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Young

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[54] **CAPILLARY FEED BOILER**

[75] Inventor: **Niels Owen Young**, Boise, Id.

[73] Assignee: **Allports LLC International**, Boise, Id.

[21] Appl. No.: **946,033**

[22] Filed: **Oct. 7, 1997**

Related U.S. Application Data

[63] Continuation of Ser. No. 439,093, May 10, 1995, Pat. No. 5,692,095.

[51] **Int. Cl.**[6] **F24F 6/98**; F23D 11/04

[52] **U.S. Cl.** **392/395**; 431/208; 431/241

[58] **Field of Search** 392/395; 431/206, 431/207, 208, 241, 258, 259, 261, 262; 126/44, 45

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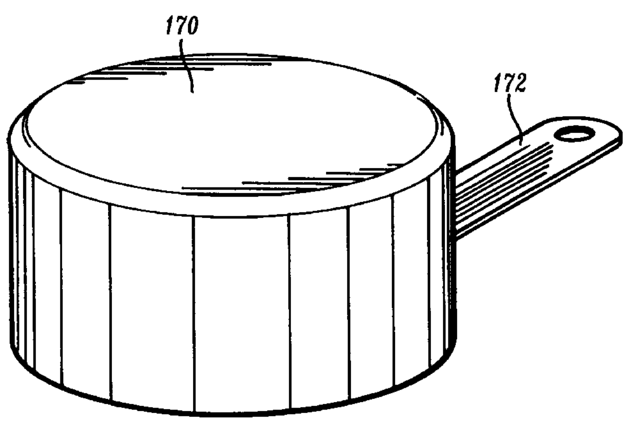
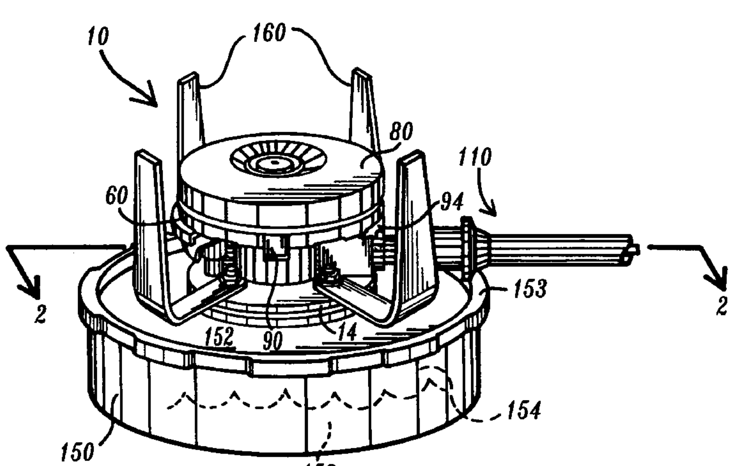
Primary Examiner—Teresa Walberg
Assistant Examiner—Sam Paik
Attorney, Agent, or Firm—Ann W. Speckman; Janet Sleath

[57] **ABSTRACT**

The invention is an improved boiler for generating vapor at low pressure from liquid in reservoirs that are not pressurized. Liquid from a reservoir is fed through a supply wick by capillary action to a boiler wick in which the liquid is heated and boiled to a vapor. The heat for vaporization is transmitted by a porous hot seat which sits atop and is in contact with the boiler wick. The boiler wick and hot seat are contained within an insulating cylindrical shroud, which forms a tight seal with the edges of the boiler wick. If the liquid to be vaporized is a fuel for a burner, then combustion heat can be used to supply the heat to the boiler. A resistive heat source can also be used to heat the hot seat and boiler wick.

