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[54] CONCENTRATION CONTROL FOR MULTIPLE STAGE ABSORPTION REFRIGERATION SYSTEMS

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[58] **Field of Search**.....62/101, 103, 141

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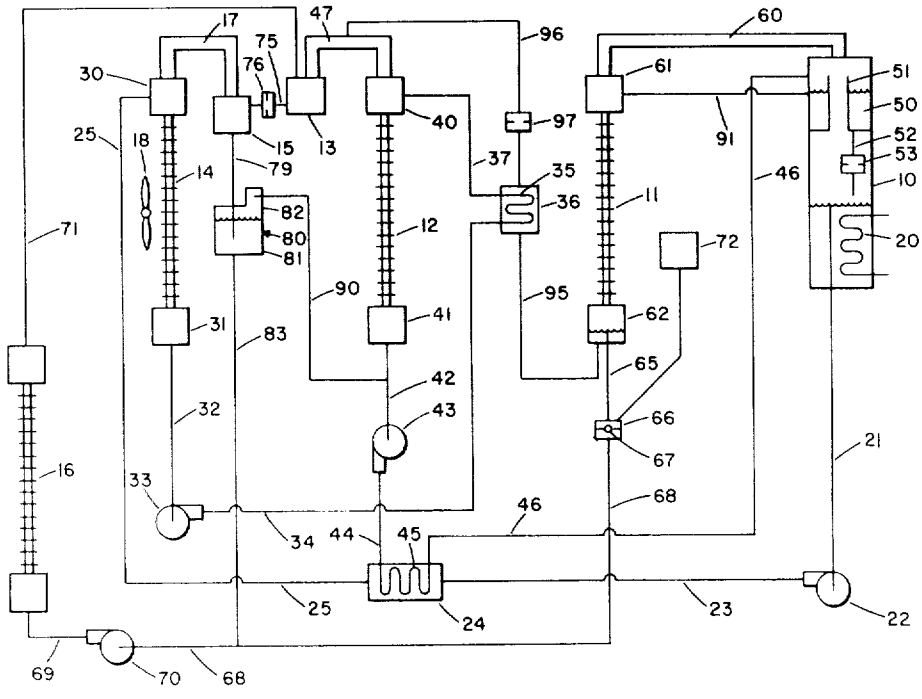
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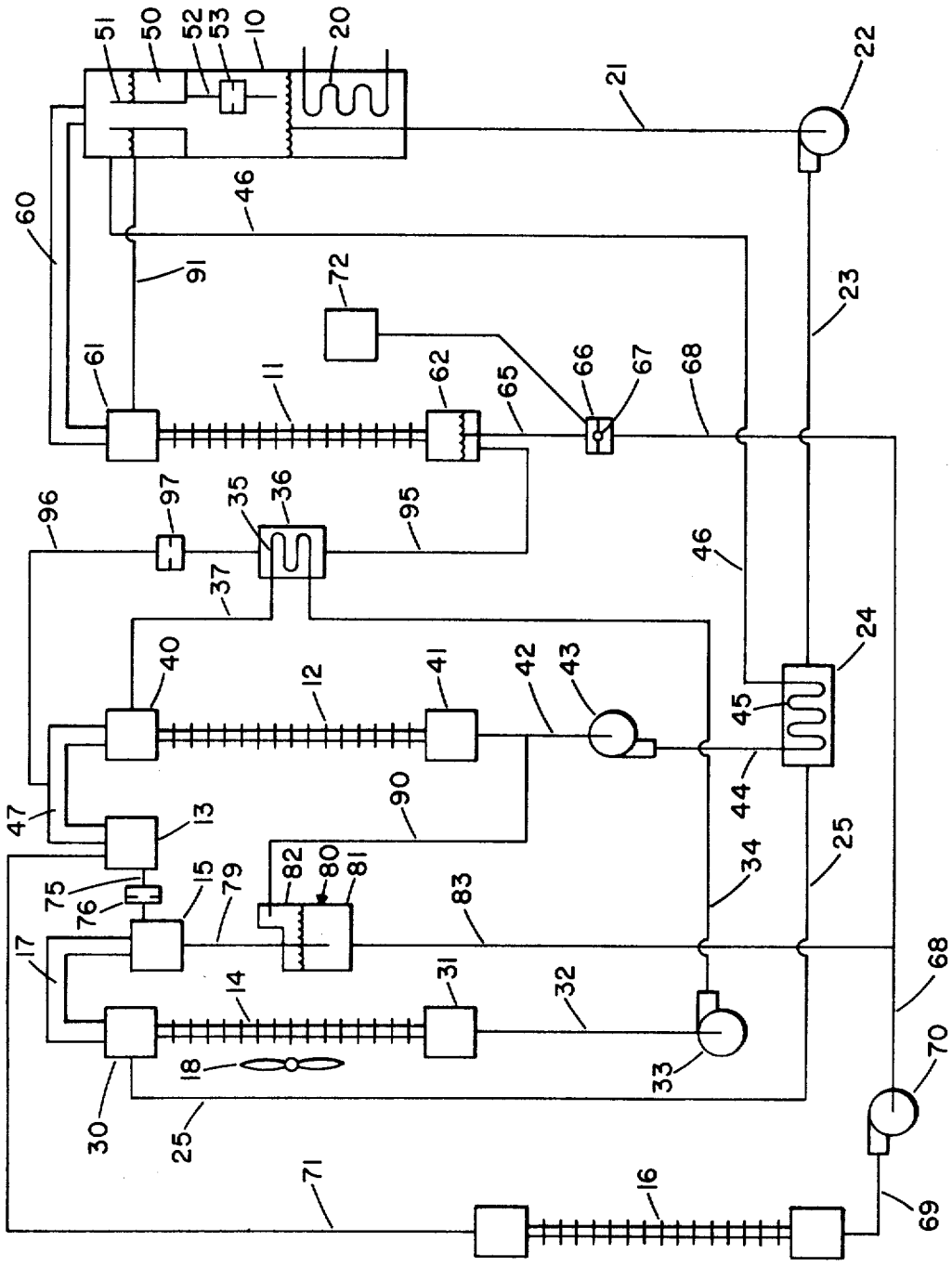
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[57] **ABSTRACT**

