Dec. 5, 1967 F. DAMBRINE 3,356,124

CONTROL ARRANGEMENT FOR A MULTIPLE EFFECT EVAPORATOR

Filed Oct. 12, 1965 2 Sheets-Sheet 1

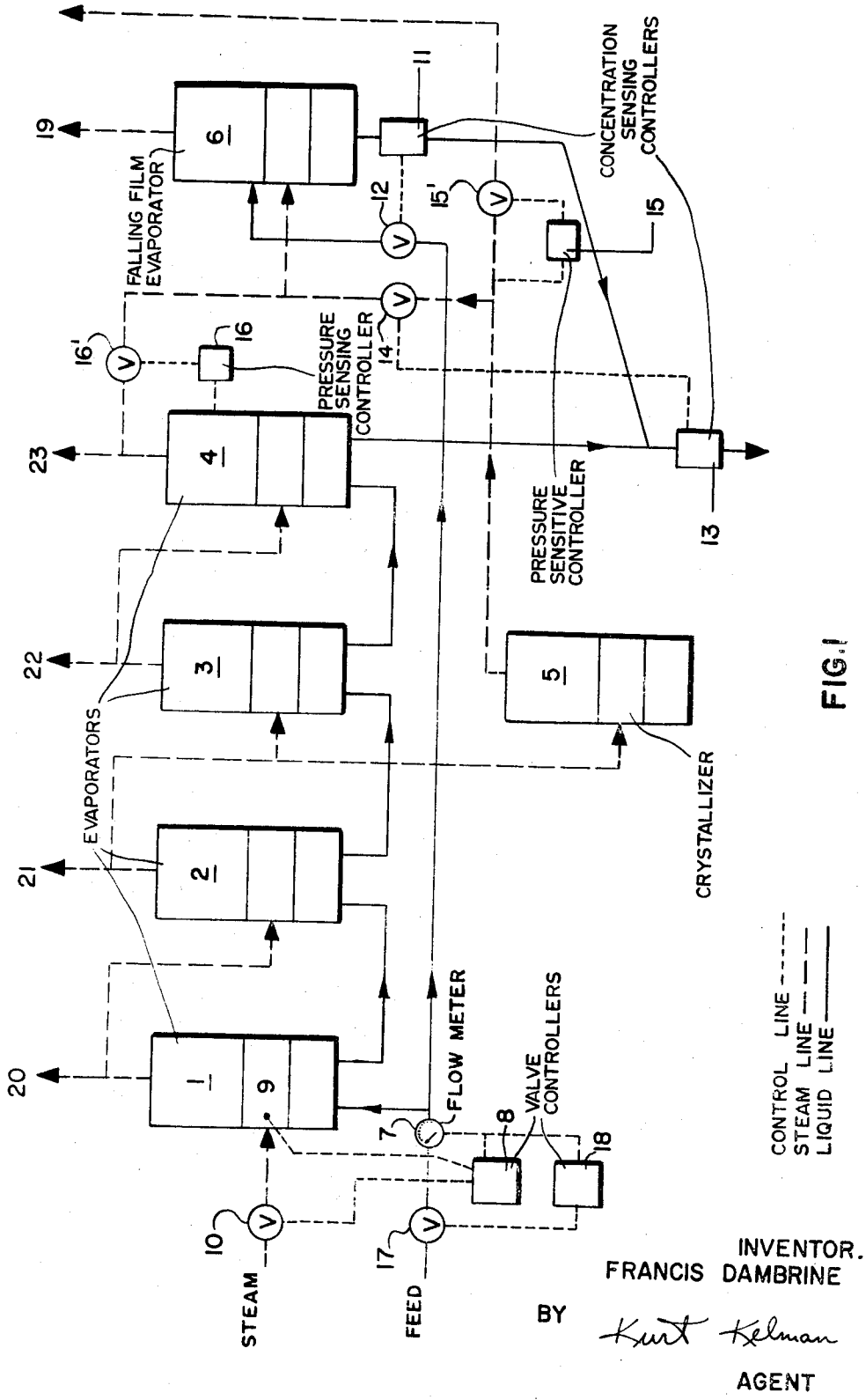


FIG. 1

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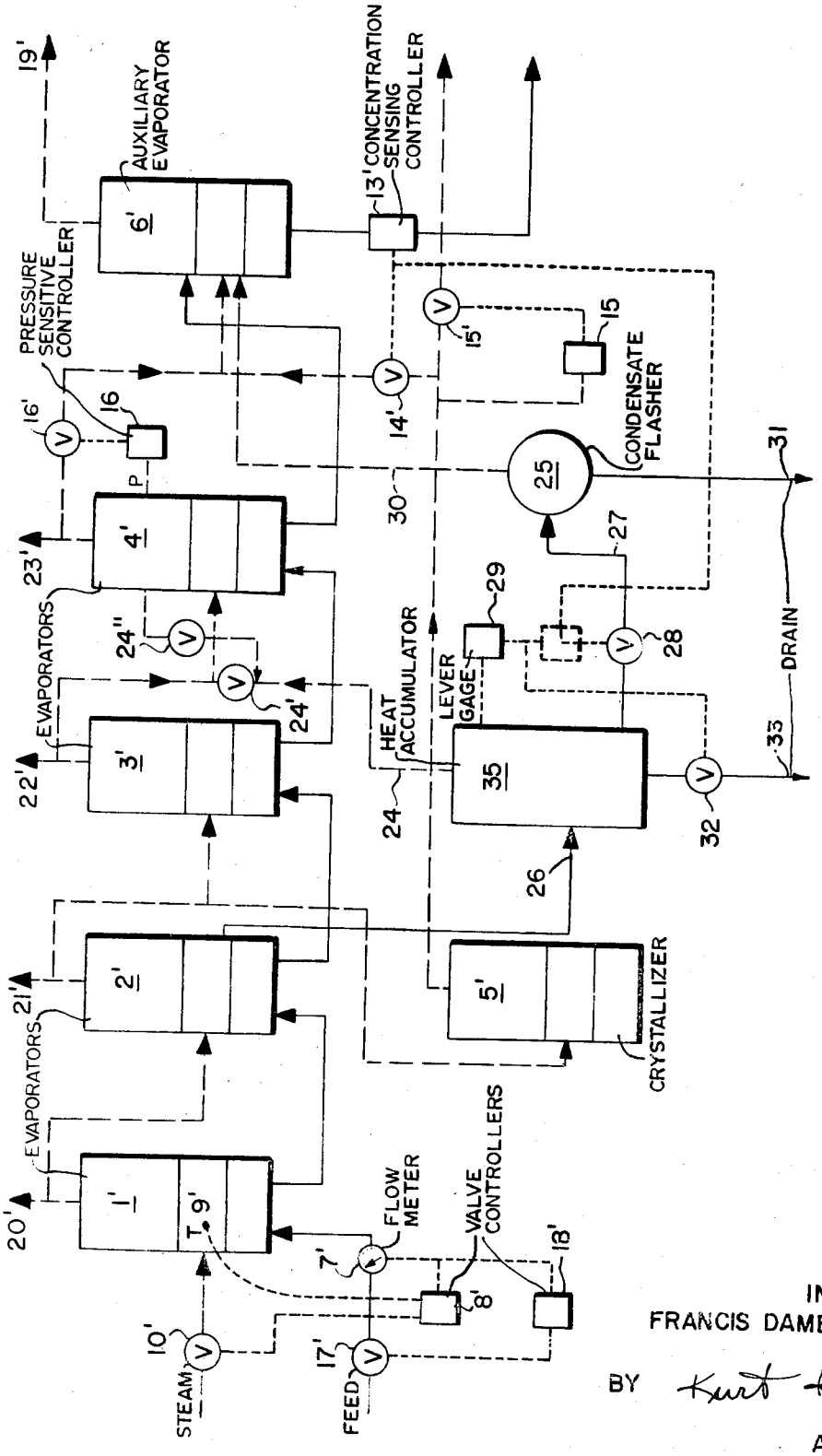


