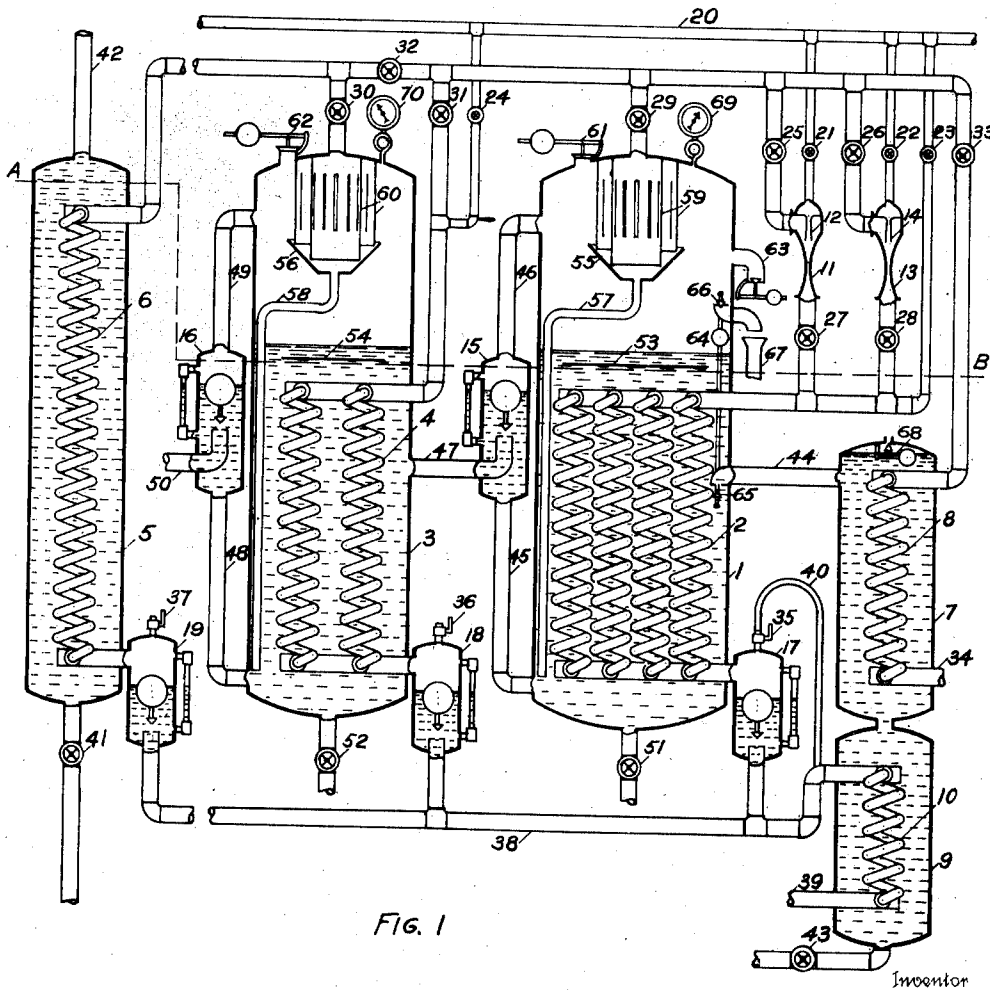
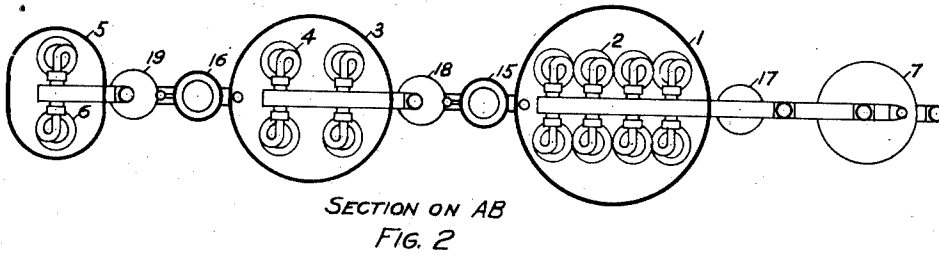


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EVAPORATING APPARATUS.
APPLICATION FILED MAR. 13, 1917.

