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UTILIZATION OF LIQUEFIED AIR IN THE PRODUCTION OF MECHANICAL ENERGY.

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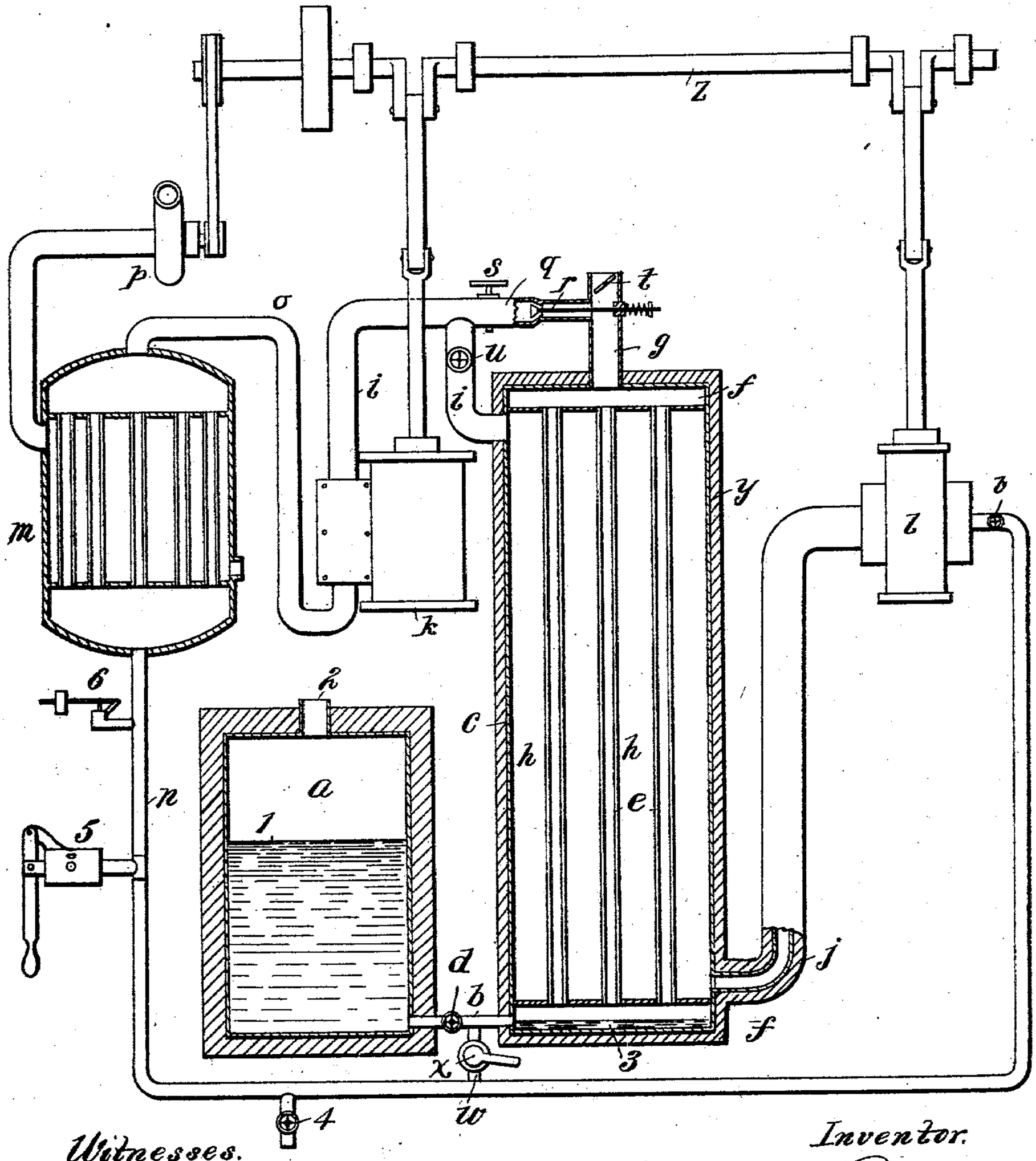
NO MODEL.



