

Sept. 28, 1943.

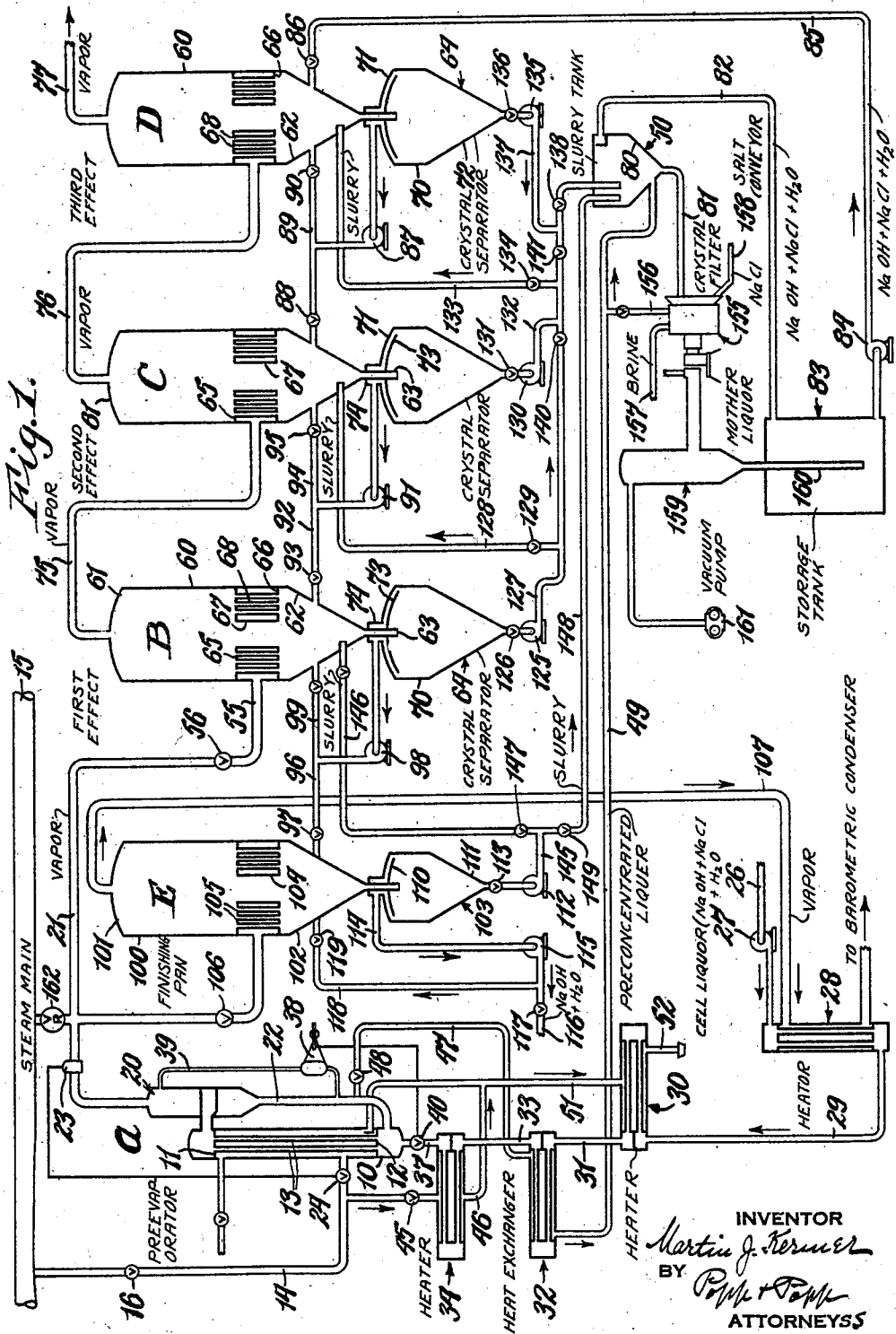
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UPON CONCENTRATION DEPOSIT CRYSTALS AND LEAVE
A RESIDUAL CONCENTRATED LIQUOR

Filed Oct. 4, 1937

2 Sheets--Sheet 1



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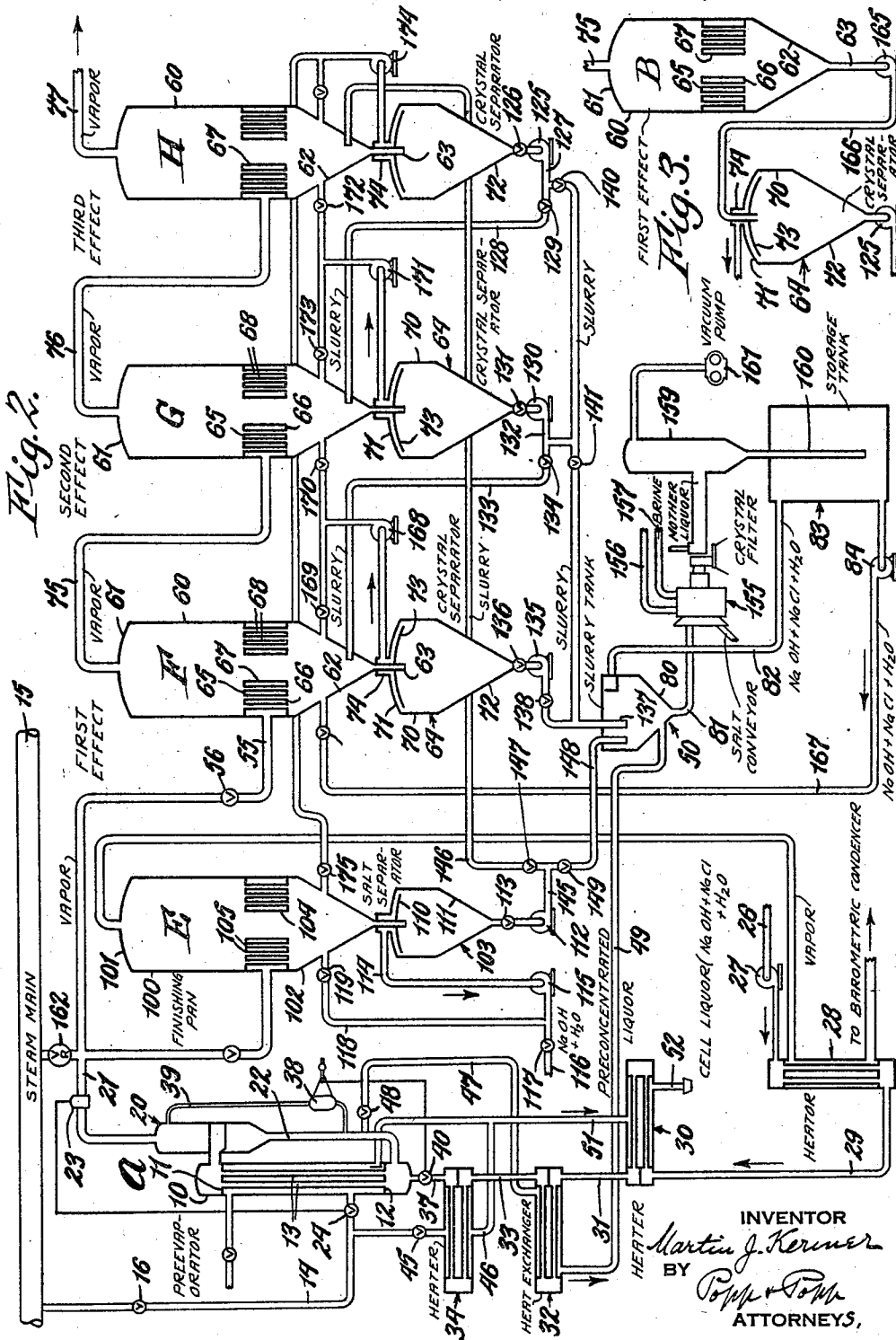
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UNITED STATES PATENT OFFICE