27 Claims, 11 Drawing Sheets





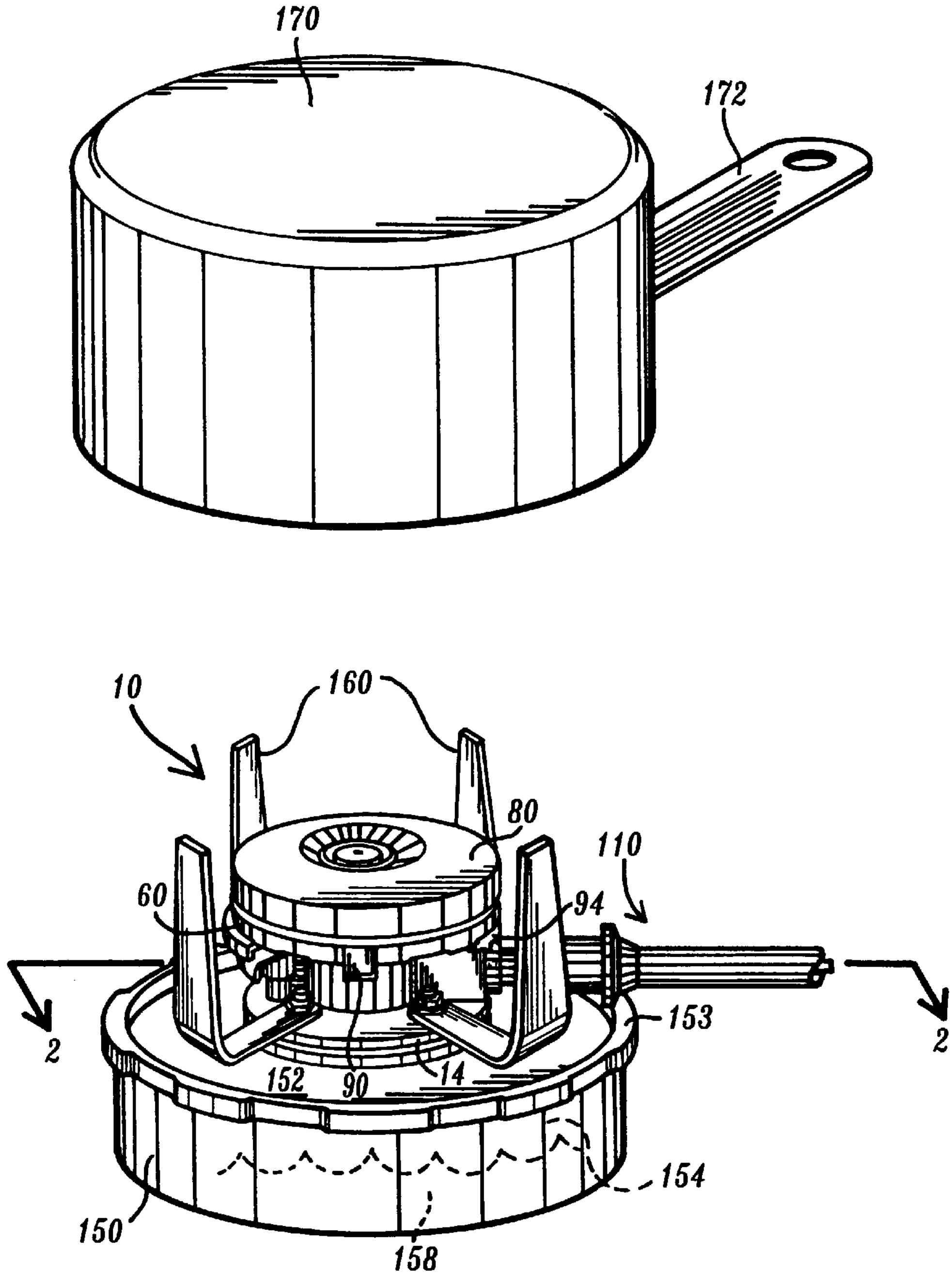


Fig. 1

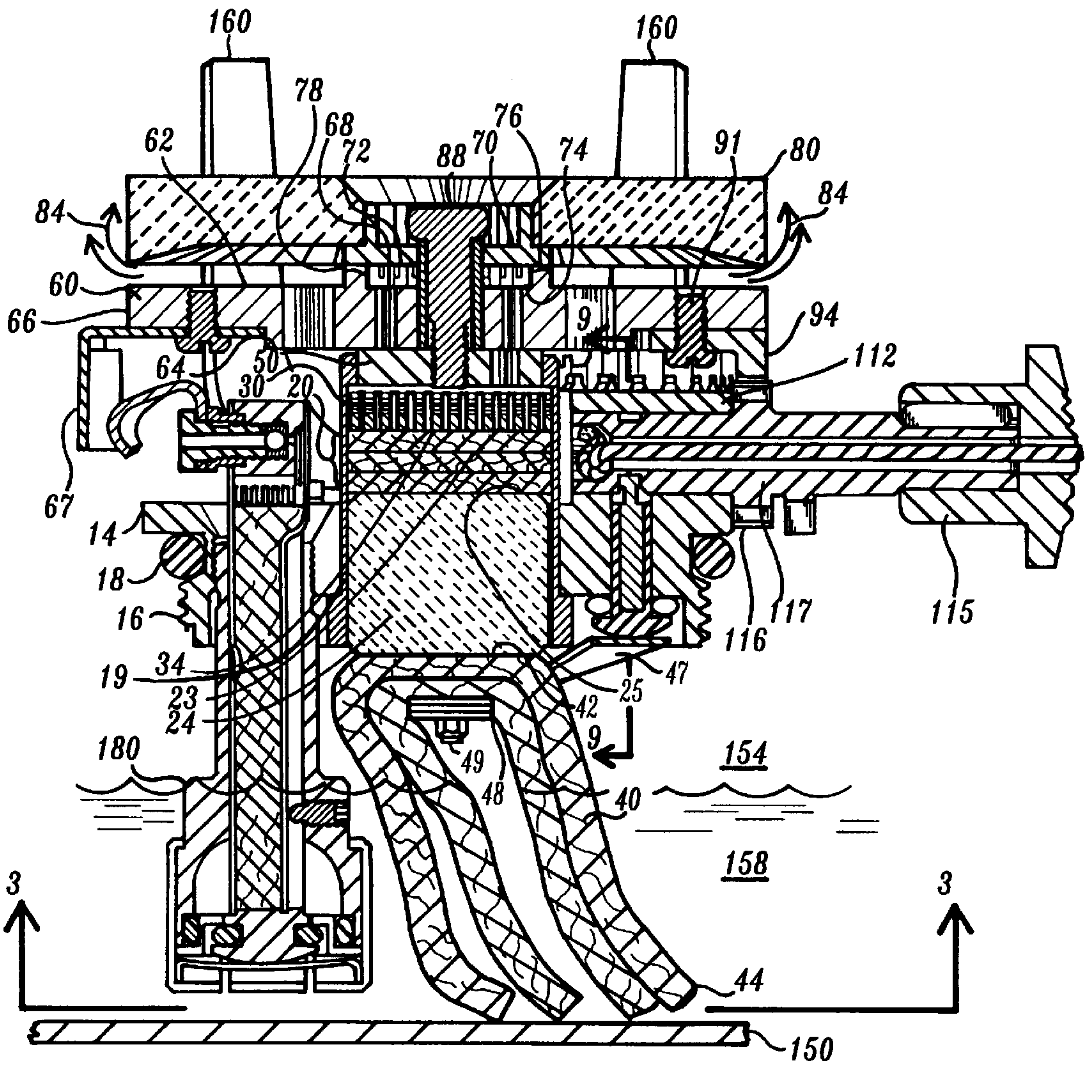

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Fig. 2

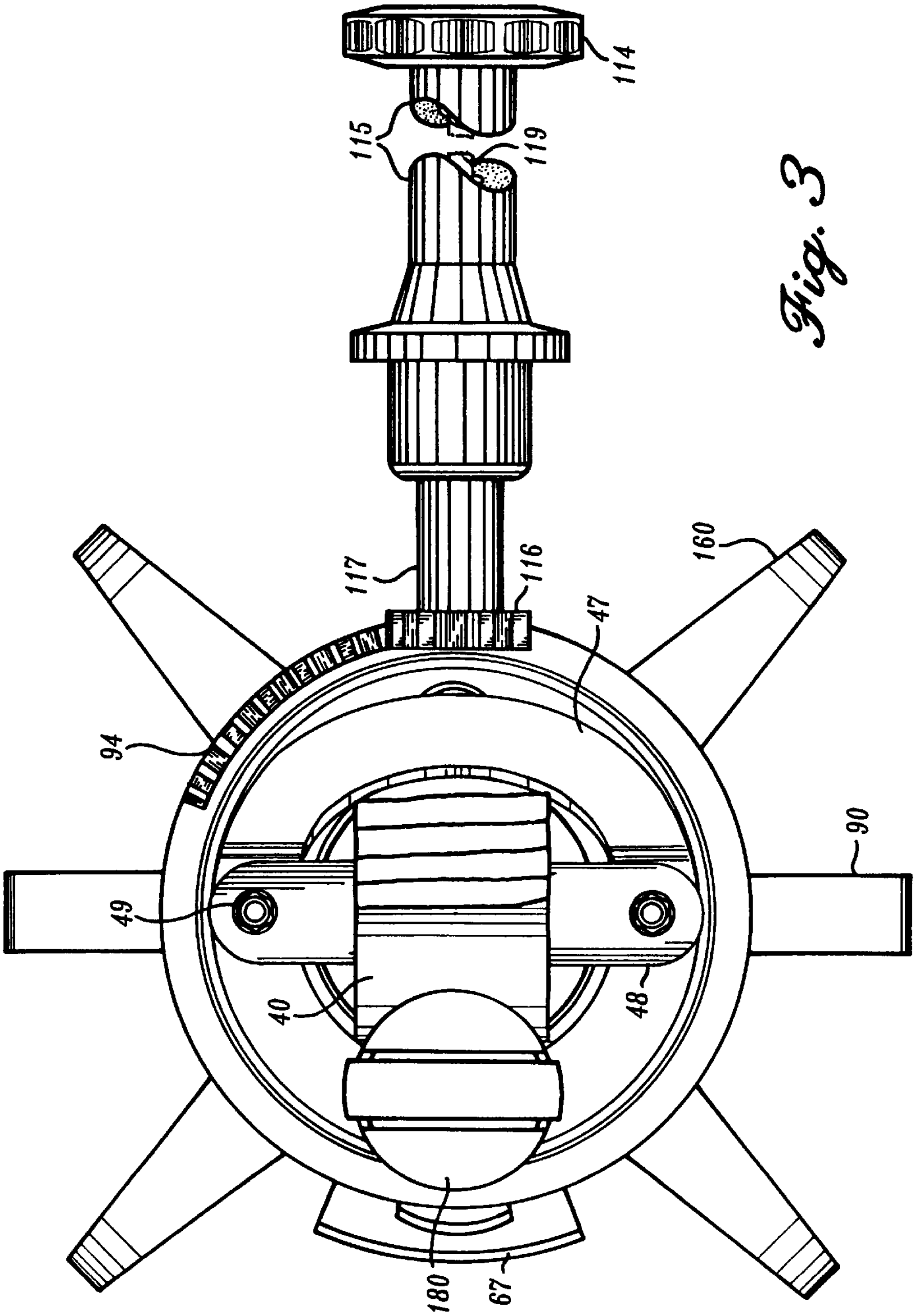

Fig. 3

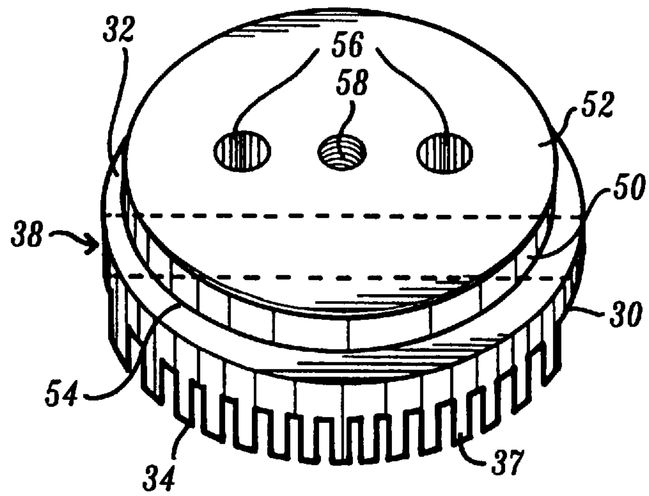

Fig. 4

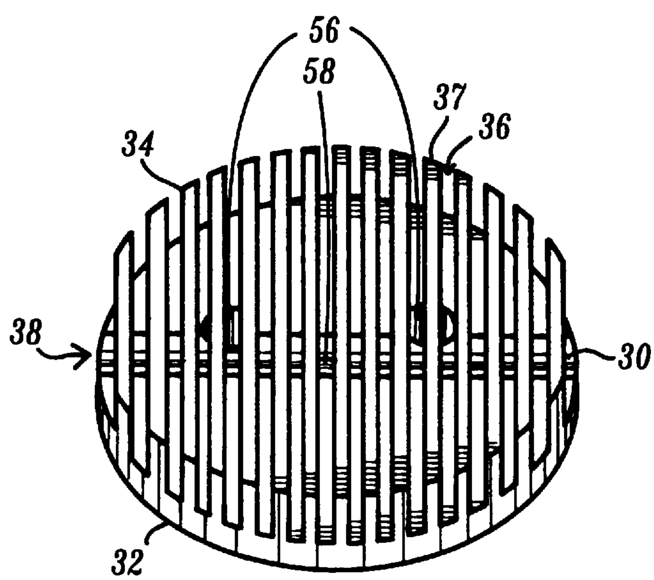

Fig. 5

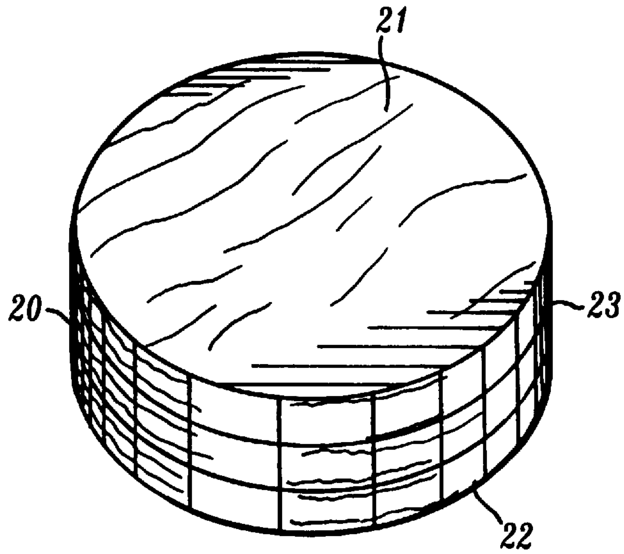

Fig. 6