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UTILIZATION OF LIQUEFIED AIR IN THE PRODUCTION OF MECHANICAL ENERGY.

SPECIFICATION forming part of Letters Patent No. 720,778, dated February 17, 1903.

Application filed April 1, 1899. Serial No. 711,376. (No model.)

To all whom it may concern:

Be it known that I, CHARLES S. BRADLEY, a citizen of the United States, residing at Avon, in the county of Livingston and State of New York, have invented certain new and useful Improvements in Utilization of Liquefied Air in the Production of Mechanical Energy, of which the following is a specification.

This invention relates to improvements in fluid-pressure engines, and has especial reference to the utilization of liquefied air in the production of mechanical energy.

When liquefied air is confined in a receptacle and allowed to absorb heat without expansion until an ordinary temperature—say 15° centigrade—is reached, the pressure attained and the ratio of expansion required to reduce it to substantially atmospheric pressure will be far too great to be utilized in any usual construction of expansion-engine and its use would in any case be dangerous and difficult. To avoid this difficulty, I use the liquefied air only or mainly as a refrigerating agent for another fluid-pressure medium which is used as the direct motive agent. Thus gaseous air may be refrigerated by contact with or preferably by conductive transmission of heat to the liquefied air or to the air evaporated therefrom, and the air thus refrigerated may be compressed by a pump and then heated in any suitable manner and delivered to an engine. The thermodynamic cycle may be completed by allowing the exhaust-air from the engine to pass again to the refrigerator, the heater, engine, refrigerator, and pump being thus connected in circuit, or such exhaust-air may be allowed to escape. In any case the maximum pressure may by the above manner of operation be set at any convenient amount, and the drop in temperature, and consequently the ratio of expansion, can also be reduced to convenient limits by proportionate increase of the quantity of air used as the direct motive agent compared to the quantity of refrigerating agent.

A further feature of my invention is the maintenance of the liquid-air supply at substantially atmospheric pressure and the introduction of same into the motor system without the use of any special injecting-pump. The liquefied air may flow to the refrigerator by gravity or by slight expansion-pressure, such refrigerator or the heat-absorbing side thereof being at substantially the same pressure as the liquid-air reservoir. To this end it is desirable to use a refrigerator of the surface-condenser type and to supply the liquid air or the vapor thereof to the refrigerator out of contact with the motive medium.

The accompanying drawing represents an embodiment of my invention wherein the motive fluid operates in a closed cycle, the exhaust-air being returned to the refrigerator to be used over again.

In such drawing, *a* represents the tank for liquefied air, and *b* a pipe leading therefrom to the refrigerator *c*. A valve *d* controls the passage of the liquid air through pipe *b*. The refrigerator-tank *c* may be of any construction usual for analogous apparatus, but is preferably of the surface-condenser type. The form shown has a heat-absorbing side comprising a plurality of tubes *e*, connecting end spaces *f f*, and a heat-delivering side constituted by the space surrounding these tubes. The heat-absorbing side is connected at opposite ends, respectively, to the liquid-air tank *a* and to a vent-pipe *g*. That portion *h* of the refrigerator which surrounds tubes *e* is connected by pipes *i j*, respectively, to the exhaust of engine or air-motor *k* and to the admission-point or valve-chest of a pump *l*. A heater *m* of similar construction to the refrigerator, but smaller, has its heat-absorbing side connected at opposite ends by pipes *n o* to the delivery-outlet of pump *l* and to the admission-point or valve-chest of air motor or engine *k*. The heat-delivery side of this heater is connected at opposite ends, respectively, to the blower or artificial-draft apparatus *p* and to the outer air. A pipe connection *q* is shown between exhaust-pipe *i* and vent-pipe *g*, such connection including an automatic valve *r*, which when the difference of pressure in such pipes exceeds a certain amount admits air to the exhaust-pipe from the vent-pipe. Valves *s t u* 4 may also be provided, respectively, in such connection in the vent-pipe, in the exhaust-pipe, and in the pipe *n*, leading to the heater *m* from the pump *l*. A pipe connection *w*, with a valve *x*, is also shown leading from liquid-air-supply pipe *b* to the pump-delivery pipe *n*. All pipes and parts containing liquefied or very cold air are

sheathed or insulated by suitable heat-insulating material *y* except pipe *n*, which is shown bare, as the absorption of heat thereby is advantageous.