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METHOD AND APPARATUS FOR CONCENTRATING LIQUIDS WHICH UPON CONCENTRATION DEPOSIT CRYSTALS AND LEAVE A RESIDUAL CONCENTRATED LIQUOR

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This invention relates to a method and apparatus for concentrating liquids which upon concentration deposit crystals and leave a residual concentrated liquor. More particularly, the invention relates to the separation from each other of chemically and physically different components which are carried in substantial proportions in solution in a common solvent, one of which components crystallizes out in said solution, and the other component does not, when said solution reaches at least a particular concentration of said one component. Such liquids are, for example, electrolytic caustic soda which on withdrawal from the electrolytic cells contains a large amount of unconverted sodium chloride or other salt; chemical caustic soda containing sodium sulfate and sodium carbonate; brines containing sodium chloride, calcium chloride and magnesium salts and glycerine containing sodium chloride or other salt. The invention is more specifically described with reference to electrolytic caustic soda which because of its caustic character is difficult to handle.

In the manufacture of electrolytic caustic soda, the cells are charged with sodium chloride brine which is partly converted through electrolysis into caustic soda, the by-products being hydrogen and chlorine. In commercial practice the average cell produces approximately a 9% caustic soda solution with a 50% decomposition factor resulting in about 13% sodium chloride in the cell liquor withdrawn. To separate the salt from the caustic it is necessary to concentrate the cell liquor to crystallize most of the salt after which the salt is removed, washed and reused, it being important that the brine fed to the cells be as free from impurities as possible.

It is now the common practice in the industry to concentrate cell liquor to approximately 30% caustic soda in a triple effect evaporator and then to approximately 50% in a single effect evaporator. At times a double or triple effect evaporator is used for concentrating the cell liquor to 50%, depending upon the steam pressure available and quantity to be handled. It frequently happens that there is an insufficient supply of low pressure steam for the triple or double effect evaporator which receives the cell liquor and under these conditions high pressure steam is reduced to low pressure. The demand for pure and iron free caustic has resulted in the use of nickel evaporators which, of course, has greatly increased the cost of the apparatus and it is therefore highly desirable to reduce the size of such apparatus or increase the capacity of existing equipment without increasing its size.

As now practiced, the salt precipitated in each effect is collected as a sludge in a salt receiver which is connected by a valve to the cone bottom of each effect. When the receivers become filled with salt slurry they are disconnected from the evaporators by closing the valves between the cone bottoms of the effects and the salt receivers. Each receiver also has a cone bottom with a valve which in turn is connected to a slurry pump which discharges the entire contents of each salt receiver into one main receiving tank in which all the salt slurry is collected from all the effects. In this tank the salt precipitates and the clear liquor is used to refill the empty salt receivers. The clear liquor so removed is, of course, a mixture of the different concentrations from the several effects. Therefore this removal of the slurry not only disturbs the operation of the apparatus but the return of the clear liquor disturbs the balance of the system because the liquor in the several effects is at different degrees of concentration whereas the returned liquor is a mixture of the liquor from all of the effects and its concentration different from any one of the effects. In addition the separated salt is usually first washed with the cell liquor and since the cell liquor is not saturated with salt part of the removed salt so washed is redissolved.

One of the objects of the invention is to provide an automatic, continuous and balanced method of concentrating liquor which upon concentration deposits crystals and leaves a residual concentrated liquor which method, by the use of the pre-evaporator, permits greater steam economy and the use of smaller units for the same capacity. The pre-evaporator can be added to existing evaporator installations in order to increase capacity without proportionately increasing steam consumption.

Another object is to provide such a method which can be carried out with equipment costing far less, especially where expensive metals are employed as the evaporating surface, than present equipment of the same capacity.

Another object of the invention is to replace the present method of mixing the salt from the several effects in the unsaturated cell liquor by an automatic, continuous and balanced method of washing the salt with the saturated liquor in the evaporator system. This washing method can also be carried out in existing installations by installing a set of salt separators.

Another object is to provide such a continuous method of washing the salt which reduces the salt losses as compared with present processes.

Another object is to provide such a process in

which the liquor is substantially saturated in a pre-evaporator and used for washing all of the salt.

Another object is to effect a large saving in steam by the use of the pre-evaporator, by the continuous countercurrent washing of the salt and by the use of heat interchangers as hereinafter set forth, the amount of steam required being reduced from the usual consumption of about 41 pounds for each hundred pounds of cell liquor treated to about 29 pounds in a triple effect evaporator and finishing pan.

Another object of the invention is to provide such method and apparatus which are particularly applicable to the continuous separation from each other of two chemically and physically different components carried in substantial proportions in solution in a common solvent, one of which components crystallizes out in said solution, and the other component does not, when said solution reaches at least a particular concentration of said one component.

Another object of the invention is to provide such a process and apparatus in which the residual solution is removed in a substantially crystal free condition and to permit the progress of the solution through the several effects with a minimum disturbance with the separation of the crystals from the solution and with the maximum opportunity for the crystals to separate out and be locally segregated.

Another object of the invention is to provide such a method and apparatus in which the liquor is reduced in temperature between those stages where a lower temperature is desirable for washing the crystals and for obtaining the maximum economy and in which the cooling is effected without heat loss.

In the accompanying drawings:

Fig. 1 is a diagrammatic representation of the preferred form of apparatus for carrying out my improved process.

Fig. 2 is a view similar to Fig. 1, showing a modified arrangement of the multiple effect evaporators.

Fig. 3 is a diagrammatic representation of a modified form of crystal separator.

As best shown in Fig. 1 the letter A represents a film type of pre-evaporator or pre-concentrator. This is shown as consisting of a vertical cylindrical body 10 closed at its upper and lower ends and having upper and lower tube sheets 11 and 12 connected by tubes 13. Steam is supplied to the space around the tubes 13 from a steam inlet pipe 14 connecting with a high pressure steam main 15. A shut off valve 16 is arranged in the steam supply pipe 14. The vapors generated within the tubes 13 are discharged into a vapor separator 20, the vapors passing upwardly through a vapor outlet conduit 21 and the separated liquor returned through a return pipe 22.

A pressure responsive instrument 23 of any suitable construction is placed in the vapor outlet line 21 and is responsive to the pressure therein. This instrument 23 controls, in any suitable manner, a valve 24 which in turn controls the amount of steam admitted to the pre-evaporator A. By the setting of the instrument 23 or the valve 24 the pre-evaporator can be set to maintain, within very close limits, any desired vapor outlet pressure.

