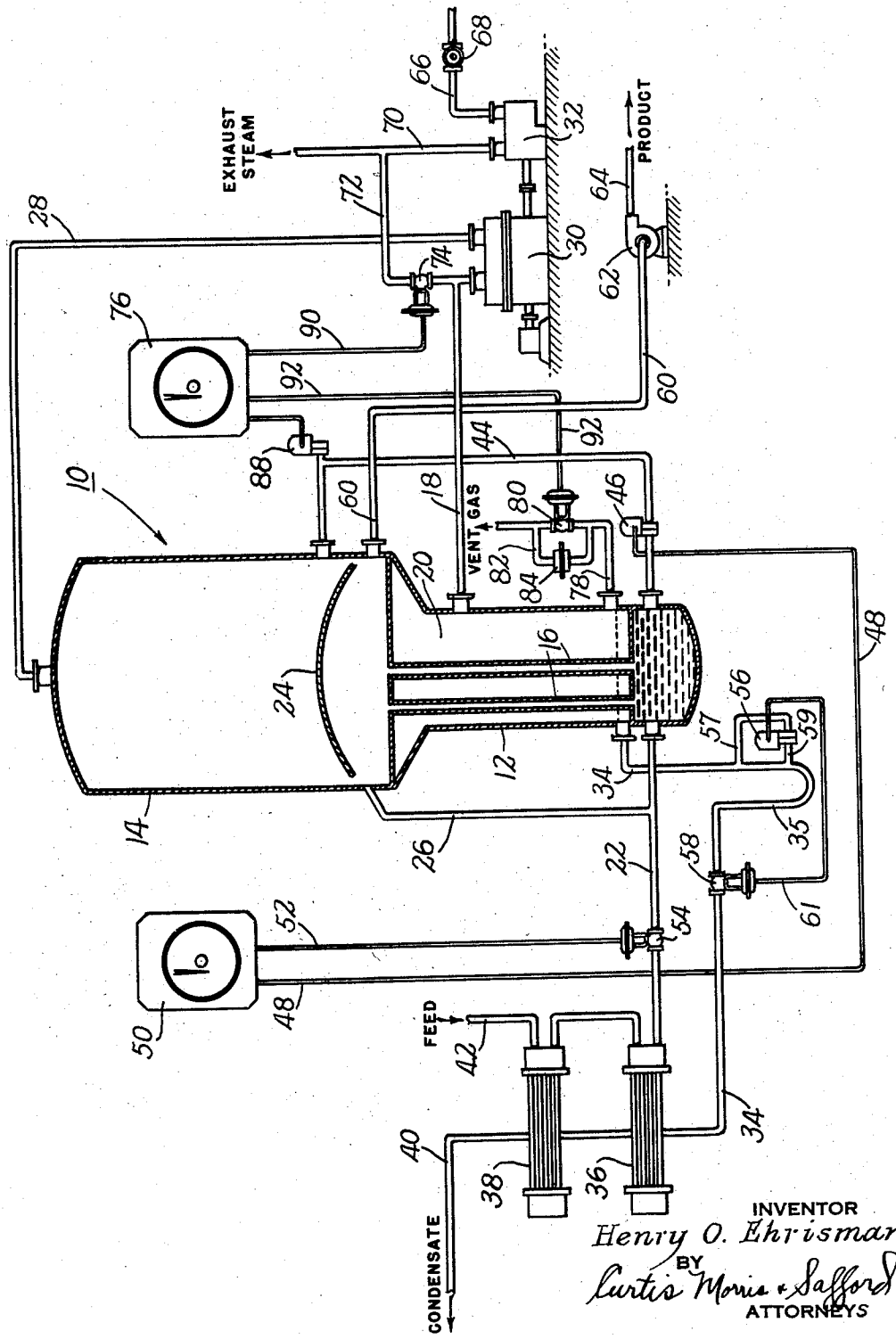
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COMPRESSION EVAPORATOR CONTROL AND METHOD THEREFOR

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COMPRESSION EVAPORATOR CONTROL AND METHOD THEREFOR

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This invention relates to compression evaporation and more particularly to a novel method and apparatus for controlling the addition of auxiliary heat to such an evaporator. Since most evaporation processes are concerned with the evaporation of aqueous solutions the present invention will be described in connection with its use for evaporating such a solution, although as the description proceeds it will be evident that the invention can also be used with advantage in connection with the evaporation of non-aqueous liquors as well.

In recent years there has been an increasing interest in compression evaporation as a method of increasing the thermal efficiency of various evaporation processes. In accordance with this method vapors distilled from the liquid being evaporated are removed from the evaporator body, compressed by a suitable compressor, and returned to the evaporator steam chest to be used as a heating medium for evaporating further quantities of the liquor to be evaporated. In such a compression evaporation process it is customary to preheat the feed liquor with condensate from the evaporator steam chest, and if this heat exchange between feed liquor and condensate is carried out efficiently, an evaporative process is achieved which has exceptionally high thermal efficiency, i. e. a process which will vaporize a relatively large quantity of water per unit of heat input.

