United States Patent [19]

Asselman et al.

[11] **3,817,322**

[45] **June 18, 1974**

[54] **HEATING SYSTEM**

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[22] Filed: **Oct. 3, 1972**

[21] Appl. No.: **294,652**

[30] **Foreign Application Priority Data**

Oct. 21, 1971 Netherlands 711447

[52] **U.S. Cl.** **165/105,** 165/104, 60/517, 60/523, 60/524

[51] **Int. Cl.** **F28d 15/00**

[58] **Field of Search** 165/105, 104; 126/400; 60/517, 523, 524

[56] **References Cited**

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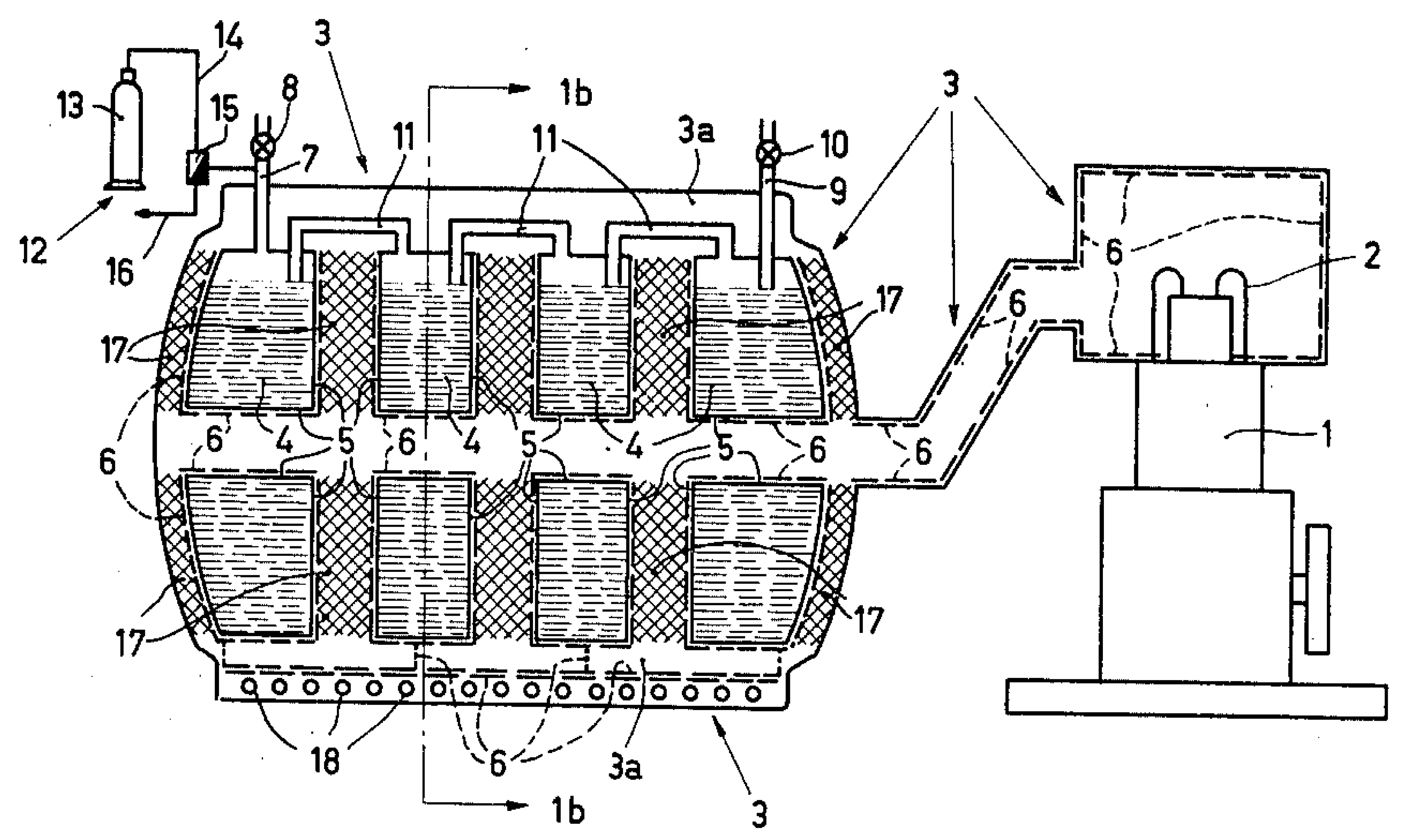
Primary Examiner—Albert W. Davis, Jr.
Attorney, Agent, or Firm—Frank R. Trifari