In the following description it will be assumed that it is desired to evaporate and remove the salt from the liquor withdrawn from electrolytic cells producing caustic soda. This liquor is with-

drawn from the cells through a cell liquor supply line 26 by a pump 27 which delivers it to a heater 28. The cell liquor passes through the tubes of this heater and through a line 29 to a heat exchanger 30. The cell liquor passes through the tubes of this heat exchanger 30 and through a line 31 to a second heat exchanger 32. The cell liquor passes through the tubes of this heat exchanger 32 and through a line 33 to a heater 34. On passing through the tubes of this heater 34 the cell liquor enters the bottom of the pre-evaporator A through a line 37. The desired level of liquor within the tubes 13 of the pre-evaporator is maintained by a float valve 38, this float valve being connected with a branch pipe 39 connected with the bottom of the return leg 22 and the upper part of the vapor separator 20. The float valve 38 controls, in any suitable manner, a valve 40 in the line 37, this valve thereby controlling the amount of preheated cell liquor admitted to the pre-evaporator in response to the float valve 38. The heater 34 is supplied with steam from the branch steam line 14 under control of a valve 45 and the condensate is withdrawn from this heater through a line 46 which conducts the condensed water to the heat exchanger 30. The heat exchanger 32 is heated by the pre-concentrated liquor withdrawn from the pre-evaporator A through a line 47, this being under control of a valve 48. This liquor passes around the outside of the tubes of the heat exchanger 32 in the heat exchanging relation to the original solution or feed liquor and into a pipe 49 which conducts the cooled pre-concentrated liquor to the bottom of a slurry tank 50. The heat exchanger 30 is heated by the condensate of the steam supplied to the pre-evaporator A and the heater 34, this condensate passing out through a condensate line 51 and around the outside of the tubes of the heat exchanger 30 to a boiler return line 52. The heater 28 is heated by vapor from the apparatus, as hereinafter described. It will be understood that the system of cell liquor preheaters shown is set forth purely as an example of how savings can be effected and the number, use and arrangement of such preheaters will depend upon the conditions encountered in each installation such as the steam pressure available, the degree of concentration of the feed liquor, the degree of concentration desired, etc.

The vapor from the liquor evaporated in the pre-evaporator or pre-concentrator A and passing out through the outlet pipe 21 is conducted to a line 55 leading to the unit or first effect B of a multiple unit or multiple effect evaporator, the other units or effects of which are designated at C and D respectively. The vapor supplied to the first unit or effect B is under control of a valve 56. The several units or effects B, C and D are shown as being identical in construction and therefore a description of one will be deemed to apply to all.

Each of the effects can be of any usual and well known construction to provide an evaporating chamber and can be of either the natural circulation type, as shown, or can be of the forced circulation type. Each of the effects consists of a large cylindrical evaporating chamber 60 having a rounding dome 61 and a conical bottom 62 leading to a downwardly directed discharge 63 through which the crystal laden liquor is discharged into a salt or crystal separator indicated generally at 64. Upper and lower tube sheets 65 and 66 are arranged within the cham-

ber 60 and are connected by a large central tube 67 and a plurality of smaller tubes 68. The vapor from the branch line 55 is conducted to the steam chamber around the tubes 67 and 68, the condensate being withdrawn in any suitable manner. The liquor in each effect circulates upwardly through the small tubes 68 and downwardly through the large central tube 67, the vapors passing out through a central outlet provided in the dome 61.

The salt or crystal separator 64 consists of an upper cylindrical portion 70 covered by a dome 71 and a lower conical part 72. Immediately under the dome 71 is arranged a baffle 73 and above this baffle the dome 71 is formed to provide a small chamber 74 which receives the practically crystal free liquor and is connected with the outlet pipe. The crystal bearing liquor discharged from the discharge pipe 63 of the multiple effect evaporator fans out and flows to the perimeter of the baffle 73. During this period the action of gravity causes a precipitation of the salt crystals to the bottom of the conical portion 72 from which the crystalline salt, in the form of a sludge, is removed. An individual salt or crystal separator is provided into which each of the effects solely discharges, and it will be seen that each separator has an outlet for liquid in an upper zone which is spaced materially in a horizontal direction from the inlet from its related effect and has an opening in its bottom zone for the discharge of crystals settling out therein.

The vapors generated in the first effect B are conducted through a line 75 to the steam chamber of the second effect C and the vapors from the second effect C are conducted through a vapor conduit 76 to the steam chest of the third effect D. The vapors generated in the third effect D are conducted, through a conduit 77, usually to a condenser, this effect being usually maintained under a vacuum.

The slurry tank 50 is shown as having a conical bottom 80 leading to an outlet 81. The pre-concentrated liquor from the line 49 overflows in the slurry tank through an outlet line 82 which discharges into an evaporator storage tank 83. The pre-concentrated liquor is withdrawn from this tank by a pump 84 and conducted through a line 85 to the third effect D under control of a valve 86. In this third effect D the liquor is concentrated and in this concentration an amount of salt crystallizes out of solution and is segregated in the salt separator 64 arranged below this effect D. The liquor from the third effect D is withdrawn from the dome of this salt separator by a pump 87 and is conducted to the second effect C under control of a valve 88. The outlet line from the pump 87 is also connected by a branch 89 with the third effect D under control of a valve 90. By this means any desired proportion of the liquor from the effect D can be recirculated through this effect and the amount of liquor circulating through the separator be maintained constant regardless of the demand for liquor of the effect C. It will be understood that a certain amount of seed crystals may be carried through the system, these seed crystals serving to facilitate the precipitation of the salt in the evaporating chamber in crystalline form.

The liquor from the second effect C is withdrawn from the dome of the salt separator arranged thereunder by a pump 91 which delivers it through a line 92 to the first effect B under control of a valve 93. The line 92 is also con-

nected by a recirculation line 94 with the second effect C under control of a valve 95, this valve serving to regulate the rate of discharge of this effect C.

The liquor from the first effect B is withdrawn from the dome of the salt separator arranged thereunder by a pump 98 which discharges it through a line 96 under control of a valve 97 into a finishing pan indicated generally at E or into a storage tank (not shown) if no finishing pan is provided. As with the other effects a part of the liquor delivered by the pump 98 can be returned to the effect B through a valved recirculation line 99.

This finishing pan is of the same general construction as the several effects B, C and D and comprises a large cylindrical body 100 having a vapor dome 101 and a conical bottom 102 terminating in a discharge spout which leads into a salt separator 103. The steam tube assembly within this finishing pan consists of a large central tube 104 and a plurality of smaller tubes 105 through which the liquor is circulated. The steam chamber around the tubes 104 and 105 is supplied, under control of a valve 106, with the vapors generated in the pre-evaporator A through the pre-evaporator outlet line 21 which connects with the inlet to the steam chest of the finishing pan.

The vapor outlet line 107 from the finishing pan E or the vapor outlet line 77 from the third effect D can be arranged to conduct the vapor to the heater 28 and thence to a barometric condenser or other means for withdrawing the vapors and maintaining the finishing pan E or the third effect under vacuum.

The crystal bearing liquor entering the salt separator 103 of the finishing pan is forced to flow at slow velocity horizontally to the perimeter of a baffle 110 in the top of this salt separator and because of this reduced velocity most of the crystals which are suspended in this liquor drop to the conical bottom 111 and are removed as a sludge by a pump 112 under control of a valve 113. The practically crystal free liquor flowing around the upper side of the baffle 110 is pumped out through a line 114 by a liquor discharge pump 115 which delivers the substantially salt free sodium hydroxide solution to a liquor discharge line 116 under control of a valve 117. To permit of adjusting the rate of flow through the separator 103 under the finishing pan a branch line 118 connects the outlet of the pump 115 with the finishing pan under control of a valve 119.

The sludge from each of the salt separators is washed with the salt-saturated liquor of the next evaporator, this salt being progressively washed in liquor having a smaller amount of caustic soda so that when it is subjected to the final washing the amount of sodium hydroxide in the salt is very small and can be readily removed. For this purpose the sludge is removed from the bottom of the salt separator under the first effect B by a pump 125 through a valve 126 and is discharged through lines 127 and 128, under control of a valve 129, into the conical lower part of the second effect C.