FIG.2

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United States Patent Office 3,356,124 Patented Dec. 5, 1967

3,356,124

CONTROL ARRANGEMENT FOR A MULTIPLE EFFECT EVAPORATOR

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Filed Oct. 12, 1965, Ser. No. 495,124
Claims priority, application France, Oct. 13, 1964, 991,198
7 Claims. (Cl. 159—17)

This invention relates to multiple effect evaporators for concentrating a solution, and particularly to an arrangement for controlling the concentration of the solute in the output of a multiple effect evaporator.

The thermal energy of the vapor, such as steam, released from the last effect of such an evaporator is normally lost in a condenser, and the thermal efficiency of the apparatus is thereby diminished. It is conventional to withdraw steam from the several effects for use in other devices in order to minimize the amount of steam transferred to the condenser and thereby to obtain a more favorable heat balance.

Such steam withdrawals are generally of two types. A portion of the steam is withdrawn at a rate proportional to the input of the solution to be evaporated and is used, for example, for preheating the feed solution. Another portion of the steam is withdrawn at a variable rate not directly related to the solution input. The sugar industry provides a major field of application for multiple effect evaporators, and it is common in sugar plants to withdraw steam from the evaporators for feeding crystallizers, the amount of steam supplied to the crystallizers not being proportional to the liquid input of the evaporators.

The concentration of the solute in the liquid discharged from the last evaporator effect does not vary with the amount of steam withdrawn by operations of the first type but it is affected by steam withdrawals of the second type. The resulting variation in the concentrate composition has been compensated heretofore by devices which vary the amount of steam transferred to the condenser, whereby heat losses are incurred at the condenser, and the total amount of steam lost by condensation is greater than would otherwise be necessary. It has also been attempted to compress the steam and to inject it into one of the effects which requires relatively costly auxiliary equipment.

The overall object of the invention is to provide a control arrangement for the composition of the concentrate obtained from a multiple effect evaporator which is simple and effective in improving the thermal balance of the apparatus.

Another object is the utilization of the thermal energy contained in the condensate formed in the multiple effect evaporator and in the low pressure steam of an associated crystallizer or other auxiliary heat exchanger provided with steam by the principal evaporating installation, which is wasted in conventional installations, for removing water from the principal process stream.

According to this invention, the supply of thermal energy from such auxiliary sources to the process stream is controlled in response to the amount of solute contained in the concentrate produced.

The invention in one aspect thus resides in a multiple effect evaporator arrangement in which several evaporator effects are arranged in series to constitute a basically conventional principal evaporating installation. Thermal energy is withdrawn from this installation and an auxiliary evaporating installation is supplied with exhaust steam corresponding to the withdrawn energy. A controller responsive to the concentration of the liquid concentrate discharged by at least one of the installations controls the steam supply to the auxiliary installation.

In operating the arrangement, a first solution of a solute, such as sugar, in a solvent, such as water is heated in a first evaporating zone by indirectly applied steam heat until steam is produced from the solution, whereby the residual sugar solution is concentrated. A portion of the steam is transferred to a second zone in which a second sugar solution, which may by the afore-mentioned concentrate, is heated by thermal contact with the steam, whereby more steam is evaporated and a second residual concentrate is formed. The transfer of steam from the first to the second zone is controlled in response to the sugar concentration in the second concentrate.

While water is being referred to herein as a solvent, sugar as a solute, and steam as a vapor of the solvent, it will be appreciated that the invention is not concerned with chemical reactions but with physical changes, and is not limited to the specific materials.

Other objects, features and advantages of this invention will be readily appreciated as the same is better understood from the following description of preferred embodiments with reference to the attached drawing in which.

FIG. 1 is a flow sheet of a first multiple effect evaporator arrangement of the invention; and

FIG. 2 illustrates a similar arrangement in a corresponding manner.