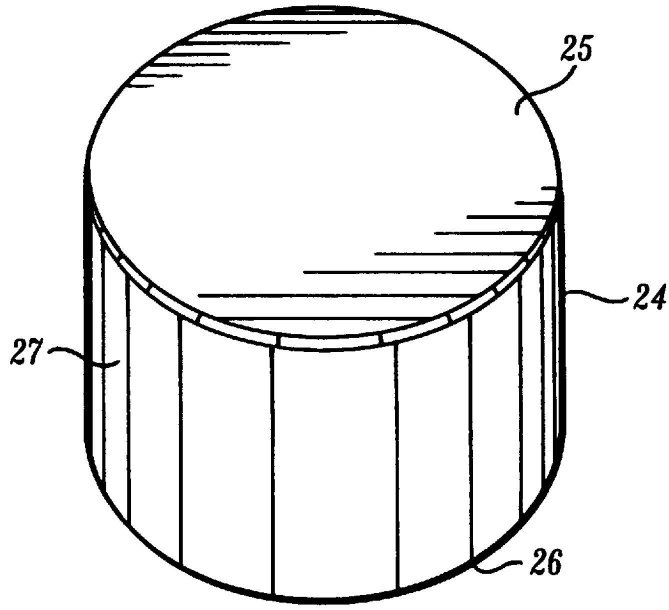

Fig. 7

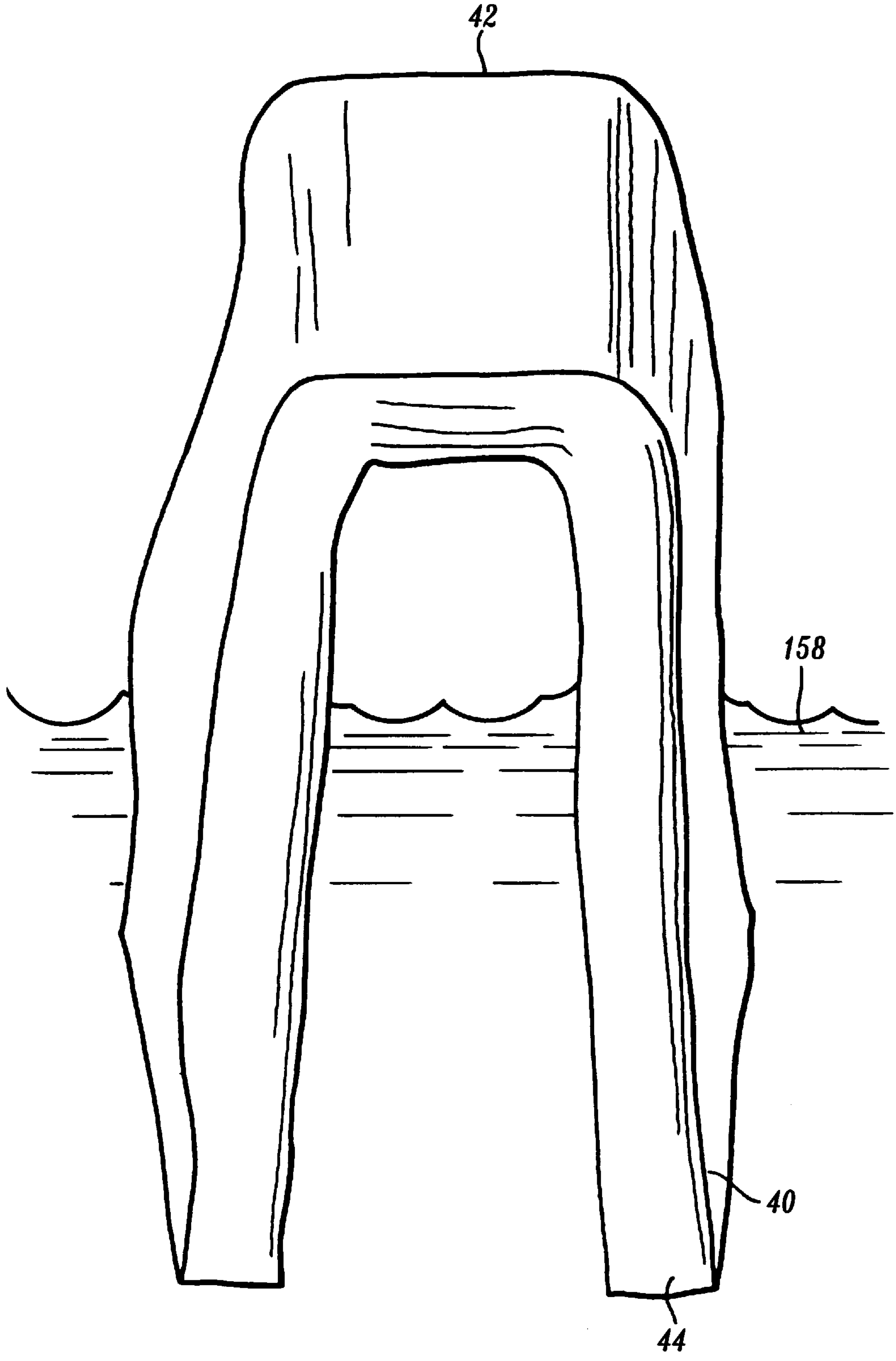

Fig. 8

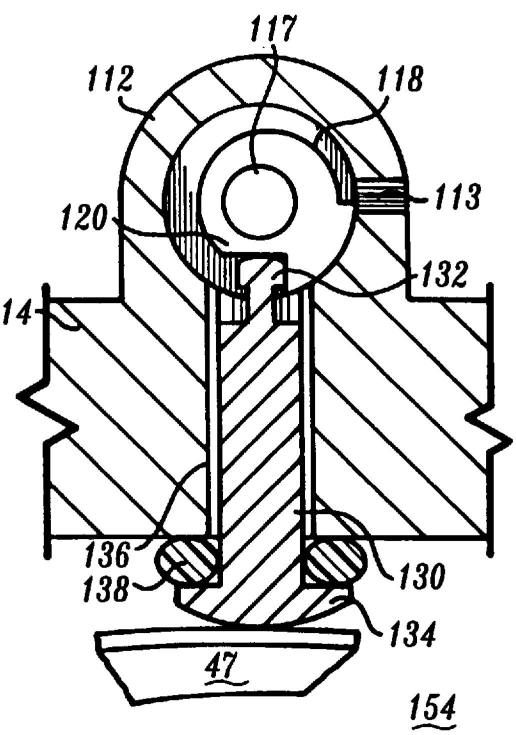

Fig. 9

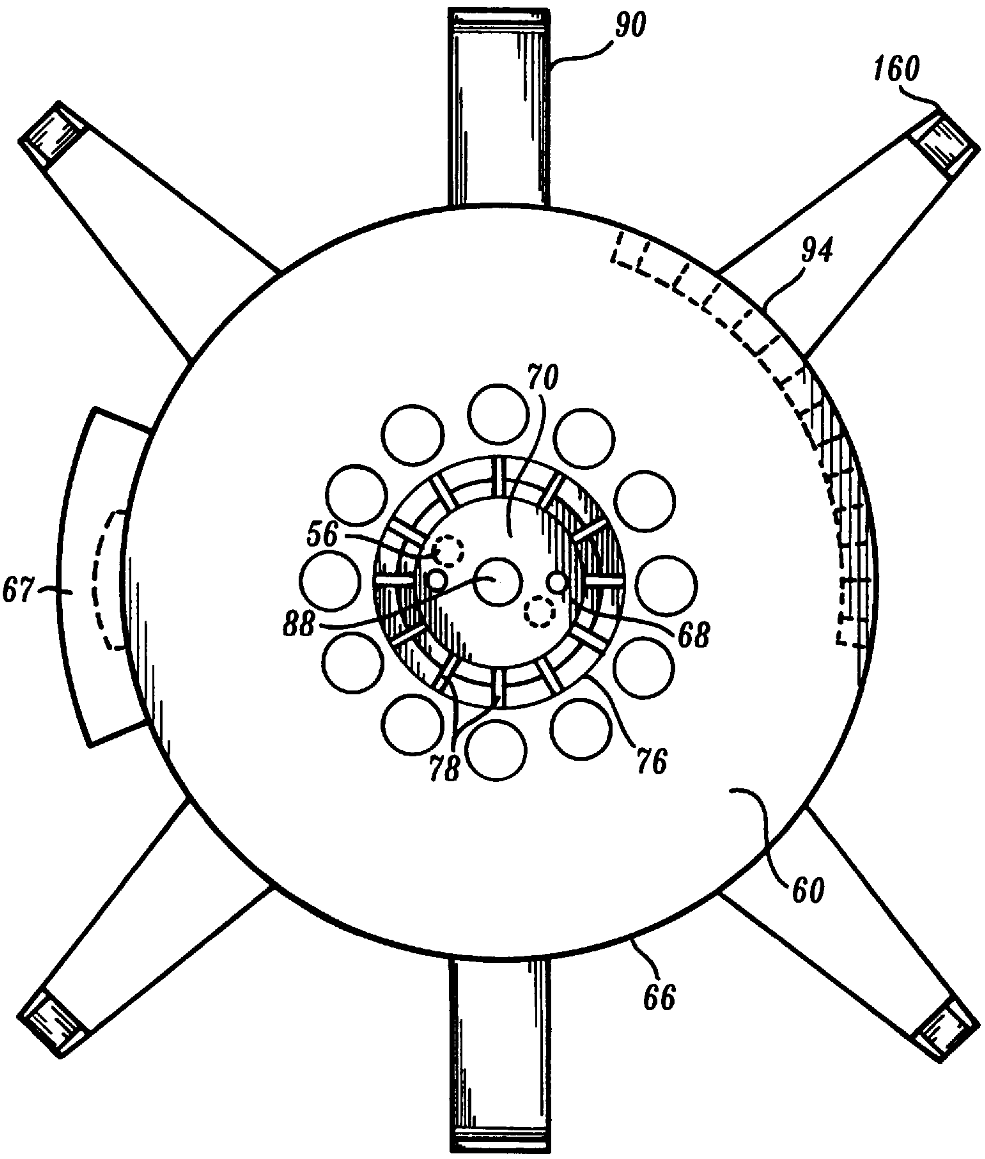

Fig. 10

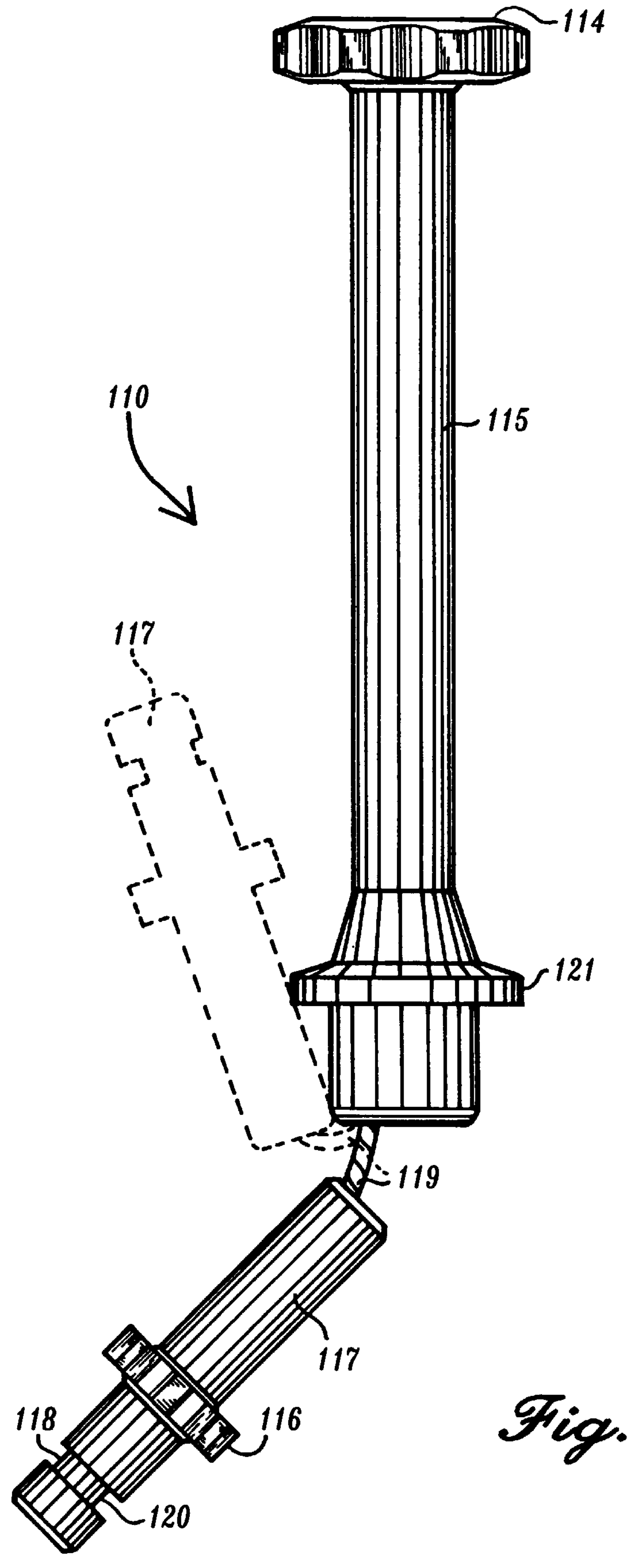

Fig. 11

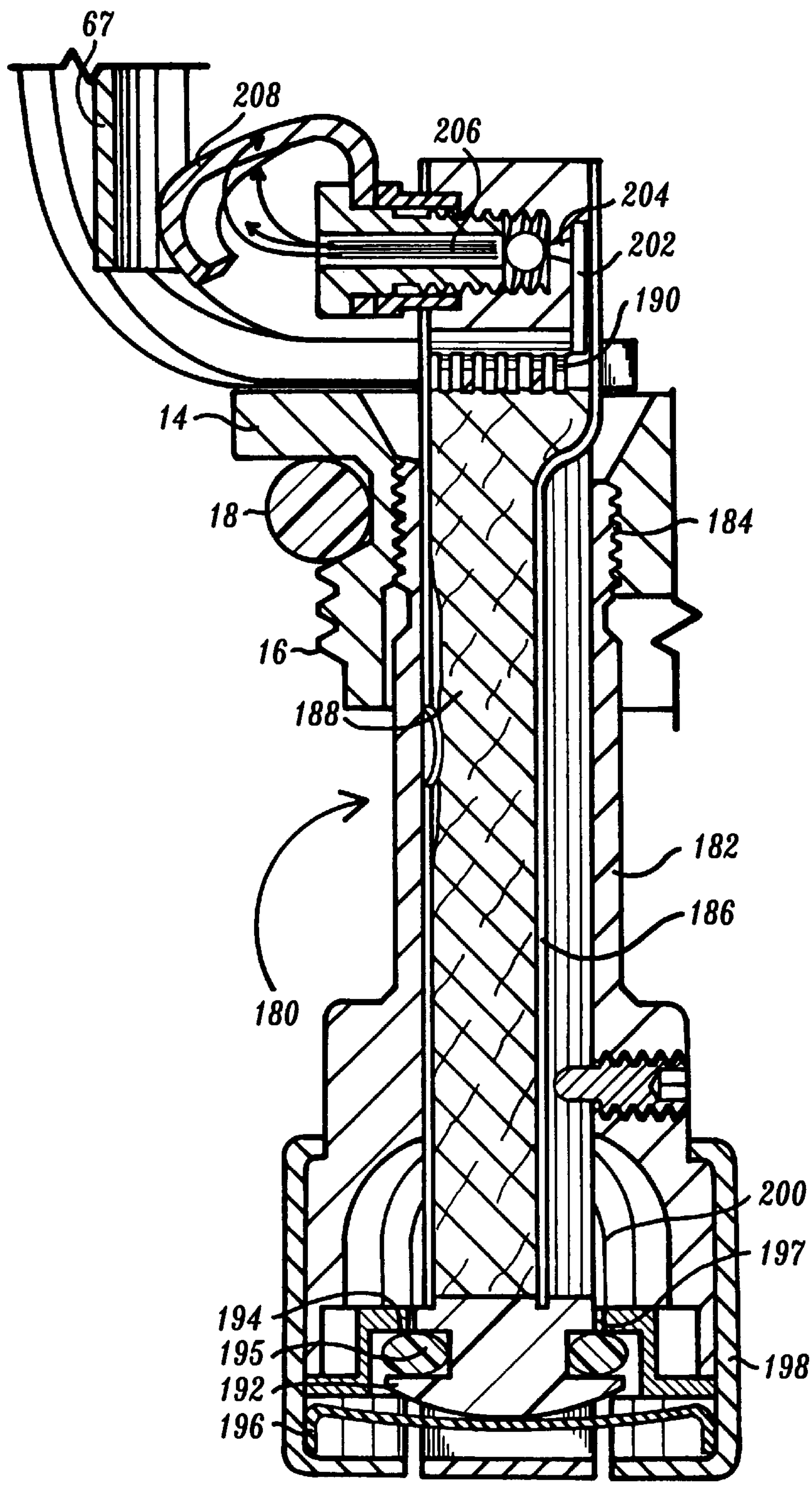
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Fig. 12

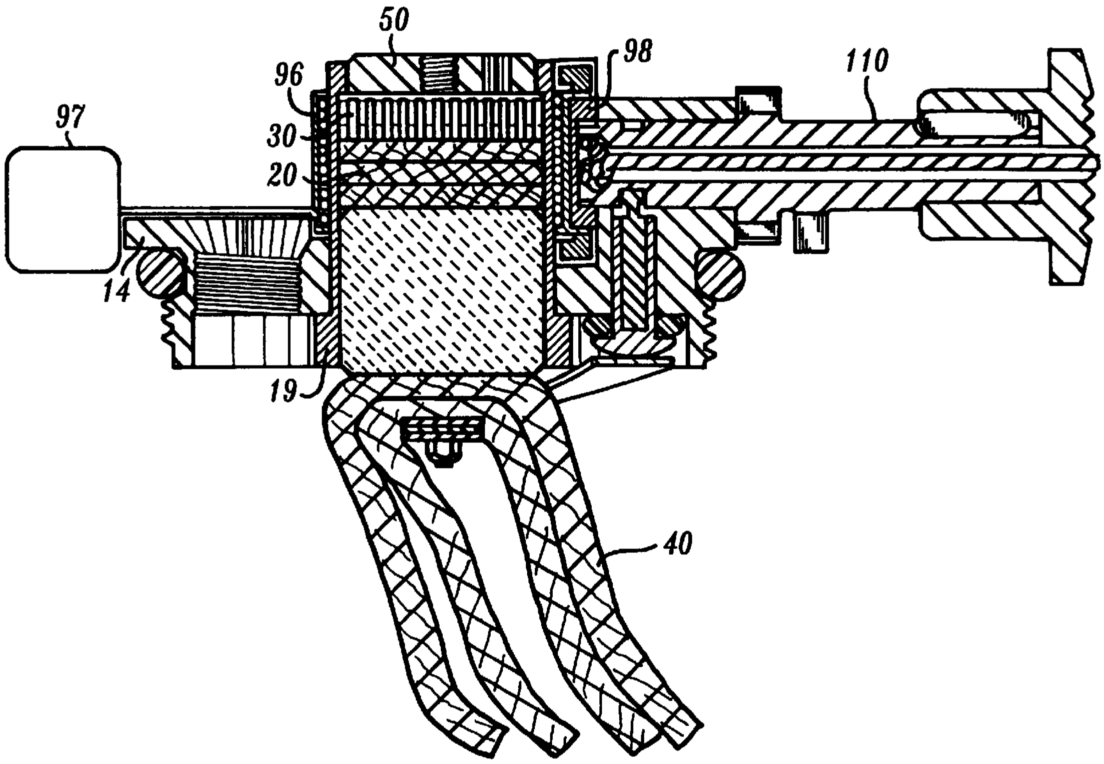

Fig. 13

CAPILLARY FEED BOILER

This application is a continuation of application Ser. No. 08/439,093, filed May 10, 1995, U.S. Pat. No. 5,692,095 allowed Mar. 20, 1997.

BACKGROUND OF THE INVENTION

1. Technical Field. This invention relates to boilers for generating vapor from liquid. More particularly, this invention relates to a boiler in which the liquid to be vaporized is fed by capillary action.