The sludge from the separator under this second effect C is withdrawn by a pump 130 through a valve 131 and is discharged through lines 132 and 133 into the conical lower part of the third effect D under control of a valve 134.

The sludge from the third effect D is withdrawn by a pump 135 through a valve 136 and

discharged through a line 137 into the sludge tank 50 under control of a valve 138.

At the end of the week's operation it is necessary to drain the contents of each of the effects and also the salt separators into the sludge tank 50. For this purpose and also to permit of cutting either of the effects C or D out of operation, the sludge discharge line 127 from the first effect B is connected by a by-pass valve 140 with the discharge line 132 from the second effect C and likewise the discharge line 132 from this second effect C is connected by a by-pass valve 141 with the sludge discharge line 137 of the third effect D.

The slurry withdrawn from the separator 103 under the finishing pan E by the pump 112 is preferably discharged into a line 145 and then into a line 146 under control of a valve 147. The line 146 leads to the conical bottom of the first effect B and hence it will be seen that the slurry from the finishing pan E will be progressively washed in the three effects B, C and D before being discharged into the slurry tank 50 for final washing. The amount of salt crystallizing in the finishing pan E is, however, very small in amount and it is practicable to conduct the slurry from the finishing pan through a line 148 and valve 149 directly to the slurry tank 50, should this be desired.

The salt settling in the bottom of the sludge tank 50 passes out through the outlet line 81 into a rotary or other filter 155 in which the salt is first washed with pre-evaporated liquor supplied from a line 156 connecting with the line 49 and then with brine supplied by a line 157. The salt is discharged from the filter into a conveyor 158 and the mother liquor and the wash from the filter passes into a separator 159 having a stand pipe 160 which discharges into the evaporator storage tank 83, a vacuum being maintained in the chamber 159 by a vacuum pump 161. The amount of the brine used in the filter is, of course, very small because of the countercurrent washing of the salt crystals in the evaporators.

If for any reason it becomes impossible for the pre-evaporator A to deliver vapor at sufficiently high pressure for the operation of the effects B, C and D and the finishing pan E, means are provided for admitting steam from the high pressure main 15 directly to the line 21 which supplies vapor to the several effects and the finishing pan. This is shown as comprising a reducing valve 162 located in a line extending from the main 15 to the vapor line 21 and which supplies steam at reduced pressure to the line 21 if the pressure in this line should drop below a predetermined minimum.

In changing over existing equipment to my continuous system of salt removal it is not always practicable to locate the salt separators at the same places as the removed salt receivers and it may be desirable to employ the modified form of the salt separator shown in Fig. 3. For reasons of economy or head room requirements, the arrangement shown in Fig. 3 can also be employed in original installations. Under these circumstances, as indicated in Fig. 3, the outlet 63 from the bottom of each of the effects can be connected to a pump 165 which discharges into a line 166 extending downwardly through the small dome 74 of a salt separator 64, this salt separator being arranged alongside the corresponding effect instead of directly under, as illustrated in Fig. 1. In other respects the installation could follow the form of the invention shown in Fig. 1.

With existing installations it frequently happens that the flow of materials through the several effects is concurrent to the flow of steam. When such a situation is encountered the invention can be carried out as illustrated in Fig. 2. The construction shown in Fig. 2 is identical with the construction shown in Fig. 1, the vapor from the pre-evaporator A being supplied to a first effect F and the vapors from this effect supplied to a second effect G which in turn supplies vapors for the operation of a third effect H. Instead of supplying the pre-evaporated liquor from the evaporator storage tank 83 to the third effect, as in the preferred construction, the pump 84 delivers this pre-evaporated liquor through a valved line 167 to the first effect F. The clear liquor from this first effect F is withdrawn by a pump 168 and delivered to the second effect G and in part back to the first effect F depending upon the setting of valves 169 and 170 in the branch outlet lines from the discharge of the pump 168. Similarly, the clear liquor from the second effect G is delivered by a pump 171 past a valve 172 to the third effect H or, by opening the valve 173, a part of this liquor is recirculated through the second effect G. The clear liquor from the third effect H is shown as being delivered by a pump 174 under control of a valve 175 to the finishing pan E. In other respects the installation shown is identical with that shown in Fig. 1, the slurry from the finishing pan being discharged into the cone bottom of the effect H or into the slurry tank 50. It will also be understood that with the arrangement shown in Fig. 2, countercurrent washing of the salt slurry is effected by passing the slurry progressively through the effects H, G and F.

Operation

The original solution such as cold cell liquor which contains as its main constituents, caustic soda, sodium chloride, and water as a common solvent of these two chemically and physically different components, and which is unsaturated in regard to the first two components, is pumped from the yard storage tanks by the pump 27, through the heater 28. In this heater, the incoming cell liquor is heated by the vapors generated in the finishing pan E and then passes through the heat exchanger 30 in which its temperature is further raised by heat absorbed from the steam condensate from the steam space of the pre-evaporator A and of the preheater 34. The cell liquor is then further heated in the heat exchanger 32 in which its temperature is further raised by being brought into heat exchanging relation with the preconcentrated liquor discharged from the pre-evaporator at a temperature close to the boiling point of this liquor under the pressure maintained in the pre-evaporator. The cell liquor is then passed through the preheater 34 in which the temperature of the cell liquor is raised in proximity of the temperature maintained in the pre-evaporator itself.

The advantage of preheating the cell liquor close to the boiling point before it is permitted to enter the pre-evaporator is that otherwise extra steam must be provided for preheating and a certain amount of heating surface has to be provided in the pre-evaporator for this purpose, which would be less economical, in particular in construction of expensive metals. To accomplish this part of the process in the steps indicated permits the use of a minimum amount of steam in preheater 34, provides for cooling of the steam

condensate below its flashpoint under atmospheric pressure in exchanger 30 and also of cooling the preconcentrated liquor below its boiling point at atmospheric pressure to a temperature at which it can be used conveniently for washing purposes in slurry tank 50.

The stream of cell liquor at approximately its boiling point is then introduced into the pre-evaporator A, in which this liquor is preferably concentrated near its saturation point in regard to sodium chloride at the temperature at which it leaves preheater 32 in order that no crystals of sodium chloride may separate until the preconcentrated liquor has passed this point, although a slightly higher concentration and the separation of a small amount of crystals, either temporarily or continuously, does little harm unless it is carried to the extent that the salt crystals will cause incrustation of the heating surfaces or clogging of the pipe lines.

In order to operate the pre-evaporator under most favorable conditions with the least amount of supervision and trouble, the controlling factors which govern operation, such as liquor level, steam and vapor pressure, may be automatically controlled by suitable instruments such as float valve 38 and pressure control 23 which automatically regulates the steam inlet valve 24 in response to any variation in the steam outlet line 21 and thereby maintains a uniform pressure in this line by governing the amount of high pressure steam flowing to the pre-evaporator.

By such means the pressure of the vapors generated in the pre-evaporator can be maintained at any desired point, usually substantially above atmospheric pressure. The amount of vapors generated and the corresponding degree of concentration of the cell liquor obtained in the pre-evaporator can be established in accordance with local plant conditions and can be varied as needed within the limits of vapor pressure and steam pressure available. The pressure under which the vapors are maintained also can be varied within certain practical limits as desired and as is most economical in connection with the pressure of any low pressure steam available from other sources, the final concentration of the caustic liquor, the number of effects of the multiple effect evaporator and the provision or omission of a separate finishing pan as part of the concentration system.