A two-stage air cooled lithium bromide absorption refrigeration system having a generator, a refrigerant condenser, a high pressure absorber coupled with a high temperature evaporator, a low pressure absorber coupled with a low temperature evaporator and an air conditioning fan coil unit for passing cooled refrigerant in heat exchange with ambient air is provided with a concentration control system for automatically diluting the absorbent solution under conditions of either low ambient temperatures or an inadequately purged low pressure absorber. The concentration control includes a refrigerant storage tank connected directly to the refrigerant condenser. Intermediate strength absrobent solution discharged from the low pressure absorber is passed through a heat exchanger in the refrigerant storage tank, in heat exchange relation with refrigerant therein, to the high pressure absorber. A refrigerant overflow passage is provided from a refrigerant sump to a location containing absorbent solution. Ambient air passes serially over the low pressure absorber and then over the refrigerant condenser so that when the low pressure absorber is poorly purged or the ambient air temperature is relatively low, these events will be reflected by a drop in the intermediate solution temperature passing through the refrigerant storage tank and a simultaneous drop in the condensing temperature. Consequently, the difference in pressure between the refirgerant storage tank and the condenser will drop and refrigerant will pass into the system from the storage tank and will cause the refrigerant level in the sump to overflow into absorbent soulution through the refrigerant overflow passage to prevent solidification.

5 Claims, 1 Drawing Figure





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CONCENTRATION CONTROL FOR MULTIPLE STAGE ABSORPTION REFRIGERATION SYSTEMS

BACKGROUND OF THE INVENTION

This invention relates to a concentration control for a multiple stage absorption refrigeration system.

