Oct. 7, 1969 J. E. POTTHARST, JR 3,471,373

AUTOMATIC CONTROL SYSTEM FOR VAPOR COMPRESSION DISTILLING UNIT

Filed Feb. 17, 1967 2 Sheets-Sheet 1

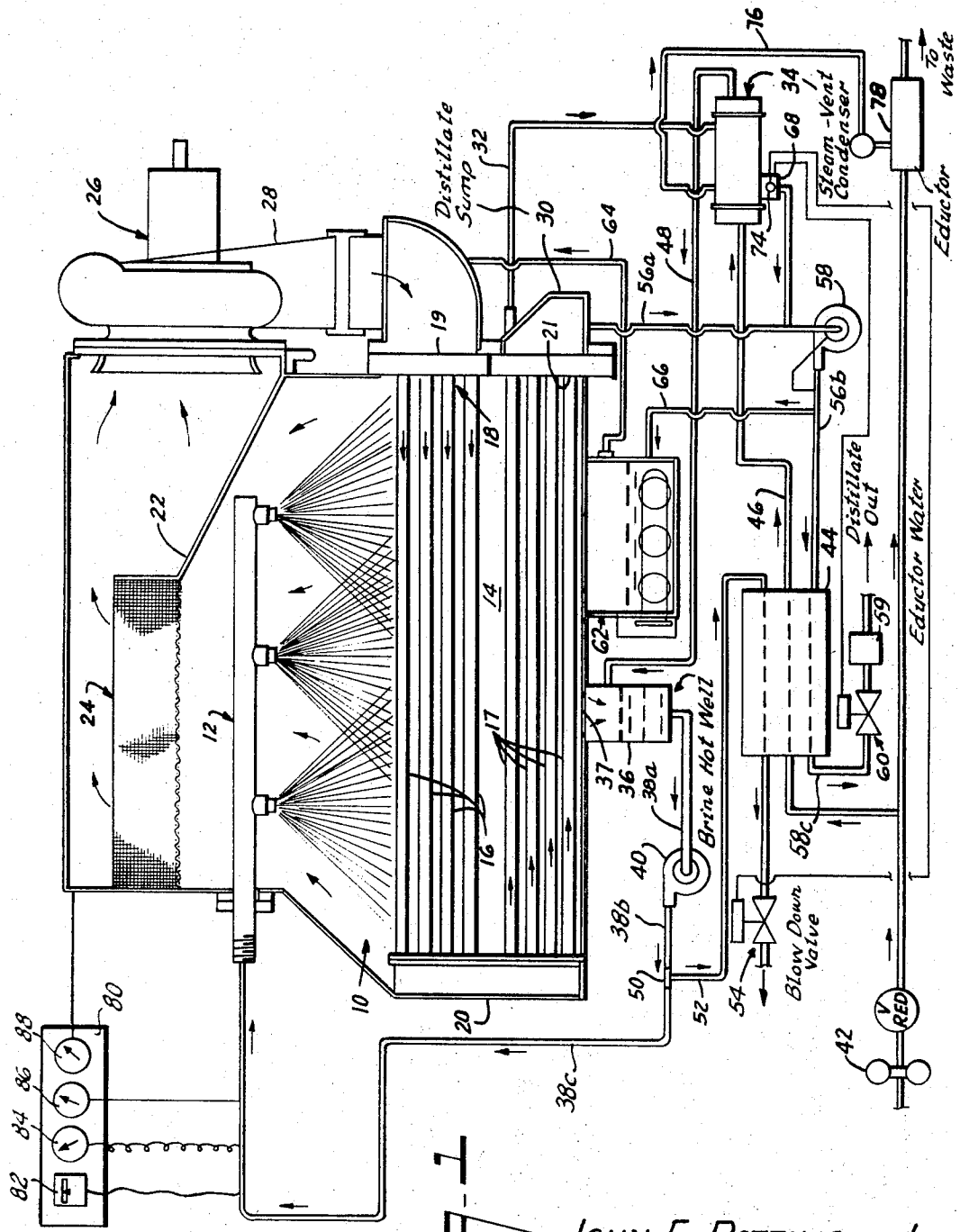


FIG. 1

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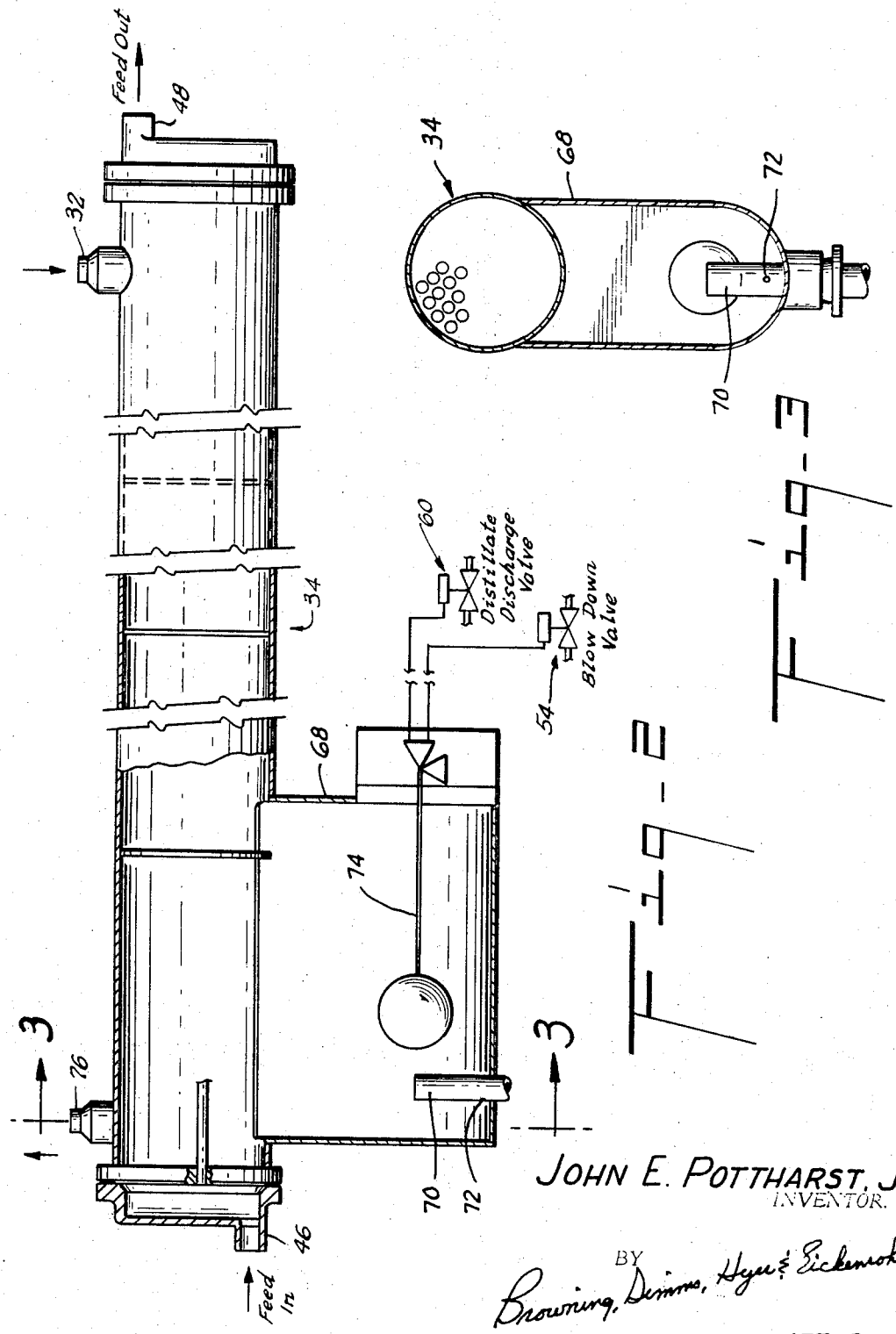


FIG. 3

FIG. 2

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AUTOMATIC CONTROL SYSTEM FOR VAPOR COMPRESSION DISTILLING UNIT

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U.S. Cl. 202—181 1 Claim

ABSTRACT OF THE DISCLOSURE

A horizontal tube-type evaporator vapor compression distilling unit provided with automatic controls to hold a starting charge of distilled fluid within the evaporator during starting-up operation, to discharge distillate during steady state operation, and to retain the starting charge in the evaporator upon shutting down of operation. To accomplish this, a steam vent line extends from the evaporator and is fed into a vent condenser unit. As the steam condenses, the condensate flows into a sump which is provided with a float switch. The sump has provisions to pass low flow, however higher flow causes the fluid level in the sump to rise actuating the float switch which is operatively connected to the distillate discharge valve.

