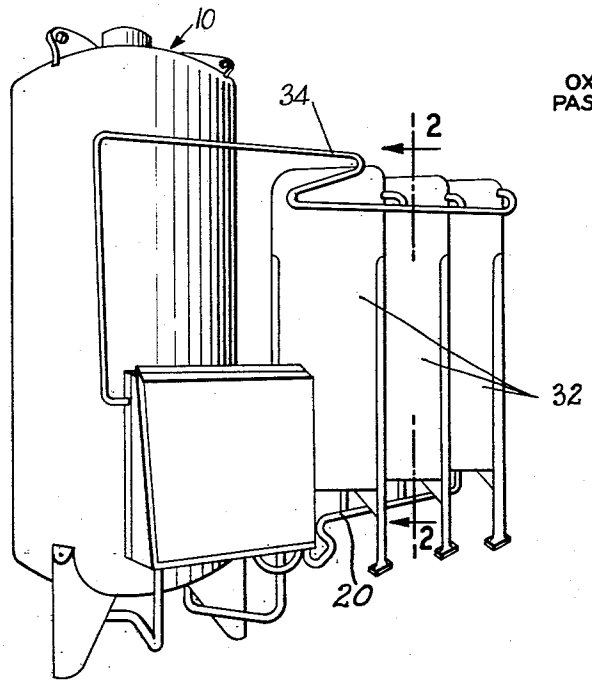
Dec. 12, 1961 W. E. PERKINS ET AL 3,012,408

METHOD AND APPARATUS FOR VAPORIZING LIQUEFIED GASES

Filed July 22, 1958 2 Sheets-Sheet 1

Fig. 1.



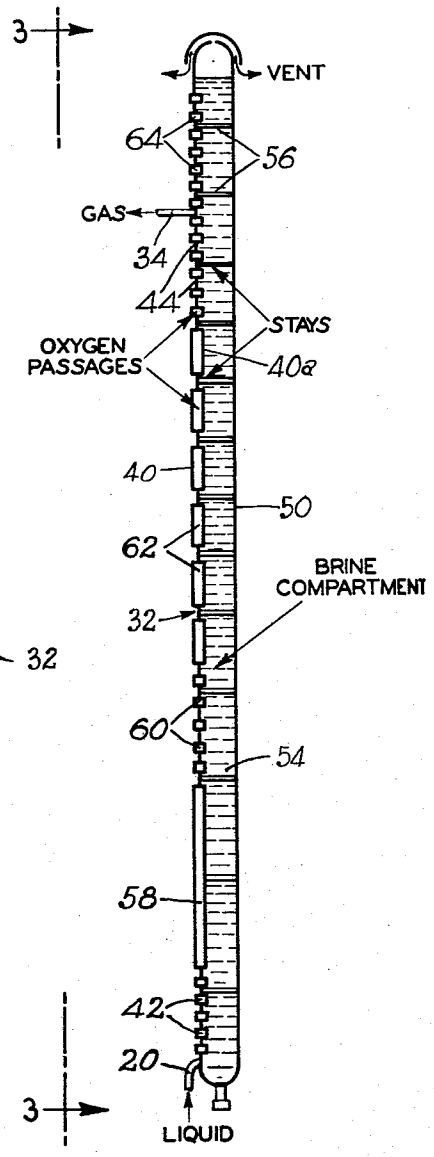


Fig. 2.

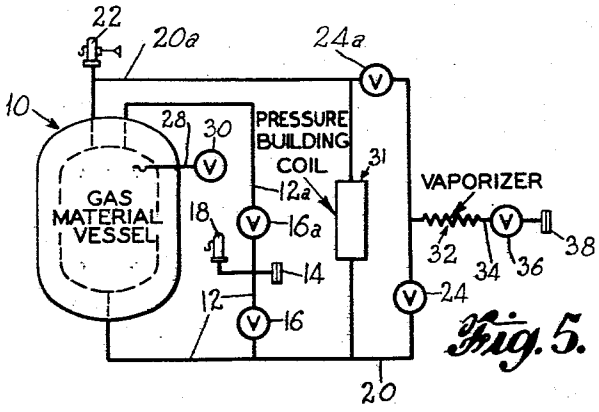


Fig. 5.