2. Background: Boilers are used to convert liquid to vapor in applications in which vapor is necessary, or preferable, to liquid. All boilers serve to add heat to an inflow of liquid in order to vaporize the liquid and create an outflow of vapor. The pressure of vapor generated by a boiler cannot exceed the pressure of the supplied liquid. Therefore, to supply vapor under pressure, an inflow of liquid to the boiler must be supplied under at least as much pressure as is desired for the vapor.

Liquid inflow to large industrial boilers is commonly supplied by a mechanical or jet-ejector feed pump that draws liquid from a reservoir at atmospheric pressure. These feed pumps deliver liquid to the boiler at a pressure at least as great as that desired for the vapor. A throttle valve is typically used to control the flow of vapor from the boiler, and the pressure of the vapor exiting the boiler is a function of the position of the throttle valve. Feed pumps maintain a constant liquid level in a boiler. They do this over a reasonable range of vapor flow and pressure as determined, for example, by a throttle valve position. The liquid flow produced by mechanical or jet ejector feed pumps on boilers is therefore servo controlled to maintain a constant liquid level in the boiler. It is not practical to scale down this kind of system for producing the low vapor flow requirements of devices such as domestic stoves, camp stoves, or mantle lamps.

Camping stoves and other portable burners require the production of gaseous fuel to be mixed with air and combusted. Fuels, such as propane and butane, which are gasses at atmospheric temperature and pressure, are liquids under pressure and occupy smaller volumes for economical storage and transport. This necessitates the use of pressurized containers, with the attendant explosion hazards. Similar hazards exist when the liquid fuel is supplied to a boiler from a reservoir pressurized with gas or air, as in the case of gasoline stoves and mantle lamps.

The boiler of propane and butane stoves is the reservoir or storage tank itself, in which the gasses are liquified under pressure. When vapor is drawn from the reservoir, the reservoir acts as a boiler, and draws the required heat of vaporization from ambient air outside the tank. These types of stoves have many disadvantages. For example, the vapor pressure depends upon ambient temperature, the vapor pressure is generally higher than that needed for satisfactory combustion in a burner and, as previously mentioned, the fuel and vapor are at hazardous pressures. While butane fuel has an advantageous lower vapor pressure than propane, stoves using butane have difficulty producing sufficient vapor pressure at low ambient temperatures. The pressure of propane does not fade at low ambient temperatures. But the vapor pressure of propane nonetheless varies with the tank or ambient temperature and the pressure is inconveniently high. A needle valve can control propane vapor at tank pressure to regulate the heat output of a burner. But burner control by a needle valve tends to be delicate and sensitive

to ambient temperature. Alternatively, a pressure regulator can be used to generate a constant and less hazardous pressure of propane that is independent of tank temperature. These are reasons why pressure regulators are commonly used in cookout grilles, recreational vehicles, boats, and domestic propane installations. Unfortunately, regulators are seldom practical for applications at the scale of camp stoves.

It is, therefore, an object of this invention to provide vapor at pressures higher than the pressure of the liquid from which the vapor is created without the use of feed pumps.

It is another object of the present invention to provide vapor at pressures higher than the pressure of the liquid from which the vapor is created without pressurizing the liquid.

It is a further object of the present invention to provide vapor at an approximately constant pressure that is not strongly dependent upon ambient temperature or upon mass flow of the vapor.

Another object of this invention is to provide vapor at a steady flow rate.

Yet another object of the present invention to provide an economical portable stove fueled by unpressurized liquid fuel without the use of feed pumps.

DISCLOSURE OF INVENTION

These and other objects are accomplished by means of a capillary feed boiler in which liquid fuel contained within a fuel reservoir is fed through a supply wick by capillary action to a boiler wick in which the liquid fuel is heated and boiled to a vapor at the point within the boiler wick where it is at the boiling temperature. The heat for vaporization is supplied by a porous hot seat which sits atop and is in contact with the boiler wick. The boiler wick, hot seat, and the upper portion of the supply wick are all contained within an insulating cylindrical shroud, which forms a seal with the edges of the boiler wick, so that the vapor formed in the boiler wick is able to force liquid in a direction away from the hot seat, rather than simply blowing past the boiler wick. Fuel vapor flows upward through the boiler wick, porous hot seat, through a throttle valve, and finally through jet forming orifices into the atmosphere where it mixes with air and burns.

A capillary feed boiler feeds itself with vaporizable liquid under control of a "thermal servo." An example of this thermal servo is the events that follow upon the vapor valve being adjusted to a more closed setting: The vapor pressure rises slightly and momentarily. The increment of vapor pressure forces liquid in a direction away form the hot seat. Heat from the hot seat then arrives at the boiling location within the boiler wick through a greater length of boiler wick. Because the boiler wick is a poor heat conductor less heat is then available to vaporize the liquid. Liquid continues to move in a direction away from the hot seat until its rate of vaporization absorbs a heat flow equal to that heat flow which can be conducted through the increased length boiler wick. Therefore, the location of boiling within the boiler wick adjusts itself automatically in response to the vapor valve setting. Not only the location of boiling, but also the inflow of liquid adjusts itself automatically to the vapor valve setting.

A capillary feed boiler therefore feeds itself liquid by this thermal servo action so that vapor is always available at any flow. Moreover, the vapor pressure is nearly constant, and always very nearly equal to the pressure required to expel liquid from the boiler wick. The lowest pressure which is able to expel liquid from a porous solid is commonly known as the bubble pressure. Bubble pressure is a key parameter used to measure the average pore size in porous solids when the liquid's surface tension is known. The capillary feed therefore has the same result as the much more complicated servo systems used with large boilers that involve mechanical feed pumps or jet ejectors.

The heat source for the hot seat, which provides the heat of vaporization, may be an external resistive electric heat source, or it may be a portion of the heat returned from the combustion of the fuel vapor. Control of the boiling rate of the boiler and hence the heat output of the device, may be either by manual control of the electric resistive heat supply to the hot seat at a constant vapor throttle setting, or by means of an empirically-correct return of combustion heat to the hot seat for all possible vapor throttle valve settings.

The stove has a starter wick for burning a small amount of fuel to provide heat to start the boiling process and to provide a flame to ignite the burning of the fuel vapor. The stove has a fuel reservoir vent which opens while the stove is in operation to provide a path for air from atmosphere into the interior of the fuel reservoir to prevent drawing a vacuum as liquid fuel is consumed.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a perspective representational view of the camp stove embodiment of the invention.

FIG. **2** is a cross sectional view along the line **2**—**2** of FIG. **1**.

FIG. **3** is a bottom plan view along line **3**—**3** of FIG. **2**.

FIG. **4** is an isometric representational view of the aperture plate and hot seat of the invention.

FIG. **5** is an isometric representational view showing the bottom face of the hot seat of the invention.

FIG. **6** is an isometric representational view of the boiler wick of the invention.

FIG. **7** is an isometric representational view of the transfer wick of the invention.

FIG. **8** is a perspective representational view of the supply wick of the invention.

FIG. **9** is a cross sectional view along line **9**—**9** of FIG. **2**.

FIG. **10** is a top plan view of the flame plate and aperture and valve plates of the invention.

FIG. **11** is a top plan view of the knob and pinion shafts of the invention showing the collapsibility feature.

FIG. **12** is a detail view of a portion of FIG. **2** showing the starter assembly of the invention.

FIG. **13** is a side sectional elevational view of the second embodiment of the invention.

BEST MODE FOR CARRYING OUT INVENTION

While it should be noted that the shrouded capillary feed boiler of the invention will find many applications, among them small scale steam supplies, mantle lamps, etc., for simplicity, and by way of example only, the invention will be described in the context of a portable camp stove.

Referring first to FIGS. **1** and **2**, fuel reservoir **150** is a tank for holding liquid fuel **158**. Fuel reservoir lid **152**, having lip **153** and carrying boiler frame **14** and associated apparatus, provides an air-tight closure to fuel reservoir **150**. Boiler frame **14** screws into fuel reservoir lid **152** by means of threads **16**, with resilient O-ring **18** providing a fluid tight seal between boiler frame **14** and fuel reservoir lid **152**. In the preferred embodiment, fuel reservoir **150**, fuel reservoir lid **152**, and boiler plate **14** are made of aluminum, which provides a light, sturdy structure. However, in other embodiments these parts could be formed of other materials.

Shroud **19** is an elemental cylindrical member which passes vertically through, and is supported by, boiler frame **14**. Shroud **19** is made of a thin wall of solid material which is a poor conductor of heat. Shroud **19** houses transfer wick **24**, boiler wick **20**, hot seat **30**, and aperture plate **50**.

Referring now to FIGS. **3** through **7**, the top **42** of supply wick **40** is pressed against the lower surface of transfer wick **24** by means of clips **48** and nuts **49**. The ends **44** of supply wick **40** dangle freely submerged in liquid fuel **158**. Supply wick **40** is made of Kevlar felt in the preferred embodiment, though other porous flexible materials or rigid porous materials, such as glass frit or ceramic may be utilized. Whatever material is used for supply wick **40**, the pores should be of appropriate size to wick fuel **158** from fuel reservoir **150** from supply wick ends **44** up and out the top **42** through transfer wick **24** under capillary action and provide liquid fuel **158** to boiler wick **20** at the appropriate boiling pressures. It should be noted that in alternative embodiments, a portion of transfer wick **24** could be directly submerged in liquid fuel **158**, obviating the need for supply wick **40**.