Referring initially to FIG. 1, there are seen the four effects 1, 2, 3 and 4 of a four-effect evaporator, which are connected for series flow of a solution to be evaporated through a motor-operated feed control valve 17 and a flow meter 7 to the first evaporator effect 1, and for discharge of concentrate from the last effect 4 through a concentration sensing controller 13, conventional in itself.

Steam is fed through a motor-operated steam control valve 10 to a bundle 9 of heat exchanger tubes, not shown in detail, in the effect 1. The valve 10 is opened and closed by its motor in response to signals from an automatic controller 8 connected to the flow meter 7 and to a non-illustrated sensing device responsive to the pressure or saturation temperature of the steam in the heat exchanger 9 for maintaining the proper relationship between the amount of liquid admitted to the apparatus and sensed by the flow meter 7 and the amount of steam admitted by the valve 10.

The partial evaporation of water from the solution in the first effect 1 provides steam for heating the residual partly concentrated solution in the effect 2, and the effects 3 and 4 are similarly heated by the exhaust steam from the preceding effects. The return of steam and condensate from the several bundles of heat exchanger tubes in the effects 1 to 4 to the steam source has not been shown in the flow sheet of FIG. 1.

A portion of the steam generated in the second effect 2 is utilized for heating a crystallizing evaporator 5, conventional in itself, in which heat exchange between the steam and a concentrated sugar solution causes crystallization of sugar and discharge of steam from the concentrate. The crystallizer 5 is connected to the steam input of a single auxiliary evaporator 6 arranged for a small temperature drop for recovering the thermal energy of the steam discharged from the crystallizer 5. The evaporator 6 may be of the falling film or surface spray type.

The liquid supply for the evaporator 6 is drawn from the input conduit of the first effect 1, and is regulated by a motor-operated valve 12 controlled by a concentration responsive controller 11 in the concentrate line of the evaporator 6. The rate of liquid feed to the evaporator 6 is controlled in such a manner that the boiling temperature of the liquid is only slightly increased by evaporation.

The concentrate output of the evaporator 6 is mixed with that of the fourth effect 4 prior to passage through

the concentration sensing controller 13. The latter is connected with the motor of a valve 14 which controls steam flow from the crystallizer 5 to the evaporator 6. A pressure sensitive controller 15 in an exhaust line of the crystallizer 5 maintains constant pressure in the latter, regardless of the rate of steam withdrawal to the evaporator 6, by opening and closing a vent valve 15'. The steam pressure in the vapor space of the fourth effect 4 is similarly held constant by a pressure sensitive controller 16 and a valve 16' which connects the effect 4 to the steam pipes in the evaporator 6. The valve 16' should normally remain closed under proper operating conditions, and releases steam to the steam pipes in the evaporator 6 when open.

A controller 18 connected to the flow meter 7 and to the feed valve 17 serves as a program source for maintaining a desired input rate in the evaporator. This rate may be constant. Steam taps 20 and 23 permit the steam generated in the effects 1 to 4 to be withdrawn for other purposes, as far as consistent with the operation of the next effect, and a similar tap 19 is provided on the evaporator 6.

When this apparatus is operated, the valve 10 admits an amount of steam to the first effect 1 which is commensurate with the admitted liquid, as sensed by the flow meter 7. A major portion of this liquid passes successively through the four effects 1–4, and the minor remainder enters the evaporator 6 through the valve 12. The liquid is concentrated in the effects 2 to 4 by respective portions of the steam generated in the preceding effects at gradually decreasing pressure, the remainder of the steam being withdrawn for operating auxiliary equipment, as is customary in sugar factories, and the remainder being condensed.

The crystallizer 5 which draws thermal energy from the evaporator effect 2 is an example of such auxiliary equipment. The amount of steam needed for running the crystallizer varies in a manner unrelated to the operation of the four-effect evaporator, and thus causes variations in the composition of the concentrate discharged from the fourth effect 4. These variations are compensated by changes in the amount of the more dilute liquid discharged by the evaporator 6 and held at uniform concentration by the controller 11.

