

METHOD, PROCESS AND APPARATUS FOR THE VERY LOW TEMPERATURE EVAPORATION SYSTEM

FIELD OF INVENTION:

The invention relates to the method, process and apparatus for very low temperature
5 evaporation and concentration system to recover the water vapours from any wastewater
solutions or liquids or fluids or industrial effluents or spentwash or industrial wastewater
or juices or syrups or slurry or sludge or brine or sewer or wastewater or other
evaporative materials at very low temperature difference in vacuum with heat exchanger
and mechanical vapour recompression system.

10 BACKGROUND TO THE INVENTION (PRIOR ART):

In recent years, industries are continuously striving to reduce the energy and water
consumption at high temperature. Recovery of clean water vapours from waste liquids or
solutions and utilisation of the waste heat in the process is essential for conservation of
energy and water in any industry. Evaporation of water vapours from solutions or liquids
15 is the major consumer of energy in any plant at high temperature. A huge scope is there if
somehow these water recovery and energy losses can be reduced during evaporation of
the waste solutions or liquids. Evaporation is an operation used to remove water from a
solution, suspension, or emulsion by boiling off the water using heat energy and
concentration of solutions. Evaporation and concentration of liquids are very common
20 processes and equipments in industries for recovery of water vapours and concentration
of the solutions by boiling the solutions using heat energy at high temperature and
pressure.

According to Patent No. US2732008A entitled for process of low temperature
evaporation is a continuous process for the concentrating of juice at relatively low
25 temperatures comprising forcing a supply of juice at about room temperature as a film
over a heating medium for a period of a few seconds wherein the heating medium has a
temperature not greater than about 212° F, discharging the heated juice at a temperature
about 45° higher than its initial temperature into a vapor separator, drawing off released

water vapor in a generally upward direction, drawing off juice concentrated by extraction of water in a generally downwardly direction, recirculating a portion of said concentrated juice into the incoming juice during passage of the incoming juice to the heating medium and tapping off another portion of the concentrated juice when the concentrate reaches a
5 predetermined degree of concentration.

EP0780146, the steam-heated evaporator or thickener is especially suitable for sea water or sugar beet juice. Its plate heat exchangers accept pre-distributed fluid flow from above, which falls as a film on the inner surfaces of vertical channels within, hence being heated in cross- and counter-current flow.

10 Patent No. US 20070151840A1 entitled 'Method and device for treating water' is a multi-effect falling-film evaporator, purified water for special purposes. In each effect, a steam phase and water phase is produced from the feed water. The steam phase is used for heating in the subsequent effect, whereby it condenses to product water, and the water phase becomes the feed stream for the subsequent effect.

15 Patent No. US 699038A entitled 'Multiple Effect' relates "to improvements in multiple effects for the evaporation or concentration of liquids or solutions in which the vapor of each preceding effect is used for the further evaporation in each succeeding effect.

Indian Patent Application No. 2319/DEL/2012 and 2468/DEL/2013 suggests that a heat exchanger assembly and modular evaporator comprising of heat exchange plate packs
20 modules and entrainment separator arranged horizontally and vertically in a novel configuration forming a unique multi effect evaporator. The modular heat exchanger assembly is arranged for expanding heating surface by joining each module or more modules in series or parallel combinations for expanding in the same effect or in series or parallel combinations for additional effects without use of vapour lines.

25 The arrangements described in the prior art, the concentration of liquids suffer from the following disadvantages:

1. Need of boiler for steam generation.

2. Need of cooling tower, condenser and other heat rejection units.
3. Fuel requirement for firing into the boiler for steam generation.
4. Higher energy consumption.
5. Fast scaling of evaporation heating surface due to high temperature operation.
- 5 6. Higher intake water from earth.
7. Higher foot print area requirement.
8. Higher operating and maintenance cost.

The energy and water requirements are reduced by providing the evaporation and concentration at lowest possible temperature differences under the vacuum.

- 10 The present invention obviates the drawbacks of the prior art by providing a novel approach for processing the evaporation at very low temperature difference based on heat exchanger and mechanical vapour recompression technology with minimum electrical energy consumption. This process operates at very low temperature and pressure differences. The low temperature water vapour generated during evaporation and
- 15 concentration of the liquids or solutions by heat exchanger is recompressed by mechanical vapour recompression to raise the temperature of vapours for further utilization into evaporation in a closed loop under vacuum. The present invention is directed to providing a novel and unique process of low temperature evaporation comprising heat exchanger and mechanical vapour recompression are arranged in a
- 20 specific synergistic arrangement, results in a complete process for evaporation and concentration system. Such innovative process eliminates the use of boiler, cooling tower, condenser and other heat energy losses in the process resulting in high energy efficiency, compactness of size, better economy of construction, transportation and operation.

