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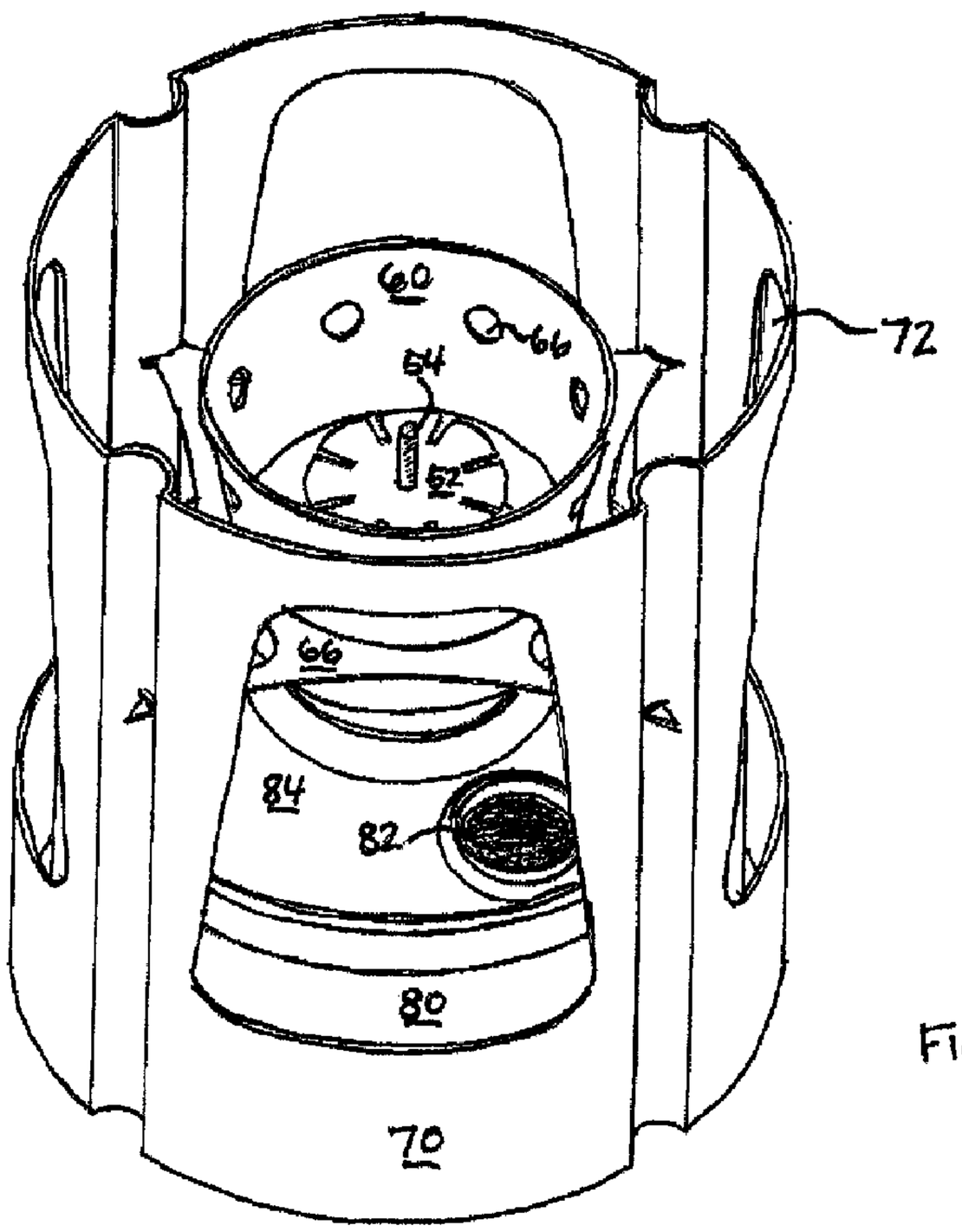



FIG. 3

(57) Abrégé/Abstract:
Gas generation apparatus and methods are provided, including apparatus and methods for efficient vaporization, and optional burning, of meltable fuels. The apparatus and methods provide controlled generation and combustion of any low melting point dimensionally stable combustible meltable fuel. This is preferably accomplished by first converting the solid or semi solid meltable fuel material into a liquid state, then into vapor, and finally mixing with an air source or other oxidizer before combustion.

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(54) **Title**: MELTABLE FUEL GAS GENERATION APPARATUS AND METHODS

(57) **Abstract**: Gas generation apparatus and methods are provided, including apparatus and methods for efficient vaporization, and optional burning, of meltable fuels. The apparatus and methods provide controlled generation and combustion of any low melting point dimensionally stable combustible meltable fuel. This is preferably accomplished by first converting the solid or semi solid meltable fuel material into a liquid state, then into vapor, and finally mixing with an air source or other oxidizer before combustion.

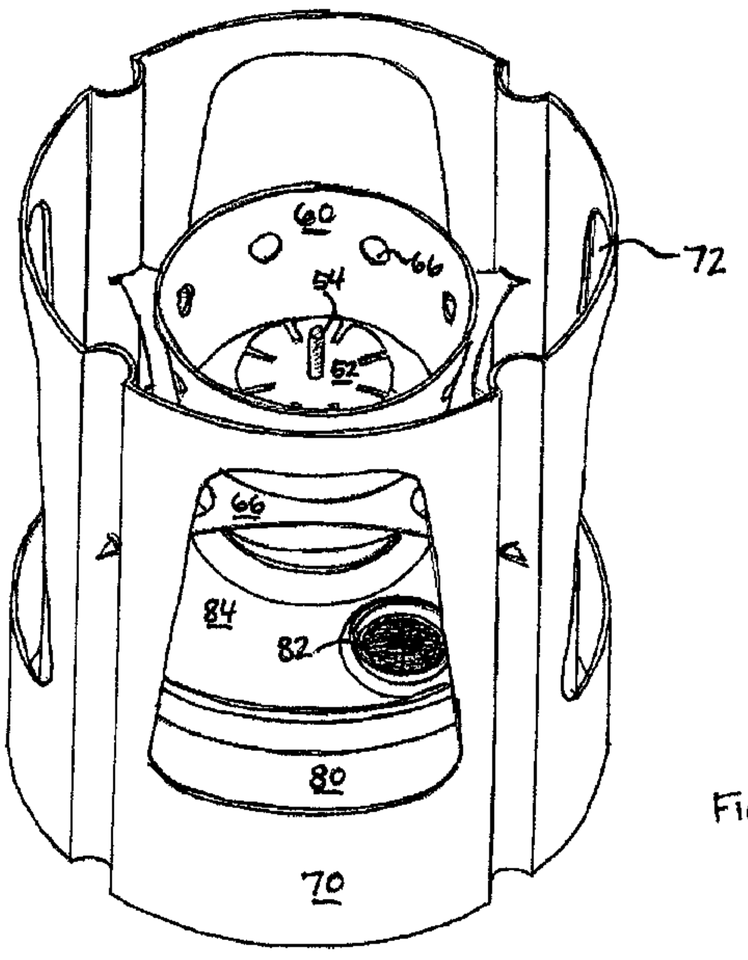



FIG. 3

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A. TITLE

MELTABLE FUEL GAS GENERATION APPARATUS AND METHODS

B.

**[0001]**

C.-E. Not Applicable.

F. BACKGROUND

**[0002]** Gas generation apparatus and methods are provided, including apparatus and methods for efficient vaporization, and optional burning, of meltable fuels.

**[0003]** Known fuel burning apparatus utilize various fuels such as alcohols, kerosene, and other petroleum products in either liquid state and/or vapor ("vapor" also referred to herein as "gas") states. For example, portable camp stoves and heaters commonly utilize kerosene, which in its ambient temperature, unpressurized form is a liquid state fuel. Kerosene and other known liquid state fuels are volatile, flammable, explosive, and sometimes corrosive, making their transport, handling, and use inherently dangerous to a user and the surrounding environment.

**[0004]** In another example, stoves, furnaces, and other combustion apparatus are known to utilize gas state fuels such as propane, butane, isobutane, and the like. For example, propane is provided as a pressurized liquid that converts to gas upon release of pressure from the tank, such as by opening a valve in a supply line to a connected stove or heater. Liquid fuels and pressurized gas fuels are subject to safety, health, and other regulatory restrictions as a result of their flammable, volatile, explosive, corrosive, and other undesirable properties. The inherent properties of known liquid state and gas state fuels

present serious challenges in storage, transportation, and use. Commercial transportation of such fuels is highly regulated and restricted, requiring special permits and compliance with health and safety laws, regulations, and procedures, such as HAZMAT, environmental, and Homeland Security, for example. Recreational storage, transportation, and use of known liquid and gas fuels can be just as dangerous, and just as challenging, especially for consumers such as hikers and campers who need to travel through commercial governmentally regulated means such as airlines, trains, ships, and even tunnels. For example, hikers who are traveling to remote locations by air, with few exceptions, cannot carry pressurized propane tanks or liquid fuel for their camp stoves. They must rely upon the availability of such fuels at their ground destination – which may not be available depending upon the location and nature of the destination. Additionally, transport and use of pressurized gas and/or liquid fuel by campers, military personnel, or other users presents a real risk of harm by spillage and/or leakage that can result in severe personal injury whether by flame, explosion, ordinance, or combination thereof. For example, liquid fuel famine relief stoves known as "panda stoves" have been banned from importation into Africa because of the proliferation of fires resulting from kerosene liquid fuel spillage, as well injuries resulting from the design of such stoves. The irony of injuring a starving person or burning down their home by providing a dangerous stove is not lost on the author. Neither is the irony of a soldier surviving combat conditions only to find that his liquid fuel leaked and that he has none left for heat to survive the night. We have a solution, as described herein.

G. SUMMARY

**[0005]** Apparatus and methods for providing safe, efficient burning of meltable fuel are provided herein. In one embodiment, an apparatus is provided for generating a gas vapor state of at least one meltable fuel, the device comprising a gas generator assembly, wherein the gas generator assembly is configured and disposed to receive a meltable fuel and to

convert the received meltable fuel to a gas vapor state. In another embodiment, the gas generator assembly includes a heat transfer element in communicable connection with a heat source and a meltable fuel source.

**[0006]** In another embodment, the apparatus is a gas generation apparatus comprising a reservoir configured for receiving a meltable fuel; a heat transfer element having an inlet end and an outlet end, wherein said inlet end is in communicable connection with the reservoir, the heat transfer element comprising a thermally conductive material, in thermal connection with a heat source, the heat source configured and disposed to transfer heat to the heat transfer element in a sufficient amount to convert at least a portion of a meltable fuel received by the reservoir to at least a liquid state. Optionally, the apparatus includes a capillary element such as a wick for drawing meltable fuel to the heat transfer element. Optionally, the apparatus may include a heat sink in thermal communication with the heat transfer element for heating meltable fuel contained in a fuel reservoir. Optionally, the heat transfer element may include an outlet for gas vapor to escape.

**[0006.1]** In accordance with one aspect of the present invention, there is provided a method of generating a gas or vapor state of a wax, the method comprising the steps of providing a gas generator assembly, introducing a meltable fuel consisting essentially of wax into the gas generator assembly, converting the wax to a wax gas or vapor, releasing the wax gas or vapor from the gas generator assembly, and utilizing the released wax gas or vapor as a fuel source by combusting the released wax gas or vapor in an apparatus selected from the group consisting of stoves, fumigation devices, lanterns, lamps, heaters, combustion engines, Stirling engines, boilers, generators, furnaces and fireplaces, and wherein the method is not part of a refinery.

**[0006.2]** In accordance with another aspect of the present invention, there is provided a method of generating a gas or vapor state of a wax, the method comprising the steps of providing a device comprising a gas generator assembly that is not a candle, introducing a meltable fuel consisting essentially of wax into the gas generator assembly, converting at least a portion of the meltable fuel to a gas or vapor, releasing the gas or vapor from the gas generator assembly, and providing released wax gas or vapor as a fuel source for at least one apparatus selected from the group consisting of stoves, fumigation devices, lanterns, lamps, heaters, combustion engines, Stirling engines, boilers, generators, furnaces and fireplaces, and wherein the method is not part of a refinery.

## H. BRIEF DESCRIPTION OF THE DRAWINGS

**[0007]** Fig. 1 is an exploded perspective view of an exemplary gas generation apparatus.

**[0008]** Fig. 2 is a cross-sectional perspective view of the exemplary gas generator assembly of Fig. 1.

**[0009]** Fig. 3 is a side perspective view of the exemplary apparatus of Fig. 1 in a fully assembled, closed position.

**[0010]** Fig. 4 is a cross-sectional perspective view of the exemplary apparatus of Fig. 3.

**[0011]** Fig. 5 is a side perspective view of the exemplary apparatus of Fig. 1 in a fully assembled, open position.

**[0012]** Fig. 6 is a cross-sectional side view of gas generation apparatus.

**[0013]** Fig. 7 is a top perspective view of the apparatus of Fig. 6.

**[0014]** Fig. 8 is a cross-sectional side view of the apparatus of Fig. 6 showing the wick flame and combustion flame.

**[0015]** Fig. 9 is a cross-sectional side view of another exemplary apparatus.

**[0016]** Fig. 10 is a cross-sectional side view of another exemplary apparatus.

**[0017]** Fig. 11 is a cross-sectional side view of another exemplary apparatus.

**[0018]** Fig. 12 is a cross-sectional side view of another exemplary apparatus.

## I. DETAILED DESCRIPTION

**[0019]** Apparatus and methods for providing safe, efficient burning of meltable fuel are provided herein. Without limitation, "meltable fuel" as used herein includes any fuel that is substantially solid or semi-solid at an ambient and/or room temperature and an ambient and/or atmospheric pressure, but that converts to a liquid and/or vapor state at an elevated temperature and/or reduced pressure. By way of non-limiting example, meltable fuel include waxes such as paraffin waxes, alcohol gels and other gels, flora waxes, fauna waxes, insect waxes, animal waxes, petroleum products, alcohol and other distillates, fats such as fauna fats, flora fats, and any other solid or semi-solid material that is functional as a fuel, and preferably as a combustible fuel when mixed with air or other oxidizers. The apparatus herein are additionally and alternatively adaptable to burning known liquid fuels such as kerosene, diesel, alcohols, and gasolines (hereinafter collectively referred to as "traditional liquid fuels"), by way of non-limiting example.

