Oct. 6, 1959 K. TSUNODA ET AL 2,907,176

APPARATUS FOR VAPORIZING NORMALLY GASEOUS MATERIAL FROM LIQUEFIED FORM

Filed March 12, 1956 4 Sheets-Sheet 1

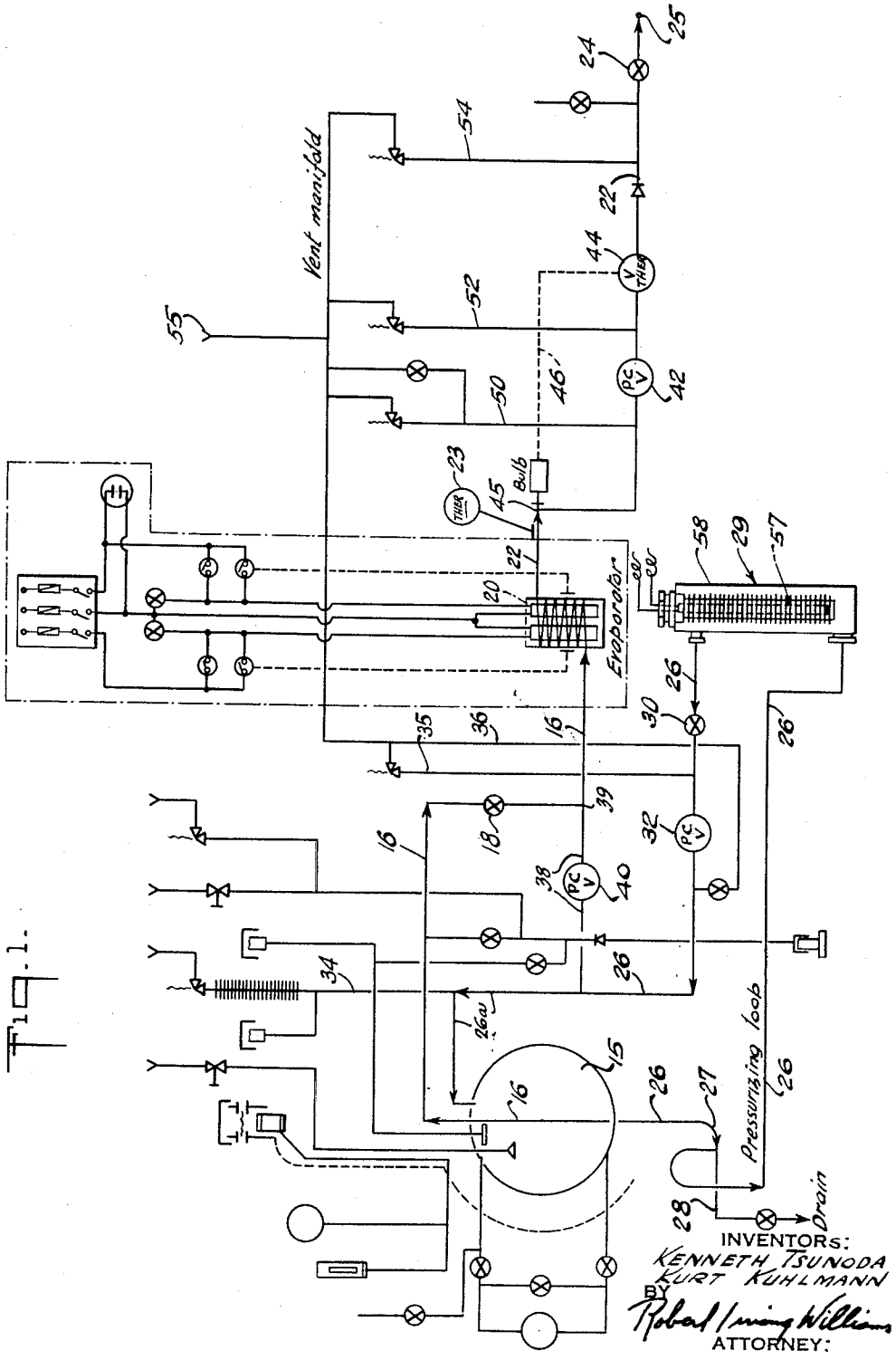

Fig. 1.