It is evident however that even with the high efficiencies obtainable with such a compression evaporator some heat losses inevitably occur, and accordingly it is necessary that auxiliary or makeup heat be added in order to carry out the evaporation on a continuous basis. It is accordingly an object of the present invention to provide an improved method and apparatus for supplying auxiliary heat to a compression evaporator. It is another object of the invention to control the supply of heat to a compression evaporator in such manner that the evaporation proceeds in a more nearly uniform manner than has heretofore been achieved. It is still another object of the invention to provide a method and apparatus for controlling the supply of heat to the steam chest of a compression evaporator in such manner as to maintain the pressure in the vapor space of the evaporator substantially constant. Other objects of the invention will be in part obvious and in part pointed out hereafter.

The many objects and advantages of the present invention can best be understood and appreciated by reference to the accompanying drawing which illustrates diagrammatically apparatus incorporating a preferred embodiment of the present invention and capable of carrying out the method of the invention.

Referring to the drawing, the numeral **10** generally designates an evaporator body having a heat exchange section **12** and vapor body **14**. The evaporator body **10** is a conventional vertical tube, natural convection evaporator wherein the heat exchange section **12** contains a bundle of vertical tubes **16**. Although only two tubes **16** are shown for purposes of illustration, it will be understood that the tube bundle comprises a large number of tubes largely filling the space within the heat exchange section **12**. The space around tubes **16** is supplied with steam through a pipe **18** and will be referred to herein for convenience as the steam chest **20** of the evaporator.

The liquor to be evaporated is supplied to the base of the heat exchange section **12** through a pipe **22** and flows up into the tubes **16**. Within the tubes it is heated by a steam in the steam chest **20** and partially vaporized. As a result of this vaporization process a mixture of vapor and hot liquor is delivered from the upper ends of the tubes **16** and impinges against a baffle **24** in the vapor body **14**. The liquor and vapor are separated in the vapor body **14** and the liquor flows downwardly through a pipe **26** and is recycled through feed pipe **22** to the bottom of heat exchange section **12**. Concentrated liquor is continuously withdrawn from vapor body **14** through a pipe **60** and pumped by a pump **62** through a product pipe **64** to a suitable point of storage or use.

As indicated above, the present evaporator is a compression evaporator wherein the vapor is compressed and used as a heating medium in the steam chest of the evaporator. Still referring to the drawing, the vapor leaves the vapor body **14** through a pipe **28** and flows to the inlet of a compressor **30** that is driven by a steam turbine **32**. The compressed vapor is delivered by the compressor **30** to the pipe **18** through which it flows to the steam chest **20** of the evaporator body.

In order to improve the thermal efficiency of the unit the feed liquor is preheated by being caused to flow in heat exchange relationship with the condensate formed in the steam chest **20**. More particularly, condensate is withdrawn from steam chest **20** near the bottom thereof through a pipe **34** and flows successively to the shell sides of the heat exchangers **36** and **38** and thence to a suitable point of disposal through the pipe **40**. Feed liquor to be evaporated enters the system through a pipe **42** and flows through the tube sides of heat exchangers **38** and **36** in sequence to the feed pipe **22** referred to above. It is thus apparent that the feed liquor and condensate are caused to flow in generally countercurrent heat exchange relation to cause the liquor to be heated by the sensible heat in the condensate leaving the system.

The rate of introduction of feed liquor into the evaporator body is determined by the liquor level in the heat exchange portion **12** of the evaporator body **10** and control mechanism is provided for maintaining this liquor level at the desired point. Thus a gauge pipe **44** is provided which is connected at its upper end to vapor body **14** and at its lower end to the lower portion of heat exchange section **12** below the bottom of the tube bundle **16**. Mounted in the lower portion of gauge pipe **44** there is a differential pressure responsive device **46** which may be of conventional construction, and for example of the specific construction shown in Cook Patent 2,539,892. Thus if a device such as that shown in the Cook patent is used the passage 111 of the Cook patent is connected to the vertical portion of the pipe **44** and the passage 98 of the Cook patent is connected to the liquid space at the bottom of evaporator **10**.

The differential pressure responsive device **46** is effectively responsive to the height of the liquor level in the tubes of tube bundle **16** and operates to generate a pneumatic pressure proportional to the liquor level. This pneumatic pressure is transmitted by a pipe **48** to a controller **50** which is in turn connected by a pipe **52** to a pneumatically operated regulating valve **54** located in the feed liquor pipe **22**. (If a device like the Cook device is used, pipe 30 of the Cook patent corresponds with pipe **48** of the present application.) The controller **50** operates to generate a pneumatic pressure which is

a function of the liquor level in the tubes **16** and supplies this pneumatic pressure to the valve **54** to so regulate the feed liquor rate as to maintain the desired liquor level in the evaporator. Pneumatically operated controllers capable of operating in this way are conventional and well-known in the art and hence the construction of controller **50** need not be described in detail herein.