**[0020]** By way of non-limiting example, apparatus embodiments incorporating the inventor's gas generation technology are illustrated in Figs. 1-9. As used herein, "stove" is intended as non-limiting, and includes any apparatus having the claimed elements of a gas generation apparatus, and optionally further including a source of ignition for combustion of

generated vapor, regardless of its use. For example, the inventor contemplates that the gas generation apparatus and the gas or vapor state fuel it generates can be used as a stove to heat a surrounding or remote space, such as by directing a mixture of vapor and air to an ignition source for combustion and radiating or convecting the resulting combustion heat to a desired area, to heat or sterilize food and beverages for consumption, to provide light, to disperse scents or fumigants, to power engines such as internal combustion and/or external combustion and/or Stirling engines, among other uses described herein and that will be apparent from study of the instant disclosure. Additionally, it may be desirable to provide the gas generation apparatus in the absence of an ignition and/or combustion source, such as to provide a non-ignited gas vapor stream to disperse scents or fumigants, for example.

**[0021]** The principal underlying the apparatus and methods herein involves a gas generation cycle wherein a meltable fuel and/or liquid fuel is converted to a gas or vapor state by the gas generation assembly of the apparatus. In any embodiment, the conversion is accomplished by the application of energy to the fuel to convert the fuel from a solid state to a liquid and/or vapor state. The energy may be provided in any number of individual or combined forms, such as heat, light, radiation, microwaves, electricity, energy pulses, laser, solar, and the like.

**[0022]** For example, in one embodiment, a meltable solid fuel provided is melted to a liquid and/or vapor state by heat transition from a heating assembly of the gas generation assembly. The heating assembly includes a heat source that is selected from any number of types, such as burning capillary member such as a wick element, or electrical coil, radiator, or other available energy sources. The heating assembly includes a heat transfer element in thermal connection with the heat source, and further in thermal connection with a meltable fuel source. The heat transfer element is configured and disposed to be heat-conductive, and preferably highly heat conductive at selected operating temperatures compatible with the heat

source, meltable fuel, and other features of the apparatus and its intended uses. For example, "highly heat conductive" as used in a paraffin wax stove embodiment described herein means the heat transfer element has a thermal conductivity sufficient to transfer heat from a wick flame heat source to a paraffin wax meltable fuel in an amount sufficient to raise the wax to a temperature above its solid-to-liquid state melting point, e.g. to raise the wax to a temperature above 140°F, for example. In other words, heat transmitted from the heat transfer element is received by meltable fuel. For example, the meltable fuel is preferably contained, such as in a fuel reservoir, so that the fuel is efficiently heated by the heat transfer element to a selected temperature, causing the meltable fuel to change physical state(s). For example, in the example of solid state wax fuel, the transferred heat would convert at least a portion of the solid wax to a liquid state. In that example, the liquid state fuel is then further heated in a controlled manner, such as in a heating chamber, so that it is further converted to its gas vapor state. Such heating and physical state transitions can be selectively controlled to occur in a single fuel reservoir, in a heating chamber, or in any combination thereof, whether as separate or combined processes. For example, liquid state fuel in a first fuel reservoir that is heated by a heat transfer element can be permitted to exit the reservoir by seeping or draining through apertures, wicks, or other communicable means to a heating chamber, where at least a portion of the liquid state fuel is converted to a vapor state, whether by heat, reduced pressure, capillary action, and/or increased surface area. In one embodiment, the heating chamber is incorporated into the heat transfer element (such as a heated conduit, for example, as further described herein). In some embodiments, the apparatus includes a capillary member that serves as a means to increase the surface area of the meltable fuel contained within the reservoir and/or heating chamber, thereby promoting rapid transition and conveyance of a meltable fuel from a solid state through a liquid state and eventually to a vapor state. The capillary member may be made of any material capable of capillary action

for transporting meltable fuels in their liquid and/or vapor states. For example, fibrous materials such as woven or nonwoven natural or synthetic fibers and combinations thereof, porous composite materials such as macroporous or microporous ceramics and the like, and porous metal structures such as sintered metal compositions, by way of non-limiting example. Preferably, the capillary member is comprised of non-consumed materials, i.e. materials that are not quickly degraded or easily consumed by exposure to meltable fuels and temperatures consistent with the apparatus and methods described herein.

**[0023]** Prior art teaches away from intentionally heating fuel, whether gas or liquid, that is contained in a reservoir, such as a reservoir in a kerosene lantern or kerosene stove, for example. Such heating causes traditional known liquid and gas state fuels to expand, causing undesired pressure in the reservoir that can result in leaks. Worse, heating of known traditional liquid or gas state fuels creates the risk of unintentionally exceeding the ignition and/or spontaneous temperature of the fuel, creating an explosion hazard. For those reasons, we note that prior art lanterns and stoves are designed to ensure that any open flame is kept remote from, and not in thermal communication with, the fuel reservoir. For example, we note that U.S. Patent No. 6,347,936 (the "936" Patent"), which relates to portable survival stoves using flammable liquid fuels such as kerosene, white gas, and the like, and discloses an integrated sealed reservoir for containing the flammable liquid fuel. The '936 Patent is representative of prior art teachings that specifically emphasize that heat from a combustion zone is to be thermally isolated from the fuel reservoir. The '936 patent describes a stove wherein the "system comprises a porous fuel wick 50 having a low thermal conductivity retained in a feed wick shroud 52." See, '936 Patent Col. 13, lines 26-28. The '936 Patent further describes the wick shroud surrounding the feed wick as "preferably constructed from a rigid, vapor and liquid impermeable material that is non-corrosive in liquid fuels and has a generally low thermal conductivity." See, '936 patent at Col. 13, lines 52-56. From a further

reading of the '936 Patent, it is clear that heating of the liquid fuel reservoir is intentionally and desirably avoided. Indeed, the embodiments described in the '936 Patent expressly teach away from any transfer of heat to the fuel reservoir. For example, in addition to the low thermal conductivity feed wicks and wick shrouds that are in contact with liquid fuel in the reservoir and the wick, the '936 Patent instructs that the liquid fuel wick and feed assembly is thermally insulated from a very hot "vaporization zone" by a "substantially vapor impermeable barrier" assembly. In the embodiments of the '936 Patent, that vapor impermeable assembly comprises a series of non-thermally conductive and low-thermally conductive elements arranged to allow heat transfer only from a heated plate to the adjacent surfaces of a porous member, and specifically does not transfer heat to the wick or other liquid feed surfaces and assemblies located beneath the porous member – with no heat transfer suggested or motivated to reach the fuel reservoir.. For example, the '936 Patent provides that "in an embodiment preferred for use in liquid fuel combustional applications, the substantially vapor impermeable barrier is provided as a shroud 24, constructed from a rigid material having a generally low thermal conductivity , and plate 26, constructed from a rigid material having a generally high thermal conductivity . The generally low thermal conductivity of shroud 24 is sufficiently low to prevent a substantial portion of thermal energy from immigrating from the vaporization zone toward liquid feed surface 12 of porous member 14. The thermal conductivity of shroud 24 is preferably less than about 200 watts per meter-Kelvin ("W/m K"), and more preferably less than about 100 W/m K. The generally high thermal conductivity of plate 26 [located between the heat source 20 and the vaporization zone above the porous member 14] is sufficiently high to transfer the heat required for vaporization to the vaporization zone of the porous member. The thermal conductivity of plate 26 is preferably greater than about 200 W/m K and more preferably greater than about 300 W/m K. This arrangement promotes heat transfer to and within porous

member 14 in proximity to vapor release surface 18 and vaporization zone 16, yet it advantageously minimizes heat transfer through porous member 14 between vaporization zone 16 and liquid feed surface 12, and into the liquid feed system and any liquid reservoir." See, '936 Patent at Col 9, lines 37-59 (emphasis added). The '936 Patent further teaches that the porous members "preferably comprises a material having a low thermal conductivity and a substantially uniform pore size. The thermal conductivity of porous member 14 is preferably sufficiently low to maintain a thermal gradient from ambient temperature of liquid feed surface 12 to the temperature of vaporization at vaporization zone 16, and to prevent substantial heat transfer out of vaporization zone 16. Materials having a thermal conductivity of less than about 10 W/m K are suitable for porous member 14, materials having a thermal conductivity of less than about 1.0 W/m K are preferred, and materials having a thermal conductivity of less than about 0.10 W./m K are especially preferred. See, '936 Patent at Col. 10, lines 36-48 (emphasis added). This arrangement promotes "thin walled Section 80 is provided to reduce thermal conductivity of shroud 64 where it interferes with porous member 67 thereby reducing and minimizing heat transfer between shroud 64 through porous member 62 (emphasis added). Stainless steel is a preferred material for shroud 64, although many other materials having a low thermal conductivity, such as titanium alloys, are suitable." We note that stainless steel is generally recognized as having a thermal conductivity of about 12 to about 45 W/m K, and that pure aluminum is generally recognized as having a thermal conductivity of about 237 W/m K, with aluminum alloys having a thermal conductivity of generally between about 120 to about 180 W/m K.

**[0024]** Importantly, the apparatus described in the '936 patent is not compatible or combinable with the meltable solid fuels described herein, and does not anticipate the inventions described herein. Indeed, the '936 patent lacks a heat transfer element in thermal communication with a heat source and further in thermal communication with the fuel

reservoir. The low thermal conductivity of the porous member and shroud assemblies of the 936 Patent are incompatible with the present invention. The '936 Patent teachings teach away from and prevent any significant heating of fuel placed in the reservoir, thus preventing a meltable solid fuel from being heated and becoming a liquid moveable by capillary or other action. Indeed, any meltable fuel placed in the apparatus of the '936 Patent will remain in its existing, ambient or room temperature solid state, and would not liquefy or migrate to be converted to vapor state fuel as in the present invention.

**[0025]** Importantly, the inventor has discovered that the use of meltable fuels in combination with the apparatus and assemblies described herein provides a high volume of dense vapor gas that exceeds any known apparatus using meltable fuels, such as candles. Indeed, even in the wick flame embodiments described herein, the volume of dense gas vapor generated greatly exceeds the combustion capacity of the wick flame, producing a continuous stream of excess gas vapor that can be used for a number of purposes, including but not limited to downstream mixing with air for combustion, uncombusted fumigation, and as a power source for internal combustion and/or external combustion and/or and Stirling engines, for example.

**[0026]** In an example of the gas generation assembly herein, a heat transfer element is in thermal communication with a heat source, and is further in thermal communication with a meltable fuel reservoir containing a meltable fuel. The heat transfer element preferably includes at least one inlet opening for receiving heated fuel from the reservoir, the heated fuel in a liquid and/or vapor state. The heat transfer element in this embodiment may include one or more heating chambers that receives heated fuel from the inlet opening(s). The heat transfer element in this embodiment further includes at least one outlet to permit vapor state fuel to exit the heating chamber. Optionally, the heat transfer element may include one or more air inlets for receiving air to mix with the heated fuel, and/or to control

the pressure within the heating chamber and ensure that the heated fuel exits the outlet opening at a desired rate and/or temperature. In another example, the outlet is configured so that the exiting vapor state fuel promptly mixes with air and therefore can be ignited to form a continuous flame. In other embodiments, the outlet is disposed to permit the exiting vapor to be conveyed to another combustion source, fumigation source, storage vessel, or other gas utilization apparatus. In some embodiments, the fuel vapor production can be increased or supplemented, such as by utilizing a capillary element such as a wick to pull heated fuel from the reservoir and allowing it to evaporate to form an unignited second source of vapor fuel. As shown and described in the figures and specification herein, for example, such a second source of fuel vapor can be created when a diffuser and nozzle assembly are provided in a close proximity position to a heating element and a capillary element such as a wick containing meltable fuel. For example, when the heating element includes an ignited (burning) capillary wick producing a wick flame, lowering a diffuser and nozzle assembly controllably and desirably reduces the air supply available to the wick flame, causing some of the liquid meltable fuel in the wick element to be released as uncombusted dense vapor. The dense, oxygen-deprived uncombusted gas vapor travels away from the wick element, preferably entering into a nozzle assembly. This dense vapor can then be selectively mixed with air in the nozzle assembly to form a combustible mixture that can optionally be ignited to form a combustion flame. Alternatively, the dense vapor can be selectively directed to another destination, such as a storage tank, internal combustion engine, fumigation area, or other apparatus or use. In some stove embodiments shown and described herein involving a wick flame as the heat source, a self-generated or spark-induced combustion flame is formed distinct from the wick flame, appearing as high as several inches above the wick flame depending upon the air-fuel mixture characteristics provided by the diffuser and nozzle assemblies.

**[0027]** As further shown and described herein, where a diffuser and nozzle assembly is optionally provided, adjusting the diffuser and/or nozzle position relative to a wick flame heat source can provide adjustment of the volume of gas vapor generated by the gas generation assembly can control the wick flame, as well as the flame characteristics of any downstream combustion flame. The diffuser element is preferably adjustable so that its proximity to the heat source, such as a wick flame, can be adjusted by a user. Moving the diffuser element closer to a heating element such as a burning wick flame will reduce the amount of air and associated oxygen getting to the flame, thereby reducing the intensity and size of the wick flame. In this manner, the wick flame is caused to emit unburned fuel vapor - not only from vapor exiting the heating chamber, but also supplemental vapor from the heated wick proximate the wick flame due to the lack of sufficient oxygen for combustion as a result of the close diffuser location. Conversely, moving the diffuser element further from the wick flame heating element allows more air and associated oxygen to reach the wick flame causing it to increase in size and allowing it to consume the otherwise unburned fuel vapor emission. The inventor has observed that the location of the diffuser and nozzle can be controlled so that the wick flame will burn in a clean blue sphere, much like a pilot light, generating enough heat to maintain the thermal cycle of melting fuel and vaporizing it in the heating chamber, yet allowing copious volumes of the generated vapor to pass through and around the wick flame without combusting. In contrast, spacing the diffuser and nozzle assembly far from the wick flame (or removing the diffuser entirely) allows the wick flame to consume more vapor fuel (whether generated from the wick or the heating chamber) – and produces a very dirty, sooty, orange flame that lacks the heat intensity of a downstream nozzle-controlled combustion flame in the diffuser/nozzle examples later described herein. In other embodiments, no diffuser is provided or necessary, because the air flow to the wick flame is controlled by other means such as the size of any provided gap between the capillary

member and a downstream nozzle, for example. Optionally, a porous element, such as a mesh screen made of metal or other porous materials, can be provided on or adjacent the outlet end of the capillary member, such as to control the shape of the capillary member and/or the flame. When present, the nozzle assembly is configured and disposed to combine dense, oxygen-poor gas state fuel exiting the heating chamber outlet (along with any dense gas vapor from the wick element) with air containing oxygen. In stove embodiments, the nozzle mixes the vapor with air to form a combustible mixture. The nozzle assembly preferably includes features to direct and mix the fuel vapor flow with air, control vapor and air flow rate, and directing flow. The nozzle may include a converging and/or diverging inner nozzle surface configured to contain the gas vapor and to control its flow rate, and/or to direct flow towards a desired location for combustion or storage. Optionally, in the nozzle assembly, additional air is added (whether by apertures, openings, forced air, fans, or otherwise) to the gas vapor thereby providing an oxygen-rich, combustible mix of air and fuel for combustion at a desired location. In other example, the nozzle can direct air against the wick flame and/or other heat source, altering the heat source's temperature and other properties. Optionally, when remote combustion is desired for cooking or other application, a combustion flame is produced downstream of the nozzle assembly.