[57] **ABSTRACT**

A heating system for a machine having a closed thermo-dynamic cycle, the system comprising a closed space within which several containers for heat-accumulating material are present as well as a medium transporting thermal energy by evaporation and condensation. The containers communicates with a common supply duct for heat-accumulating material, with spacing members arranged between the walls of the closed space and the containers as well as between the containers mutually.

8 Claims, 3 Drawing Figures



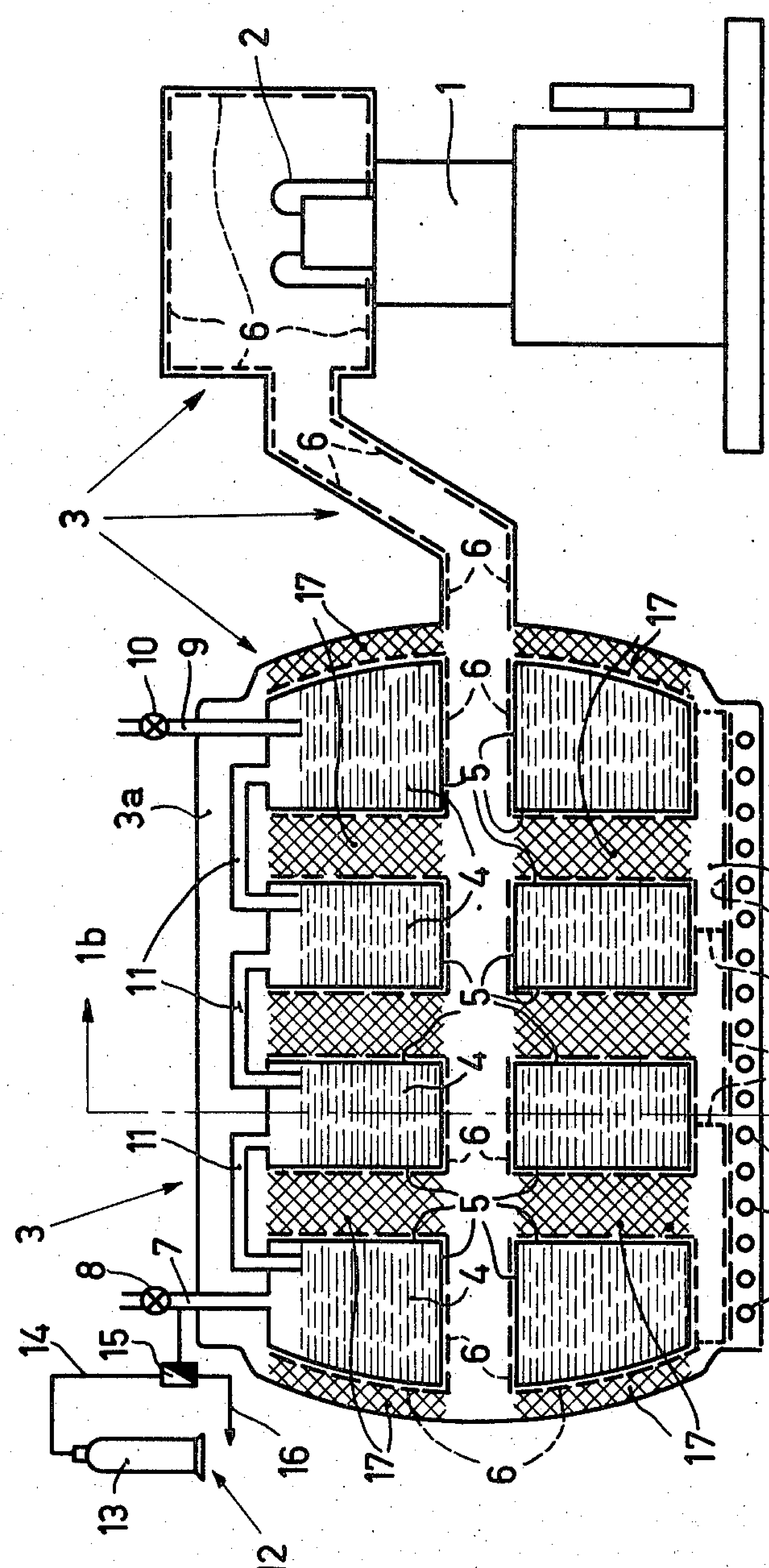


Fig. 1a

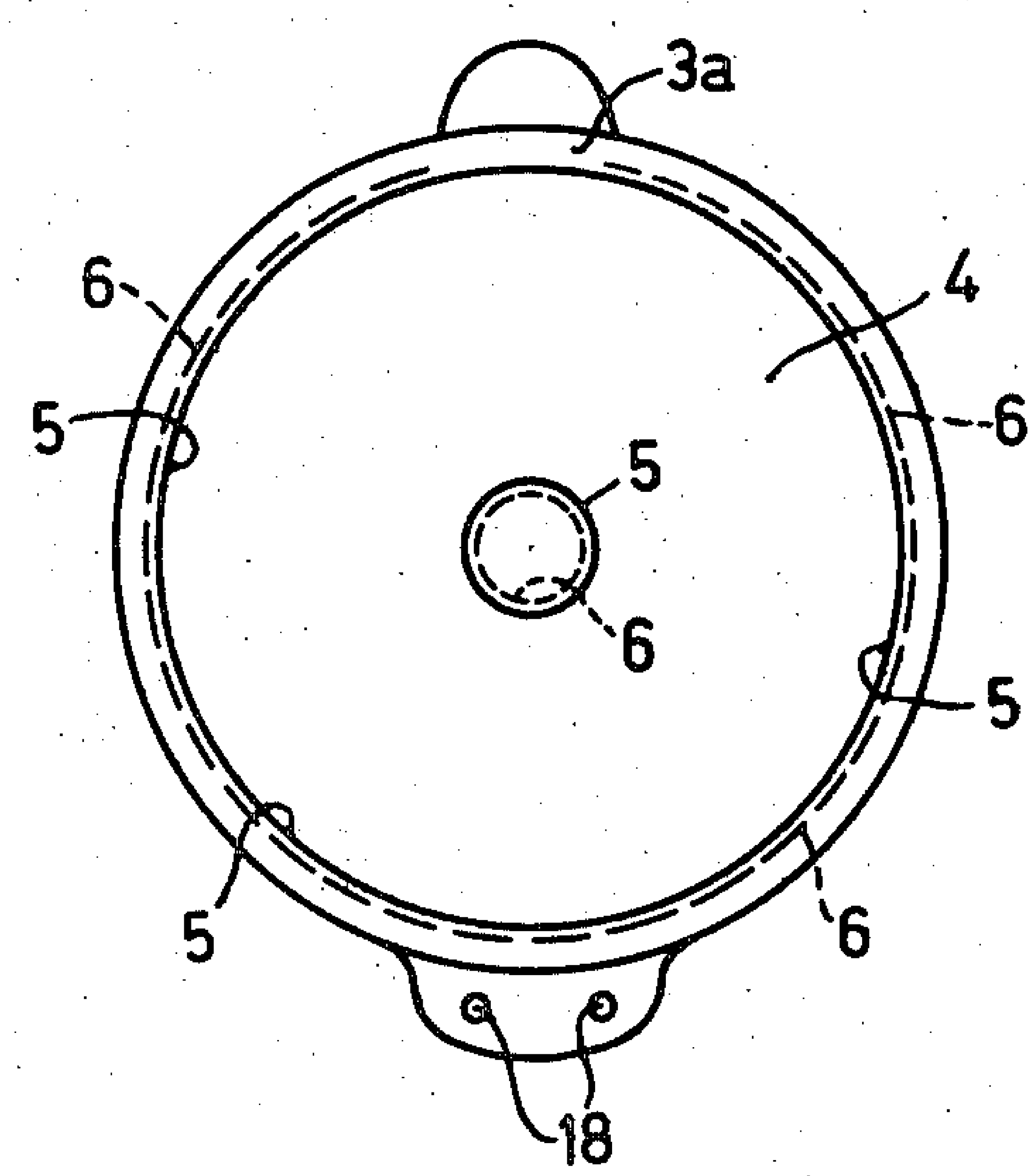


Fig.1b

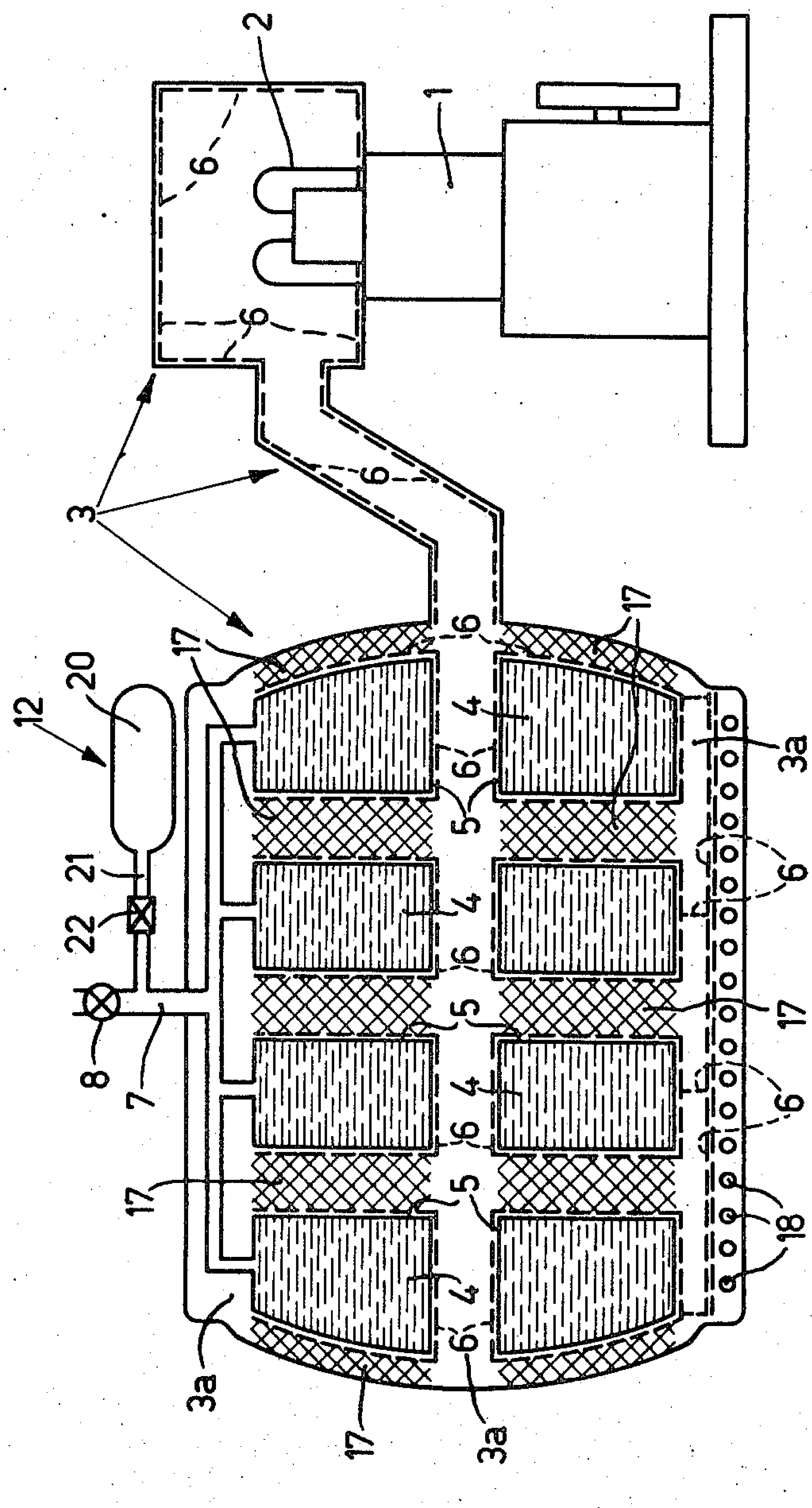


Fig.2

HEATING SYSTEM

BACKGROUND OF THE INVENTION

The invention relates to a heating system for the supply of thermal energy to a heater of a machine in which a working medium performs a thermodynamic cycle. The system comprises a closed space within which several containers for heat-accumulating, meltable material are arranged. Each container has at least one heat transmission wall through which heat-accumulating material can exchange thermal energy with a heat transporting medium which is present in the closed space and which during operation transports thermal energy from the containers to the heater by an evaporation-condensation process. The heater communicates