Aug. 23, 1966 N. CAMP 3,267,678

VAPOR-GENERATING DEVICE

Filed May 6, 1964 2 Sheets-Sheet 1

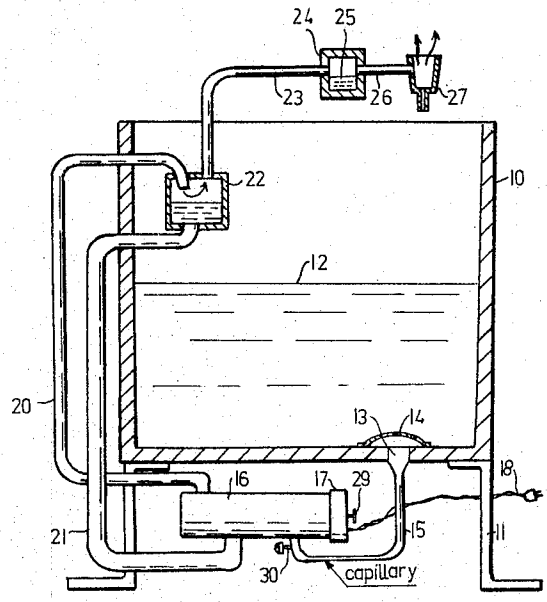


FIG. 1

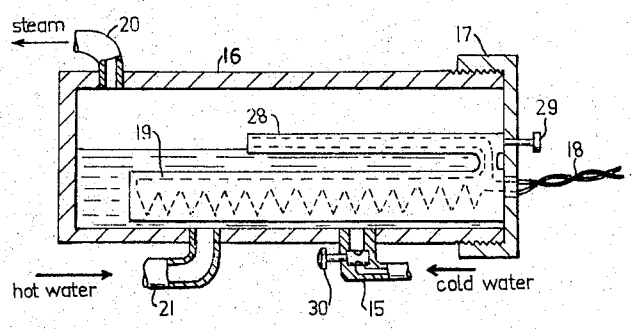


FIG. 2

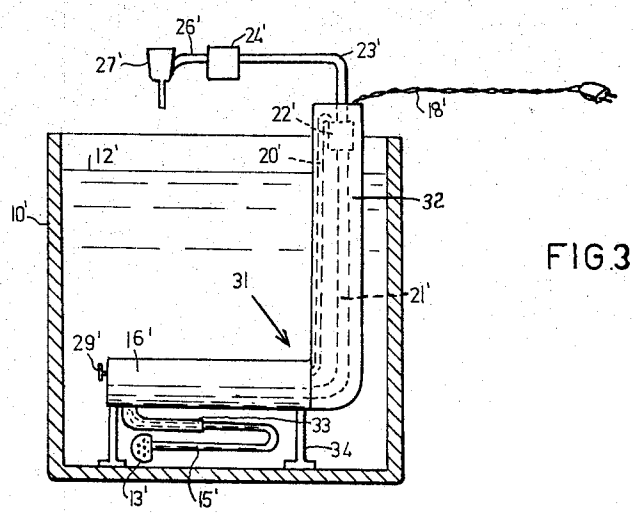


FIG. 3

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VAPOR-GENERATING DEVICE

Filed May 6, 1964 2 Sheets-Sheet 2

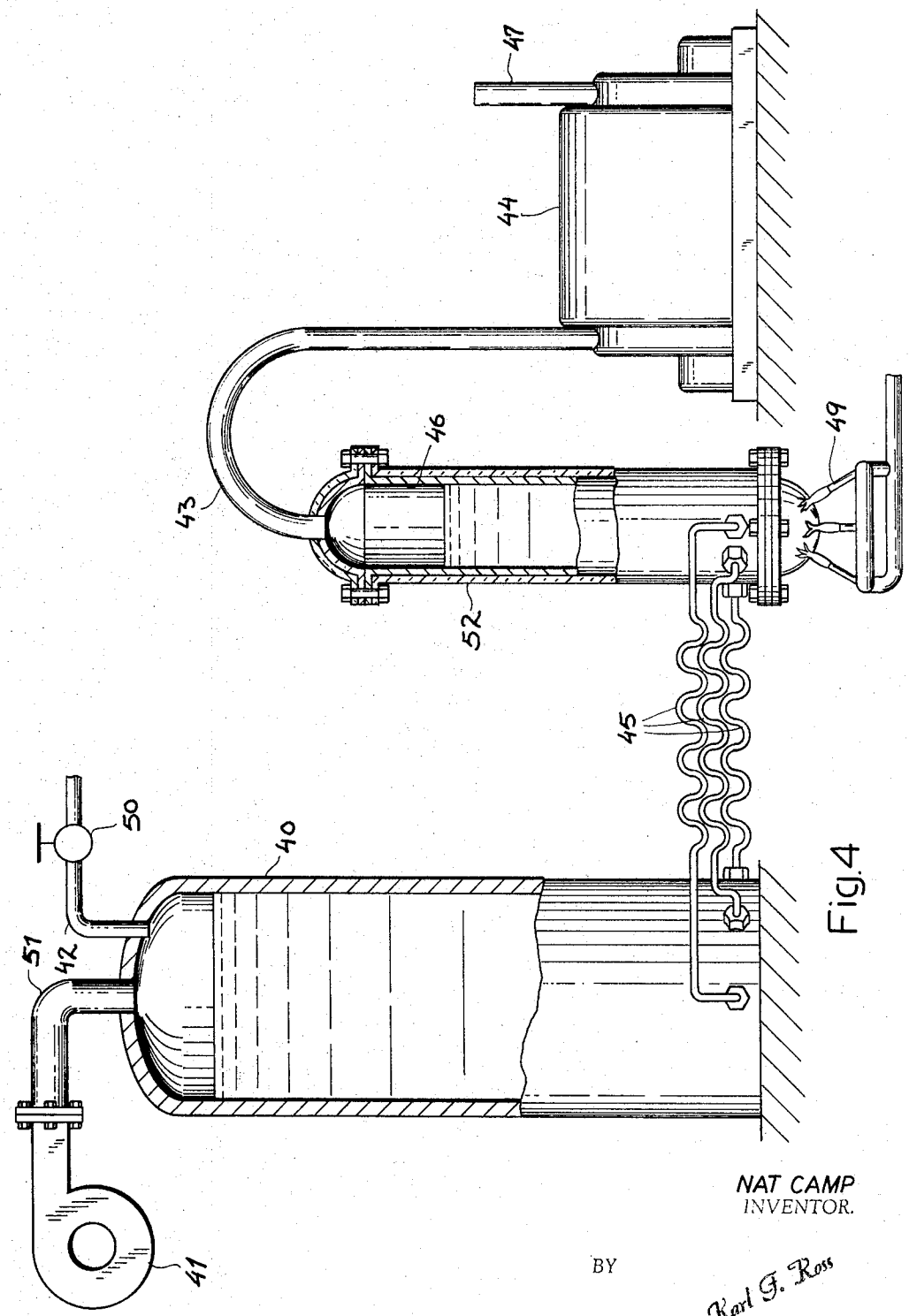


Fig. 4

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United States Patent Office 3,267,678 Patented August 23, 1966

3,267,678

VAPOR-GENERATING DEVICE

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Filed May 6, 1964, Ser. No. 370,750
7 Claims. (Cl. 60—108)

This application is a continuation-in-part of my copending application Ser. No. 94,611, filed March 9, 1961 and now abandoned.

My present invention relates to a vapor-generating device adapted to be used for the dispensing of various substances in vapor form, for humidification of the atmosphere of a room or the like, for distillation of sea water and other fluids, for the operation of apparatus using vapor pressure as a source of motive power, and for related purposes.

A principal object of this invention is to provide a vapor generator adapted to operate in a highly economical and efficient manner by concentrating the output of an available heat source on a relatively small volume of liquid (generally water) to be vaporized.

A more particular object is to provide a source of low-pressure steam operating on a very limited caloric input and with a short warmup period.

Another specific object of the instant invention is to provide a portable steam generator capable of being incorporated, for example, in a compact unit immersible in a large body of water in such manner as to vaporize only a small fraction thereof at a time.

It is also an object of this invention to provide effective means for both thermally and hydrostatically isolating a steam generator from a relatively large body of water from which this generator is continuously supplied.

I have found, in accordance with the present invention, that the above objects can be realized through the use of one or more capillary tubes inserted in a fluid path between a relatively large body of liquid, specifically water, and a relatively small boiler chamber, the capillary tube or tubes serving the dual purpose of regulating the influx of liquid to the boiler chamber and preventing any backflow of hot water or steam from that chamber to the reservoir which, of course, would constitute a loss of thermal energy. More particularly, I utilize the capillary tube or tubes as a means for creating a hydrostatic pressure differential Δp of such magnitude that a given input pressure p_i is substantially balanced by the sum of Δp and a predetermined output pressure p_o, the latter term being represented at least in part by the hydrostatic head in the boiling chamber which is therefore maintained filled with water to a substantially constant level.