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Fig. 2.

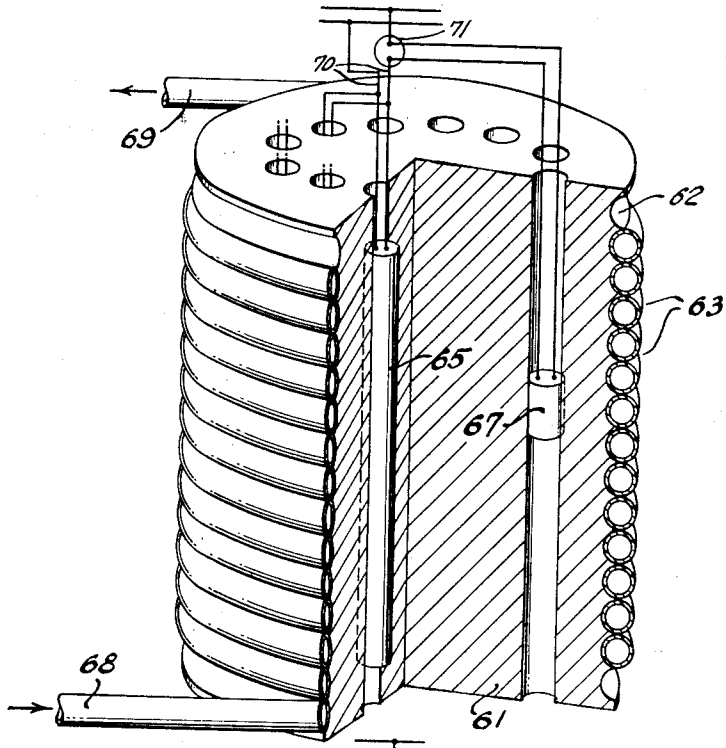

Fig. 3.