Boiler wick **20** is a disk shaped member compressed between the upper surface **25** of transfer wick **24** and the lower surface **34** of hot seat **30**. In the preferred embodiment, boiler wick **20** is made of three discs of Kevlar felt. However, in other embodiments, boiler wick **20** may be made of other porous materials, such as ceramic, of appropriate pore size. Also, in other embodiments, boiler wick **20** may be of unitary, versus laminar, construction. Boiler wick **20** is designed to fit snugly within shroud **19** so that a seal is formed between circular edge **23** of boiler wick **20** and the inner surface of shroud **19**, so that fluid flow will be through the pores through wicking and not through any edge gaps exceeding the average pore size of the boiler wick. Boiler wick **20** must be of appropriate pore size and material so that capillary action provides a supply of liquid fuel and so that heat transferred from hot seat **30** to the boiler wick provides for a boiling transition from liquid to fuel vapor over an appropriate range of temperatures and pressures. If the boiler wick **20** is made of a rigid, porous material, such as a ceramic or metal, a vapor tight seal between edge **23** and shroud **19** may be accomplished by precise manufacture, isometric seals, or by the use of caulking type adhesives. However, it may be more practical to construct boiler wick **20** of a pliable soft material such as plastic foam, conformable bat or felt, as in the preferred embodiment, which can be compressed into the needed sealing contact.

Transfer wick **24** is a generally cylindrical rigid member made of porous material with pore size compatible with that of supply wick **40** and boiler wick **20**. In the preferred embodiment, transfer wick **24** is made of ceramic, though it may also be made of metal.

Referring specifically to FIG. **4**, hot seat **30** and aperture plate **50** are generally cylindrical members formed or assembled as a unit. In the preferred embodiment, they are unitary in construction. The upper surface **32** of hot seat **30** forms an interface with the lower surface **54** of aperture plate **50**. Both are formed of heat conductive materials, such as metals, for conducting heat from heat returns **90** through valve plate **60**, and into boiler wick **20** for boiling the liquid fuel. Hot seat **30** and aperture plate **50** may be made of different materials, but in the preferred embodiment both are formed of aluminum.

Referring now specifically to FIG. **5**, in the preferred embodiment the lower surface **34** of hot seat **30** is provided with a series of narrow slots or grooves cut into the lower surface and extending approximately half of the vertical, or axial, length of hot seat **30**. The material between the notches **36** form a series of parallel vanes **37** which contact the upper surface **21** of boiler wick **20**. The vanes **37** provide a means of conducting heat from the hot seat to the boiler wick, while the notches **36** between the vanes provide flow passages for the vapor boiling out of boiler wick **20**. The upper surface **32** of hot seat **30** is provided with a channel **38** extending sufficiently deep into the vertical length of the hot seat, so that fluid communication is provided from lower surface **34** through notches **36** and through channel **38** for boiling fuel vapors escaping from boiler wick **20** and on to aperture plate **50**.

Referring again specifically to FIG. **4**, aperture plate **50** is a generally cylindrical disk having upper and lower surfaces **52** and **54**, respectively. Lower surface **54** mates with upper surface **32** of hot seat **30**, and in the preferred embodiment is formed integrally therewith. Aperture plate **50** is provided with apertures **56** extending through the plate from upper surface **52** to lower surface **54** which provide fluid communication and flow passages for boiled fuel vapor from hot seat **30** to valve plate **60**. Screw hole **58** in aperture plate **50** receives screw **88**, as shown in FIG. **2**, for holding valve plate **60** and additional portions of the apparatus in place.

Referring again to FIGS. **1** and **2**, valve plate **60** is a generally cylindrical member having upper and lower surfaces **62** and **64**, respectively, and generally circular edge **66**. Valve plate **60** provides the dual functions of conducting heat from heat return tabs **90** to aperture plate **50** and thence to hot seat **30**, and a means for throttling the flow of fuel vapor out of apertures **56** in aperture plate **50** and on to jet former **70**. Heat return tabs **90** extend from edge **66** of valve plate **60**, and may be formed integrally therewith. In the preferred embodiment, however, heat return tabs **90** are made of copper and attached to valve plate **60** by means of screws **91**.

Starter guard **67**, fixedly attached to valve plate **60**, prevents operating starter assembly **180** unless valve plate **60** is rotated to align the boiler system for operation, as described below. Ports **68** extend generally vertically through valve plate **60** from lower surface **64** to upper surface **62**, and when valve plate **60** is properly aligned, provide fluid communication for fuel vapor between apertures **56** in aperture plate **50** and jet former **70**.

Upper surface **62** of valve plate **60** fixedly mates with lower surface **74** of jet former **70**. Lower surface **64** of valve plate **60** closely and rotatably contacts upper surface **52** of aperture plate **50**. By rotating valve plate **60** about screw **88** through action of control shaft **110**, ports **68** in valve plate **60** can be made to come into varying alignment with apertures **56** in aperture plate **50**, and thereby adjustably throttling the flow of fuel vapor exiting aperture plate **50** and escaping into jet former **70**. In this way, the flame strength, and consequently the heat output, of the stove, may be regulated. In the preferred embodiment, valve plate **60** is made of aluminum, though in other embodiments it may be made of any heat conducting material.

Referring now to FIGS. **2** and **10**, jet former **70** is a generally cylindrical member forming a generally cylindrical hollow chamber, and having upper and lower surfaces **72** and **74**, respectively, and an outer edge **76**. A series of jet orifices **78** cut through outer edge **76** provide fluid paths for fuel vapor escaping from the central chamber of jet former **70**. Jet orifices **78** are sized to form jets of escaping fuel vapor which mix with ambient air, the mixture being then burned to form flames **84**. In the preferred embodiment, jet orifices **78** are narrow elemental slots. In the preferred embodiment, jet former **70** is integral with the upper surface **62** of valve plate **60**. Jet former **70** rotates about screw **88** along with valve plate **60**.

Flame plate **80** is a generally circular disk which sits atop, and is in fixed contact with upper surface **72** of jet former **70**. Flame plate **80** rotates about screw **88**, along with jet former **70** and valve plate **60**. Flame plate **80** is sized in diameter to divert flames **84** horizontally outward from jet orifices **78** and form an essentially circular flame ring, suitable for cooking and heating purposes. In the preferred embodiment, flame plate **80** is made of ceramic, but in other embodiments it could be made of any suitable flame and heat proof material.

Referring specifically to FIG. **10**, heat return tabs **90** are fixedly attached to, and extend horizontally outward from, edge **66** of valve plate **60** at equal intervals. The purpose of heat return tabs **90** is to transfer a portion of heat from flames **84** back to hot seat **30**. Heat return tabs **90** are empirically sized and shaped to transfer the appropriate amount of heat through valve plate **60** and aperture plate **50** on to hot seat **30**. At high vapor flow, a high heat flow is required to vaporize fuel in the boiler; while at low vapor flow, only a little heat is required to vaporize fuel in the boiler. Heat return tabs **90** are shaped and arranged to intercept a portion of flames **84**. The size and location of flames **84** depends upon the setting of valve plate **60** relative to aperture plate **50**. Therefore, the portion of flames **84** intercepted by heat return tabs **90** varies with the amount of the vapor throttling. This action provides a heat flow into heat return tabs **90** which is appropriate to any setting of the stove. As can be seen in the figures, heat return tabs **90** are angled upward from the horizontal at their ends, such that the larger flames **84** at higher burner settings will impinge upon the upturned ends of the heat return bars. In this way, more of the flames' heat is transferred to heat return tabs **90** and on to hot seat **30** for increased boiling rate. In the preferred embodiment, heat return tabs **90** are made integral with the valve plate **60**.

Referring now to FIGS. **2** and **11**, control shaft **110** interfits within, and extends from, shaft housing **112**, which itself sits atop boiler frame **14**. Control shaft **110** is comprised of two portions, knob shaft **115** and pinion shaft **117**, one end of pinion shaft **117** being received within one end of knob shaft **115**. Knob shaft **115** and pinion shaft **117** are generally cylindrical, hollow members tied together by internal resilient shock cord **119**. This arrangement permits quick reassembly after collapsing the two shafts into a smaller length for ease of portability. Flange **121** of knob shaft **115** is specially shaped to prevent its sliding past fuel reservoir lid lip **153** and detaching from pinion shaft **115** unless control shaft **110** is in a position to shut all valves, thereby providing a stowage interlock.

Control shaft **110** is used to manually control the heat output of the stove by varying the angular position of valve plate **60** relative to aperture plate **50**. This is achieved by means of pinion **116** on pinion shaft **117**. Pinion **116** interfits with face gear **94**, which extends down from valve plate **60**. When knob **114** is rotated by hand, causing pinion **116** to rotate and face gear **94** to translate relative to pinion **116**, valve plate **60** is caused to rotate about screw **88**, thus changing the throttling between aperture plate **50** and valve plate **60**, and hence the vapor escaping to jet former **70** and the size of flames **84** exiting jet ports **78**. Referring to FIG. **9**, pinion shaft **117** is provided with slot **118** and detent **120** within slot **118**. Slot **118** is an annular cut extending for 270° rotation of pinion shaft **117**. Detent **120** is a flattened, slightly deeper section at one end of slot **118**. Slot **118** and detent **120** control the position of vent piston **130** to provide an air path from vent hole **113** into gas space **154** within fuel reservoir **150**, as described below.

Referring now to FIGS. **2** and **9**, vent piston **130**, having tip **132** at its upper end and head **134** at its lower end, is slidably received into vent hole **136** in boiler frame **14**. Spring **47** is a resilient, thin metallic semicircular member, the ends of which are fixed by nuts **49**. Spring **47** acts on head **134** of vent piston **130**, both to hold vent piston **130** in place, and to provide a positive, generally upward force on the piston to force tip **132** into positive engagement with slot **118** of control shaft **110**. The diameter of the central portion of vent piston **130** is designed so that there is sufficient clearance between the piston and the inner walls of vent hole **136** to permit the passage of air. Tip **132** of vent piston **130** rides in slot **118** of control shaft **110** as control shaft **110** is rotated to control the heat output of the stove. Slot **118** is designed so that all angular positions of control shaft **110**, except when tip **132** is seated in detent **120**, vent piston **130** will be in a downward "open" position, permitting the passage of air from atmosphere through vent hole **113** into shaft housing **112**, through vent hole **136** along the gap between vent piston **130** and the inner wall of vent hole **136** into gas space **154** of fuel reservoir **150**. This air path prevents the drawing of a vacuum in gas space **154** as fuel is consumed and the level of liquid fuel **158** in fuel reservoir **150** decreases.