Background of the invention

This invention relates to a self-contained horizontal tube-type evaporator vapor compression distillation unit, and more particularly to automatic controls for such a unit to retain the starting charge in the unit during starting-up operations, to discharge produced distillate during steady state operation, and to hold the starting charge of distillate within the unit upon shutting down.

Horizontal tube type evaporator compression distilling units are often used in the production of potable water from sea water. Such units have a vaporization chamber within which vapor is evolved from the feed liquid. The vapor is compressed to raise its temperature and then placed in an indirect heat exchange relationship with the feed liquid in a two-pass horizontal tube evaporator, thereby condensing the steam and forming distillate.

In order to start up such a unit, a supply of distillate is heated to form the initial steam which is used to re-energize the system. The initial steam may come from the cooling jacket of an engine if the unit is engine-driven or from an immersion heater if the unit is electric motor-driven. In addition to providing the initial steam supply, such external apparatus is used during operation to provide makeup heat and maintain the heat balance of the unit. During steady state operation, a supply of distillate for use in the external apparatus is easily kept available by tapping the distillate discharge line. However, it is desirable that a starting charge of distillate be automatically retained in the horizontal tube evaporator during starting-up operations and upon the unit being shut down. In other words, in vapor compression distillation units, whether engine or electric motor-driven, it is desirable to automatically retain a starting charge of distillate within the horizontal tube evaporator during starting-up operations and upon shut-down. In addition, it is essential that automatic means be provided to discharge the distillate from the horizontal tube evaporator as it is produced when steady state operation has been achieved.

The two-pass spray evaporator is a very efficient design for vapor compression units. However, due to its efficiency, it is difficult to maintain sufficient heat in the system to provide proper heat balance. Accordingly, if the starting charge is retained in the system until the rate of production of distillate has built up to a predetermined level such as 25 to 35%, a large charge of hot distillate

will pass through the feed water heat exchanger heating the plates and gaskets of the heat exchanger as well as the feed water. Therefore, the heat balance will not be adversely affected as it would be if a large charge of cold feed water was initially introduced into the system. Moreover, by retaining the starting charge in the unit until such time, additional distillate is built up which is desirable to overcome any minor leakage.

Another advantage from retaining the starting charge in the unit until a predetermined level of production has been reached is that it is necessary, when starting up the unit, to purge the air out of the individual tubes of the evaporator. Letting the condensate build up in the second pass of the evaporator by not discharging produced distillate prior to a predetermined level of production blocks off several tube layers in the second pass and increases the steam velocity in the clear tubes thereby flushing out non-condensible gases during the starting-up period so that by the time the distillate discharge valve is opened most of the non-condensible gases will have been purged. Sudden flow upon opening of the distillate discharge valve will tend to sweep additional non-condensible gases so that when steady state operation is reached the steam side of the evaporator will be well cleaned.

It is an object of the present invention to provide a system in a horizontal tube evaporator vapor compression distillation unit for automatically retaining the starting charge of distillate in the horizontal tube evaporator during starting-up operations until a predetermined level of operation has been reached, discharging the distillate as it is produced when steady state operations are in process and retaining the starting charge of distillate in the horizontal tube evaporator upon shut-down.

Summary of the invention

Vapor compression distilling units are usually formed of a vaporization chamber within which vapor is evolved from the feed liquid which is to be distilled. Means for compressing the vapor to elevate its temperature are provided and the compressed vapor is fed into a two-pass horizontal tube evaporator and passed in indirect heat exchange relationship with the feed liquid. In order that non-condensible gases may be continuously purged from the evaporator, a vent line extends from the evaporator. Steam is mixed with the vent gas stream, and by feeding the vent line into a vent condenser where the stream is in indirect heat exchange relation with the incoming heated feed fluid most of the heat in the vent gas stream is recovered.