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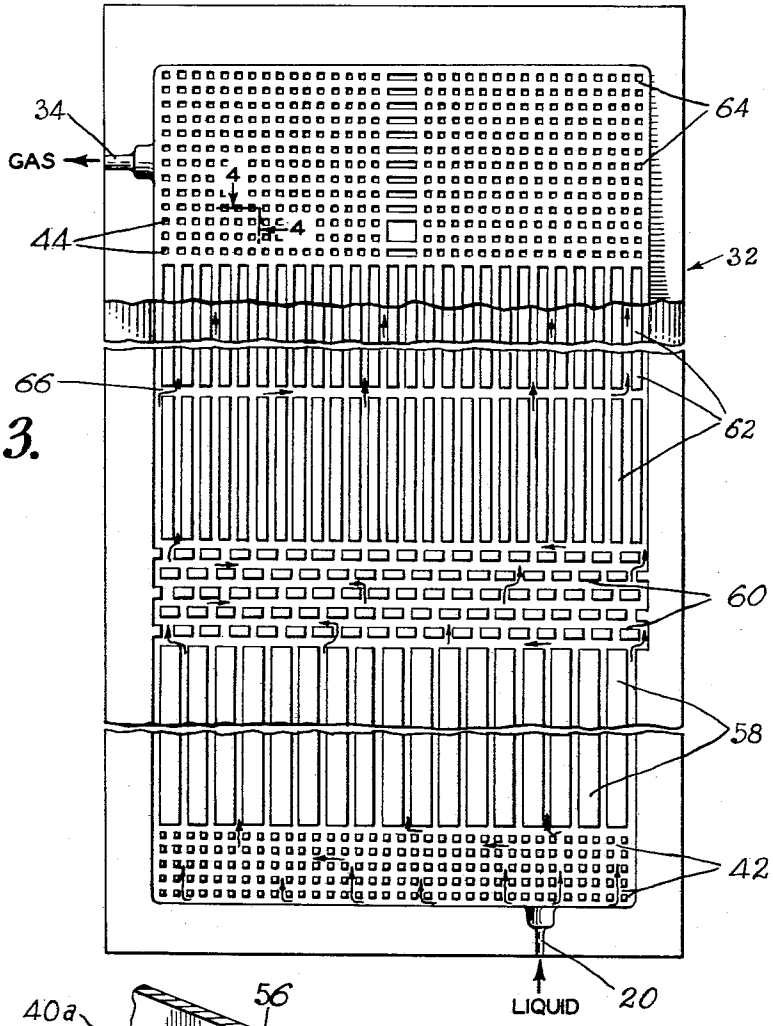


Fig. 3.

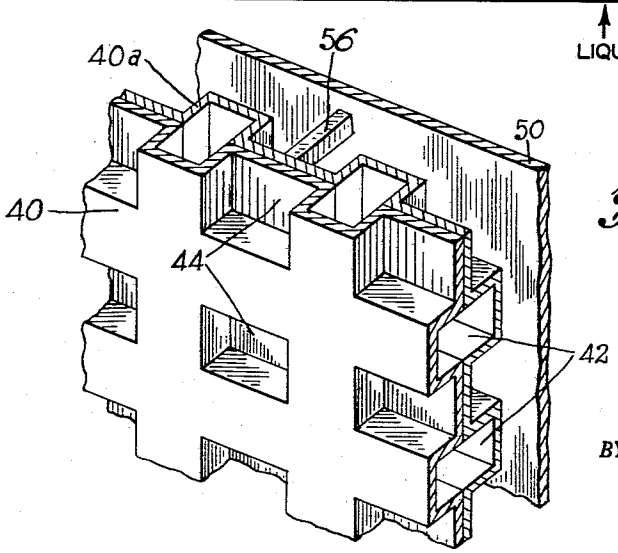


Fig. 4.