**[0028]** The apparatus and method provides the additional benefit that when the heat source is turned off, removed, or otherwise deactivated, the meltable fuel in the apparatus (whether in a reservoir, heat transfer element, wick, or elsewhere) returns to its solid or semi-solid state, making it substantially spill proof and leak proof for storage and transport between uses. In one example, when the wick flame is extinguished, the meltable fuel in the wick and in the fuel reservoir returns to its normal, ambient substantially solid or semi-solid state. This is caused by extinguishing the wick flame and halting the transfer of heat from the heat source to the heat transfer element, thereby halting heat transfer to the meltable fuel

reservoir, and thereby stopping the generation of meltable fuel liquid and vapor states. The return of the meltable fuel to substantially solid or semi-solid state makes the apparatus spill-proof, and also substantially non-flammable if exposed to a low-intensity flame or other ignition source. When paraffin wax is the fuel, the fuel is non-flammable in its solid state, and is nearly infinitely storable without degradation. Once the thermal cycle is re-initiated by turning on the heat source, the wax will again cycle through its liquid and vapor states without clogging, pressurizing, priming, or other fueling activity by the user. These features and advantages are unprecedented in known portable camping stoves and any other combustion or gas generation devices fueled by known liquid and/or gas fuels.

**[0029]** Moreover, the apparatus described herein have allowed the inventor to reach the full thermal potential of meltable fuels. Using the examples herein, the inventor has produced an intense, large, hot, continuous flame of over 1400 degrees Fahrenheit. That result shows that the inventive embodiments described herein are harnessing the energy potential of paraffin wax, which has a heating value of about 18,500 BTU per pound. Notably, the BTU of liquid kerosene is nearly identical – yet cannot be achieved without the safety hazards of spillage and explosion as described herein. In contrast, paraffin wax has a flash point of over 250°C (about 480°F) and solidifies to a non-combustible solid upon cooling. Solidification begins almost immediately upon any drip or spill from a reservoir of liquid state paraffin wax. Ask your local manicurist or spa – people soak their hands in hot paraffin by choice. They don't soak in kerosene.

**[0030]** The gas generation cycle disclosed herein, further including apparatus for the generation of combustible mixtures of vapor and air, is much more powerful than any existing candle-type solid fuel apparatus. Indeed, the combustion flame produced by the apparatus and methods herein appear to be as powerful, or more powerful, than known catering apparatus. Such known sterno apparatus uses a volatile jellied alcohol and produces

a clear blue flame that is dangerous if spilled fuel is ignited because it burns hot and is difficult to spot. In contrast, the present apparatus uses meltable solid and semi-solid fuels to avoid those undesirable risks. Furthermore, the non-volatile, non-explosive, and waterproof nature of meltable fuels such as waxes makes the apparatus suitable for military use by amphibious personnel, even if exposed to gunfire and explosions. Indeed, meltable fuels such as wax can safely be carried on a person's body and even with food supplies without concern. In contrast, personnel and vehicles carrying fueled stoves using any other known liquid and gas fuel risk a significant increased risk of exposure to flammable leaks and spills, which may cause property damage, injury and even death. The above and other advantages will be further evident by the following examples and illustrations.

**Examples**

**[0031]** A first, non-limiting example of an apparatus is illustrated in Figs. 1-8 hereof. The apparatus embodiment shown in Figs. 1-8 accomplish the above-described thermal fuel (and optional combustion) cycle by the use of the elements as shown and described. In the Figs. 1-8, elements are described and shown individually, and as an assembly, in both perspective and cross-sectional views. The figures also show some exemplary shapes and other features of the elements and assemblies, although any number of geometric shapes and sizes of elements are contemplated by the inventor to form additional embodiments.

**[0032]** Note that, although Figs. 1-12 illustrate the examples of the apparatus as being generally circular having a diameter of approximately 1 inch to about 10 inches, and a height of about 2 to about 12 inches, the apparatus can be provided in any shape or size, and can be tuned and adjusted to provide a desired structural rigidity, flame size, selected number of heating elements, reservoirs, gas generator assemblies, nozzles, and other elements to provide the desired generation of fuel vapor from a meltable fuel (or even a traditional liquid

fuel) to meet the intended purposes of a user. Indeed, the inventor has conceived and reduced to practice several miniaturized embodiments, without sacrificing the heat and other performance characteristic advantages of the invention. Exemplary apparatus have been assembled and tested, and have provided excellent results. The assemblies have been shown to efficiently generate vapor state fuel from meltable fuels including paraffin, bees wax, and soy wax in accordance with the previously described gas generation cycle, using apparatus and features described herein. The generated vapor state fuel is rich and dense, and requires mixing with air to be suitable for combustion. Otherwise, the dense vapor fuel can be used for fumigation, lubrication, deposition onto surfaces and substrates, and for any other use appropriate for vapor state meltable fuels in their vapor state or upon return to a liquid or solid state. When mixed with air and ignited in an exemplary stove embodiment, the result is a windproof, continuous wick flame and downstream combustion flame that will boil a full cup of room-temperature water in less than 10 minutes. In stark contrast, a large candle ("candle" as used herein is defined as a device having one or more wicks, each wick embedded with and immediately surrounded by a mass of paraffin or other known meltable solid fuel) was unable to boil the cup of water in more than 30 minutes. Indeed, previous attempts to harness significant thermal energy from candles, including multiple wick candles, have failed.

**[0033]** In an exemplary embodiment shown in Figs. 1-8, meltable fuel **130**, such as paraffin wax, is received and contained in a reservoir **80** of the apparatus **10**. The meltable fuel **130** can be provided by a number of ways, including: loading a block of solid state meltable fuel **131**, into the reservoir **80** of a disassembled stove apparatus **10**, then assembling the **apparatus10**; pouring heated liquid meltable fuel **132** into the reservoir **80** (whether before or after assembly of the stove **10**); and/or by inserting small wax pieces of solid meltable fuel **131** into an opening **82** in the reservoir **80** or reservoir lid **84**. Additionally or

alternatively, the lid **84** may include a concave portion so as to permit placing of solid state fuel **131** pieces onto the lid **84** and having the heat of the apparatus melt the solid state fuel **131** so that it converts to liquid state fuel **132** and drains from the lid **84** through the opening **82** into the reservoir **80**. During operation of the stove **10**, such heat may be transferred to the lid **82** from the heat transfer element **30** and/or radiant heat from the heat source **22** (shown in the embodiments of Figs. 1-8 as a wick flame **26**). Still further, a gap (not shown) may be provided between the lid **84** adjacent the heat transfer element **30** to allow melted liquid state fuel **131** to drain from the lid **84** into the reservoir **80**, such as by providing an inward slope of the lid **84** towards the heat transfer element **30** and causing the melted wax to drain through a gap provided therebetween. The opening **82** may be sized to enable wax sticks (such as crayons), pellets, or other desirable and manageable forms of meltable fuel **130** to be inserted into the reservoir **80**, where they melt by the heat of the heat transfer element **30** and by the heat of the liquid state fuel **132** formed thereby. As shown, in one embodiment, the heat transfer element **30** may include an enlarged base **36**, such as a disk shaped structure, to act as a heat sink within the reservoir **80**, adjacent inlet end **32** of heat transfer element **30**. In another embodiment, the opening **82** is mated to a section of heat conductive (e.g. copper) tubing (not shown) that is disposed in thermal contact with the heat transfer element **30** and/or liquid state fuel **132**, so that the opening **82** and associated tubing is heated and will rapidly melt inserted solid state meltable fuel **131**, such as wax crayons, to a liquid state, thereby refilling the reservoir **80**. In any of these manners, and due to the non-pressurized and non-volatile nature of the meltable fuel **130**, the stove **10** can be safely and easily refueled even when fully operating with the heat source **22** providing heat, and even with an open reservoir **80**, and with an optional hot continuous downstream combustion flame **122**.

**[0034]** When provided, a capillary element, here a wick element **40**, is preferably in thermal contact with a heat source **22**, such as a wick flame **26**. The wick element **40** is also

shown in thermal contact with a heat transfer element **30**, here shown as a generally cylindrical hollow pipe. In the example shown, the desired thermal contact and thermal transfer is accomplished by lighting the wick member **40** at the outlet end **42** of capillary wick member **40**, and further by encasing or surrounding the lower reservoir end **44** of the wick member **40** with a heat transfer element **30**. Heat transfer element **30** is preferably made of high heat conductive material, preferably copper. The heat transfer element **30** may be provided as a solid, semi-solid or hollow structure. Preferably it is hollow to permit partial or complete surrounding of the capillary wick member **40**, except for a protruding outlet end **42**. The heat transfer element **30** may additionally or alternatively include one or more internal heat transfer elements **39**. Although shown in the figures as a divider that is plate-like and bifurcates the center chamber **38** of the heat transfer element **30**, the internal heat transfer element **39** may additionally or alternatively be any heat-conductive or heat-retaining structure, such as a rod, tube, or other structure in thermal contact with the internal surfaces of the wick member **40**, and/or as heat-conductive fibers woven into the wick member **40**, for example. For example, in one embodiment shown, a first surrounding heat transfer element **30** surrounds the lower wick portion adjacent outlet end **42**, while a thin center heat transfer element **39** shaped as a dividing plate is located in a central hollow chamber **38**, bifurcating the wick member **40** within the heat transfer element **30**. This embodiment also allows the center heat transfer element **38** to act as a mount for the diffuser rod **54**, which in turn vertically adjustably holds the diffuser disk **52** of the diffuser assembly **50** in a desired position relative to the wick flame end **42** and the wick flame heat source **26**.

**[0035]** In order to generate the gas generation cycle, a heat source **22** is needed. In the embodiment of Figs. 1-8 and 10, the heat source is a wick flame **26**, although any source of heat or other energy to convert meltable fuel **130** from its solid state fuel **131** to its liquid state fuel **132** and/or vapor state fuel **134** is contemplated. In these examples, with the stove

apparatus **10** in its open position as shown in Fig. 5, it is characterized by the upper housing **70** and fixed nozzle assembly **60** in a position slidably up and away from the reservoir **80** and wick member **40**. To light the stove apparatus **10** in this embodiment the user inserts a match through vents **72** provided in the upper housing **70** to reach the outlet end **42** of the wick member **40**. Once the outlet end **42** of the wick member **40** (opposite the reservoir end **44**) is lit, the lighted end portion of wick member **40** forms a wick flame **26**. The wick flame **26** causes meltable fuel **130** impregnated in the wick element **40** to liquefy, and to gas off and burn at the surface of the wick member **40** in almost candle-like fashion. The burning at the outlet end **42** of the wick member **40** causes the heat transfer element **30** (preferably made of copper material or other highly heat conductive material) to absorb heat from the wick flame **26**. Due to the preselected heat conductive properties of the heat transfer element **30**, heat from the wick flame **26** is conducted along the entire heat transfer element **30**, reaching the reservoir end **44** adjacent the heat transfer member inlet end **32**. The inlet end **32** may be open, and/or may include apertures **33** to permit liquid state fuel **132** to enter a heating chamber **38** formed in the heat transfer element **30**. Heat from the heat transfer element **30** melts any solid meltable fuel **131** in the reservoir **80** into a liquid state fuel **132**, which then freely flows into the chamber **38**, whether by autogenous pressure of the heating of the reservoir **80**, capillary action of a capillary member such as wick member **40**, vacuum created from the chamber **38** and wick flame **26**, and/or combinations thereof. Once inside the chamber **38**, the liquid state fuel **132** is quickly converted to its vapor state, whether by heat, reduced pressure, evaporative action, or combinations thereof. The vapor state fuel **134** then exits the outlet opening **34** of the heat transfer element **30**. In the embodiment of Figs. 1-8, the outlet opening **34** is in immediate proximity to the wick flame **26**. However, as previously described herein and as shown in Fig. 5, the closing of the stove, by sliding upper housing **70** fully downward onto reservoir **80**, also closes the gap **90** provided between the

wick member **40** adjacent the outlet end **42** and the diffuser disk **52**, restricting air flow to the wick flame **26**. This closed position results in very low, controlled, and sustainable combustion at wick flame **26** to minimize consumption of meltable fuel **130** by the wick flame **26**, and allows the dense vapor state fuel **134** to pass out of the outlet opening **34** and past the wick flame **26** without combusting. The diffuser disk **52** further acts to spread the vapor state fuel **134** into a broader stream before it enters the lower portion **62** of the nozzle assembly **60**. Once in the nozzle assembly **60**, the gas mixes with air drawn through the gap **90** and the apertures **66** provided in the upper diverging portion **64** of the nozzle assembly **60** to produce a combustible mixture of gas and air in a combustion zone **120** that can optionally be ignited to form a downstream combustion flame **122** that appears above the diffuser disk **52**.

**[0036]** Again, any number of heat transfer elements **30** may be provided in thermal contact with the heat source (here a wick flame **26**), with the common functional feature being that heat from the heat source **22** is conducted to meltable fuel **130** received by the reservoir **80** to convert the meltable fuel **130** to a vapor state fuel **134** in a controlled manner to sustain the gas generation (aka fuel vaporization) cycle described herein. In the examples of Figs 1-9 and 10, heat from the heat source **22** (here a wick flame **26**) is conveyed by the heat transfer element **30** to meltable fuel **130** in the reservoir **80**. Solid state fuel **131** in the reservoir **80** is converted by the transferred heat to a liquid state fuel **132**. The resulting liquid state fuel **132** seeps, whether under pressure or by capillary action or otherwise, into inlet end **32** and/or apertures **33** provided in the heat transfer element **30**. Once inside the heat transfer element **30** the center conduit of the heat transfer element acts as a heating chamber **38** to hold and heat the liquid state fuel **132** using the surrounding heated walls, capillary wicking material **40** and meltable fuel **130** in the reservoir **80** as chamber boundaries. As a result, the liquid state fuel **132** in the heating chamber **38** is heated to a

point where it transitions to a vapor state fuel **134**, and wherein the vapor pressure of the vapor state fuel **134** exceeds any atmospheric or other external applied pressure, allowing generated vapor state fuel **134** to escape the heating chamber **38**, such as through outlet opening **34**. In the case where the heating chamber **38** is formed as the central conduit of the heat transfer element **30**, the vapor rises upward to the outlet opening **34** opposite the reservoir inlet end **32**, and preferably adjacent the outlet end **42** and wick flame **26**. Importantly, and surprisingly, the inventor has noted that this embodiment generates a very high volume of dense vapor state fuel **134** that blows past the heat source **22** (such as the wick flame **26** and/or electrical element **28**) without igniting.