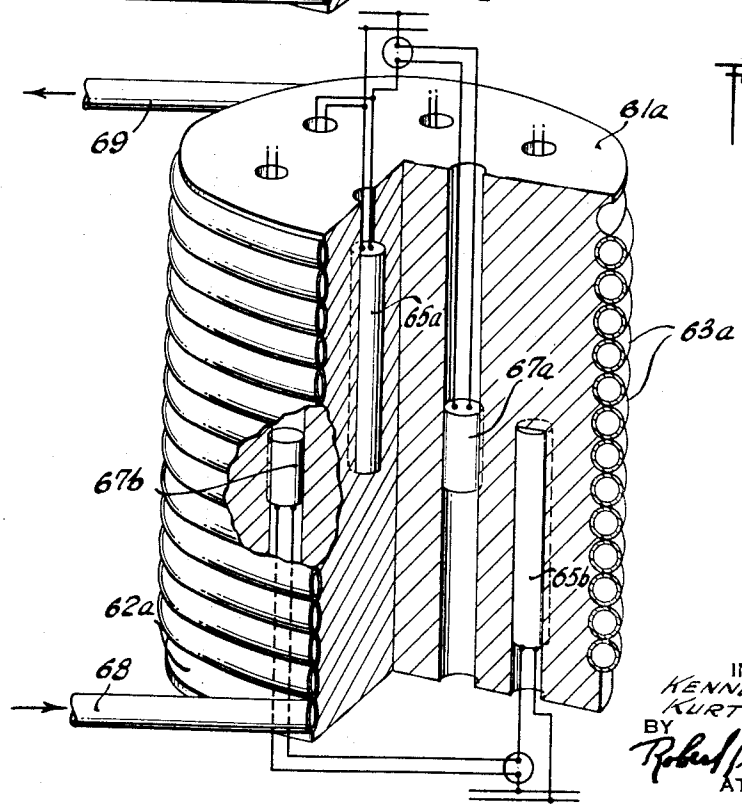

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Fig. 4

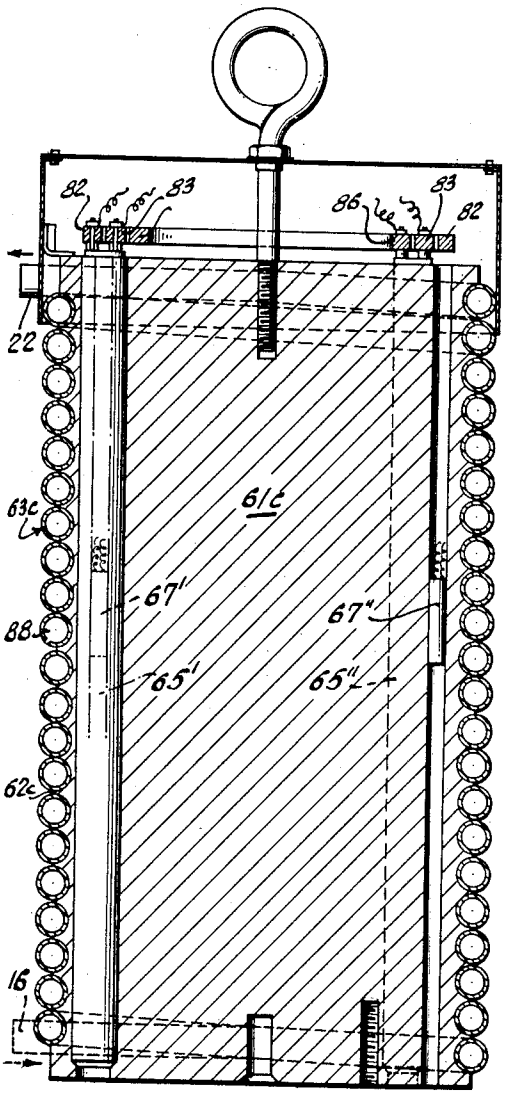

Fig. 5

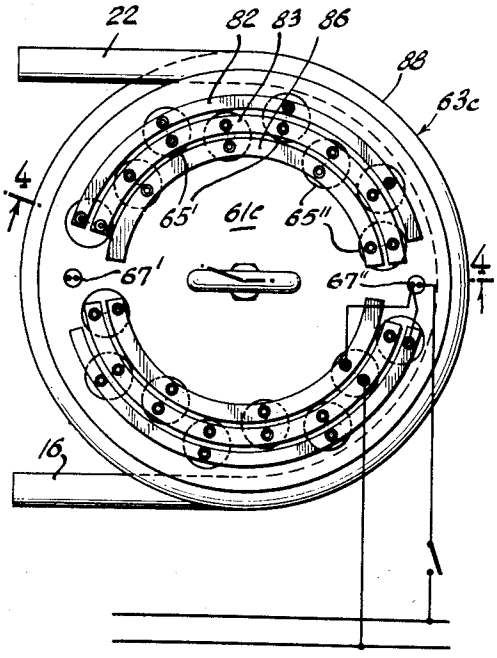

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Fig. 6.

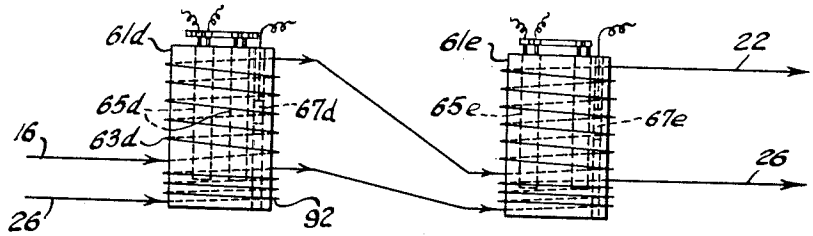


Fig. 7.