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METHOD AND APPARATUS FOR VAPORIZING LIQUEFIED GASES

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6 Claims. (Cl. 62—52)

This invention relates to method and apparatus for vaporizing volatile liquids and more particularly concerns apparatus for vaporizing low boiling, volatile liquids such as oxygen and nitrogen at service pressures above atmospheric pressure.

Several difficulties have been encountered in the vaporization of liquefied gas at relatively low rates of flow for delivery at warm temperature and superatmospheric pressure to a consumer. For example, many vaporizers are heated by steam or electrical means, and whereas the provision of such utilities may be justified for a large consumer, it is often not convenient or desirable for the small consumer. Furthermore, it may be advantageous to make the supply of gas independent of a utility since this improves the dependability of the supply, and facilitates the use of vaporizers on mobile equipment. Dependability is of special importance to consumers desiring a guaranteed supply, such as hospitals.

Atmospheric vaporizers are not necessarily dependent upon a utility for heat and are frequently employed for small demands. However, such vaporizers are normally relatively bulky and must frequently be provided with large excess capacity to accommodate momentary peak demands at the desired pressure and temperature levels. To obtain dependability and to ensure adequate delivery rates under all conditions, it may be necessary to provide an expensive auxiliary equipment as a source of heat or have in readiness additional sources of heat supply.

Another problem involved in the design of atmospheric vaporizers is the achievement of rated performance under a wide variety of weather conditions. Normally, the atmospheric vaporizer unit is located out of doors where the deposition of snow, ice, or frost on the vaporizer walls can reduce heat transfer and impair the proper functioning of the unit, particularly when the humidity is high and the ambient air temperature is about 30° F. to 40° F.

For these and other reasons, such problems are difficult to solve in atmospheric vaporizers and have added to the need for a low cost atmospheric vaporizer which can meet the requirements of small industrial users.

It is therefore an important object of the present invention to provide an improved atmospheric vaporizer apparatus for the out-of-doors conversion of valuable liquefied gas products and adapted to absorb sensible heat from the atmosphere under varying weather conditions for dispensing gaseous product from said vaporizer.

Another object of the invention is to provide an improved low pressure atmospheric vaporizer apparatus for converting relatively small amounts of valuable low boiling liquefied products and dispensing same in gaseous form at a temperature and pressure suitable for use by small industrial users without using utility power such as gas, steam, or electricity.

Another object of the invention is to provide a low pressure atmospheric vaporizer for valuable low boiling liquefied gas material which is simple to manufacture, easy to operate and low in cost.

Other objects, features and advantages of the present invention will be apparent from the following detailed description of a preferred embodiment thereof taken in conjunction with the drawings, in which:

FIG. 1 is a perspective view of a cold converter apparatus embodying the principles of the present invention;

FIG. 2 is an enlarged schematic view taken along line 2—2 in FIG. 1 of the vaporizer portion of the converter unit;

FIG. 3 is an enlarged front elevational view looking in the direction of the arrows along the line 3—3 of FIG. 2;

FIG. 4 is an enlarged partial isometric view of the vaporizer unit taken approximately along the line 4—4 of FIG. 3; and

FIG. 5 is a schematic flow diagram of the apparatus of the invention.

In FIG. 1 is shown an assembly of a gas material holding container or vessel **10** embodying the features of the present invention. By the term "gas material" is meant a low temperature product, such as oxygen or nitrogen in the liquid or gaseous state. The vessel **10** may be of more or less conventional construction for stationary or portable use of the type having a double walled, thermally insulated pressure vessel for holding a supply of liquefied gas material, for example oxygen. The intervening space between the vessel walls may be filled with a comminuted insulating material and evacuated to reduce heat leakage from the outside to the body of liquefied gas in the vessel.

For simplicity, the operation involving the conversion of liquid oxygen will be described but it is to be understood that the invention is not limited to this service.

For filling or replenishing the supply of liquid oxygen in the vessel **10**, a suitable liquid phase pipe **12**, see FIG. 5, provided with a filling connection **14** and controlled by a liquid fill valve **16**, extends through suitable gas tight openings into liquid space in the lower portion of the vessel **10**.