**[0037]** Optionally, in another embodiment illustrated in Fig. 10 where the wick flame **26** is desired to fuel a combustion flame **122**, one or more air inlets **37** are provided in the heat transfer element **30** and/or reservoir **80** to introduce air at a rate sufficient to produce a combustible mixture of vapor state fuel **134** and air immediately adjacent the outlet end **34**, allowing the wick flame **26** or other heat source **22** to ignite the mixture to produce a combustion flame **122**. For example, in such an embodiment, as the vapor state fuel **134** travels up the heat transfer element **30**, chamber **38** wick **40** and/or vapor chamber **35**, ambient air is introduced through an air intake **37** provided in the sidewall of the heat transfer element **30** which mixes air with the vapor state fuel **134** to produce a combustible air fuel mixture. However, in a preferred stove embodiment, any air mixture prior to the wick flame **26** is controlled so that upon exit from the heat transfer element **30** only a small portion of the combustible mixture is ignited by the wick flame **26** and the rest travels into a provided nozzle assembly **60** where additional air is added before further activity, such as ignition, to form continuous combustion flame **122**. When desirable, the diffuser disk **52** is made from a highly heat conductive material, such as copper, by non-limiting example, so that it can ignite or re-ignite the combustible mixture of air and vapor state fuel **134** once adequately heated by

the wick flame **26** or other heat source **22**. As shown in Fig. 1 and Fig. 10, the diffuser disk **52** may be substantially solid, may include slots or apertures or tabs, and may be flat, concave, convex, or finned so as to produce the desired separation of the wick flame **26** from the combustion zone **120**, and to tune the wick flame **26** as well as the gas and air mixture entering the nozzle **60**. In cases where the disk **52** is highly heat conductive, such as comprising copper, the stove **10** is windproof in that the disk **52** will re-ignite the wick flame **26** and the combustion flame **122** by igniting the vapor gas and air mixture that continues to spew from the apparatus **10** so long as the chamber **38** (and optionally vapor chamber **35**) is emitting vapor state fuel **134**. That period of reignition can be from milliseconds up to several minutes. Along with fortifying the wick flame **26** by contributing additional vapor state fuel **134**, the diffuser disk **52** and nozzle apparatus **60** and other apparatus described herein provide a method of routing and directing additional air for efficient combustion and reduced soot output, for example.

**[0038]** As shown in Fig. 9, and as can be accomplished in the apparatus of Figs 1-8 by removal of nozzle assembly **60**, nozzle assembly **60** is optional where an open, sooty flame is desired, and/or when the gas vapor is not desired to be locally ignited. For example, where the meltable fuel **130** has fumigant properties (such as citronella wax), it may be desirable to simply allow the excess gas vapor state fuel **134** to dissipate from the heat transfer element **30**, outlet opening **34**, and/or outlet end **42** of wick member **40** in a dense stream, without igniting it, so that a surrounding area fills with vapor, such as to mitigate against insects in a wooded campground, greenhouse, or other space in need of fumigation. Citronella wax mixed in the reservoir **80** or dropped onto the lid **84** or diffuser disc **52** is suitable for this purpose, in this embodiment and also in other embodiments.

**[0039]** However, in stove embodiments and other embodiments where a combustion flame **122** is desired, a nozzle assembly **60** is provided. Preferably, the nozzle assembly **60** is

movable, such as by mounting on the slidable upper housing **70** of the apparatus **10**. Desirably, the nozzle assembly **60** can be adjustably lowered to be placed in close proximity to the wick **40** and any wick flame **26**. In this position, the air supply to the wick flame **26** is reduced, causing the wick flame **26** to consume very little meltable fuel **130**, including a minimal amount of any vapor state fuel **134**, and thereby allowing the gas vapor state fuel **134** escaping from the heat transfer element outlet **34** to pass by unignited, and further allowing some of the meltable fuel **130** impregnated in the wick member **40** to vaporize without igniting. Any unignited vapor state fuel **134** then travels into the nozzle assembly **60**. In the nozzle assembly **60** additional air can be added (whether by an aperture **66**, fan, or otherwise) facilitating desirable combustion. In the closed position of Figs. 2, 3 and 4, the closed position of the nozzle assembly **60** controls a gap **90** that restricts air flow to the wick flame **26**, causing the wick flame **26** to achieve a very efficient, pilot-like clean blue appearance that keeps the gas generation cycle of the gas generator assembly continuously churning while burning a minimum of meltable fuel **130**.

**[0040]** Optionally, vapor introduction and flame tuning and control can be provided through adjustable means, as shown in the accompanying examples of Figures 1-8 and 10-11. For example, as expressly shown in Fig. 2 and Fig. 8, the distance between the wick flame **26** adjacent the outlet end **42** and the diffuser disk **52** can be adjustable, such as by mounting on a threaded rod **54**, to allow the diffuser disk **52** to be raised to allow more air flow through the gap **90** to the wick flame **26** and also allowing greater air mixing (such as at higher elevations where air is thinner) in the nozzle assembly **60** prior to combustion by combustion flame **122**, or lowered to reduce air to the wick flame **26** (e.g. making fuel burn richer and/or slower due to less air introduction). In examples wherein an internal heat transfer element **39** is provided within the heat transfer element **30**, the heat transfer element **30** can be hollow or solid, and the wicking material of any capillary element, such as wick member **40**, selected to

permit vapor state gas **134** to percolate up through the wick member **40**, and/or through the chamber **38** before reaching the outlet opening **34** and/or wick flame **26**.

**[0041]** Some additional elements used in the present example and attached drawings include a reservoir **80** used to enclose and hold fuel, as well as to provide a base to the entire apparatus **10** for placing on a surface, and allowing the upper housing **70** and associated nozzle assembly **60** to be adjusted in relation to the outlet end **42** of the wick member **40**. Reservoir **80** provides a rigid structure to the assembly, it is preferably strong enough to support pots, pans, and any special use attachment etc. The reservoir **80** and housing **70** can bear weight, yet are preferably made of lightweight materials which can be rolled, cast, molded, laminated or otherwise fabricated. Examples given in the embodiments shown include, outer side walls that are upright, spiral, perforated, or otherwise disposed. In either case, the walls of the reservoir **80** and upper housing **70** provide support for the apparatus **10**, and contain the elements as an assembly. As shown in other figures, the reservoir **80** may be movable relative to the diffuser assembly **50** and nozzle assembly **60**. Although not shown, the reservoir **80** and housing **70** and other parts described herein may include hinges, support legs, and/or other attachment means to keep the stove parts movably or fixedly connected in desirable positions. Further, leg members and/or bases members can be provided to stabilize the apparatus **10** from tipping, and/or to support pots and items to be heated in a desired proximity to the combustion flame **122**. Any such legs and/or base elements can be retractable and/or removable to permit the device to have an overall reduced diameter, and to fit inside small carrying means such as cups, survival packs, and the like.

**[0042]** Nozzle assembly **60** and diffuser assembly **50** have a combined effect of containing, shaping, introducing, and mixing vapor state fuel **134** and air, optionally resulting in a controlled low soot combustion flame **122** which can be used for cooking, heating and other functions as desired. The assemblies **60** and **50** are preferably adjustable, such as by

connection to the upper housing **70** in a manner so their relative positions in relation to one another and to the heat source **22** such as wick flame **26** is adjustable. In the example of Fig. 3, the nozzle assembly **60** includes a mounting base **66** that is fixed by inserting tabs through perforations provided in the housing **70**. Additional perforations or vents **72** may be provided in the housing **70** to promote mixing, heat dispersion, gas dispersion, access to the wick **40**, nozzle **60**, diffuser assembly **50**, and other parts of the apparatus **10**.

**[0043]** Reservoir lid **84** provides the means to contain the meltable fuel **130** in the reservoir **80**, and to protect the meltable fuel **130**, whether as solid fuel **131**, or liquid state fuel **132**, from direct and unintended contact with a user, water, or other environmental surroundings. Further, lid **84** optionally facilitates refueling by directing solid meltable fuel **131** to contact against the heat transfer element **30** to promote melting to form a liquid state fuel **132**. In some embodiments, the lid **84** is concave, sloped, and/or angled to direct melted liquid state fuel **132** into the lower fuel reservoir **80** through recessed opening **82**, or another opening or gap leading to the inside of reservoir **80**.

**[0044]** Vapor gas generator assembly **20** with its sub assemblies **30**, **40**, and **50** (and in conjunction with reservoir **80** and other features shown and described herein is configured to support continuous gas vapor generation by utilizing the resultant heat generated at the wick flame **26** or other heat source **22** to melt the meltable solid fuel **131** and vaporize it. The assembly **20** also has the function of moving melted liquid state fuel **132** from the fuel reservoir **80** by capillary action and other forces, such as through the wick member **40** as a capillary material, to a location where it can be collected and/or ignited. In the particular embodiments of Fig. 1-8 and 10-11, the center chamber **38** of the heat transfer element **30** acts as a chimney tube to trap and further heat a portion of the melted fuel causing it to vaporize into a vapor stream and move the resulting vapor state fuel **134** it in an upwardly direction to emanate from the outlet opening **34** where it becomes a vaporized fuel supply for

the nozzle assembly **60** positioned above. The nozzle assembly **60** also allows for the addition of air to the vapor stream at various points for the purpose of providing a secondary source of combustible air fuel mixture. Another vapor fuel source for the nozzle assembly **60** is produced at the wicking material surface adjacent wick outlet end **42**. The amount of vapor production in relation to wick flame **26** consumption is regulated by moving the nozzle **60** and diffuser assembly **50** down so as to locate it closer to the wick member **40** outlet end **42**, effectively blocking, or damping off, some of the combustion air supply to the wick flame **26** causing a very distinct stream of vapor to gas off the wick outlet end **42** without being ignited by wick flame **26**. In other embodiments, such as in FIGS. 9 and 12, no diffuser is provided or necessary, because the air flow to the wick flame 26 is controlled by other means such as the size of any provided gap 90, for example. Optionally, a porous element, such as a mesh screen made of metal or other porous materials, can be provided on or adjacent the outlet end 42 of the wick member 40, to control the shape of the wick member and/or the flame 26, and/or to retain and/or conduct heat to or away from the flame 26, the wick outlet end 42 and/or the heat transfer element 30.

**[0045]** Optionally, the apparatus **10** and gas generation assembly **20** can include features to permit pressurization of the meltable fuel **130** in the reservoir **80** and/or chamber **38** and secondary chamber **35**, with fantastic results in flame intensity and length. Exemplary pressurization apparatus can be provided by, for example, applying an air source to opening **84** and/or providing one or more heat conductive chimney-like vapor chamber assembly **31** in addition to chamber **38** and/or secondary chamber **35**. In one such example shown in Fig. 11, a narrow straw-like vapor chamber assembly **31** is inserted down through the center of the heat transfer element **30** towards the bottom inlet end **32**, the vapor chamber assembly **31** having a significantly restricted (yet open) opposite outlet end **152**, which may be adjacent an outlet end **150** of secondary chamber **35** and/or outlet opening **34** of chamber **38** of heat

transfer element **30**. In the embodiment of Fig. 11, when the solid state fuel **131** melts, the resulting liquid state fuel **132** enters the chamber **38** of heat transfer element **30**, and the secondary chamber **35**. Air and/or vapor state fuel **134** trapped in secondary chamber **35** becomes heated and exerts pressure on the surface of liquid state fuel **132** in secondary chamber **35**, forcing liquid state fuel in the secondary chamber **35** into the vapor chamber assembly **31**. The heat conducted to the liquid state fuel **132** by the vapor chamber assembly **31**, as well as by the wick flame **26** and the surrounding secondary chamber **35**, wick **40**, and heat transfer element **30**, causes at least some of the liquid state fuel **132** in vapor chamber assembly **31** to vaporize. The resulting pressurized vapor state fuel **134**, and possibly some liquid state fuel **132** then exits the vapor chamber assembly **31** through outlet opening **152**. Optionally, the vapor chamber assembly **31** and outlet **152** can be positioned downstream of the diffuser disk **52** to allow some meltable fuel **130** to be combusted and/or vaporized at, or downstream, of the diffuser assembly **50**. Additional or alternative pressurization may be accomplished, for example, by pumping of air, and/or by forcing liquid state fuel **132** through increasingly reduced channels and conduit in the reservoir **80** and/or heat transfer element **30**, among other methods and apparent from this disclosure. By way of additional example, meltable fuel **130** can be converted into a liquid state fuel **132** and pressurized either manually (by a pumping device), by an externally powered device or a trapped air or other pressure-inducing medium that will naturally expand when heated (air, gas, solid substance), or anything that has the potential to impart stored energy on the liquid state fuel **132** in an open and/or closed version of reservoir **80**, including but not limited to a spring-loaded and/or air-loaded bellows baffle, or other known pressurizing devices. By further example, in a closed reservoir **80** embodiment, the heat transfer element **30** may heat any air trapped at the top of the closed reservoir **80**, causing pressure that in turn bears down on the surface of fuel **130** in reservoir **80**, forcing heated melted liquid state fuel **132** into the inlet opening **32**

and/or apertures **33**, adding to the pressure in the chamber **38**, secondary chamber **35** and ultimately the vapor chamber assembly **31**.