Air cooled absorption refrigeration systems are subject to sudden and widely varying changes in the temperature of air passing over the absorber. In systems of the type utilizing lithium bromide as an absorbent solution, it is necessary to restrict the concentration of the absorbent solution so that it will not solidify under normally encountered operating temperatures. However, the existence of even relatively small quantities of noncondensible gases in the absorber reduces the absorption of refrigeration into absorbent solution which may result in solidification of the relatively undiluted solution in the absorber.

Because of the possibility of solidification of the absorbent solution in an air cooled system, it has been necessary to provide some type of concentration control which is effective to limit the concentration of the solution under those conditions where the danger of solidification is imminent. It has, therefore, been previously proposed to provide a refrigerant storage tank having an internal pressure which is a function of the absorber cooling medium temperature and arranged so that refrigerant is discharged from the tank into absorbent solution to prevent solidification thereof upon a drop in ambient cooling medium temperature. It has been discovered, however, that passing absorber cooling air directly over the exterior of a refrigerant storage tank may result in a sluggishly responding dilution control because the effective heat transfer coefficient between air and the refrigerant is relatively low, and it becomes necessary to utilize a relatively large amount of heat transfer surface to obtain the desired speed of response. It has also been discovered that in a multiple stage absorption refrigeration system using relatively strong solution in the low pressure absorber stage, the danger of solidification is surprisingly greater in the intermediate solution passage between the low pressure absorber and the high pressure absorber than in the strong solution passage or the solution heat exchanger, which are the locations most prone to solidification in conventional refrigeration systems. Consequently, the concentration control should be directly responsive to the condition of the intermediate solution for most effective operation.

It is an object of this invention to provide an improved concentration control, specifically designed for use with multiple stage absorption refrigeration systems, which is more responsive and more effective than prior systems.

SUMMARY OF THE INVENTION

A multiple stage absorption refrigeration system having a generator, a refrigerant condenser, a low temperature evaporator, a low pressure absorber, a high temperature evaporator and a high pressure absorber is provided with a concentration control arrangement which includes a refrigerant storage tank, a refrigerant sump, a refrigerant overflow passage and means for passing cooling medium first in heat exchange relation with absorbent solution in the low pressure absorber and then in heat exchange relation with refrigerant vapor in the refrigerant condenser. The refrigerant storage tank is connected by a refrigerant condensate passage to receive sufficient liquid refrigerant from the condenser to balance the difference in pressure between the tank and the condenser. Intermediate strength absorbent solution is passed from the low pressure absorber through the refrigerant storage tank, in heat exchange relation with refrigerant therein, to the high pressure absorber.

When either the absorber ambient temperature drops or when absorption of refrigerant vapor in the low pressure absorber is reduced for any reason, such as the accumulation of noncondensible gases, the temperature of the cooling medium passing from the low pressure absorber to the condenser is reduced which reduces the condensing temperature. At the same time, the temperature of the intermediate solution passing through the refrigerant storage tank is reduced due to less heat of dilution and condensation being absorbed by the solution in the absorber or due to increased cooling by a lower cooling medium temperature. However, because the condenser is at a higher temperature, its pressure drops faster than that of the refrigerant tank. Consequently, the difference in pressure between the refrigerant storage tank and the condenser is reduced and the level of refrigerant in the tank drops. The refrigerant discharged from the tank causes the level of refrigerant in the refrigerant sump to rise, which in turn causes refrigerant to overflow into absorbent solution to dilute it, thereby reducing the likelihood of solidification occurring.

When the absorber becomes completely purged or when the ambient temperature again rises, the difference in pressure between the condenser and the refrigerant storage tank will rise so that refrigerant is supplied to the tank from the condenser to balance the pressure difference until it is again needed for dilution.

A concentration control in accordance with this invention provides much faster response with reduced heat transfer surface due to the higher coefficient of heat transfer obtainable between the intermediate solution and the refrigerant, thereby reducing the cost of the system. Further, the system is extremely sensitive to changes in the temperature of the intermediate solution which, it has been discovered, is a more reliable precursor of solidification in a multiple stage absorption refrigeration system than other system conditions previously suggested.