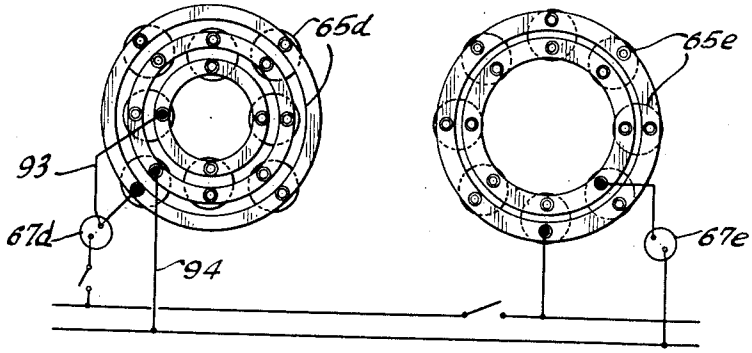
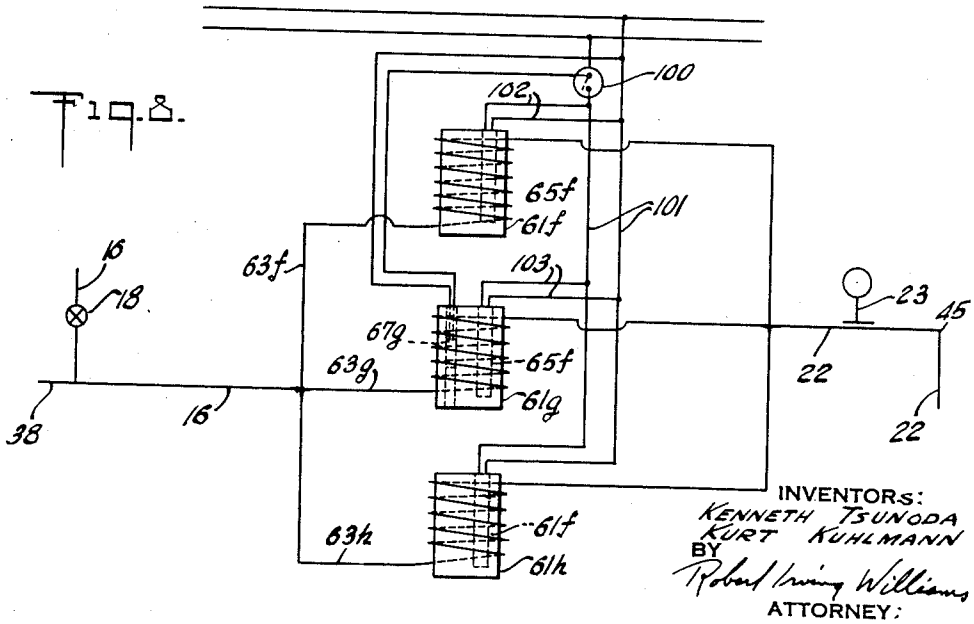


Fig. 8.



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2,907,176

APPARATUS FOR VAPORIZING NORMALLY GASEOUS MATERIAL FROM LIQUEFIED FORM

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Application March 12, 1956, Serial No. 571,039

4 Claims. (Cl. 62—50)

This invention relates to the vaporization of fluids which are stored in liquid form and are adapted to be utilized in gaseous form, and in certain of its more specific aspects relates to improved heat vaporization means for converting flowing liquids into the gaseous phase.

Apparatus embodying the invention is particularly well suited to supply gaseous oxygen, nitrogen, argon, or the like, as needed from a storage tank of liquefied gas, since many of the uses of such fluid are of such nature as to be subject to sudden, widely varying, and discontinuous demands which are reflected on the flow requirements, and the present apparatus embodies a variety of features contributing to effective and rapid responsiveness to such demands.

Among the features of the invention in various of its aspects are the provision of various automatic and semi-automatic controls, the provision of a pressurization loop to compensate for undue pressure-reduction in the storage tank, the provision of means to compensate for excessive pressure in the storage tank, and the provision of an improved type of vaporization means.

In the provision of vaporization means for a normally-gaseous fluid in a liquid state, an important consideration is that the fluid passing thru the heater should always be subjected to the desired heating effect, and should be warmed or vaporized as required, in spite of sudden flow volume surges and the always-prevalent time delays of manual or automatic heater controls. Obviously, since controls and heat sources require a finite time to take effect, an instantaneously-acting heat storage must provide the initial input of heat into the fluid which passes thru the system. In accordance with the invention, this heat storage is established by means of a mass of metal from which heat can be drawn during that period which is necessary for the heater power source and its controls to take effect, satisfying the heat input for the system. The fluid to be heated, the source of heat, the heat-storing metal mass and the thermal control devices are brought into mutual thermal contact in such a manner that their interaction results in the desired effect.