More specifically, let it be assumed that the controller 13 senses a lowering in the concentration of the outflowing liquid because of increased steam consumption in the crystallizer 5 or otherwise. This causes the valve 14 to be opened for increased supply of steam from the crystallizer to the evaporator 6. The resulting incipient higher concentration of the effluent from the evaporator 6 is detected by the controller 11 and the flow of fresh solution to the evaporator 6 is increased by opening of the valve 12, whereby the amount of liquid entering the first effect 1, and the rate of outflow from the last effect 4 are decreased, and the concentration of that outflow is increased.

This chain of events causes the concentration of the product to be restored to the desired value for which the controller 13 is set.

This result can usually be achieved without the provision of the controller 16 if the withdrawals of steam from the multiple effect evaporator are kept within limits that are readily determined by experiment for each individual plant, and can be calculated at least to some extent according to know design principles.

The modified evaporator arrangement shown in FIG. 2 has a principal evaporating installation consisting of four effects 1' to 4' connected in series, as in the apparatus of FIG. 1, the first effect 1' being provided with steam and the solution to be evaporated through valves 10' and 17', respectively, which are regulated by controllers 8', 18', a flow meter 7' and a temperature sensing device (not shown) in the bundle 9' of heat exchanger tubes in the first effect 1', as described with reference to the corresponding elements illustrated in FIG. 1.

An auxiliary evaporator 6' is connected to the vapor space of the fourth effect 4' through a valve 16' operated by a pressure-sensitive controller 16, as described hereinabove, and steam is or may be withdrawn through taps 19' to 23' to secondary consumers of thermal energy or to a condenser.

A crystallizer 5' draws steam from the second effect 2' and supplies exhaust steam to the evaporator 6' through a valve 14' which is opened and closed by a controller 13' in response to the concentration of the liquid discharged from the evaporator 6' which may be identical with the afore-described evaporator 6. A constant pressure is maintained in the crystallizer 5' by a pressure-sensitive controller 15 acting on a vent valve 15'.

The entire concentrate discharged from the fourth effect 4' is conducted to the evaporator 6' as the sole liquid feed for the latter but the arrangement of the elements so far described is otherwise substantially identical with that of correspondingly numbered elements in the apparatus of FIG. 1.

The hot condensate produced in the steam pipes of the second effect 2' by partial evaporation of water from the process liquid in the second effect 2' is collected in a heat accumulator 35 to which it is led by a conduit 26. A conduit 24 and valves 24', 24'' connect the accumulator 35 with the steam pipes and with the vapor space of the fourth effect 4', respectively, for producing steam therein if so desired at the pressures prevailing in the fourth effect 4' which are lower than that of the accumulator 35. A flash evaporator 25, which is a closed vessel communicating with the steam pipes of the evaporator 6' through a conduit 30, is connected to the heat accumulator 35 by a conduit 27 having a valve 28 connected to the controller 13' and to a level gage 29 on the accumulator 35. The accumulator 35 is equipped with a drain 33 whose valve 32 is connected to the gage 29 and the controller 13'.

When the apparatus shown in FIG. 2 is operated, liquid and steam are respectively admitted to the first effect 1' in amounts determined by the controllers 8', 18', and variable amounts of steam may be withdrawn from the several evaporator effects, as described hereinabove. The variations in these withdrawals, as well as the variation in the steam demand of the crystallizer 5' are compensated, at least in part, by variations in the steam supply to the evaporator 6' controlled by the concentration sensing controller 13'.

When the controller 13' has reached the limit of control of the valve 14' without fully restoring the desired concentration in the outflowing liquid, it opens the valve 28 to admit hot water from the accumulator 35 to the evaporator 25 for generating steam in the latter, and thereby to augment the steam supply of the evaporator 6', whereby the concentration of the product discharged from the apparatus is increased.

When this concentration approaches the desired value, the valve 28 is closed first by the controller 13', and the valve 14' is partly closed when proper concentration is reached.