In view of the increasing concentration of the residual component in the concentrated liquor in the several effects the boiling point in each effect is considerably above that of water under the same pressure, particularly in case of caustic soda. In order to maintain good circulation of the liquor in each effect and substantial temperature differences between vapor in the steam space and liquor in the evaporating chamber, the last effect and finishing pan generally are placed under a subatmospheric pressure or vacuum and the pressure of the steam in the first effect and in the steam space of the finishing pan, if provided, as well as that of the vapors in the pre-evaporator preferably are kept considerably above atmospheric pressure. The multiple effect evaporator B, C, D operates in the usual manner, the vapor from the first unit or effect B being utilized to heat the second unit or effect C and the vapor from the second effect C being utilized to heat the third unit or effect D, the vapors from the third effect and from the finishing pan being condensed in the same or in separate condensers; the pressure dropping progres-

sively through the three effects and the temperature dropping correspondingly.

In the pre-evaporator the cell liquor is reduced to a point where it is nearly saturated with salt unless requirements of low pressure steam are less than necessary to concentrate the liquor to this point. The progressively moving solution of preconcentrated liquor after leaving the pre-evaporator and cooling in the heat exchanger 32, enters the slurry tank 50 where it is used for washing the salt which has crystallized out in the multiple effect evaporator and finishing pan and is thence conducted to the evaporator storage tank 83. From this tank the pre-evaporated liquor is pumped by pump 84 into the third effect D, in which effect a certain amount of water is evaporated from the portion of the stream passing therethrough and in which a certain amount of salt is precipitated which settles in the salt separator connected thereto. A certain amount of liquor is circulated through the salt separator by means of pump 87 sufficient to maintain the desired circulation in this separator and allow all or most of the salt to settle out. Part of this circulated liquor is conducted to the subsequent evaporating unit or second effect C and the balance is returned to effect D. The same procedure takes place in the second effect C and in the first effect B, from which a regulated amount of settled liquor is carried to the finishing pan E, if provided, or to a storage tank for residual liquor in case a finishing pan does not form part of the installation.

As evaporation takes place in the transfer of the stream of solution passing from stage to stage progressively through the several evaporating chambers, the progressive concentration stages of the residual component in the liquor increases from one effect to the next and from the first effect to the finishing pan. The amount of low pressure steam used in the first effect of the multiple effect evaporator and the amount of water evaporated in each effect are determined by the total amount of water evaporated from the preconcentrated liquor on its way through the multiple effect evaporator, the initial and final concentration of the liquor and the initial and final pressure maintained, so that these amounts and the temperatures maintained in each effect are balanced in such a way that the heat given up by the steam or vapor in condensing in the steam chamber in each effect is the same as the amount of heat taken up by the liquor circulating through the tubes of the steam chamber where the heat is used for concentrating the liquor, and other purposes connected with the evaporator process. In the finishing pan, low pressure steam is used directly for the final concentration of the liquor, the amount of which is determined by the concentrations, pressures, and temperatures maintained. From the finishing pan E the liquid is continuously removed through the liquor discharge line 116 as one final product.

Each effect of the multiple effect evaporator therefore is operated at a different pressure and temperature which drop from the first to the second and to the third effect, while the progressive concentrations of the liquor in regard to the residual component increases in sequence from the third to the second to the first effect and then to the finishing pan. As this concentration increases, the solubility of the salt decreases and crystallization of this salt takes place in each effect and in the finishing pan, the amount of

salt which separates in each effect being determined by the saturation point of the salt in each one of the effects at the temperature maintained therein. The finishing pan may be omitted; and the liquor raised to the final concentration in the multiple effect evaporator, which may be a triple or double effect evaporator as governed by practical considerations.

The suspended salt crystals segregated in the first effect B which are in contact with liquor of highest concentration of the residual component in the multiple effect evaporator are periodically or continuously removed from the salt separator connected thereto and are added to the solution being circulated through the evaporating chamber of the second effect C and its connected separator, this being a more dilute solution, but saturated with regard to the crystallizing component. In this effect the more concentrated solution adhering to the crystals is removed and replaced by the more dilute liquor in effect C without dissolving any of the crystallizing component. These crystals together with those crystallizing out in effect C are locally segregated, removed and carried in succession in the same way to the third effect D in which they are washed by a still more dilute solution, but still saturated with regard to the crystallizing component.

The slurry from all three effects is pumped into the slurry tank 50, where it is washed by the preconcentrated liquor from the pre-evaporator A. It will be therefore most advantageous, as far as washing is concerned, if this preconcentrated liquor be as nearly saturated in regard to the crystallizing component as possible so that the least amount of crystals will be redissolved. It is evident that this method is a great advance over the use of cell liquor for washing the slurry, because this cell liquor is not saturated in regard to the crystallizing component and therefore will redissolve a certain amount of the crystals, which then will enter the multiple effect evaporator and increase the amount of crystals to be separated therein. The method of progressive washing also is a great improvement over the method of simultaneous removal of the salt from all effects and washing the combined salt with cell liquor because the concentration of the liquor, removed with the salt, in regard to caustic soda then is much greater and more cell liquor has to be used for washing purposes.

In the progressive method, the greater part of the washing has been effected by the time the salt is ready for final washing on the filter 155 by means of brine.

The crystals removed from the separator 103 connected to the finishing pan E in the same way can be pumped by the pump 112 to the first effect B and carried through the other effects. These crystals generally are much finer and in their passage through the multiple effect are afforded an opportunity to grow in size. On account of its smaller quantity, however, it may be preferred to pump these crystals directly to the slurry tank 50 without greatly affecting the economy of the process.

In the arrangement shown in Fig. 2, the liquor enters the multiple effect evaporator in the first effect and flows through the second into the third effect. In this case the crystals are carried from the separator connected to the third effect H into the second effect G and then into the first effect F. The adhering liquor in this form of the invention is carried into an effect operating at

higher temperature, which will heat this adhering liquor, and may make it slightly unsaturated in regard to the crystallizing component whereby a small amount of the crystals may be redissolved. This arrangement therefore may be slightly less efficient than the arrangement shown in Fig. 1. Cooling of the preconcentrated liquor in this case is less desirable because this preconcentrated liquor is fed to the first effect F and if cooled too much will have to be reheated to the boiling point in this effect.

In the absence of the pre-evaporator concentration to the salt saturation point will take place in the effect to which the cell liquor is fed. The same progressive method of washing can be followed except that cell liquor is used for washing in the slurry tank, if desired.

An important feature of my invention consists in effecting a large economy in steam consumption in concentrating, for example, caustic soda and removing the salt therefrom. The following will serve as an example of the saving in steam consumption obtained by the installation of a pre-evaporator and system of heat interchangers in connection with a triple effect evaporator and finishing pan in the concentration of electrolytic caustic soda as described and illustrated herein.