1,390,677.

Patented Sept. 13, 1921.



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EVAPORATING APPARATUS.

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To all whom it may concern:

Be it known that I, WILLIAM L. DE BAUFRE, a citizen of the United States, residing at Annapolis, in the county of Anne Arundel and State of Maryland, have invented a new and useful Evaporating Apparatus, of which the following is a specification.

My invention relates to apparatus for evaporating and concentrating solutions and for recovering the products of distillation by condensation, and has for its object the arranging and proportioning the several parts of such apparatus so as to secure the most economical and efficient operation, especially in those systems employing vapor compressors for regenerative working.

With the foregoing and other objects in view, my invention consists of the novel construction, combination and arrangement of parts as hereinafter specifically described and illustrated in the drawings wherein is shown the preferred embodiment of my invention, but it is understood that changes, variations and modifications can be resorted to which come within the scope of the claims hereunto appended.

In the drawings of the herein described embodiment of my invention, Figure 1 shows a sectional view in elevation of my improved evaporating apparatus; Fig. 2 is a sectional view taken through AB of Fig. 1.

In the evaporating apparatus as shown in the two figures, the evaporator shells 1 and 3 constitute evaporating chambers, and within them are located the condensing chambers 2 and 4 respectively. The latter are illustrated as composed of helical coils of tubing connected to headers at top and bottom. The condenser shell 5 contains a similar condensing chamber 6, the preheater shell 7 a similar condensing chamber 8, and the heat exchanger shell 9 a similar cooling chamber 10. Eleven and 12 are vapor compressors of the type shown more in detail in Figs. 3, 4 and 5. The numbers 15, 16, 17, 18 and 19 refer to devices for removing liquids from the several evaporating and condensing chambers as will be explained later.

The plant is represented as having two "effects" only, shell 1 with coils 2 being the "first effect," and shell 3 with coils 4 being the "second effect." While this number of effects is sufficient to illustrate the operation of the apparatus, any number of additional effects may be added between the second effect (shell 3) and the condenser (shell 5).

The primary vapor is supplied by main 20 through valves 21 and 22 to the steam nozzles 12 and 14 of vapor compressors 11 and 13 respectively, through valve 23 directly to the condensing chamber 2 of the first effect, through valve 24 directly to the condensing chamber 4 of the second effect, and to such additional effects, pumps, etc., as may be required. Valves 25 and 26 control the supply of secondary vapor from the evaporating chambers to the vapor compressors 11 and 13 and valves 27 and 28 control the discharge therefrom of the commingled primary and secondary vapors to the coils 2. A by-pass not shown could readily be provided to convey these commingled vapors to the coils 4 of the second effect. Valves 29 and 30 control the discharge of vapor from shells 1 and 3 respectively. Valve 31 controls the flow of vapor from the shell 1 of the first effect into the coils 4 of the second effect. Valve 32 is a vapor by-pass from the first to the effects following the second and to the condenser. Through valve 33, vapor is supplied the coils 8 of the preheater.

From pipe 34 the liquid resulting from the condensation of vapor within coils 8, is drained away either by a valve manually operated or automatically by a "trap" such as indicated by 17, 18 and 19 for discharging the liquid formed in the condensing chambers 2, 4 and 6, respectively. Upon these traps are mounted gage glasses at the side to indicate by the liquid level the proper working of the float or bucket within the trap. At the tops of these traps are connected the air cocks 35, 36 and 37 to discharge the "non-condensable gases" which collect just above the liquid within them. The liquid is discharged by these traps through drain main 38 to the coils 10 of the heat exchanger and thence through pipe 39 to a storage tank not shown or to waste. The non-condensable gases may also be discharged through coils 10 by connections such as 40 from air cock 35 to drain main 38. By this means the heat in the non-condensable gases and the saturated vapor commingled with them is conserved, as well as the heat in the condensed vapor. It would be impractical to discharge these gases with the condensed steam without discharging a considerable amount of vapor. If it is desired to operate the condenser and last effects at less than atmospheric pressure, the corresponding condensing chambers must be connected to

pumps to remove both the liquid and non-condensable gases under a vacuum.