The capacity of the heat accumulator 35 must be chosen so as to provide a sufficient reserve of thermal energy for periods of peak steam consumption by the crystallizer 5' and other, non-illustrated, secondary steam consuming units. When the condensate in the accumulator 35 rises above a set maximum level, the gage 29 opens the valve 28 to cause evaporation of a portion of the condensate from the accumulator 35, and opens the valve 32 in the drain 33 when the concentration in the discharged product sensed by the controller 13' and caused by the increased steam supply to the evaporator 6' exceeds a set limit while the gage 29 senses an oversupply of condensate in the accumulator.

In a typical run of the apparatus shown in FIG. 1, sugar juice having a concentration of 15% was fed through the valve 17 at a rate depending upon the rate of production of the factory. Steam was admitted to the first effect 1 at a rate sufficient to maintain a steam saturation

temperature of 125° C. in the steam pipes of the evaporator effect **1**. The four evaporator effects were operated at approximate vapor temperatures of 125/117, 117/108, 108/94 and 94/70° C. Of the total sugar juice fed to the evaporator arrangement, approximated 80/85 percent were normally passed through the four-effect evaporator and the remaining 15/20 percent through the falling film evaporator **6** whose concentrate was kept at a concentration of 30% of solid material by the controller **11**. The steam valve **14** was operated by the controller **13** to maintain the concentration of the combined concentrates at 60% of solid material.

Sugar juice and steam were fed to the apparatus of FIG. 2 in the same manner as described with reference to the apparatus of FIG. 1. The pressures in the four-effects were kept substantially to the same values as in the above case. The controller **13'** was set to maintain a constant concentration of the effluent liquid of 60% by action on the valves **14'** and **28**.

In this case, the invention permits to make an economy of steam of about 10% when the variable steam withdrawals represent about 40% of the total consumption of the multiple effect evaporator arrangement.

Many features of the two illustrated embodiments of the invention are readily interchangeable. The evaporator **6** of the first embodiment may be fed the output of concentrate from the fourth evaporator effect **4** instead of drawing a supply of dilute liquid from the flow meter **7**. Conversely, the evaporator **6'** shown in FIG. 2 may be supplied with dilute original liquid in the manner of FIG. 1. The principal evaporating installation constituted by four effects in both illustrated embodiments and the auxiliary evaporating installation constituted by the evaporators **6** or **6'** may thus be arranged for series flow or parallel flow of the process liquid. Obviously, the number of effects in the principal installation may be increased or reduced, and the auxiliary installation may contain more than one evaporator, and such multiple evaporators may be arranged in series or in parallel.

The exhaust steam employed for providing thermal energy to the auxiliary evaporating installation **6, 6'** has been shown in FIGS. 1 and 2 to be derived from such secondary heat exchangers as the crystallizers **5, 5'**. If the external steam demand from the taps **20–23, 20'–23'** can be expected to be so low from time to time to make excess steam available at the fourth effect **4, 4'**, such excess steam may be utilized for heating water which in turn may be evaporated in the manner of the condensate vaporized in the evaporator **25** for supplying low-pressure steam for an auxiliary evaporator installation.

Obviously, other modifications and variations of the present invention are possible in the light of the above teachings. It is therefore to be understood that, within the scope of the appended claims, the invention may be practiced otherwise than as specifically described.

What is claimed is:

1. In a multiple effect evaporator arrangement, in combination:

(a) a plurality of evaporator effects arranged in series and constituting principal evaporating means for partly evaporating a solution fed to the first effect in said series, at least one of said effects being indirectly steam heated, whereby a first concentrate is formed from said solution, and a hot condensate is formed from the heating steam by the partial evaporation of said solution in said one effect;

(b) auxiliary evaporating means for partly evaporating a solution fed to said auxiliary evaporating means and for thereby forming a second concentrate;

(c) heat accumulator means connected to said one effect for receiving said condensate at a predetermined pressure;

(d) condensate evaporator means interposed between said accumulator and said auxiliary evaporating means for evaporating said condensate at a pressure lower than said predetermined pressure, and for transferring the evaporated condensate to said auxiliary evaporating means for heating the solution fed thereto; and

(e) control means responsive to the concentration of one of said concentrates for controlling the rate of said evaporation of said condensate.