The composition of the liquor at each stage of the process will be approximately as follows:

	Cell liquor	Leaving pre-evaporator	Leaving triple effect evaporator	Leaving finishing pan
	Per cent	Per cent	Per cent	Per cent
Caustic soda.....	9.0	11.9	30.0	49.0
Sodium chloride.....	13.15	17.4	6.4	2.0
Water.....	77.85	70.7	63.6	49.0

For every 100 lbs. of cell liquor of the above composition the quantity of material leaving each stage at the above composition and the amount of water evaporated in each stage will be:

	In the pre-evaporator	In the triple effect evaporator	In the finishing pan
	Pounds	Pounds	Pounds
Liquor.....	75.5	30.0	18.4
Caustic soda.....	9.0	9.0	9.0
Sodium chloride.....	13.15	1.9	0.4
Water in liquor.....	53.35	19.1	9.0
Water evaporated.....	24.5	34.25	10.1

To accomplish this amount of evaporation the approximate amount of low pressure steam of 30 lbs. gage pressure required when operating under 26 inches vacuum will be:

	In the triple effect evaporator	In the finishing pan
	Pounds	Pounds
Low pressure steam.....	13.7	10.8
Vapor to be condensed in condenser.....	10.9	10.1

The amount of low pressure steam at 30 lbs. gage pressure to be produced in the pre-evaporator will therefore be a total of 24.5 lbs. With cell liquor entering the pre-evaporator at its boiling point under this pressure the approximate amount of high pressure steam at 100 lbs. gage pressure to be supplied to the steam chest of the pre-evaporator will be 25.8 lbs.

Without a pre-evaporator the cell liquor is directly concentrated to 30% caustic soda in the triple effect evaporator whereby a total amount

of 58.75 lbs. has to be evaporated which requires approximately 23.5 lbs. of low pressure steam. Including the 10.8 lbs. of steam for the finishing pan, total steam consumption in this case will be approximately 34.3 lbs. Saving in steam by the installation of the pre-evaporator therefore will be $34.3 - 25.8 = 8.5$ lbs. for very 100 lbs. of cell liquor. In addition only 21 lbs. of vapor will have to be condensed in place of 28.9 lbs.

An additional saving in steam and cooling water is obtained by the system of heaters provided for preheating the cell liquor to the boiling point. First of all the cell liquor which is supplied from storage at about 70° F. is heated in a heater 28 by the vapors from the finishing pan which have a temperature of about 125° F. under 26 inches vacuum and will heat the cell liquor to about 122° F. whereby about 4.5 lbs. of the vapor will be condensed. Hereby a further reduction in the amount of vapor to be condensed will be obtained from 21 lbs. to 16.5 lbs. per 100 lbs. of cell liquor.

Next the cell liquor at about 122.0° F. will be passed through heat exchanger 30 where it will be heated to about 165° F. by the steam condensate from the pre-evaporator and the pre-heater 34, which condensate thereby is cooled from about 338° F. to about 208° F.

From the heat exchanger 30 the cell liquor at about 165° F. is passed through the heat exchanger 32 in which it is heated to about 256° F. by the pre-evaporated liquor from the pre-evaporator which thereby is cooled from about 295° F. to about 175° F. At this temperature the pre-evaporated liquor is passed through the slurry tank into the last effect of the triple effect evaporator, where the boiling point under 26 inches vacuum is about 155° F.

Finally the cell liquor is heated in the pre-heater 34 from about 256° F. to about 295° F., the boiling point of the liquor in the pre-evaporator. Steam at 100 lbs. gage pressure is used for this purpose, about 4.0 lbs. of which are required, which is the only steam used for heating the cell liquor.

Without the pre-evaporator the cell liquor enters the third effect of the triple effect evaporator, in which in this case the liquor boils at a temperature of about 145° F. under 26 inches vacuum. To heat the 100 lbs. of cell liquor from 70 to 145° F. requires about 7.3 lbs. of low pressure steam at 30 lbs. gage pressure.

The provision of the system of heat interchangers and heater in connection with the pre-evaporator therefore results in a further saving of $7.3 - 4.0 = 3.3$ lbs. of steam per 100 lbs. of cell liquor. Total steam saving amounts to 11.8 lbs. or 28.4%.

For a plant handling 1,000,000 lbs. of cell liquor per day and operating 350 days per year steam saving alone will amount to 118,000 lbs. per day which at 40 cents per 10000 lbs. will have a value of \$16,500.

In existing installations consisting of a triple effect evaporator and finishing pan the amount of water evaporated per 100 lbs. of cell liquor is 58.75 lbs. in the triple evaporator. By installing a pre-evaporator this amount is reduced to 34.25 lbs. and the same evaporator would be able to handle almost 72% more liquor except that capacity per square foot heating surface is somewhat reduced by increasing the concentration of the liquor in regard to caustic soda in the several effects.

The introduction of the countercurrent washing system of the crystals also results in a sav-

ing in steam consumption because heretofore the crystal slurry from the several effects has been withdrawn periodically and transferred to a common slurry tank, from which the settled clear liquor is returned to the salt receivers connected to the effects, which procedure results in a loss of temperature and heat. On the filter the crystals are washed with cell liquor and brine in considerably larger amount than in the countercurrent system. The increase in efficiency produced by countercurrent washing results in a saving in steam which is appreciable.

From the foregoing it is apparent that the use of the pre-evaporator permits greater steam economy and the use of smaller triple effect units for the same capacity. Furthermore, the pre-evaporator can be added to existing installations in order to increase capacity without proportionally increasing the steam consumption. Furthermore, the countercurrent washing of the salt provides an automatic continuous and gradual method of washing the salt with saturated liquor in the evaporator itself and can be applied to existing installations by installing a set of continuous salt separators as shown. It will further be seen that the pre-evaporator is of value in combination with the method of salt washing in that the pre-evaporator produces a liquor substantially saturated with regard to salt for final washing of the salt while the cell liquor heretofore used necessarily has a tendency to dissolve a substantial amount of the crystalline salt.

I claim as my invention:

1. The continuous process of concentrating liquors of mixed components which upon concentration deposit crystals of one component and leave a liquor containing a residue of another component, which process comprises introducing the feed liquor to a preconcentrating chamber having a heating surface, applying said feed liquor to said heating surface, maintaining said heating surface at high temperature to preconcentrate said feed liquor, withdrawing said preconcentrated liquor in a condition in which no substantial amount of the crystallizing component has yet been precipitated therefrom, passing said preconcentrated liquor successively through a system including a series of evaporating chambers, heating the liquor in one of said evaporating chambers by heat exchange with the vapors generated in said preconcentrating chamber, heating the liquor in the other of said evaporating chambers by heat exchange with the vapors generated in said first evaporating chamber, said liquor being further concentrated in said series of evaporating chambers and its crystallizing component crystallized, separating a slurry of the crystals from said concentrated liquor, conducting said liquor from the last of said series of evaporating chambers to a finishing chamber, maintaining a vacuum in said finishing chamber, heating the liquor in said finishing chamber by heat exchange with the vapors generated in said preconcentrating chamber to continue the concentration of said liquor and the crystallization of said crystallizing component, separating a slurry of the crystals from the liquor concentrated in said finishing chamber and subsequently continuously removing said concentrated liquor from the system.

2. The continuous process of concentrating liquors of mixed components which upon concentration deposit crystals of one component and leave a liquor containing a residue of another component, which process comprises introducing

the feed liquor to a preconcentrating chamber, applying heat at high temperature to said liquor while in said chamber to preconcentrate the same, withdrawing said preconcentrated liquor in a liquid condition in which no substantial amount of the crystallizing component has yet been precipitated therefrom, preheating said introduced liquor passing it in heat exchanging relation with the vapors generated by the final concentration of the liquor, passing the preconcentrated liquor through a system including an evaporating chamber, applying heat at lower temperature to said liquor in said evaporating chamber to continue the concentration of said liquor to said final concentration and crystallize said crystallizing component, withdrawing a slurry of the crystals from said concentrated liquor and subsequently continuously removing said concentrated liquor from the system.