In like manner the rate of withdrawal of condensate from steam chest **20** is regulated so as to maintain the steam chest substantially free from accumulated condensate. More particularly the pipe **34** has a U-section **35** to the right-hand leg of which a differential pressure responsive device **56** is connected by pipes **57** and **59**. The device **56** may be similar to the device **46** and generates a pneumatic pressure that is supplied through pipe **61** to a regulating valve **58**, also located in the pipe **34**. (If a device such as that shown in Cook Patent 2,539,892 is used the passage 111 of the Cook patent is connected to pipe **57** and the passage 98 of the Cook patent is connected to pipe **59**.) The differential pressure responsive device **56** operates to supply to valve **58** a pneumatic pressure which positions the regulating valve **58** to maintain the flow of condensate through the pipe **34** at such a value that the condensate level in the right-hand leg of U-section **35** remains between the points at which pipes **57** and **59** are connected to pipe **34**. Thus condensate formed in steam chest **20** immediately flows into pipe **34** and no substantial amount of condensate accumulates in the steam chest.

As pointed out above, in a compression evaporation system of the type shown certain heat losses occur and hence auxiliary heat must be supplied to permit the evaporator to operate on a continuous basis. This auxiliary heat can manifestly be obtained from any of various sources. However in the preferred embodiment of the invention here being described the compressor **30** is driven by a steam turbine **32** and the exhaust steam from the steam turbine is used as a source of this auxiliary heat. More particularly the steam turbine **32** is driven by high pressure steam supplied through a pipe **66** which contains a regulating valve **68**. Exhaust steam from turbine **32** flows through a pipe **70** to a low pressure steam system (not shown) which is maintained at a pressure of say 50 lbs. per square inch. A portion of the exhaust steam flows through a branch pipe **72** containing a regulating valve **74** to the steam supply pipe **18** that supplies steam to the steam chest **20** of the evaporator. The flow of auxiliary steam from the exhaust of steam turbine **32** to steam chest **20** is controlled by a controller **76** in a manner that is further described hereafter.

As an incident of the normal operation of evaporators, the steam supply to the evaporator commonly contains small quantities of fixed gases and these gases accumulate over a period of time in the evaporator steam chest. To effect removal of these fixed gases the present evaporator system is provided with a vent system comprising a pipe **78** connected to steam chest **20** just above the condensate level. The pipe **78** contains a pneumatically operated regulating valve **80** and is provided with a by-pass **82** around the valve **80** which contains an orifice **84**. The orifice **84** is so selected as to withdraw the vent gas and admixed steam from steam chest **20** at such a rate as to maintain the vent gas concentration within the steam chest at a relatively low value with the valve **80** closed. The valve **80** forms part of the control system for the evaporator which will now be described.

In the operation of an evaporator it is important in securing efficient evaporation that the evaporation rate be maintained relatively uniform and that vaporization occur smoothly and continuously. In accordance with the present invention such uniform continuous operation is obtained by maintaining the pressure in the vapor space of vapor body **14** substantially constant, and this constant pressure in the vapor space within body **14** is achieved by conjoint regulation of the steam supply

through pipe **72** and of steam withdrawn from steam chest **20** through pipe **78**. More particularly the gauge pipe **44** is provided near its upper end with a pressure responsive device **88** which may be like the devices **46** and **56** previously referred to but which is exposed to atmosphere on one side thereof and hence measures the pressure in the vapor space **14**. (If a device such as that shown in Cook Patent 2,539,892 is used the passage 111 of the Cook patent is connected to the upper end of gauge pipe **44** and the passage 98 of the Cook patent is left open to the atmosphere.) The device **88** generates a pneumatic pressure proportional to the pressure in vapor space **14** which pneumatic pressure is supplied as a control pressure to the controller **76**. The controller **76** in response to the pressure values received from device **88** generates a pneumatic pressure that is applied through the pipe **90** to the valve **74** and through the pipe **92** to the valve **80**. The regulating valves **74** and **80** are so adjusted in relation to the pressure supplied by the controller **76** that the valve **74** is open only when the controlled pressure, i. e. the pressure within the vapor body **14**, is below the desired value and the valve **80** is open only when the controlled pressure is above the desired value.

The cooperative action of the valves **74** and **80** and controller **76** can best be clarified by a specific example.

Assume for example that:

(1) The desired pressure in the vapor space of the evaporator is 5 lbs. per square inch.