Self-contained vapor compression distilling units require a starting charge of distilled liquid which is utilized to furnish the initial charge of steam for unit start-up. This is true whether the unit is entirely electric motor-driven or engine-driven. A certain amount of distillate is also turned into steam by the same external means, i.e., immersion heater boiler or engine cooling jacket, during operation to provide makeup heat for the operation. During operation of the unit, a certain portion of the produced distillate is diverted for utilization in the external heating unit. The present invention provides automatic means for retaining the starting charge in the horizontal tube evaporator during starting-up operations until a predetermined level of operation has been achieved, discharging the produced distillate during steady state operation, retaining the starting charge in the horizontal tube evaporator upon shut-down.

It has been found that the vent condenser provides a convenient source of control since no significant amount of steam arrives in the vent condenser until the unit begins producing distillate. The vent condenser is provided with a condensate sump which has an overflow pipe having an orifice. The orifice in the overflow pipe is sized to drain

off the low flow during starting-up operations. The orifice is so sized that it will permit drain-off of condensate until the unit reaches a predetermined state of distillate production, preferably in the neighborhood of 25 to 35%. By retaining the starting charge in the unit until such time, the sudden surge of cold feed liquid is prevented thereby aiding in maintaining heat balance; also, the retention assists in purging of non-condensible gases from the system. When production of distillate reaches a predetermined level condensate flow has increased to such a level that the sump begins to fill. A float switch is provided in the sump and is actuated upon the liquid level in the sump reaching a predetermined level. The float switch is operatively connected to the distillate flow valve. Upon actuation of the float switch, the distillate valve is opened to permit the discharge of the produced distillate from the unit. If desired, the float switch may also be operatively connected to the blowdown discharge whereby the blowdown fluid will also be retained in the unit until steady state operation has been achieved. Accordingly, during starting-up operations the starting charge of distillate is retained in the unit, but upon the unit reaching steady state operation the produced distillate is immediately discharged. Immediately upon the shutting down of the unit, there is no longer a production of steam and the sump begins to drain, resulting in actuation of the float switch. At this time, the float switch closes the distillate valve prohibiting any further flow and retaining in the unit the starting charge of distillate.

Accordingly, the retention of a starting charge and the discharge of distillate is performed automatically in a unit which is simple in construction, reliable in performance and low in cost.

Brief description of the drawings

FIG. 1 is a schematic view of the vapor compression distillation unit having the automated control of the present invention incorporated therein.

FIG. 2 is a cross-sectional view of a vent condenser illustrating the incorporation of a by-pass and float valve.

FIG. 3 is a sectional view taken generally along line 3—3 of FIG. 2.

Description of the preferred embodiment

Referring now to the drawings, it can be seen that the vapor compression distillation unit is formed of a vaporizing chamber **10** within which vapor is evolved from feed liquid. For the purposes of illustration it will be assumed that the unit is designed for converting sea water to potable liquid.

Located in the vaporizing chamber **10** is a spray nozzle manifold **12** which sprays the liquid to be distilled upon a two-pass horizontal tube evaporator **14** formed of a pair of horizontal tube bundles **16** and **17** and manifolds **18** and **20**, one of which is located at each end of the tube bundles **16** and **17**. The manifold **18** is provided with an upper chamber **19** and a lower chamber **21**. The region above the spray manifold **12** is the area into which the vapor rises and is separated from the remainder of the chamber **10** by a wall **22** which has an opening provided with a mist separator **24**. A centrifugal compressor blower **26** is located in the vapor region. A duct **28** connects the compressor blower **26** to the upper chamber **19** of the manifold **18** of the horizontal tube evaporator **14**.

Accordingly, in steady state operation, the liquid to be distilled is fed into the spray manifold **12** and sprayed upon the tube bundles **16** and **17** of the horizontal evaporator **14**. Running through the tubes of the evaporator **14** is compressed vapor. Therefore, as the sprayed feed liquid runs over the heated tubes of the evaporator **14** some of the liquid is vaporized and rises in the vaporization chamber toward the vapor region passing the mist separator **24** which extracts any impurities, and then through the centrifugal compressor blower **26** where the vapor is compressed. The compressed vapor flows through the ducts **28** to the upper chamber **19** of the manifold **18** of the evaporator **14** and flows through the upper bundle **16** of the horizontal tubes to the manifold **20** and then through the lower bundle **17** of tubes to the lower chamber **21** of the manifold **18**. The vapor flowing through the horizontal tube bundles **16** and **17** of the evaporator gives up its heat to the sprayed feed liquid and forms distillate. The produced distillate flows from the manifold **18** into a distillate sump **30** at the lower end of manifold **18**. The distillate sump **30** is provided with a vent line **32** through which uncondensed vapor flows to a vent condenser unit **34**.