3. The continuous process of concentrating liquors of mixed components which upon concentration deposit crystals of one component and leave a liquor containing a residue of another component, which process comprises introducing the feed liquors to a preconcentrating chamber, applying heat to said liquor while in said chamber to preconcentrate the same, withdrawing said preconcentrated liquor in a substantially crystal-free condition, passing said preconcentrated liquor in a substantially crystal-free condition through one evaporating chamber and then through the other of a series of evaporating chambers, heating the liquor in said other evaporating chamber by heat exchange with the vapors generated in said preconcentrating chamber, heating the liquor in said one evaporating chamber by heat exchange with the vapors generated in said other evaporating chamber, said liquor being further concentrated in said series of evaporating chambers and its crystallizing component crystallized, separately withdrawing a slurry of the crystals from said other evaporating chamber, introducing said slurry of withdrawn crystals into said one evaporating chamber whereby the crystals thereof are progressively washed in counterflow relation to the liquor and in a solution which is increasingly dilute with regard to the residual component, and continuously removing the concentrated substantially crystal-free liquor from said other of said evaporating chambers.

4. The continuous process of concentrating liquors of mixed components which upon concentration deposit crystals of one component and leave a liquor containing a residue of another component, which process comprises introducing the feed liquor to a preconcentrating chamber, applying heat to said liquor while in said chamber to preconcentrate the same, withdrawing said preconcentrated liquor in a liquid substantially crystal-free condition, passing said preconcentrated liquor in a substantially crystal-free condition successively through one evaporating chamber, an intermediate evaporating chamber and a final evaporating chamber, heating the liquor in said final evaporating chamber by heat exchange with the vapors generated in said preconcentrating chamber, heating the liquor in said intermediate evaporating chamber by heat exchange with the vapors generated in said final evaporating chamber, heating the liquor in said one evaporating chamber by heat exchange with the vapors generated in said intermediate evaporating chamber, said liquor being further concentrated in said series of evaporating chambers

and its crystallizing component crystallized, separately withdrawing a slurry of the crystals from said final evaporating chamber, introducing said slurry of withdrawn crystals into said intermediate concentrating chamber to wash said crystals thereof in the solution therein which is more dilute with regard to the residual component, separately withdrawing the slurry of crystals from said intermediate concentrating chamber and introducing said slurry of crystals in said one evaporating chamber whereby the crystals thereof are washed in a solution which is more dilute with regard to the residual component, withdrawing the slurry of crystals from said one evaporating chamber and washing said slurry of last withdrawn crystals in the preconcentrated liquor from said preconcentrating chamber, and continuously removing the concentrated substantially crystal-free liquor from said final evaporating chamber.

5. The continuous process of concentrating liquors of mixed components which upon concentration deposit crystals of one component and leave a liquor containing a residue of another component, which process comprises introducing the feed liquor to a preconcentrating chamber, applying heat to said liquor while in said chamber to preconcentrate the same, withdrawing said preconcentrated liquor in a substantially crystal-free condition, passing said preconcentrated liquor through one evaporating chamber and then through the other of a series of evaporating chambers, heating the liquor in said other evaporating chamber by heat exchange with the vapors generated in said preconcentrating chamber, heating the liquor in said one evaporating chamber by heat exchange with the vapors generated in said other evaporating chamber, said liquor being further concentrated in said series of evaporating chambers and its crystallizing component crystallized, withdrawing a slurry of the crystals from said other evaporating chamber, introducing said slurry of withdrawn crystals into said one evaporating chamber whereby the crystals thereof are progressively washed in counterflow relation to the liquor and in a solution which is increasingly dilute with regard to the residual component, separately withdrawing a slurry of the crystals from said one evaporating chamber, washing the crystals thereof so withdrawn in the preconcentrated liquor from said preconcentrating chamber and continuously removing the concentrated substantially crystal-free liquor from said other of said evaporating chambers.

6. In the approximately continuous process of separating from each other, two chemically and physically different components carried in substantial proportions in solution in a common solvent, one of which components crystallizes out in said solution, and the other component does not, when said solution reaches at least a particular concentration of said one component, by passing all of said solution progressively and continuously through a plurality of concentration stages, that improvement which comprises locally separating and segregating from each other, in one zone of each of said stages, a slurry of crystals of said one component and a substantially crystal-free mother liquor, removing said substantially crystal-free mother liquor from each of said stages, beginning with the first stage into which the solution is introduced, and delivering it to the solution in the next stage at a point remote from the said zone of local segregation of slurry in that next stage to produce progressive movement of

all of said solution from stage to stage, until the last stage is reached, discharging such separated substantially crystal-free mother liquor from said last stage as a concentration of said other component in solution and as one final product of the process, to aid the continuous movement of said solution through said stages, locally removing the segregated slurry crystallized component from each of said stages, delivering the slurry of crystallized component removed from each of said stages after that stage into which the solution is first passed, into the solution of a preceding stage in said progression of movement of said solution, and separating the crystals from the removed slurry of crystallized component from said first stage as another final product of the process.

7. In the approximately continuous process of separating from each other, two chemically and physically different components carried in substantial proportions in solution in a common solvent, one of which components crystallizes out in said solution, and the other component does not, when said solution reaches at least a particular concentration of said one component, by passing all of said solution progressively and continuously through a plurality of concentration stages, that improvement which comprises locally collecting a slurry of the crystals of one component in the solution while in each of said stages, removing relatively crystal free solution from each of said stages, beginning with the first stage into which the solution is introduced, and delivering it to the solution in the next stage to produce progressive movement of all of said solution from stage to stage, until the last stage is reached, discharging such separated substantially crystal-free mother liquor from said last stage as a concentration of said other component in solution and as one final product of the process, to aid the continuous movement of said solution through said stages, and locally removing the segregated slurry of crystallized component from each of said stages.

8. In the improved process of separating a crystallizable substance from a solution of that substance, in which the solution is passed progressively through a plurality of effects of a multiple effect evaporator while the solution is progressively concentrated, that improvement which comprises locally separating and segregating from each other, in one zone of each of said effects, a slurry of crystals of said one component and a substantially crystal-free mother liquor, removing said substantially crystal-free mother liquor from each of said effects, beginning with the first effect into which the solution is introduced and delivering it to the solution in the next effect at a point remote from the said zone of local segregation of slurry in that next effect to produce progressive movement of all of said solution from effect to effect, until the last effect in said progressive movement is reached, removing said segregated mother liquor from the solution contained in said last effect to promote the progressive movement of said solution through said effects, separately removing the segregated slurry of crystallized substance from each of said effects following that effect into which the original solution is first introduced, and adding it to the solution of a preceding effect in said progression of movement of said original solution at a zone remote from said zone of segregation of said slurry, and removing entirely from the progressively moving solution the segregated slurry of crystals in that one of said effects into which said original solution is first introduced.

9. In the process of separating a crystallizable substance from a solution of that substance in which a stream of the solution is passed progressively through a plurality of evaporator units of a multiple unit evaporator in which the solution is progressively concentrated, that improvement which comprises preconcentrating said solution in said stream in one stage of its transfer to said evaporator and to a temperature substantially higher than the temperature of the solution in the first unit of said evaporator through which the solution passes, heating the solution in the first unit of said evaporators through which said solution passes by heat exchange with the vapors generated from said solution while in a subsequent unit in the progression through which said solution passes, heating the solution in said subsequent unit, and effecting a heat exchange between the portion of said stream of said solution before said preconcentration and the portion of said stream after said preconcentration to cool the preconcentrated solution before it enters said first unit.