BRIEF DESCRIPTION OF THE DRAWING

The drawing is a schematic illustration of an absorption refrigeration system embodying a concentration control in accordance with this invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

A generator **10**, a refrigerant condenser **11**, a high pressure absorber **12**, a high pressure refrigerant evaporator **13**, a low pressure absorber **14** and a low pressure evaporator **15** are connected in the illustrated embodiment to provide an absorption refrigeration system. In the system illustrated, two evaporator stages of the adiabatic type are employed, which directly cool the refrigerant liquid by evaporating a portion of the

refrigerant and the remaining cooled refrigerant passes through an air conditioning heat exchanger **16** such as a fan coil unit to directly cool air being conditioned. Direct expansion or conventional spray type evaporators may be used with suitable modifications in the system. Also, more than two stages of evaporation and absorption may likewise be employed.

Water is employed as the refrigerant and an aqueous solution of lithium bromide is employed as the absorbent although other absorbent refrigerant combinations may be utilized. As used herein, "strong solution" refers to a concentrated absorbent solution which is strong in absorbing power and "weak solution" refers to a diluted absorbent solution which is weak in absorbing power. "Intermediate solution" is used to designate absorbent solution which is intermediate in absorbing power between that of strong and weak solution and, in particular, to designate the absorbent solution passing from the low pressure absorber to the high pressure absorber. In the illustrated system, the refrigerant condenser and the absorbers are illustrated as being of the air cooled type but other cooling media such as water may be employed by suitably modifying the heat exchanger constructions.

A quantity of absorbent solution in the bottom of generator **10** is boiled by passing a suitable heat source such as steam, hot liquid or flue gas from a fuel burner through heat exchanger **20** in heat exchange relation with the solution. The strong solution formed in generator **10** by vaporization of refrigerant therefrom passes through strong solution passage **21**, pump **22**, the outside passage of heat exchanger **24** and strong solution passage **25** to the upper header **30** of low pressure absorber **14**. The strong solution flows downwardly through a plurality of heat exchange tubes joined by headers **30, 31** forming low pressure absorber **14**, in contact with refrigerant vapor passed to absorber **14** through vapor passage **17** from low temperature evaporator **15**. The absorbent solution is cooled in absorber **14** by passing a cooling medium such as ambient air by fan **18** over the exterior of the heat exchange tubes of absorber **14**. Refrigerant vapor from low temperature evaporator **15** is absorbed into the strong solution as it passes downwardly through the tubes of low pressure absorber **14**, thereby diluting the strong solution and forming an intermediate strength solution which collects in lower header **31**. The cooling medium absorbs the heat of condensation and heat of dilution introduced by the absorption of refrigerant vapor into the solution and assists the absorption process by cooling the solution to a low vapor pressure.

The intermediate solution passes through intermediate solution passage **32**, intermediate solution pump **33**, intermediate solution passage **34**, heat exchanger **35** in refrigerant storage tank **36** and intermediate solution passage **37** into upper header **40** of high pressure absorber **12**. The intermediate solution passes downwardly through the heat exchange tubes of high pressure absorber **12** while being cooled by passage of ambient air thereover, and absorbs additional refrigerant vapor passed from high temperature evaporator **13** through vapor passage **47**. The resulting weak solution is collected in weak solution header **41** and passes through weak solution passage **42**, weak solution pump **43**, weak solution passage **44**, the interior passage **45** of solution heat exchanger **25** and weak solution passage **46** to weak solution sump **50**.

Weak solution sump **50** is preferably located above the heating portion of generator **10** and may be of annular shape surrounding a tubular vapor passage **51** for refrigerant vapor formed in the generator. The weak solution passes from sump **50** by gravity through weak solution passage **52**, having a suitable restriction **53**, and is discharged into the heating section of generator **10** for reconcentration therein.