The spray from the nozzles **12** which is unvaporized settles to the bottom of the vaporizing chamber **10** and flows into a hot well **36** which is in fluid communication with the interior of the vaporizing chamber **10** through an opening **37**.

To provide feed water for the unit, raw sea water or other liquid to be distilled is fed into the system through a meter **42**. The feed water then passes through a heat exchanger **44** where it is initially heated. The feed water then runs through conduit **46** to the vent condenser unit **34** where it is further heated by the condensing steam which flows through the vent line **32** of the distillation unit. The heated feed stream then flows through conduit **48** to the hot well **36** where it joins the unvaporized stream from the spray manifold **12**. Conduit **38***a* connects brine hot well **36** to pump **40**, which recirculates the hot brine through vapor chamber **10** by returning the hot brine to spray manifold **12** through line **38***b*, T **50**, and line **38***c*.

To keep the level in the hot brine sump **36** at a somewhat constant level and to prevent mineral laden water from concentrating in the sump, part of the discharge of the brine circulating pump is removed from the system through line **52**, which is connected to T **50**, and blowdown valve **54**. Before leaving the system, however, some of the heat from this blowdown water is transferred to the incoming feed stream in heat exchanger **44**.

Accordingly, when the vapor compression distillation unit is in steady state operation, the feed water is first heated by the heat exchanger **44** and then subsequently heated by the vent condenser **34**. The feed water is then fed into the hot well **36** where it mixes with the unvaporized spray water and the combined liquid is then recirculated by conduit **38** through the vapor compression distillation unit. The sprayed water which is vaporized during contact with the horizontal tube evaporator **14** is collected by the centrifugal compressor **26** and fed through the horizontal tube evaporator **14** where the condensed steam flows into the distillate sump **30**. From here the distillate flows through line **56***a* to pump **58**, which pumps the distillate to storage through line **56***b*, heat exchanger **44**, where it gives up some of its heat to the incoming feed stream, line **58***c*, valve **60**, and meter **59**. As explained above, a portion of the recirculated water also flows through the heat exchanger **44** and is discharged through the blowdown valve **54** to control the level in hot brine well or sump **36**.

The vapor compression distillation unit chosen for purposes of illustration is an all-electrical driven unit and is provided with an immersion heater tank **62** to provide the initial steam for starting up operation and makeup heat. A conduit **64** runs from the immersion heater tank **62** to duct **28** to provide steam to the unit. The immersion heater tank **62** is provided with distillate by a conduit **66** which is tapped into the distillate discharge conduit **56***b*. In an engine-driven distillation unit, a starting charge of steam comes from the engine cooling jacket. In either event, a starting charge of distillate is required to start up the unit. In order to retain a starting charge in the vapor compression distillation unit until the unit has reached a predetermined level of distillate production the discharge of the distillate is automatically

controlled. In the present invention this is accomplished by the vent condenser.