2. In an arrangement as set forth in claim **1**, a conduit connecting said heat accumulator means and the last evaporator effect of said principal evaporating means for establishing vapor equilibrium between said condensate in the accumulator means and said vapor in said last effect.

3. In a multiple effect evaporator arrangement, in combination:

(a) a plurality of evaporator effects arranged in series and constituting principal evaporating means for partly evaporating a solution fed to the first effect in said series and for thereby producing vapor in each effect and a first concentrate;

(b) steam heated auxiliary evaporating means for partly evaporating a solution fed to said auxiliary evaporating means and for thereby forming a second concentrate;

(c) heat exchanger means connected to one of said effects and to said auxiliary heat exchanging means for exchanging thermal energy between vapor produced in said one effect and an aqueous liquid, and for thereby producing low pressure steam from the liquid for heating said auxiliary evaporating means; and

(d) control means responsive to the concentration of one of concentrates for increasing the admission of said low pressure steam to said auxiliary evaporating means when said concentration decreases.

4. In an arrangement as set forth in claim **3**, means for transferring said first concentrate to said auxiliary evaporating means for additional partial evaporation therein, said control means responding to the concentration of the second concentrate formed by partial evaporation of said first concentrate in said axuiliary evaporating means.

5. In a multiple-effect evaporator arrangement, in combination:

(a) a plurality of evaporator effects arranged in series and constituting principal evaporating means for partly evaporating a solution fed to the first effect in said series, and for thereby producing a first vapor and a first liquid concentrate,

(1) at least one of said effects being indirectly steam heated, whereby a hot condensate is formed from the heating steam by the evaporation of said solution in said one effect;

(b) auxiliary evaporating means for partly evaporating therein a solution fed to said auxiliary evaporating means and for thereby producing a second vapor and a second liquid concentrate;

(c) heat accumulator means connected to said one effect for receiving said condensate at a predetermined pressure;

(d) condensate evaporator means interposed between said accumulator means and said auxiliary evaporating means for evaporating said condensate at a pressure lower than said predetermined pressure;

(e) means for withdrawing thermal energy from said first vapor and for transferring said energy to the solution in said auxiliary evaporating means; and

(f) control means responsive to the concentration of one of said concentrates for increasing the rate of energy transfer to said auxiliary evaporating means when said concentration decreases,

(1) said control means including means for controlling the rate of evaporation of said condensate, and

(2) said transferring means including means for transferring the evaporated condensate to said

auxiliary evaporating means for heating the solution fed to the same.

6. In a multiple-effect evaporator arrangement, in combination:

(a) a plurality of evaporator effects arranged in series, and constituting principal evaporating means;

(b) auxiliary evaporating means;

(c) feed means for feeding respective portions of a solution to be evaporated to said principal and to said auxiliary evaporating means, said evaporating means each being effective partly to evaporate the fed portions of said solution and thereby to produce respective concentrates, a vapor being produced in said principal evaporating means from the partly evaporated solution;

(d) means for withdrawing thermal energy from said vapor and for transferring said energy to the portion of said solution in said auxiliary evaporating means;

(e) mixing means for mixing said concentrates; and

(f) control means responsive to the concentration of the mixed concentrates for increasing the transfer of

energy from said vapor to said portion of the solution in said auxiliary evaporating means in response to a decrease in said concentration.

7. In an arrangement as set forth in claim 6, means for maintaining the combined amount of said solution portions respectively fed to said evaporating means at a predetermined value.

References Cited

UNITED STATES PATENTS

1,598,301	8/1926	Mugler	159—17
2,330,221	9/1943	Kermer	159—45 X
2,941,590	6/1960	Rosenblad	159—47

FOREIGN PATENTS

609,769	1/1927	France.
587,121	4/1947	Great Britain.
587,122	4/1947	Great Britain.

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