Slot **118** and detent **120** are placed so that when control shaft **110** has been rotated to close off the fuel vapor escape path through apertures **56** in aperture plate **50**, and thus shut down the stove, tip **132** on vent piston **130** will be engaged in detent **120**. Detent **120** is cut deeper into pinion shaft **117** than is slot **118**, so that when detent **120** engages tip **132** of vent piston **130**, vent piston **130** will slide higher into vent shaft **136**, seating O-ring **138** at the lower end of vent shaft **136** to seal off the air flow path from atmosphere to gas space **154** and fuel reservoir **150**. In this way, when the stove is shut down, fuel reservoir **150** is sealed closed to allow for the stove to be transported in any position relative to horizontal without the danger of leaking or spilling liquid fuel.

Referring now to FIGS. **2** and **12**, starter assembly **180** is comprised of a generally cylindrical sheath **182** attached to boiler frame **14** by means of threads **184**, and extending down into fuel reservoir **150**. Generally cylindrical wick tube **186** is slidably disposed within, and extends a distance above sheath **182**. Plunger **192**, fixedly attached to the lower end of wick tube **186**, moves vertically with wick tube **186**. Spring bar **196** applies a generally upward force on plunger **192** and wick tube **186**. O-ring **194**, disposed within groove **195** in plunger **192**, seals shut fuel inlet **197** when plunger **192** is in its uppermost position. Fuel chamber **200** communicates with fuel reservoir **150** when fuel inlet **197** is not blocked by O-ring **194**. Starter hot seat **190** is fixedly disposed within wick tube **186** near its upper end. Starter hot seat **190** is a vaned, channeled disc similar to hot seat **30** described above. Starter wick **188** is disposed within sheath **182** and extends from fuel chamber **200** up to the lower surface of starter hot seat **190**. Starter wick **188** is made of Kevlar felt in a preferred embodiment, though other porous, flexible materials, or rigid porous materials, such as glass frit or ceramic, may be utilized. Whatever material is used for starter wick **188**, the pores should be of appropriate size to wick fuel **158** from fuel chamber **200** up to starter hot seat **190** through capillary action and provide liquid fuel **158** to its upper end at the appropriate boiling pressures. The upper end of starter wick **188** is designed to be at its upper end pressed firmly against the lower surface of starter hot seat **190** and the inner surface of wick tube **186**. With wick tube **186** acting as a shroud, starter hot seat **190** and the adjacent portion of starter wick **188** are designed to function as a capillary feed boiler for boiling liquid fuel **158** transferred by the starter wick **188** from fuel chamber **200**. Heat transferred from starter hot seat **190** to the upper portion of starter wick **188**, provides for a boiling transition from liquid to fuel vapor over the appropriate range of temperatures and pressures.

Boiled fuel vapor from starter hot seat **190** flows upward through passageway **202**, through orifice **204**, and out through jet tube **206**, where the fuel vapor is mixed with air. A combustible mixture of air and fuel vapor exits jet tube **206** while flowing toward the left as shown in FIG. **12** and impinges upon flame shaper **208**. Flame shaper **208** divides this gas flow into two equal portions to either side, and generally reverses its direction so that the flow moves toward the right as shown in FIG. **12**. After division and redirection, the flow of combustible mixture burns and makes flames which heat the lower surface **64** of valve plate **60**. At the same time, flame shaper **208**, fixedly connected to the upper end of wick tube **186**, captures some of the heat from the combusted starter fuel vapor and returns it back to starter hot seat **190**.

Retaining clip **198** holds spring bar **196**, plunger **192**, and wick tube **186** in place relative to sheath **182**.

Operation of starter assembly **180** is as follows: After rotating control shaft **110** to rotate valve plate **60**, and with it starter guard **67** away from flame shaper **208**, flame shaper **208** is depressed momentarily. Depressing flame shaper **208** will cause wick tube **186**, and with it plunger **192**, to move downward within sheath **182** against the resistance offered by spring bar **196**. When plunger **192** is moved downward, O-ring **194** will no longer block fuel inlet **197**, thus allowing fuel **158** from fuel reservoir **150** to flow upward into fuel chamber **200**. Once flame shaper **208** is released, wick tube **186** and plunger **192** will return upward, sealing O-ring **194** against fuel inlet **197** and trapping a predetermined amount of fuel into fuel chamber **200**. The fuel trapped in fuel chamber **200** will be transported upward under capillary action by starter wick **188**, until the liquid fuel reaches the upper end of starter wick **188** in the vicinity of starter hot seat **190**.

A flame source is then directly applied to flame shaper **208**, which transfers the heat of the flame source to starter hot seat **190**. Starter hot seat **190** will transfer the heat to the upper portions of starter wick **188**, increasing the temperature of the transported liquid fuel contained within the upper portion of starter wick **188**. When the temperature of this liquid fuel reaches the boiling point for the prevailing pressure, the liquid fuel begins to boil. The fuel vapor produced will travel upward through the slots and channel in starter hot seat **190**, through passageway **202** and orifice **204**, and out through jet tube **206**, whereupon it will mix with air and be ignited by the external flame source being applied to flame shaper **208**. Once this ignition occurs, the flame source being applied to flame shaper **208** can be removed, since a portion of the heat released by the ignited fuel vapor will be returned through the flame shaper **208** back to starter hot seat **190** to produce a self sustaining capillary feed boiling action.

Flame shaper **208** is designed to direct the flame produced by the combusted starter fuel vapor upward on to valve plate

60, which will transfer the heat through aperture plate **50** to hot seat **30** to begin the main capillary feed boiling action in boiler wick **20**. Once the fuel vapor produced by boiler wick **20** exits jet orifices **78**, that fuel vapor will mix with air and be ignited by the flame from starter assembly **180** being directed upward by flame shaper **208**. Heat return tabs **90** will return sufficient heat from the flames produced at jet orifices **78** to sustain the capillary feed boiling action in boiler wick **20**. Once the liquid fuel in fuel chamber **200** has been exhausted by the combustion in the starter assembly **180**, starter assembly combustion will cease. Fuel chamber **200** is designed to provide sufficient fuel for commencing a self-sustaining capillary feed boiling action in boiler wick **20** before the combustion in starter assembly **180** ceases.

Referring again to FIG. **1**, support prongs **160** provide a surface for setting the cooking pan or other item to be heated by the stove. Support prongs **160** are bent metal tabs fixedly attached to boiler frame **14**.

Top **170** is also provided and sized to accommodate the outer circumference of fuel reservoir **150** forming an enclosure for easy transportation of the stove. Handle **172** permits top **170** to function as a cooking pot when inverted. The operation of the stove is as follows: First, liquid fuel **158** is added to fuel reservoir **150** by unscrewing boiler frame **14** and associated apparatus from fuel reservoir lid **152** at threads **16** to expose the interior of fuel reservoir **150**. Liquid fuel may be added through the void left in lid **152** by the removed boiler frame **14**. A sufficient amount of liquid fuel **158** is added so that when boiler frame **14** is reinstalled, ends **44** of supply wick **40** and plunger **144** will be submerged in fuel. Boiler frame **14** is then screwed back into place in lid **152** of fuel reservoir **150** until O-ring **18** is firmly compressed between boiler frame **14** and fuel reservoir lid **152**, providing a tight seal between the interior of the fuel reservoir and atmosphere.

Knob **114** is then turned counter clockwise to rotate control shaft **110**, and with it pinion gear **116** so that face gear **94**, and with it valve plate **60**, rotate clockwise as seen from above about screw **88** to open a fluid communication path between boiler wick **20** and jet former **70**. As valve plate **60** rotates, starter guard **67** will move with it to expose flame shaper **208** on starter assembly **180**. As control shaft **110**, and with it pinion shaft **117**, rotate, tip **132** of vent piston **130** disengages from detent **120** and moves counter clockwise along concentric cam slot **118** in pinion shaft **117**. This movement causes vent piston **130** to move downward against spring clip **47** and open an air path from atmosphere through vent shaft **136** and into gas space **154** of fuel reservoir **150**. The fluid communication path thereby created provides a means for air from the atmosphere to move into gas space **154** to fill the void created by the liquid fuel, which is consumed as the boiler operates.

Next, flame shaper **208** of starter assembly **180** is depressed through wick tube **186**, plunger **192** and associated components downward against the resistive force of spring bar **196**. This action will open fuel inlet **197** and allow liquid fuel **158** in fuel reservoir **150** to flow upward into fuel chamber **200**. Flame shaper **208** is held down momentarily to allow fuel chamber **200** to fill. When flame shaper **208** is released, it, along with wick tube **186**, plunger **192**, and associated apparatus will move upward, sealing off fuel inlet **197** with O-ring **194**. A few seconds delay is here necessary to give time for the liquid fuel in fuel chamber **200** to be transported via capillary action by starter wick **188** upward into the vicinity of starter hot seat **190**. Then, an external flame source is applied to flame shaper **208** to heat it and concomitantly starter hot seat **190** to begin the boiling of the liquid fuel in starter wick **188**. When fuel vapor exits jet tube **206** and mixes with air, it will be ignited by the external flame source to begin self sustaining combustion and capillary feed boiling of the starter assembly **180**.

The combustion flame produced by starter assembly **180** is directed upward and inward by flame shaper **208** and impinges against the adjacent portions of valve plate **60**, heating it. This heat is transferred through valve plate **60**, aperture plate **50**, and hot seat **30** into boiler wick **20**.

