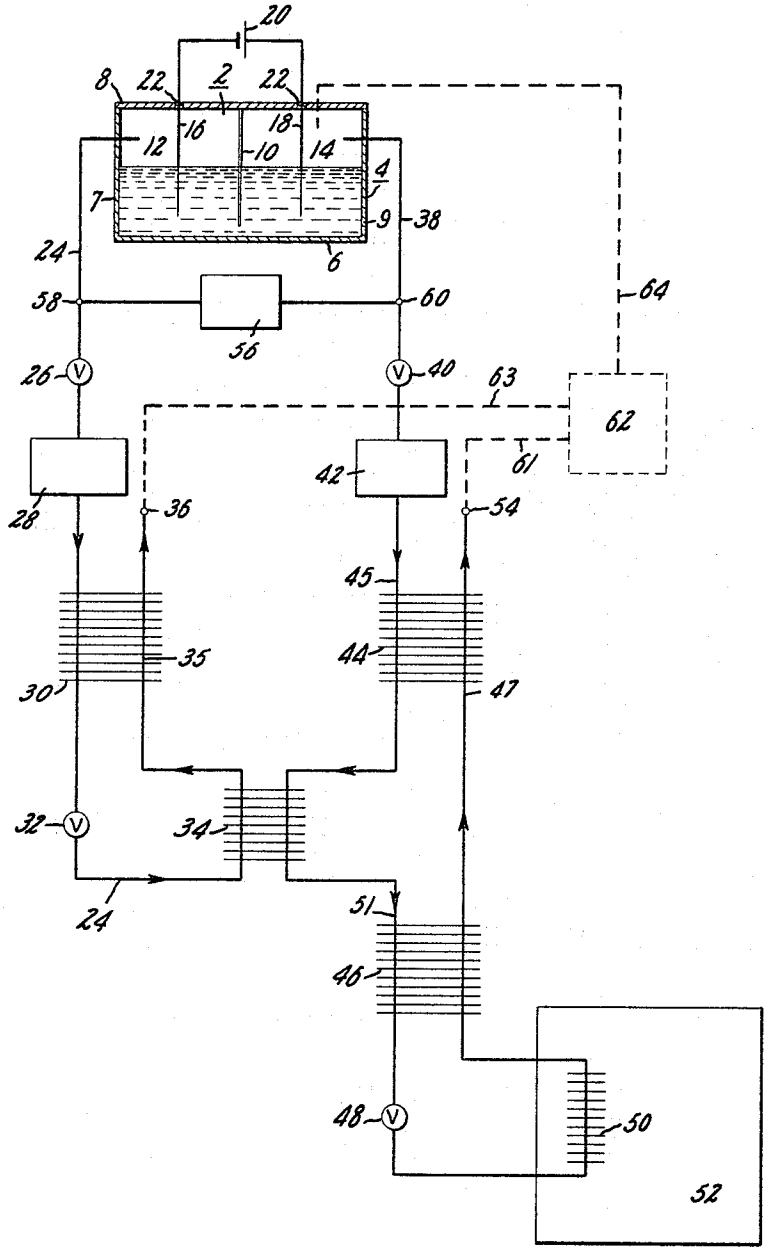
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REFRIGERATION SYSTEM

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Inventor:
Loyd B. Nesbitt,
by Paul A. Frank
His Attorney.

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REFRIGERATION SYSTEM

Loyd B. Nesbitt, Alplaus, N.Y., assignor to General Electric Company, a corporation of New York

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My invention relates to a low temperature refrigeration system and more particularly to a compact portable low temperature refrigeration system composed essentially of stationary immovable parts.

With the widening use of refrigeration systems in a multitude of applications, especially those where weight and reliability are important as when the system is to be used in inaccessible areas, a refrigeration system is needed which is composed entirely of stationary parts so that the inherent unreliability of moving parts is eliminated. Refrigeration systems presently employed, especially those operating at low temperatures, in the vicinity of 77° K. and below, require the use of moving parts such as pumps, motors and compressors and thereby are readily subject to failure if any moving part malfunctions. Such a malfunction, when the system is essential to the proper operation of other equipment, could lead to serious and possibly irreparable damage to that equipment. Also, in many locations where refrigeration systems are employed, the possibility of repairing a moving part is almost impossible, due to the inaccessibility of these locations to proper repair equipment. Therefore, because of the moving parts presently employed in refrigeration systems, especially low temperature refrigeration systems, the use of these systems in applications where portability in combination with reliability are required, is limited. A refrigeration system is then needed that is capable of operating at temperatures as low as 20° K. by being composed substantially of stationary parts so that the need for the conventional moving parts normally used in refrigeration systems is essentially eliminated, and thus the reliability of the refrigeration system is greatly improved. My invention envisions a refrigeration system which produces cooling by the expansion of high pressure gas, which gas is formed by electrolytic action, so that cooling is provided in a system which employs substantially no moving parts.

