AUTOMATIC CONTROL SYSTEM FOR VAPOR COMPRESSION DISTILLING UNIT

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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 until the charge is being 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 distillation 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 electrically 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 tube thereby flushing out non-condensable gases during the starting-up period so that by the time the distillate discharge valve is opened most of the non-condensable gases will have been purged. Sudden flow upon opening of the distillate discharge valve will tend to sweep additional non-condensable gases 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-condensable 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 steam 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 returned 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
3,471,373 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 to the liquid level to the point where all the distillate has been removed. 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 shut-down of the 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 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 38b, T 50, and line 38c.

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 56a to pump 58, which pumps the distillate to storage through line 56b, heat exchanger 44, where it gives up some of its heat to the incoming feed stream, line 58c, 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 to control the level in the 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 56b. 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 condenser 34 until the unit begins producing distillate, so a system of distillate outlet control at the beginning of sub-stream 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. Moreover, 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 a 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 this 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 sub-combinations are of utility and may be employed without reference to other features and sub-combinations. 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 distillate 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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