Refrigerant vapor formed in generator **10** passes upwardly through tubular vapor passage **51** and refrigerant vapor passage **60** to the vapor header **61** of condenser **11**. Condenser **11** may comprise a plurality of vertical heat exchange tubes connected by upper and lower headers located adjacent low pressure absorber **14**. While only one refrigerant condenser is illustrated, the system may embody one or more additional parallel connected refrigerant condensers such as one located adjacent high pressure absorber **12** and may employ an additional fan to pass air over high pressure absorber stage **12** and the other condenser section.

Air or other cooling medium is moved by fan **18** or other means so that it passes first over low pressure absorber **14** and then over refrigerant condenser **11** whereby the condensing temperature in condenser **11** is a function of both the ambient air temperature and the heat rejected from the low pressure absorber. Air passing over condenser **11** cools refrigerant vapor therein causing the refrigerant to condense and collect in liquid header **62**. Liquid refrigerant passes through condensate passage **65** to a condensate sump **66** containing a refrigerant metering float valve **67**. The refrigerant condensate then passes through condensate passage **68** and is pumped by refrigerant pump **70** through refrigerant passage **69**, air conditioning heat exchanger **16** and refrigerant passage **71** into the high temperature evaporator **13**.

Refrigerant is evaporated in high temperature evaporator **13**, thereby cooling the remaining liquid refrigerant. The partially cooled refrigerant passes refrigerant passage **75** containing restriction **76** into low temperature evaporator **15**. Additional refrigerant is evaporated from the refrigerant low temperature evaporator **15**, thereby cooling the remainder of the liquid refrigerant. The cold liquid refrigerant passes through refrigerant passage **79** into refrigerant sump **80** having a large cross sectional area, lower section **81** and a small cross sectional area upper section **82**. The cold refrigerant passes from sump **80** through refrigerant passage **83** and mixes with condensate in passage **68** where it cools the condensate and the cold mixture is pumped through air conditioning heat exchanger **16** by refrigerant pump **70**.

A refrigerant overflow passage **90** extends from the small cross section portion **82** of refrigerant sump **80** at a predetermined level therein above the normal refrigerant level, to weak solution passage **42** or some other location containing absorbent solution, preferably at a lower elevation. A solution overflow passage **91** extends from refrigerant sump **50** at a level above the normal solution level to upper header **61** of condenser **11** or other location containing refrigerant. Under low ambient temperature conditions, the level of absorbent solution will rise in sump **50** and will over-

flow into condenser **11** to reduce the vapor pressure of the refrigerant in the system so as to prevent freezing thereof and maintain a constant evaporator temperature. When ambient temperature rises, after the refrigerant has been diluted with absorbent, the level of diluted refrigerant in sump **80** will rise sufficiently to overflow through passage **90** into the weak solution until most of the absorbent solution has been removed from the refrigerant or until the refrigerant is sufficiently concentrated to provide the desired capacity at the higher ambient temperature condition. Refrigerant overflow passage **90** also serves as a portion of the concentration control system as will be subsequently described.

Refrigerant storage tank **36** is connected by a refrigerant condensate passage **95** comprising a depending loop or trap. Tank **36** may be vented by a passage **96** having restriction **97** therein to one of the absorbers to prevent the accumulation of noncondensible gases at the top of the tank. The passage **96** must be highly restricted so that no substantial amount of refrigerant vapor passes therethrough and may comprise a capillary tube instead of restrictor **97**.

In accordance with this invention, weak solution is passed directly through the heat exchanger **35** in the refrigerant storage tank **36** in heat exchange relation with liquid refrigerant therein. Consequently, the temperature and pressure of refrigerant in tank **36** is directly related to the temperature of the intermediate solution passing between low pressure absorber **14** and high pressure absorber **12**. The condensing temperature and pressure in condenser **11** are also directly related to the heat rejected from low pressure absorber **14** because the air or other cooling medium passes in series from low pressure absorber **14** to refrigerant condenser **12**. Accordingly, a quantity of liquid refrigerant will accumulate in tank **36** from liquid header **62** which is just sufficient to balance the condensing pressure with the pressure and liquid head in tank **36**.