When the liquid fuel within boiler wick **20** is heated to its vaporization temperature for the extant capillary pressure, the fuel boils and the released fuel vapor escapes upward through the remainder of boiler wick **20**, through notches **36** and channel **38** in hot seat **30**, through apertures **56** and aperture plate **50**, through ports **68** and valve plate **60** and into jet former **70**, where it finally escapes through jet port **78**. Upon exiting jet port **78** and mixing with air, the released fuel vapor is ignited by the flame from starter wick **140**, thus starting the stove. Once the stove has been started, some of the heat from flames **84** is transmitted via valve plate **60**, aperture plate **50** and hot seat **30** to boiler wick **20** to sustain the boiling process.

At higher stove outputs, determined by the position of valve plate **60** relative to aperture plate **50**, flames **84** will extend a sufficient horizontal distance from jet port **78** to impinge upon heat return tabs **90** and thus provide additional heat transfer back to boiler wick **20** to sustain higher boiling rates necessary for higher fuel vapor production rates. As noted above, heat return tabs **90**, as well as the other heat transfer components of the device, are constructed so that an empirically correct amount of heat is transferred to boiler wick **20** to sustain the boiling.

Once the stove is operational, a cooking pan or other item to be heated may be placed atop spider **160**. As the cooking or other heating progresses, knob **114** may be used to rotate control shaft **110** as appropriate to throttle the flow of fuel vapor through valve plate **60** and into jet former **70**, thus regulating the output of the stove. As different amounts of fuel vapor flow are demanded from the boiler, the heat transfer through hot seat **30** and into boiler wick **20** will automatically adjust to sustain boiling, as described above.

A second embodiment of a liquid fuel stove employing the capillary feed boiler is depicted in FIG. **13**. In this embodiment, heat return bars **90** are replaced by resistive heat elements **96** attached to shroud **19**, and powered by battery **97**. Other embodiments may employ a variety of other electrical power sources. In this embodiment, some heat from combustion inadvertently reaches the boiler by stray conductive, convective, and radiative heat paths. Resistive heat elements **96** add to this stray heat enough to maintain vapor flow. The electrical heat is controlled electronically to maintain the hot seat at a controllable temperature.

The temperature of hot seat **30** is sensed by the resistance of the heat elements **96** using well-known electronic control techniques. With a knob, this temperature is controlled manually.

The second embodiment of the invention does not require a vapor valve. Vapor flows unimpeded from the boiler to the jet forming orifices. The vapor flow depends upon the heat input to the boiler, which in turn depends upon the temperature of the hot seat. Therefore, the output of combustion heat depends upon the manually controlled temperature of the hot seat.

In the first embodiment control of the stove output is achieved by throttling the fuel vapor flow by means of the relative positions of aperture plate **50** and valve plate **60**. In this second embodiment, once valve plate **60** is rotated into an open position relative to aperture plate **50**, valve plate **60** remains fixed, and stove output is controlled by controlling the heat output of resistive heat elements **96** and hence the boiling rate in boiler wick **20**. Rheostat **98**, attached to and manually controlled by the rotation of control shaft **110**, varies the electrical supply to resistive heat elements **96**, and hence the heat output of the heat elements. This arrangement provides an exacting method of controlling the output of the stove for applications in which accurate control is desired. Remaining portions of the camp stove of this second embodiment, such as jet former **70**, vent piston **130** and starter wick **140**, are similar to those of the first embodiment.

Thus the invention provides a safe, portable, leakproof stove without the need for hazardous pressurized fuel.

While there is shown and described the present preferred embodiment of the invention, it is to be distinctly understood that this invention is not limited thereto but may be variously embodied to practice within the scope of the following claims.

I claim:

1. An apparatus for generating vapor from a liquid comprising:

means for supplying liquid to be vaporized to a capillary boiler wick;

the boiler wick being capable of transferring liquid from a first end to a second end by capillary action, the first end being in liquid transfer contact with the means for supplying liquid to the boiler wick, the boiler wick having a continuous peripheral edge, the second end and the continuous peripheral edge of the boiler wick being contained within a boiler wick containment means that is impermeable to liquids and vapors;

a heat source for supplying heat of vaporization to liquid in the boiler wick; and

at least one aperture in the boiler wick containment means in proximity to the second end of the boiler wick for releasing vapor at a pressure higher than the pressure of the liquid entering the first end of the boiler wick from which the vapor is created.

2. The apparatus of claim **1** wherein the means for supplying liquid to the boiler wick comprises a porous, capillary action supply wick.

3. The apparatus of claim **1** wherein the liquid is a liquid fuel and the vapor is vaporized fuel.

4. The apparatus of claim **3** additionally comprising means for combusting the vaporized fuel.

5. The apparatus of claim **4**, additionally comprising a jet former having a series of jet orifices providing fluid paths for vaporized fuel.

6. The apparatus of claim **5**, additionally comprising a flame plate mounted in proximity to the jet former and sized to divert flames horizontally outward from the jet orifices.

7. The apparatus of claim **4**, additionally comprising a manual control for varying the heat output of the stove.

8. The apparatus of claim **4**, additionally comprising a starter assembly for initiating vaporization and combustion of liquid fuel.

9. The apparatus of claim **4** wherein the heat source derives heat from combustion of vaporized fuel.

10. The apparatus of claim **1** wherein the heat source is electrical.

11. The apparatus of claim **1** wherein the heat source is capable of providing a variable amount of heat to the boiler wick.

12. The apparatus of claim **1** additionally comprising a liquid reservoir.

13. The apparatus of claim **1** wherein the means for releasing vapor is an adjustable vapor valve.

14. The apparatus of claim **1** wherein the boiler wick containment means comprises a shroud in proximity to the continuous peripheral edge of the boiler wick and an aperture plate in proximity to the second end of the boiler wick.

15. The apparatus of claim **1** wherein the boiler wick containment means comprises a first member constructed from a material which is a poor conductor of heat and a second member constructed from a heat conductive material.

16. The apparatus of claim **14**, additionally comprising a hot seat having an upper surface in proximity to a lower surface of the aperture plate, the hot seat deriving heat from combustion of vaporized fuel.

17. A stove capable of generating heat by combustion of a vaporized liquid fuel comprising:

a capillary boiler wick having a first end in liquid transfer contact with a means for supplying liquid fuel to the boiler wick, a second end from which vaporized fuel exits, and one or more peripheral edges;

a boiler wick containment means in proximity to the second end and one or more peripheral edges at the capillary boiler wick;

a heat source for supplying heat of vaporization to liquid fuel in the boiler wick; and

at least one aperture in the boiler wick containment means in proximity to the second end of the boiler wick for releasing fuel vapor from the boiler wick containment means at a pressure higher than the pressure of liquid fuel supplied to the first end of the boiler wick, whereby upon release from the boiler wick containment means, fuel vapor is mixed with oxygen to form a combustible mixture.

18. A lamp capable of generating light by combustion of a vaporized fuel comprising:

a capillary boiler wick having a first end in liquid transfer contact with a means for supplying liquid fuel to the boiler wick, a second end from which vaporized fuel exits, and one or more peripheral edges;

a boiler wick containment means in proximity to the second end and one or more peripheral edges at the capillary boiler wick;

a heat source for supplying heat of vaporization to liquid fuel in the boiler wick; and

at least one aperture in the boiler wick containment means in proximity to the second end of the boiler wick for releasing fuel vapor from the boiler wick containment means at a pressure higher than the pressure of liquid fuel supplied to the first end of the boiler wick, whereby upon release from the boiler wick containment means, fuel vapor is mixed with oxygen to form a combustible mixture.

19. An apparatus for generating vapor from a supply liquid and providing the vapor at a pressure higher than the pressure of the supply liquid, the apparatus comprising:

a boiler wick in which the liquid is heated and vaporized;

a heat source in thermal transfer relationship with the boiler wick;

a vapor impermeable shroud in proximity to peripheral edges of the boiler wick; and

an aperture plate having at least one aperture in proximity to the boiler wick, the aperture plate and the vapor impermeable shroud forming an enclosed space in which the boiler wick operates, and the aperture plate providing passage for vapor to be released from the enclosed space at a pressure higher than the pressure of the supply liquid.

20. The apparatus of claim **19** wherein the liquid is a liquid fuel and additionally comprising means for combusting the vaporized fuel.

21. The apparatus of claim **20** wherein the heat source derives heat from combustion of vaporized fuel.

22. A method for vaporizing a liquid comprising:

introducing the liquid to a first end of a boiler wick capable of transporting liquid by capillary forces, the boiler wick being contained within a boiler wick containment means;

establishing a thermal gradient within the boiler wick, wherein the temperature at the first end is generally ambient and the temperature at another area of the boiler wick corresponds to the vaporization temperature of the liquid;

vaporizing liquid in proximity to the area of the boiler wick at a temperature corresponding to the vaporization temperature of the liquid to produce vapor; and

pressurizing the vapor within the boiler wick containment means prior to releasing it, whereby vapor is released from the boiler wick containment means at a higher pressure than the pressure of the liquid introduced to the first end of the boiler wick.

23. The method of claim **22** wherein the liquid is fuel, additionally comprising releasing vapor from the boiler wick containment means, mixing the vapor to produce a combustible mixture, and igniting and burning the combustible mixture.

24. The method of claim **23**, additionally comprising returning a portion of the heat generated during burning of the combustible mixture to a portion of the boiler wick for vaporizing the liquid fuel.

25. The method of claim **22**, wherein the introduction of liquid adjusts itself automatically to the release of vapor.

26. The method of claim **22**, wherein the location of vaporization within the boiler wick adjusts itself automatically to the release of vapor.

27. The method of claim **22**, wherein the boiler wick is under control of a thermal servo.

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