The engine *k* and pump *l* are preferably connected together mechanically in any suitable manner, as by being connected to a main shaft *z*, which also drives the blower *p*.

It will be understood that the pump *l* is of smaller capacity—for example, has a smaller piston—than engine *k*, as it acts upon the air in a less expanded condition.

The operation of the apparatus is as follows: The tank *a* is charged with liquefied air, (represented at 1,) the said tank being left open at the top, as indicated at 2, so that the air is free to evaporate, and thus accumulation of pressure in the tank is prevented. The valve *d* being opened, liquefied air passes from tank *a* to refrigerator *c*, the quantity of liquid admitted being sufficient to reduce the refrigerator to the proper degree of cold and to maintain it at that point. Evaporation of the liquid air may take place wholly at the point where it leaves pipe *b*, or the liquid may be allowed to accumulate in the refrigerator, as indicated at 3. In case of small loads, requiring only a small difference of pressure, the system will operate as soon as the refrigerator is thus cooled, provided that valve *s* is closed, so that a vacuum may be produced in the connection between the exhaust of the engine and the admission-valve of the pump. The piston of the engine being larger than that of the pump, the apparatus will be set in motion, provided that the load is not too heavy, and on such light loads the machine will continue to operate as follows: The cold air passing from the pump through pipe *n* is heated and expanded in the heater *m*, it being understood that the word "heated" is here used in a relative sense, since the heating apparatus shown would only heat it to about atmospheric temperature. If desired, however, special means of any kind may be provided for heating the heater and the air passing through same to any desired extent above atmospheric temperature. The heated or warmed air passes through the engine *k*, which is provided with the usual valve mechanism to cut off and expand the air, the air during its admission and expansion in the engine developing the certain amount of mechanical energy which is applied to the shaft *z*. The air is cooled in thus expanding, and it then passes to the heat-delivery side of the refrigerator *c*, where it is further cooled by the absorption of heat therefrom by the liquid air or by the cold air evaporated from such liquid air. In thus cooling it contracts, and it passes in this contracted condition to the pump *l*, which pumps it back to pipe *n*, absorbing in this operation a certain amount of mechanical energy, which is less than the amount of energy furnished by the engine *k*. The energy which is not expended in the pump *l*, in the blower *p*, and in friction may be utilized for any purpose. It will be observed that the system would be operative if the pipe *n* were opened to the outer air, as by a valve 4, or were omitted altogether; but I prefer to connect the delivery end of the pump to the heater, as shown, so that the same air is used over and over again, thus avoiding trouble due to condensation of moisture. To increase the capacity of the system, it is desirable that the fluid-pressure delivered to the engine should be of some considerable amount, and to this end I may provide any suitable means, such as a hand-pump, (indicated at 5,) for accumulating pressure in the pressure end of the apparatus. A more convenient way of accomplishing the same result is, however, to admit a definite amount of liquid air to the pipe *n*, as by the valve *x*, the valve then being closed and the air being allowed to evaporate and produce pressure in the heater.

