A. B. FOSTER.

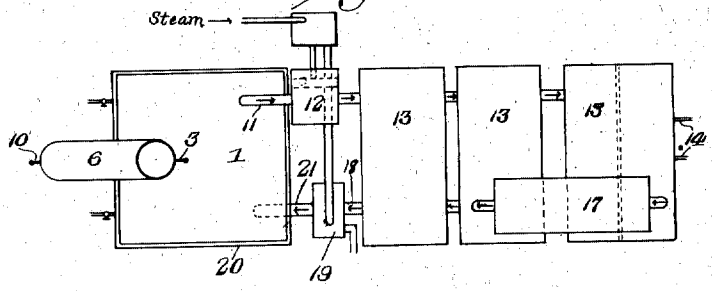
PROCESS AND APPARATUS FOR DISTILLING.

APPLICATION FILED FEB. 15, 1913.

1,277,895.

Patented Sept. 3, 1918.

Fig. 2.



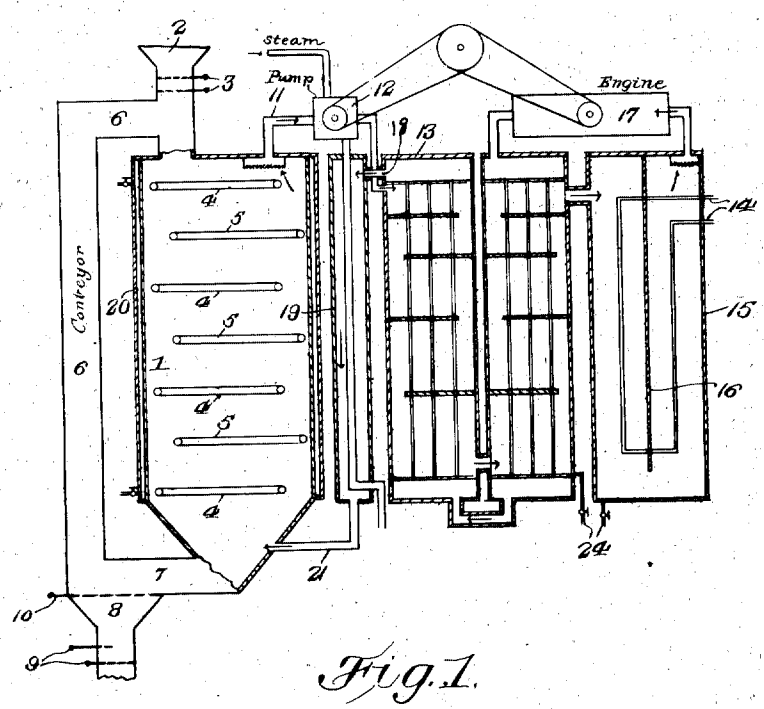


Fig. 1.

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PROCESS AND APPARATUS FOR DISTILLING.

1,277,895. Specification of Letters Patent. Patented Sept. 3, 1918.

Application filed February 15, 1913. Serial No. 748,580.

To all whom it may concern:

Be it known that I, ARTHUR B. FOSTER, a citizen of the United States, residing at Washington, District of Columbia, have invented new and useful Improvements in Processes and Apparatus for Distilling, of which the following is a specification.

This invention relates to the separation of mixtures of substances having different boiling points, or in other words to distillation.

The object is to economize the amount of heat, refrigeration, and power necessary, and this is accomplished by transferring heat and by utilizing the otherwise waste power.

It is well known that when gases are compressed, the power used for compressing the gases is transformed (at least in part) into heat; and conversely, when gases expand while performing work, the temperature of the gases is lowered. The compression of the gases requires power, and all the power may be regained, theoretically, upon the expansion of the gases. As a matter of fact, however, a part of the energy is always lost, through friction, lack of perfect efficiency, etc.

It has been proposed, in distillation to evaporate the liquid under reduced pressure, and to condense the gases under super-atmospheric pressure, but here the suction in the still lowers the temperature, which requires the application of additional heat; and compressing the gases into the condenser system generates heat which requires additional cooling, and consequently the heat and cold are generated at the wrong places. My plan is to transfer, by the mode and devices hereinafter to be described, this heat and cold, and to thereby utilize these.

Another feature consists in developing and utilizing the energy represented by the compression of the gases, when the same pass from high to low pressure, in such a manner as to furnish power, which power may be used as a part of the power necessary for producing the gas pressure on the one hand, and the partial vacuum on the other hand, or this power may be used for any desired purpose.