The invention accordingly comprises apparatus embodying features of construction, combinations and arrangement of parts, and the relation of elements which will be exemplified in the apparatus hereinafter described, the scope of the application of which will be indicated in the claims.

For a fuller understanding of the nature and objects of the invention, reference should be had to the following detailed description taken in connection with the accompanying drawings, in which:

Figure 1 is a diagrammatic view illustrating one form of apparatus embodying the invention;

Fig. 2 is a perspective view of one form of vaporizer embodying the invention with a section thereof cut away to reveal the interior;

Fig. 3 is a similar view of a modified form of vaporizer;

Fig. 4 is a side view of another form of vaporizer;

Fig. 5 is a top view of the vaporizer of Fig. 4;

Fig. 6 is a diagrammatic side view showing a modified vaporizer arrangement;

Fig. 7 is a top view thereof on an enlarged scale; and

Fig. 8 is a similar view showing another form of vaporizer arrangement.

In the embodiment of the invention exemplified in Fig. 1, liquid oxygen, stored in an insulated spherical storage tank **15**, is drawn from the bottom of the tank thru a flow-line conduit **16**, past a shut-off valve **18** to heater vaporizer means **20** which may be one of the forms hereinafter described and in which the liquid oxygen is transformed into the gaseous phase. The gaseous oxygen is carried from the vaporizer by a flow line conduit **22**, past a thermometer **23** and a shut-off valve **24** to a connection **25** for attachment to conduit means to one or more positions in which the oxygen gas is to be utilized.

In order to assure against an uneven pressure-drop in the tank due to extra heavy demands or other causes, there is provided, in accordance with the invention, a pressurizing-loop conduit **26—26*a***, running from the bottom of the tank **15** to trap **27** having a drain **28**, to a heater vaporizer means, which may be part of the heater vaporizer means **20** as hereinafter exemplified, but which, as shown in Fig. 1, is an independent heater vaporizer means **29**, and back to the upper portion of the tank **15**. A shut-off valve **30**, and an adjustable but automatically-operating pressure-controlled valve **32** are provided in the portion of the conduit **26** beyond the vaporizer **29**. The valve **32** will be set for operation at a pressure lower than that normally desired in tank **15**. Thus, any drop in pressure in the tank **15** will cause the valve **32** to open permitting immediate flow thru conduit **26—26*a***, vaporization by vaporizer **29** and restoration of the pressure in the top of tank **15**. Safety escape means are provided at **34**, **35**, and **36**.

In order to assure against excessive pressure in tank **15**, there is provided in accordance with the invention a pressure-controlled connection **26*a*—38** between the upper portion of the tank **15** and a point **39** in the conduit **16** beyond the valve **18**, and a valve in the tank set at a pressure somewhat above that normally desired in tank **15**. This connection, as exemplified, comprises the later portion **26*a*** of conduit **26** and a bridging conduit **38**, extending therefrom to conduit **16**. An adjustable but automatically-operating pressure-controlled valve **40** is disposed in the conduit **38**.

Further in accordance with the invention, there is provided in the conduit **22** an adjustable pressure-controlled valve **42** whereby the pressure at **25** may be kept as low as possible consistent with the user's requirements in order to have the greatest possible leeway for taking up vaporization losses. There is also provided a temperature-controlled valve **44** to protect the user's piping system from temperatures below an admissible minimum. The valve **44** is controlled by the temperature at an earlier point **45** of the conduit **22** (near the vaporizer **20**), as indicated by the dotted line **46**. Safety escape means are provided at **50**, **52**, and **54**. A single vent **55** may be provided for several escape means, as **35**, **36**, **50**, **52**, and **54**.

The vaporizer **29** is in the form of a finned tube **56**, which is heated, for instance, by electrical heating element **57**, and about which an expanded portion **58** of the conduit **26** runs.

Various forms of construction which may be utilized at **20** or otherwise utilized in accordance with the invention are illustrated in Figs. 2–7.