Circulating water flows through shell 5 over coil 6 of the condenser, the rate of flow being controlled by valve 41 and the circulating water pump not shown. This circulating water is discharged through pipe 42. In the case of evaporating apparatus intended primarily for the production of fresh water, the "raw water" to be fed through valve 43 may be taken from pipe 42. In any case, the rate of feed of the liquid to be evaporated is controlled by valve 43 and a feed pump not shown. Passing through the shell 9 of the heat exchanger and the shell 7 of the preheater, the solution enters the first effect through pipe 44.

The partially evaporated liquid passes from shell 1 through pipe 45 to trap 15 from which it is automatically discharged through pipe 47 to shell 3 of the second effect. Pipe 46 serves to equalize the pressures within trap 15 and within shell 1. A gage glass on the trap 15 indicates by the liquid level the proper working of the bucket or float within the trap to maintain the proper liquid level within shell 1. From the second effect the liquid not evaporated therein is similarly discharged through pipe 50 to the succeeding effect or to a storage tank or to waste, by trap 16 with supply pipe 48 and equalizing pipe 49. The valves 51 and 52 are provided for draining the shells 1 and 3 respectively.

Baffle 53 within shell 1 prevents columns of liquid being projected into the vapor space due to the boiling within the coils 2 below it. The vapor produced is caused by pan 55 to pass to the circumference of the shell, and from the circumference the vapor must pass to the vapor pipe through a number of perforated openings staggered in two or more concentric cylinders 59. The moisture separated thereby drips down into pan 55 and is conveyed by pipe 57 either without the shell or to within the solution as shown. Within shell 3, the submerged baffle 54, separator 60, pan 56 and pipe 58 perform similar functions.

Upon shells 1 and 3 are mounted safety valves 61 and 62 so disposed that the escaping vapor does not pass through the separators for removing moisture from the vapor before it reaches the vapor pipes. On shell 1 there is also shown a vacuum break valve 63 to prevent the pressure within the shell becoming much less than atmospheric. A similar valve can be provided on shell 3.

To the float 64 is attached the valves 65 and 66, the former to throttle the feed and the latter to discharge at first vapor and then liquid should the latter rise abnormally. The pipe 67 conveys the liquid discharged to waste or to a storage tank.

Upon the top of the preheater an auto-

matic device 68 is mounted to discharge non-condensable gases collecting therein.

Pressure gages may be provided as at 69 and 70 to aid in the proper operation of the apparatus.

Referring to Fig. 1, during normal operation of the system, primary vapor is supplied through main 20 at a pressure slightly higher than that for which the vapor compressors 11 and 13 are designed to operate. By throttling either manually by the valves 21 and 22 or automatically by reducing valves, the pressure is reduced to that for which the De Laval nozzles in the vapor compressors are designed. This reduction in pressure near the compressors dries the primary vapor and may somewhat superheat it if the drop in pressure is sufficient, thus improving the action of the compressor.

With valves 25, 26, 27, 28 and 29 open, secondary vapor is drawn from shell 1, compressed, and forced at a higher pressure and temperature into coils 2 commingled with the expanded primary vapor from the De Laval nozzles 12 and 14. Within the coils 2, the commingled vapors are condensed, the resulting liquid trickling down through the coiled tubes to the trap 17 into which the non-condensable gases are also driven by the flow of the vapor. It is particularly desirable when vapor compressors are used, to so arrange the condensing chamber of the evaporator to produce a definite and rather high velocity over the condensing surface of the vapors to be condensed in order to attain a high rate of heat transfer. Also, the non-condensable gases, which are ordinarily denser than condensable vapor of the same pressure and temperature, should be driven downward by the flow of vapor. Both of these objects are obtained by the arrangement of heating surface shown in Fig. 1.

The vertical coiled tube in transmitting heat to the liquid within the coils form a column of mingled liquid and vapor less dense than the solid mass of liquid near the shell. This difference in specific gravity results in a flow up within the coil and down outside of it, with a consequent improvement in heat transfer from the outside surface of the coil to the solution. This also is particularly advantageous when vapor compressors are employed.