As a specific example, the invention may be applied to the recovery of volatile solvents from solvent-extracted materials, *e. g.* the recovery of benzene, carbon tetra-chlorid, etc., from the presscake left after extracting cotton seed oil from crushed and pressed cotton seed, by means of solvents.

Referring to the accompanying drawing, which illustrates diagrammatically the apparatus in accordance with my invention; Figure 1 representing an elevation of the apparatus, partly in section, and Fig. 2 representing a plan (the hopper 2 being omitted) of the same.

The evaporating vessel 1, provided with a hopper 2, having a vacuum sealed inlet 3 and also preferably provided with agitating means, *e. g.*, traveling belts 4, which transport the material to the right where it drops on to other belts 5 which carry it toward the left. These belts may run on small rollers operated in any suitable manner, and both belts and rollers preferably extend the entire width of the vessel.

This is merely one of many suitable means for spreading out the material to offer a large surface for evaporation of the solvent, by contact with the hot gases.

The material, on reaching the bottom of the chamber may be discharged by a conveyer located in the passage 7, hopper 8, double gates 9 the gate 10 being open, or if not sufficiently freed from the solvent it may be passed again, or several times through the vessel 1, until freed from the solvent to any desired extent, a suitable conveyer for carrying the material back to the inlet end of the vessel 1, being located in the casing 6, which is under the same degree of vacuum as the vessel 1.

During the passage of the material through the vessel it is subjected to the action of a heated current of air or other gas, in a partial vacuum and because of the heat and vacuum the solvent vaporizes readily, and the vapors thereof mix with the gas and are carried off thereby.

Any suitable gas can be used, air will answer in case carbon tetrachlorid is being recovered, while if gasolene is being recovered it will not do to use air, on account of the explosiveness of the mixtures of air and gasolene vapors. Nitrogen, or chimney gases may be preferable to use with gasolene-holding material, chimney gases should

preferably be washed and filtered, or otherwise treated to remove soot, flue dust, etc.

It is obvious that the gas must also be something that will not injuriously affect the solid material, *e. g.*, cotton seed meal, for the purpose for which it is to be ultimately used, *e. g.*, cattle feed, fertilizer, etc.

To produce this vacuum and the gas current, I provide a pump 12 which draws the gas laden with vapors from the upper part of the vessel 1, through pipe 11, (which is preferably provided with a burlap screen, across its inlet end, to prevent solid matter from being carried along by the gas current,) and force it into the first heat interchanger. The action of the pump further heats the gases and vapors, and these then pass around the pipes of the one or more heat interchangers 13, which may be of any suitable construction. These gases may then be further cooled, for example by the refrigerating coils 14 in the condenser chamber 15, which may be provided with one or more baffles 16, to cause the gases to take a tortuous course.

The result of the cooling and higher pressure is to cause the whole, or a large part of the vapors of solvent to condense, in the heat interchangers and in the refrigerated chamber 15.

The solvent collected in the heat interchanger and in the refrigerated chamber may be drawn off, intermittently or continuously through suitable pipes 24 for this purpose, connected to the bottoms of these vessels.

The gases deprived of their vapors pass out through the turbine 17, which causes a still further reduction of the temperature, and also thereby developing power to be used for any purpose, *e. g.* a part of the power necessary for operating the pump 12. The cold gases pass through the tubes of the heat interchanger and become heated up thereby, nearly to the temperature in the vessel 1, and after leaving the heat interchangers, pass through the pipe 18, into the heat exchanger 19, where they may be still further heated by all or a part of the hot exhaust fluid from the engine operating the pump 12, which fluid may be the exhaust gases of an internal combustion engine used for operating said pump, or may be the exhaust steam from a steam engine used for operating said pump.

In place of this or in addition to this the said fluid, or a part thereof, may be used to directly heat the vessel 1, by means of the jacket 20.

Thus it will be seen that the gas circulates, through vessel 1, pump 12, around the tubes of the heat interchangers 13, through refrigerated chamber 15, turbine 17, through the tubes of heat interchangers 13, thence through supplemental heater 19, and back into vessel 1, through pipe 21.

Thus it will be seen that the solvent may be recovered by use of a minimum amount of heat and power.

In case we are working for the fractional distillation of such product as petroleum, the vessel 1 will preferably be made in shape of a rotating cylinder, provided interiorly with scoops, blades, or buckets and also provided at its end with the gas inlet and outlet pipes, 21 and 11.

The pump 12 and engine or turbine 17 may be of any known or desired construction.

It is obvious that all parts of the system must be gas tight, and all parts will preferably be surrounded by suitable heat insulating jackets (not shown, as these are well known). The air locks 3 and 9 are of any preferred construction, and of the two gates 3, one is not opened until the other is closed, as is well known in the art.

I claim:—

1. A cyclical process of distilling a volatile substance which comprises (1) subjecting a moving material containing said volatile substance to a counter current of gas at a pressure materially below atmospheric and at a temperature sufficient to induce vaporization of said substance (2) then raising the pressure of the gas carrying the vaporized substance and lowering the temperature sufficiently to condense at least some of the vaporized substance, (3) then lowering the pressure of the gas, (4) causing an interchange of heat units between the compressed gas containing the vaporized substance and the cooler gas of lower pressure, at least a part of the heat of compression of said compressed gas being thereby transferred to said cooler gas, before the latter comes again into contact with material containing the volatile substance, and utilizing the power developed by the gas in passing from high to low pressure.

2. A cyclical process of distilling a volatile substance which comprises subjecting a moving material containing said volatile substance to a counter current of gas at a low pressure and at a temperature sufficient to induce vaporization of said substance, then raising the pressure of the gas carrying the vaporized substance, transferring heat from said gases, without previous cooling thereof, to gas about to enter said vaporization step, and lowering the temperature of the compressed gas and vapor sufficiently to condense at least some of the vaporized substance, then lowering the pressure of the gas, causing an interchange of heat units between the compressed gas containing the vaporizied substance and the cooler gas of the lower pressure, before the latter comes again into contact with material containing

the volatile substance, and utilizing the power developed by the gas in passing from high to low pressure.

3. A cyclical process of distilling a volatile substance which comprises subjecting a moving material containing said volatile substance to a counter current of gas at a pressure materially below atmospheric and at a temperature sufficient to induce vaporization of said substance, then raising the pressure of the gas carrying the vaporized substance and lowering its temperature sufficiently to condense at least some of the vaporized substance, then lowering the pressure of the gas, causing an interchange of at least a portion of the heat produced by compression and at least a portion of the sensible heat in the hot compressed gas, between such gas containing the vaporized substance and the cooler gas of lower pressure, before the latter comes again into contact with material containing the volatile substance, and utilizing the power developed by the gas in passing from high to low pressure, as a part of the power necessary for compressing the gas and vapors leaving the vaporizing vessel and removing the volatile substance condensed in the cold-pressure stage.

4. A cyclical process of distilling a volatile solvent which comprises agitating a material containing the same while subjecting such material to a current of gas at a low pressure and at a temperature sufficient to induce vaporization of said volatile solvent, then raising the pressure of the gas carrying the vapor of the solvent whereby heat is generated therein, and lowering its temperature sufficiently to condense at least some of the vapors, then lowering the pressure of the gas, causing an interchange of heat units between the so-heated compressed gas containing the vapors and the cooler gas of lower pressure, before the latter again comes into contact with the material containing the volatile solvent, and utilizing the power developed by the gas in passing from high to low pressure.

5. A cyclical process of distilling a volatile solvent which comprises agitating a material containing the same and subjecting the same to a current of gas at a low pressure and at a temperature sufficient to induce vaporization of said volatile solvent, then raising the pressure of the gas carrying the vapor of the solvent whereby heat is developed therein and lowering its temperature sufficiently to condense at least some of the vapor, then lowering the pressure of the gas, causing an interchange of heat units between the compressed gas containing the vapor while still carrying at least a part of the heat developed in said pressure-raising operation, and the cooler gas of lower pressure, before the latter again comes into contact with the material containing the volatile solvent, and utilizing the power developed by the gas in passing from high to low pressure as a part of the power necessary for compressing the gas and vapor leaving the vaporizing vessel, and further heating the gases with which said material is contacted and by means of a hot exhaust fluid from the pressure producing means.

6. A cyclical process of distilling a volatile solvent which comprises agitating a material containing the same and subjecting such material to a current of gas at a low pressure and at a temperature sufficient to induce vaporization of said volatile solvent, then raising the pressure of the gas carrying the vapor of the solvent and lowering its temperature sufficiently to condense at least some of the vapor, then lowering the pressure of the gas causing an interchange of heat units between the compressed gas containing the vapor directly after leaving the compression step, and cooler gas of lower pressure, before the latter again comes into contact with the material containing the volatile solvent, and utilizing the power developed by the gas in passing from high to low pressure as a part of the power necessary for compressing the gas and vapor leaving the vaporizing vessel, and further heating the gas with which said material is contacted and by means of hot exhaust fluid from the pressure-producing means and by removing the volatile substance condensed in the cold-pressure stage.

7. A cyclical process of distilling a volatile solvent which comprises subjecting an agitated material containing the same to a current of gas incapable of injuriously affecting said volatile solvent, while at a pressure materially below atmospheric and at a temperature sufficient to induce vaporization of said volatile solvent, then raising the pressure of the gas carrying the vapor of the solvent whereby heat is developed therein and lowering its temperature sufficiently to condense at least some of the vapor, then lowering the pressure of the gas, causing an interchange of heat units between the so heated compressed gas containing the vapor and cooler gas of lower pressure, before the latter again comes into contact with the material containing the volatile solvent, and utilizing the power developed by the gas in passing from high to low pressure.

8. A cyclical process of distilling a volatile solvent which comprises subjecting an agitated material containing the same to a current of gas incapable of injuriously affecting either said volatile solvent or the material with which it is associated at a low pressure and at a temperature sufficient to induce vaporization of said volatile solvent, then raising the pressure of the gas carrying the vapor of the solvent thereby adding an increment of heat thereto, and

lowering its temperature sufficiently to condense at least some of the vapor, then lowering the pressure of the gas, causing an interchange of heat units between the compressed gas containing the vapor and containing said increment of heat, and the cooler gas of lower pressure, before the latter again comes into contact with the material containing the volatile solvent, and utilizing the power developed by the gas in passing from high to low pressure.

9. A cyclical process of distilling a volatile solvent which comprises subjecting an agitated material containing the same to a current of gas incapable of injuriously affecting either said volatile solvent or the material with which it is associated, at a low pressure and at a temperature sufficient to induce vaporization of said volatile solvent, then raising the pressure of the gas carrying the vapor of the solvent and lowering its temperature sufficiently to condense at least some of the vapor, then lowering the pressure of the gas, causing an interchange of heat units between the compressed gas containing the vapor directly from the compression step, and the cooler gas of lower pressure, before the latter again comes into contact with the material containing the volatile solvent, and utilizing the power developed by the gas in passing from high to low pressure as a part of the power necessary for compressing the gas and vapor leaving the vaporizing vessel, and further heating the gas with which said material is contacted and by means of hot exhaust fluid from the pressure producing means.

10. A cyclical process of distilling a volatile solvent which comprises subjecting an agitated material containing the same to a current of gas incapable of injuriously affecting either said volatile solvent or the material with which it is associated, at a pressure materially below atmospheric and at a temperature sufficient to induce vaporization of said volatile solvent, then raising the pressure of the gas carrying the vapor of the solvent and lowering its temperature sufficiently to condense at least some of the vapor, then lowering the pressure of the gas, causing an interchange of heat units between the compressed gas containing the vapor and carrying the heat increment developed in the pressure-raising step, and the cooler gas of lower pressure, before the latter again comes into contact with the material containing the volatile solvent, and utilizing the power developed by the gas in passing from high to low pressure and as a part of the power necessary for compressing the gas and vapor leaving the vaporizing vessel.

11. An apparatus for distilling a volatile substance comprising the combination of a vaporizing vessel provided with a gas inlet and a gas and vapor outlet, a material inlet and outlet, heating means located in operative relation with said vessel, a pump for causing a current of gas through said vessel, a condenser provided with a gas and vapor inlet and a gas outlet, and with means for withdrawing the condensate from said condenser, cooling means, in operative relation therewith, a gas expanding means, a heat interchanger arranged to effect a transfer of heat units between the gases coming directly from said pump and the gases from expanding means, and means for conveying kinetic energy from said gas expanding means to said pump.

12. An apparatus for distilling a volatile substance comprising the combination of a vaporizing vessel provided with a gas inlet and a gas and vapor outlet, a material inlet and outlet, heating means located in operative relation with said vessel, a pump for causing a current of gas through said vessel, and for causing an increase of pressure in the gases, a condenser provided with a gas and vapor inlet and a gas outlet and with means for withdrawing the condensate from said condenser, cooling means in operative relation therewith, a gas expanding means capable of converting the energy of compression of the gases into mechanical power, and a heat interchanger arranged to effect a transfer of heat units between the gases leaving the pump and gas of lower pressure and temperature leaving the expanding means, and means for reintroducing the gas from the expanding means, after passing through said heat interchanger, into said vaporizing vessel.

13. An apparatus for distilling a volatile substance comprising the combination of a vacuum vaporizing vessel provided with a gas inlet and a gas and vapor outlet, a material inlet and outlet, heating means located in operative relation with said vessel, a pump for causing a current of gas through said vessel, and for causing an increase of pressure in the gas, a condenser provided with gas and vapor inlet and a gas outlet, and with means for withdrawing the condensate from said condenser, cooling means in operative relation therewith, a gas expanding means capable of converting the energy of compression of the gas into mechanical power, and a heat interchanger arranged to effect a transfer of heat units between the gases leaving the pump and the gases of lower pressure and temperature leaving the expanding means, and means for further heating and reintroducing the gases from the expanding means, after passing through said heat interchangers into vaporizing vessel.

14. An apparatus for distilling a volatile substance comprising the combination of a jacketed vaporizing vessel provided with a gas inlet and a gas and vapor outlet, a ma-

utilization of power between the high pressure and low pressure stages, the herein described improvement which comprises directly passing the gas and vapor from the compressor and the gas from expanding means into heat conducting relation with each other, whereby the heat of compression is at least in part imparted to the expanded gas.

22. A cyclical process of distilling a volatile substance which comprises subjecting a material containing said volatile substance to a current of gas at a low pressure and at a temperature sufficient to induce vaporization of said substance, then raising the pressure of the gas carrying the vaporized substance and lowering the temperature thereof sufficiently to condense at least some of the vaporized substance, then lowering the pressure of the gas, causing an interchange of heat units between the compressed gas containing the vaporized substance and the cooler gas of lower pressure, before the latter comes again into contact with material containing the volatile substance, and utilizing the power developed by the gas in passing from high to low pressure, and further heating the gas with which the material is to be contacted by means of the hot exhaust fluid from the pressure-producing means and removing the volatile substance condensed in the cold-pressure stage.

23. A cyclical process of distilling a volatile substance which comprises subjecting a moving material containing said volatile substance to a counter current of gas at a low pressure and at a temperature sufficient to induce vaporization of said substance, then raising the pressure of the gas carrying the vaporized substance and lowering the temperature thereof sufficiently to condense at least some of the vaporized substance, whereby the temperature of said mixture is raised, thereafter lowering the pressure of the gas, causing an interchange of heat units between the compressed gas containing the vaporized substance directly after the compression step, and the cooler gas of lower pressure, before the latter comes again into contact with material containing the volatile substance, and utilizing the power developed by the gas in passing from high to low pressure as a part of the power necessary for compressing the gas and vapor leaving the vaporizing vessel, and further heating the gas with which the material is to be contacted by means of the hot exhaust fluid from the pressure-producing means, and removing the volatile substance condensed in the cold-pressure stage.

24. A process which comprises subjecting a material containing a volatile ingredient to a current of gas incapable of injuring such volatile ingredient at the highest temperatures employed in any stage of the process, said step being performed at low pressure and at a temperature sufficiently elevated to at least partially vaporize said ingredient, compressing the mixture comprising said vapor and gas, whereby the temperature thereof is raised, effecting an interchange of heat between said so-heated gas-and-vapor mixture, and a cooler expanded gas about to enter the first step, further cooling the said compressed gas-and-vapor mixture, to cause the condensation of at least a material part of the vapor of said volatile ingredient, and removing the condensed ingredient.

25. A process which comprises subjecting a material containing a volatile ingredient to a current of gas incapable of injuring such volatile ingredient at the highest temperatures employed in any stage of the process, said step being performed at low pressure and at a temperature sufficiently elevated to at least partially vaporize said ingredient, compressing the mixture comprising said vapor and gas, whereby the temperature thereof is raised, effecting an interchange of heat between said so-heated gas-and-vapor mixture, and a cooler expanded gas about to enter the first step, further cooling the said compressed gas-and-vapor mixture, to cause the condensation of at least a material part of the vapor of said volatile ingredient, and further heating the gas about to enter the first step of the process, by the hot exhaust fluid of the compressor operating means.

Signed at Washington, D. C., this fifteenth day of February, 1913.

ARTHUR B. FOSTER.

Witnesses:
M. D. WATERS,
HENRY C. FINKEL.