The chief object of my invention is the provision of an improved portable refrigeration system composed essentially of stationary parts.

Another object of my invention is the provision of such a system which produces cooling by the use of high pressure gas formed by electrolytic action.

A further object of my invention is the provision of such a system which operates reliably at low temperatures.

These and other objects of my invention will be more readily perceived from the description which follows:

In carrying out the objects of my invention, I provide a highly reliable portable refrigeration system which is essentially composed of stationary parts. The working media for the system, high pressure oxygen and hydrogen, are generated by the decomposition of water in an enclosed portable electrolytic cell. Hydrogen, the basic cooling agent which acts to absorb heat from the object to be cooled, and oxygen which travels in a path separate from the hydrogen, acts to cool the hydrogen and lower its temperature sufficiently so that the system functions properly. The oxygen is cooled, expanded and passed in heat transfer relationship with the hydrogen, that has also been cooled, to absorb heat from the hydrogen and thereby lower its temperature. The temperature of the hydrogen is still lowered further and then it is passed in heat transfer relation with the refrigeration load to be cooled. The hydrogen and oxygen after they have served their

cooling function are still at a sufficiently low temperature and are used to cool their respective incoming gases which then may be vented to the atmosphere or recombined to form water in a manner which produces usable energy therefrom.

The attached drawing illustrates a diagrammatical view of a preferred embodiment of the refrigeration system of my invention.

In the drawing there is shown a schematic view of a refrigeration system embodying my invention which is composed of stationary parts.

The construction of my refrigeration system includes a compact electrolytic decomposition cell composed of an enclosed chamber **4** constructed of a material, such as steel, which is not affected by the decomposition process taking place in the cell. Chamber **4** comprises lower section **6**, which is generally cubic in shape, covered by lid **8** to form a completely enclosed unit. A thin sheet of asbestos or other suitable insulating material forms a barrier **10** therein which extends across chamber **4** to divide it into compartments **12** and **14** but projecting through cover **8** and into chambers **12** and **14** respectively, are electrodes **16** and **18**. The electrodes are connected to a suitable source of direct current electrical energy. If the system is to be portable, a battery **20** is employed as a source of voltage for the electrolytic decomposition process. For example, battery **20** is connected by suitable electrical leads to electrodes **16** and **14**, as will subsequently be described, to effectuate the electrolytic process. Suitable seal means **22** is provided at the point where electrodes **16** and **18** pierce cover **8** of chamber **4** so that the contents of chamber **4** are not accidentally spilled therefrom. Also, suitable fastening means may be provided to secure cover **8** to chamber **40** so that, in a like manner, the contents of chamber **4** are also not discharged inadvertently therefrom.

From electrolytic cell **2** hydrogen and oxygen travel through two separate, but interrelated paths to provide the requisite cooling to the system. Beginning with the oxygen system: tubular member or passageway **24** projects through wall **7** from chamber **12** of the electrolytic cell to lead into a suitable pressure regulator **26**. From pressure regulator **26**, tube **24** passes into cleaning and drying means **28** so that the gas passing through tube **24** is in proper condition to be used for the refrigeration process. Tube **24** then passes through heat exchanger **30**, into expansion valve **32**, into exchanger **34**, where it is in heat transfer relationship with the hydrogen path and back through heat exchanger **30** to a point **36** where the gas is either discharged to the atmosphere or reused, as will subsequently be described.