After the engine is once started the pressure in the heater may be regulated by admitting air at valve *s* to the "vacuum" side of the instrument, it being clear that the greater the pressure or the less the vacuum of the air that passes to the pump the greater will be the pressure of the air delivered from the pump. This regulation may be effected automatically by the valve *r*, which admits air from the atmosphere or from the vent-pipe *g* to the vacuum side of the system when the vacuum falls below a certain amount, the heat-absorbing side of the refrigerator constituting a vacuum-chamber which communicates by a connection including pipe *q* and *q* and valve *r* with a part of the system between the exhaust of the engine and the intake of the pump—that is, with the low-pressure side of the system. Thus assuming that the pump and the engine have expansion and compression ratio of thirty, then if the engine be started with the valves *s t* closed and a pressure of one atmosphere (fifteen pounds per square inch) in the heater the action of the pump will draw air from the refrigerator until the pressure therein is reduced to one-half pound per square inch. Then by admitting air at *s t* the pressure in the refrigerator may be raised to any desired extent—say to five pounds per square inch—and if valve 4 be closed the pressure will correspondingly increase in the heater to about one hundred and fifty pounds per square inch, and by proper adjustment of regulator *r* this pressure may be maintained, a safety-valve 6 being provided to relieve any excess of pressure over this amount.

The quantity of air passing through the engine during a given time in the operation of this system may be greater in any desired proportion than the quantity of air evaporated from the liquefied air during the same time, with the result that while the range of working temperature is decreased the working capacity of the system may be greatly increased.

Inasmuch as the power of this engine depends on the contraction of the working air by the liquefied air before it passes into the pump, the apparatus may be considered as utilizing this contraction of the gaseous air to produce mechanical energy.

Having thus described my invention, what I claim as new therein, and desire to secure by Letters Patent, is—

1. An apparatus for the production of mechanical energy comprising an expansion-engine adapted to operate by the expansion of a gaseous medium, a refrigerator into which said engine exhausts, a pump connected to said refrigerator to draw the gaseous medium therefrom, a source of liquid air connected to said refrigerator to cool the gaseous medium, heating means for passing atmospheric air in heat-conductive relation to the gaseous medium after it leaves the pump, and a communication for leading the gaseous medium from such heating means to the expansion-engine.

2. An apparatus for the utilization of liquefied air in the production of mechanical energy comprising a heater, an expansion-engine having its admission side connected thereto, a refrigerator connected to the exhaust of such expansion-engine, a pump having its intake connected to such refrigerator, liquid-air-supply means for supplying liquid air to such refrigerator, and a connection from the liquid-air-supply means to the expansion-engine.

3. An apparatus for the utilization of liquefied air in the production of mechanical energy, comprising a heater, an expansion-engine, a refrigerator of the surface-condenser type and constituting a vacuum-chamber and a pump, all such parts being connected in a closed circuit and containing gaseous air as a motive medium, a valve connected to the vacuum-chamber and provided with controlling means tending to hold it closed against the pressure of the external air and responsive to a deficiency of pressure at the low-pressure part of the circuit to admit air thereto, and means responsive to excess of pressure at the high-pressure part of the system to remove air therefrom, and means for supplying liquid air to the refrigerator, out of contact with the motive medium.

4. An apparatus for the utilization of liquefied air in the production of mechanical energy, comprising a source of liquid air, an expansion-engine and a pump, a refrigerator having a heat-delivering side connected to the exhaust side of said engine and to the intake of the pump and a heat-absorbing side connected to the source of liquid air, a connection including a valve, leading from the heat-absorbing side of the refrigerator to a point in the system between the exhaust of the engine and the intake of the pump, a heater connected to the outlet of the pump and to the inlet of the engine.

5. An apparatus for the utilization of liquefied air in the production of mechanical energy, comprising an expansion-engine, a refrigerator into which said engine exhausts, a pump connected to said refrigerator to draw air therefrom, and a source of liquid air exposed to the atmosphere so as to be at atmospheric pressure, and having a supply connection leading to said refrigerator.

6. An apparatus for the utilization of liquefied air in the production of mechanical energy, comprising a heater, an expansion-engine, a refrigerator of the surface-condenser type, and a pump, all such parts being connected in closed circuit and containing a gaseous motive medium, and means for supplying liquid air to the refrigerator, out of contact with the motive medium, such means comprising a liquid-air-supply tank communicating with the atmosphere so as to be at atmospheric pressure.

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