with the heat transmission container walls via a porous mass having a capillary structure for the return of heat transporting medium condensate from the heater to the containers. A heating system of the above-described type is known from FIG. 2 of the Belgian Patent Specification 758,330.

Examples of machines in which a working medium performs a thermodynamic cycle and to which working medium thermal energy is supplied from without through the wall of a heater, are hot-gas engines and hot-gas turbines.

The heating system in which thermal energy stored in containers is transported to the heater of a thermodynamic machine by means of an evaporation-condensation process a heat transporting medium presents several advantages. First of all, a large quantity of thermal energy can be transported substantially without temperature drop, without the use of a pumping device and without further moving parts. Due to the presence of the porous mass having a capillary structure, return of heat transporting medium condensed on the heater to the containers takes place in all circumstances as a result of capillary action while using the surface tension of the condensate. Return of condensate thus takes place even against gravity or without the action of gravity.

The porous mass having a capillary structure may consist, for example, of a ceramic material, of layers of gauze of wire or band-shaped material, from arrangements of glass fibres, pipes or rods, of systems of grooves in the walls, whether or not in combination with one of the above-mentioned alternatives. Said porous mass may fully or partly cover the walls of the closed space, the heat transmitting container walls, as well as the heater wall. All kinds of materials, for example potassium, sodium, calcium, lithium, cadmium, cesium, metal mixtures, and so on are to be considered as heat transporting media. A compact assembly is obtained by arranging the heater within the closed space.

By using containers which are filled with heat-accumilating material, the thermal energy stored in the said material can be used for operating the thermodynamic machine, for example a hot-gas engine, in places where fuming gases may not be allowed to develop or in places where no combustion air is available for a normal burner (mines, submarines, and so on). An example of a heat-accumulating meltable material to be considered is lithium fluoride (LiF).

Since the heater is separated from the containers filled with heat accumulating material, the volume of

the containers and hence the heat capacity thereof is not restricted; this in contrast with heating systems in which the heater which is normally constructed from a number of pipes is placed directly in the heat accumulating material. In the latter case the maximum volume of the container in question and hence the maximum heat capacity thereof is restricted, owing to the fact that the heater pipes are restricted to given maximum length dimensions, in connection with the optimum thermodynamic cycle of the working medium in the machine which may be, for example, helium or hydrogen. Moreover, the thermodynamic machine should then carry the weight of the container filled with heat accumulating material, which necessitates a heavier machine construction.

The known heating system exhibits a few drawbacks. The containers are filed with heat accumulating material one by one, closed, and arranged inside the closed space separately. The separate filling and closing of the containers is time-consuming and expensive and makes the assembly of the heating system less suitable for series production. Since the containers are arranged separately relatively movable, the position of the heating system is restricted. This lack of independence of position means a serious restriction in the possibilities of application. Independence of position is required, for example, in aeronautics or on board submarines in which a hot-gas engine which is equipped with such a heating system may be present as a power source without exhaust gases.