The hydrogen path in a like manner as the oxygen path begins with tubular member or passageway **38** projecting from the interior of chamber **14** through wall **9**, and through pressure regulator **40** which is preferably similar to pressure regulator **26** of the oxygen path. The gas then passes into cleaner and dryer **42**, through heat exchanger **44** and into heat exchange relationship with the gas flowing in tube **24**, by means of heat exchanger **34** as aforementioned. Heat is thereby transferred from the hydrogen gas flowing within tube **38** to the oxygen gas flowing within tube **24** to lower the temperature of the hydrogen gas. After passing through heat exchanger **34**, tube **38** passes through another heat exchanger **46**, into expansion valve **48** and into heat exchange relationship by means of heat exchanger **50** with load **52** that is the object desired to be cooled. After the cooling is effectuated, the hydrogen gas in tube **38** passes back through both heat exchangers **46** and **44** to arrive at point **54** which corresponds to point **36** in the oxygen half of the system, wherein the gas within tube **38** is either discharged to the atmosphere or reused, as will be discussed.

A suitable differential pressure regulator 56 is connected between tube 24 and tube 38 at points 58 and 60, respectively, which are located between the electrolytic cell and the pressure regulating valves 26 and 40 so that the pressure relationship between the oxygen and hydrogen paths and thereby the efficiency of the system is properly maintained. Heat exchangers 30, 34, 44, 46 and 50 are shown as composed of suitable heat exchange fins, but it will be appreciated that any suitable heat exchangers may be employed, such as for example coils or other well known configurations to achieve the purposes of the present invention. Also, the material of these heat exchangers may be composed of copper, steel, aluminum or any of the other well known heat conducting materials.

In operation, water or other suitable decomposition liquid is placed within chamber 40 so that both compartments 12 and 14 contain proportional amounts thereof. Barrier 10 which separates compartments 12 and 14 preferably does not extend to bottom 6 of chamber 4 so that water or other liquid therein may readily seek the same level in both compartments to insure the proportional volumes therein. Alternatively a membrane may be provided which permits the passage of the liquid to the exclusion of the gas. A voltage, as by means of battery 20, is impressed across electrodes 16 and 18, located in compartments 12 and 14, respectively, to produce an electrical discharge which chemically breaks down the water to form hydrogen and oxygen. Hydrogen forms in chamber 14, adjacent electrode 18, which is connected to the positive end of battery 20 and oxygen forms in chamber 12 adjacent electrode 16 which is connected to the negative end of battery 20. Barrier 10 now serves the function of preventing the oxygen and hydrogen gases from remixing and thereby substantially interfering with the separate oxygen and hydrogen paths of the refrigeration system. The oxygen gas formed in compartment 12 flows out through tube 24 and the hydrogen gas formed in compartment 14 flows out through tube 38 to be employed in the refrigeration system. A sense of the pressure of both the oxygen and hydrogen travelling in passages 24 and 38 is input to differential pressure regulator 56 to maintain an interrelationship between the pressure of the oxygen and hydrogen paths so that the pressures are equivalent or substantially the same. The differential pressure regulator 56, which is of a standard variety, may be provided with a suitable pressure gauge so that any discrepancy from the desired pressure is readily observed. The oxygen then passes through pressure control 26 and the hydrogen through a similar pressure control 40, which adjust the respective individual pressures in accordance with any discrepancy in pressure from the desired pressure, as indicated by differential pressure regulator 56. Pressure regulators 26 and 40, which consist of suitable restrictions in the flow line, are preferably controlled by differential pressure regulator 56.

