed with a propellant.

14. A water heater as claimed in claim 13 where in said fire blanketing foams mixed with a propellant are

activated when the temperature adjacent said flame trap is 300 °C -500°C.

15. A water heater as claimed in any one of claims 10 to 12, wherein said container has two nozzles extending from opposite end portions thereof, each nozzle being directed to opposing edge portions of said flame trap.

16. A water heater as claimed in claim 1, wherein said at least one inlet having a plurality of ports, each port having a limiting dimension less than a minimum quenching distance applicable to said extraneous fume species, thereby confining ignition and combustion of said extraneous fume species within said combustion chamber.

17. A water heater as claimed in claim 1, wherein said at least one inlet having a plurality of ports, each said port having a quenching distance not larger than about 0.6 mm, being thereby able to confine ignition and combustion of said extraneous fume species within said combustion chamber.

18. A water heater as claimed in claim 16 or 17, wherein said inlet is constructed such that peak natural frequencies of vibration of said inlet in combination with said combustion chamber structure are different from peak frequencies generated by an extraneous fume combustion process on the inlet within the combustion chamber.

19. A water heater as claimed in any one of claims 16 to 18, wherein during combustion of said extraneous fume species over a prolonged period, a surface of said at least one inlet located outside of said combustion chamber remains sufficiently cool so as to prevent heating the extraneous fume species and air with it before it passes through said at least one inlet to a temperature above an ignition temperature of said extraneous fumes species and air.

20. A water heater as claimed in any one of claims 16 to 19, wherein said ports are spaced apart on said at least one inlet by a distance which enables the temperature of mixtures of extraneous fume species with air adjacent to the surface of the walls of said ports to remain below the ignition temperature of said mixtures.

21. A water heater as claimed in any one of claims 16 to 20, wherein said ports are spaced apart from each other so that a closest point between boundaries of adjacent ports is a distance of no less than about 1.1 mm.

22. A water heater as claimed in any one of claims 16 to 21, wherein at least one of said ports is adjacent a pilot burner associated with said combustion chamber to ignite said extraneous fumes as they pass into said combustion chamber and before there is a potentially explosive accumulation of fumes in said combustion chamber.

23. A water heater as claimed in any one of claims 16 to 22, wherein said ports include slots and wherein said limiting dimension is the width of said slots.

24. A water heater as claimed in any one of claims 16 to 23, wherein said ports include slots which have an L/W ratio of between about 2 to about 15, wherein L is the length of said slots and W is the width of said slots

25. A water heater as claimed in any one of claims 16 to 24, wherein the shortest distance between adjacent ports is substantially the same.

26. A water heater as claimed in any one of claims 16 to 25, wherein said ports are arranged in rows.

27. A water heater as claimed in claim 26, wherein a first port in every alternate row has its location offset with respect to a port of an adjacent row.

28. A water heater as claimed in claim 1, wherein said ports are slots arranged in rows, with at least one peripheral row of said at least one inlet including slots arranged parallel to each other and which have their

longitudinal axes at an angle of about 90° the orientation of each of the longitudinal axes of slots in other rows.

29. A water heater as claimed in any one of claims 26 to 29, wherein one of said rows is a peripheral row having a larger interport spacing than others of said rows.

30. A water heater as claimed in claim 1 or any one of claims 16 to 24, or any one of claims 30 to 33, wherein said at least one inlet is constructed from a sheet material and said ports are elongated and spaced apart, said ports being arranged so that there are at least two regions of ports, an inner region which is included of a group of said ports, and an outer region which is included of the remainder of said ports, said outer region having an interport spacing between adjacent ports which is greater than the interport spacing of said ports in said inner region.

31. A water heater as claimed in any one of claims 16 to 30, wherein said ports are slots about 0.5 mm in width.

32. A water heater as claimed in any one of claims 16 to 30, wherein said ports are circular holes about 0.5 mm in diameter.

33. A water heater as claimed in any one of claims 1 to 32, wherein said water heater emits an audible signal when said extraneous fumes pass through said at least one inlet and are burning inside said combustion chamber.

34. A water heater as claimed in any one of claims 1 to 33, wherein an audible signal is produced by the action of said extraneous fumes burning near to said at least one inlet, inside of said combustion chamber.

35. A water heater as claimed in any one of claims 16 to 34, wherein said ports are formed in a metal plate by photochemical machining.

36. A water heater as claimed in any one of claims 1 to 35, wherein said combustion chamber is formed with a surrounding skirt having an end cap joined at one end thereof, with another end of said surrounding skirt being a surface of said combustion chamber.

37. A water heater as claimed in claim 36, wherein an enclosure which encloses said container also forms both of said surrounding skirt and said end cap.

38. A water heater as claimed in claim 36, wherein said surrounding skirt and said end cap are formed separate from an enclosure which encloses said container and said combustion chamber.

39. A water heater as claimed in any one of claims 1 to 38, wherein said water heater includes an outlet spaced apart from said at least one inlet allowing products of combustion to exit said combustion chamber.

40. A water heater as claimed in any one of claims 1 to 39, wherein each said at least one inlet includes a plate having said plurality of ports.

41. A water heater as claimed in claim 40, wherein said plate is made of metal.

42. A water heater as claimed in claim 40, wherein said plate is 0.4 mm to 1 mm in thickness.

43. A water heater as claimed in any one of claims 1 to 42, wherein said at least one inlet has a heat dissipation region at its periphery.

44. A water heater as claimed in claim 43, wherein the heat dissipation region includes a metal to metal overlap portion between a peripheral edge of a plate forming said at least one inlet and a peripheral edge of an opening in the combustion chamber.

45. A water heater as claimed in claim 40, wherein said plate includes a skirt;

said combustion chamber has an opening which sealingly receives said plate, said opening having a surrounding skirt; and

said skirts are sized so that inwardly facing surfaces of said skirt of said plate engage outwardly facing surfaces of said surrounding skirt.

46. A water heater as claimed in claim 40, wherein said plate includes a skirt;

said combustion chamber has an opening which sealingly receives said plate, said opening having a surrounding skirt; and

said skirts are sized so that outwardly facing surfaces of said skirt of said plate engage inwardly facing surfaces of said surrounding skirt.

47. A water heater as claimed in claim 43, wherein the heat dissipation region includes an additional surface area in the form of at least one fin extending from the inlet.

48. A water heater as claimed in claim 43, wherein the heat dissipation region includes an increased interport spacing adjacent said periphery.

49. A water heater as claimed in claim 40, wherein the plate is a ferrous based material about 0.5 mm thick.

50. A water heater as claimed in claim 49, wherein an interport spacing of the ports adjacent a peripheral portion of the ports in said plate is in the range of about 2 mm to 4 mm and the interport spacing of remaining ports is in the range of about 1 mm to 1.5 mm.

51. A water heater as claimed in any one of claim 1 to 53, wherein edge portions of the ports have flame lift promoters.

52. A water heater as claimed in claim 51, wherein the flame lift promoters are sharp edges at upstream extremities of the ports.

53. A water heater as claimed in claim 51, wherein the flame lift promoters have undercut cross-sectional profiles wherein the intersection of the ports with at least an inside surface of the plate is an angle of less than 90°.

54. A water heater as claimed in any one of claims 1 to 53, wherein the ports are constructed so that in cross-section, said ports have substantially parallel sides.

55. A water heater as claimed in any one of claims 1 to 53, wherein the ports are constructed so that in cross-section said ports have sides which converge.

56. A water heater as claimed in claim 55, wherein said ports converge in an upstream direction.

57. A water heater as claimed in claim 56, wherein said ports terminate with substantially parallel sides.

58. A water heater as claimed in any one of claims 1 to 57, wherein the ports are slot shaped and not more than about 0.6 mm wide and spaced apart from each other at least about 1mm.

59. A water heater as claimed in any one of claims 1 to 58, wherein the ports include peripheral extrusions extending inwardly into the combustion chamber to act as flame lift promoters.

60. A water heater as claimed in any one of claims 1 to 6359 wherein the ports are formed in a plate in a pattern, said pattern acting as a flame lift promoter.

61. A water heater as claimed in claim 60, wherein the ports are arranged in a pattern including solely

apertures in the form of an aligned and spaced array of slots.

62. A water heater as claimed in claim 61, wherein there is a first pattern of slots in a centre portion of said inlet and a second pattern of slots at a peripheral portion, with said second pattern including a larger interport distance than said first pattern.

63. A water heater as claimed in any one of claims 1 to 62, wherein the ports are arranged in a radial pattern.

64. A water heater as claimed in any one of claims 1 to 62, wherein the ports are arranged in a circumferential pattern.

65. A water heater as claimed in any one of claims 1 to 64, wherein said at least one inlet further includes a cooling mechanism.

66. A water heater as claimed in claim 65, wherein said cooling mechanism includes a water applicator for said inlet.

67. A water heater as claimed in any one of claims 51 to 53, wherein said flame lift promoters are interport spacings of at least about 3 mm.

68. A water heater as claimed in any one of claims 1 to 67, wherein said inlet is constructed such that the peak resonant frequencies of said inlet are different from peak resonant frequencies of a combination of said combustion chamber and an exhaust gas flow path when extraneous fumes are being combusted at the inlet.

69. A water heater as claimed in claim 43, wherein the heat dissipation region includes an additional surface area in the form of at least one fin extending from the combustion chamber.

70. A water heater as claimed in claim 69, wherein the water applicator directs water to a face of the inlet external to the combustion chamber.

71. A water heater as claimed in any one of claims 1 to 70, wherein the ports are formed with cross-sections which, within a single port, both converge and diverge.

72. A water heater as claimed in any one of claims 40 to 42, wherein the metal plate is deformed from a flat form to include stiffening members extending across at least a portion containing said plurality of ports.

73. A water heater as claimed in claim 72, wherein said stiffening members intersect with ports.

74. A water heater as claimed in any one of claims 40 to 42, wherein the metal plate is deformed from a flat form to include stiffening members extending across unported portions which subdivide said plurality of ports into an integral number of sub-portions.

75. A water heater as claimed in any one of claims 1 to 23, wherein said air inlet is formed from a ceramic material having a thickness of about 12 mm or more and having openings of about 36.5 to 73 openings per square centimetre and wherein said openings include about 64% to 80% of the surfaces of said air inlet.

76. A water heater as claimed in claim 75, wherein said ceramic material is extruded.

77. A water heater as claimed in claim 75 or 76, wherein said openings are square.

78. A water heater as claimed in any one of claims 75 or 76, wherein said air inlet has its plurality of ports including slots having an L/W ration of between about 3 to about 20, wherein L is the length of said slots and W is the width of said slots.

79. A water heater as claimed in any one of claims 75 or 76, wherein said ports are circular holes having a quenching distance which is a diameter of about 1.1 mm to 1.3mm.

80. A water heater as claimed in claim 44, wherein the plate includes a ceramic plate having a thickness in the range about 9 mm to 12 mm and ports in the range of about 1.1 mm to 1.3 mm diameter.

81. A water heater as claimed in any one of claims 1 to 23, wherein said air inlet includes two layers of woven metal mesh arranged to be in contact with each other over substantially all of their respective contacting surfaces and being formed in a non-planar orientation to facilitate substantially even layer contact during expansion and contraction.

82. A water heater as claimed in claim 81, wherein said layers are dome-shaped.

83. A water heater as claimed in claim 81 or 82, wherein said at least one inlet comprises a woven metal mesh having transverse wires of thickness about 0.2 to 0.5 millimetres defining a plurality of ports, each said port having a quenching distance equal to the greater of the side lengths of four-sided open areas between said wires and in a range of about 0.3 to 0.5 mm, being thereby able to confine ignition and combustion of said extraneous fume species within said combustion chamber.

84. A water heater as claimed in claim 36, wherein said another end of said surrounding skirt abuts a surface of said water container to form an upper wall of said combustion chamber.

85. A control valve for supplying fuel to a water heater containing a main burner and a pilot burner including:

a fuel inlet adapted to connect to a supply of fuel;

at least one fuel outlet adapted to connect to the main burner;

a conduit for fuel flow between the inlet and outlet;

a closure associated with the conduit to control flow of fuel from the inlet to the outlet;

a circuit associated with the valve and including a thermally actuated device associated with the closure, said device, when heated by the pilot burner providing a signal to the closure to open or close the closure; and

a combustion sensitive fuse connected to the circuit and positioned to be exposed to extraneous sources of flame and/or heat external to and adjacent the control valve.

86. The control valve defined in Claim 85 further including an externally accessible socket in the circuit into which the fuse is removably insertable.

87. The control valve defined in Claim 85 or 86, wherein the socket is adapted to receive the fuse independently separate from the thermally actuated device.

88. The control valve defined in any one of Claims 85 to 87, wherein the socket is accessible from an underside of the valve.

89. The control valve defined in any one of Claims 85 to 88. wherein the fuse is positioned at an underside of the valve.

90. The control valve defined in any one of Claims 85 to 89, wherein the closure includes a member located in a portion of the conduit and is normally resiliently biased in a closed position.

91. The control valve defined in any one of Claims 85 to 90, wherein the circuit further includes a solenoid associated with the closure, the solenoid being capable of receiving an electrical signal from the thermally actuated device and opening said closure in response.

92. The control valve defined in any one of Claims 85 to 91, wherein the fuse is temperature sensitive.

93. The control valve defined in any one of Claims 85 to 92, wherein the circuit further includes an over temperature energy cut out switch associated with a temperature sensitive thermostat probe, said energy cut out switch being capable of interrupting gas flow through said control valve to the main burner and the pilot burner.

94. The control valve defined in any one of Claims 85 to 93, wherein the thermally actuated device is a thermocouple.

95. The control valve defined in any one of Claims 85 to 94, wherein the circuit further includes a manual switch connected to the thermally actuated device and having on, off and pilot positions, said pilot position causing the closure to open until such time as the thermally actuated device is capable of providing a signal to open the closure.

96. A control valve as claimed in any one of claims 85 to 95, wherein closure includes a member located in a portion of the conduit and which is normally resiliently biased in a closed position.

97. A control valve as claimed in any one of claims 85 to 96, wherein said circuit associated with the valve includes a solenoid associated with the closure, the solenoid being capable of receiving output from the thermocouple and maintaining open said closure in response to output indicative of a flame at said pilot burner.

98. A control valve as claimed in any one of claims 85 to 97 including an energy cut out switch associated with a temperature sensitive thermostat, the energy cut out switch being associated with a temperature sensitive thermostat probe, said energy cut out switch being capable of interrupting gas flow through said control valve to the main burner and the pilot burner.;

99. A control valve as claimed in any one of claims 85 top 98, wherein there is included a combustion sensitive fuse connected to the control valve circuit and positioned to be exposed to extraneous sources of flame and/or heat external to and adjacent the control valve.

100. A water heater as claimed in nay one of claims 1 to 84 including a control valve as claimed in any one of claims 85 to 93.

101. A water heater as claimed in any one of claims 1 to 84 or 100, wherein said at least one inlet is positioned below and adjacent said pilot burner.

102. A water heater as claimed in claim 100 further including a venturi extending into said combustion chamber to supply combustion air to said main burner.

103. A water heater as claimed in any one of claims 1 to 84 or 100 to 102 further including a lint trap positioned exteriorly of said at least one inlet and across said opening.

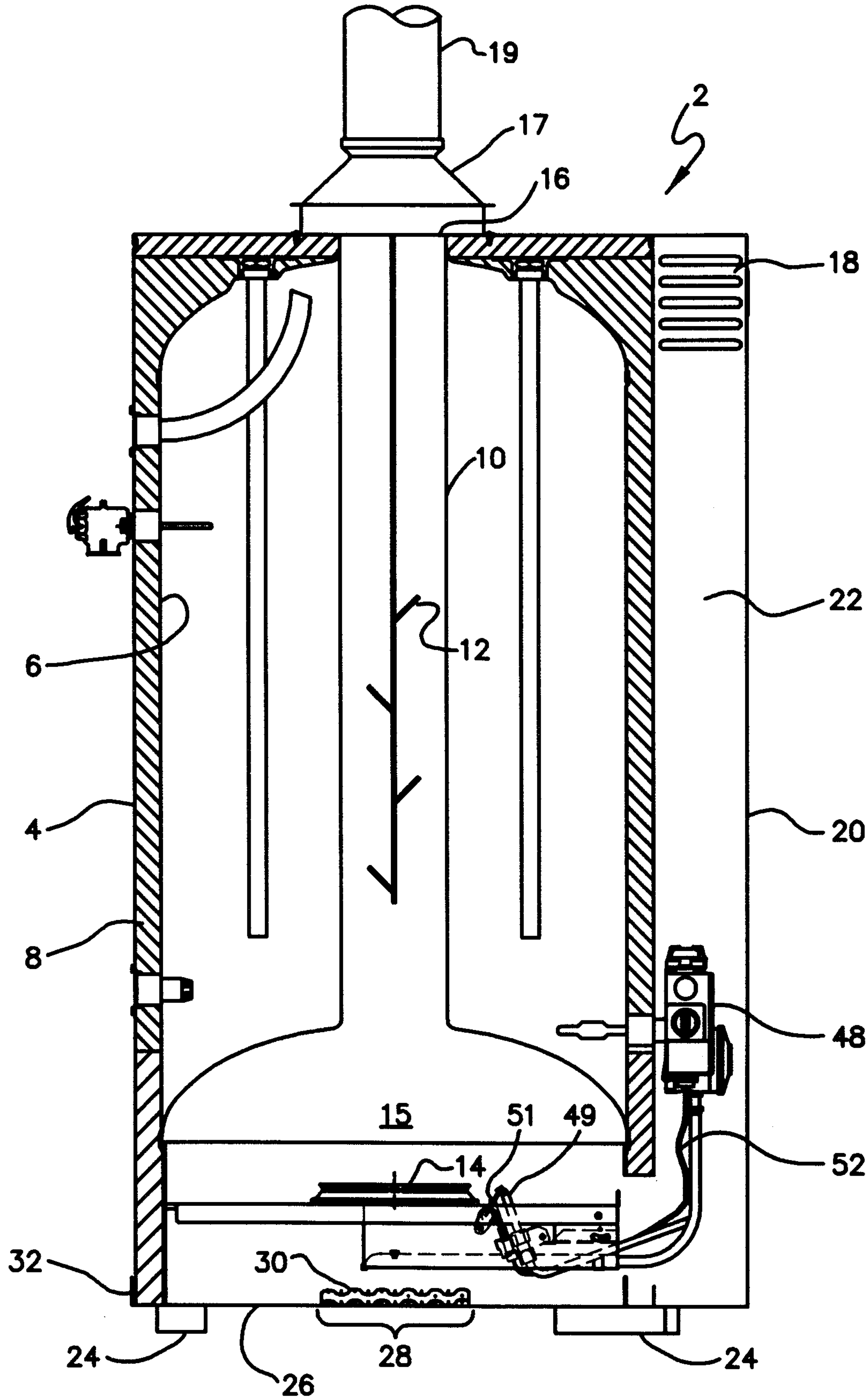

FIG.1

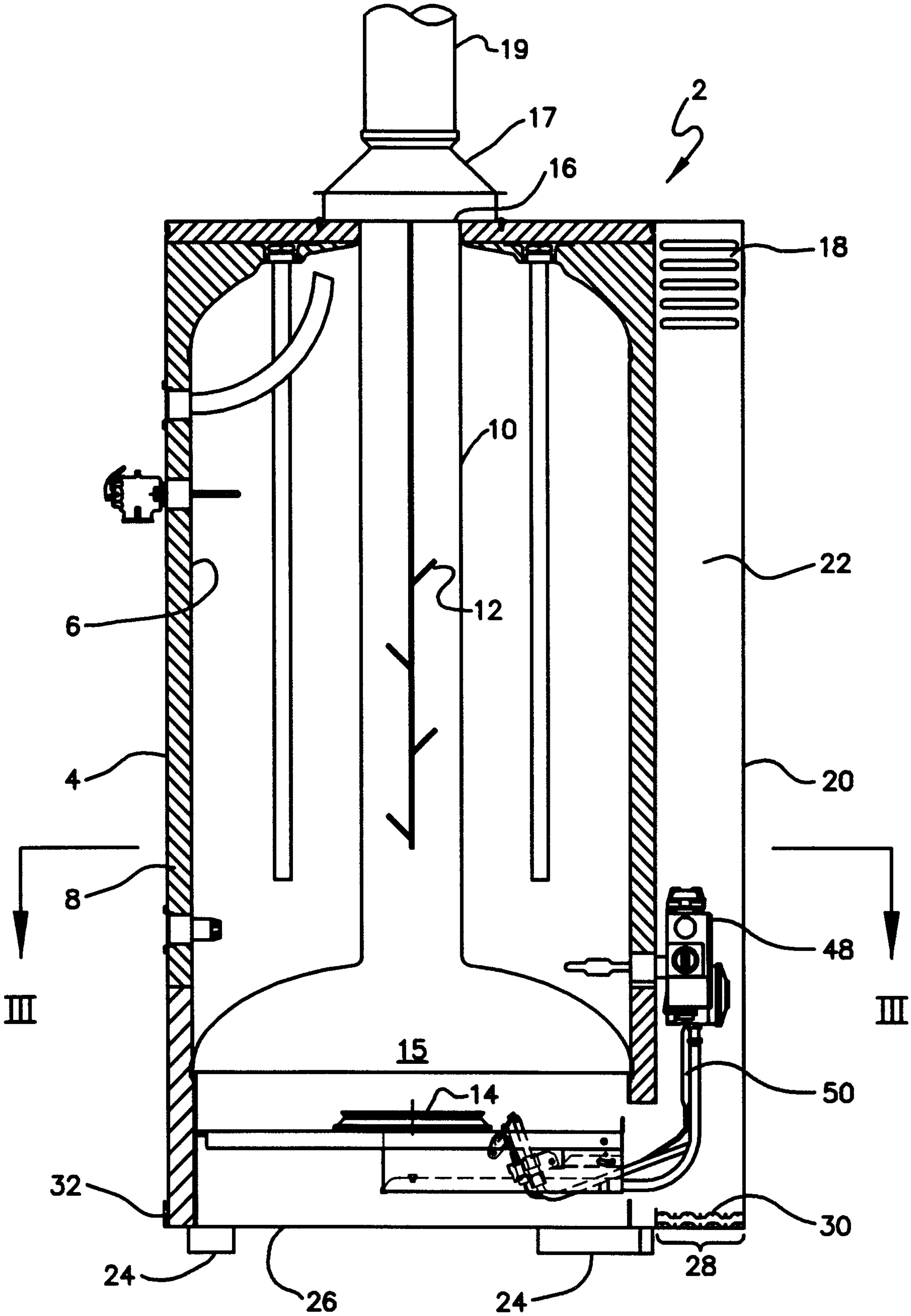

FIG.2

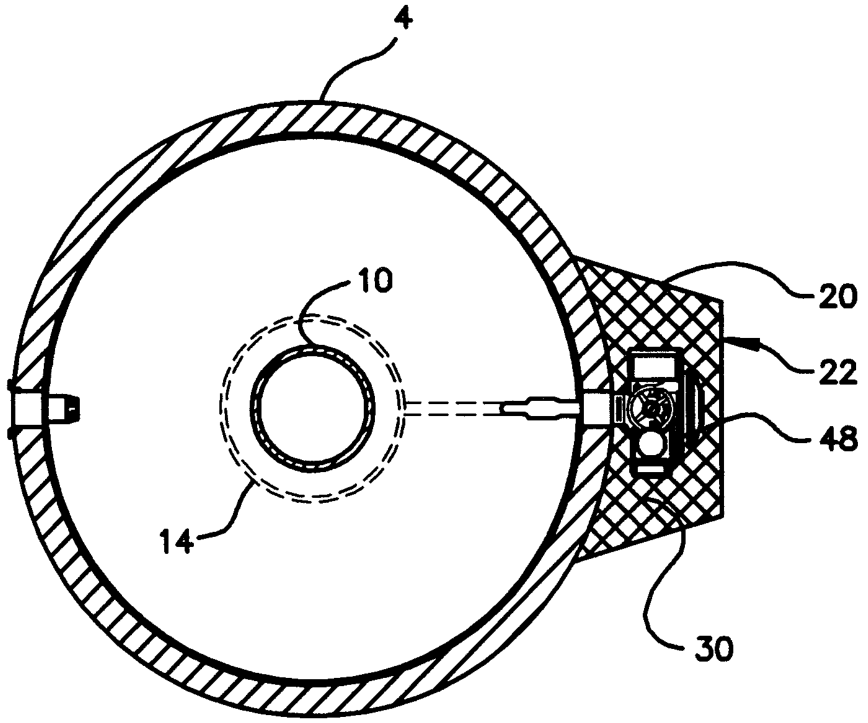

FIG.3

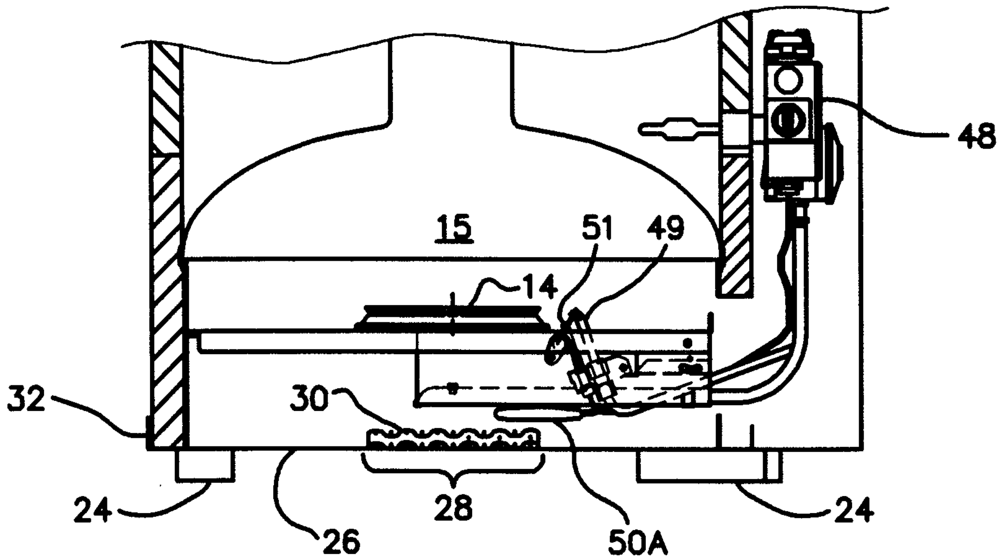

FIG.3A

SUBSTITUTE SHEET (Rule 26)