The columns of mingled liquid and vapor bubbles are prevented from being projected into the vapor space by the baffle 53 placed just above the coils. The vapor bubbles are separated to a great extent from the liquid and escape under the edges of the baffle to the vapor space above. The pan 55 deflects the rising vapor to the circumference of the shell, and to reach the vapor pipe the vapor must pass in a number of small streams through the holes or slits in the cylinders 59. The holes or slits are staggered in order

to deflect the streams and thus separate the moisture which drips into pan 55 and is conveyed by pipe 57 to within the solution. The pipe 57 may be arranged to convey the moisture without the shell. It is very desirable that the vapor to be compressed by this form of compressor be free from moisture, as is accomplished by the means described.

With valves 24 and 32 closed, a part of the vapor produced in shell 1 passes through valves 29 and 31 into the condensing chamber 4 of the second effect, where it is condensed by imparting its latent heat through the surface of coils 4 to the liquid within shell 3. Of the total quantity of secondary vapor produced in shell 1, from one-half to four-fifths will be compressed by the vapor compressors and discharged into coils 2 to be there condensed with the primary vapor, while the remainder of the secondary vapor passes to the coils 4 of the second effect. With the same temperature difference between vapor within the coils and liquid outside of them in the second effect as in the first effect, it is evident that there should be only one-half to one-fifth the condensing surface in the second effect as in the first effect.

The vapor produced in shell 3 by the condensation of secondary vapor from shell 1, passes through valve 30 to the coils 6 constituting the condensing chamber of the condenser having the shell 5. A continuous flow of circulating water is maintained through shell 5 by regulating the valve 41 and the circulating water pump not shown.

During normal operation, the liquid resulting from condensation of the vapor within the condensing chamber 2 of the first effect, is automatically removed by the trap 17; and, what is of the greatest importance in an evaporator operated by a vapor compressor, the non-condensable gases are continuously discharged from directly over the liquid surface where they collect. This latter is accomplished through the cock 35, which is represented as of the hand operated type, but an automatic device may be provided which will allow gas with but very little vapor to escape. Similar traps 18 and 19 with cocks 36 and 37 remove the condensed vapor and non-condensable gases from condensing chambers 4 and 6 respectively.

The condensed vapor escapes at a temperature approaching that of the vapor from which it is formed. Passing through drain pipe 38 to the coils 10 of the heat exchanger, it is cooled by the incoming feed before being discharged by pipe 39. In some installations it may be desirable to keep separate the condensate from the first effect, because it contains whatever impurities may be in the primary vapor operating the vapor compressors.

During normal operation, the liquid to be evaporated is fed at a constant rate through valve 43. Passing through the heat exchanger shell 9 and the preheater shell 7, the liquid is heated nearly to the boiling point. This heating causes a separation of much of the contained gases, and these are automatically removed by the device 68, or provision for their escape may be made by a manually operated cock at 68. The removal of the gases before they enter the evaporator shell improves the performance of the vapor compressors which would otherwise have to remove them.

Entering the shell 1, the heated liquid boils by reason of the further addition of heat from the coils 2. The partially evaporated liquid passes through pipe 45 to the trap 15 from which it is automatically discharged through pipe 47 to the shell 3 of the second effect. The liquid in pipe 45 is denser than the mixture of liquid and vapor bubbles within the shell 1. Consequently, the liquid level in 15 will be lower than the surface of the solution in the shell. The heating surface is most efficacious when the level within the shell stands just about the top of the heating surface, the solution level in the trap 15 and attached gage glass then being from 0 to 10 inches lower. In an evaporator employing a vapor compressor, therefore, the most efficient operation is obtained by maintaining the apparent liquid level as indicated by an external gage glass attached to the shell, from 0 to 10 inches below the top of the coils.

The liquid entering shell 3 is further evaporated therein and is discharged in a manner similar to that for shell 1 by the trap 16, a constant level being maintained within shell 3. Should valve 43 be opened too wide, the circulation will be so rapid that the liquid escaping from pipe 50 will be only slightly concentrated; if the valve 43 be not opened sufficiently wide, the escaping liquid at pipe 50 will be too highly concentrated. Consequently, valve 43 should be regulated during normal operation according to the concentration desired at pipe 50.