In order that the evaporation-condensation process of the heat transporting medium in the closed space can occur smoothly, said space is normally evacuated. A problem is that in a number of cases, dependent upon the heat transporting medium chosen, the vapour pressure of the heat transporting medium in the closed space lies below the ambient pressure not only at room temperature but also at the high operating temperature of the heating system. For example, if sodium is present in the evacuated closed space as a heat transporting medium, the vapour pressure at 800° K is 8 Torr (1 Torr = 1 mm mercury pressure) and at 1,100° K it is 450 Torr. This means that in particular in heating systems of which the closed space has flat walls of large dimensions, said walls are subjected to a considerable mechanical load. Notably at high operating temperatures of the heating system in which the rigidity of said walls is considerably lower than at room temperature, this results in deformation and cracking of the said walls with the danger of implosion of the closed space.

The porous mass having capillary structure may work loose from the walls and/or be damaged to such an extent that it is no longer useful for the return of heat transporting medium condensate from the heater to the containers. Thicker and hence more rigid walls of the closed space are usually not possible for reasons of weight, cost-price and dimensions.

It is the object of the present invention to provide an improved construction of the heating system of the above-described type in which the drawbacks described are avoided.

SUMMARY OF THE INVENTION

The heating system according to the invention is characterized in that the containers communicate with a common supply duct for heat-accumulating material, and this closable supply duct is passed through a wall of the closed space to the outside. Spacing members are present between the walls of the closed space and the containers as well as between the containers mutually to permit flow of heat transporting medium vapour.

The filling of the containers with heat accumulating material can now be carried out in a simple and rapid manner in one single operation after the complete assembly of the heating system. The containers may be connected mutually in series or parallel to the common supply duct. The filling of the containers with liquid heat accumulating material may be carried out by first evacuating the containers via the common supply duct and then communicating them with the storage container for heat accumulating material.

Due to the presence of the spacing members, the heating system has not only become independent of position, but the closed space is also protected from implosion since, as a matter of fact, the spacing members also support the walls of said low pressure space against the atmospheric pressure ferces exerted theron from without. The spacing members furthermore ensure that the porous mass having capillary structure remains in its place so that the transport of heat transporting medium condensate through said mass is not disturbed.

In a favourable embodiment of the heating system according to the invention the containers also communicate with a common outlet duct, said closable outlet duct being also passed to the outside through a wall of the closed space. The outlet duct may be arranged so as to serve as a desaeration duct during filling the containers and as a suction duct for heat accumulating material after filling, so as to obtain a certain filling level in the containers. The outlet duct may also be used in employing the containers provided with heat accumulating material.

Finally, the common supply and outlet duct may be used collectively in rinsing the containers with an inert gas, for example, after filling of containers mutually arranged in series, so as to obtain equalisation of the filling levels in the various containers. In a further favourable embodiment of the heating system according to the invention, a pressure control device is present for controlling the pressure in the containers.

Transition of heat accumulating material in the containers from the solid to the liquid phase is associated with a considerable increase in volume of said material which may result in high pressure in the containers; This pressure still further increases when the temperature of the molten heat-accumulating material increases. By means of the pressure control device it is insured that the pressure in the containers remains within certain acceptable limits. Thus it is also possible to use the maximum filling degree of the containers as a result of which for a given heat-accumulating power, the dimensions of the heating system and the heat insulation losses thereof are minimum.

A further favourable embodiment of the heating system according to the invention is characterized in that the spacing members are formed by a porous filling mass the pores of which have larger dimensions than the pores of the porous mass.

Since the pores of the filling mass are larger than those of the porous mass, the suction effect of the filling mass is negligibly small as compared with that of the porous mass. This means that transport of heat transporting medium condensate from the heater to the containers takes place exclusively through the porous mass having capillary structure, while on the way no condensate passes from the porous mass to the filling mass either. Comparatively large pores of the filling mass are also desirable to keep the flow losses of heat transporting medium vapour and hence the temperature gradient between the heat transmission container walls and the heater small. Thus, vapour transport takes place substantially unhindered.

According to the invention, compressed steel wool is preferably used as a filling mass. Steel wool presents the advantage of a low price, can easily be compressed in all kinds of shapes and can receive considerable surface pressure in the compressed condition.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be described in greater detail with reference to the drawing.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. **1***a* and **2** show diagrammatically and not to scale embodiments of heating systems in sectional elevation views. FIG. **1***b* is a cross-sectional view taken on the line I*b* — I*b* of FIG. **1***a*.