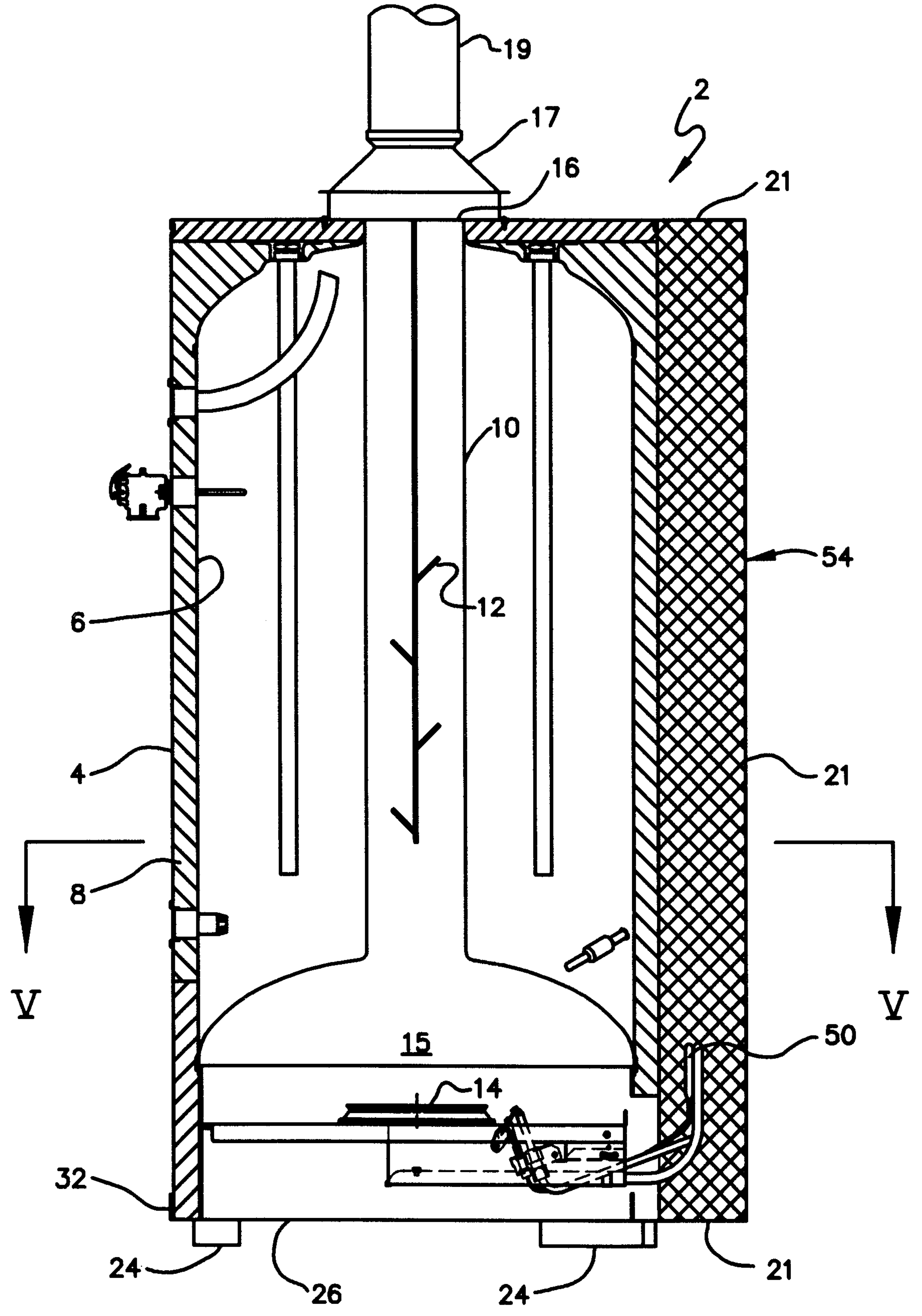

FIG.4

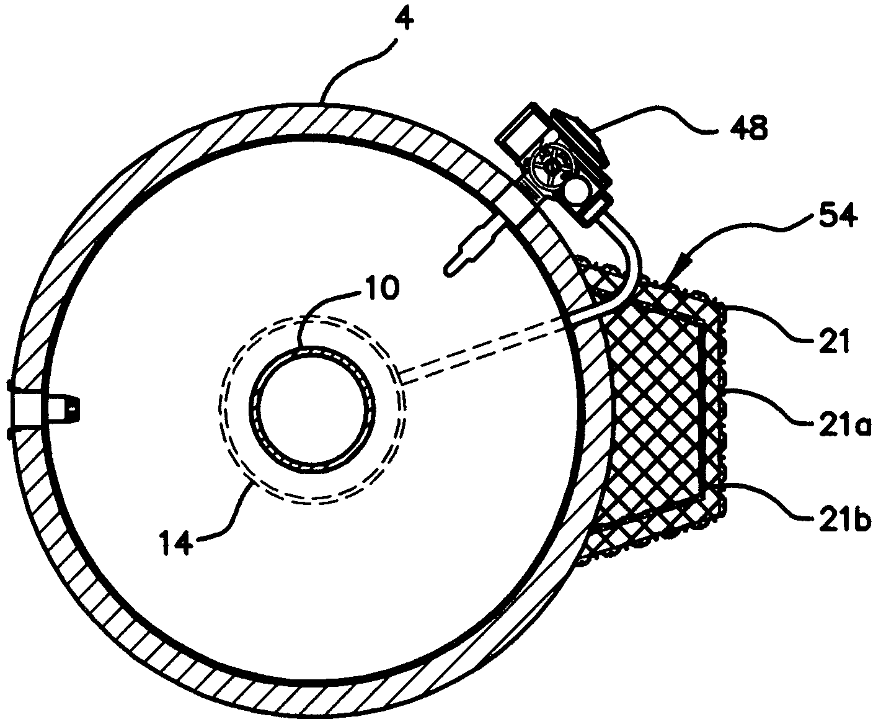

FIG.5

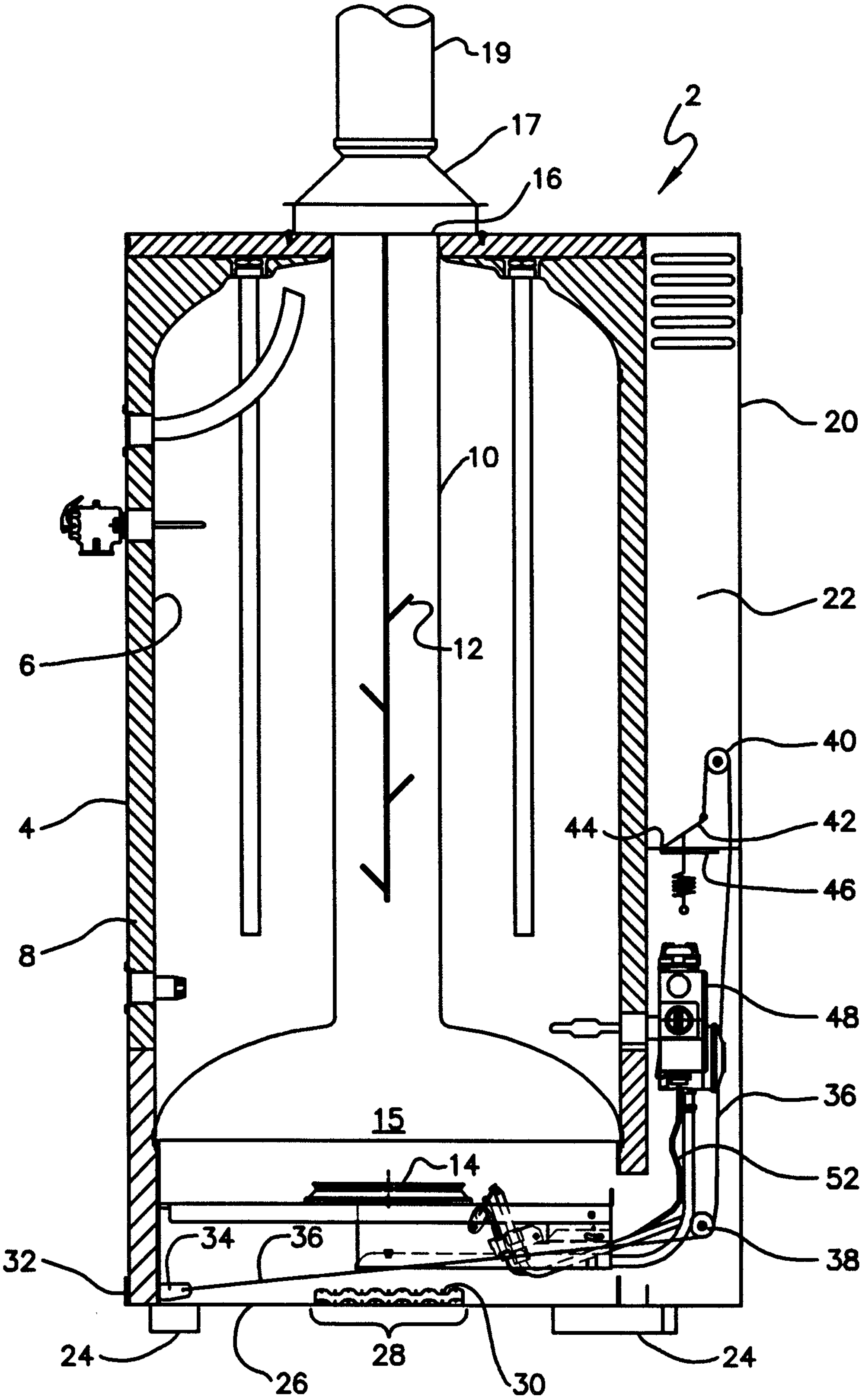
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FIG.6

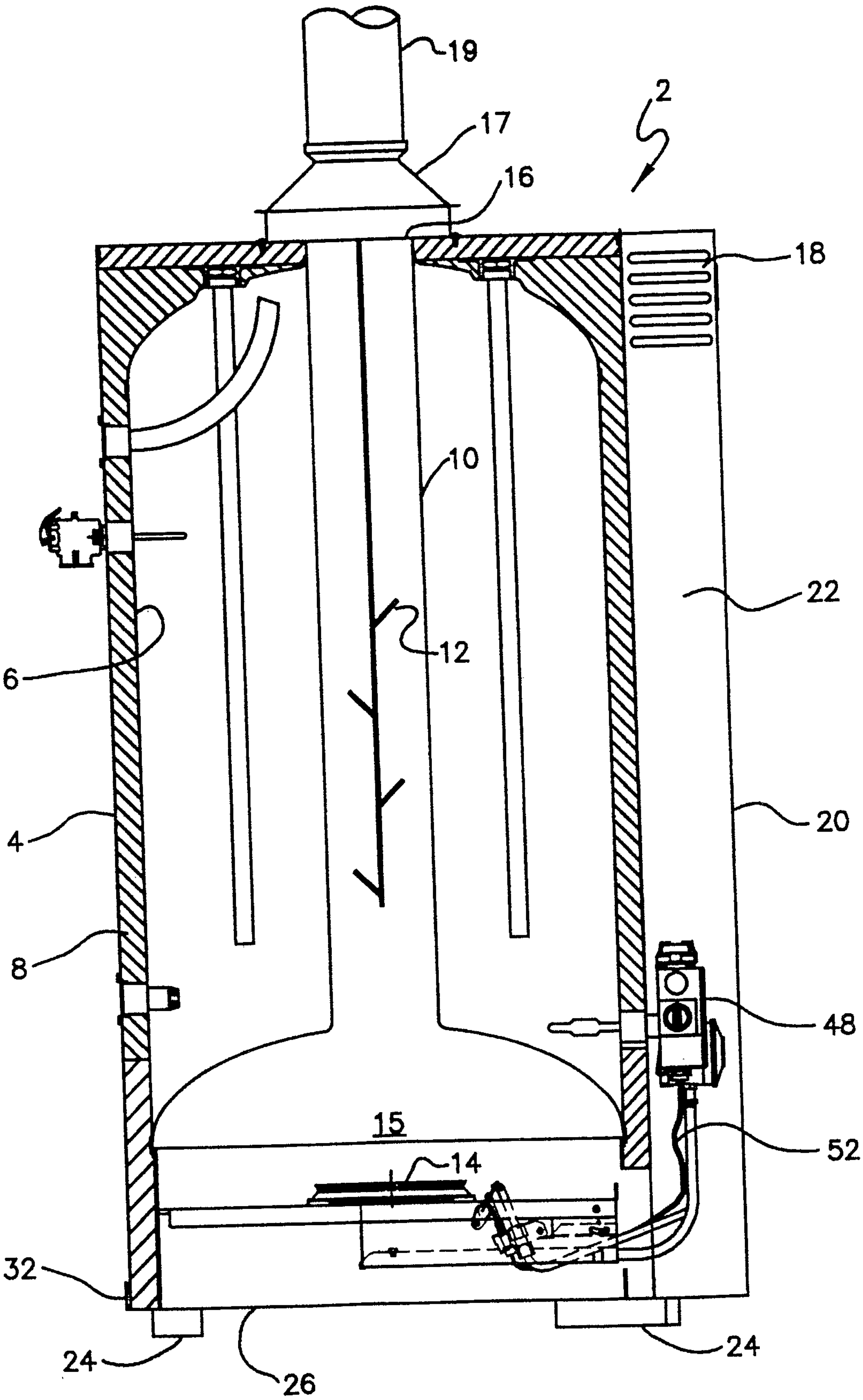


FIG.7

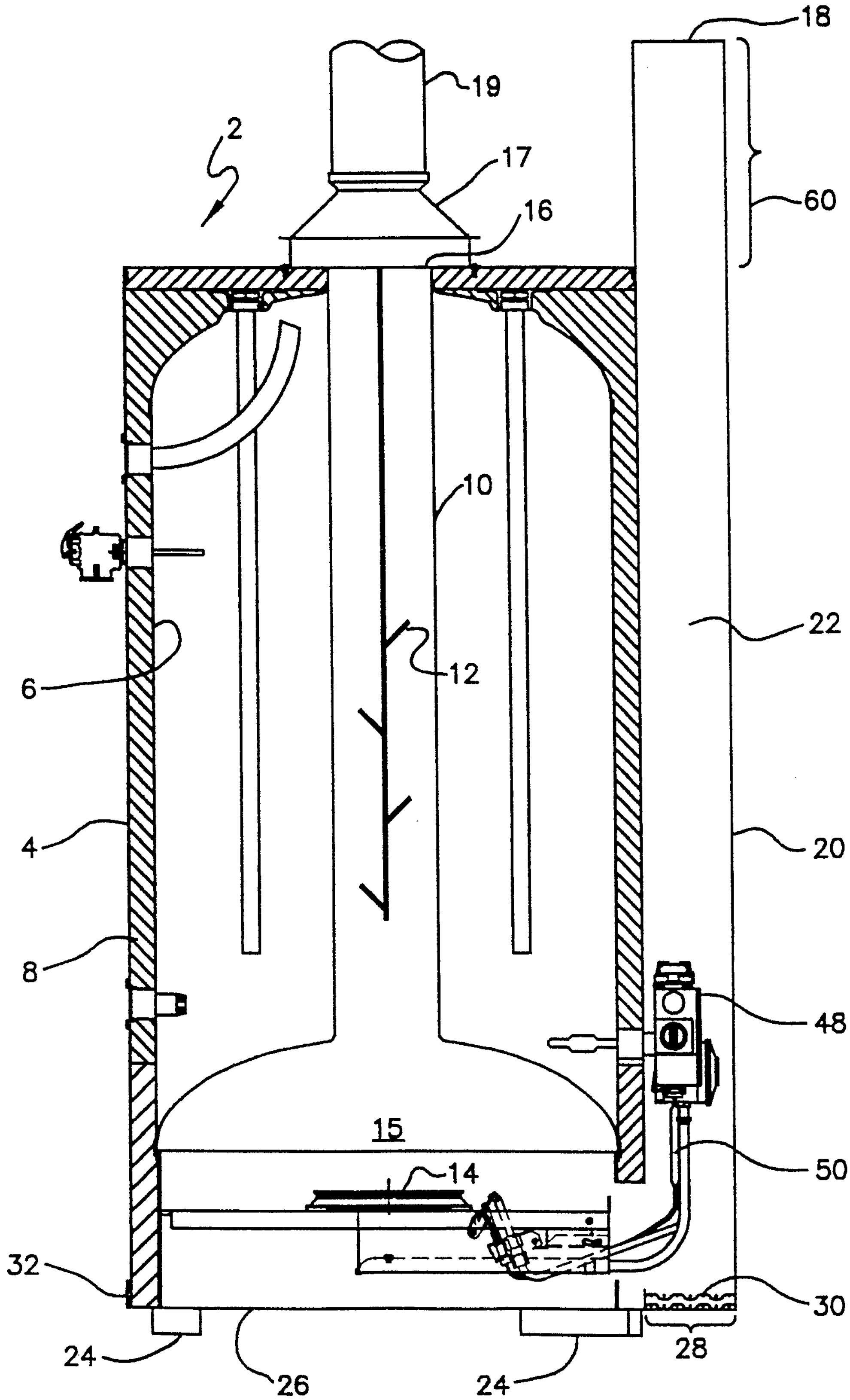
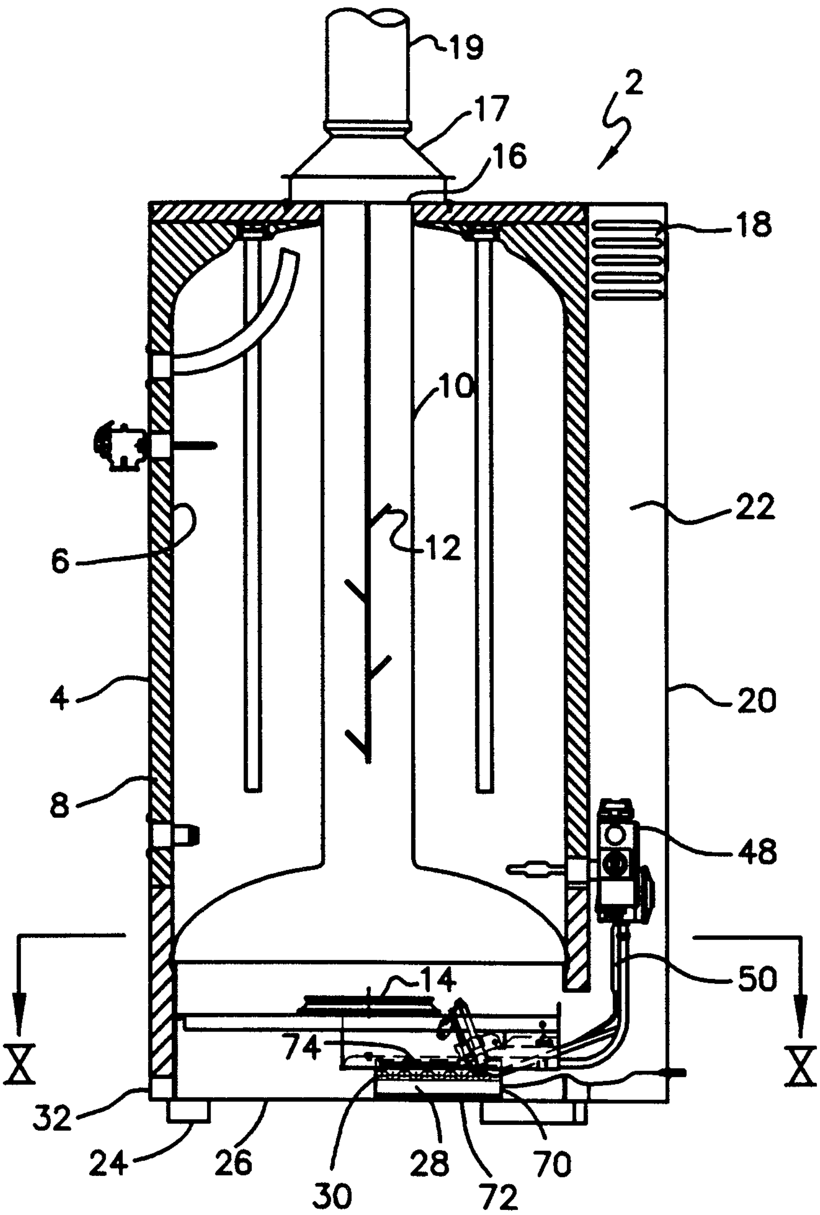


FIG.8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74
X
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32
24
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70
30
72

FIG.9

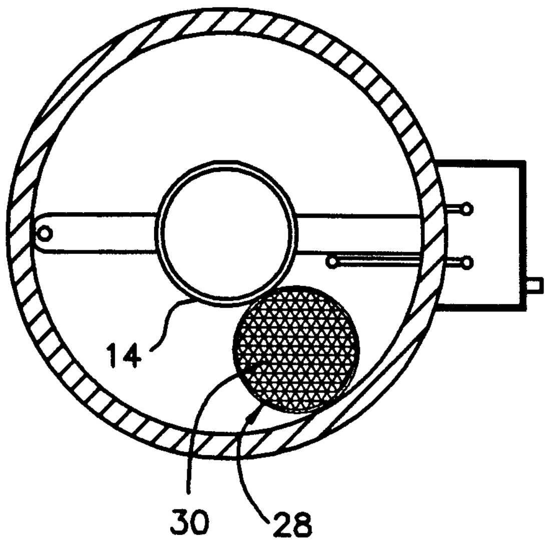
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FIG.10