The oxygen gas passes from pressure regulator 26 into cleaning and drying means 28 and in a like manner the hydrogen gas passes from pressure regulator 40 into a cleaning and drying means 42. Suitable chemical absorbants are contained in these cleaning and drying means to absorb any water or other moisture in the flow lines, and also to remove any material foreign to the gases that might also be present therein. From gas cleaner and dryer 28 the oxygen flows through tubular member 24 and into heat exchanger 30 wherein its temperature is lowered in giving up heat to colder exiting oxygen gas which passes in the opposite direction through the same heat exchanger 30. A typical value of temperature for the oxygen entering heat exchanger 30 from cleaner and dryer 28 would be 300° K., whereas the temperature of the oxygen gas passing in the reverse direction through heat exchanger 30 along path 35 would be 93° K. Thus, it is seen that the incoming oxygen gas is readily cooled by passing in heat exchange relation with the exiting oxygen gas. The oxygen gas is thereby employed partially as its own cooling medium. The cooled oxygen gas now enters valve 32, which is an isenthalpic (Joule-Thompson) expansion valve, wherein it undergoes a substantial decrease in both temperature and pressure, at constant enthalpy. Typically the temperature might be 185° K. and the pressure 140 atmospheres at the entrance of valve 32 and 93° K. and 1.2 atmospheres at the exit thereof. The low pressure and temperature oxygen now flows through heat exchanger 34, which is located so that the oxygen cycle is brought into heat transfer relationship with the hydrogen cycle to employ the cooler oxygen to lower the temperature of the hydrogen so that the latter is at the proper temperature to cool the refrigeration load. Even though heat is absorbed from the hydrogen gas, the temperature and pressure of oxygen gas leaving heat exchanger 34 is substantially the same as upon entering. There may be a slight decrease in pressure because of an increase in volume of the gas or the frictional effect of travelling through the pipe but it is essentially unchanged. For example, a temperature of 93° K. entering heat exchanger 34 is maintained upon exiting and a pressure of 1.2 atmospheres would probably drop to 1.1 atmospheres. Thus, the conditions of temperature and pressure, as the oxygen leaves heat exchanger 34, are those with which the oxygen leaves heat exchanger 34 and enters heat exchanger 30. The temperature of the oxygen gas at this point is lower than the temperature of the oxygen about to enter heat exchanger 30 in the incoming line as aforementioned. Therefore, the temperature differential, as for example between a temperature of 93° K. and a temperature of 300° K., provides for a substantial cooling of the incoming oxygen by employing the exiting oxygen that has already served its primary function, of cooling the hydrogen gas. The oxygen gas now arrives at point 36 wherein it is alternatively exhausted to the atmosphere or recycled into the system to be reemployed, as will subsequently be explained.

The hydrogen, in a like manner as the oxygen, after passing through pressure control 40 and cleaner and dryer 42 passes through heat exchanger 44, wherein it is cooled by passing in heat transfer relationship with substantially colder exiting hydrogen, in the same manner as with heat exchanger 30 for the oxygen. For example, the temperature of the entering hydrogen at point 45 might be about 300° K. whereas the temperature of the exiting hydrogen at point 47, before it enters heat exchanger 44 would be about 92° K. The wide temperature differential causes a substantial flow of heat from the incoming hydrogen to the exiting hydrogen and thereby substantially cools the incoming hydrogen. The hydrogen then passes through heat exchanger 34 where heat is given up therefrom to the colder oxygen to cause the temperature of the hydrogen to drop to a temperature substantially equal to that of the oxygen. As an example, if the temperature of the oxygen incoming to heat exchanger 34 is 93° K. and the temperature of the incoming hydrogen is 105° K., the temperature of the hydrogen gas emanating from heat exchanger 34 would be reduced to the 93° K. temperature of the oxygen gas. In this example, approximately 14 joules per hour of heat are transferred across heat exchanger 34 to effectuate the cooling process.

The cooled hydrogen gas now passes through heat exchanger 46 where it passes in heat transfer relationship with somewhat colder hydrogen gas, that has already cooled the load, to thereby have its temperature reduced still further. For example, the temperature of the hydrogen incoming to heat exchanger 46 at point 51 would be about 93° K. and the same gas exiting therefrom would be about 78° K., so that the temperature of the incoming hydrogen gas has been substantially reduced by means of these series of heat exchangers. Hydrogen

gas now passes through a constant enthalpy expansion valve (such as a Joule-Thompson valve) to cause an isenthalpic expansion thereof. It is noted that with valve 48, as with valve 32, the key to successful operation is the reduction of temperature and pressure while enthalpy is kept constant. Many valves are presently known which achieve these results and any one that operates efficiently may be successfully employed with my refrigeration system. Typically, in passing through expansion valve 48, the temperature is reduced from 78° K. to 70° K. while the pressure is reduced from 140 atmospheres, which is the incoming pressure of the hydrogen, to 1.2 atmospheres. It will be appreciated at this point that with proper heat exchangers and expansion valves the temperature of the hydrogen leaving valve 48 could be reduced below 77° K., if desired.

The hydrogen gas exiting from the Joule-Thompson expansion valve then passes into heat transfer relationship, such as by means of heat exchanger 50, with load 52, which is the object desired to be cooled. Typically, with the values aforementioned, the system would have .001 watt or 3.6 joules per hour of net refrigeration. The hydrogen gas now passes back through heat exchanger 46 to pass in heat transfer relationship with the incoming hydrogen and thus absorb heat therefrom. As a typical example, the temperature of the hydrogen at point 53 incoming to heat exchanger 46 in the exiting part of the cycle is 77° K. and the temperature of the hydrogen at point 51 incoming to heat exchanger 46 is 93° K. This difference in temperature through the heat exchanger 46 causes a significant cooling of the incoming hydrogen for purposes of properly effectuating desired cooling of load 52.