Liquid oxygen, supplied through the fill connection **14**, may also be passed through a gas phase connecting line **12*a*** controlled by a valve **16*a*** and which is gas-tightly joined at one end to the liquid fill line **12** and at the other end to the gas space in the upper region of the vessel **10**. The valves **16** and **16*a*** are used to proportion the flow of liquid oxygen supply between the liquid and gas spaces of the vessel **10** so that the pressure in the vessel **10** can be controlled during filling to maintain a desired operating pressure as is disclosed in U.S. Patent No. 2,368,215. Relief valve **18** in communication with fill lines **12** and **12*a*** allows vapors which may become entrapped between control valves **16** and **16*a*** to escape.

The vessel **10** is customarily supplied with auxiliary devices such as liquid level and pressure indicating means.

The proper filling level may be indicated by a trycock line **28** at the upper filling level and including an external trycock valve **30**.

Suitable pressure building means indicated generally at **31** may also be provided to prevent reduction in the container pressure, such as might occur in periods of sustained liquefied gas withdrawal. Such pressure builder circuit may be of the type disclosed in U.S. Patent No. 2,500,249, and may include suitable heat exchanger and regulator equipment.

The oxygen material from either the liquid or gas line is passed through a conversion apparatus, or vaporizer which when combined with the container **10** and the necessary controls, forms an apparatus known as a cold converter. The conversion apparatus of the invention illustrated in FIGS. 1, 2, 3, 4, and 5 comprises an atmospheric vaporizer **32** having at one end a liquid withdrawal line conduit **20** which joins liquid phase line **12** below the fill valve **16**, and at the other end a discharge line **34** having interposed near the end thereof a check valve **36**, at the outer end of which is a service coupling **38**. By opening the liquid withdrawal valve **24** in line **20**, liquid oxygen is passed to the vaporizer **32** where it is evaporated and superheated for delivery at the conditions required by the consumer.

To prevent excessive gas pressure buildup in the vessel **10**, provision is made for gas withdrawal through a gas phase line **20***a* in communication with the gas space in the vessel **10** having therein a gas phase pressure relief valve **22**. A back pressure gas valve **24***a* is set to open at a predetermined higher pressure within the desired operating range. Gas thus withdrawn may also be passed through vaporizer **32** to superheat the gas to near ambient temperature.

An acute problem in atmospheric vaporizers employing warm air for heat exchange with the liquefied gas, is that of evaporating the liquefied gas and suitably superheating it under severe weather conditions without using any utilities such as steam, gas, or electricity, either for supplying heat of vaporization or for the operation of circulating fans, pumps, or defrosting heaters. In accordance with this invention, a low temperature liquid such as liquid oxygen is converted to a warm gas in a vaporizer employing only atmospheric heat as a source of energy. The process and apparatus may readily be made independent of all industrial sources of power, yet it will perform satisfactorily even under adverse weather conditions and is capable of supplying a widely fluctuating demand with more severe peak loads than could be accommodated with known atmospheric vaporizer.

As a means of accomplishing this, the vaporizer unit is provided with a heat storage system for supplying latent and sensible heat from the atmosphere to liquid oxygen and for minimizing the effect of cold moist weather conditions upon the proper functioning of the vaporizer unit. As shown in FIGS. 2 and 4, the vaporizer **32** comprises a pair of elongated thermally conductive plates **40**, **40***a*, preferably of aluminum or other heat conductive metal, disposed in spaced contact to form a cellular structure having therebetween a labyrinth of internal passages **42**, **58**, **60**, **62** and **64** for oxygen flow. These passages may be formed by placing flat sheet **40** upon flat sheet **40***a*, and bonding together in suitable manner the marginal edges and registering areas **44**, illustrated here in the form of rectangular and square buttons, and hydraulically expanding the areas adjacent thereto to form walls **40** and **40***a* of the internal passageways. This expansion can be accomplished by providing inlet and an outlet connections opening into the unbonded areas between the sheets **40** and **40***a*, and through which hydraulic fluid is introduced for expanding such areas to provide passages. The internal passages formed thereby may be of varying shape and dimension through the length of vaporizer **32** to suit the character of the fluid flowing in the passages at each point therein. The passages adjacent the liquid inlet are preferably of the type shown in FIGURE 4 which permit low and approximately equal flow resistance in either vertical or horizontal directions. Such pattern is conducive to good distribution of the liquid across the width of the vaporizer so that the operating load is uniform.