The insertion of a capillary tube between the reservoir and the boiler chamber, in accordance with my invention, thus establishes the relationship:

$$p_i > p_o$$

so that, for example, a partially filled boiling chamber may be disposed substantially below the level of its water supply if both the reservoir and the boiling chamber are substantially unrestrictedly open toward the atmosphere, as in the case of a vaporizer. If, on the other hand, the steam generated in the boiling chamber is to drive a useful load, e.g. a turbine, a steam pressure equal to the load reaction will build up in the boiling chamber and will be superimposed on the hydrostatic head thereof to constitute the output pressure p_o. In order to provide a commensurately increased input pressure p_i, I may constitute the supply reservoir as a closed vessel whose internal pressure is increased by the admission of high-pressure fluid, e.g. water or air delivered by a pump or compressor. Advantageously, in order to prevent a draining of the boiling chamber toward the reservoir upon partial or complete failure of the input pressure (e.g.

stoppage of the pump or compressor in the arrangement just described), the capillary tube or tubes should be so designed that $p_o < \Delta p$.

As the cross-sectional area of the capillary tube is essentially determined by the viscosity of the liquid employed, little variation in that cross-sectional area is possible for the purpose of varying the rate of flow therethrough. To maintain a desired flow rate it will, therefore, often be convenient to connect two or more capillaries in parallel; this mode of connection does not materially alter the magnitude of the existing pressure drop which in the case of each tube is proportional to its length.

The boiling chamber may be designed in a variety of ways. A substantially cylindrical boiling chamber, horizontally disposed, has the advantage that a relatively small drop in liquid level will result in a relatively large decrease of the surface of the water bath and, therefore, in a commensurate reduction in the back pressure of the developing steam, if the latter is allowed to escape only through a restricted outlet and/or by way of a load, once the bath level in the boiling chamber has fallen below its horizontal median plane. With an upright boiling chamber, on the other hand, an excess of rate of vaporization over rate of supply will result in a more rapid decrease of hydrostatic pressure in that chamber so that equilibrium will be more promptly restored independently of steam pressure.

The heating of the boiling chamber may be effected by various means disposed either within that chamber or externally thereof, an electrical heating element within the chamber being particularly advantageous in the case of immersible or other compact steam generators.

The invention and its advantages will be better understood from the following detailed description of certain embodiments, reference being made to the accompanying drawing in which:

FIG. 1 is an elevational view, partly in section, of a water tank equipped with a steam generator according to my invention;

FIG. 2 is a sectional view, on a larger scale, of the boiling chamber of the steam generator shown in FIG. 1;

FIG. 3 is an elevational view of a modified steam generator similar to the one illustrated in FIGS. 1 and 2 but designed as an immersible unit; and

FIG. 4 is a diagrammatic view, partly in section of still another embodiment.

In FIG. 1 I have illustrated a tank **10** supported on legs **11** and filled with water to a level **12**. The bottom of the tank is formed with a drain **13** overlain by a strainer **14** to prevent any clogging thereof by entrained solids. Drain **13** merges into a capillary tube **15**, with an inner diameter of one or two millimeters, terminating at the underside of a cylindrical boiling chamber **16**. The chamber is closed at one end by a cap **17** through which pass a pair of wires **18** for connecting a heater **19** (FIG. 2) in its interior to a source of electric current. Chamber **16** is also provided with a discharge tube **20** for generated steam, rising from its upper surface, and with a return pipe **21** for hot condensate, entering it from below.

A small sealed container **22**, serving as a water separator, is shown suspended by the conduits **20**, **21** within tank **10** above the liquid level **12**. Tube **20** enters the container **22** from above to let any entrained on recondensed water flow back at its bottom into the pipe **21**. An outlet tube **23** for the nearly dry vapor extends upwardly from container **22** to a vessel **24** serving for the storage of a volatile substance **25**, e.g. an inhalant to be entrained into the atmosphere by the vapor passing through an extension **26** of tube **23** terminating in an upwardly open thimble **27** having a depending spout for the return of any residual water to the tank **10**.

The interior of chamber **16**, visible in FIG. 2, also contains a thermostatic switch **28** connected in series with the resistance element of heater **19** across the wires **18** to prevent overheating of the device. When switch **28** has been tripped open by an excessive rise in temperature, it may be manually reset by a button **29** after water has again been admitted to the boiling chamber. The discharge end of inlet tube **15** is shown provided with a shutoff valve **30** to stop the influx of water into the chamber **16** during periods of non-use, thereby reducing the time needed to start the generation of steam when the device is put into operation.