If noncondensible gases accumulate in absorber **14**, less refrigerant vapor will be absorbed into the solution in the absorber. This will result in less heat of condensation and heat of dilution being present in the intermediate solution. Consequently, the heat rejected from the absorber will be reduced and the intermediate solution will be cooled to a lower than normal temperature by the air or other cooling medium used to cool the absorber. Under these conditions there is a possibility of solidification of the intermediate absorbent solution occurring unless the concentration of the solution is reduced. The temperature and pressure of refrigerant in tank **36** will also be reduced because it is in heat exchange relation with the cooler intermediate solution. At the same time, the condensing temperature of condenser **11** will drop because the lessened heat rejection from low pressure absorber **14** will result in cooler air passing over condenser **11**. As the temperature in both tank **36** and condenser **11** drops, the difference in pressures therebetween will be reduced and less liquid head in tank **36** will be required to balance this new pressure difference. Consequently, refrigerant will flow out of tank **36** through condensate passage **95** into header **62** of the condenser and will be discharged through metering device **67** into refrigerant passage **68** until the lower pressure difference is balanced by the head of refrigerant in tank **36**. The increased volume of refrigerant circulating in the system will eventually be reflected in a rise of the level of refrigerant in refrigerant sump **80**. When the refrigerant in sump **80** reaches the level of overflow passage **90**, it will overflow into the weak solution passage **42** to dilute the solution in sump **50**. Eventually, all of the absorbent solution in the system will be diluted by the refrigerant overflowing through passage **90**, so that the concentration of the intermediate solution will be reduced sufficiently to prevent solidification occurring.

After the low pressure absorber is completely purged, the additional refrigerant vapor being absorbed therein will increase the temperature of the intermediate solution passing through tank **36** and the increased absorber heat rejection will increase the temperature of air passing over condenser **11**. As the temperature of both the condenser and the refrigerant storage tank rise, the pressure difference between them will become greater and refrigerant will pass from header **62** to tank **36** until the increased pressure difference is balanced by the liquid head of refrigerant in the tank. Refrigerant storage tank **36** will then remain substantially full of liquid refrigerant until some other condition occurs requiring dilution.

The concentration control system described is also effective in the event of a sudden drop in ambient air temperature to prevent solidification of the absorbent solution. Under these conditions, both the temperature in absorber **14** and condenser **11** will drop which will result in the pressure difference between tank **36** and absorber **11** being reduced. The reduced pressure difference between tank **36** and condenser **11** will cause refrigerant to flow out of tank **36** through passage **95** and eventually through overflow passage **90** into absorbent solution to prevent solidification under conditions of lower ambient temperatures than the system is normally designed to accommodate.

It has been found in accordance with this invention that the direct passage of intermediate solution through refrigerant storage tank **36** results in extremely rapid response to changes in absorber conditions without the necessity of employing a large or costly amount of heat transfer surface in the tank. Intermediate solution pump **33** can create substantial intermediate solution velocities in heat exchanger **35** and, consequently, a relatively high heat transfer coefficient is obtained which allows a relatively small size heat exchanger to provide the desired speed of response.

It has also been discovered that the temperature of the intermediate solution is an especially accurate precursor of imminent solidification in a multiple stage system and is, therefore, more effective in controlling the dilution of the machine than other system temperatures.

While the preferred embodiment of this invention has been described, it will be appreciated that the invention may be otherwise embodied in the scope of the following claims.