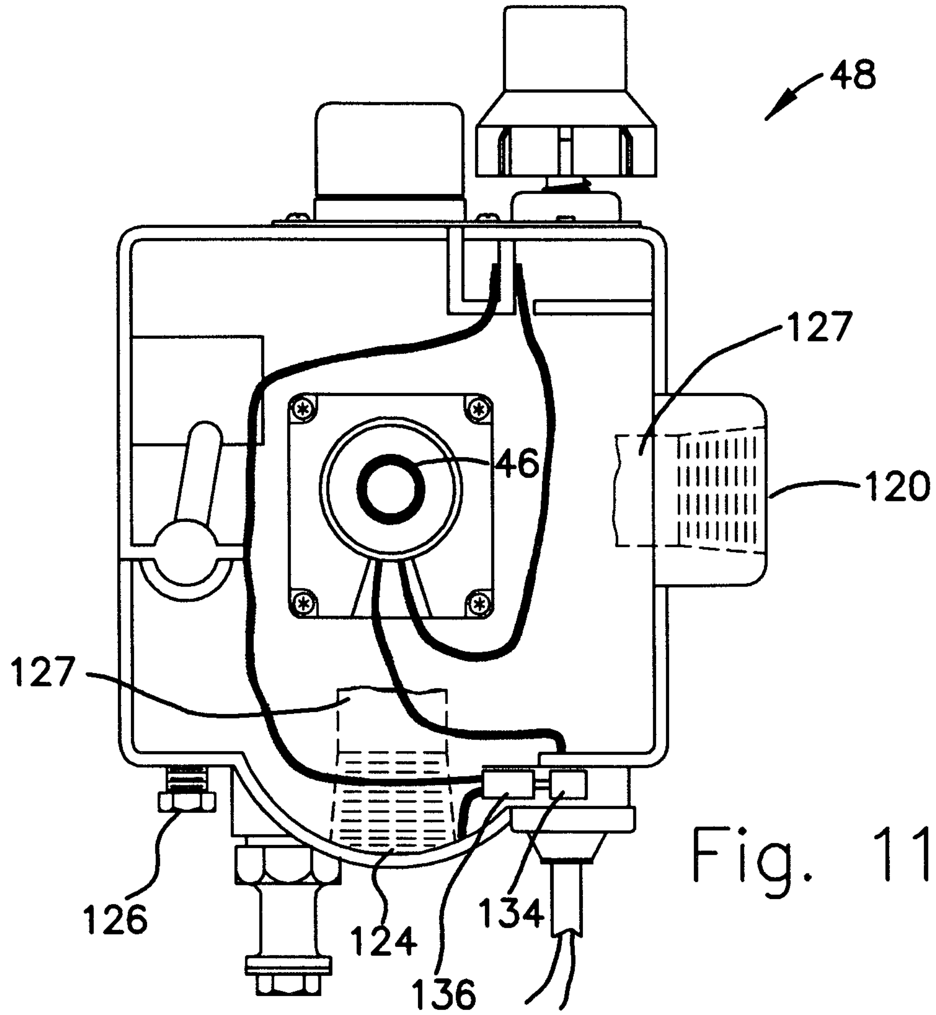


Fig. 11

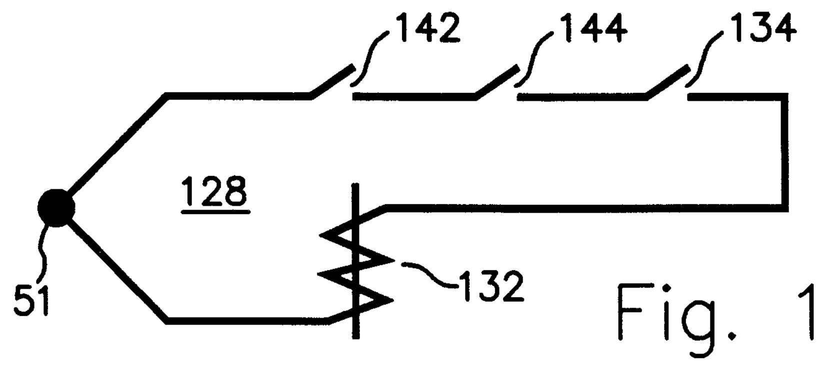
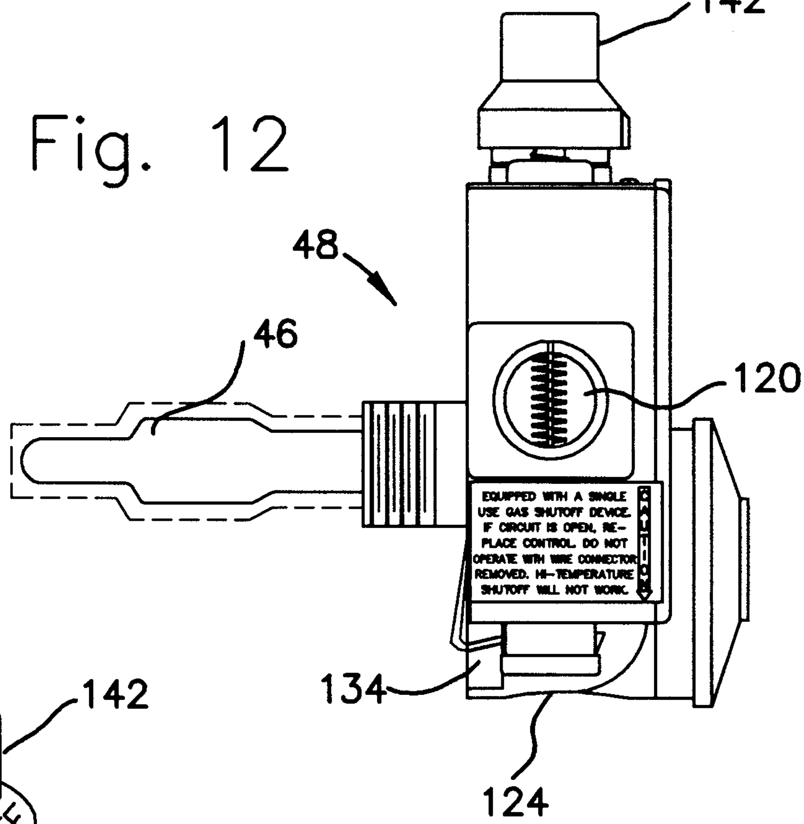


Fig. 15

Fig. 12


142
48
46
120
EQUIPPED WITH A SINGLE USE GAS SHUTOFF DEVICE. IF CIRCUIT IS OPEN, REPLACE CONTROL. DO NOT OPERATE WITH WIRE CONNECTOR REMOVED. HI-TEMPERATURE SHUTOFF WILL NOT WORK.
CAUTION
134
124

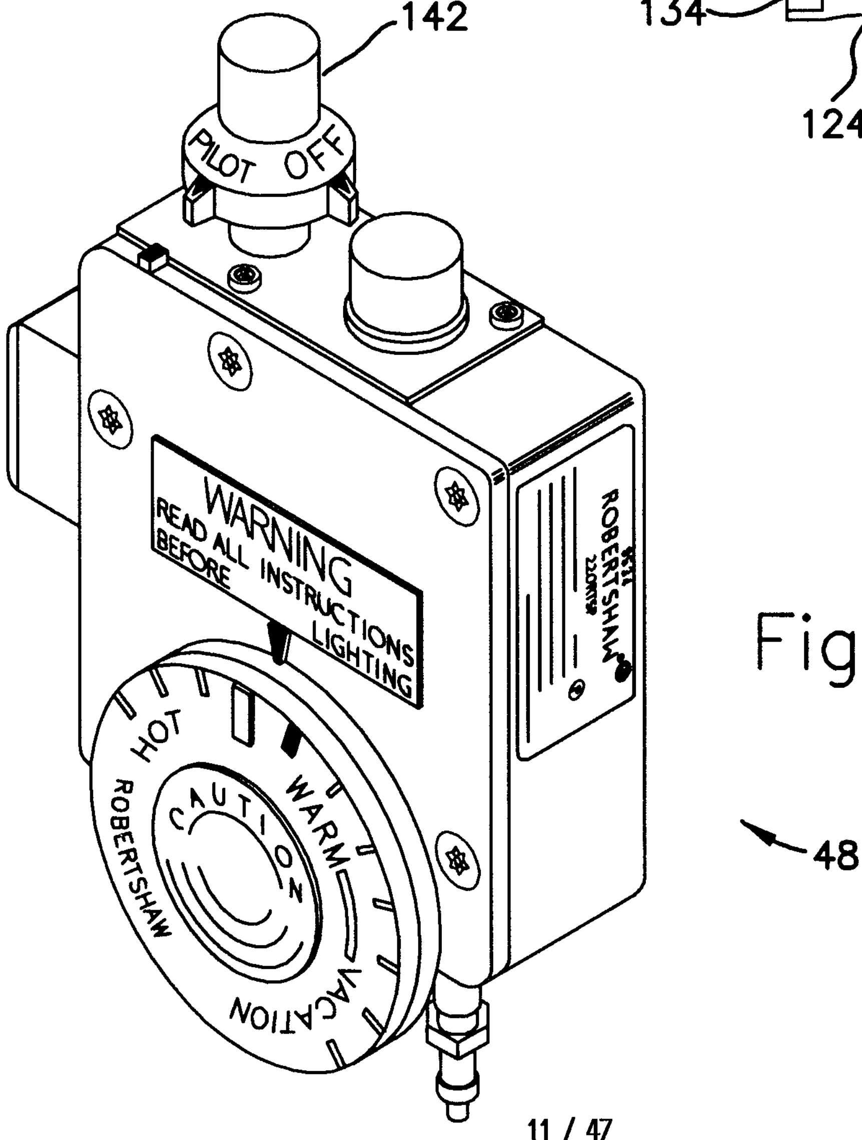

142
PILOT OFF
WARNING
READ ALL INSTRUCTIONS BEFORE LIGHTING
ROBERTSHAW
HOT
WARM
VACATION
CAUTION
ROBERTSHAW
48

Fig. 13

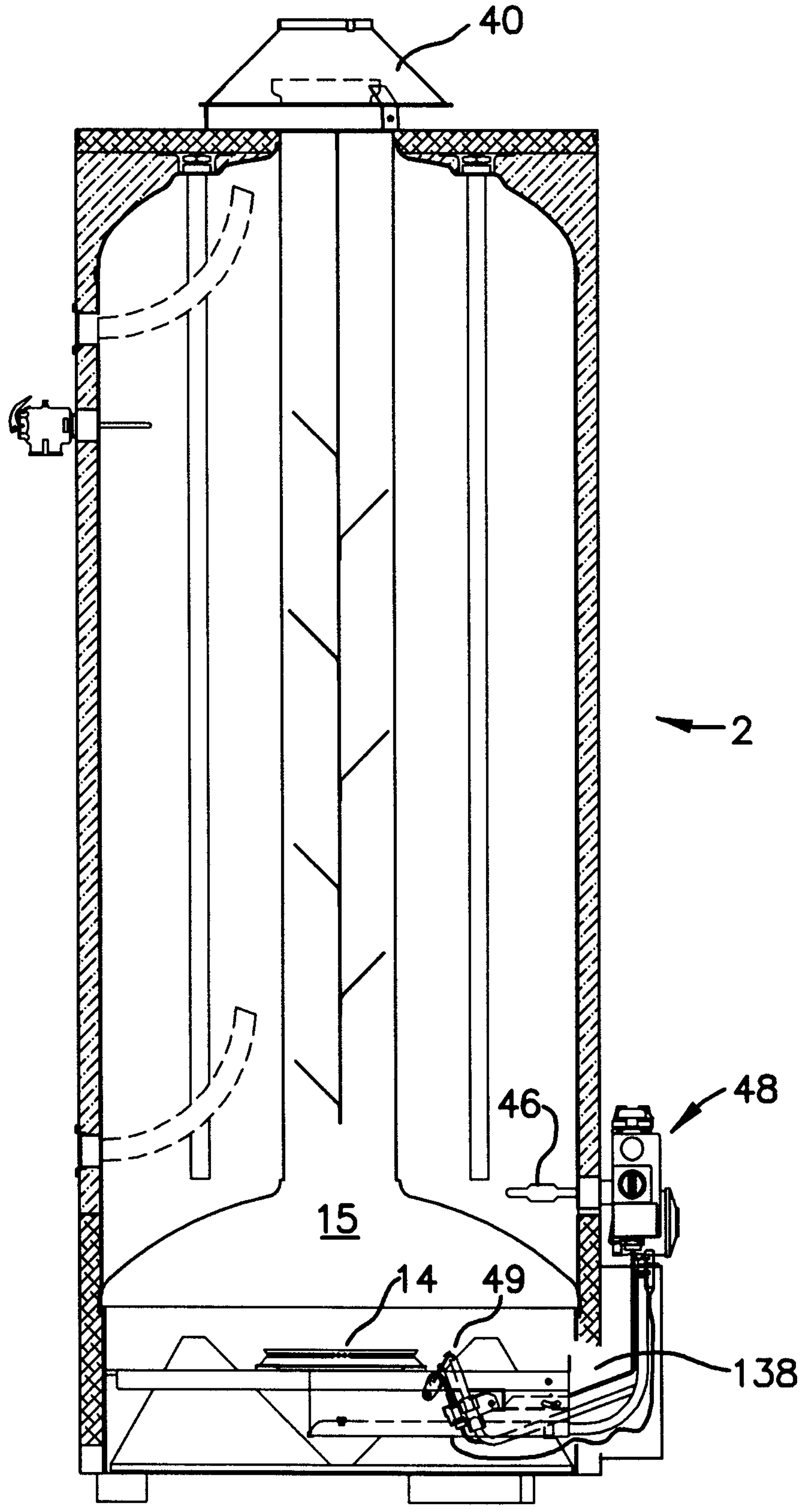


Fig. 14

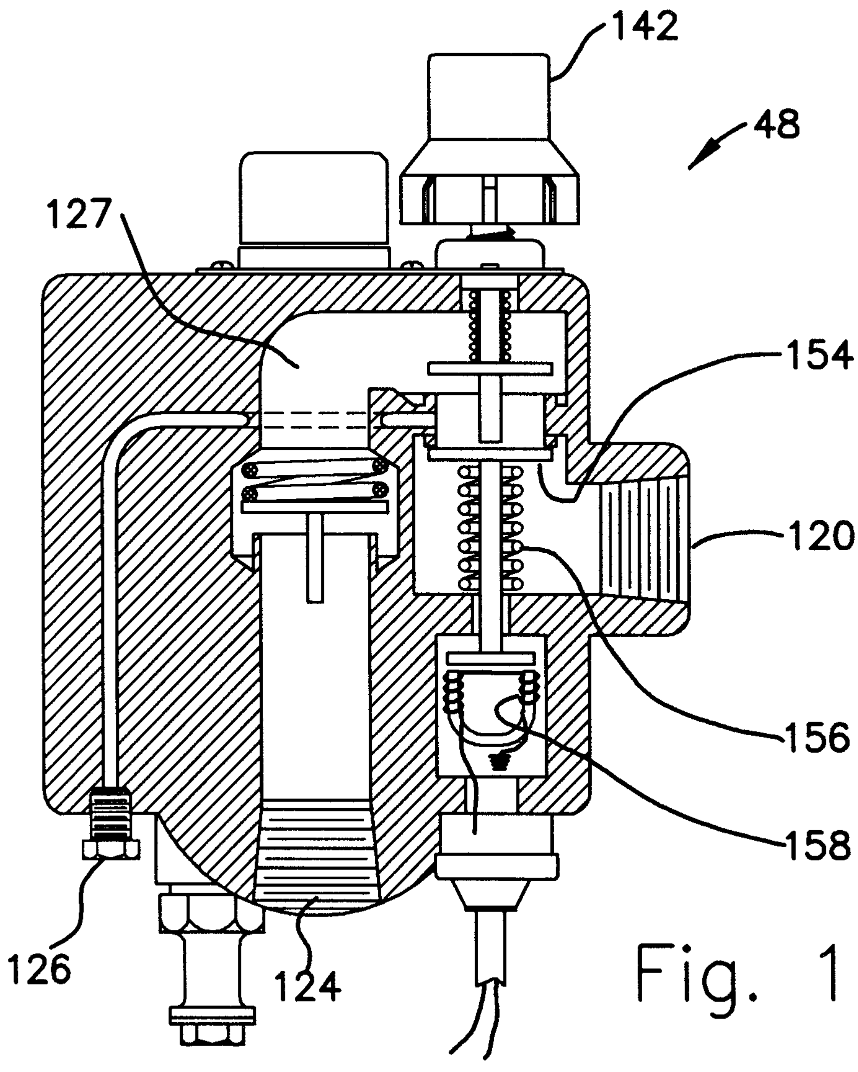


Fig. 16

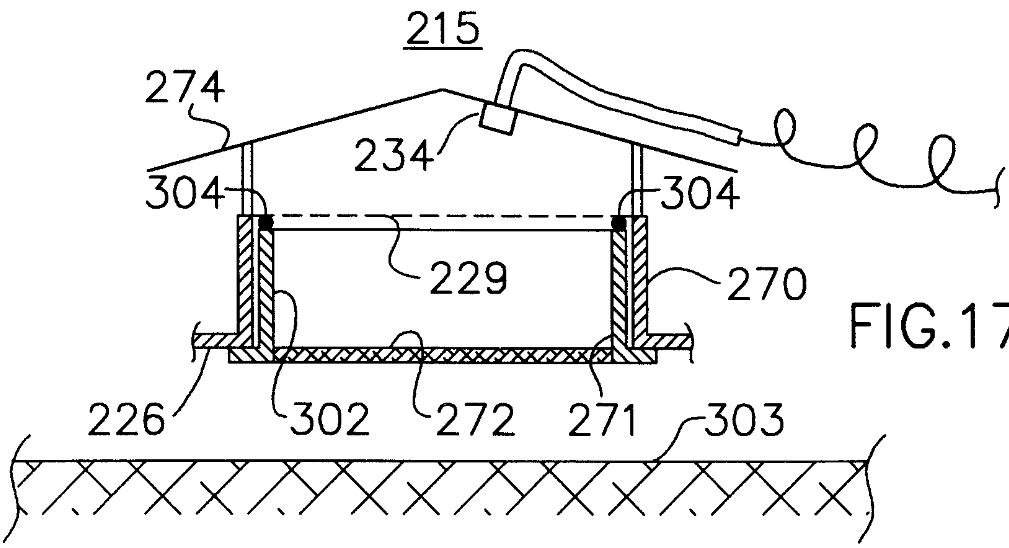

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FIG.17

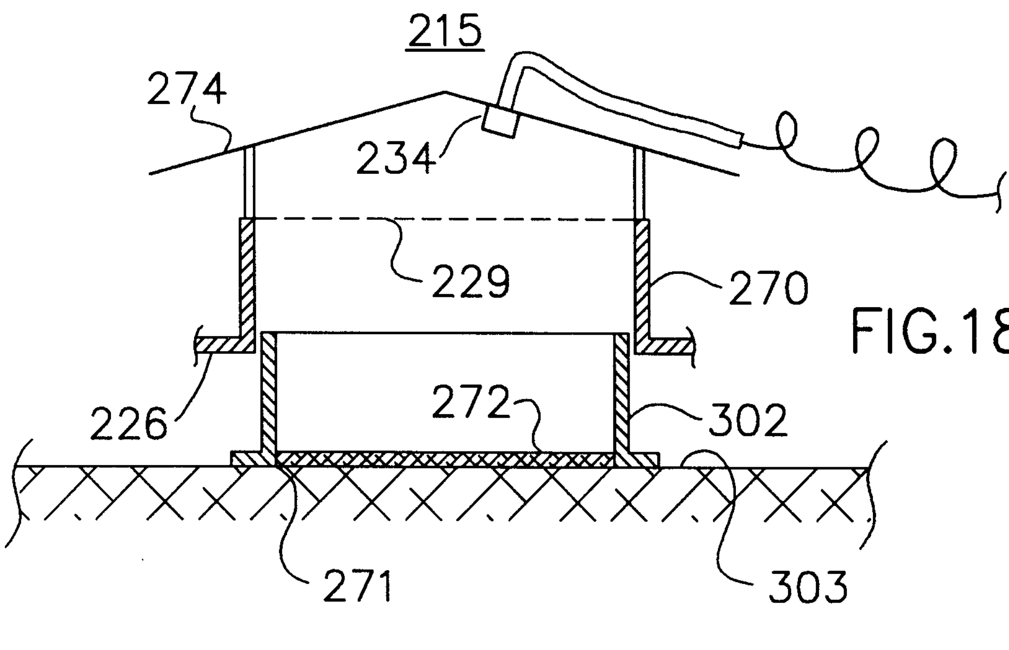
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FIG.18

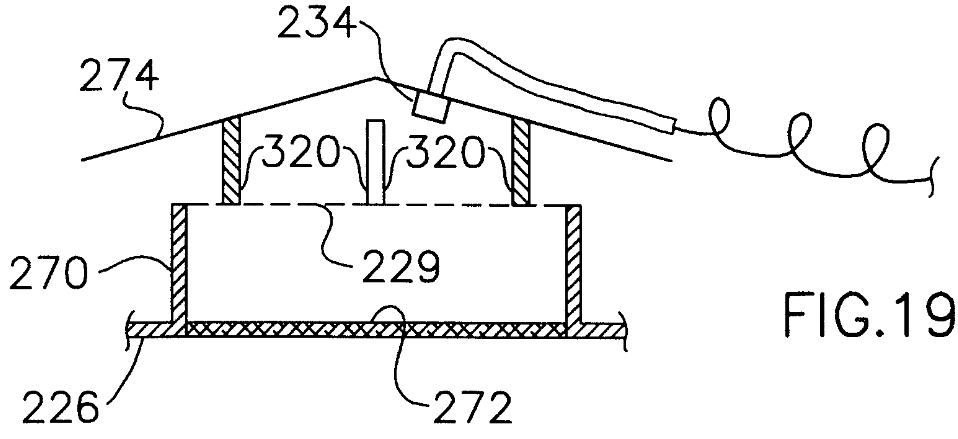

FIG.19

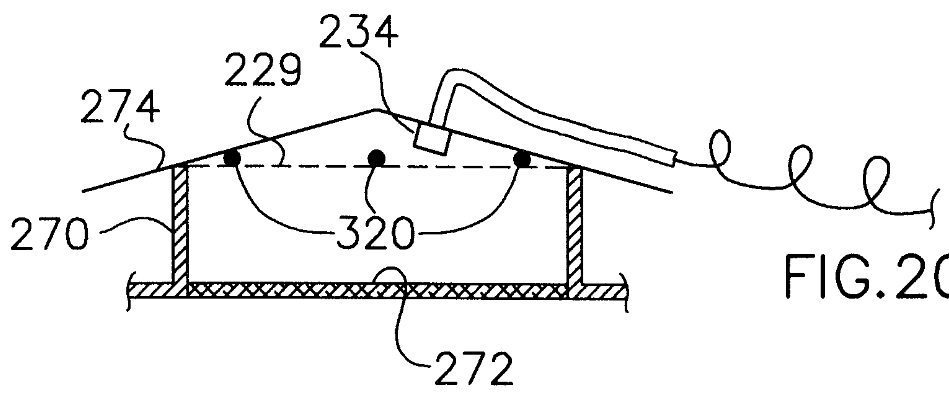

FIG.20

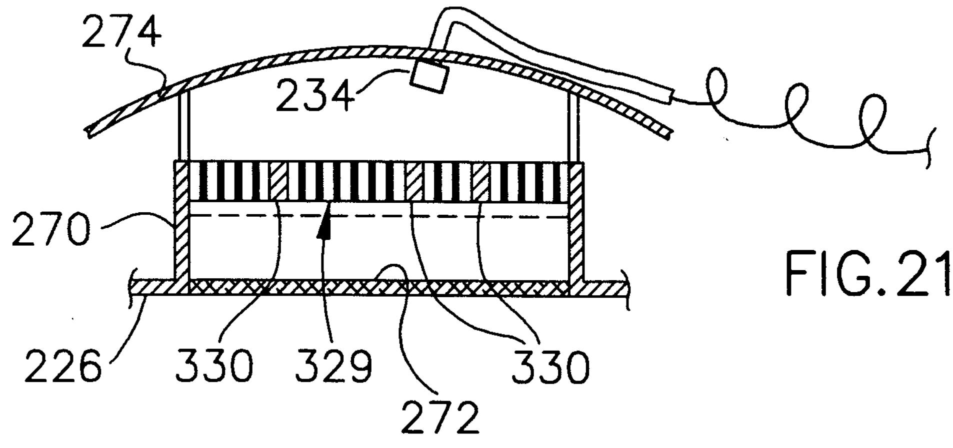

FIG.21

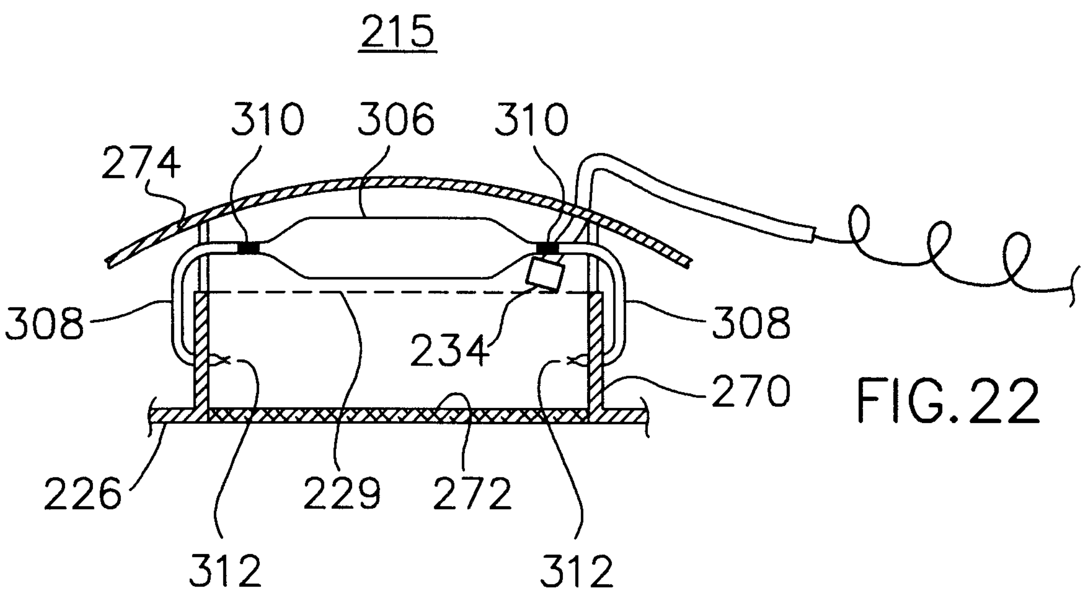
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FIG.22