In use, wires **18** are plugged into an electric outlet to energize the element **19** which heats the water in chamber **16**. As steam begins to develop, it expels from tube **20** any water that may have risen therein and discharges it into container **22** whence it is returned to chamber **16** via pipe **21**. The steam then passes out through thimble **27**, entraining the substance **25** in vessel **24**. Fresh water enters the chamber **16** through capillary **15** at a relatively slow rate which matches the rate of vaporization only after the pressure in the chamber has dropped sufficiently to accelerate the travel of the liquid through this tube. As a result, steam will evolve rapidly enough to dissipate the heat of element **19** at temperature close to the boiling point of water at atmospheric pressure. I have observed, for example, that a boiling chamber of 22 mm. inner diameter and 10 cm. length, heated by a 250-watt element and supplied with water at 15° C. through a capillary of 1.5 mm. diameter and 33 cm. length, began to generate water at an appreciable rate only two or three minutes after the heater had been energized. The length of tube **15**, while not critical, should be sufficient to afford thermal insulation between the boiling chamber **16** and the tank **10**, in addition to providing the flow-retarding action necessary to prevent the escape of steam through drain **13** into the tank. The conduits **20** and **21**, whose inner diameters and cross-sectional areas should of course be considerably larger than those of tube **15**, could, if properly insulated to minimize heat losses, also be led through the interior of the tank, in the general manner illustrated in FIG. 3. Thimble **27**, which acts as a secondary liquid separator, may be omitted or replaced by some other outlet termination, if the device is to be used for purposes other than room humidification and the entrainment of small quantities of water by the steam is not objectionable.

In FIG. 3 I show a modified system generally similar to that described in connection with the preceding figures and comprising a tank **10'** filled with water; a unit **31**, removably immersed therein, consists essentially of a boiling chamber **16'** with thermally insulated walls and an insulated jacket **32** rising from this chamber to a height above the water level **12'**. The jacket **32** contains the conduits **20'**, **21'** along with the liquid separator **22'** and a portion of the supply conductors **18'**. Outlet tube **23'**, extending upwardly from container **22'**, again directs the developing steam through a vessel **24'** for the purpose described in connection with FIG. 1; its extension **26'** terminates in a thimble **27'**. An insulating sleeve **33** partly envelopes the tube **15'**.

Chamber **16'**, whose internal construction is similar to that of chamber **16** shown in FIG. 2 and which is also shown provided with a reset button **29'**, rests on legs **34** and has attached to it the inlet capillary **15'** capped at its free end by a strainer **13'**. Since the unit **31** will normally be immersed in water only during and immediately before use, a shutoff valve will not be needed. The operation is otherwise identical with that discussed in connection with the preceding embodiment. I have observed that the water separator **22** or **22'** as well as the thimble **27** or **27'** will accumulate liquid only at the initial stages of operation, i.e. while the boiling chamber **16** or **16'** is substantially filled and has not yet reached its state of equilibrium. Thus, either or both of these receptacles may be omitted in many instances.

In the embodiment shown in FIG. 4 a sealed storage tank **40** is provided with an air compressor **41** in a duct **51** and a water-inlet pipe **42** normally closed by a valve **50**. The tank **40** communicates with a somewhat smaller boiler **46** by means of a plurality of coiled capillary tubes **45**, extending from the lower part of reservoir **40** to the lower part of boiler **46**.

A source of heat shown diagrammatically as a gas heater **49**, located at the base of boiler **46**, is provided for the heating of its contents.

The boiler **46** also communicates with a steam turbine **44** by means of a conduit **43**. A pipe **47** leading from the turbine **44** to the atmosphere acts as an escape duct for the used steam. Thermal insulation **52** surrounds the wall of boiler **46**.

In operation, water is introduced into the reservoir **40** via the inlet pipe **42** to the descent level whereupon the valve **50** is closed. Thereupon, compressor **41** and heater **49** are actuated. Water from the reservoir **40** enters the boiler **46** through the capillary tubes **45** under the combined pressure of air from compressor **41** and the hydrostatic head in vessel **40**, this combined pressure being balanced by the sum of the hydrostatic head in boiling chamber **46**, the steam pressure in that chamber and the pressure drop across the three parallel-connected tubes **45**. Because of the small size of the boiler **46**, the water entering it is rapidly heated to produce steam which is piped through conduit **43** to the turbine **44**, the steam driving the turbine **44** and being then released through the outlet pipe **47**.