**[0046]** In yet another embodiment illustrated in Fig. 12, the apparatus includes features for introducing air and/or other combustion-enhancing materials into the stream of gas vapor generated by the gas generation assemblies **20** and apparatus **10**. For example, the inventor has found that providing a supply of focused air to a location downstream of the wick flame **26** significantly enhances the combustion flame **122**. In the example shown in Figure 12, the apparatus includes an exemplary air conduit **150** that feeds air, whether pressurized or ambient (such as by convection or thermal draw) to a location for mixing with generated vapor gas **134**. For example, as shown in Fig. 10, the location can be a downstream combustion zone **120**. The air conduit **150** includes a feed end **152** that may be open to the ambient environment, or may be communicably attached to a source of air or other combustion-enhancing materials compatible with the gas vapor **134** generated by the apparatus. The air conduit **150** also includes at least one outlet **154** for conveying air or other combustion-enhancing material introduced into the feed end **152** to the desired location. In an efficient example of this embodiment, the inventor found that by attaching the air conduit feed end **152** to a low-pressure air source, and locating the outlet end **154** slightly downstream of the wick flame **26**, such as proximate the center of the combustion flame **122**, combustion flame properties were significantly and surprisingly enhanced. For example, the combustion flame in "passive" mode (i.e. with no forced air provided through the air conduit **150**) was nearly silent, approximately 3 inches long and tapered from blue at the base to yellow at about the last 1/3 of the flame length. When a low pressure air supply was attached to feed end **152**, and the outlet end **154** was placed at the center of the combustion flame **122**, the flame **122** grew louder, shrunk in length by over 50%, narrowed, and became pure light blue from base to tip. The inventor further observed that the combustion flame **122**

temperature increased from a passive flame temperature of about 1330 degrees Fahrenheit to an air-fed torch-like combustion flame **122** temperature of over 145014501460 degrees Fahrenheit In this example, the fuel was commercially available paraffin wax labeled specified to have a melting point of about 140 degrees Fahrenheit. The air supply was provided by a small electrically powered compressor. Thus, in this embodiment, the inventor has demonstrated the surprising result that a gas torch-like flame (with appearance and flame properties much like a pressurized propane torch) can be generated from solid meltable fuels such as wax using the apparatus **10** and inventive methods described herein.

**[0047]** While the examples herein describe a self-contained apparatus **10** wherein the meltable fuel **130** is stored as solid state fuel **131**, heated to a liquid state fuel **132**, and converted to vapor state fuel **134** within the self-contained unit, it is contemplated that those steps can be performed in combination with remote units, with the liquid state fuel **132** and/or vapor state fuel **134** being transported, such as through a pipe or other suitable gas vapor conduit, to an ignition source for combustion. Moreover, it is contemplated herein that the fuel state conversion may be provided at multiple locations within or remote from the ignition source. In this manner, a single gas generation unit may be provided with more fuel that it can self-generate, thereby providing an increased combustion zone **120** result, with attendantly higher thermal output and/or light output. Moreover, the inventive concept herein is extendable to provide multiple gas generation assemblies **20** and apparatus **10**, whether in series, parallel, or otherwise to provide a desired gas generation result.

**[0048]** Moreover, it is contemplated that the adjustable mechanism for the nozzle assembly **60** and diffuser assembly **50** position and height can incorporate any number of adjustment means. By way of non-limiting example, friction devices can be provided to maintain a desired height, such as compressible material and spring metal mounted on the nozzle assembly **60** and/or on the housing **70** and/or reservoir **80** body. The apparatus **10**

incorporates passive and automatic apparatus, assemblies, materials, each of which are selectable depending on variables such as shape, size, flexibility, plasticity, hardness, heat conductivity, and other characteristics of the material and the assembly and functions desired to be associated therewith.

**[0049]** The present apparatus and methods provide controlled generation and combustion of any low melting point dimensionally stable combustible material. This is preferably accomplished by first converting the solid or semi solid material into a liquid state, then into vapor, and finally mixing with an air source or other oxidizer before combustion. The liquid state conversion can be accomplished by any number of energy transfer activities, whether by heat, light, microwave, energy pulse, electricity, or other energy source operable as a heat source, whether on-site or remote. Once a solid meltable fuel **131** has reached a liquid state **132** and/or vapor state **134** it can be delivered to a consumption or storage site by capillary means or any suitable means including pumps, gravity, venturi, convection, pressure, and/or vehicles such as compressed gases such as air etc. Desired performance requirements such as combustion flame **120** versus fumigation will permit selection and design of the nozzle assembly **60**.

**[0050]** Other features novel to the apparatus and methods described herein are provided by the new use of meltable fuels **130** as a storable, stable, non-toxic, and non-volatile fuel source. For example, a wax fueled heater, furnace, and/or fireplace that is either self sustaining in a wick flame **26** embodiment or that is electrically enabled by an electrical heat source **22** using meltable solid fuels **130** will be safe and able to remain dormant for an extended period of time without compromising fuel integrity or power. Lastly, the unit can include elements not shown, including but not limited to heater boxes to convect heat from a combustion flame **122** to another site, and/or a mantle installed (such as in or near the combustion zone **120**) to permit operation of the apparatus **10** as a lantern. Additionally,

features such as carrying handles, legs and/or base plates for stability, wind screens or thermal screens for absorbing or reflecting heat, and other features are contemplated.

**[0051]** The above description is intended as non-limiting, and the inventor has contemplated that any method or apparatus of using solid wax or other meltable fuels as a fuel source that can be liquefied and/or converted into vapor state is within the scope of the invention. While this description is made with reference to exemplary embodiments, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope. In addition, many modifications may be made to adapt a particular situation or material to the teachings hereof without departing from the essential scope. Also, in the drawings and the description, there have been disclosed exemplary embodiments and, although specific terms may have been employed, they are unless otherwise stated used in a generic and descriptive sense only and not for purposes of limitation, the scope of the claims therefore not being so limited.

Moreover, one skilled in the art will appreciate that certain steps of the methods discussed herein may be sequenced in alternative order or steps may be combined. Therefore, it is intended that the appended claims not be limited to the particular embodiment disclosed herein.

**What is claimed is:**

1. A method of generating a gas or vapor state of a wax, the method comprising the steps of providing a gas generator assembly; introducing a meltable fuel consisting essentially of wax into the gas generator assembly; converting the wax to a wax gas or vapor, releasing the wax gas or vapor from the gas generator assembly; and utilizing the released wax gas or vapor as a fuel source by combusting the released wax gas or vapor in an apparatus selected from the group consisting of stoves, fumigation devices, lanterns, lamps, heaters, combustion engines, Stirling engines, boilers, generators, furnaces and fireplaces; and wherein the method is not part of a refinery.

2. The method of claim 1, further comprising a step of providing the released wax gas or vapor as a fuel for an apparatus that is not a candle or a refinery apparatus.

3. The method of claim 1, wherein the step of introducing a meltable fuel consisting essentially of wax comprises introducing a wax selected from the group consisting of paraffin wax, flora wax, insect wax, bees wax, soy wax, vegetable wax, animal wax, fossil fuel wax, palm wax, and plant wax.

4. The method of claim 1, wherein the step of converting the wax to a wax gas or vapor produces a continuous stream of wax gas or vapor.

5. The method of claim 1, wherein the step of introducing a meltable fuel consisting essentially of wax into the generator assembly is performed subsequent to any process of refining the meltable fuel.

6. The method of claim 5, wherein the step of providing a heat source in thermal connection with the wax comprises providing a heat transfer element in thermal connection with the heat source, the heat transfer element comprising a material having a thermal conductivity of greater than 10 W/m K.

7. The method of claim 1, wherein the step of providing a gas generator assembly comprises providing a heat source in thermal connection with the wax.

8. The method of claim 7, wherein the step of providing a heat source comprises providing a heat source selected from the group consisting of fire, flame, thermal heating elements, microwave heating elements, radiation, electricity, and electrical heating elements, solar, and laser.

9. The method of claim 8, wherein the heat source is a flame fueled by the wax.

10. The method of claim 9, further comprising the step of limiting the consumption of the wax by the flame by controlling the amount of air available to the flame.

11. The method of claim 7, wherein the step of providing a gas generation apparatus further comprises providing a fuel reservoir configured and disposed for receiving the meltable fuel consisting essentially of wax, and providing the heat source in thermal connection with the fuel reservoir.

12. The method of claim 1, further comprising the step of combining the wax gas or vapor with a second gas to form a combustible mixture.

13. The method of claim 12, wherein the step of combining the wax gas or vapor with a second gas to form a combustible mixture comprises introducing the wax gas or vapor and the second gas into a nozzle assembly.

14. The method of claim 12, further comprising the step of utilizing the combustible mixture as a fuel source for an apparatus selected from the group consisting of stoves, fumigation devices, lanterns, lamps, heaters, combustion engines, Stirling engines, boilers, generators, furnaces and fireplaces.

15. The method of claim 1, further comprising the step of providing released wax gas or vapor as a fuel source for at least one apparatus that is not a candle.

16. A method of generating a gas or vapor state of a wax, the method comprising the steps of providing a device comprising a gas generator assembly that is not a candle; introducing a meltable fuel consisting essentially of wax into the gas generator assembly; converting at least a portion of the meltable fuel to a gas or vapor; releasing the gas or vapor from the gas generator assembly, and providing released wax gas or vapor as a fuel source for at least one apparatus selected from the group consisting of stoves, fumigation devices, lanterns, lamps, heaters, combustion engines, Stirling engines, boilers, generators, furnaces and fireplaces; and wherein the method is not part of a refinery.

17. The method of claim 16, wherein the step of providing a device comprising a gas generator assembly comprises providing a gas generator assembly that comprises a heat source in thermal connection with a heat transfer element, and wherein the heat source is selected from at least one of fire, flame, thermal heating elements, microwave heating elements, radiation, electricity, and electrical heating elements, solar, and laser and wherein the heat transfer element is in thermal connection with the wax.

18. The method of claim 16, further comprising the step of combusting the gas or vapor.

19. The method of claim 18, wherein the apparatus is selected from the group consisting of stoves, fumigation devices, lanterns, lamps, heaters, combustion engines, Stirling engines, generators, furnaces, boilers, and fireplaces.