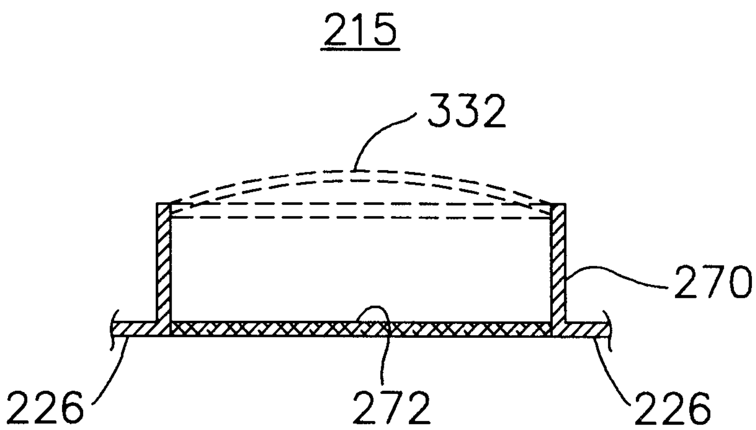
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FIG.23

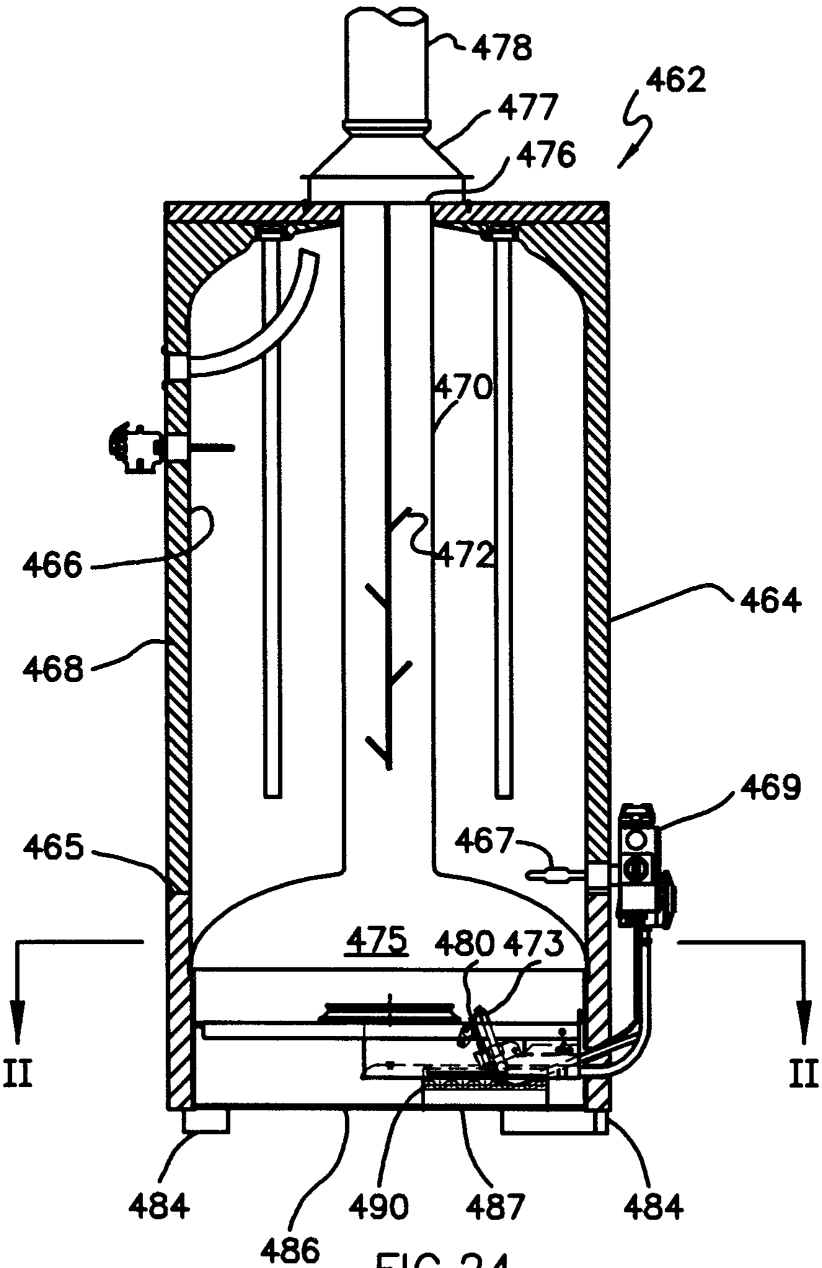
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FIG.24

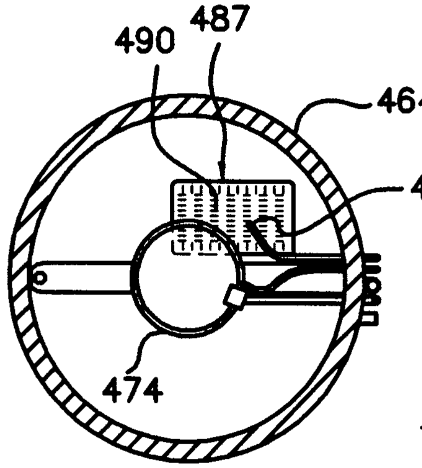
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FIG.25