The embodiment shown in Fig. 2 is in the form of a vaporizer for liquid oxygen, i.e., a heating device which converts a flow of oxygen, which is in its liquid phase and therefore at very low temperatures (depending on pressure, approximately −200° F. to −300° F.), into a flow of gaseous oxygen at ambient temperature. The

flow volume may vary at any time, and instantaneously within the entire range from zero capacity to full capacity. A fundamental requirement of such a device is that at no time should the temperature of the effluent gas fall below a specified temperature.

A metal block **61** which may, for example, be about a foot in diameter and three feet long, is provided. As exemplified, it is formed of high-conductivity bronze. Other metals having a high thermal conductivity, e.g., copper, copper alloys, or aluminum, may be used. The block **61** is provided on its cylindrical surface with a helical groove **62** of semi-circular cross section. A tube **63**, which may connect the conduits **16** and **22** in Fig. 1, is wound around the block **61**, the tube **63** resting with a close fit in the groove **62** whereby the tube **63** and metal block **61** are in good thermal contact with each other.

A number of bores **64** are provided within the block **1** and these bores accommodate cylindrical heating elements **65**.

One bore **66** is located near the grooved, cylindrical surface of the block, within which a thermostatic sensing element **67** is located at a position about midway of the length of the bore.

The inside surface of the tubing coil **63** provides the heat-exchange area which is needed to transfer heat radially and axially from the heater into the fluid which is to be warmed. Lower tubing end **68** is connected with a source of liquid oxygen (e.g., conduit **16**) and upper tubing end **69** leads into a reception means (e.g., conduit **22**).

The heating elements **65** are connected with a source of electrical power by electrical connectors **70** by closing a switch **71** under control of the temperature-control primary element **67**.

Any type of thermo-sensing element may be installed, as vapor tension bulbs, gas pressure bulbs, resistance thermometers, thermocouples, etc., their choice being dictated mainly by the instruments with which they are to work in conjunction, but their and their instrument's speed of response being a factor which influences the quantity of metal to be provided in the heat-storing metal blocks.

The embodiment described above relates to the warming to ambient temperature of a gas which enters at very low temperatures. The heat storage is maintained at ambient temperature which is adequate, since ambient temperature can be considered being high, relative to the temperature of liquid oxygen.

However, these operating conditions can be fully extrapolated, in principle, to a heating process which takes place at a higher temperature level, where the gas or liquid to be heated meters at near or above ambient temperature. In that case, while the unit is dormant but ready for operation, the metal block should be maintained above ambient temperature. This condition will be automatically maintained by appropriate setting of the temperature-control primary elements which then will occasionally switch on the heating elements in order to maintain an elevated block temperature against the leak of heat into the surroundings.

In operation, assuming that the vaporizer is initially dormant, i.e., that no oxygen vapor is drawn via upper tubing end **69** and therefore no liquid oxygen enters the lower tubing end **68**, and the metal block **61** and the thermostat sensing element **67** are both at ambient temperature, while the temperature-control primary element is set to keep the heating elements disconnected from the electric power circuit: oxygen vapor is now drawn from the upper tube end **69**, which will at the same moment cause liquid oxygen to enter the heater tube **63** via the lower tubing end **68**. Heat exchange will take place, with heat transfer from the metal block into the cold oxygen, with the result that the oxygen becomes warmed and vaporized and will exit from upper tube end **69** at a temperature only slightly below ambient. The heat which is absorbed by the fluid is drawn from the heat capacity represented in the metal mass and this heat is available readily and without delay since tube walls **63** and the storage mass **61** are of metal, which is characterized by a very large thermal conductivity coefficient. Heat-conduction in the metal block is both radial and axial.