In continuing the process, the exiting hydrogen passes through heat exchanger 44 wherein substantial amount of heat absorbed from the incoming hydrogen, as aforementioned, to effect substantial cooling thereof. The incoming hydrogen at point 45, for example, has a temperature of 300° K. and the exiting hydrogen entering heat exchanger 44 at point 47 has a temperature of 92° K., so that it is readily seen that the temperature of the incoming hydrogen is substantially reduced by the use of heat exchanger 44. The temperature of the exiting hydrogen after it leaves heat exchanger 44 is correspondingly increased because of the absorption of heat from the incoming hydrogen, so that typically it would be about 295° K. The hydrogen gas has now completed its function and arrives at point 54, where it is exhausted to the atmosphere in the same manner as with the oxygen at point 36, or alternatively is recombined by a suitable chemical process to reform water. As for instance, the oxygen from point 36 is passed through tube 63 into container 62 and similarly the hydrogen from point 54 is passed through tube 61 into the same container 62 wherein the two are chemically combined, as by burning or catalytic combination to produce the desired water and additionally some heat or power. The water may be transferred by means of pipe 64 from chamber 62 back to the electrolytic cell to be reused in the refrigeration process. It is noted that if the recombination process is not effectuated, and the oxygen and hydrogen are exhausted to the atmosphere, water must be periodically added to the electrolytic cell for proper functioning thereof.

Alternatively, the oxygen path is employed as the refrigeration system itself. One side of heat exchanger 34 is connected to the oxygen path as in the figure, and the other side is connected directly to the load to provide the cooling thereto. Thus the thermal drop across heat exchanger 34 refrigerates the load instead of cooling the separate hydrogen path as in the illustration. Operation of the oxygen path is in the same manner as aforementioned, and the hydrogen path is eliminated with the hydrogen gas being dissipated to the atmosphere or otherwise disposed of.

It is noted that in my refrigeration system, eight grams of oxygen are used for every one gram of hydrogen, which conveniently is also the same ratio of oxygen to hydrogen as normally produced in the electrolytic cell by the decomposition process.

It will be appreciated that my refrigeration system employs only stationary parts and has no moving parts which might lead to vibration, noise and the repair problems inherent therein. The system is light in weight and may be easily carried and made compact as desired. A typical use would be in the cooling of infrared detectors which require a portable refrigeration system for proper functioning.

It is noted that I have described typical values as to temperatures and pressures when using my refrigeration system, but it will be appreciated that these values are only exemplary of the many that may be employed for the successful operation thereof.

It will be apparent from the foregoing that my invention attains the objectives set forth. Apparatus embodying my invention is sturdy in construction and well adapted for use in conjunction with various environments. Because of the elimination of moving parts, refrigeration is accomplished in a highly reliable manner.

A specific embodiment of my invention has been illustrated but the invention is not limited thereto since many modifications may be made by one skilled in the art and the appended claims are intended to cover all such modifications as fall within the true spirit and scope of my invention.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. A refrigeration system comprising
a gas generating apparatus for producing at least two distinctive gases,
means for cooling one of these gases,
means for bringing these two gases in heat transfer relationship so that heat is passed between the two for substantially reducing the temperature of one, and
means for passing the gas having the reduced temperature into heat transfer relationship with the load desired to be cooled to effectuate that cooling.

2. A refrigeration system comprising
an electrolytic decomposition cell for producing gas when a source of voltage is impressed across it,
means for cooling that gas
means for passing the gas into heat exchange relationship with a load to be cooled.

3. A low temperature refrigeration system adapted to operate below 77° K. comprising
an electrolytic decomposition cell adapted to produce gas when connected to a source of voltage,
means for lowering the temperature of the gas and
heat exchange means for passing the low temperature gas into heat transfer relationship with the load to be cooled to effectuate cooling thereof to temperatures below 77° K.

4. A refrigeration system comprising
an enclosed sealed electrolytic decomposition cell which produces hydrogen and oxygen when a source of voltage is applied thereto,
means for cooling the oxygen gas,
heat transfer means for bringing the hydrogen and oxygen in heat exchange relationship so that heat is passed from warmer hydrogen gas to colder oxygen gas to substantially reduce the temperature of the hydrogen gas, and
means for passing the cold hydrogen gas into heat transfer relationship with a load to be cooled.

