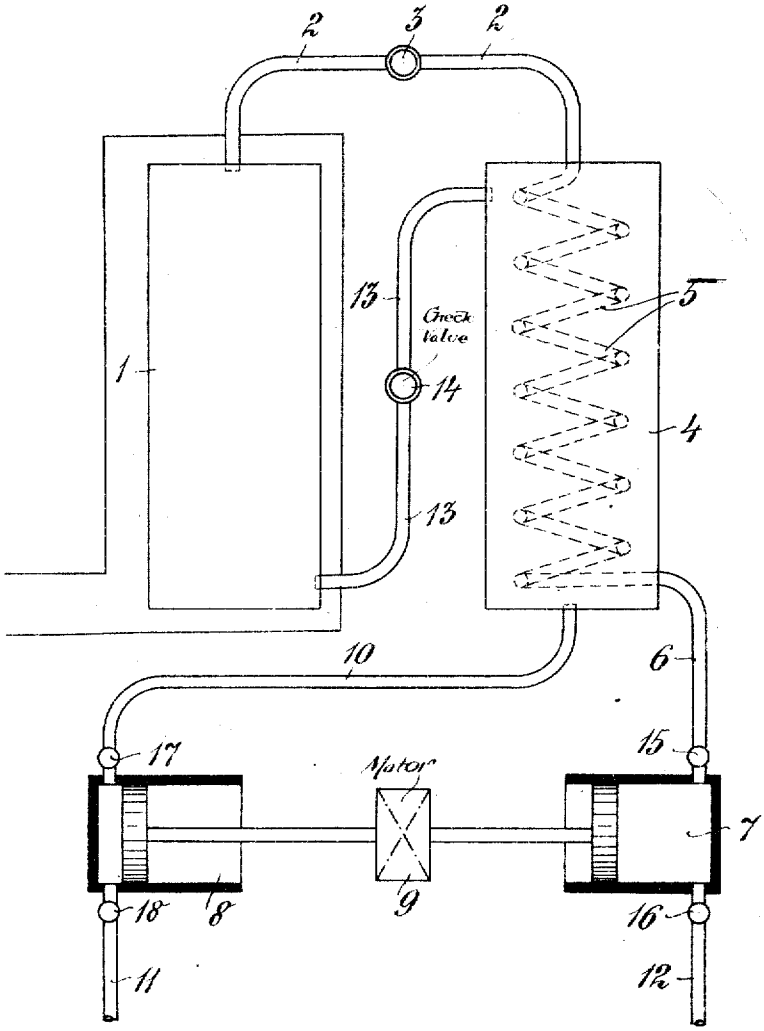
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METHOD OF EVAPORATION AND DISTILLATION OF LIQUIDS.

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METHOD OF EVAPORATION AND DISTILLATION OF LIQUIDS.

1,204,716. Specification of Letters Patent. Patented Nov. 14, 1916.

Application filed September 8, 1914. Serial No. 860,707.

To all whom it may concern:

Be it known that I, CARL THEODOR THORSSELL, a subject of the King of Sweden, residing at Gottenborg, in the county of Malmöhus, Sweden, have invented certain new and useful Improvements in Methods of Evaporation and Distillation of Liquids, of which the following is a specification.

This invention has for its object the evaporation and distillation of liquids.

In the evaporation, distillation and like treatment of liquids the greatest part of the cost is required for the supply of the heat corresponding to the total heat of evaporation of the liquid in question. An attempt has previously been made to reduce this expense by bringing about a more or less complete regeneration of this heat of evaporation but for apparatus of this kind a considerable amount of power is required. According to that method the vapor leaving the still is compressed to a pressure somewhat higher than the pressure prevailing in the still so that the vapor will be condensed, whereupon it is brought into a heating apparatus in this vessel, in which it yields its heat of evaporation to the liquid to be distilled. Assuming that such an apparatus evaporates 2000 kilograms of water per hour and the evaporated steam is compressed from one kg. per sq. cm. to 1.3 kg. pressure per square centimeter, the compressor must compress the volume $2000\ (1.67-1.2)=940$ cubic meters, since the volume of 1 kilogram of steam at a pressure of 1.0 kg. per square cm. is 1.67 cubic meters and the volume of 1 kg. of steam at a pressure of 1.3 kg. per square cm. is 1.20 cubic meters. If this compression be carried out in a cylinder with a cross-sectional area of 1 square meter, the piston must travel 940 meters. The pressure on the piston amounts to $1.3\times10000=13000$ kg. Thus the work done amounts to $13000\times940=12220000$ kilogram-meters in an hour, which corresponds to a power of 46 H. P. To obtain a better result it has been suggested that a calorific motor may be used for this compression and that the heat of its exhaust gases may be used for preheating the liquid to be distilled.

My invention relates to a method by means of which the cost for the compensation of the heat of evaporation is eliminated in a more efficient way, by the use of means that require only a minimum of power. This result is obtained by carrying out the distillation at the critical temperature of the liquid in question or at a temperature somewhat lower than the critical temperature. As the heat of evaporation at the critical point is $=0$, it is evident that the compensation of this heat and thus the cost of the same are avoided.

For the sake of making the invention clear the new method applied to the distillation of water is hereinafter explained. The critical point of water is reached at a temperature of 374° Cels. and at a pressure of 217.5 atmospheres (224.24 kg. per square cm.) according to *Physikalisch-Chemische Tabellen*, 1912, page 447, by Landolt-Bornstein (experiments by Holborn and Baumann 1910).

The invention is illustrated by way of example in the accompanying drawing, which shows an apparatus for use in carrying out the invention.

As shown, the outlet pipe 2 leads from the distillation vessel 1 to a cooling coil 5 in a vessel 4, the coil 5 being connected with the pump cylinder 7 by means of a pipe 6. A valve 3 in the pipe 2 is arranged in such a way that it opens when a certain difference of pressure is established. A valve 15 is arranged in the pipe 6, and another valve 16 is arranged in the pipe 12 leading from the system. The inlet pipe 11 of the system with the valve 18 is connected with a suction and compression pump 8 or the like, the piston of which is driven from a driving gear or a motor 9 and also connected with the piston in another cylinder 7 or the like. A pipe 10 provided with a valve 17 leads from the pump cylinder 8 to the vessel 4 which latter is connected with the distillation vessel 1 by means of a pipe 13 having a check valve 14.

The vessel 1 is filled with water to a certain level and the valve 15 is closed. Heat is supplied to the vessel 1, whereby the pressure is increased. When the pressure has risen to that amount at which the valve 3 opens and which in what follows is assumed to be 3 kg. per square cm., the steam passes over into the cooling coil 5. On account of the pressure decreasing when the steam passes through the valve 3, the steam will be condensed to water in the coil 5 (the Joule-Thomson effect). When the pressure in the vessel 1 has risen to 225 kg. per sq. cm. the critical point is passed and the temperature is maintained at 374° C. Now a

pressure of 225—3=222 kg. per square cm. prevails in the coil 5, but the water here has not yet the temperature of steam at this pressure. If now the liquid is set in motion in the way hereinafter described, so that the water condensed in the coil 5 is drawn off successively without the pressure in the coil being decreased, and if fresh water is pumped into the vessel 1 through the pipe 10, the vessel 4, the pipe 13 and the check valve 14 which prevents a return flow, while the pressure and the temperature in the vessel 1 are maintained, then the temperature of the coil 5 must in course reach the point required according to the physical laws.

According to the investigation of Davis (publications from Harvard University 1909) the Joule-Thomson effect, expressed in fall of temperature per fall of pressure of 1 kg. per square cm. for water is as follows: at 200° C.=2.2° C.; at 250° C.=1.5° C.; at 300° C.=1.1° C. and at 360° C.=0.9° C. From this one may come to the conclusion that the fall of temperature at 374° C. is 0.85° C. for a fall of pressure of 1 kg. per square cm. and thus 2.55° C. for a fall of pressure of 3 kg. per square cm. Thus the pressure and the temperature in the coil 5 are respectively 222 kg. per square cm. and 374—2.55=371.45° C. But the pressure of saturated steam at a temperature of 371.45° C. is 217.59 kg. per square cm., and consequently the water in the coil is liquid.

If the motion of the liquid be maintained in the manner described, *i. e.*, in such a way that the temperatures and pressures stated are not altered, the operation of the apparatus will result in the water being distilled from the vessel 1, without consuming the quantity of heat corresponding to the heat of evaporation, and condensed into the coil 5.

In order to cause the water to pass into the vessel 1 it will be requisite to force it in at a pressure higher than 225 kg. per square cm. To this end a rather considerable amount of work ought to be required, but in order to avoid this additional work as far as possible, the energy in the water or in a part of the water that is condensed in the coil 5 at a pressure of 222 kg. per square cm. is utilized. For this purpose the following device may be used: By connecting the two pistons in the cylinders 7 and 8 with a common piston rod the pressure on the piston in the cylinder 8 may be balanced by means of the piston in the cylinder 7. If water of a pressure of 222 kg. per square cm. is admitted through the valve 15, while the valve 16 is closed, and the power required for compensating the difference of pressure between the pipe 10 (227 kg. per square cm.) and the cylinder 7 (222 kg. per square cm.) is supplied by the motor 9, then the piston in the pump will move forward and press the water into the pipe 10 and thence through the vessel 4 and the pipe 13 into the vessel 1. On the return stroke of the piston the valves 17 and 15 are closed but the valves 18 and 16 opened. The water is drawn into the cylinder 8 through the valve 18 and it is drawn off the balancing cylinder 7 through the valve 16.

The newly admitted water absorbs heat from the water in the coil 5 on its passage through the vessel 4 so that the water in the coil attains a temperature of 30° C. when it is drawn off. The pressure in the coil 5 falls by this fall of temperature so very little that it need not be taken into consideration. According to Thomson's formula, for which see Chwolson, *Lehrbuch der Physik*, vol. 3, page 562 (Brunswick, 1905); Drecker: *Wiedermanns Annalen*, vol. 20, p. 870 (1883); Joule: *Phil. Transact.*, vol. 149, p. 133 (1859); *Phil. Mag.* (4), vol. 15, p. 17 (1858); Burton and Marshall: *Proc. R. Soc.* vol. 50, p. 130 (1891), for the calculation of increase in temperature by the compression of liquids this increase is as follows:

$$\theta = 10333 \frac{A \cdot T \cdot \alpha V_0 \cdot p}{C_p}$$

"A" equals the mechanical equivalent of heat, namely $\frac{1}{E}$, if E is the thermal equivalent alpha is the increase in volume corresponding to a rise in temperature of one degree. V_0 is the volume at 0°. C_p is the thermal capacity at constant pressure.

In this formula α appears in the numerator of the fraction and thus θ is proportional to this quantity. For water between 200 and 500 atmospheres α=about $10^{-6} \times 600$ (Chwolson *Lehrbuch der Physik*, band 3, page 562). This is confirmed by the experiments of Joule with compression of water at +30° C. and 26.19 atmospheres when the increase in temperatures amounted to 0.0544° C.

If the apparatus be worked in the manner described, the amount of heat and power required is as follows: when the apparatus is running: If the vessel 4 and the coil 5 are constructed and dimensioned according to the counter current principle in such a way that the water leaves the coil 5 with a temperature of +30° C. and the water forced into the vessel 4 by means of the pump 8 has a temperature of +15° C., while the quantity of water passing through the apparatus per hour amounts to 2000 kilograms, then the quantity of heat required for heating 2000 kilograms of water from 15° to 374° C. amounts to 2000(374—15)=718000 calories. The water in the coil 5 delivers to the water in the surrounding vessel 2000(371—30)= 682000 calories. Thus, in order to maintain the temperature in the vessel 1, it is

necessary to supply 718000−682000=36000 calories per hour, this constituting the theoretical amount of heat required for the apparatus.

If the velocity in the pipes is assumed to be 1 meter per second, the area of the pipe will be

$$\frac{2000}{3600.10}=0.0552$$

square decimeters and its diameter = 26 millimeters. The pressure on this area =5.52×5=27.6 kilograms which must be covered by the motor 9. This corresponds to an amount of work = 27.6 kilogrammeters, *i. e.*

$$\frac{27.6}{75}=0.37 \text{ H. P.},$$

constituting the theoretical amount of power required for the apparatus.

It is evident that the heat in the distilled water or a part thereof in some cases also may be used for purposes other than for heating the freshly admitted liquid, and also that its pressure may be used for other purposes. A part of the distilled liquid may also be used for forcing more liquid into the distillation vessel.

In some cases the distillation may be carried out at a temperature that is somewhat lower than the critical temperature.

Having now particularly described and ascertained the nature of my said invention and in what manner the same is to be performed, I declare that what I claim is:—

1. A method of evaporation and distillation of liquids characterized by carrying out the evaporation or distillation at the pressure and temperature corresponding to or near the critical point of the liquid, as and for the purpose specified.

2. A method of evaporation and distillation of liquids consisting in generating the vapor at or near the critical point of the liquid and exposing the vapor, when leaving the distillation vessel, to a small fall of pressure and temperature in such manner that the vapor is condensed, *i. e.*, so that its pressure becomes higher than the pressure corresponding to the pressure of saturated vapor at the prevailing temperature.

3. A method of evaporation and distillation of liquids, consisting in generating the vapor at or near the critical point of the liquid and conducting the liquid to be distilled in such a path to the distillation vessel that it may receive heat from the liquid already distilled, in order that this heat or a part thereof may be used to bring more liquid to the critical point.

4. A method of evaporation and distillation of liquids, consisting in generating the vapor at or near the critical point of the liquid and using the distilled liquid, still under high pressure, or a part thereof as motive fluid for forcing more liquid into the vessel in which the distillation takes place.

5. A method of evaporation and distillation of liquids, consisting in generating the vapor at or near the critical point of the liquid and causing the liquid to be distilled to pass the liquid already distilled by means of the pressure of the latter liquid in such a path that it becomes heated before it is forced into the vessel (1), in order that both the pressure and the heat of the liquid distilled may be utilized.

In testimony whereof I have affixed my signature in presence of two witnesses.

CARL THEODOR THORSSELL.

Witnesses:

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T. G. BRANZELLY.