Obviously the metal block **61** will cool down as heat is drawn from it, this cooling process beginning in the lower part where the cold gas enters and progressing upwards as the heat exchange proceeds into regions where the block **61** is still relatively warm and provides high temperature differentials against the cold fluid in tube **63**. Throughout this progressive cooling process the upper part of the metal block **61** will remain at or near ambient temperature and the gas will exist at almost constant temperature from upper tube end **69**. At a certain moment the cooling process will reach the metal mass in the vicinity of the thermostat sensing element **67** and cool said element to a temperature at which it is set to actuate the switching mechanism which connects the heating elements to electric power. This heater control circuit will require a finite time until it achieves a state in which full power is fed from the electric heating elements into the block **61**. During the delay action period, the parts of the metal block which are still warm will continue to carry the heating duty of the system. Before the heat storage in block **61** is exhausted, i.e., before the uppermost section of the block drops appreciably in temperature, the electric heating system should come in to take over further heating duty.

On the other hand, when the flow of fluid thru the heater is stopped, or is decreased to a point where the heat output is not absorbed in full, the average metal block temperature will rise with the result that the thermostatic sensing element will attain a temperature a which it will trigger the electric control mechanism to disconnect power from the heating elements.

Obviously, the quantity of metal mass which has to be provided in this arrangement is a function of the maximum heater capacity, the speed of response of the electric heater circuit and its thermostatic controls. Furthermore, the heat storage in the mass provides a thermal flywheel effect which will have a direct effect on the switching frequency of the electric circuit, with the result that the large metal mass will reduce the frequency of switching and thereby lengthen the service life of electrical components.

Smoother control and fewer and lower electric power surges can be achieved by connecting the multitude of heating elements in two or more groups, controlled by as many temperature-control primary elements as there are groups of heaters. The advantage is that when only partial capacity of the heater is used not all of the electrical heater elements need to be actuated, which results in fewer switching cycles and switching of lower electric power. In a design of splitting the total heating capacities into two or more separate circuits, it appears advantageous to install these heating elements which cut in first in the lower, colder section of the metal block while the heaters, which cut in only when full capacity is approached, should be installed in the upper part of block. Such arrangement offers uniform heat transfer at high flow capacity, but avoids overheating of the upper parts of the metal block, when operating at low capacity.

In Fig. 3 there is shown such an arrangement, a block **61*a*** having a spiral groove **62*a*** similar to the groove **62**, and a tube **63*a*** similar to the tube **63** and similarly arranged and connected. Heating elements **65*a*** under control of temperature-control primary element **67*a*** are provided in the upper part of the block, and heating elements **65*b*** under control of temperature-control primary element **67*b*** are provided in the lower part of the block. The temperature-control primary element **67*a*** is respon-

sive to a lower temperature than the temperature-control primary element 67*b*.

A preferred form of vaporizer for use at 20 in Fig. 1 is shown in Figs. 4 and 5. A cylindrical high-heat-conductivity bronze block 61*c* is provided on its cylindrical periphery with a spiral groove 62*c* in which there is tightly fitted a copper tube 63*c*, the inlet portion of which forms part of the flow line 16 the major portion of which is in the form of a coil 88 and the outlet portion of which forms the initial part of the flow line 22. Two sets of heating elements are provided. One, which is composed of heating elements 65′, is located somewhat nearer the periphery than the other, which is composed of heating elements 65″. A temperature-control primary element 67′ responsive when the temperature actuates the heating elements 65′, and a temperature-control primary element 67″ responsive when the temperature of the block falls below a relatively lower temperature actuates the heating elements 65″. Electrical connections 80 and 81, the latter controlled by a switch 82 under control of elements 67′, lead respectively to connector rings 87 and 84 which are connected to the heating elements 65′ and electrical connections 80 and 82, the latter controlled by a switch 85 under control of element 67″, lead respectively to electrical connection rings 83 and 86 which are connected to the heating elements 65″.

In Figs. 6 and 7 there is shown a form of construction utilizing two blocks in series, each having a pair of tubes therein. One tube 63*d* leads from a source of liquid oxygen (e.g., conduit 16) and is suitably brought into effective heat-transfer relationship with spiral groove in the upper portion of a metal block 61*d* as by being coiled spirally upwardly around the major portion of the periphery of a block 61*d*, which, as shown, is cylindrical in shape like the block 61, but which, like the block 61, may be any suitable shape. Thence the tube 63*d* leads to a spiral groove in the upper portion of a similar block 61*e* and winds upwardly around the block in the groove, and leads thence to a reception means (e.g., conduit 22).