Above the liquid distributing section containing passages **42**, the passages are preferably formed as long, vertical channels **58** comprising the vaporizing section. Such passages are advantageous in promoting a priming action wherein the fluid with increasing vapor content accelerates upward through the channels and by its turbulence brings the fluid in good heat exchanger relation with the vaporizer walls.

As the fluid emerges from the upper ends of vaporizing channels **58**, any remaining unvaporized liquid will either be disengaged from the vapor in passages **60** above, or will be reduced to tiny vapor-borne droplets or mist. The passages **60** forming the separator section are somewhat similar to passages **42**, providing low flow resistance in vertical and horizontal directions favorable to disengagement of remaining liquid. Passages **60** also provide much extended wall surfaces on which any disengaged liquid is held and vaporized.

A vapor superheating section above the separator section contains long vertical passages **62** similar to vaporizing channels **58**. If desired, passages **62** may be interrupted by one or more horizontal passages **66** for assuring good distribution of the fluid among the superheating channels.

Above the superheating section, a gas collecting section is formed of passages **64** similar to passages **42**. The warm gas leaving passages **62** flows upwardly and horizontally to the withdrawal connection **34**, and the horizontal flow must be accompanied by very low pressure difference across the width of the vaporizer so as not to upset the flow distribution.

It will be noted that the vaporizer section (passages **58**) and superheating section (passages **62**) of FIGURE 3 are fore-shortened. These sections provide the majority of the heat transfer into the gas material and comprise the major portion of the vaporizer length.

Spaced from the inner wall **40***a* is a solid flat plate **50** which, together with wall **40***a* forms a thin rectangular heat storing container **54** for holding a heat storing liquid.

The atmospheric vaporizer of the invention is adapted to function satisfactorily under temporary adverse weather conditions during which heat transmitted directly from the atmosphere to the gas material is insufficient for the delivery of gas at the required rate and heat content. This is accomplished by employing in the container **54** a low-freezing or low-boiling heat storing liquid having a reasonably high latent heat of fusion or vaporization within the low temperature range expected to be encountered, such as brine or ethylene glycol solution. Brine is the preferred liquid, having a low cost, high specific heat capacity and a freezing temperature of about —2° F. Using approximately a 22% brine solution as the heat storing liquid, the gas delivery range for oxygen should be preferably between about —40° C. and ambient temperature.

It is to be understood that this invention is not limited to brine as the heat storing liquid, and that the choice of heat storing fluid may be determined by the conditions under which the vaporizer of the invention is expected to function. Some of the factors which will affect the selection of a heat storing liquid are weather conditions, the boiling point of the heat storing liquid and the desired outlet temperature of the gaseous material to be dispensed.

The container **54** and the cellular wall structure **40**, **40***a*, forming a side of said container, are suitably braced by metal reinforcing stays or bands **56** to avoid bulging.

In operation under normal atmospheric conditions, relatively low rates of flow of liquefied gas material may be vaporized and superheated in the atmospheric vaporizer **32** at equilibrium conditions; i.e., the heat absorbed by the gas material being balanced by the ambient heat transferred primarily through cellular walls **40**, **40***a*, and secondarily through plate **50** and the brine solution. When the unit is vaporizing gas material at such equilibrium rate the brine solution in the vicinity of the liquid distributing passages **42** may freeze, but since only a minor part of the total heat is transferred from the atmosphere through the brine solution, the insulating effect of the ice on the overall heat transfer rate from the atmosphere will not be serious.