I claim:

1. An absorption refrigeration system comprising:

A. a generator for concentrating absorbent solution by heating the solution and vaporizing refrigerant therefrom;

B. a refrigerant condenser for condensing refrigerant vapor formed in the generator;

C. a low temperature evaporator for evaporating refrigerant at a relatively low temperature to produce a refrigeration effect;

D. a low pressure absorber for absorbing refrigerant vapor evaporated in the low temperature evaporator into absorbent solution;

E. a high temperature evaporator for evaporating refrigerant at a relatively higher temperature to produce a refrigeration effect;

F. a high pressure absorber for absorbing refrigerant vapor evaporated in the high temperature evaporator into absorbent solution; and

G. means to serially pass a cooling medium in heat exchange relation with absorbent solution in said low pressure absorber and thence into heat exchange relation with refrigerant in said condenser;

wherein the improvement comprises:

H. concentration control means for varying the concentration of absorbent solution in the system, said concentration control means including:

1. a refrigerant storage tank for accumulating and discharging liquid refrigerant;

2. concentration control passage means in said system, including refrigerant condensate passage means directly connecting said refrigerant storage tank with said condenser for passing sufficient liquid refrigerant from the condenser to said refrigerant storage tank to automatically balance the pressure in said condenser with the pressure and liquid head of refrigerant in the storage tank, and overflow passage means for passing liquid refrigerant into absorbent solution for mixture therewith when refrigerant is discharged from said refrigerant storage tank; and

3. intermediate solution passage means for passing intermediate strength absorbent solution from said low pressure absorber in direct heat exchange relation with refrigerant in said refrigerant storage tank to said high pressure absorber, whereby the pressure in said refrigerant storage tank is a function of the temperature of said intermediate solution, and the quantity of refrigerant stored in said storage tank and the dilution of the absorbent solution automatically varies as a function of the difference between the condensing temperature and the intermediate solution temperature of said system.

2. An absorption refrigeration system as defined in claim 1 wherein said overflow passage means includes a refrigerant overflow passage extending from a refrigerant sump to a location in said system containing absorbent solution, and said refrigerant storage tank is located in said system so that discharge of refrigerant from said refrigerant storage tank causes the level of refrigerant in said refrigerant sump to rise and overflow through said refrigerant overflow passage into said location containing absorbent solution and to mix with the absorbent solution.

3. An absorption refrigeration system as defined in claim 1 including a restricted vent passage for venting relatively noncondensible gases from said refrigerant storage tank to a low pressure region in the system.

4. An absorption refrigeration system as defined in claim 1 wherein said refrigerant condensate passage means comprises a depending loop connecting the liquid header of the condenser with the refrigerant storage tank.

5. A method of producing refrigeration and operating an absorption refrigeration system having a generator, a refrigerant condenser, a low temperature evaporator, a low pressure absorber, a high temperature evaporator, a high pressure absorber, and a refrigerant storage tank, which comprises:

A. heating weak absorbent solution in the generator to concentrate it by vaporizing refrigerant therefrom;

B. condensing in the refrigerant condenser refrigerant vapor formed in the generator;

C. evaporating liquid refrigerant in the high temperature evaporator and in the low temperature evaporator to produce refrigeration;

D. absorbing refrigerant vapor formed in the high pressure absorber, and absorbing refrigerant vapor formed in the low temperature evaporator into absorbent solution in the low pressure absorber;

E. passing a cooling medium serially into heat exchange relation with absorbent solution in the low pressure absorber and then into heat exchange relation with refrigerant vapor in said refrigerant condenser;

wherein the improvement comprises:

F. passing liquid refrigerant from the refrigerant condenser to the refrigerant storage tank in an amount sufficient to balance the pressure difference between the refrigerant condenser and the storage tank;

G. varying the quantity of refrigerant stored in the refrigerant storage tank by passing intermediate strength absorbent solution from the low pressure absorber to the high pressure absorber in heat exchange relation with refrigerant in the storage tank to thereby vary the refrigerant pressure in the tank; and

H. mixing liquid refrigerant with absorbent solution to dilute the absorbent solution by overflowing liquid refrigerant from a location containing refrigerant into a location containing absorbent solution upon discharge of refrigerant liquid from the refrigerant storage tank due to a drop in the pressure difference between said refrigerant condenser and said refrigerant storage tank.

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