25 **OBJECTS OF THE INVENTION:**

The principal object of the present invention is to provide a novel process of evaporation at low temperature between 5°C to 80°C using heat exchanger or plate packs and mechanical vapour compression system for maximum recovery of water vapour from wastewater liquids or solutions or industrial effluents or spentwash or industrial

wastewater or juices or syrups or slurry or sludge or brine or sewer or wastewater or any other evaporative liquid materials.

Another object of the present invention is to provide a novel concept for concentration of liquids or solutions or syrups or juices or other substances at low temperature using heat exchanger or plate packs and mechanical vapour compression to recover of water vapours from wastewater liquids or solutions or spentwash or industrial effluents or industrial wastewater or juices or syrups or slurry or sludge or brine or sewer or wastewater or any other evaporative liquid materials.

Yet another object of the invention is to provide an energy efficient process for evaporation and concentration at very low temperature for recovery of water vapours from liquids or solutions or industrial effluents or spentwash or industrial wastewater or juices or syrups or slurry or sludge or brine or sewer or wastewater or any other evaporative liquid materials using heat exchanger and mechanical vapour recompression system.

Yet another object of the invention is to provide an energy efficient method, process and apparatus for evaporation and concentration designed for very low temperature operation ranges in a single or multi-effect plate heat exchanger stages for maximum recovery of clean water from waste liquids or solutions or industrial effluents or spentwash or industrial wastewater or juices or syrups or slurry or sludge or brine or sewer or wastewater or any other evaporative liquid materials.

Yet another object of the invention is to provide an energy efficient method, process and apparatus for further evaporation and concentration designed for very low temperature operation using forced circulation evaporator in a single or multi-effect plate heat exchanger stages for maximum recovery of clean water from waste liquids or solutions or industrial effluents or spentwash or industrial wastewater or juices or syrups or slurry or sludge or brine or sewer or wastewater or any other evaporative liquid materials.

Yet another object of the invention is to provide an energy efficient method, process and apparatus for evaporation and concentration designed for very low temperature operation ranges from 5°C to 80°C in a single or multi-effect plate heat exchanger stages arranged in horizontally or vertically or both manners for maximum recovery of clean water from

5 waste liquids or solutions or industrial effluents or spentwash or industrial wastewater or juices or syrups or slurry or sludge or brine or sewer or wastewater or any other evaporative liquid materials

SUMMARY OF THE INVENTION:

The novelty of the invention lies in the concept of method, process and apparatus for

10 evaporation and concentration at very low temperature to recover water vapours from liquids or solutions or industrial effluents or spentwash or industrial wastewater or juices or syrups or slurry or sludge or brine or sewer or wastewater or any other evaporative liquid materials in single or multiple effect plate packs heat exchanger arranged in horizontal or vertical manner with mechanical vapour (re)compression system under

15 vacuum. This novel idea results in to synergistic beneficial effect that has not been disclosed in the prior art. In the present invention, the very low temperature evaporation system designed to operate at any temperature particularly ranges from 5°C to 80°C. This low temperature evaporation system operates at lowest temperature deference for maximum water vapours recovery from liquids or solutions or industrial effluents or

20 industrial wastewater or juices or syrups or slurry or sludge or brine or sewer or wastewater or other liquid materials and concentration of the liquids or solutions. The method, process and apparatus for very low temperature evaporation and concentration system eliminates the utilization of boiler, cooling tower, condenser and other heat rejection units along with other benefits like reduces the water extraction from earth, heat

25 losses, reduction in consumption of steam and fuel.

DETAILED DESCRIPTION OF THE INVENTION:

The present invention lies in the concept of energy efficient method, innovative process and apparatus for evaporation and concentration at very low temperature between 5°C to 80°C to recover water vapours from any type of waste liquids or feed or solutions or

industrial effluents or spentwash or industrial wastewater or juices or syrups or slurry or sludge or brine or sewer or wastewater or RO reject concentration or any other evaporative liquid materials in single or multiple effects plate packs heat exchanger arranged in horizontal or vertical or both manners with mechanical vapour re-

5 compression system under the vacuum.

This specific synergistic approach of low temperature evaporation system or spray electrical dehydrator results into the major benefits which are:

- No need of boiler or steam generation unit and heat reject units
- Minimal electric energy demand
- 10 • Electrical power consumption lower than any alternative technology
- Recovery of energy in the form of Bio-Gas in case of organic wastewater
- Recovery of nutrients in the form of Bio-Fertilizer in case of organic wastewater
- Upto 99 % recovery of water of highest quality from evaporative solution
- Least footprint, closed, compact and environment friendly
- 15 • Fully automatic and eco-friendly

According to Fig. 1 to Fig. 11, a novel approach for the evaporation and concentration of feed using low temperature evaporation technology arranged in horizontal or vertical manner in single or multi effect stages comprises plate packs heat exchanger and mechanical vapour re-compression system. The innovative method, energy efficient

20 process and modern apparatus for low temperature evaporation and concentration system operates at any temperature ranges particularly from 5°C to 80°C. The feed is fed in forward or reverse feed manner into the low temperature evaporator in single or multi effects arranged in horizontal or vertical manner as per process demand under the vacuum. The compressed vapour from mechanical vapour compression or blower or

25 booster or mechanical vapour compression fan or other compression devices (MVR system) is fed to first effect to second effect or each effect through the common vapour header to the each plate packs of each effect of low temperature evaporator for maximum water evaporation. The generated vapours with first effect is passed to second effect, and in similar fashion second to third effect and so on and generated vapours from each effect

is combined and compressed by compression system (MVR technology). The feed is fed from first effect to second, second to third effect and so on i.e. forward feed manner or it can be in reverse feed manner i.e. from last to first effect as per process requirement. The low pressure water vapours of each effect get condensed while evaporating the feed due to plate packs heat exchanger. The concentrate is collected and recycles back to the process again and again for further concentration and then partially continuous or batch type concentrate taken out after maximum concentration. The vapour outlet of each effect is connected with vapour inlet of next effect and so on. The vapour outlet of last effect or each effect is connected to the mechanical vapour compression system for compression or recompression of vapour to increase vapour temperature to reuse in the process continuously in a close loop. Concentrated liquid is withdrawal as residue in the rejection tank from the last effect with or without use of the batch evaporator or force circulation evaporator. For more concentration of concentrate, forced circulation evaporator or batch pan oo both can be used in single or multiple effects arrangements. This residue can be further converted into bio-gas, bio-energy, bio-fertilizer, CNG.

Present invention enables the low temperature evaporation system, evaporation of water vapours from feed operates at any temperature particularly from 5°C to 80°C with minimum electrical demand in a closed loop by utilising the enthalpy of low temperature vapours. This low temperature evaporation maximise the water recovery from any type of feed; reduces inversion, scale & smell formation, colour formation, chemical requirements.

Benefits:

- No need of steam generation unit, heat reject units & chemicals
- Minimal electric energy demand
- Electrical power consumption lower than any alternative technology
- Recovery of energy in the form of Bio-Gas in case of organic wastewater
- Recovery of nutrients in the form of Bio-Fertilizer in case of organic wastewater
- 90 – 99 % recovery of water of highest quality
- Decentralized water recycling solution

- Small footprint, closed, compact and environment friendly
- Automatic system

Suitable for integration with district cooling, heating and recovery of deficit water to make zero fresh water intake and zero liquid discharge for maximum recovery of waste vapour lost in conventional process and use for further application till the lowest possible sink temperature which further provides many other additional advantages.

BRIEF DESCRIPTION OF THE DRAWINGS:

Fig. 1: Front view of vertical low temperature evaporator

Fig. 2: Enlarge front view of vertical low temperature evaporator

10 Fig. 3: Enlarge top view of compression system of low temperature evaporator

Fig. 4: 3D transparent view of vertical low temperature evaporator

Fig. 5: Schematic diagram of vertical low temperature evaporation system

Fig. 6: Isometric view of horizontal single effect low temperature evaporator

Fig. 7: Front view of horizontal single effect low temperature evaporator

15 Fig. 8: Process flow of horizontal multi-effect low temperature evaporator

Fig. 9: Isometric view of horizontal multi-effect low temperature evaporator

Fig. 10: Front view of horizontal multi-effect low temperature evaporator

Fig. 11: 3D view of horizontal multi-effect low temperature evaporator

NUMBERING DETAILS:

- 20 101 – Low Temperature Evaporator or Spray Electrical Dehydrator
- 102 – Plate Pack (Plate Heat Exchanger)
- 103 – Distribution Assembly

- 104 – MVR Suction and Delivery Arrangement
- 105 – MVR Booster or MVR Fan or MVR Blower or other compression or recompression system
- 106 – Bearing Plate
- 5 107 – Demister Pad Assembly
- 108 – Feed Inlet
- 109 – Feed Outlet
- 110 – Feed Tank
- 111 – Feed Pump
- 10 112 – Re-circulation Out
- 113 – Re-circulation In
- 114 – Recirculation Pump
- 115 – Condensate Pump
- 116 – Condensate Outlet
- 15 117 – Condensate Tank
- 118 – NCG Outlet
- 119 – Sight Glass
- 120 – Light Glass
- 121 – Man Hole
- 20 122 – Impeller with Hub
- 123 – Diffuser Vane

- 124 – Dish and Flanges
 - 125 – Dish End
 - 126 – Mechanical Seal
 - 127 – Catcher
 - 5 128 – PHE (Plate Heat Exchanger)
 - 129 – Direct Contact Heater (DCH)/Stripper Column
 - 130 – Batch Evaporator/Force Circulation Evaporator
 - 131 – Rejection Tank
 - 132 – Residue
 - 10 Described below referring to figs. 1 to fig.11 an innovative method, process and apparatus at very low temperature evaporation is used in recycling of wastewater to clean water at lowest temperature comprises plate heat exchanger or plate packs and mechanical vapour re-compression system arranged in horizontal or vertical manners implementing the process, method and apparatus in accordance with the invention.
 - 15 DESCRIPTION OF THE PREFERRED EMBODIMENT
- The installation shown in Fig. 1 to Fig. 11 comprises of a low temperature evaporator (101) comprises plate packs (102) and mechanical vapour recompression (105) made of an outer stainless steel shell mounted upon a bearing plate (106). The evaporation liquids or solutions or feed or industrial effluents or spentwash or industrial wastewater or juices
- 20 or syrups or slurry or sludge or brine or sewer or wastewater or any other evaporative liquid materials in single or multiple effect heat exchanger (102) arranged in horizontal or vertical manner with mechanical vapour compression system (105) under vacuum in which feed is conveyed through the feed inlet (108) by feed pump (111) from feed tank (110) to the plate heat exchanger (128). This hot feed is fed to the direct contact heater
 - 25 (DCH)/stripper column (129) and feed to heat by the compressed non-condensate gas or

compressed vapours or vapours of the evaporation system or feed can be directly send to the distribution assembly (103) depending upon the types of the feed. After maintaining the certain level of feed in the distribution assembly (103), the feed is sprayed on the plate packs (102) of single or multi-effect stages arranged in horizontal or vertical
5 manner with the help of recirculation pump and then evaporation phenomena takes place due to temperature difference in the feed and inlet compressed vapours which is coming from the MVR suction and delivery arrangement (104) after re-compression by MVR fan (105). The concentrated liquid is collected at the bottom of the low temperature evaporator and recirculated and partially transferred to the next effect for further
10 concentration. After the desired concentration the feed is transferred through the recirculation pump to the force circulation evaporator (130) or batch evaporator in single or multi-effects arrangement for further evaporation and concentration. In the forced circulation evaporator, compressed vapours of MVR fan (105) or non-condensate gas or both have been used as a heating media for further evaporation and concentration.
15 Concentrate is collected in the bottom of the forced circulation evaporator (130) in rejection tank (131) as residue (132) and generated water vapours are passed through the demister pad assembly (107) for separation of vapours and liquids. After condensation of water vapours, clean water is collected at the bottom of each plate pack (102) of low temperature evaporator and forced circulation evaporator along with batch evaporator and
20 taken out through the condensate outlet (116) into the condensate tank (117) by condensate pump (115). The feed collected at the bottom of the low temperature evaporator or spray electrical dehydrator (101) is carried out through re-circulation outlet (112) and sent to the distribution assembly (103) placed on top of the plate pack (102) through re-circulation inlet (113) by recirculation pump (114). The distribution assembly
25 (103) which consists of at least two and ideally three distribution plates that create a constant fluid flow into the plate pack (102) below which is essential in the formation of the liquid falling film effect on the surface of the plates. A distribution assembly (103) of demister pad (107) are fitted as a vapour-liquid separator which helps to enhance the removal of liquid droplets entrained in the vapour stream. Condensate outlet (116) and
30 NCG outlet (118) are used to continuously remove the condensate and other non-condensable gases through the catcher (127) from the low temperature evaporator (101).