During other periods, it is expected that the vaporizer will be called upon to vaporize and superheat gas material more rapidly than the requisite heat can be supplied through cellular walls **40**, **40***a*. Such condition may result from an increase in demand for gaseous material or from the development of unfavorable weather conditions. During such periods, the operation of the atmospheric vaporizer of the invention is as follows:

When the heat available at equilibrium conditions is insufficient to completely vaporize the gas material, the additional heat requirement will be absorbed through wall **40***a* from the brine solution. Sensible heat will first be released from a given strata of brine until its temperature drops to its freezing point. Thereafter, the brine will freeze, releasing a large amount of latent heat for

transfer to the wall **40***a*. As long as such non-equilibrium condition exists, the brine will continue to cool and freeze, thereby supplying the heat deficiency and maintaining near-normal vaporizer service. Freezing progresses upwardly from the bottom of the vaporizer, and the solid-liquid interface slopes downwardly from the cold wall **40***a* to the warmer wall **50**.

If the heat deficiency is only minor, the vaporizer may establish a new equilibrium but with a higher ice level. Such new equilibrium is maintained by the generally lower wall temperatures existent throughout the vaporizer which tend to increase the ΔT between the walls and the surrounding atmosphere. Thus, the vaporizer can adjust itself to changes in weather conditions and to moderate fluctuations in vaporizing rates.

When the heat deficiency is considerable, as may reasonably result from a momentary demand for gaseous material far in excess of the equilibrium capacity of the vaporizer, the freezing progression line will continue to advance within the vaporizer. The duration and frequency of such peak loads are usually predictable from experience, and if the vaporizer is properly constructed for its intended service, the heat capacity of the brine will not be exhausted before normal vaporization rates are resumed.

When the vaporization rate of the gas material returns to normal or is discontinued altogether, there follows a warming period during which the heat capacity of the brine is restored; and the vaporizer is prepared to supply the next period of heat deficiency. If the flow of gas material ceases altogether, heat from the atmosphere enters the brine through wall **50** and also through extended surface walls **40**, **40***a*. If a moderate vaporizing load continues, wall **40** will supply the heat for vaporization and for superheat, while wall **50** supplies the heat for thawing the brine.

An alternative method of construction is to replace flat wall **50** with a duplication of wall **40**, **40***a* so that both faces of the vaporizer contain vaporizing and superheating passages. Such construction has the disadvantage that if both vaporizing faces are used efficiently at moderate vaporizing rates, then a warm wall will not be available for restoring heat to the brine solution.

Another alternative is to enclose the brine compartment with flat walls **50** on both sides and with vaporizer element **40**, **40***a* located midway between. The vaporizing passages are then completely immersed in the heat storage liquid with no surfaces exposed to the atmosphere. The disadvantage of this arrangement is that the heat capacity of the brine solution cannot be conserved as effectively at low rates of vaporization since all the heat transmitted to the gas material must be absorbed from the solution regardless of vaporization rate. The brine also acts as a thermal insulation and the overall heat transfer rate, inherently low due to the poor convection coefficient, is still further reduced by the resistance of the enveloping layer of brine. Finally, the extended surface area of wall **40** is not utilized effectively to improve heat transfer at the principal resistance, namely, the surface exposed to the atmosphere.

In order that the frozen brine may thaw completely between freezing periods, it is clear that the thickness of the brine compartment must not be too great. On the other hand, maximum heat storage is desirable in the brine compartment and for this reason, it should be as thick as practical. We have found that a thickness of about 2 in. is suitable for most services encountered, although thinner or thicker compartments may be used if so desired.

From the above, it will be seen that the atmospheric vaporizer of the present invention provides a fluctuating demand for gaseous material in which momentary loads may far exceed the continuous rating of the unit. The vaporizer is also admirably suited to provide a relatively steady vaporization rate for an extended period of time.

An obvious advantage of the invention is that momentary peak loads considerably in excess of the continuous rating of the vaporizer can be satisfactorily vaporized and superheated provided such peaks are followed by adequate intervals of low demand to permit restoration of the heat storing capacity of the compartment **54**. Similarly, a consumer who withdraws gasified gas material only during a part of the day can withdraw at higher rates than the continuous rating of the vaporizer. For example, a consumer may require 1,000 cu. ft. per hr. gaseous material for one 8-hour shift only, in which case the conventional vaporizer will represent idle investment 16 hours of each day. In contrast, a vaporizer embodying the principles of the present invention and having a continuous rating of only about 700 cu. ft. per hr. will be capable of supplying the customer's full requirements for the 8-hour period. The heat capacity of the unit will be restored during the 16-hour intervals, thus making continuous, round-the-clock use of the atmospheric heat absorptive capacity of the unit.