5. A refrigeration system comprising
an enclosed electrolytic decomposition cell, constructed so that liquid remains therein, and adapted to produce hydrogen and oxygen when a voltage source is connected thereto,

means through which the oxygen gas travels,
means through which the hydrogen gas travels,
expansion means for lowering the temperature of the oxygen,
heat exchange means for bringing the hydrogen and oxygen gases together in heat transfer relationship so that the colder oxygen gas serves to substantially reduce the temperature of the hydrogen gas, and
another heat exchange means for passing the cold hydrogen gas into heat transfer relationship with a load desired to be cooled to effectuate that cooling.

6. A refrigeration system comprising
a container enclosing an electrolytic decomposition cell which is adapted to produce hydrogen and oxygen, from water placed therein, upon the application of a source of voltage to the water,
a cover sealing said container so that the contents remain therein,
tubular means extending from said container to form a path through which oxygen formed in said container travels,
another tubular means through which hydrogen that is formed in said container travels,
isenthalpic expansion means to lower the temperature of the oxygen,
a first heat exchanger which interconnects both the tubular means through which the oxygen travels and the tubular means through which the hydrogen travels for bringing the two gases in heat exchanger relationship, so that heat is transferred from the warmer hydrogen to the colder oxygen to substantially reduce the temperature of the hydrogen, and
a second heat exchanger connected to said tubular means through which hydrogen gas flows to bring the hydrogen gas into heat transfer relationship with a load desired to be cooled to effectuate that cooling.

7. A refrigeration system comprising
an electrolytic decomposition cell adapted to produce hydrogen and oxygen gas when a voltage is applied to water contained therein, and
a barrier within said electrolytic cell that divides the cell into two compartments, one for hydrogen gas and one for oxygen gas,
a first passage means connected into the compartment of the electrolytic cell which is adapted to contain hydrogen to form a flow path for the hydrogen gas,
a second passage means connected into said compartment in said electrolytic cell that is adapted to contain oxygen gas to form a flow path for the oxygen gas,
an isenthalpic expansion valve connected to said second passage means which lowers the temperature of the oxygen therein,
a first heat exchanger which connects the two passage means so that they are in heat transfer relationship so that the colder oxygen absorbs heat from the warmer hydrogen to effectively impart cooling thereto, and
a second heat transfer means connected into the hydrogen flow path downstream of said heat exchange and

proximate a load desired to be cooled so that hydrogen gas is passed in heat transfer relationship with the load to thereby effectuate the cooling thereof.

8. A refrigeration system comprising
an electrode adapted to be connected to the positive terminal of a voltage source,
another electrode adapted to be connected to the negative terminal of a voltage source,
an electrolytic decomposition cell adapted to contain water
a barrier within said cell that divides the cell into two compartments, and wherein water is permitted to flow therethrough,
a cover for sealing said electrolytic cell,
a first passage means, extending from said compartment that is adapted to contain oxygen, to form a flow path for the oxygen,
a second passage means, extending from said compartment that is adapted to contain hydrogen, to form a flow path for the hydrogen,
a first heat exchanger interconnecting the two passage means so that the colder oxygen gas is brought into heat transfer relationship with the warmer hydrogen gas to effect cooling thereof,
a second heat exchanger interconnecting said first passage means before it enters said first heat exchanger with said first passage means after it leaves said first heat exchanger for cooling the oxygen therein,
a first isenthalpic valve in the flow path of the oxygen to reduce the temperature thereof before it enters said first heat exchanger,
a second isenthalpic valve in the flow path for the hydrogen to further cool the hydrogen, after it leaves said first heat exchanger to further cool the hydrogen gas, and
heat transfer means located downstream of said isenthalpic valve in said passage adapted to contain hydrogen to place the hydrogen gas in heat transfer relationship with the load to be cooled.

9. A refrigeration system as in claim 8 wherein a third heat exchanger interconnects said second passage means after it leaves said first heat exchanger with said second passage means after it cools said load to further cool the hydrogen gas therein.

10. A refrigeration system as in claim 8 in which a differential pressure regulator is provided in combination with pressure controls in both the hydrogen and oxygen flow paths to insure the desired relationship between the two gases.

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WILLIAM J. WYE, *Primary Examiner.*