The advantages of providing two or more vapor compressors are set forth in Patent No. 1,361,843 issued Dec. 14, 1920, filed September 16, 1916, for a single effect plant. These advantages also apply to a multiple effect plant as herein described. Thus assume the evaporator working at its maximum capacity with all vapor compressors in operation. The effect of shutting off one vapor compressor not only reduces the capacity but also increases the efficiency. This becomes evident when we consider that shutting off one ejector reduces the heat to be transferred by the fixed heating surface in the evaporator. Consequently, the tem-

perature difference between the solution and the vapor in the heating space is reduced with a corresponding reduction in the range of compression required in the vapor compressor. With reduced range of compression, more secondary vapor is compressed per pound of primary vapor than before the one vapor compressor was shut off. That is, shutting off one vapor compressor increases the efficiency of evaporation with the remaining vapor compressors in operation. By providing several vapor compressors in parallel for a given capacity with a given multiple effect plant, there is thus obtained a flexibility of operation with an increase of efficiency at reduced capacities not available when a single vapor compressor only is provided. Experiment shows that with a single vapor compressor, the capacity of the evaporator may be reduced by reducing the initial steam pressure but the efficiency does not increase.

Various other devices, not referred to above, are intended to take care of certain abnormal conditions. Thus, it may be necessary at times to operate at a greater capacity than possible with both compressors working with rated primary vapor pressure. While a slight increase in capacity may be obtained by opening valves 21 and 22 wide instead of throttling the primary vapor supply, a much larger increase may be obtained by opening valve 23 to by-pass the ejectors with primary vapor to the condensing chamber 2 of the first effect. A greater temperature difference can then be obtained in the several effects with a consequent increase in capacity but at poorer economy. Instead of opening valve 23, valve 24 may be opened to admit primary vapor to condensing chamber 4 and thus increase the capacity of the effects succeeding the first, obtaining the desired increase in capacity without as great a reduction in economy.

Should for any reason valve 31 be closed during the operation of the plant, the pressure within shell 1 might reach a dangerous point unless safety valve 61 opens to discharge the excess vapor. The sudden opening of a safety valve, more especially of the popping type, causes a very rapid boiling of the liquid with a consequent tendency to prime. Connecting the safety valve so that the large quantity of vapor flowing to it does not by-pass the separator through which the vapor leaving the evaporator must pass, reduces the effect of priming. This is especially advantageous when ejectors are used, as it prevents a large amount of the impure liquid being carried over into the condensing space to contaminate the condensed vapor therein.

If the trap 15 should become defective and allow the liquid level to rise within shell

1, the float 64 will also rise when the liquid reaches it, thereby throttling the feed at 65 and at the same time opening an overflow valve 66. The escape of vapor from pipe 63 will first serve as a warning, the liquid later escaping being discharged through pipe 67 to a storage tank or to waste as the case may be.

If the attempt is made to start up the evaporator with valves 25, 26 and 29 open, a vacuum will be produced within the shell. The vacuum break valve 63 will relieve this vacuum and thus prevent the collapse of a shell not designed sufficiently strong to stand the external pressure.

Pressure gages at 69, 70 and elsewhere serve in properly operating the apparatus.

Having thus described my invention, I claim and desire to secure by Letters Patent, the following:

1. A plurality of vapor compressors in combination with a multiple effect evaporating plant, each effect of said plant containing a condensing chamber and an evaporating chamber, the said vapor compressors being connected in parallel to withdraw vapor from the evaporating chamber of the first effect and to discharge the said vapor compressed and commingled with the primary operating vapor into the condensing chamber of the said first effect, passages being provided for discharging vapor from the evaporating chamber of each effect into the condensing chamber of the succeeding effect and from the evaporating chamber of the last effect, and valves being provided to reduce the number of vapor compressors in operation.

2. A plurality of vapor compressors in combination with an evaporator containing condensing and evaporating chambers, the said compressors being connected in parallel to withdraw vapor from the said evaporating chamber and to discharge the said vapor compressed and commingled with the primary operating vapor into the said condensing chamber, valves arranged to shut off the number of vapor compressors in operation, and means of preheating the liquid fed to the said evaporating chamber by the condensation of vapor from the said condensing chamber.

3. In an evaporating apparatus comprising a vapor compressor containing a De Laval nozzle in combination with an evaporator containing condensing and evaporating chambers, means of giving warning of an abnormal rise of liquid in the said evaporating chamber by automatically discharging vapor therefrom.

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