In starting a vapor compression distillation unit the steam that passes into the evaporator **14** is readily condensed on the tubes. As more steam is applied it heats the evaporator **14** and progresses toward the distillate sump **30** and vent **32**. There is not enough steam in the steam circulating system to begin production until both the suction and discharge passages are heated up and filled with steam. Therefore, no significant amount of steam gets to the vent condenser **34** until the unit begins producing distillate, so a system of distillate outlet control at the beginning of sub-steam flow to the vent condenser **34** makes an effective control. Accordingly, the vent condenser **34** is provided with a sump **68** which is in communication with the interior of the vent condenser **34**, see FIGS. 2 and 3. Any condensate which is formed from uncondensed vapor in the vent condenser **34** flows into the sump **68**. A standpipe **70** having an orifice **72** is located in the sump **68**. When there is low condensate flow such as in starting-up operations, the condensate flows out through the orifice **72**. The orifice **72** is so sized that any condensate resulting from vapor flowing from the distillate sump **30** prior to the time the unit has reached a predetermined level of production, preferably 25 to 35%, will not cause the liquid level in the sump **68** to rise. However, as the unit reaches distillate production in excess of the predetermined level, more steam is produced and a greater amount passes through the vent conduit **32** into the vent condenser **34**. The amount of condensate flowing into the sump **68** at that time will be greater than the orifice **72** can accommodate and the liquid level in the sump **68** will increase. The sump **68** is provided with a float switch **74** and as the liquid level in the sump **68** rises the float switch **74** is actuated. The float switch **74** is operatively connected to the distillate valve **60**. Accordingly, while there is a low flow of condensate during initial starting-up operation the condensate is drained off by the orifice **72** in the standpipe **70** and the distillate valve **60** is closed and there is no discharge of distillate and the initial starting charge of distillate remains in the unit. Hence, there is no distribution of the distillate until there has been a sufficient quantity of steam condensed in the vent condenser **34** to raise the liquid level in the sump **68**, actuating the float switch **74** which opens the distillate valve **60**, and permit the discharge of the distillate to the storage tank. Accordingly, the starting charge is retained in the system until there is steady state production of distillate. As shown, the float switch **74** is also operatively connected to solenoid operated blowdown valve **54**. Thus, no blowdown can occur until the unit is producing a substantial quantity of distillate.

The vent condenser **34** is provided with an outlet line **76** through which the uncondensed gases flow. If the unit is evaporating above atmospheric pressure the uncondensed gases may be vented directly to the atmosphere, otherwise the vent line **76** may be attached to an eductor **78** which will draw out the uncondensed gases from the vent condenser **34**. The eductor is operated by part of the feed stream.

Upon shutting down the unit, the steam flow through the vent line **32** decreases thereby decreasing the condensate in the sump **68** of the vent condenser **34** which causes the float to drop, actuating the float switch **74** which closes the distillate valve **60** and blowdown valve **54** to retain the starting charge in the system.

As can be seen, the retention of a starting charge of distillate in the unit and the discharge of the distillate is automatically controlled. The control is located at a place in the system at the beginning of production of distillate. The control is automatic and is simple in construction, reliable in operation and low in cost. Controls for monitoring the operation of the unit are mounted on control panel **80**. The instruments shown are temperature control **82**, circulating water temperature gage **84**, and pressure gages **86** and **88**.

From the foregoing it will be seen that this invention is one well adapted to attain all of the ends and objects hereinabove set forth, together with other advantages which are obvious and which are inherent to the apparatus.

It will be understood that certain features and subcombinations are of utility and may be employed without reference to other features and subcombinations. This is contemplated by and is within the scope of the claims.

As many possible embodiments may be made of the invention without departing from the scope thereof, it is to be understood that all matter herein set forth or shown in the accompanying drawings is to be interpreted as illustrative and not in a limiting sense.

The invention having been described, what is claimed is:

1. In a vapor compression distilling unit formed of a vaporization chamber within which vapor is evolved from a liquid to be distilled, means for compressing the vapor to elevate its temperature, a two-pass horizontal tube evaporator in heat exchange relationship with the liquid to be distilled within the vaporization chamber, a distillate sump communicating with said evaporator, a vent line from said distillate sump, a line discharging distillate from the distillate sump and a starting charge of distilled fluid within the unit to provide steam for the starting-up of the unit, an automatic control system for retaining the starting charge in the unit during starting up operation, discharging distillate during steady state operation and retaining the starting charge on unit shut-down, wherein the improvement comprises the vent line being fed into a vent condenser unit which is provided with a sump into which the condensate flows, in the sump to drain off condensate during steady state operations, the standpipe having an orifice located in the side of the standpipe through which condensate can flow from the sump into the standpipe to prevent the accumulation of condensate during starting-up operations, the orifice being sized so that the liquid level in the sump does not appreciably rise until the unit has reached a predetermined level of distillate production, a float switch in said sump operatively connected to a valve in the distillate line to open the valve when the level of the condensate in the sump reaches a predetermined level and allow distillate to be discharged from the unit and to close the valve when the level in the sump drops to a predetermined level to retain the starting charge of distillate in the unit.

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