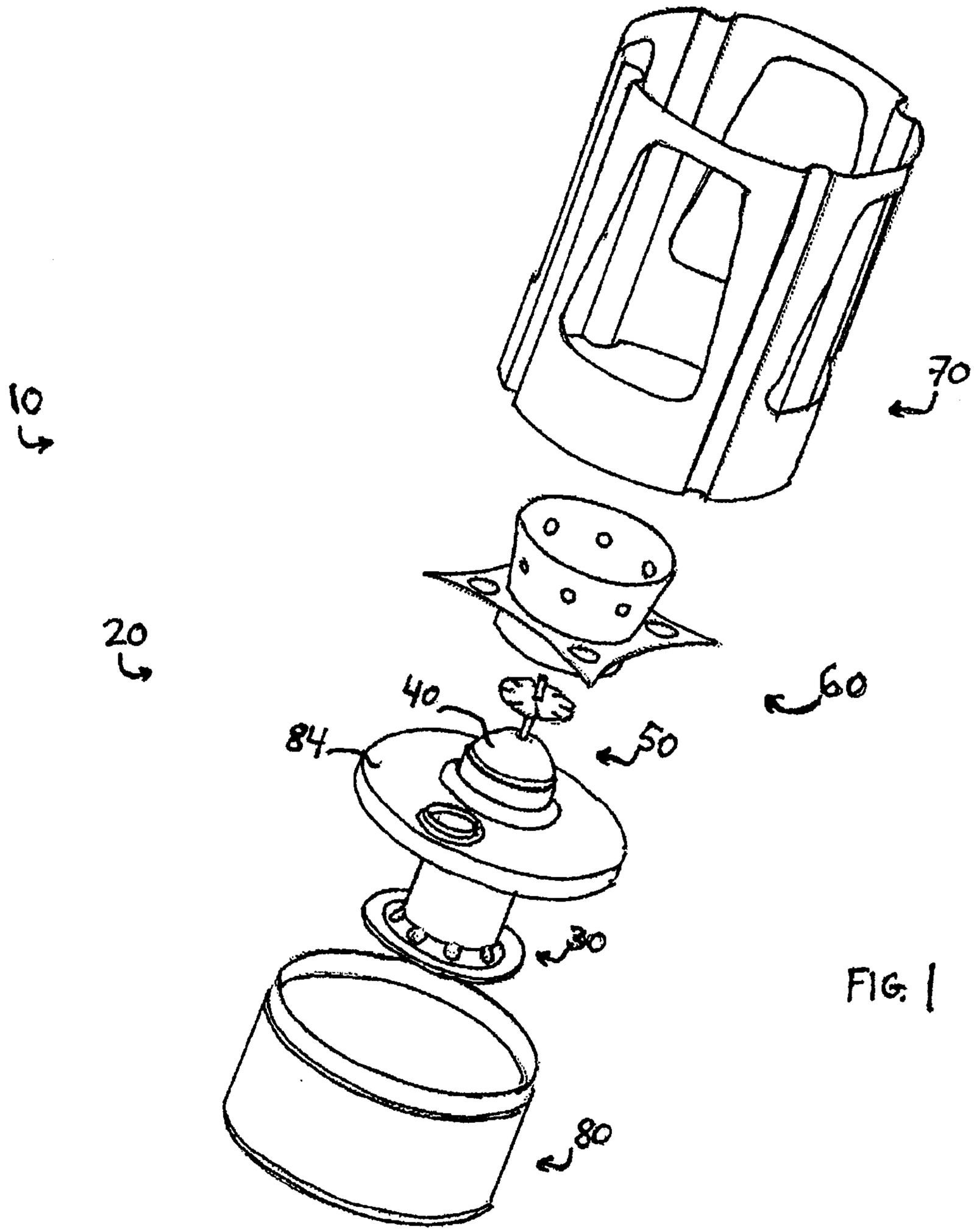



FIG. 1

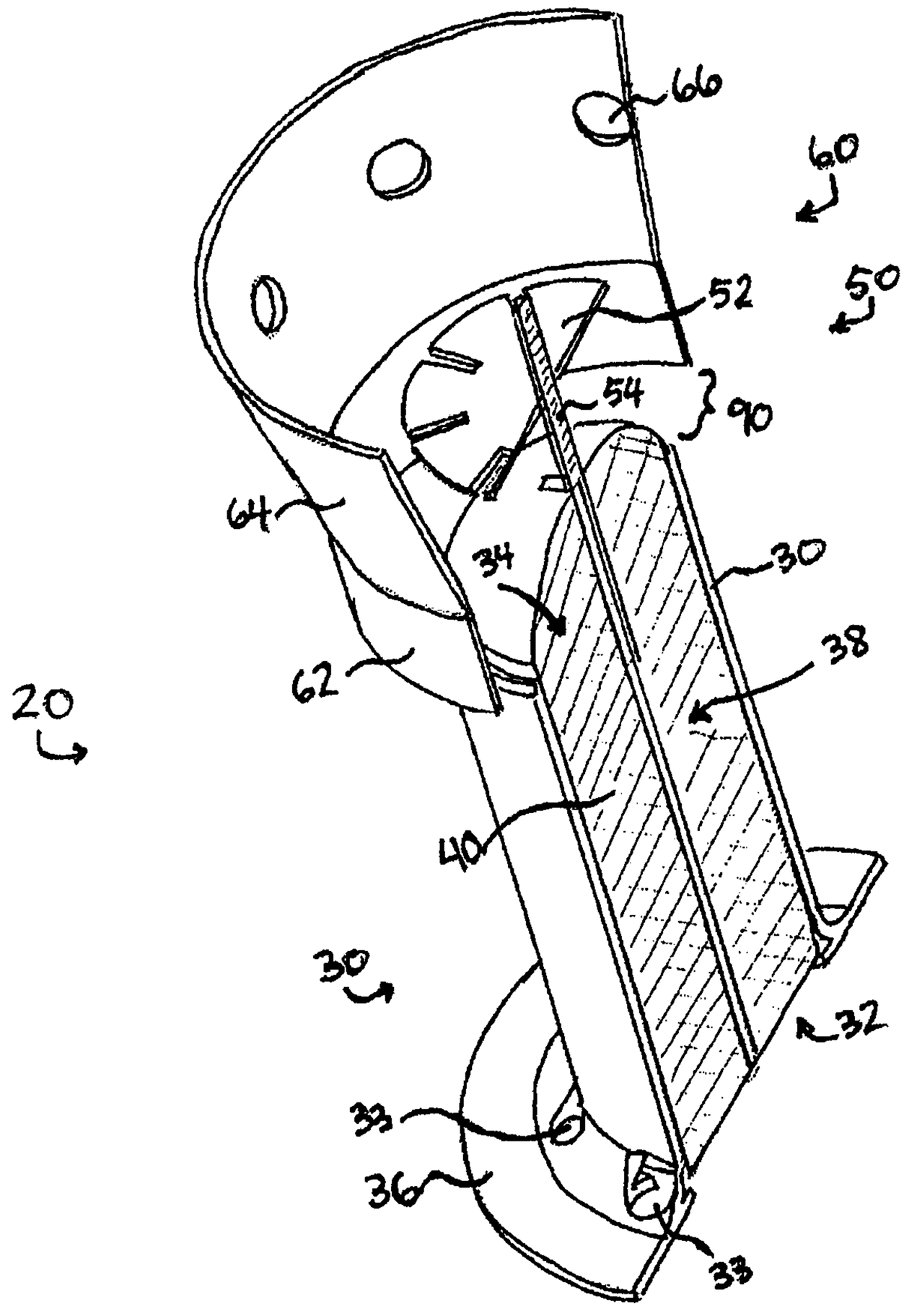



FIG. 2

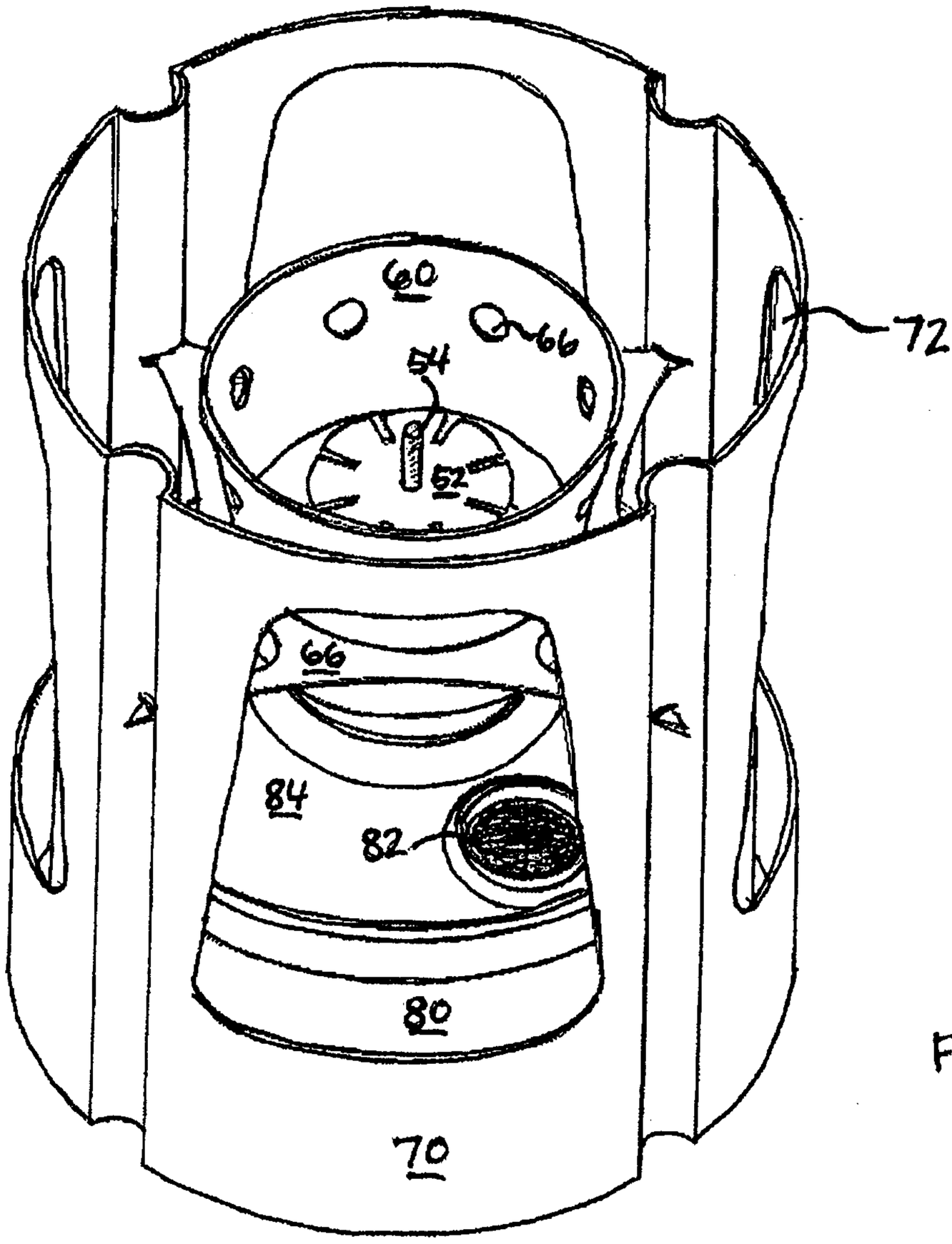



FIG. 3

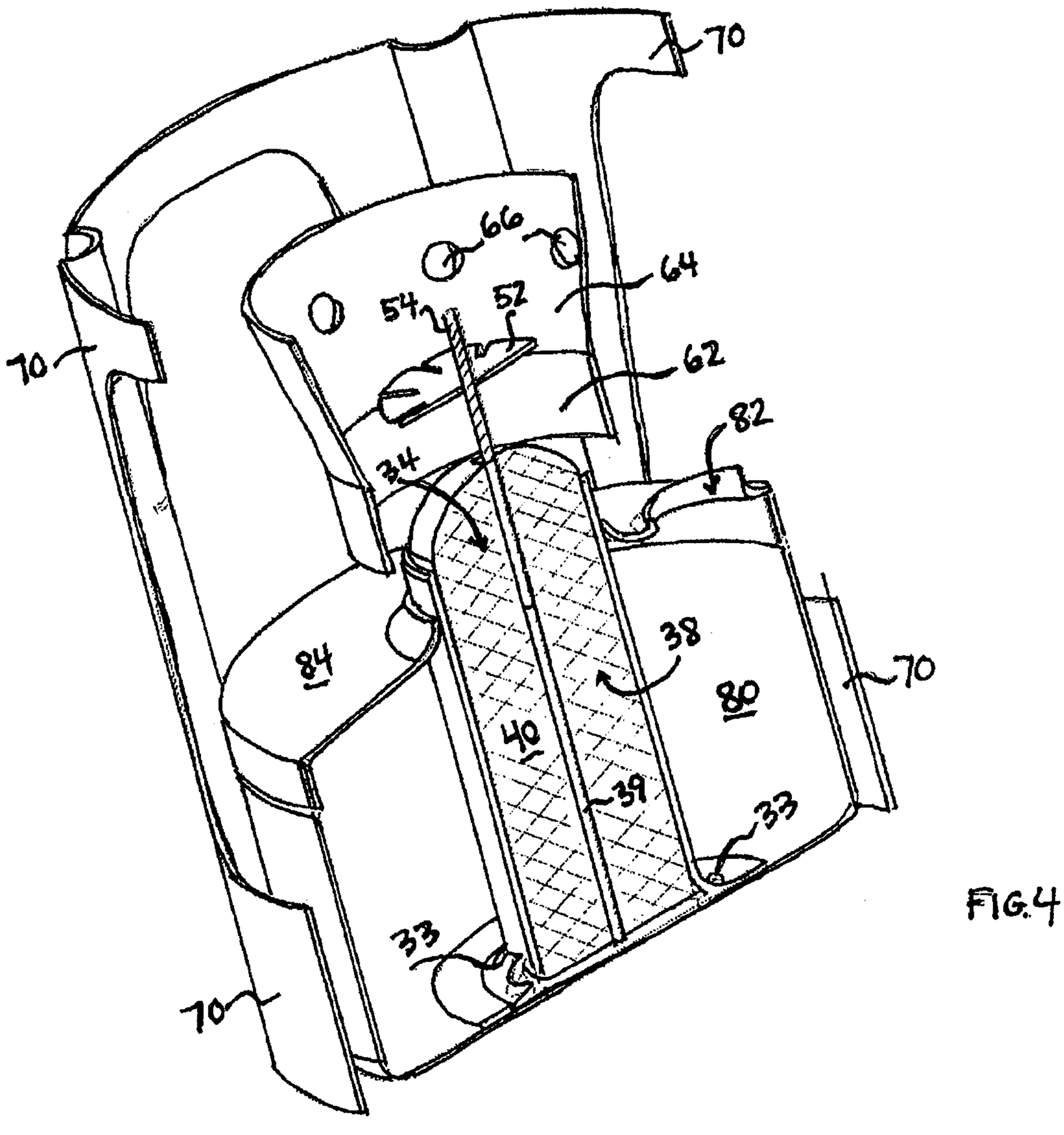



FIG.4

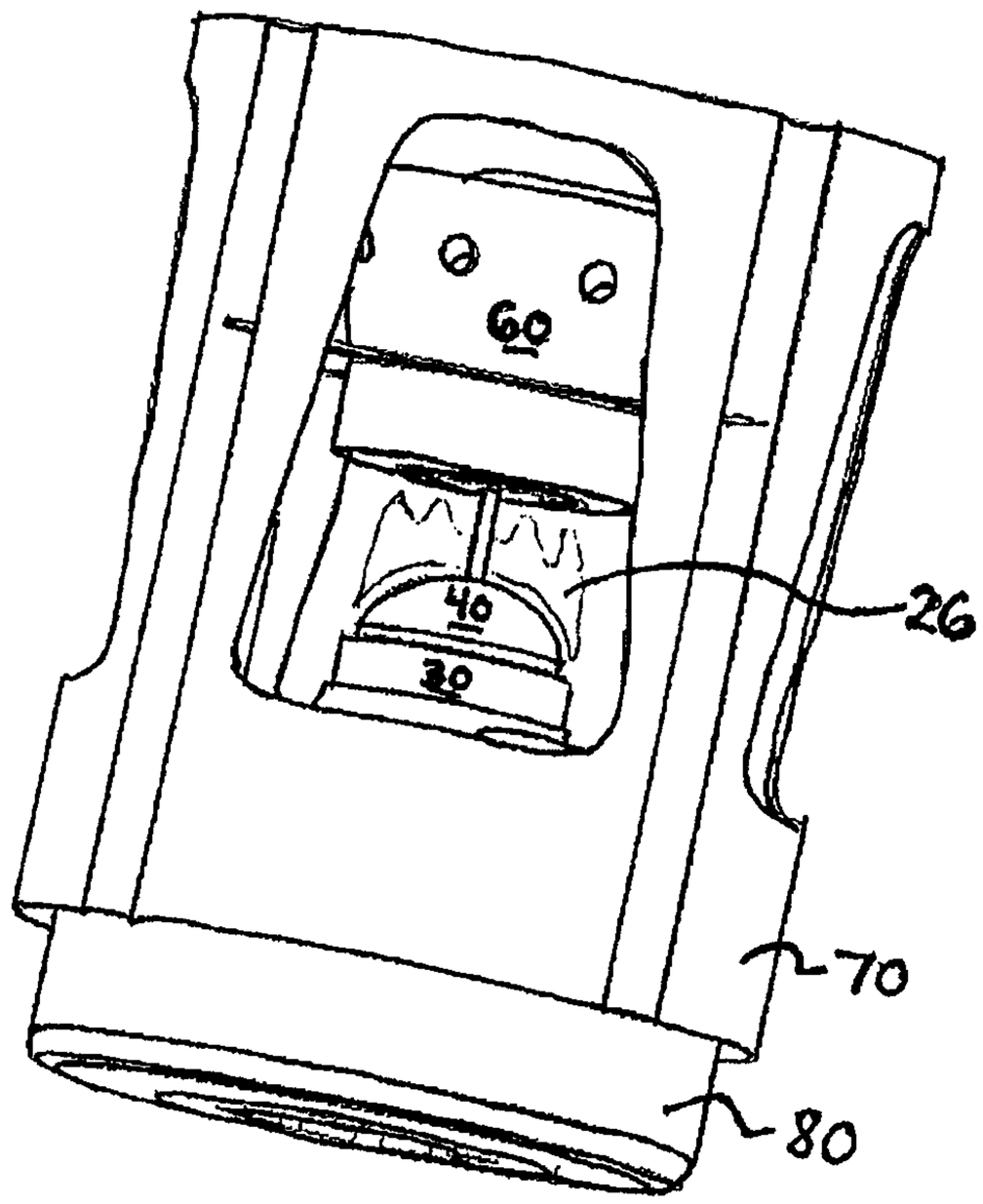