DESCRIPTION OF THE PREFERRED EMBODIMENT

In FIG. **1**, reference numeral **1** denotes a hot-gas engine which comprises a heater **2** to which thermal energy is to be supplied. The heater **2** is accommodated inside a closed space **3**. Said space furthermore comprises several containers **4** for heat accumulating meltable material, for example L*i*F. Each container **4** comprises at least one heat transmission wall **5**. In this embodiment the containers are constructed as annular cylinders which are arranged in a cylindrical compartment **3***a* of the closed space **3**, so that the annular cylinder axes coincide. A quantity of sodium as a heat transporting medium is also present in the closed space. The heater **2** communicates with the heat transmission container walls **5** via a porous mass **6** which has capillary structure.

All the containers **4** communicate with a common supply duct **7** for heat-accumulating material which is passed to the outside through the wall of the closed space **3** and there comprises a cock **8**. All the containers also communicate with a common outlet duct **9** which also debouches outside the closed space **3** and is there provided with a cock **10**. In this embodiment the containers are connected in series via communication ducts **11**.

The pressure inside the containers **4** is maintained within certain limits throughout the accurring temperature range by means of a pressure control device **12**. The pressure control device **12** comprises a bottle **13** which is filled with an inert gas **14** and which communicates with a common supply duct **7** via a duct **14** in which a pressure control valve **15** with exhaust **16** is incorporated.

In order to maintain the containers **4** inside the cylindrical compartment **3***a* of the closed space **3** in their places and hence make the heating system entirely independent of position, a porous filling mass **17** of compressed steel wool is present between the containers mutually and between the walls of the closed space **3** bounding the compartment **3***a* and the containers. Said filling mass has pores, the dimensions of which are larger than those of the pores of the porous mass **6**. The heating system finally comprises an electric heating element **18** which is arranged in the closed space **3**.

Making the heating system ready for use may be done as follows. Thermal energy is supplied to the closed space **3** by means of the heating element **18**. As a result of this, the present in said space evaporates so that the heating is heated at a high temperature. Sodium condensed in comparatively cold places is returned through porous mass **6** on the basis of capillary action to the heating element **18** to be evaporated there again. The heating element **18** is for that purpose also lined with a porous mass **6** which locally communicates with a porous mass **17** on the outer walls of the containers **4**. Since the porous filling mass **17** has pores of comparatively large dimensions, sodium vapour can flow through it substantially unhindered.

When the heating system is at the desirable temperature, the containers **4** are filled with liquid heat-accumulating material, for example melted LiF, via the common supply duct **7**. Common outlet duct **9** then serves as a desaeration duct.

Filling is carried out in only one batch. The containers are filled successively via the communication ducts **11**. By means of a flow of inert gas from the gas bottle **13**, the containers are then rinsed, excessive heat-accumulating material being conducted away through the common outlet duct **9**. The level of the heat-accumulating material then reaches up to the insertion depth of the communication ducts **11** and of the common outlet duct **9**. A certain inert gas pressure is finally adjusted in the containers. The pressure control valve **15** ensures that the inert gas pressure remains within certain limits. Should the pressure increase to excessively high values, said valve ensures that inert gas is blown off via outlet **16**; in the case of too low a gas pressure, it admits gas from the bottle **13**.

In normal operation, thermal energy is delivered to the sodium by the heat-accumulating material in the containers **4** via the heat transmission walls **5**, said sodium consequently evaporating and flowing in the vapour phase to the heater **2** due to the lower vapour pressure prevailing there as a result of a slightly lower temperature at that area. Sodium vapour condenses on the heater **2** while giving off thermal energy. Sodium condensate is then returned through the porous mass **6** to the heat transmission walls **5** of the container **4** to be evaporated there again. Return of condensate again takes place by capillary action.

The sodium-containing closed space **3** is otherwise evacuated. In operation, the sodium vapour pressure is considerably lower than 1 atm. Porous filling mass **17** not only maintains the containers **4** in their places but also supports the large wall surface of the closed space **3** against pressure forces excerted thereon from without, as a result of which the danger of implosion is prevented. The porous filling mass **17** also maintains the porous mass **6** in its place for the greater part so that the transport of sodium condensate does not experience any difficulties. I*b* — I*b* of FIG. 1*a*.