(2) When the pressure in vapor body **14** is stabilized at 5 lbs. per square inch the controller **76** generates a pneumatic pressure of 9 lbs. per square inch.

(3) As the pressure in vapor body **14** varies the output pressure controller **76** can vary between 3 lbs. per square inch and 15 lbs. per square inch.

(4) As the vapor body pressure increases the output pressure of controller **76** decreases and vice versa.

(5) A change of 1 lb. per square inch in vapor body pressure corresponds to a change of 2 lbs. per square inch in controller output pressure.

(6) At the time being considered the vapor pressure in the vapor body is 2 lbs. per square inch.

It is evident that under the conditions set forth above the controller **76** will be supplying its maximum air pressure of 15 lbs. per square inch to both valves **74** and **80**. The valve **74** is an air-to-open valve and is so adjusted that it is wide open with 15 lbs. air pressure on its diaphragm. The valve **80** is an air-to-close valve and is adjusted so that it is fully closed with 15 lbs. air pressure on its diaphragm and does not begin to open until the pressure on its diaphragm drops to 9 lbs. per square inch.

With the valve **74** wide open a full flow of auxiliary steam will occur through pipe **72** and thence through pipe **18** to steam chest **20** thus increasing the rate of evaporation and the pressure within the vapor space of the vapor body **14**. This increase in vapor pressure will be reflected in a decrease in the output pneumatic pressure of controller **76** and the valve **74** will be gradually closed. When the vapor pressure in the evaporator reaches 5 lbs. per square inch both valves **74** and **80** will be fully closed. If thereafter the vapor pressure of the evaporator rises above its control value, that is 5 lbs. per square inch, controller **76** will generate a pressure below 9 lbs. per square inch and valve **80** will begin to open. As a result of the opening of the valve **80** steam will be vented from steam chest **20** thus decreasing the rate of evaporation of the liquor in the evaporator and tending to reduce the vapor pressure therein. It will thus be evident that the controller **76** operates to regulate the valves **74** and **80** conjointly to maintain the pressure in the evaporator vapor space substantially at a desired value.

From the foregoing description it should be apparent that the present invention provides apparatus capable of achieving the objectives set forth at the beginning of

the present specification. It is of course to be understood that the embodiment of the invention described herein is illustrative only and that numerous changes can be made therein without departing from the spirit of the invention as set forth in the appended claims.

I claim:

1. In a compression evaporator of the type wherein water vapor is withdrawn from the vapor space of the evaporator, compressed by a compressor, and returned to the evaporator steam chest, apparatus for maintaining the pressure in said vapor space substantially constant, comprising, in combination, an auxiliary steam conduit connected to supply steam to said steam chest, a first regulating valve in said auxiliary steam conduit, a vent conduit connected to said steam chest for venting steam therefrom, a second regulating valve in said vent conduit, and control means responsive to the pressure in said vapor space and connected to operate said first and second regulating valves, said control means operating said first regulating valve to close said valve with increasing pressure in said vapor space and vice versa and operating said second regulating valve to open said valve with increasing pressure in said vapor space and vice versa, said control means conjointly operating said two valves to maintain the pressure in said vapor space substantially constant.

2. Apparatus according to claim 1 and wherein said control means upon an increase in pressure in said vapor space causes said auxiliary steam valve to close completely before permitting said vent valve to open and upon a decrease in pressure in said vapor space causes said vent valve to close completely before permitting said auxiliary steam valve to open.

3. Apparatus according to claim 1 and wherein said compressor is driven by a steam engine and said auxiliary steam conduit is connected to the exhaust of said steam engine, whereby exhaust steam from said engine is used in the auxiliary steam for said evaporator.

4. The method of operating a compression evaporator of the type wherein water vapor is withdrawn from the vapor space of the evaporator, compressed by a steam engine-driven compressor, and returned to the evaporator steam chest to maintain the pressure in said vapor space substantially at a predetermined value, which comprises the steps of, supplying exhaust steam from the exhaust of said steam engine to said evaporator steam chest when the vapor space pressure is below said predetermined value and venting steam from said steam chest when the vapor space pressure is above said predetermined value.

5. The method of operating a compression evaporator of the type wherein water vapor is drawn from the vapor space of the evaporator, compressed by a compressor, and returned to the evaporator steam chest to maintain the pressure in said vapor space at substantially a predetermined, desired value, which comprises the steps of supplying auxiliary steam to said steam chest, venting steam from the steam chest of said evaporator and conjointly regulating in response to variations of the pressure in the vapor space of said evaporator the flow of auxiliary steam and the flow of vent steam to increase the auxiliary steam flow when the vapor space pressure is below said desired value and falling, and to increase the vent steam flow when the vapor space pressure is above said desired value and rising to maintain the vapor space pressure substantially at said desired value.

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