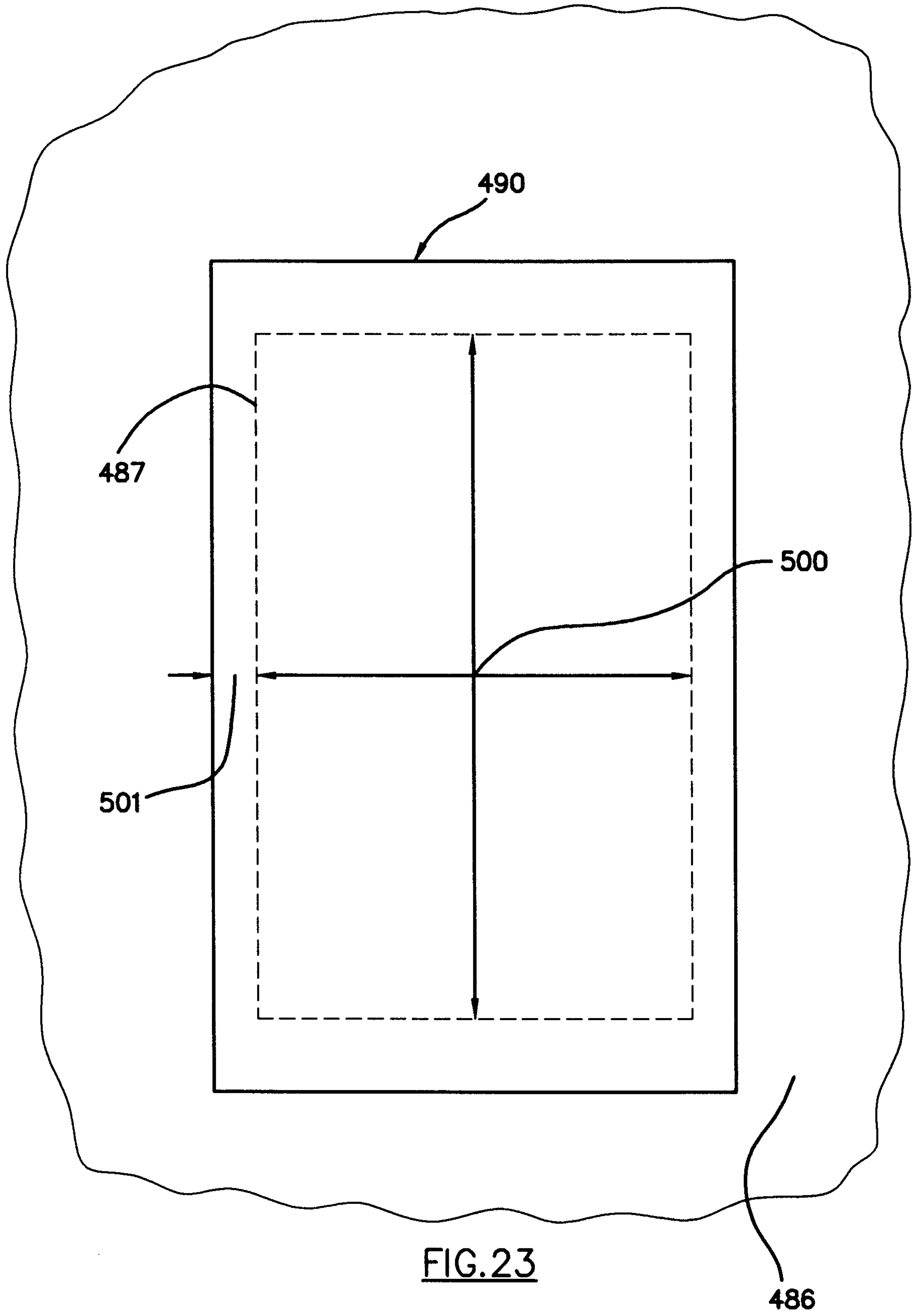


FIG.23

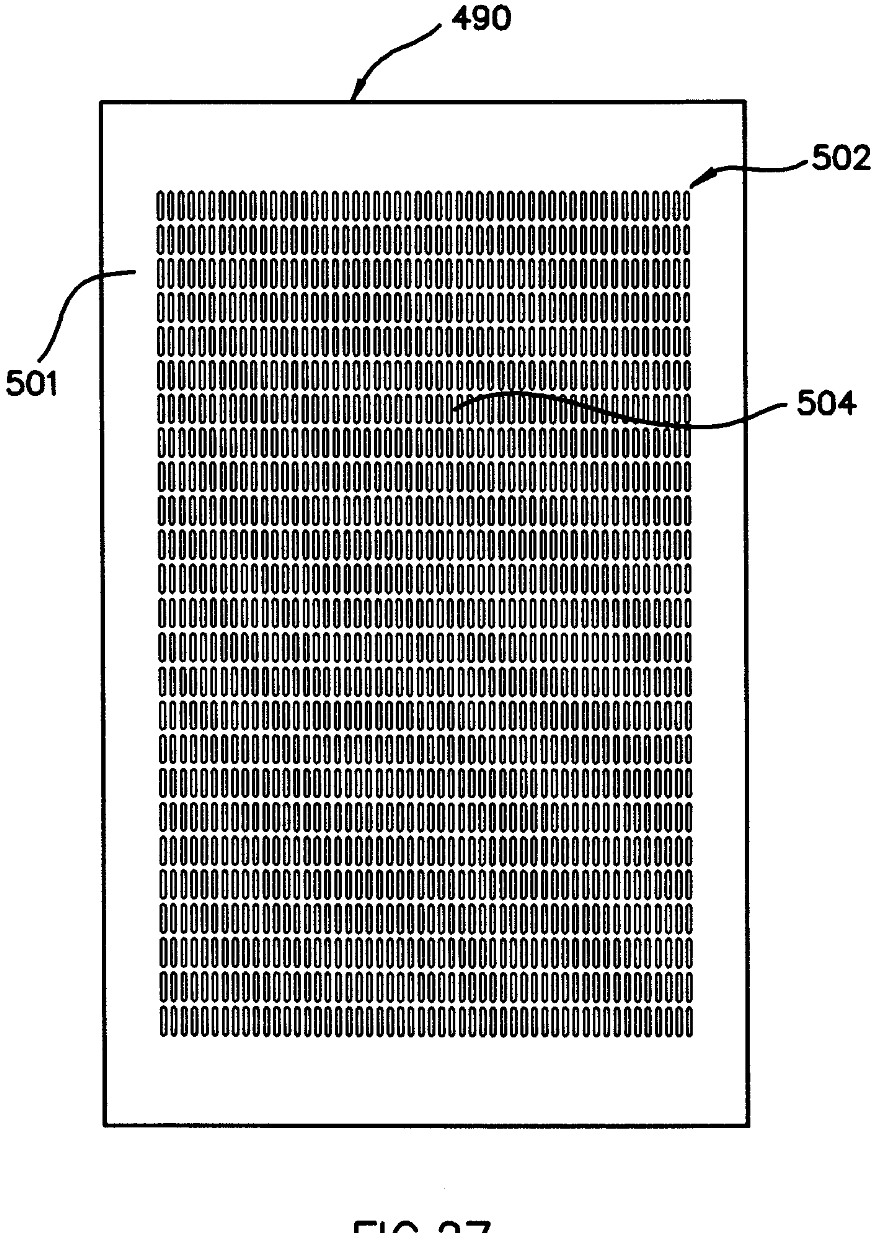


FIG.27

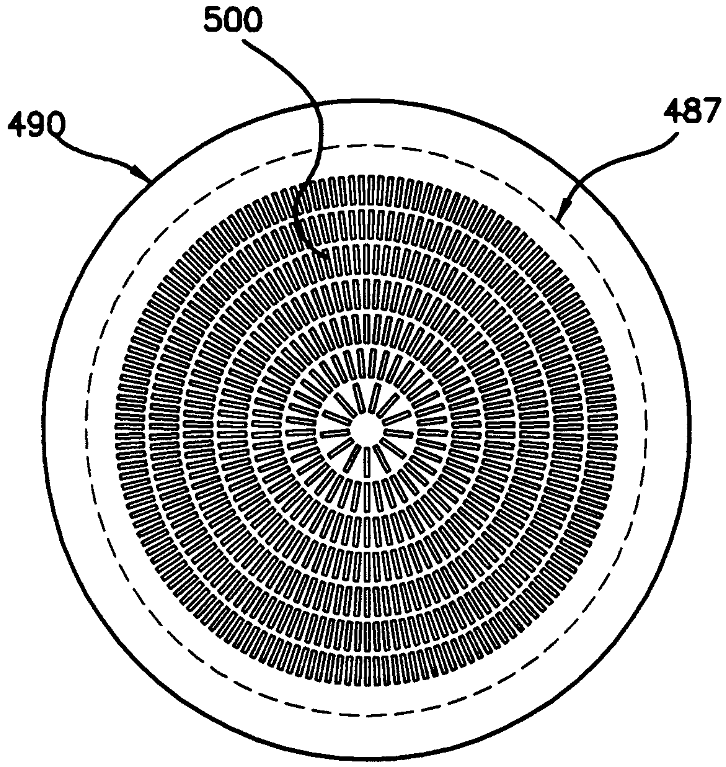


FIG.28

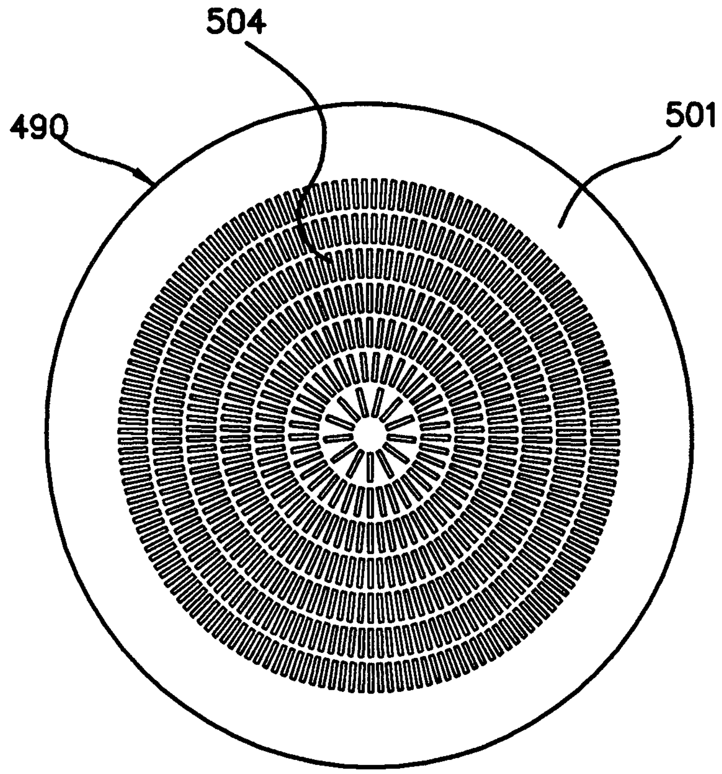


FIG.9

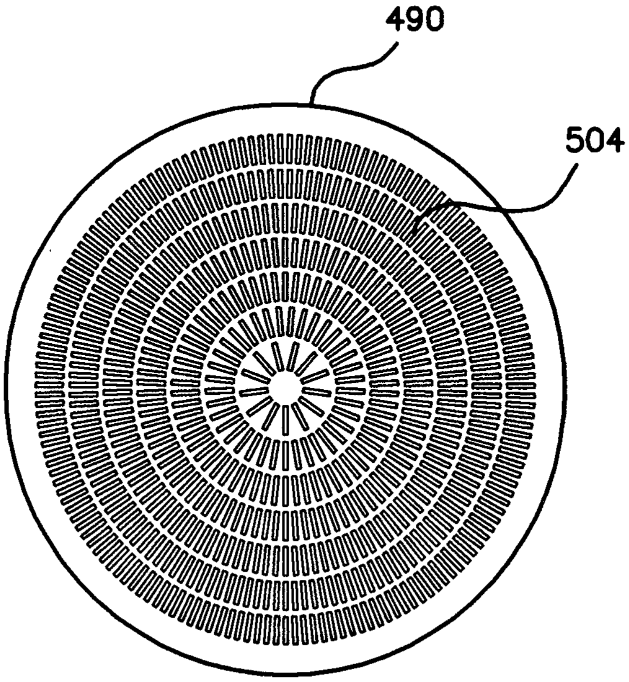


FIG.30

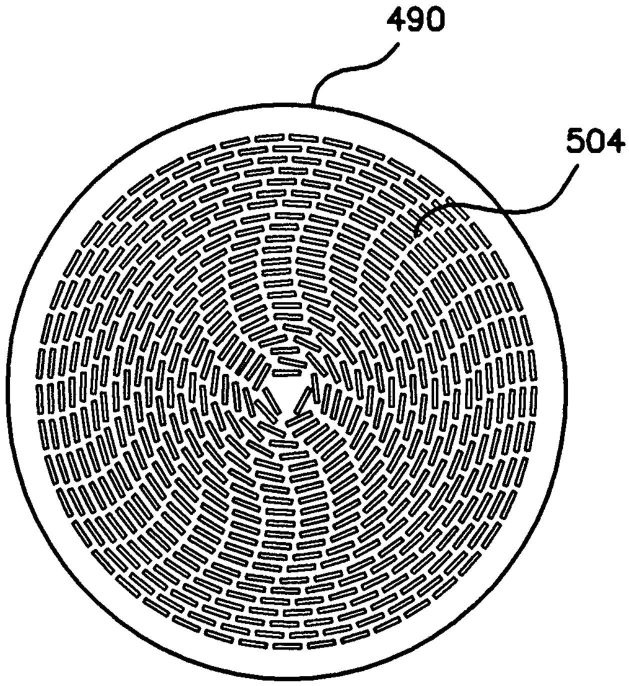


FIG.31

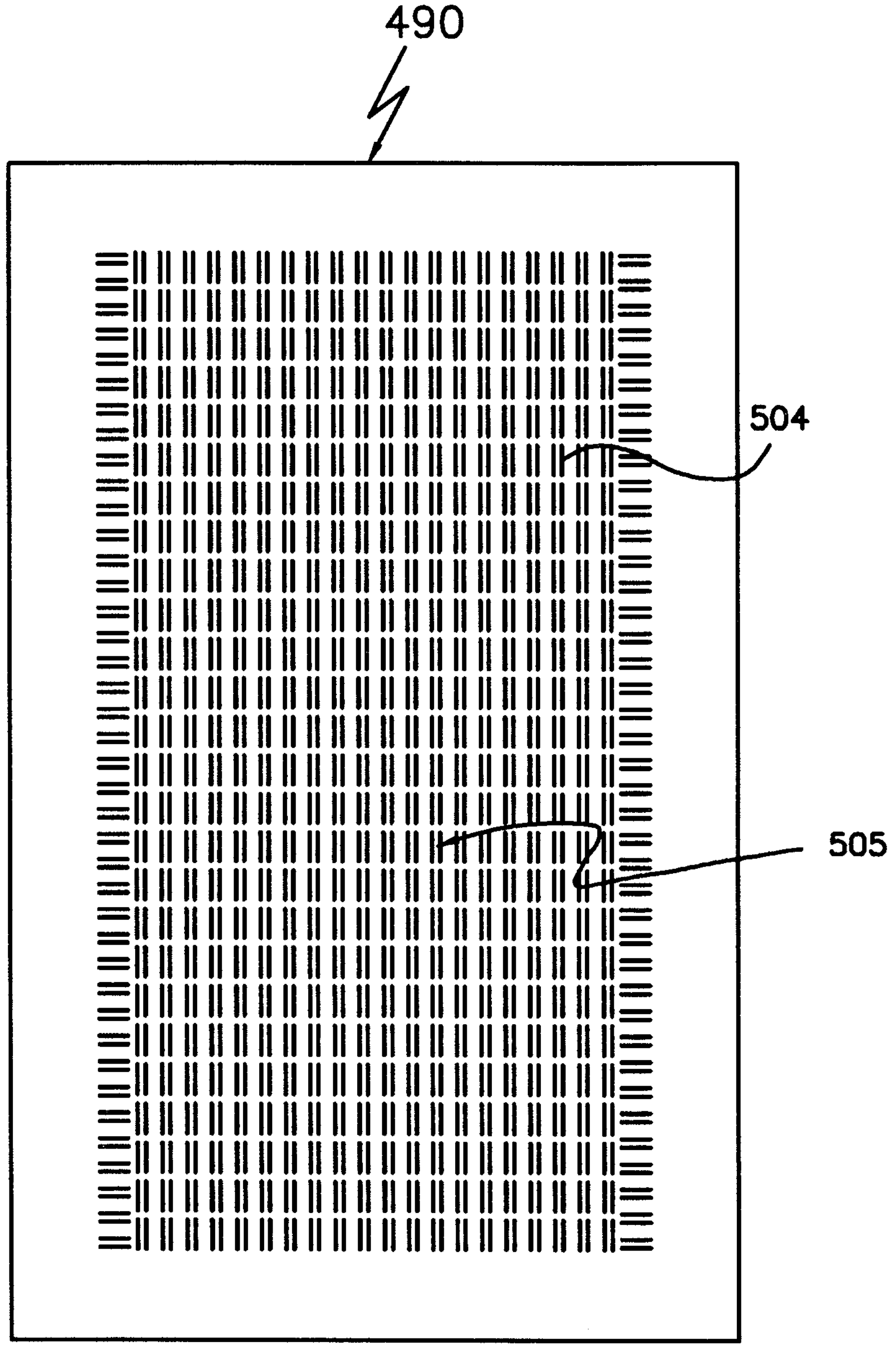


FIG.32

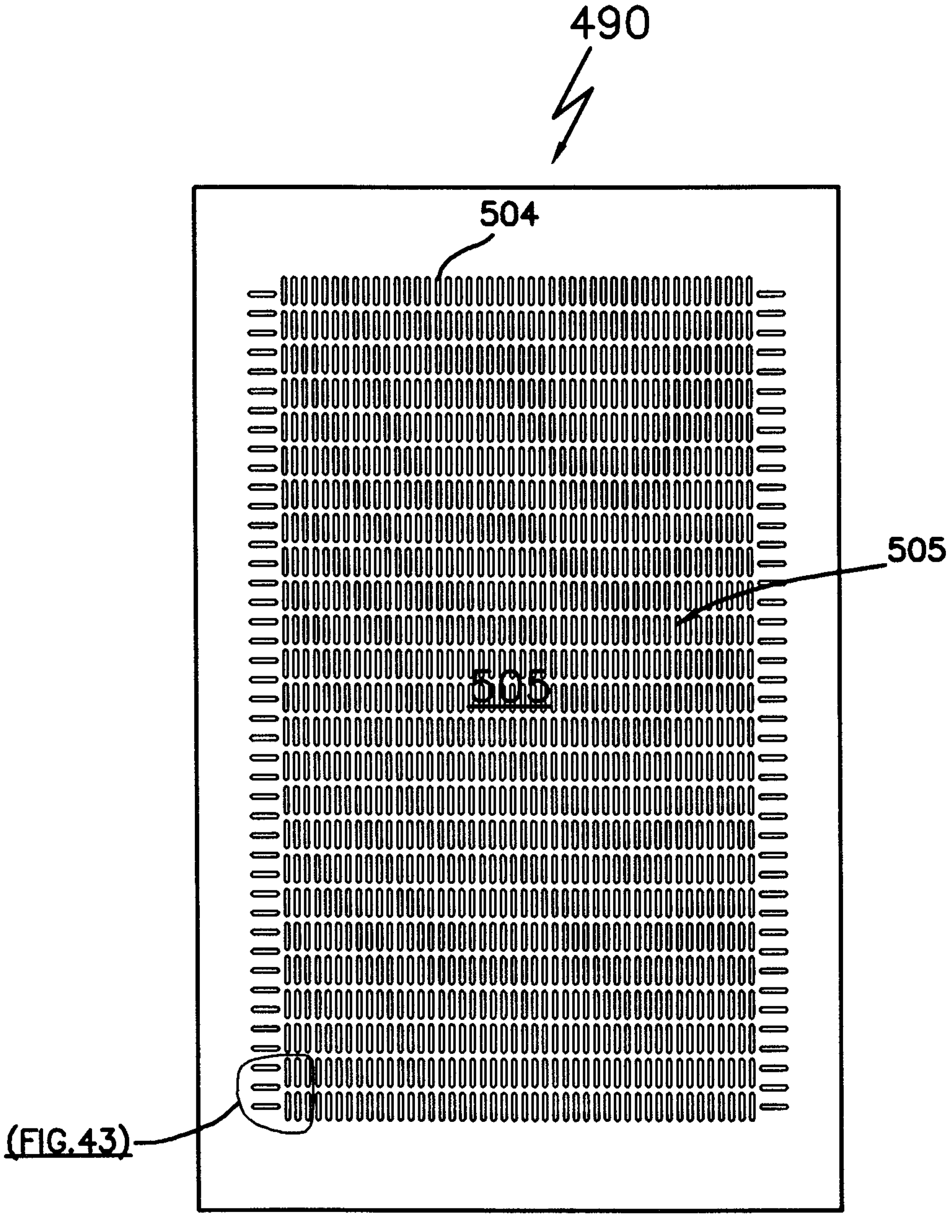


FIG.33

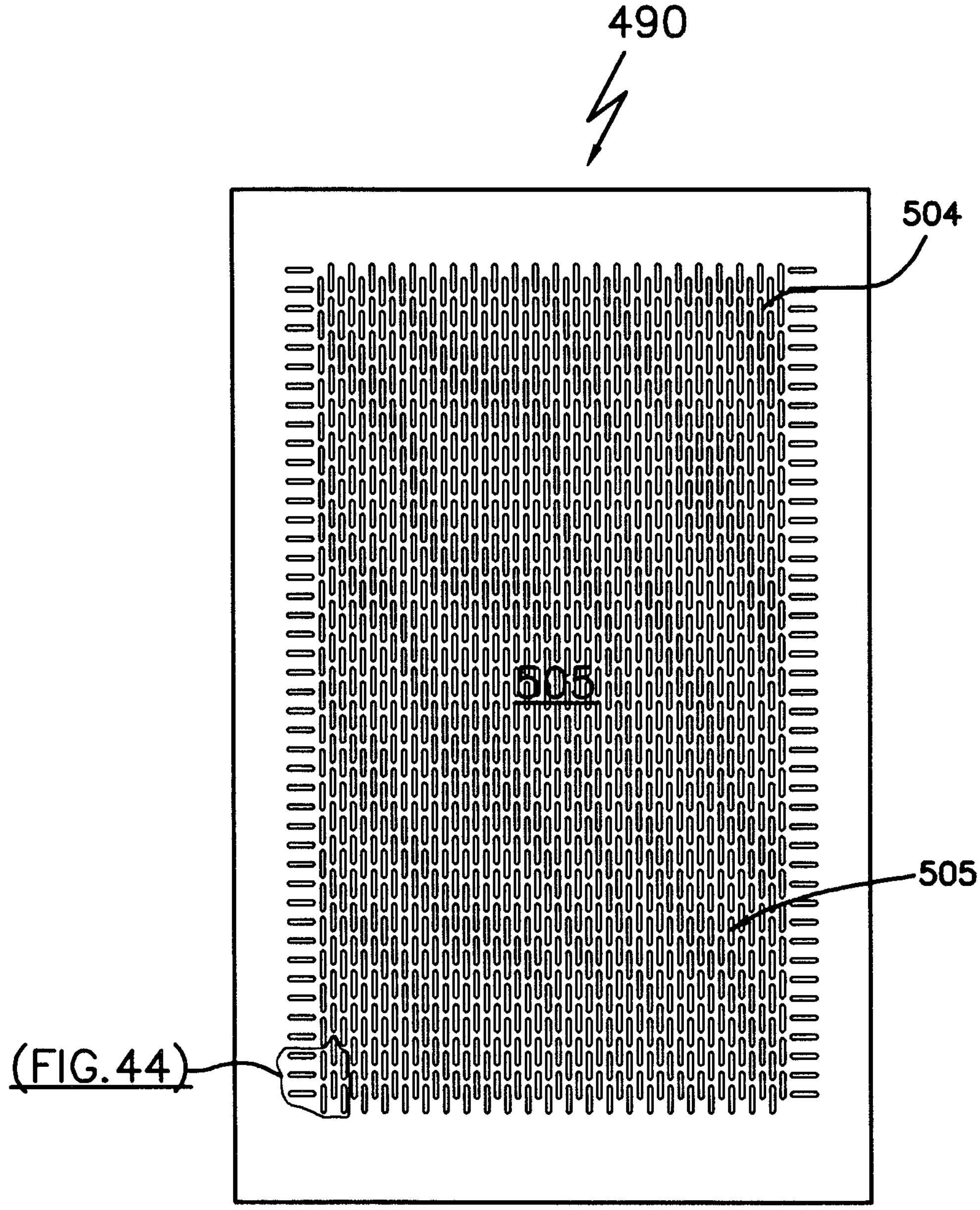


FIG.34

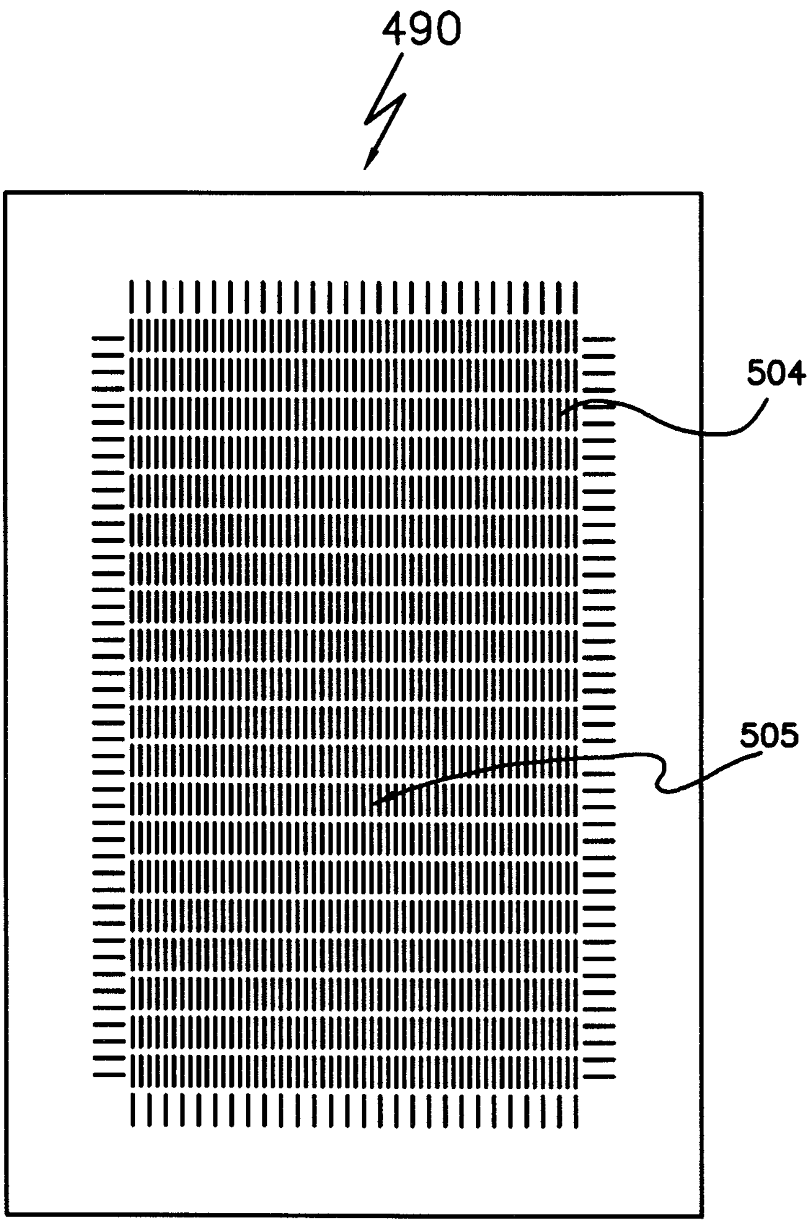


FIG.35

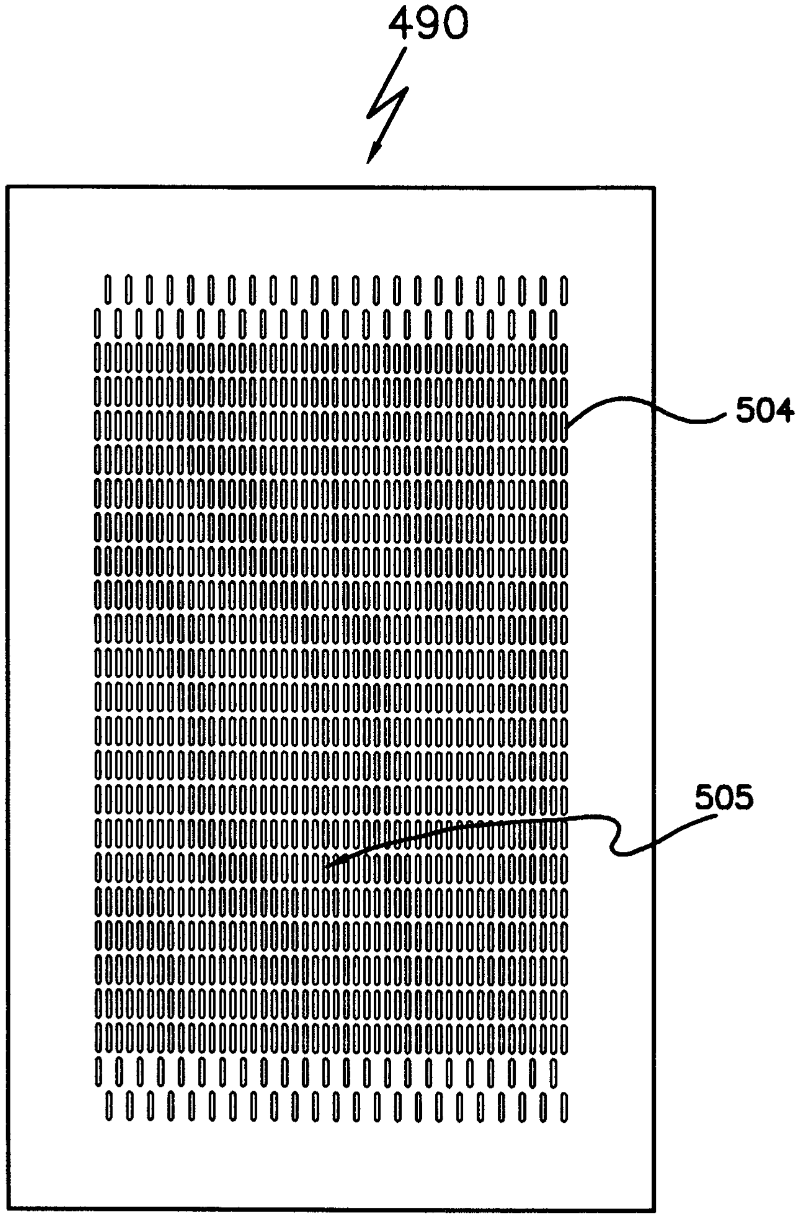


FIG.36

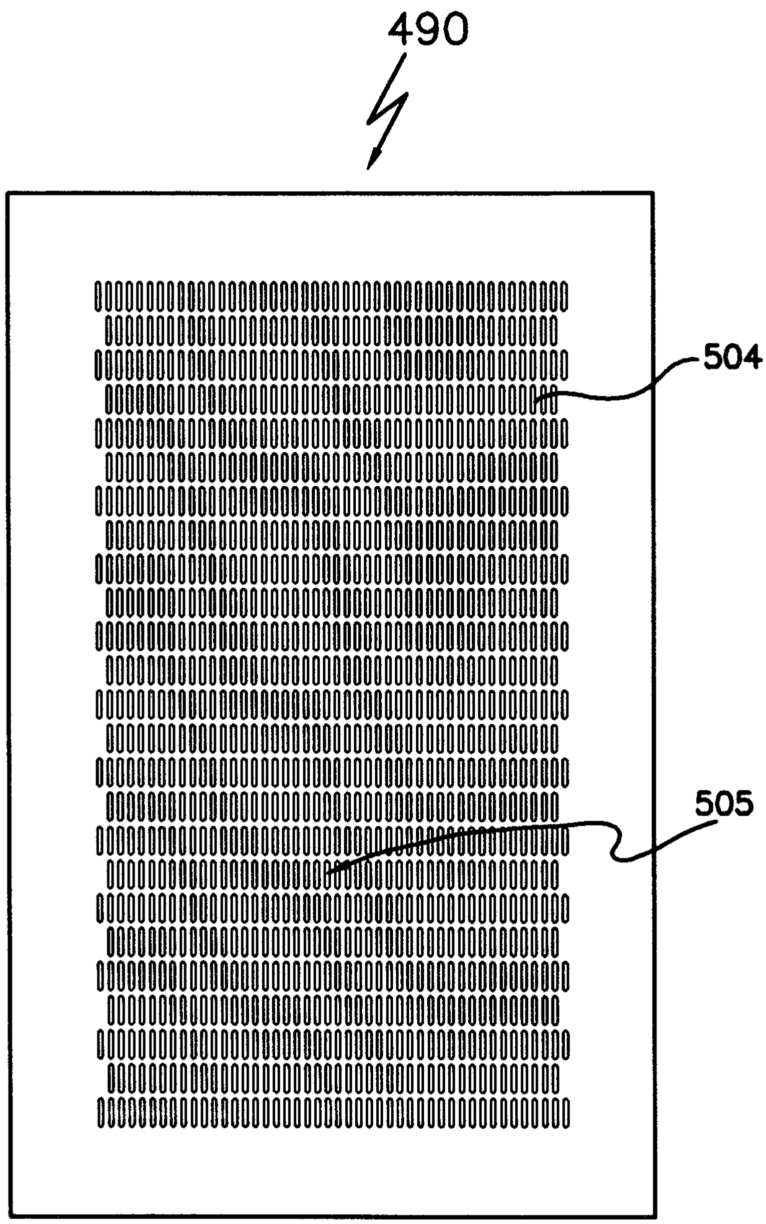


FIG.37

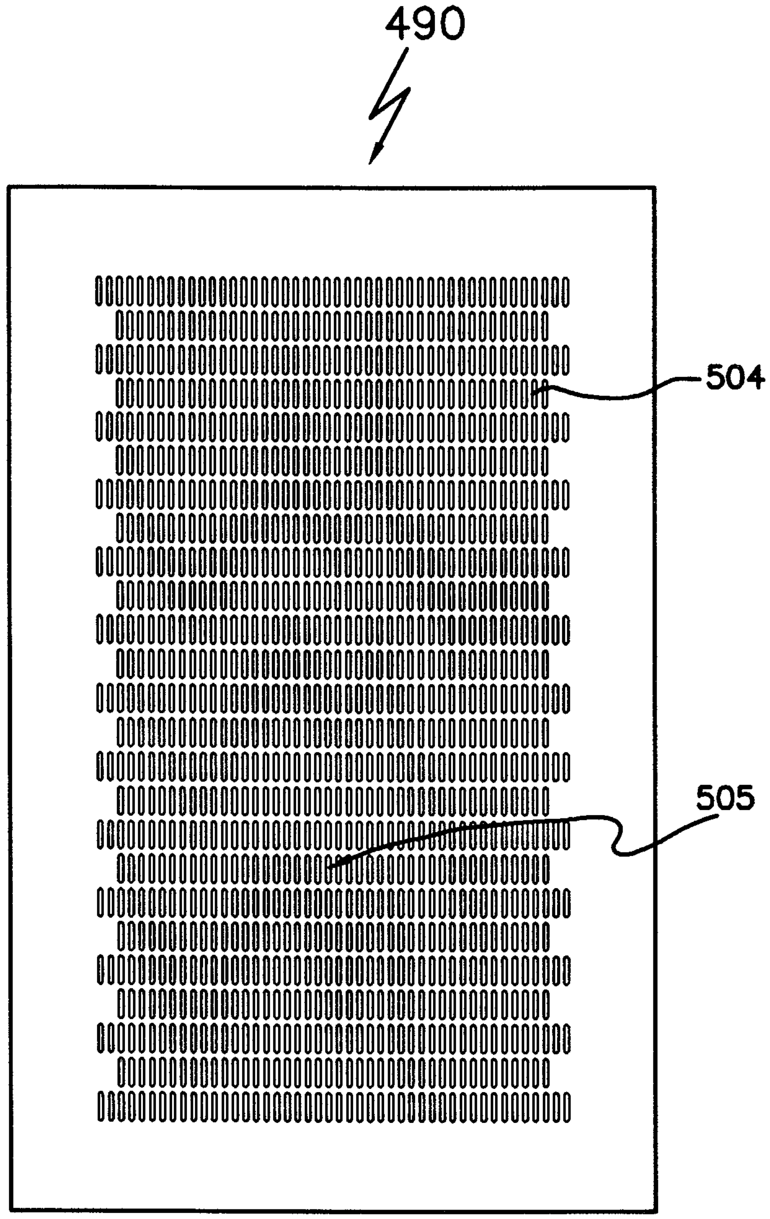


FIG.38

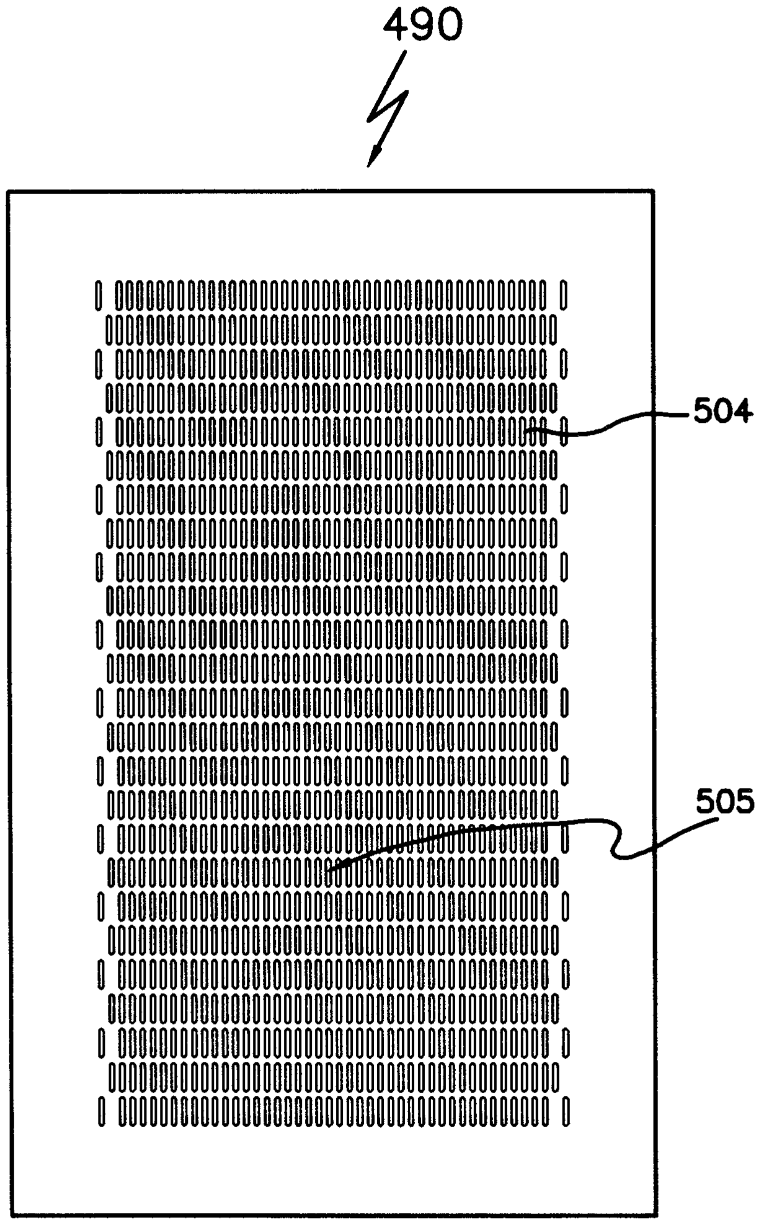


FIG.39

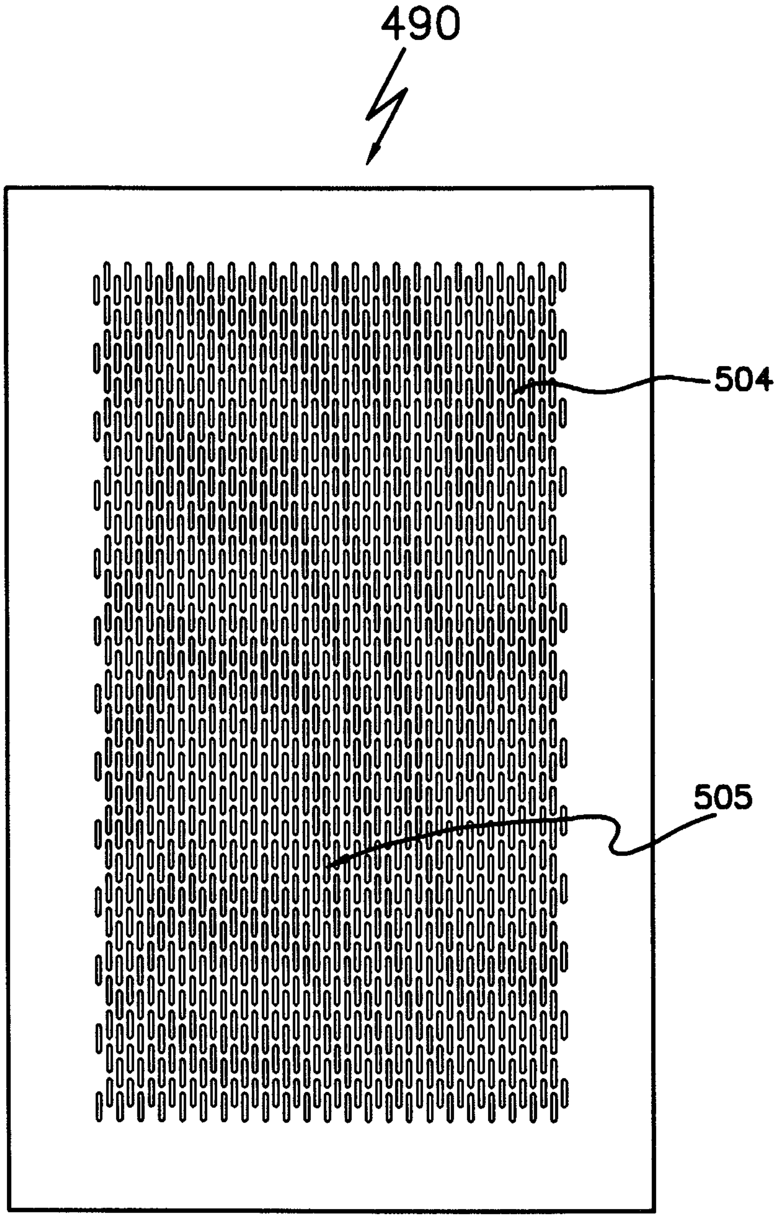


FIG.40

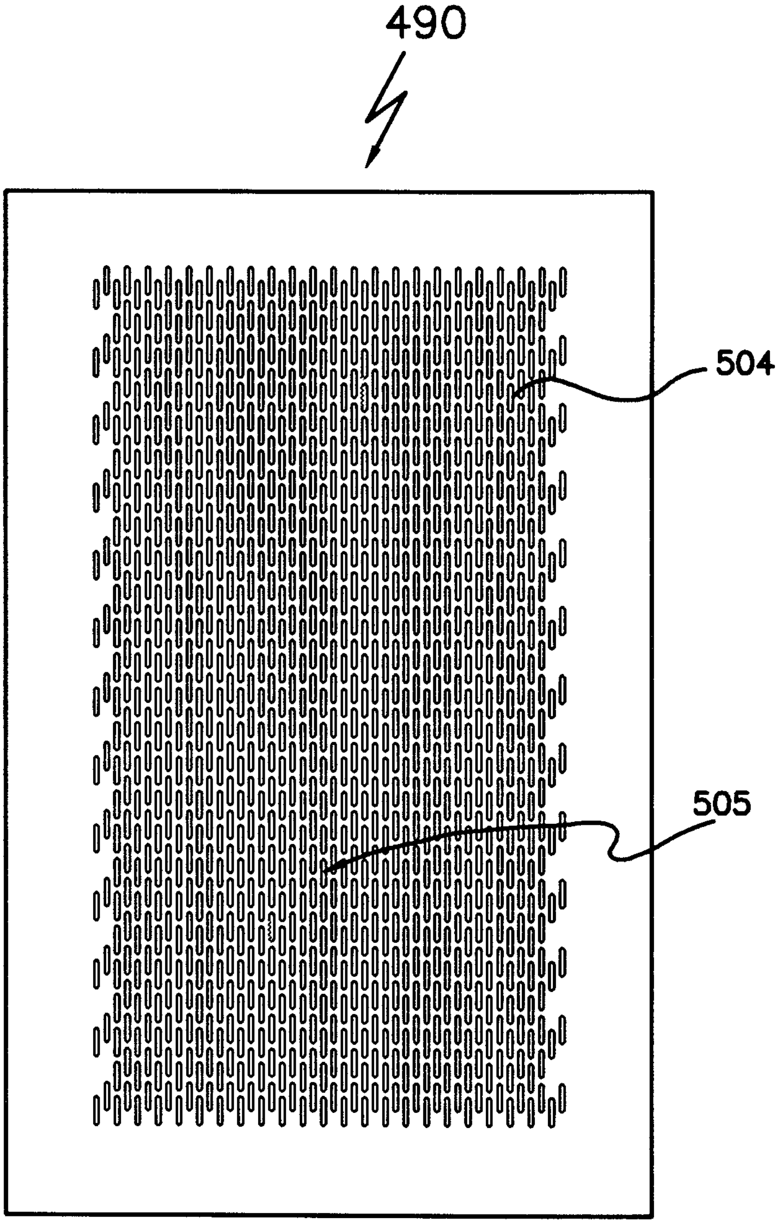


FIG. 41

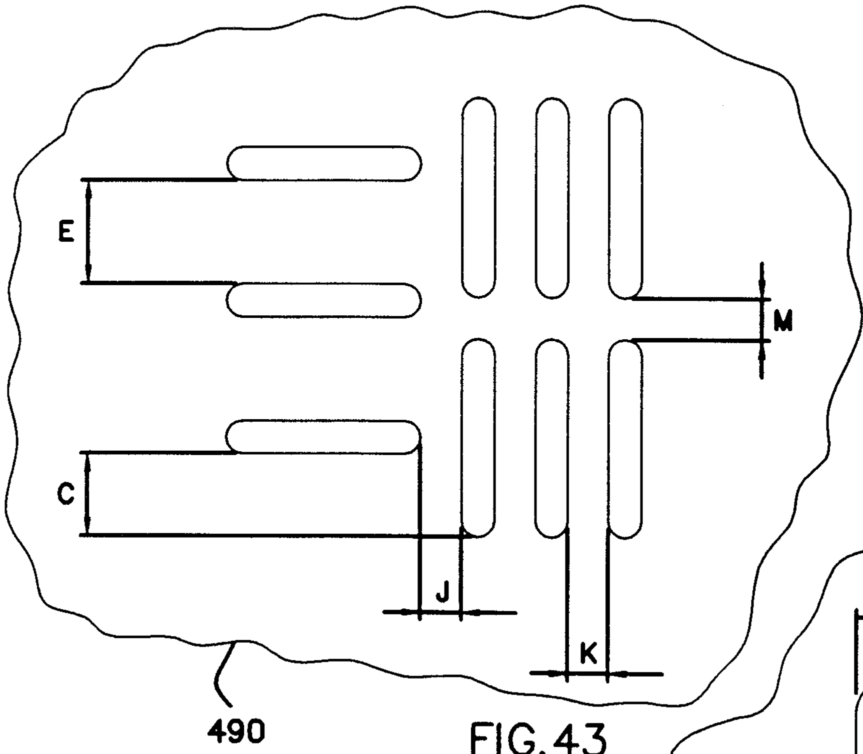


FIG.43

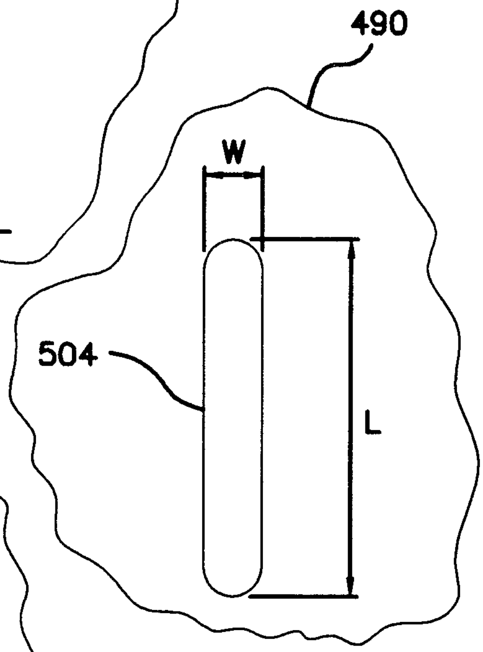


FIG.42

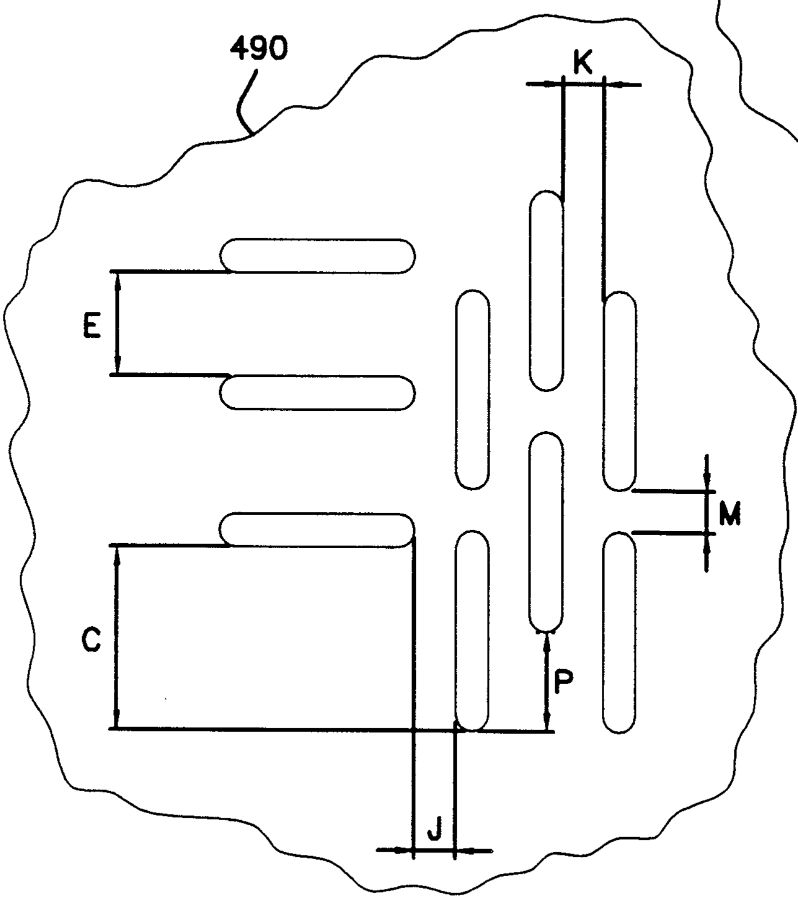


FIG.44

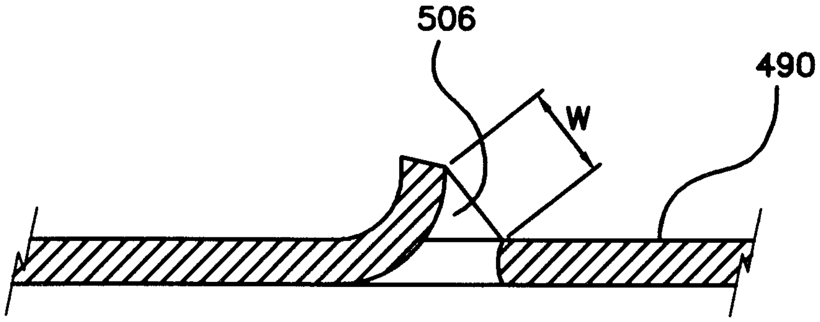


FIG.45

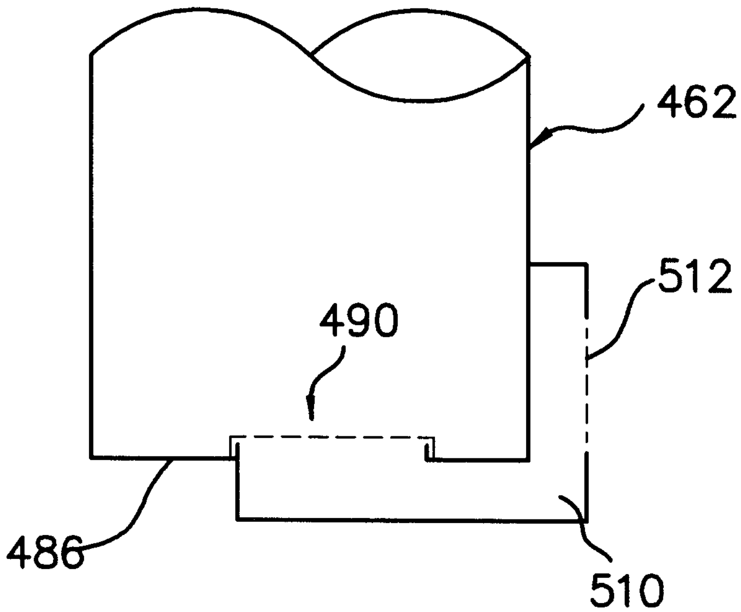


FIG.46

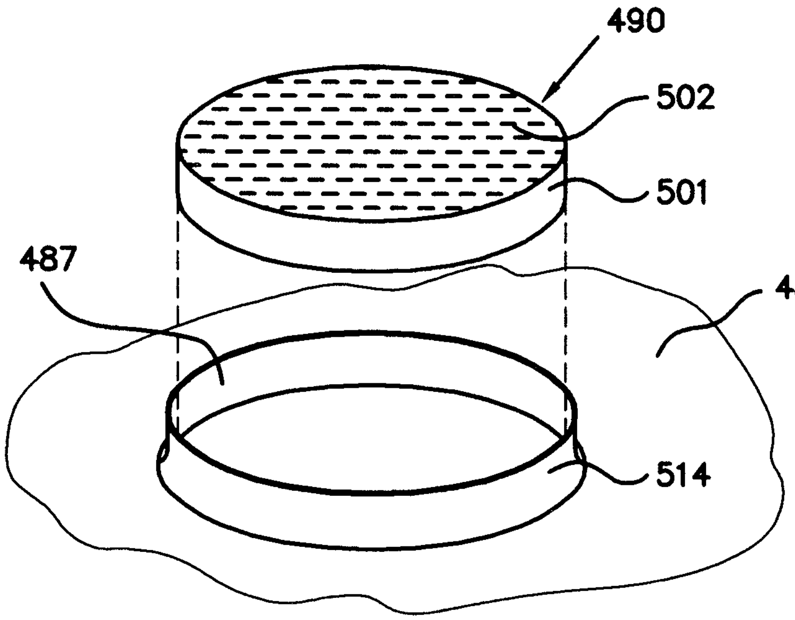


FIG.47

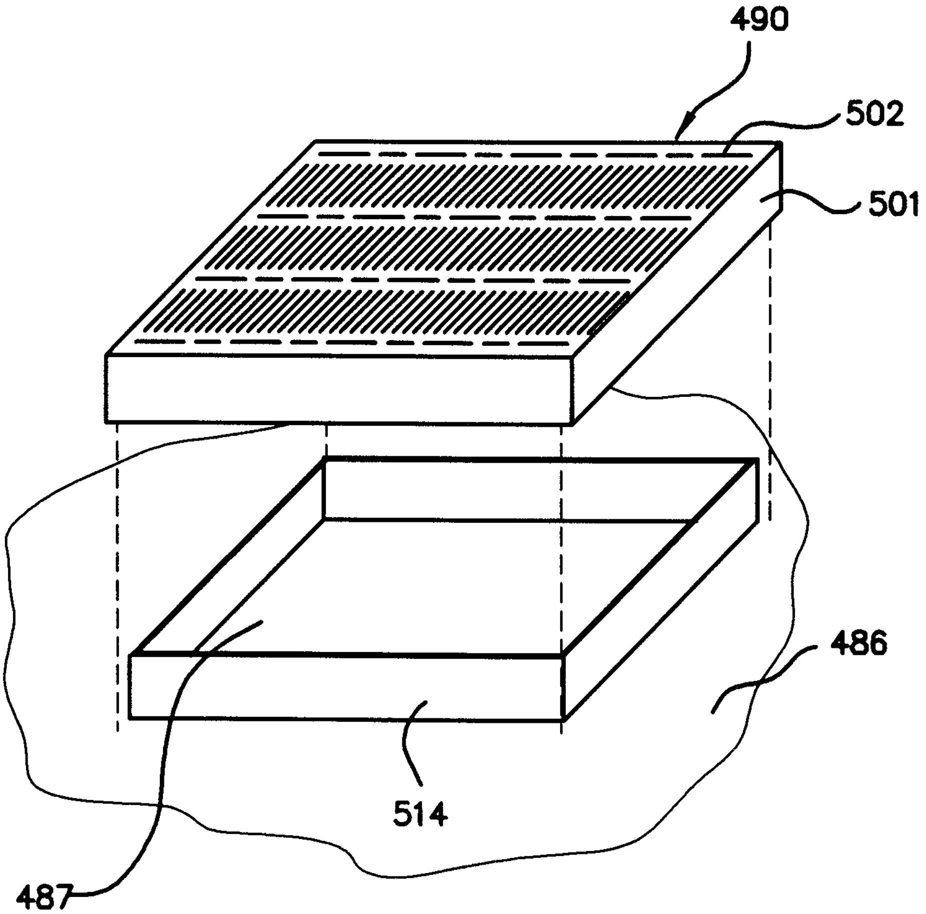


FIG.48

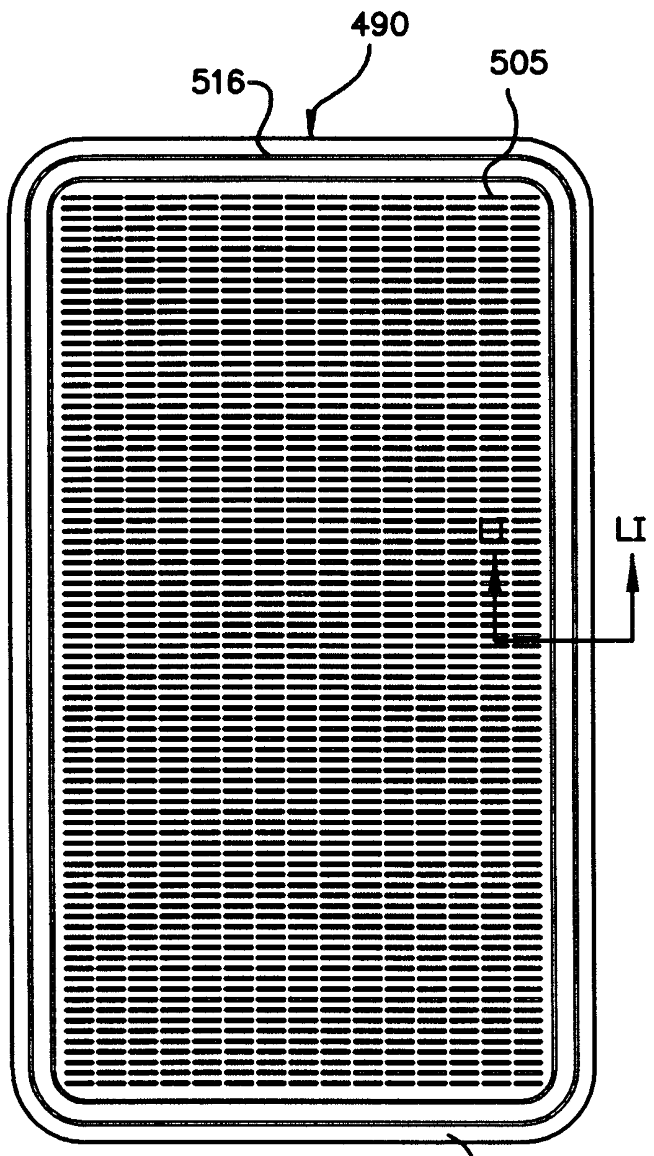


FIG. 49

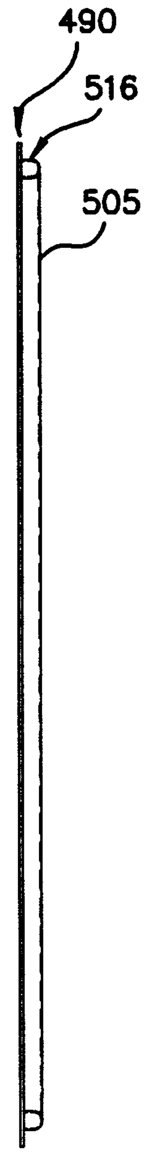


FIG. 50

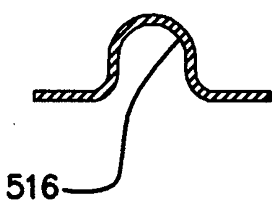


FIG. 51

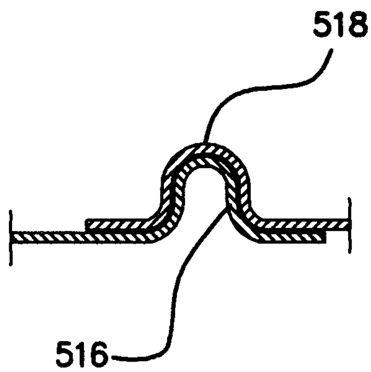


FIG. 52

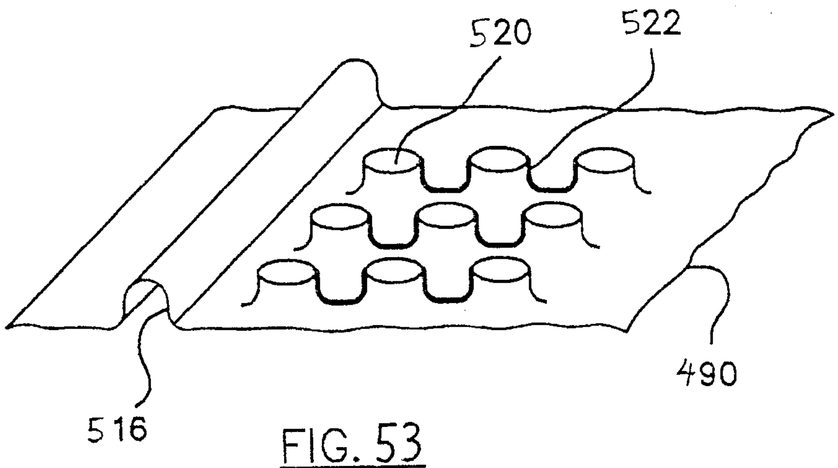


FIG. 53

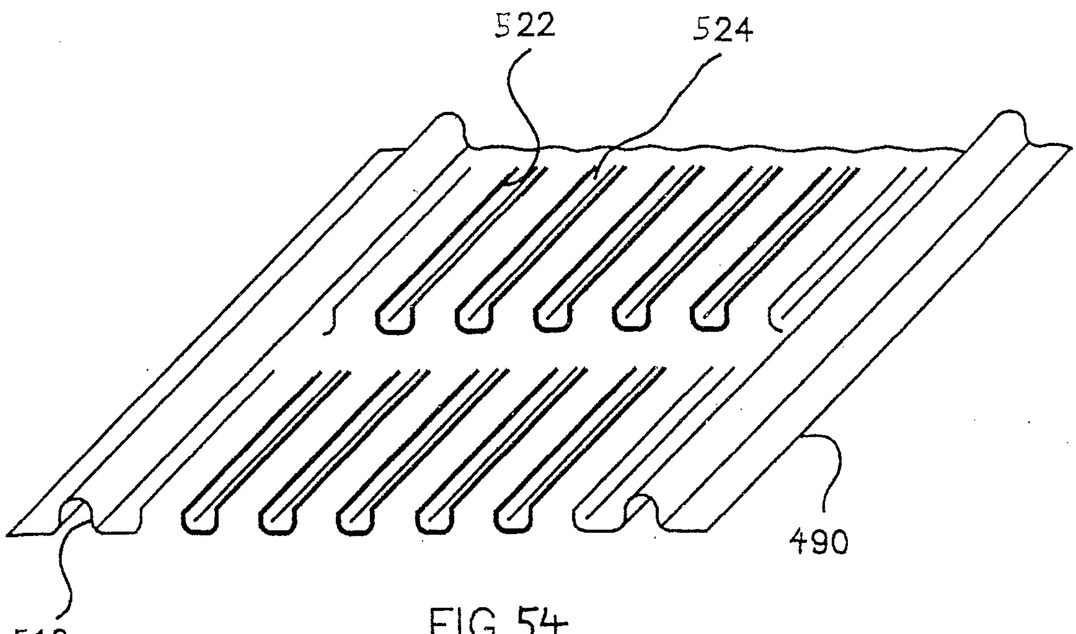


FIG.54

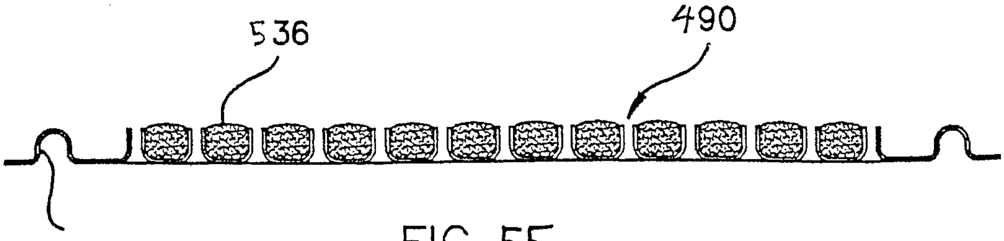


FIG. 55

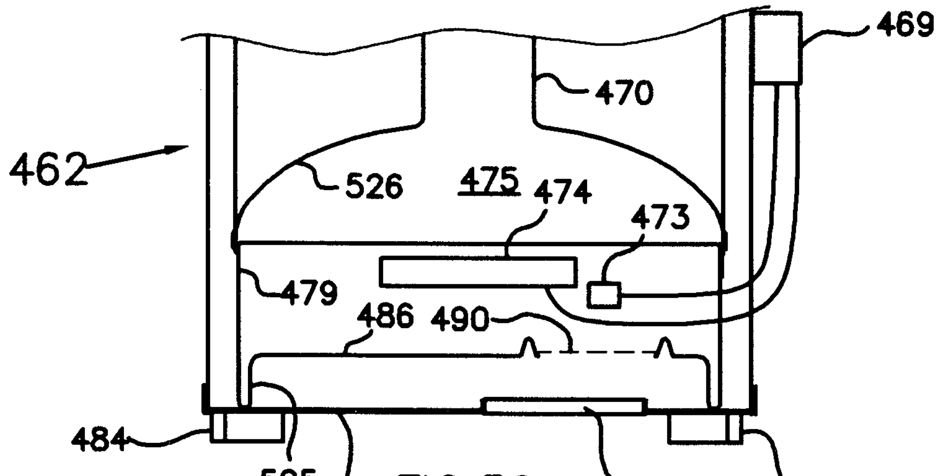


FIG.56

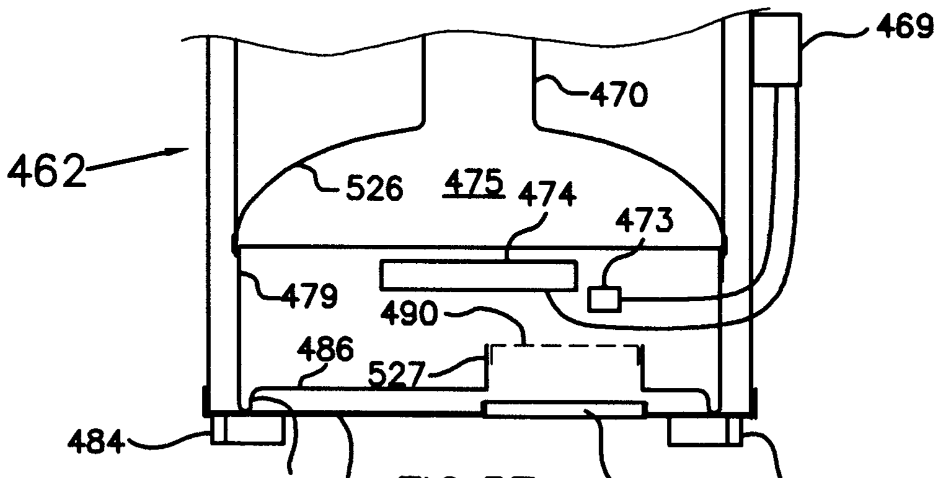


FIG.57

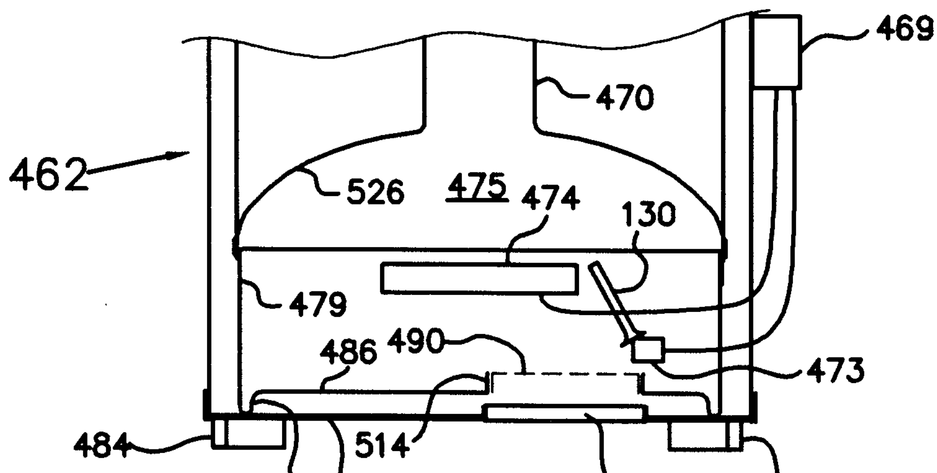


FIG.58