FIG. **2** shows a heating system which in outline is equal to that of FIG. **1**. Therefore, the same reference numerals are used for corresponding parts. In the present case, the containers **4** are not connected in series but in parallel, while the pressure control device **12** consists of an expansion vessel **20** which can be made to communicate with the common supply duct **7** via a duct **21** in which a cock **22** is incorporated. The expansion vessel **20** is filled with an inert gas which serves as a buffer.

When the pressure in the containers increases as a result of an increase in volume of the heat-accumulating material, for example, when changing from the solid phase into the liquid phase, the volume of the inert gas buffer is reduced. When the volume of the expansion vessel **20** is sufficiently large, the pressure in the containers remains substantially unvaried. The containers can now be filled simultaneously in a short period of time with liquid heat-accumulating material after evacuating the said containers. The further construction and operation of the present heating system are identical to those of the system shown in FIG. **1** so that description may be omitted.

It will be obvious from the above that the invention provides an interesting heating system which is fully independent of position and which can be assembled in a rapid and simple manner and be provided with heat-accumulating material.

What is claimed is:

1. In a heating system for supplying thermal energy to a heater of a hot gas engine, the system being operable with a supply of meltable, heat-accumulating material, and including: a housing having walls defining a closed space which encloses said heater and which has a heat receiving portion, a plurality of containers in said space, each containing said heat-accumulating material, and each having at least one heat transmission wall, a heat transporting medium in said space, which when in liquid receives thermal energy from said container through said walls and evaporates into a vapor which flows to said heater to which the thermal energy is transferred during condensation of said vapor thereon, a porous mass having a capillary structure on the outside of said heat transmission walls of said containers, and on the inside of the housing walls whereby said porous mass transports the heat transporting medium in the liquid state between the heater, the heat receiving portion of the housing and the containers, a common supply duct communicating said supply of heat-accumulating material through said housing wall to said containers within said housing, means for controlling flow of said material through said supply duct, and spacing means in said housing between and separating said containers, and between said containers and the housing walls, this spacing means being porous and permitting flow there through of said heat-transporting medium vapor.

2. A system according to claim **1** wherein said heat-accumulating material is L*i*F and said heat transporting medium is N*a*.

3. A heating system according to claim **1**, further comprising a pressure control device communicating in the said common supply duct for controlling the pressure in the containers.

4. A heating system according to claim **1**, wherein said spacing means are formed by a porous filling mass, the pores of which have larger diameters than the pores of said porous mass.

5. A heating system according to claim **4**, wherein the porous filling mass comprises compressed steel wool.

6. A system according to claim **2** wherein said spacing means are formed by a porous filling mass, the pores of which have larger diameters than the pores of said porous mass.

7. A system according to claim **2** wherein said porous filling mass comprises compressed steel wool.

8. A heat pipe system for supplying thermal energy to a heater of a hot gas engine, the system being operable with a supply of meltable, heat-accumulating material, and comprising a housing having walls defining a closed space which encloses said heater and which has a heat receiving portion, a plurality of containers in said space, each containing said heat-accumulating material, and each having at least one heat transmission wall, a heat transporting medium in said space, which when in liquid receives thermal energy from said container through said walls and evaporates into a vapor which flows to said heater to which the thermal energy is transferred during condensation of said vapor thereon, a porous mass having a capillary structure on the outside of said heat transmission walls of said containers and on the inside of the housing walls whereby said porous mass transports the heat transporting medium in the liquid state between the heater, the heat receiving portion of the housing and the containers, a common supply duct communicating said supply of heat-accumulating material through said housing wall to said containers within said housing, means for controlling flow of said material through said supply duct, and spacing means in said housing between and separating said containers, and between said containers and the housing walls, this spacing means being porous and permitting flow there through of said heat-transporting medium vapor.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,817,322 Dated June 18, 1974

Inventor(s) George Albert Apolonia Asselman ET AL

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

In "The Foreign Application Priority Data" the number should read --7114471--

Signed and sealed this 8th day of October 1974.

(SEAL)
Attest:

McCOY M. GIBSON JR.
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents