

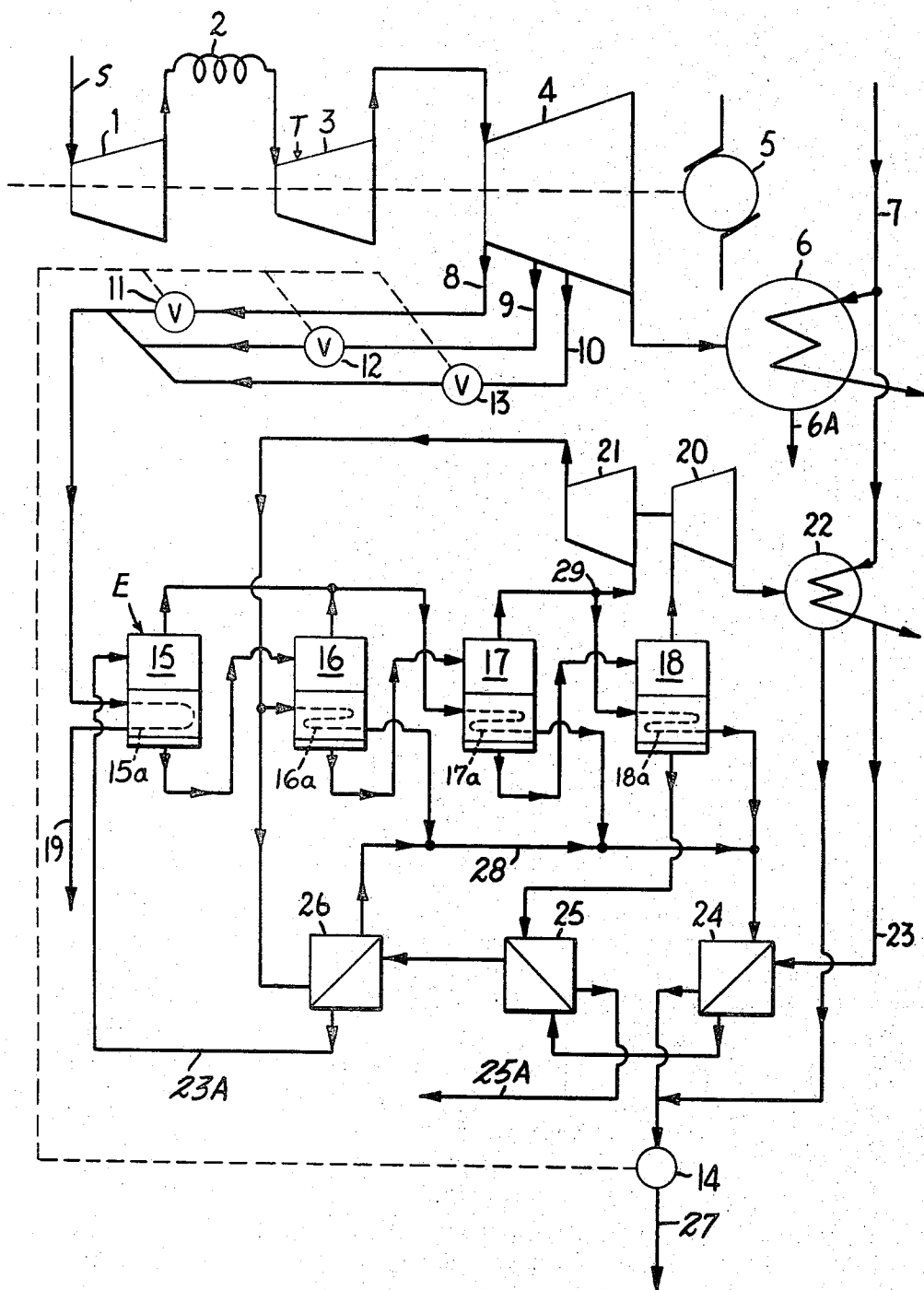
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EVAPORATING APPARATUS

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1

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EVAPORATING APPARATUS

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ABSTRACT OF THE DISCLOSURE

An electric generator is driven by a multi-stage steam turbine. Steam selectively bled from the turbine at selected states of expansion provides the heat input for an evaporator system comprising a plurality of stages. Liquid to be evaporated is fed to the first stage of the evaporator system and unevaporated portions of the liquid are fed successively to other stages. Vapor produced by one or more stages of the evaporator is fed to the heating coils of a successive stage. Moreover, vapor produced by one or more stages of the evaporator is mechanically recompressed by a compressor driven by an expansion motor and the recompressed vapor is fed to the heating coils of at least one of the evaporator stages. The expansion motor for driving the compressor is driven by vapor from one or more stages of the evaporator and exhausts into a condenser. Vapor produced by the evaporator is condensed and the heat content of the condensate and also that of unevaporated liquid is recovered and used at least in part to preheat the liquid to be evaporated.

The present invention relates to a system for producing electric power and evaporating a liquid, either to obtain a concentrate of the liquid or a condensate or both, in an efficient and economical manner. In particular, the present invention represents an improvement of the method and apparatus disclosed in Chocquet British patent specification 956,789 which provided for the evaporation of liquids, but not for the production of electric power. The present invention is particularly applicable to plants combining the production of electric power and the production of distilled water from sea or brackish water, or more generally, polluted waters unfit for consumption or industrial use. However, the apparatus is also usable in other fields where the evaporation or condensation of a liquid is desired, for example in the chemical, petroleum or sugar industries.

The consumption of steam used for heating in an evaporator system can be expressed in terms of the ratio (commonly called "effect") of the quantity of liquid evaporated to the consumption of steam. The consumption of steam represents the heat energy that is supplied to the assembly to effect vaporation. The heat lost from the evaporator system is made up of the heat content of the fluids leaving the system, that is to say, the heat content of the condensate, the heat content of any effluent vapors, and the heat content of the unevaporated liquid or concentrate. It is an object of the invention to reduce losses to a minimum and to utilize with maximum efficiency and effectiveness the available energy for the production of electric power and for evaporation of a liquid.

In a system according to the present invention, electric power is produced by an alternator or other electric generator driven by an expansion motor which is preferably a multi-stage steam turbine. The term "steam" is used for convenience in a generic sense to include any heated vapor under pressure whether of water or other liquid. Steam bled off from the turbine at selected states

2

of expansion is fed to an evaporator system to supply heat for evaporating a liquid.

The heating medium brought to the evaporator by extraction from the power turbine at a given pressure exerts an effect only by its mass but not by its energy level which is a function of its temperature. However, the extraction from the main turbine of steam which is still superheated necessarily affects the efficiency of the turbine cycle. In general, the efficiency of the cycle of the turbine will be influenced less when the extraction of steam for the evaporator occurs at lower levels of pressure and temperature. Moreover, raw waters subjected to a distillation process are generally sensitive to the effects of the heating temperature and are more corrosive when the temperature is higher. These circumstances thus impose a maximum value on the high pressure level of the evaporator, thus limiting the number of effects or stages that can from a practical point of view be utilized in the expansion cycle of a multi-stage unit while still having an industrially acceptable terminal pressure level.

In a plant of the kind herein described, the application of the process in accordance with the present invention results in an important reduction of the overall losses in the evaporating system as compared with those of a conventional multi-stage system. Increased efficiency is obtained by a mixed dynamic-static evaporating system in which the respective effects of the dynamic system and of the static system are correlated to achieve optimum use of the available energy and to reduce overall losses to a minimum.

Static expansion in a conventional multi-stage evaporator necessarily discharges into the final condenser the total heat of evaporation of the final stage, namely 620–640 cal./kg. (about 1115–1150 B.t.u./lb.). In accordance with the invention, vapor from a downstream stage of the evaporator is recompressed and recycled upstream so that this loss of calories is partially recovered through a dynamic expansion. The heat energy thus recycled at an upstream level integrates itself into the cycle and reduces by like amount the final equilibrium loss. The heat recovered by this dynamic recycling will commonly be in the range of 70 to 100 cal./g. (126–180 B.t.u./lb.). Use of the process in accordance with the invention thus represents an improvement of some 12% to 15% in the cycle efficiency. Moreover, since the steam for supplying the heat energy input to the evaporator system is taken from the main power turbine at a lower pressure level, a lighter and more economical construction can be used for the evaporator and its accessories.

Recompression of the vapor at a selected stage in the evaporator is preferably effected by a turbine-compressor unit which is correlated with the evaporator so as to constitute a stable system. Operating characteristics are established by relative dimensioning of the components so that conventional regulating devices are not required for the turbine driving the compressor. It is necessary only to provide suitable safety devices to protect against overspeed, loss of oil pressure, loss of vacuum, etc. The turbine driving the compressor will thus operate continuously at wide open throttle and with the optimum value of expansion efficiency. The condensate production capacity of the system will thus be a function of the pressure at the intake of this expansion turbine and thus of the load of the main turbine-generator set.

The production rate of the evaporator is thus controlled either by appropriate throttling of the extraction from the main turbine or preferably by moving the extraction point on the main turbine upstream or downstream in the expansion cycle. If reduction of the production rate of the evaporator is desired, the amount of steam extracted from the main turbine is reduced, for example by suitable throttling, or the point of extraction

mild mechanical treatment may, for instance, consist of striking, rubbing, brushing, or vibrating. Such treatment during the electrical treatment will not only fold out but also spread the material out.

At this point in the flow sheet of FIGURE 1 the sheet material is in a spread-out condition wherein the individual fibrils, making up the material, are parallel to the longitudinally axis of the sheet material. In many cases, and for many applications, this is a desirable configuration. However, for certain textile products the yarn used in the manufacture therein should not be lean and smooth but rather should have a high percentage of loose fibrils along the surface of the web or sheet as the case may be. For instance, in the case of blankets, carpets, and fabrics made from woolen yarns, it is essential to use a bulky yarn which is not produced under the process described in the above-identified patent.

My invention resides in forming a pile fabric from this polymeric sheet material as it emerges from the folding-out step.

With reference to FIGURES 2 and 3, after the sheet material 10 has been folded out as described hereinabove, it passes between a pair of generally cylindrical rollers 12 and 13, which are rotatably mounted in frame plates 14 and 16 respectively. These frame plates 14 and 16 extend vertically from a base plate 18 which is mounted on wheels 20. This unit is able to be wheeled into a position to receive the film 10 directly from the folding-out step described in FIGURE 1 in the event that it is desirable to make the whole process continuous. The sheet or web 10 passes from the rollers 12 and 13 to a roller 54 (see FIGURE 6) which is also rotatably mounted in plates 14 and 16.

With reference to FIGURE 6, a plurality of rollers 54 are shaped to form a crown 56 at their centers. As a result, the fibrils in the central portion of film 10 passing over the crown 56 will break while those in the edge portion of the film passing over the edge of the roller will not. This action of crowned rollers 54 (FIGURE 2) causes the fibrils in the center portion of sheet 10 to break. This web is particularly useful in making yarn and as such it is twisted by conventional yarn twisting means as it is wound onto a spool 58.

As shown in FIGURES 2 and 3, rollers 13, 54 (only one roller is shown; however, it would be within the skill of the art to connect a plurality of crowned rollers into the mechanism) and 29 are connected to a suitable driving mechanism 30. This mechanism comprises an endless belt or chain 32 which passes over a pulley or sprocket 34 which is fixed to roller 54, then over a sprocket 36 which is fixed to roller 13, then over a sprocket 38 which is fixed to roller 29, then over an idler sprocket 40, then over a drive sprocket 42, which is driven by any suitable power source such as electric motor 44, and finally back over sprocket 34. The rollers 12, 13, 54, 28, and 29 are rotated in the directions shown by the arrows.

With reference to FIGURE 4, roller 22 is provided with a plurality of grooves 24 and a plurality of needles 26 or other similar sharp, pointed implements, which project radially from the center of the grooves 24. These needles may be secured in the grooves 24 in any suitable manner. As the sheet 10 passes over the roller 22, portions of it are channelled into the grooves 24 and become impaled upon the needles which penetrate through the sheet material and cause a portion of the individual fibrils to be severed. The degree of breakage would be determined by the number of grooves in the roller and the number of pins in the grooves; however, no more than one-half of the fibers passing over the roller should be broken in order to retain sufficient web strength. In the preferred embodiment we show only one roller but it would be within the skill of the art to adapt a plurality of rollers over which the film could be passed. The film after passing over the pin-studded roller 22 is received by a pair of pick-up rollers 28 and 29 which are also rotatably

mounted in the frame plates 14 and 16. These rollers feed the bulky sheet material to a suitable take-up mandrel (not shown).