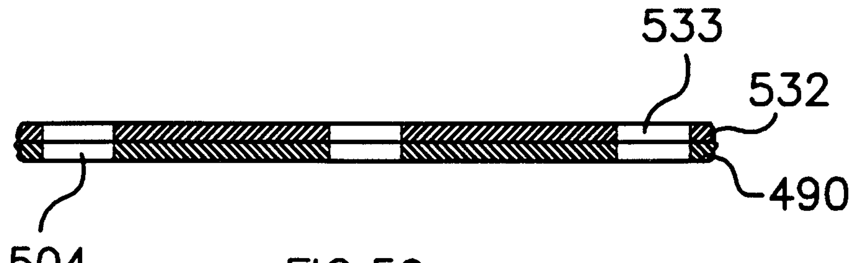


FIG.59

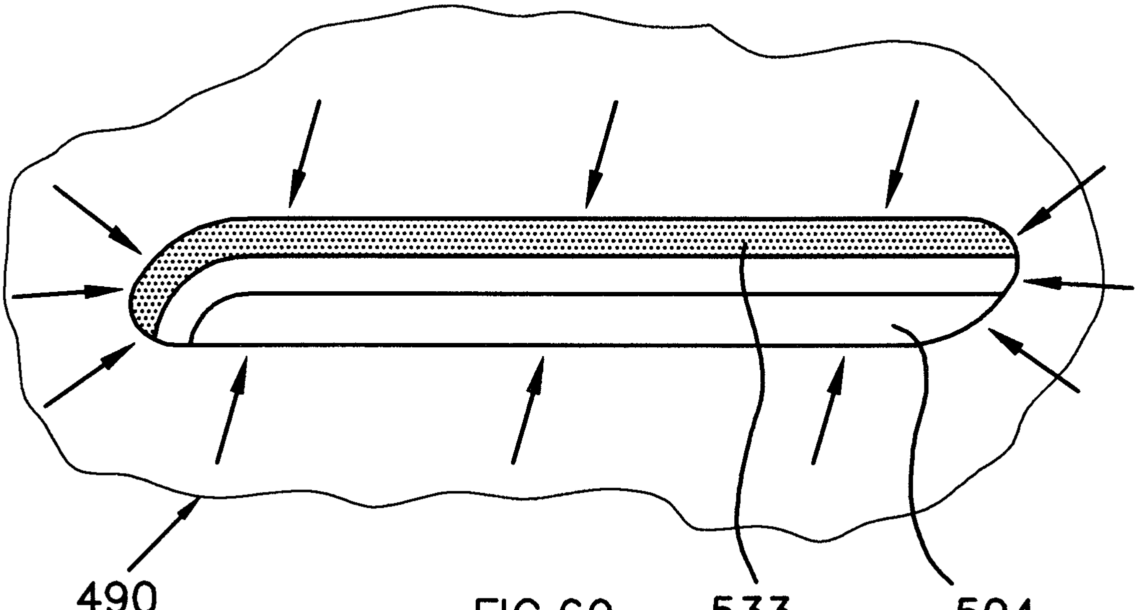


FIG.60

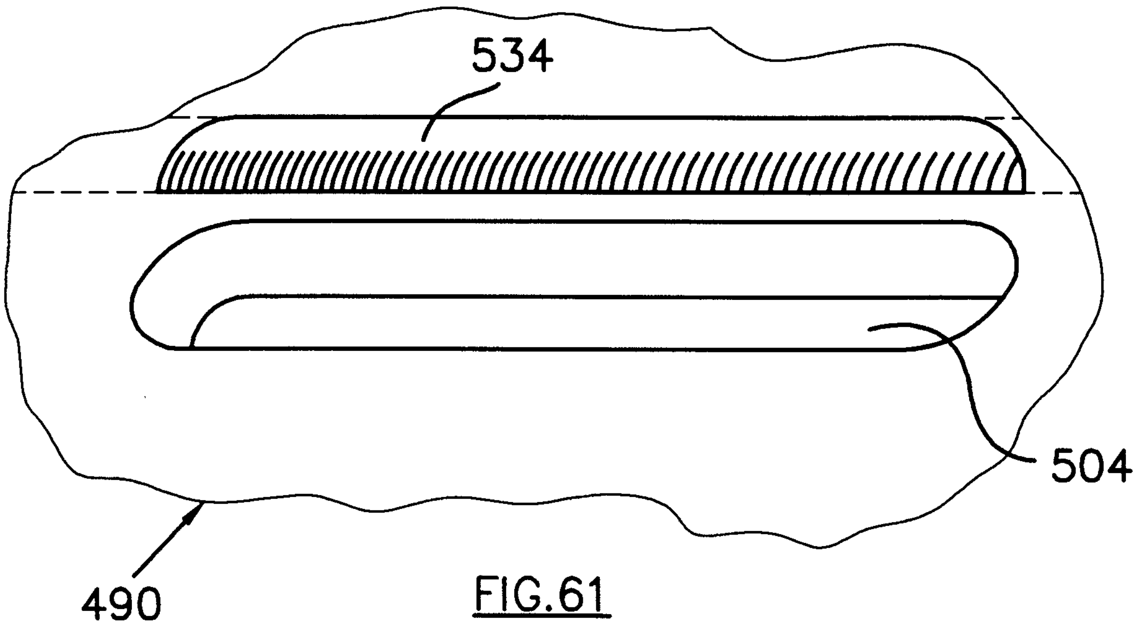


FIG.61

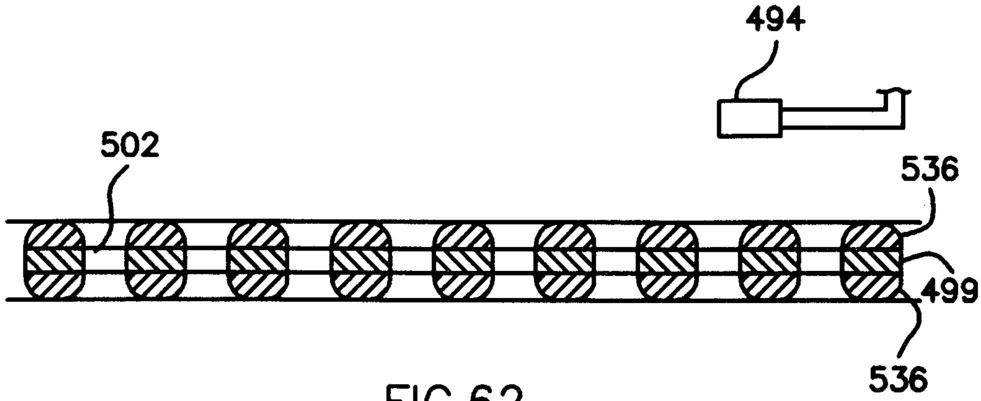


FIG.62

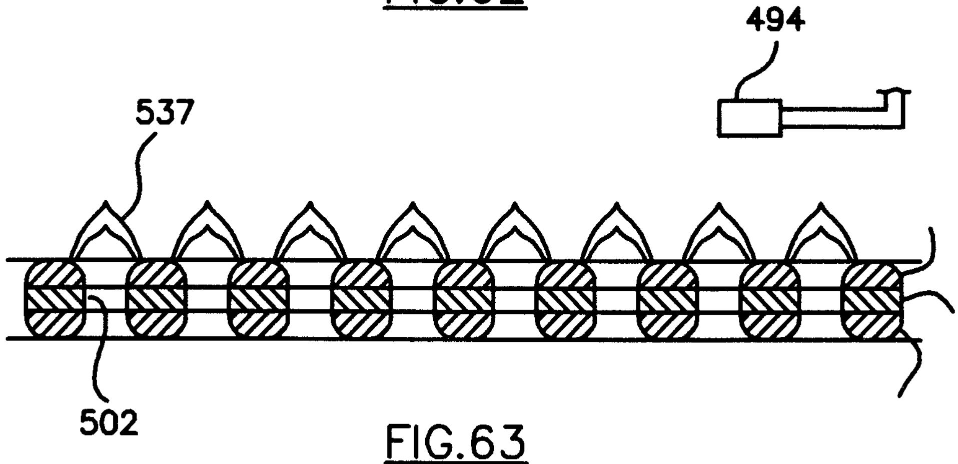


FIG.63

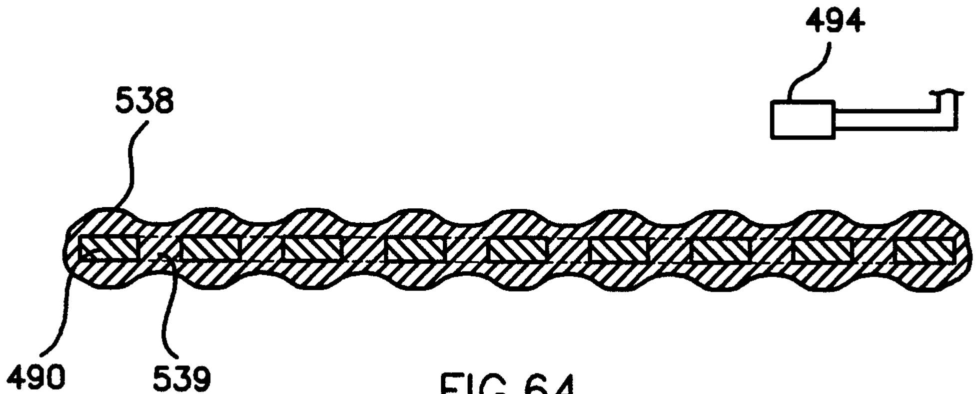


FIG.64

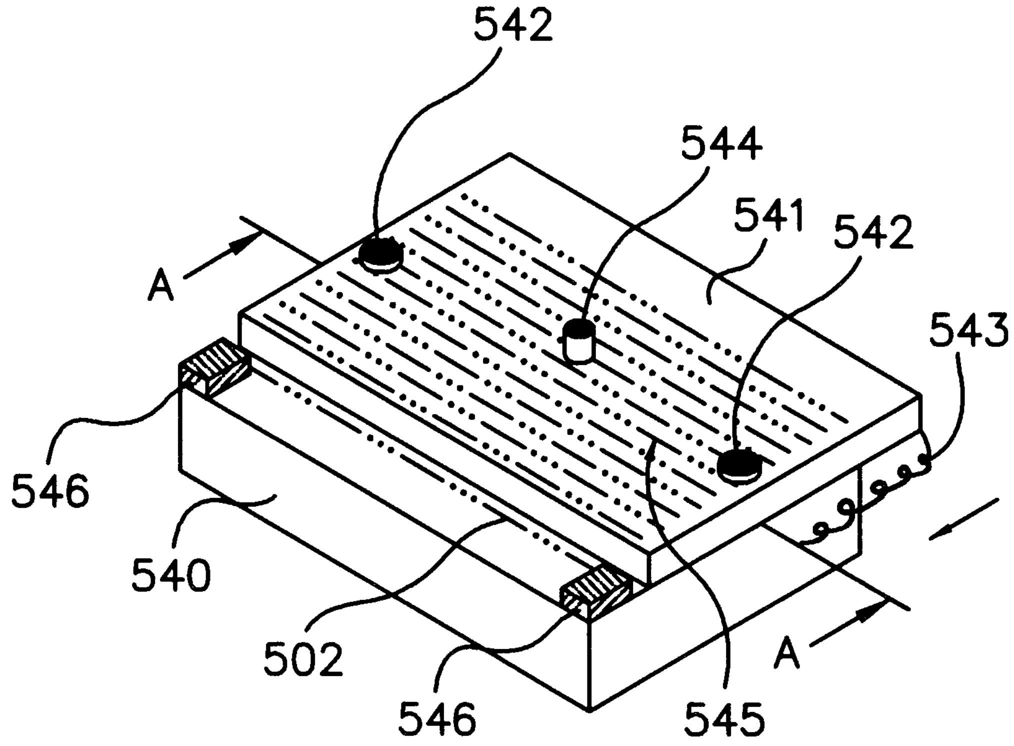


FIG.65

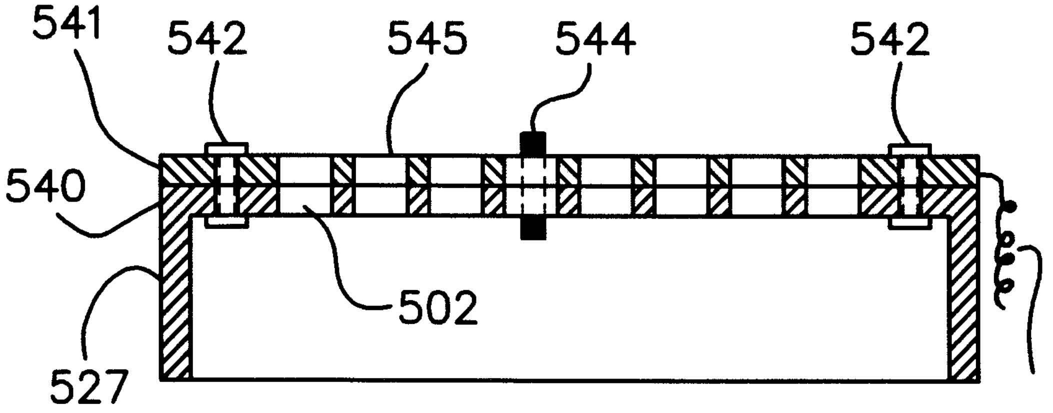


FIG.66

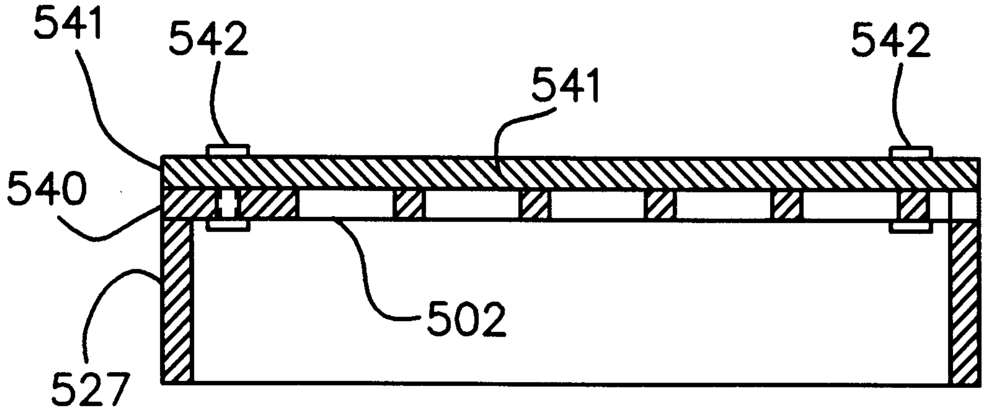


FIG.67

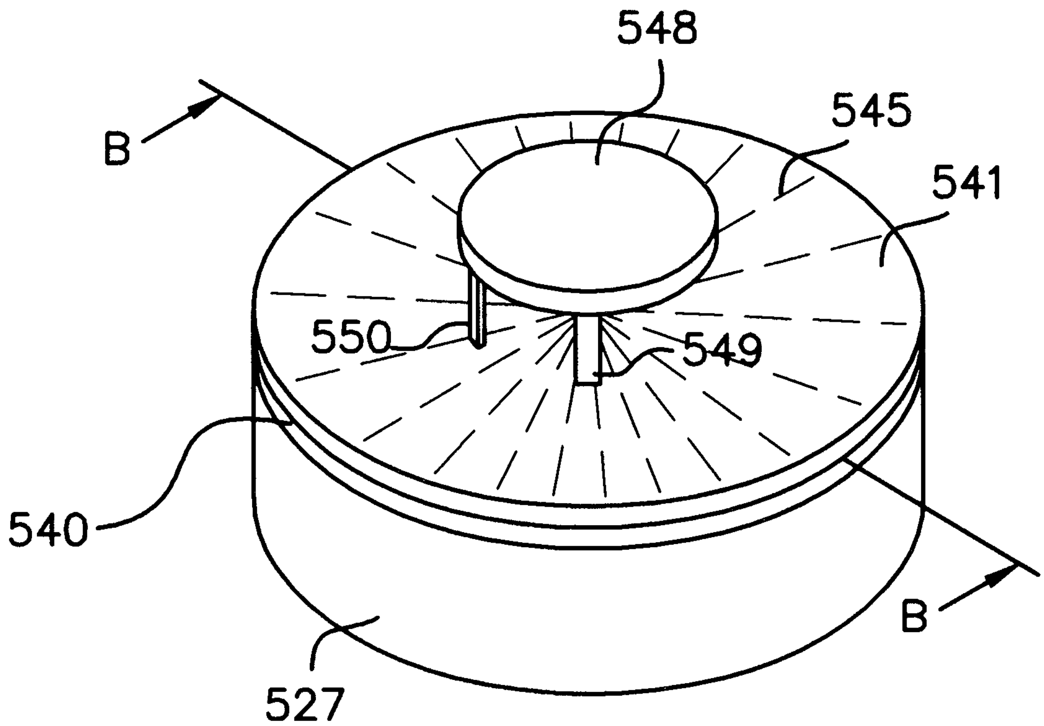


FIG.68

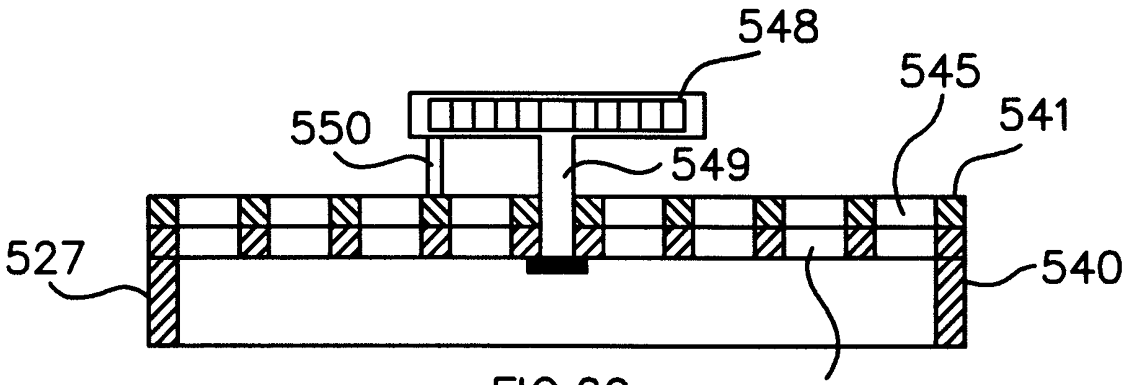


FIG.69

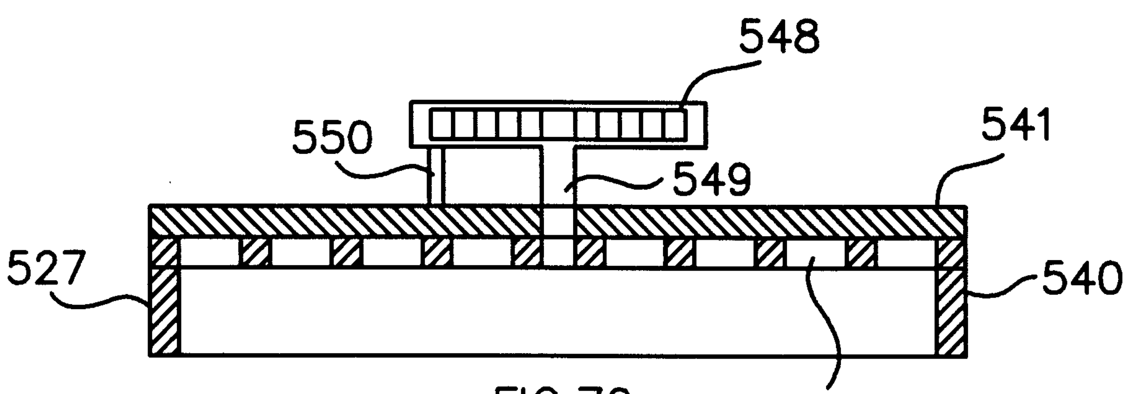


FIG.70

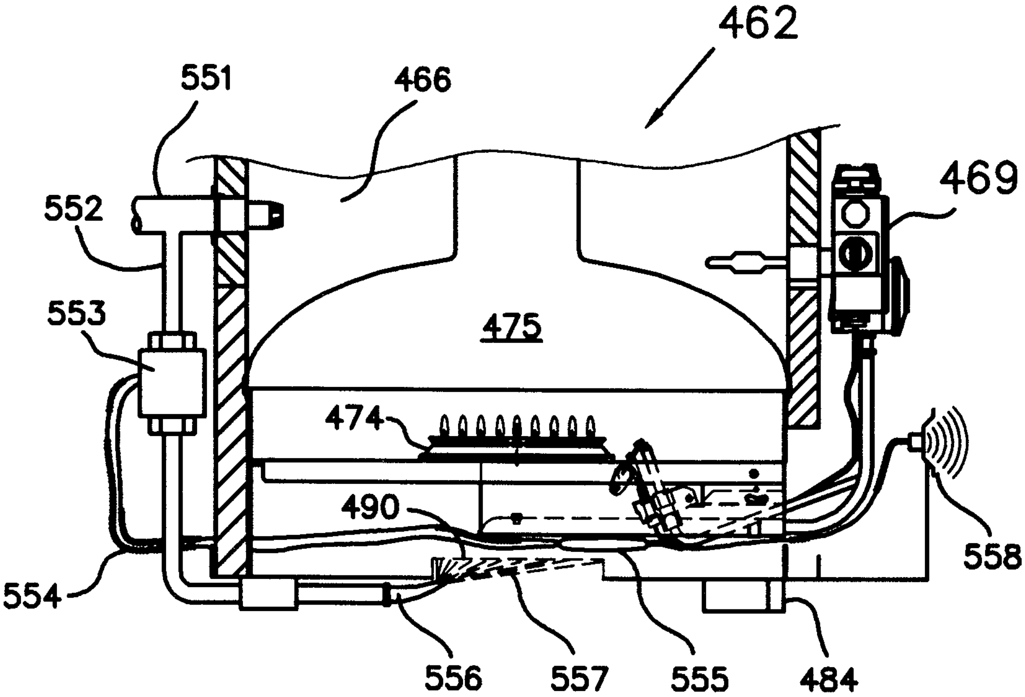


FIG 71

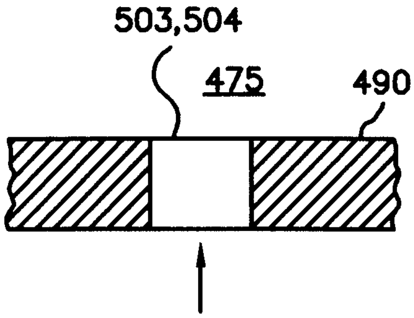


FIG. 72

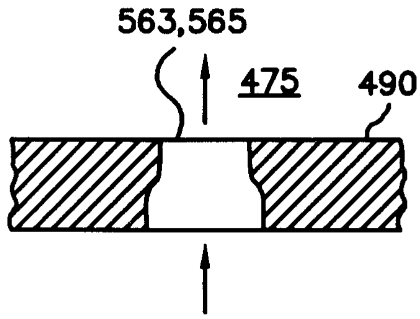


FIG. 73

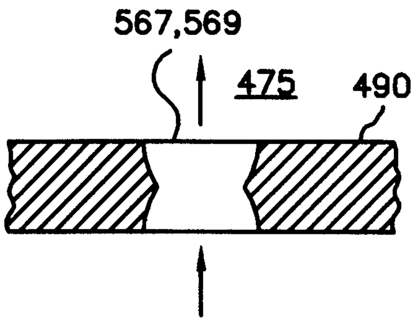


FIG. 74

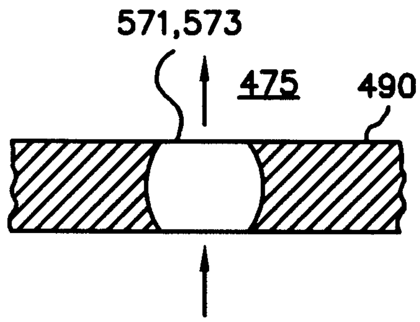


FIG. 75

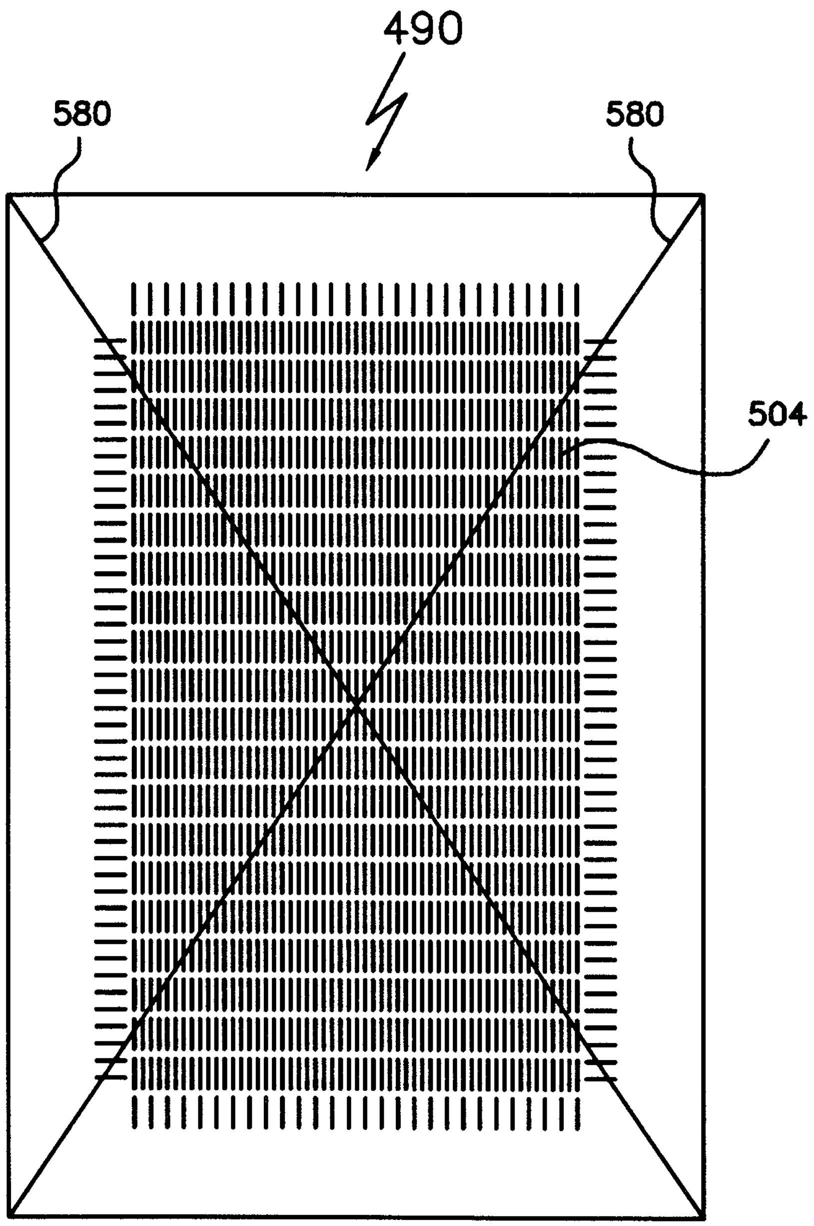
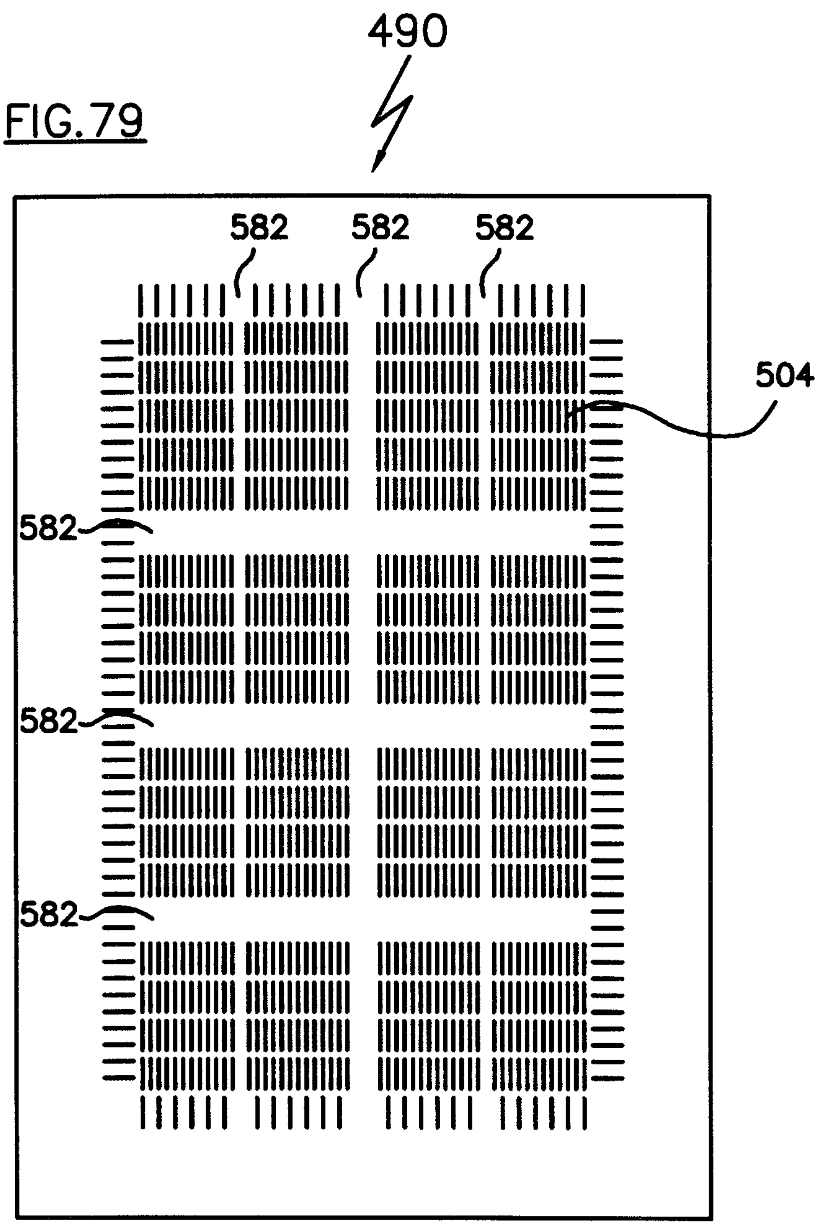


FIG.76

FIG.77

FIG.78

FIG.79



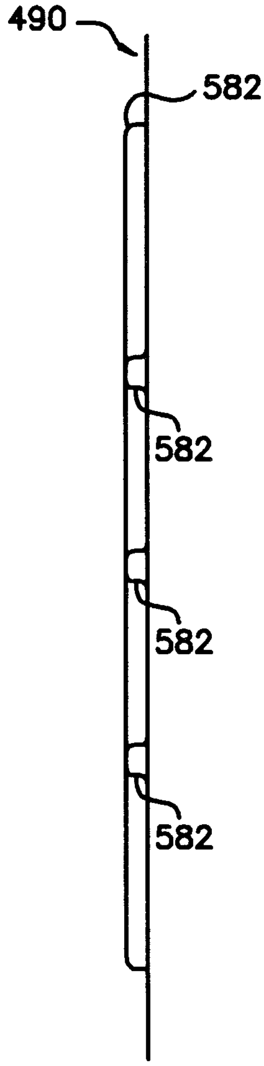


FIG.81

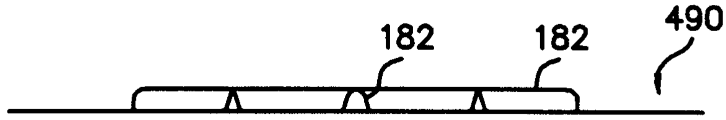


FIG.80

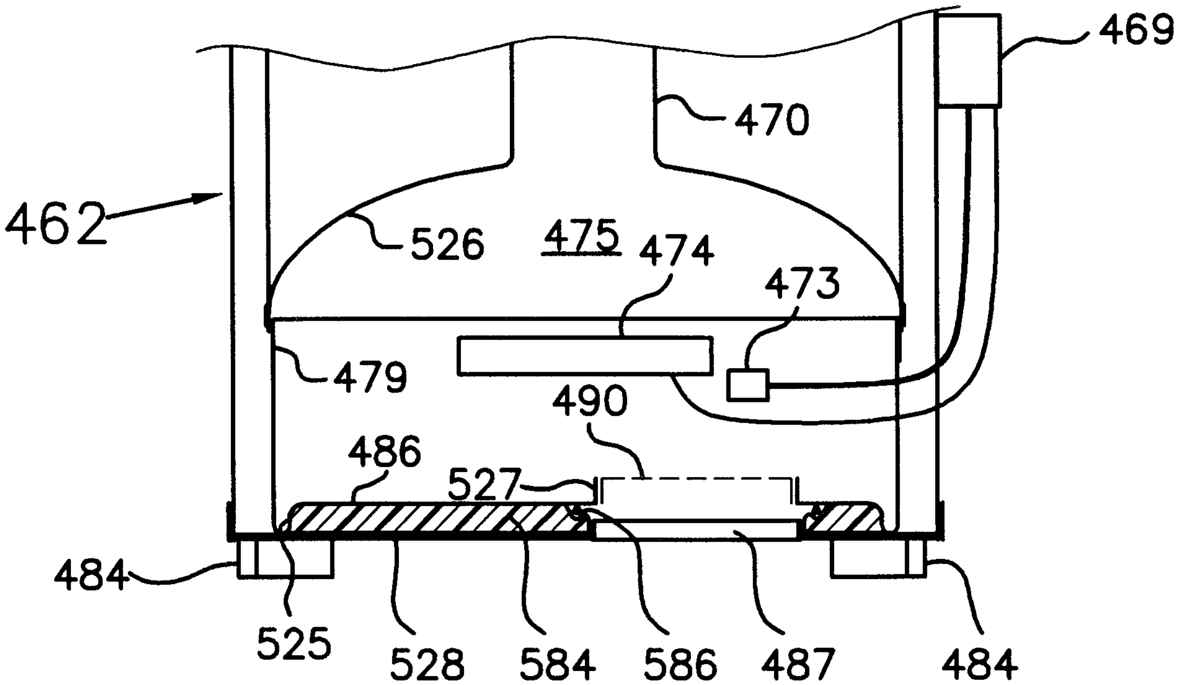

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FIG.82

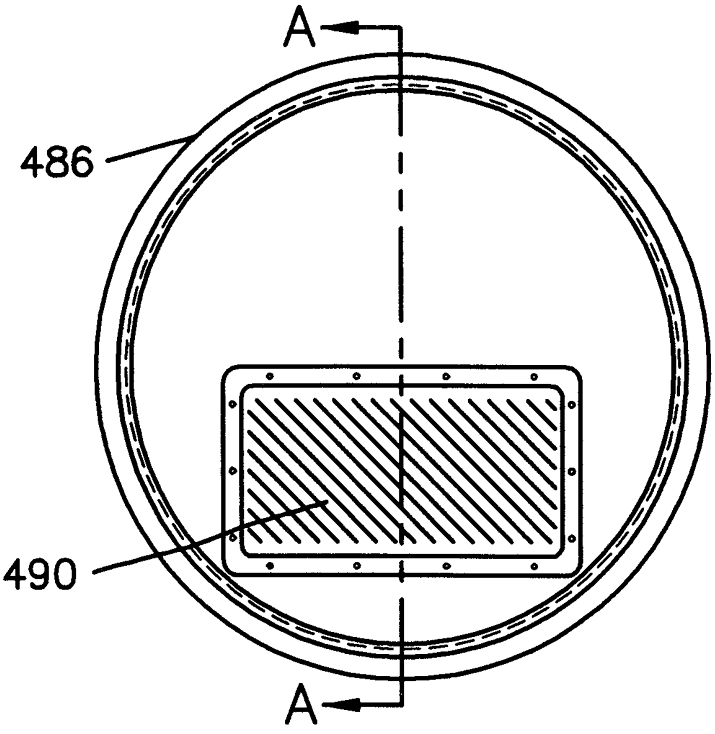

FIG.83

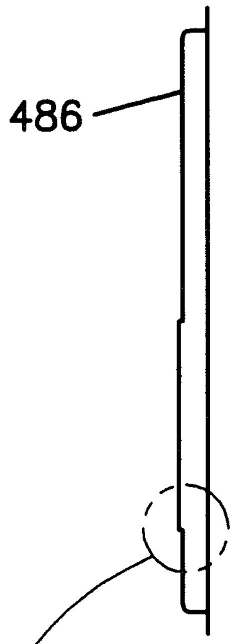

FIG.84

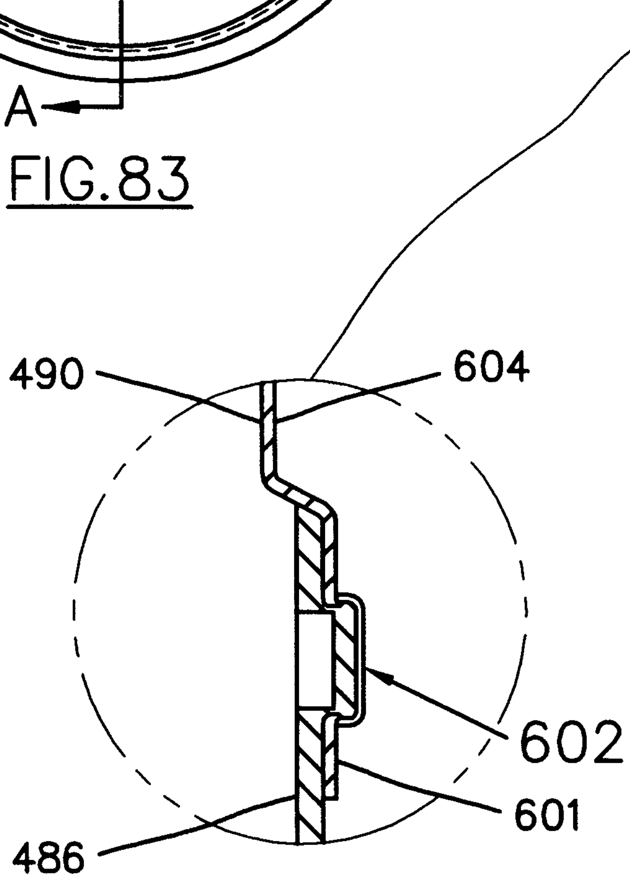

FIG.85

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU 98/00585

A.	**CLASSIFICATION OF SUBJECT MATTER**
Int Cl^6:	F23C 7/00 F23D 14/82 F24H 9/20

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)
IPC: F23C 7/00 F23D 14/70 14/82 F23M 9/04 11/02 F24H 9/20

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)