From the above, it will be seen that the present invention provides an atmospheric vaporizer for a cold converter, the vaporizer including a heat storing unit for improving the rated capacity and peak withdrawal rates of gasified gas material without resorting to gas, electric, steam or other utilities.

It will be understood that modifications and variations may be effected without departing from the spirit and scope of the novel concepts of the present invention.

What is claimed is:

1. A cold converter including a vessel having an inlet at one end thereof for the supply therein of low-boiling liquefied gas material, an outlet at the other end thereof for the discharge therefrom of gasified gas material, said vessel having at least two non-planar side walls closely spaced, being arranged and constructed to form a cellular structure with a labyrinth of internal passages for the flow of gas material, one of said non-planar side walls being disposed in direct thermal association with the atmosphere for absorbing heat therefrom for the vaporization and superheating of said liquefied gas material; a heat storing compartment for a liquid having a freezing point below atmospheric temperature and above the vaporization temperature of said liquefied gas for transferring heat to the gas material in said vessel during periods when the heat in the surrounding atmosphere is insufficient to fully vaporize said gas material, the other of said non-planar side walls of said vessel forming one side wall of said heat storing compartment and a flat surface being provided in direct thermal association with the atmosphere so as to form a second side wall of such compartment.

2. A cold converter including a vessel having an inlet at the lower end thereof for the supply therein of low-boiling liquefied gas material, an outlet at the upper end thereof for the discharge therefrom of gasified gas material, said vessel having at least two non-planar side walls closely spaced, being arranged and constructed to form a cellular structure with a labyrinth of internal vertically and horizontally interconnected passages for the flow of gas material, one of said non-planar side walls being disposed in direct thermal association with the atmosphere for absorbing heat therefrom for the vaporization and superheating of said liquefied gas material; a heat storing compartment for a liquid having a freezing point below atmospheric temperature and above the vaporization temperature of said liquefied gas for transferring heat to the gas material in said vessel during periods when the heat in the surrounding atmosphere is insufficient to fully vaporize said gas material, the other of said non-planar side walls of said vessel forming one side wall of said heat storing compartment and a flat surface being provided in direct thermal association with the atmosphere so as to form a second side wall of such compartment.

3. A cold converter according to claim 1 wherein

said non-planar side walls have irregular, waffle-like external surfaces.

4. A method for vaporizing and super heating liquefied oxygen comprising the steps of providing and flowing said liquefied oxygen in simultaneous heat exchange with atmospheric air and a heat storing liquid having a freezing point below atmospheric temperatures and above the vaporization temperature of the liquefied oxygen, thereby vaporizing and superheating such liquefied oxygen and cooling said heat storing liquid for freezing thereof, so as to transfer the heat of fusion to said liquefied oxygen; and thereafter warming the frozen heat storage material sufficiently by atmospheric heat so as to melt such material for reuse as a heating medium for said liquefied oxygen.

5. A method for vaporizing and superheating a low-boiling liquefied gas according to claim 4 wherein said superheating raises the temperature of the oxygen to between approximately ambient temperature and —40° C.

6. A method for vaporizing and superheating liquefied gas having a normal boiling point no higher than the

normal boiling point of liquid oxygen comprising the steps of providing and flowing said liquefied gas in simultaneous heat exchange with atmospheric air and a heat storing liquid having a freezing point below atmospheric temperatures and above the vaporization temperature of the liquefied gas, thereby vaporizing and superheating such liquefied gas and cooling said heat storing liquid for freezing thereof, so as to transfer the heat of fusion to said liquefied gas; and thereafter warming the frozen heat storage material sufficiently by atmospheric heat so as to melt such material for reuse as a heating medium for said liquefied gas.

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