FIG. 5

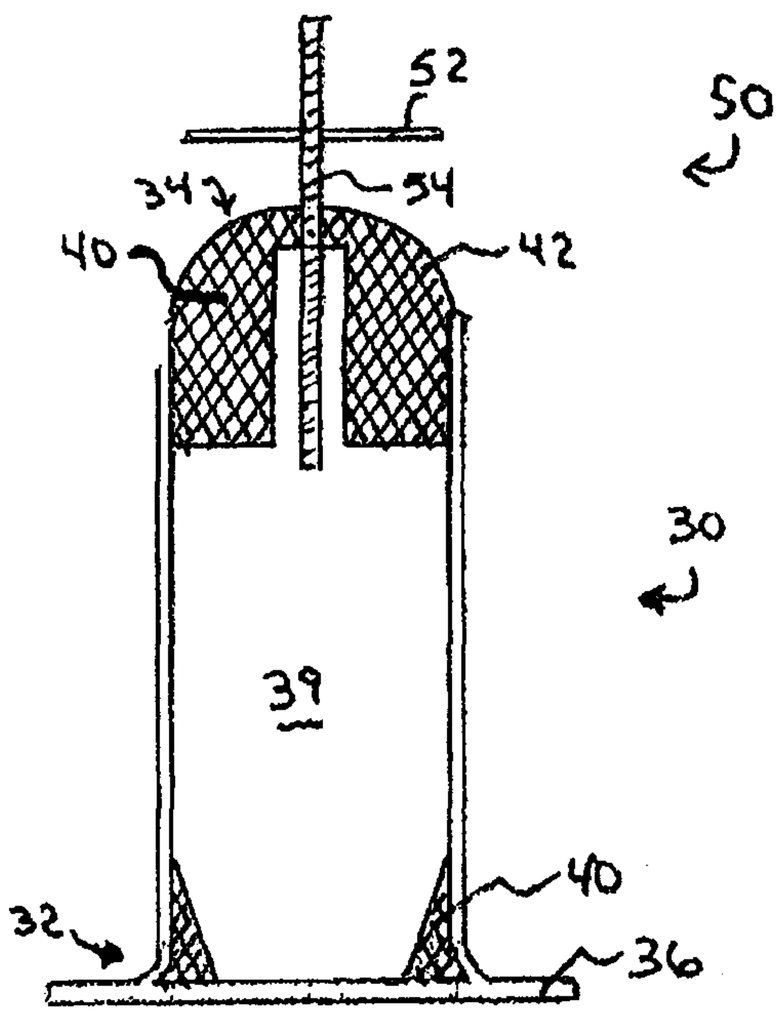



FIG. 6

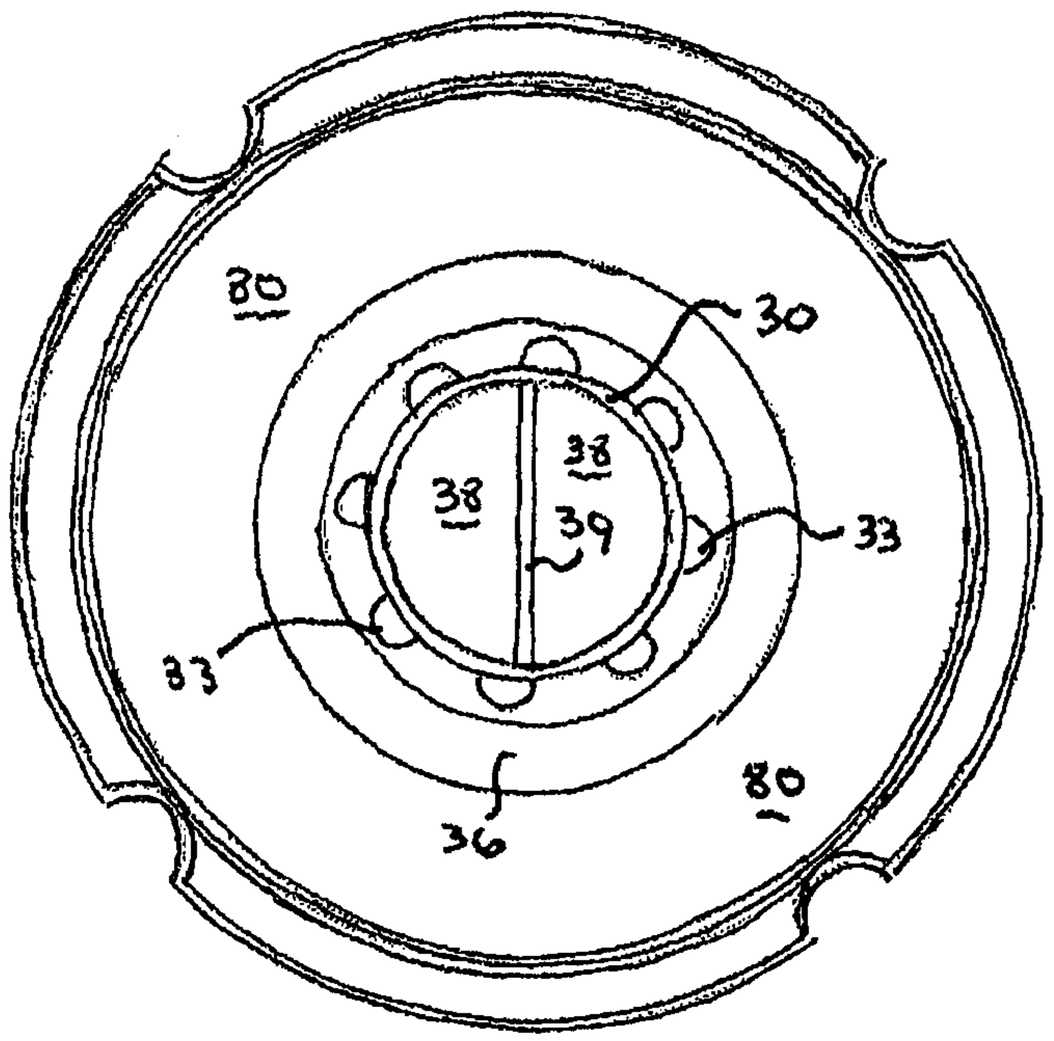



FIG. 7

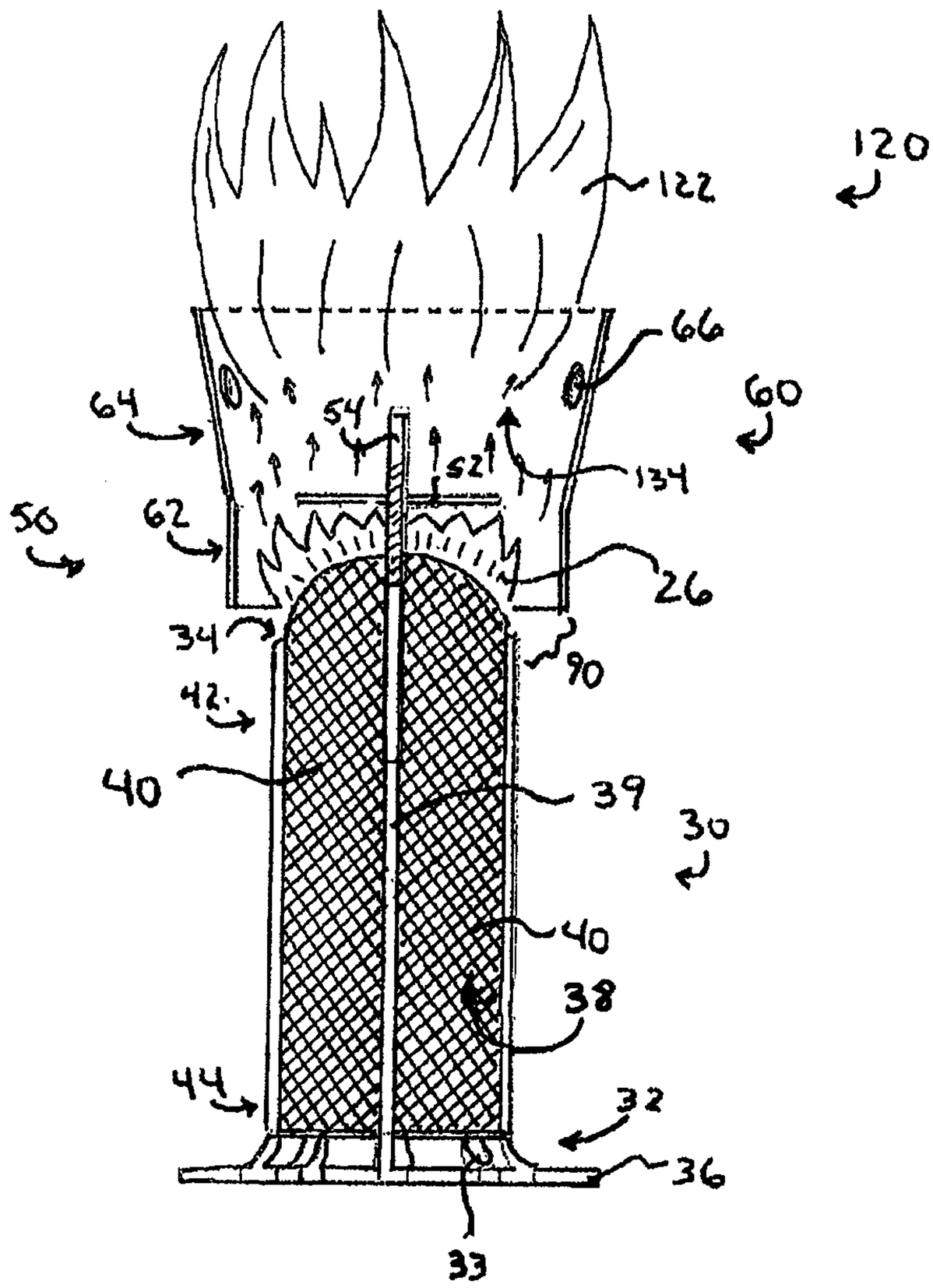



FIG. 8

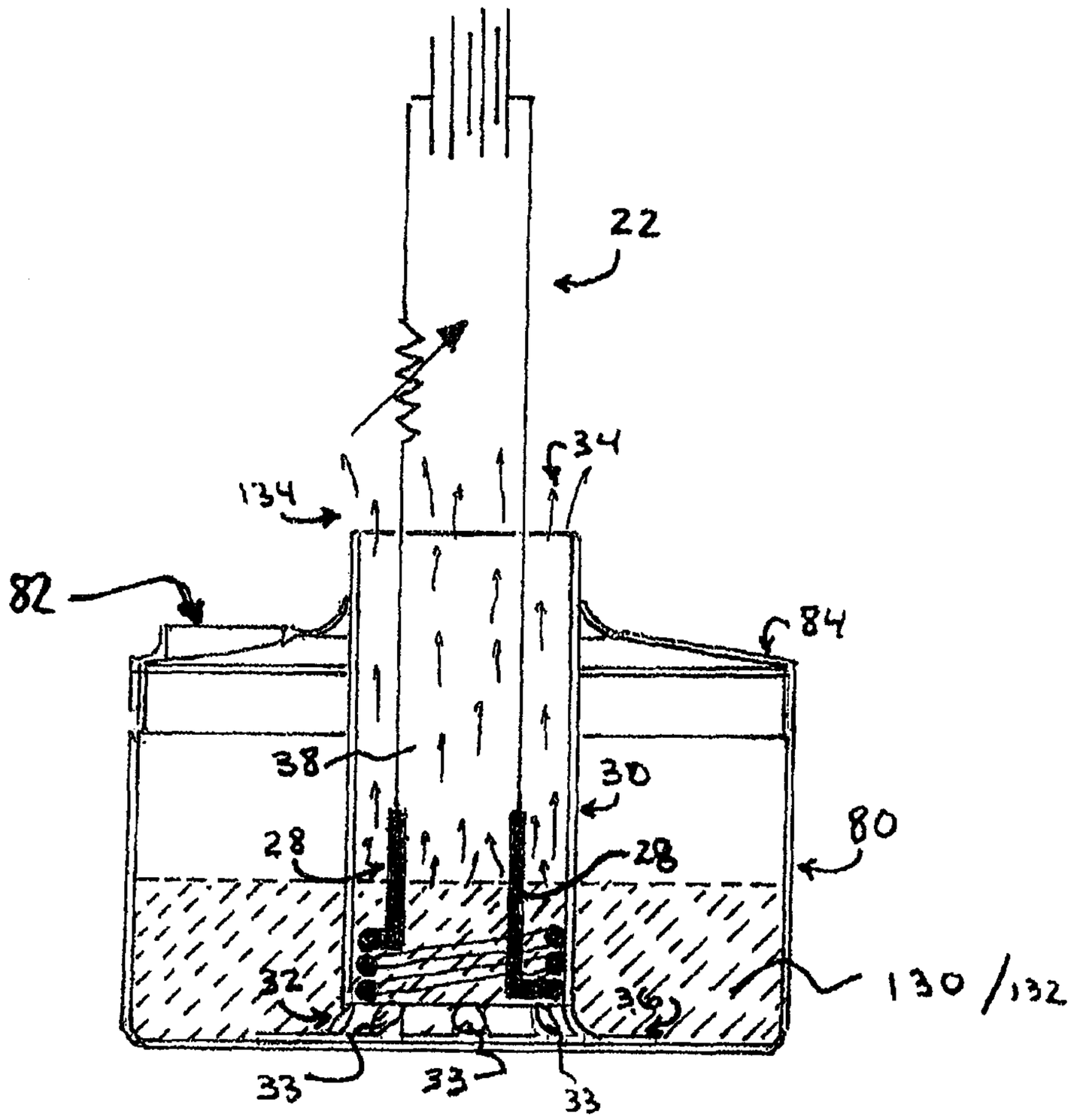



FIG. 9

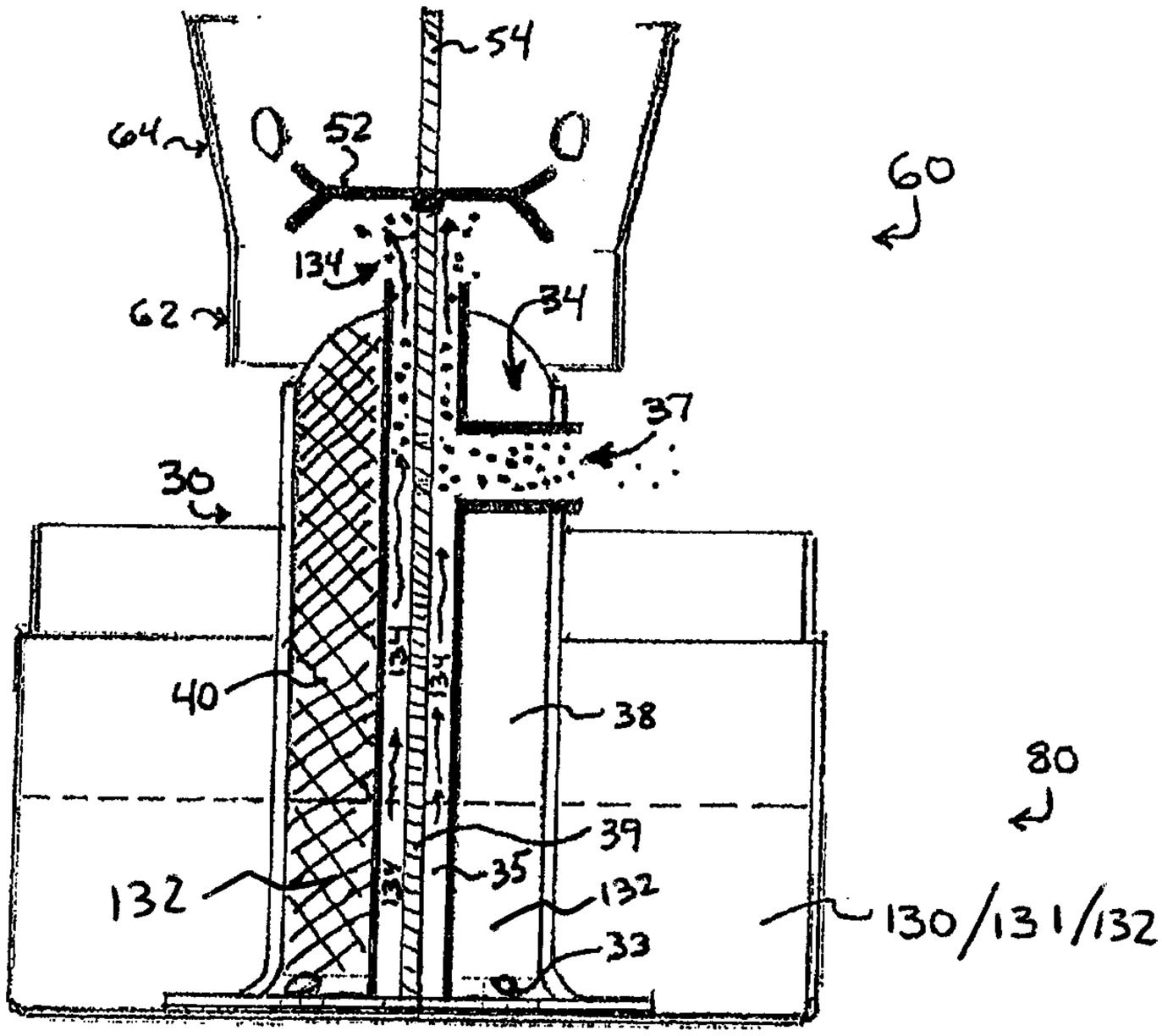