WPAT: IPC as above [arrestor OR trap OR flame OR explosion OR detonation OR fume OR quench]

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 0530945 A1 (BS & B SAFETY SYSTEMS, INC) 10 March 1993 See whole document	1
A	GB 2226124 A (THE FRYMASTER CORPORATION) 20 June 1990 See whole document	1
A	US 5765547 A (PLANTE) 16 June 1998 See Figure 5	39

[X] Further documents are listed in the continuation of Box C

[X] 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 application or patent but 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
11 August 1998	21 SEP 1998

Name and mailing address of the ISA/AU
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INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU 98/00585

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5520536 A (RODGERS et. al.) 28 May 1996 See Figure 2, item 60	1
X	WO 94/01722 A1 (BROWN) 20 January 1994 See Figure 6, item 60	85, 87, 90, 91 94-99

INTERNATIONAL SEARCH REPORT	International application No. **PCT/AU 98/00585**

Box 1 Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a)

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

Continued on extra page.

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims
2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.: 1 to 84

Remark on Protest ☐ The additional search fees were accompanied by the applicant's protest.

☐ No protest accompanied the payment of additional search fees.

Supplemental Box
(To be used when the space in any of Boxes 1 to VIII is not sufficient

Continuation of Box II

The international application does not comply with the requirements of unity of invention because it does not relate to one invention or to a group of inventions so linked as to form a single general inventive concept. In coming to this conclusion the International Searching Authority has found that there are different inventions as follows:

1. Claims 1 to 84 are directed to a water heater with at least one inlet positioned at an opening in said combustion chamber, said inlet permitting ingress of admit air and extraneous fume species into said combustion chamber and prevent egress of flames from said water heater the means to prevent egress of flames comprises a first "special technical feature".

2. Claims 85 to 103 are directed to a valve for supplying fuel to a water heater containing a main burner and a pilot burner and having a combustion sensitive fuse corrected to a circuit and positioned to be exposed to extraneous sources of flame and/or heat external to and adjacent the control valve. It is considered that the combustion sensitive fuse comprises a second "special technical feature".

These groups are not so linked as to form a single general inventive concept, that is, they do not have any common inventive features, which define a contribution over the prior art. The common concept linking together these groups of claims is a water heater. However this concept is not novel in the light of WO 9401722 (BROWN) published 20 January 1994. Therefore these claims lack unity a posteriori.

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/AU 98/00585

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report		Patent Family Member					
EP	530945	CA	2057275	JP	5256453	US	5191990
GB	2226124	JP	3122410	US	4976609	US	5101558
US	5520536	EP	809071				
WO	9401722	AU	45480/93	AU	20409/92	AU	22878/92

END OF ANNEX