A sight glass (119), a light glass (120) and a manhole (121) are fitted for the easy monitoring and maintenance of the low temperature evaporator (101). The installation of Fig. 3 which depicts the MVR arrangement (104) with MVR (105) comprises of an impeller (122) mounted with a hub whose purpose of this is to minimize leakage from the discharge side of the pump casing to the suction side. The diffuser vane (123) is attached next to the impeller hub to increase the efficiency of the impeller (122) by allowing a more gradual expansion and less turbulent area. The MVR arrangement (104) is mounted on the dished ends (125) with flanged dish (124) and dish ends (125), with a mechanical seal (126) that helps join systems or mechanisms together by preventing leakage and containing pressure attached with the extended shaft of the motor mounted on top of the evaporator, fused with the shell of the low temperature evaporator (101) to avoid any external piping or structure, with opening for water in/out for the cooling of the motor and MVR arrangement (104).

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CLAIMS

1. A very low temperature evaporation system that acts as single or multi effect multistage heat exchanger comprises:

5 - one or more plate heat exchanger modules configured with one or more distribution assemblies and one or more entrainment separator or demister pad assembly, arranged in horizontal or vertical configurations to increase the heating surface area and capacity of evaporation system;

10 - one or more mechanical vapour compression or mechanical vapour recompression systems for compression and recompression of vapour and non-condensate gas;

- one or more plate heat exchangers;

- one or more direct contact heaters or strippers;

- one or more forced circulation evaporators;

-one or more recirculation pump and condensate pumps;

15 WHEREIN the plate heat exchanger module comprises one or more plate pack heat exchangers connected to low temperature evaporator through the stripper or direct contact heater; and

20 successive evaporation and concentration configured to be carried out between 5°C to 80°C under the vacuum by using compressed vapours as feed in the distribution level of the plate pack heat exchanger module with the help of recirculation pump and condensate pumps for maximum recovery of clean water from any type of effluents or wastewater.

2. The very low temperature evaporation system as claimed in claim 1, WHEREIN compressed or recompressed vapour used for evaporation of feed and recirculation pump is used for recirculation of feed in the distribution level of the plate packs heat exchanger arranged in low temperature evaporation system without use of external heat source.

3. The very low temperature evaporation system as claimed in claim 1 to 2, WHEREIN comprises the process of feed flow from the plate heat exchanger (PHE) to low temperature evaporator through the stripper or direct contact heater in single or multi effect multi stage operation arranged in horizontally or vertically for better evaporation and concentration.

4. The very low temperature evaporation system as claimed in claim 1 to 3, WHEREIN the feed sprayed over the plate pack of first effect after maintaining at the distribution level, and concentrate and condensate liquid is collected separately at the bottom of the plate pack and further the concentrated liquid is again pumped, with the help of recirculation pump,
5 over plate packs of first effect for progressive concentration of feed and partly concentrate liquid is transferred to the next effect for further concentration.
5. The very low temperature evaporation system as claimed in claim 1 to 4, WHEREIN the feed of the last effect is transferred to the forced circulation evaporator for further
10 evaporation and concentration using compressed vapour or compressed non-condensate gases, which makes the process highly energy efficient.
6. The very low temperature evaporation system as claimed in claim 1 to 5, WHEREIN the vapour and non condensate gases (NCG) compressed by mechanical vapour compression
15 or recompression fan or blower or booster or other compression or recompression devices to increase the temperature of the vapour or non-condensate gases for usage in the process of evaporation and concentration.
7. The very low temperature evaporation system as claimed in claim 1 to 6, WHEREIN the
20 evaporation system used for the separation of solid parts and liquid parts from any type of effluents or wastewater for maximum recovery of the clean water from any type of effluents or wastewater.
8. The very low temperature evaporation system as claimed in claim 1 to 7, WHEREIN the
25 evaporation system operated using minimum electric energy demand with lowest operational and maintenance cost.
9. The very low temperature evaporation system as claimed in claim 1 to 8, WHEREIN the
30 evaporation system used for the evaporation and concentration of any type of industrial and domestic wastewater treatment and maximum recovery of clean water from wastewater.