10. In the process of separating a crystallizable substance from a solution of that substance in which a stream of the solution is passed progressively through a plurality of evaporator units of a multiple unit evaporator in which the solution is progressively concentrated, that improvement which comprises preconcentrating said solution in said stream in one stage of its transfer to said evaporator and to a temperature substantially higher than the temperature of the solution in the first unit of said evaporator through which the solution passes, heating the portion of the solution in the first unit of said evaporator through which said solution passes under sub-atmospheric pressure by heat exchange with the vapors generated from said solution while in a subsequent unit in the progression through which said solution passes, heating the solution in said subsequent unit by heat exchange with the vapors generated from said solution during said preconcentration thereof, and cooling said preconcentrated solution before it enters said first unit.

11. In the process of separating a crystallizable substance from a solution of that substance in which a stream of the solution is passed progressively through a plurality of evaporator units of a multiple unit evaporator in which units the solution is progressively concentrated sufficiently to cause formation of crystals in said units, that improvement which comprises preconcentrating said solution in said stream in one stage of its transfer to said evaporator and to a temperature substantially higher than the temperature of the solution in the first unit of said evaporator through which the solution passes, heating the solution in the first unit of said evaporator through which said solution passes by heat exchange with the vapors generated from said solution while in a subsequent unit in the progression through which said solution passes sufficiently to cause concentration of the solution and formation of crystals, heating the solution in said subsequent units to similarly cause concentration of the solution and formation of crystals, effecting a heat exchange between the portion of said stream of said solution before said preconcentration and the portion of said stream after said preconcentration to cool the preconcentrated solution before it enters said first unit, separating the formed crystals from the mother liquor in said units and using said cooled and preconcentrated solution to wash said crystals separated from said

solution as a result of solution concentration in said units.

12. In the process of separating a crystallizable substance from a solution of that substance in which a stream of the solution is passed progressively through a plurality of evaporator units of a multiple unit evaporator in which units the solution is progressively concentrated sufficiently to cause formation of crystals in said units, that improvement which comprises preconcentrating said solution in said stream in one stage of its transfer to said evaporator and to a temperature substantially higher than the temperature of the solution in the first unit of said evaporator through which the solution passes, heating the solution in the first unit of said evaporators through which said solution passes by heat exchange with the vapors generated from said solution while in a subsequent unit in the progression through which said solution passes sufficiently to cause concentration of the solution and formation of crystals, heating the solution in said subsequent unit by heat exchange with the vapors generated from said solution during said preconcentration thereof to similarly cause concentration of the solution and formation of crystals, cooling the preconcentrated solution before it enters said first unit, separating the formed crystals from the mother liquor in said units and using said cooled and preconcentrated solution to wash said crystals separated from said solution as a result of solution concentration in said units.

13. In the process of separating a crystallizable substance from a solution of that substance in which a stream of the solution is passed progressively through a plurality of at least three evaporator units of a multiple unit evaporator in which the solution is progressively concentrated, that improvement which comprises preconcentrating said solution in said stream in one stage of its transfer to said evaporator, heating the solution in each unit of said evaporator through which the solution passes by heat exchange with the vapors generated from said solution in the next subsequent unit in the progression through which said solution passes, until the last of said units through which said solution passes is reached, heating said last of said units by heat exchange with the vapors generated from said solution during said preconcentration thereof, cooling said preconcentrated solution before it passes to said evaporator and subjecting the solution in the first of said units through which the solution passes to subatmospheric pressure.

14. In the process of separating a crystallizable substance from a solution of that substance in which a stream of the solution is passed progressively through a plurality of evaporator units of a multiple unit evaporator in which the solution is progressively concentrated and crystals formed, that improvement which comprises preconcentrating said solution in said stream in one stage of its transfer to said evaporator, heating the solution in the first unit of said evaporators through which said solution passes by heat exchange with the vapors generated from said solution while in a subsequent unit in the progression through which said solution passes, heating the solution in said subsequent unit, cooling the preconcentrated solution before it passes to said first unit, separating a slurry of said crystals from the solution in said units and washing the slurry of crystals so separated from said solution as a result of solution concentration in said

units with said cooled and preconcentrated solution.

15. In the process of separating a crystallizable substance from a solution of that substance in which a stream of the solution is passed progressively through a plurality of evaporator units of a multiple unit evaporator in which the solution is progressively concentrated and crystals formed, that improvement which comprises preconcentrating said solution in said stream in one stage of its transfer to said evaporator, heating the solution in each unit of said evaporator, cooling the preconcentrated solution before it passes to the first of said units, separating a slurry of said crystals from the solution in said units and washing the slurry of crystals so separated from said solution as a result of solution concentration in said units with said cooled and preconcentrated solution.

16. In the approximately continuous process of separating from each other, two chemically and physically different components carried in substantial proportions in solution in a common solvent, one of which components crystallizes out in said solution, and the other component does not, when said solution reaches at least a particular concentration of said one component, by passing all of said solution progressively and continuously through a plurality of concentrators each heated to provide a concentration stage and having a zone in which crystals are formed and each having a crystal separator with a separating element forming a lower zone of slurry separation and an upper zone of substantially crystal-free mother liquor, that improvement which comprises introducing, in each of said stages, the crystal bearing liquor from said crystal forming zone into said lower zone of slurry separation below said separating element to separate and segregate a slurry of crystals of said one component, removing the separated substantially crystal-free mother liquor from said upper zone above said separating element in each of said stages, beginning with the first stage into which the solution is introduced, and delivering it to the crystal forming zone in the next stage to produce progressive movement of all of said solution from stage to stage, until the last stage is reached, discharging such separated substantially crystal-free mother liquor from the upper zone of substantially crystal-free mother liquor of said last stage as one final product of the process, to aid the continuous movement of said solution through said stages, and removing the segregated slurry of crystallized component from said lower zone of slurry separation of each of said stages.

17. In improved apparatus for separating from each other chemically and physically different components carried in substantial proportions in solution in a common solvent, one of which components crystallizes out in said solution, and the other component does not, when said solution reaches at least a particular concentration of said one component, the combination which comprises a plurality of evaporating chambers each including means for heating and evaporating the solution therein and each having in its bottom zone of crystal formation an individual crystal separator for each chamber and each having a bottom zone of slurry separation and a top zone of substantially crystal-free mother liquor, a conduit connecting the bottom zone of crystal formation of each chamber to the top portion of the related separator and through which crystals and solutions settling from that chamber in its

zone of crystal formation is conveyed to the said bottom zone of slurry separation of its related separator, a second conduit connected to the top portion of each separator at a point horizontally remote from the opening into that separator of the other said first conduit connected thereto for removing substantially crystal-free mother liquor from the said top zone of substantially crystal-free mother liquor of that separator, each separator having a discharge passage opening from its bottom zone of slurry separation for the removal of all of the slurry of crystals settling out therein, means for introducing into the first of said chambers said solution carrying said components, the second conduit from the separator related to said first chamber opening into a second of said chambers to cause a progressive move-

ment of solution from chamber to chamber, the second conduit from the separator related to said second chamber opening into a third of said chambers to continue the progressive movement of solution from chamber to chamber, a conduit for receiving substantially all of the slurry from said discharge passage in the bottom zone of slurry separation of each separator to the next chamber in said progression of movement but in a direction opposed to said progression of movement of said solution until said first chamber is reached, and means for receiving, as one product, all of the slurry of crystals from the bottom zone of slurry separation of the separator related to said first chamber.

MARTIN J. KERMER.