FIG. 10

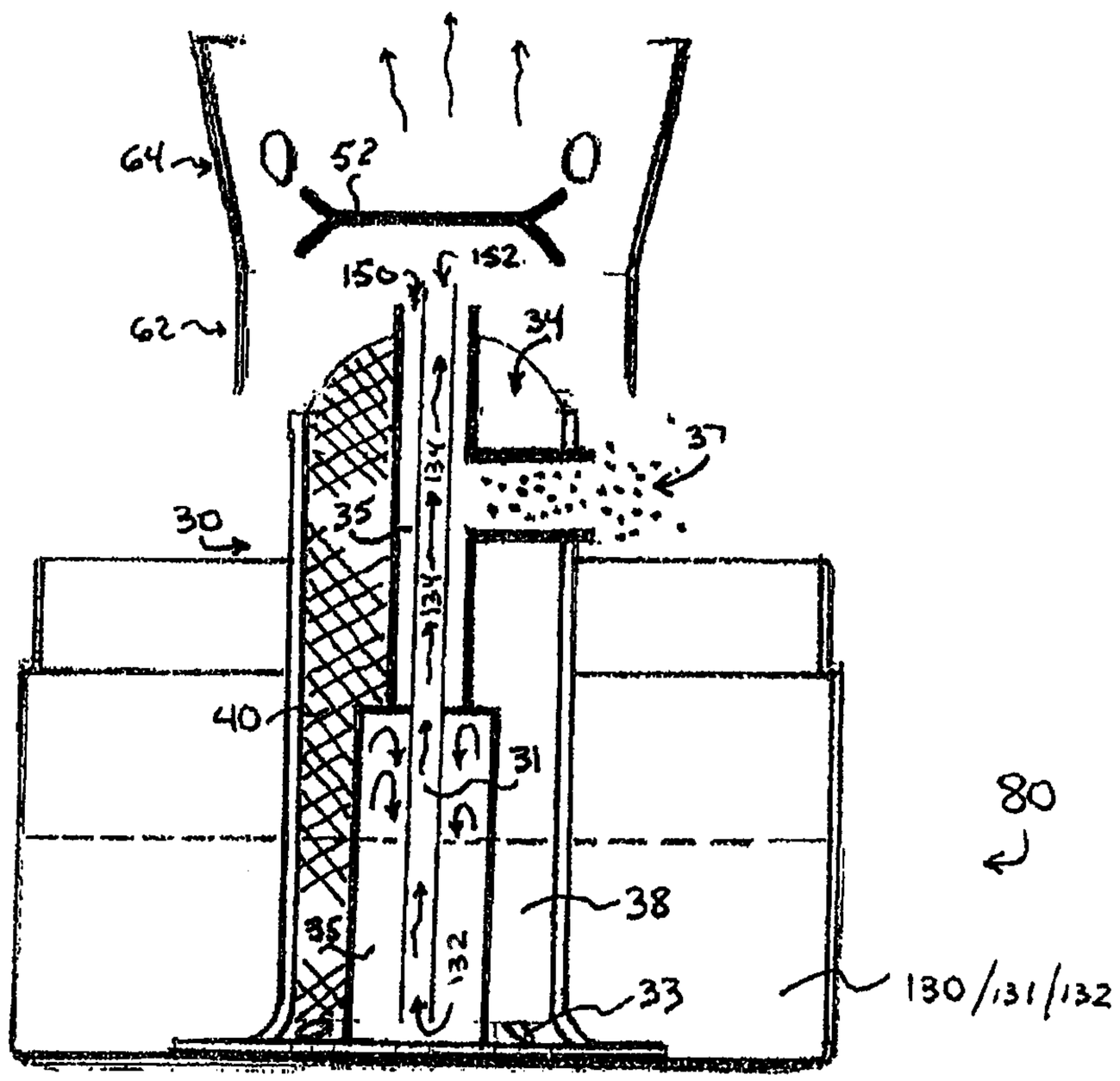



FIG. 11

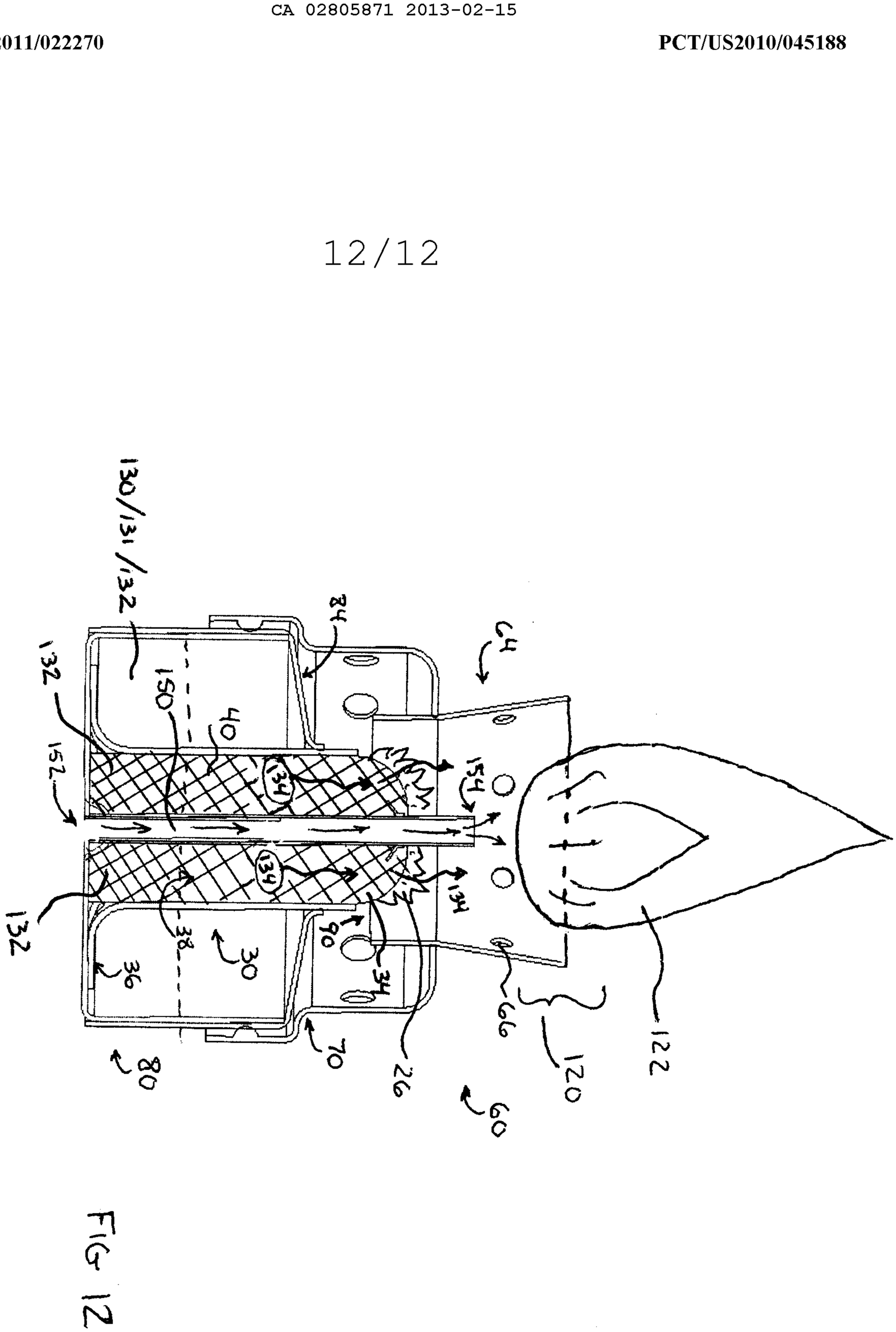

130/131/132
132
152
150
40
24
64
154
134
134
132
38
30
36
60
34
66
70
80
26
120
122
60

FIG. 2

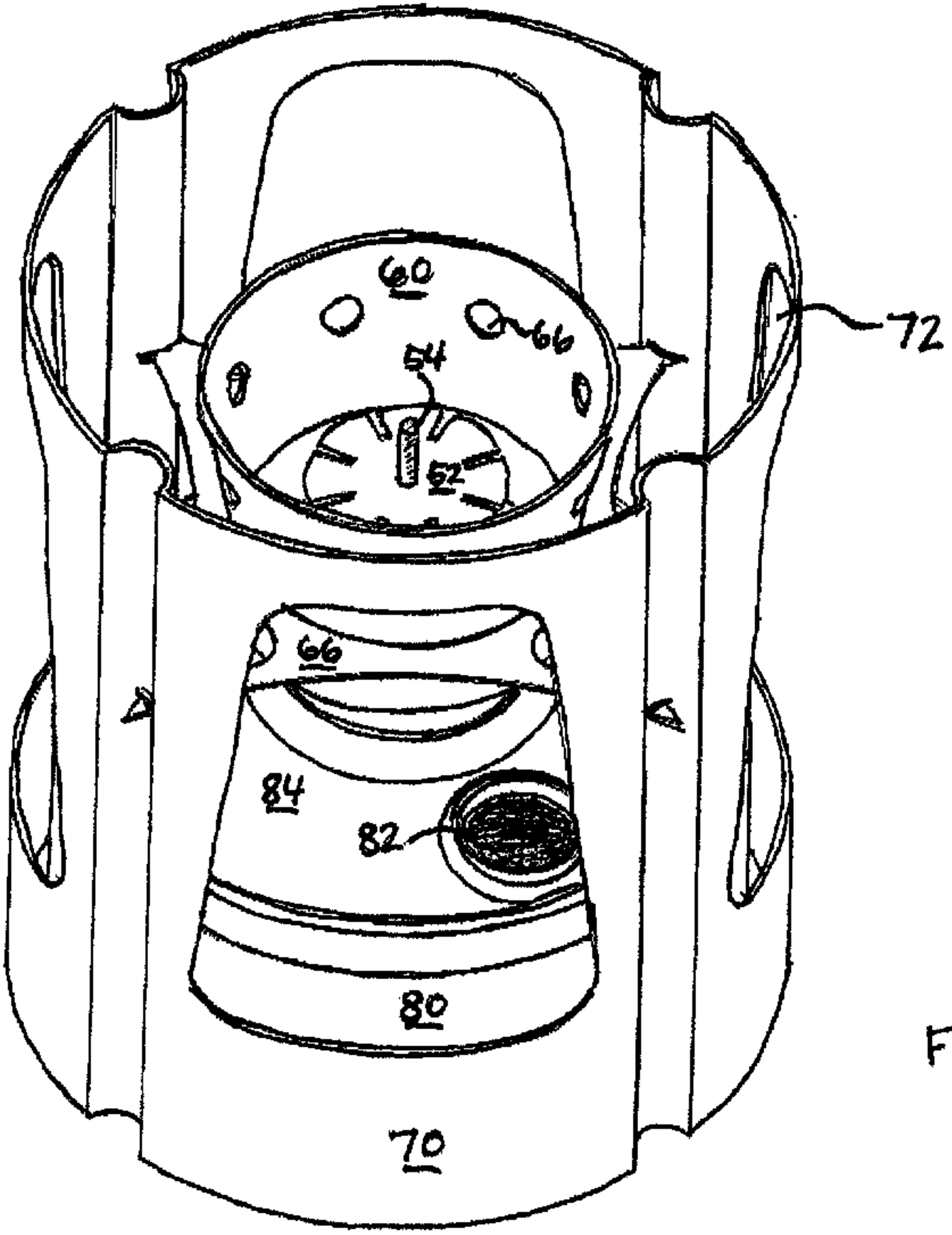



FIG. 3