In the bottom portions of blocks 61*d* and 61*e*, there are provided spiral grooves in which are wound portions of a tube 92 leading from another source of normally gaseous material in the liquid phase (e.g., the earlier portion of conduit 26) to a reception means for the material in the gaseous phase (e.g., a later portion of conduit 26).

The blocks 61*d* and 61*e* are provided, respectively, with heating elements 65*d* and 65*e*, thermostatic elements 67*d* and 67*e*, and electrical connections 93 and 94.

In Fig. 8 there is shown an arrangement of a plurality of vaporizer units in parallel as substituted for vaporizer arrangement 20 of Fig. 1. There are provided, in the present instance, three blocks 61*f*, 61*g*, and 61*h*, all identical except that no temperature-control primary elements are provided in the block 61*f* and 61*h*. A tube 63*f* leads from conduit 16 and is coiled about block 61*f* and thence leads to conduit 22. A tube 63*g* leads from conduit 16 and is coiled about block 61*g* and thence leads to conduit 22, a tube 63*h* leads from conduit 16 and is coiled about block 61*h* and thence leads to conduit 22. A set of heating elements 65*f* are provided in block 61*f*, a similar set of heating elements 65*g* in block 61*g*, and a similar set of heating elements 65*h* in the block 61*h*. A temperature-control primary element 67*g* in block 61*g* controls a switch 100 in a circuit 101 extending to heating element 65*h* and having branch circuits 102 and 103 leading to heating elements 65*f* and 65*g*, respectively.

Since certain changes may be made in the above apparatus and different embodiments of the invention could be made without departing from the scope thereof, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

We claim:

1. Apparatus for vaporizing from liquid form a material used in gaseous form, comprising a container for the material in liquid form, a valve-controlled flow line from a lower point therein, product heater vaporizer means in said flow line, a control valve in said flow line beyond said heater vaporizer means and actuated in response to the pressure in said flow line beyond the valve to maintain a substantially constant pressure in the line beyond the valve, and means to increase the pressure in said container when the pressure therein falls below a given point and comprising a conduit leading from a lower point in said container and back to an upper point in said container, auxiliary heater vaporizer means for vaporizing material in said conduit, and a pressure-controlled valve in the portion of said conduit leading back to said container from said auxiliary heater vaporizer means, the last-mentioned valve being arranged to be closed when there is excess pressure in said container.

2. Apparatus as set forth in claim 1 wherein at least the first-mentioned heater vaporizer means comprises a heat-conductive metallic block having a plurality of temperature-controlled heating elements distributed at points intermediate the center thereof and the periphery thereof to provide heat-storage capacity interiorly and exteriorly of said heating elements and between said heating elements, and a tube connecting said flow lines and in heat-conductive relationship with the block exteriorly of said heating elements.

3. Apparatus for vaporizing from liquid form a material used in gaseous form, comprising a container for the material in liquid form, a valve-controlled flow line from a lower point therein to a point of delivery of the material in gaseous form, a conduit leading from a lower point in said container and back to said container, and a heat-conductive block having temperature-actuated heating means therein, a portion of said flow line being in heat-conductive relationship with said block so that the block serves as a heater vaporizer means for the material flowing in the flow line, and a portion of said conduit being also in heat-conductive relationship with said block so that the block also serves as a heater vaporizer means for the material flowing in said conduit.

4. Apparatus for supplying in gaseous form normally gaseous material stored in liquid form, comprising a container for material in liquid form, heater-vaporizer means, delivery means extending from said heater-vaporizer means, a valve in said delivery means, a flow line leading from a lower point in said container to said heater-vaporizer means, conducting means at said heater-vaporizer means extending from said flow line to said delivery means and having an upward component so that vapor formed therein will rise therein to be carried off by said delivery means, a conduit leading from an upper point in said container to said flow line, said flow line having a portion which extends above said upper point, and pressure-responsive means for permitting flow thru said conduit while said flow line remains open to permit gas in said upper portion of the container to escape to reduce excess pressure in said container in preference to the escape of gravity-retarded liquid when the first-mentioned valve is opened at a time when excess pressure exists in said container.

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