FIGURE 5 illustrates another embodiment of my invention. In this embodiment a roller 46 contains a plurality of grooves 48 around the perimeter thereof. These grooves are cut at an angle of 45° to the horizontal axis 50 of the roller 46. This roller 46 is attached to frames 14 and 16 in place of roller 22. A plurality of knife blades 52 are positioned around the circumference of roller 53 rotatably mounted between the vertical frames 14 and 16 a predetermined distance from roller 46. The sheet 10 is passed between the roller and the blade. The blade 52 is rotated in close enough proximity to the roller 46 so that portions of the film 10 pass over the crown of the grooves 48 and are cut by the rotating blades 52. Because of the angle of inclination of these grooves a discontinuous chopping of the individual fibrils results without cutting entirely across the sheet itself. The strength of the sheet itself is not significantly affected. This fabric possesses a tremendous advantage over a normal pile fabric because the pile fibers form an integral part of the sheet and are firmly anchored to the surface of the sheet.

In order to illustrate with greater particularity and clarity the operation of my process, the following examples are offered as illustrative of the operation thereof. The specific materials and conditions given in the examples are presented as being typical and should not be construed to limit my invention unduly.

EXAMPLE I

A 60-inch wide fibrillated web of 0.8 mil polyethylene, having a density of 0.95 gram/cc. and a melt index of 0.3 (ASTM D 1238-5DT, Condition E), is threaded through the machine described in FIGURE 2. A chopper roller 53 is provided with 12 tempered spring steel blades 52 around its circumference. The blades 52 coact with a 12-inch diameter grooved roller 46, made of mild steel and coated to a thickness of 60 mils with 80 durometer rubber. Each groove 48 in roller 46 defines an ellipse in a plane making a 45° angle with the roller axis. These grooves are 1/8-inch wide, 1/8-inch deep, and spaced so that their centers are 1/4-inch apart, and having all their edges and corners chamfered and rounded on a 1/16-inch radius. Bulk film is fed to roller 12 at the rate of 20 feet per minute while the machine is being adjusted to insure clean, uniform cuts. After adjustment, the rate is increased to 150 feet per minute and about 2000 feet of the material is fed through the machine.

Air filters 2 1/2 feet square are produced from some of this material by laminating 21 layers of this bulked film together, each layer being laid at right angles to the adjacent layers 21 and being stitched together in both directions across the film at 6-inch intervals with cotton string and subsequently edged with an aluminum channel having a 1/8-inch flange.

In another application ten 8-foot sections of this bulked fibrillated web are stitched together on 4-inch centers both lengthwise and crosswise and the edges bound to make an exceptionally warm, lightweight blanket.

Example II

The rollers 46 and 53 are replaced with a 12-inch diameter pin-studded roller 22 similar to that shown in FIGURE 4. The grooves 24 are 1/2-inch center-to-center with a sharp 60° included angle peak between the grooves. In each groove 36 equally spaced cylindrical pins 26 are positioned wherein each pin is 3/32-inch in diameter and has a flat, sharp edged top portion located 3/32-inch below the peaks. Web material similar to that used in Example I is threaded through the machine and the machine is started and run at an initial rate of about 15 feet per minute output while adjustments of the film tension over the pin-studded roller 22 are made. After adjustment, the rate is increased to 150 feet per minute to produce approximately

be fed wholly or in part to the evaporator if so desired.

The vapor from evaporator unit 17 after being compressed by the rotary compressor 21 is fed to the heating coil 16a of the evaporator 16 where it is permitted to expand and condense, the resulting condensate being led to the collecting line 28. A portion of the compressed vapor from the compressor 21 may also be fed to the heating coil of the raw water preheater 26, the resulting condensate being led to the collecting line 28. The heat content of the condensate from evaporator units 16, 17 and 18 and from the preheater 26 is at least in part recovered in the heat exchanger 24 before being discharged through the condensate discharge line 27. The remaining unevaporated liquid from the last stage 18 of the evaporator is led to the heat exchanger 25 where at least a portion of its residual heat is recovered and is then discharged through line 25A either to waste or to other equipment for further processing, for example in the production of salt or recovery of other materials from the brine.