The system shown in FIG. 4 is intended for intermittent operation of the turbine **44**, with periodic replenishment of the contents of reservoir **40** to maintain the water level thereof nearly constant. Under these circumstances the water level in boiling chamber **46** will also be subject to but little fluctuation if the back pressure of the turbine is regarded as substantially constant. The tubes **45** constitute a restricted passage of predetermined hydrostatic resistance, and the principle of operation will be substantially the same as in the aforedescribed instances. It is desirable to establish such a relationship between the various pressure components referred to above that a substantial amount of liquid is present at all times in boiling chamber **46**.

For sustained operation, the system of FIG. 4 could be readily modified to admit water continuously under suitable pressure, with use of a feeding pump or a pressure-regulated water supply, if necessary, through pipe **42** so as to maintain the tank **40** always filled to the top, the compressor **41** being then replaced by an airtight seal for duct **51**.

As will be apparent from the preceding explanation of the principles underlying my invention, the embodiments described hereinabove may be modified in various ways, e.g. by a substitution of a boiling chamber as shown in FIG. 2 for the boiler **46** of FIG. 4 or by utilization of different types of heating means. My invention is, accordingly, not limited to the specific arrangements herein disclosed but is capable of numerous variations and adaptations without departing from the spirit and scope of the appended claims.

I claim:

1. A vapor-generating device comprising a boiling chamber, a reservoir containing a body of liquid substantially larger than the volume of said chamber, said body of liquid being under a substantially constant downward pressure of an overlying body of air, capillary-tube means forming a restricted passage of predetermined hydrostatic resistance between said reservoir and said chamber, and heating means for boiling a liquid in said chamber, said capillary-tube means being so dimensioned as to develop thereacross an appreciable pressure differential Δp maintaining the liquid in said chamber at a substantially constant level with development of a substantially constant

output pressure p_o at the chamber end of said capillary-tube means in the presence of a substantially constant input pressure p_i at the reservoir end of said capillary-tube means, with $P_i \approx P_o + \Delta p$.

2. A vapor-generating device as defined in claim 1 wherein said reservoir is open toward the atmosphere, said boiling chamber being entirely disposed below the level of said body of liquid.

3. A vapor-generating device as defined in claim 1, further comprising turbine means connected to said boiling chamber for operation by vapor developed therein, and a source of pressure fluid connected to said reservoir.

4. A vapor-generating device as defined in claim 1 wherein said capillary tube means comprises a plurality of capillary tubes connected in parallel.

5. A vapor-generating device comprising, in combination with an upwardly open vessel containing a relatively large body of water, a boiling chamber of relatively small volume disposed below the level of said body of water; a capillary inlet tube entering said chamber substantially at its bottom and opening into said body of water, said reservoir being closed at its bottom except for the inlet of said capillary tube; an outlet tube of substantially larger cross-sectional area than said inlet tube extending into the atmosphere from a location near the top of said chamber but below said level; and heating means at said chamber for boiling water admitted to said chamber from said vessel by way of said inlet tube, the latter being sufficiently restricted to retard the influx of water into said chamber upon operation of said heating means so that said influx matches the rate of evaporation of water from said chamber in a partly filled condition thereof whereby the water level in said chamber lies below the level of said body of water despite equal atmospheric pressures upon said body of water through the open top of said vessel and upon the water in said chamber through said outlet tube.

6. A vapor-generating device comprising, in combination with a vessel containing a relatively large body of water, an elongated boiling chamber of relatively small volume disposed substantially horizontally below the level of said body of water; a capillary inlet tube entering said chamber substantially at its bottom and opening into said

body of water; an outlet tube of substantially larger cross-sectional area than said inlet tube extending into the atmosphere from a location near the top of said chamber but below said level; and an elongated heating element extending in axial direction in said chamber along the bottom thereof for boiling water admitted to said chamber from said vessel by way of said inlet tube, the latter being sufficiently restricted to retard the influx of water into said chamber upon operation of said heating element so that said influx matches the rate of evaporation of water from said chamber only in a partly filled condition of said chamber.

7. A vapor-generating device comprising, in combination with an open-topped reservoir containing a relatively large body of water, an elongated, substantially cylindrical and horizontal boiling chamber of relatively small volume disposed entirely below the level of said body of water; a capillary inlet tube having one end connected to said chamber substantially at its bottom and having another end connected to said reservoir adjacent the bottom thereof; an outlet tube of substantially larger cross-sectional area than said capillary inlet tube extending into the atmosphere from a location near the top of the chamber but below said level; and an elongated electrical heating element extending in axial direction in said chamber along the bottom thereof for boiling water admitted to said chamber from said vessel by way of said inlet tube, the latter being sufficiently restricted to retard the influx of water into said chamber upon operation of said heating element so that said influx matches the rate of evaporation of water from said chamber only in a partly filled condition of said chamber.

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