The dynamic portion of the evaporator is of the double effect type, the compressor 21 recycling the corresponding portion of vapor furnished by the evaporator unit 17 at the level of pressure of the head of the system at unit 16. The form of coupling of the dynamic system and the static system of the evaporator is determined by considerations of the requirements of the equipment, considering the output-compression ratio of the compressor most favorable for the structure, the efficiency and the price of the mechanical portion of the expansion-compression system and other design characteristics of the equipment.

While a preferred embodiment of the invention has been illustrated by way of example in the drawings, it will be understood that the invention is in no way limited to this embodiment and that modifications may be made according to the requirements of each particular installation. For example, the number stages in the main turbine and in the evaporator may be varied as required. Moreover, the dynamic portion of the evaporator system may be connected with different stages of the evaporator. The arrangement of heat exchangers to recover heat content from the condensate and from the remaining unevaporated liquid may also be varied in accordance with the requirements of the installation. Thus, the specific arrangement of components may be varied and equivalent technical means may be substituted for the components specifically illustrated and described without departing from the scope and spirit of the invention as defined by the following claims.

What I claim and desire to secure by Letters Patent is:

1. A system for producing electric power and evaporating a liquid, which comprises an expansion motor, an electric generator driven by said motor, means for supplying steam under pressure to said motor to drive the motor, means for selectively discharging partially expanded steam from said motor at a selected state of expansion, an evaporator having heating coils and evaporation space, means for feeding to said evaporation space liquid to be evaporated, means for conveying to heating coils of said evaporator said steam selectively discharged from said expansion motor, means for condensing vapor produced by said evaporator and for recovering heat from the resulting condensate, means for applying at least part of the recovered heat to preheat the liquid to be evaporated, and means for sensing the rate of production of condensate by said evaporator and condensing means and for controlling the selective discharge of steam from the expansion motor in accordance with said rate of production.

2. A system according to claim 1, in which said expansion motor comprises a multi-stage turbine.

3. A system according to claim 2, in which means is provided for reheating the steam between two stages of the turbine.

4. A system according to claim 1, in which said expansion motor comprises a multi-stage turbine providing progressive expansion of steam supplied to the turbine with progressive decrease of pressure and in which said means for discharging partially expanded steam comprises means for selectively discharging steam from at least one of a plurality of pressure levels of said turbine.

5. A system according to claim 1, in which means is provided for recovering heat from unevaporated liquid discharged from said evaporator and applying at least part of the recovered heat to preheating the liquid to be evaporated.

6. A system according to claim 1, further comprising a preheater for liquid to be evaporated and means for conveying a selected portion of vapor from said evaporator to said preheater.

7. An evaporating system comprising a multi-stage evaporator having a sequence of stages, each stage having a heating coil and an evaporating space, means for supplying steam to the heating coil of a stage of said evaporator, means for supplying liquid to be evaporated to the evaporating space of a stage of the evaporator, means for conveying vapor produced in the evaporating space of one stage of said evaporator to the heating coil of a succeeding stage, means for conveying unevaporated liquid from one stage of said evaporator to the evaporating space of a succeeding stage, an expansion motor, a compressor driven by said motor, means for conveying vapor from a stage of said evaporator to said expansion motor to drive the motor, means for conveying vapor from a stage of the evaporator to said compressor for compression thereby and means for conveying the compressed vapor to the heating coil of a selected stage of the evaporator.

8. A system according to claim 7, in which steam to said motor and steam to said compressor are conveyed from different stages of said multi-stage evaporator.

9. A system according to claim 8, in which compressed steam from said compressor is conveyed to a stage preceding the stage from which steam is conveyed to said compressor.

10. A system according to claim 7, further comprising a second expansion motor, an electric generator driven by said second motor and means for supplying steam under pressure to said second motor to drive said generator, said steam being progressively expanded in said second motor, and in which said means for supplying steam to said evaporator comprises means for selectively discharging partially expanded steam from said second motor at a selected state of expansion and conveying said discharged steam to said evaporator.

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