Title: IMPROVED DISTRIBUTOR FOR FALLING FILM EVAPORATOR

Abstract: A distributor for falling film evaporator comprising of: a cylindrical body, upper inlet chamber, means to allow tangential entry into said upper inlet chamber, means for imparting swirl to the feed material, an outlet chamber and a single axial outlet wherein, the said distributor imparts swirl to the feed material with minimal energy loss by utilizing natural fluid flow tendencies.
FR, GB, GR, HU, IE, IS, IT, LT, LU, LV, MC, MT, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— with international search report
— with amended claims and statement

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IMPROVED DISTRIBUTOR FOR FALLING FILM EVAPORATOR

FIELD OF INVENTION:

The present invention relates to the field of mechanical engineering. More specifically it relates to processing machinery. In particular, it pertains to shell and tube heat exchangers of vertical type for falling film evaporators used for concentration of sugar syrup or the like.

BACKGROUND AND PRIOR ART TO THE INVENTION:

Definition of important terms:

1. **Calandria**: Equipment consisting of closely spaced metal tubes for heat exchange.

2. **Reynolds Number**: It is defined as the ratio of inertia force of a flowing fluid and the viscous force of the fluid. If the Reynolds number is less than 2000, the flow is called laminar. If the Reynolds number is more than 4000, it is called turbulent flow. If the Reynolds number lies between 2000 and 4000, the flow may be laminar or turbulent.

3. **Coefficient of Discharge**: The ratio of actual discharge through an orifice to the theoretical discharge.

In the sugar industry, concentration of sugar syrup is a fundamental step. It is the step requiring lot of energy inputs and also machinery and equipment designing, for optimum performance. Evaporators play a key role in reducing the water content of sugar syrup and concentrating it. Several types of evaporators are used for the purpose. All share a common goal- to achieve maximum evaporation with minimum expenses on energy. Out of the various designs which have evolved in pursuance of this goal, falling film evaporators is a preferred category. Reasons for the same are as follows:

1. Higher operating efficiency: It operates at low temperature difference between the heating medium (steam) and the heated medium (juice/syrup), due to
a) no effect of hydrostatic head; and
b) inherently higher heat transfer coefficient of Falling Film Evaporators, resulting in lower steam consumption. The fact that falling film evaporators operate at lower temperature differences makes it possible to use them in multiple effect configurations systems in modern plants with very low energy consumption.

2. More suitable for thicker fluids: The energy requirements to process thicker fluids are lower in falling film evaporators as compared to rising film or calandria type evaporators.

3. Suitable for heat-sensitive products: Since the contact time with heating surface, of the product being processed is very less, the falling film evaporator is a preferred option for heat sensitive products.

Falling Film evaporators typically include a heat exchanger chamber disposed between upper distribution chamber and a vapour separation chamber. The heat exchanger chamber has plurality of heat exchange tubes positioned therein which vertically extend between an upper tube sheet and a lower tube sheet. Evaporation occurs on the inner surfaces of tubes as the feed material falls as a film on their inner surfaces. The tubes may also be referred to as calandria. Feed material to be treated enters the upper distribution chamber through a feed inlet associated therewith and is directed downwardly through the heat exchange tubes in the form of a vertical falling film in a manner ensuring that the tubes receive approximately equal flows.

In falling film evaporators two factors are critical for evaporator efficiency viz.
   a) uniform distribution of the feed liquid
   b) even product wetting of the tubes
This is achieved by use of specially designed distribution devices whose proper functioning is decisive to the operational safety of the evaporator. The feed material to be concentrated enters the evaporator tubes, through the distributors, which occupy an ‘entry’ level position at the top of the tubes. Hence, any change
in their design considerably influences heat exchange characteristics and ultimately economy of the process.

It is known that if the feed film is thick the available heat transferred to and through the film may be insufficient to heat the film to evaporate the components, where as if the film is too thin, too much heat is transferred which could result in burning, charring, or the like of the feed material or its components which in turn can lead to incrustation either clogging or blocking of the tube or creating a hot spot. The same defect also applies to uneven thickness of film.

Patents Nos.GB 1037047, GB1206643, US3849232, DE3916235, EP0356537, GB1302623, GB1190794, DE3904357, describe various improvements relating to distributors. In these patents, only axial flow of the feed inside the evaporator tubes has been described and no mention has been made of swirling motion.

It has been found that imparting of swirling motion to the liquid under processing, results in significant advantages viz.

a. Uniform distribution of the liquid over the entire surface of the evaporator tubes,

b. Even thin feed film wetting of the evaporator tubes,

c. Swirling promotes clean in place techniques for cleaning the evaporator tubes,

d. Length of the evaporator tubes can also be reduced.

Various falling film evaporators equipped with distributing means or devices which impart swirling motion to the liquid under processing have been described in prior art (Patent Nos. US2545028 and US6958107 and Patent Application Number US2005042042). The efficiency of such evaporators can be enhanced by modifying the means or devices used for swirling the feed for uniform distribution and formation of a uniform thin layer wetting the inner walls of the evaporator tubes.
Patent Nos. US2545028, US6958107 and Patent Application Number US2005042042 disclose means or devices used to impart swirl to the feed and improve the feed distribution for uniformity of the film coverage on the internal walls of the evaporator tubes.

However, the devices used in the prior art to swirl the feed do not utilize the natural flow characteristics of the fluids. As a result they are plagued with energy losses. Also such devices are more prone to scaling and clogging and are not suitable for feed material which has higher content of salts, both dissolved and non-dissolved, and suspended particles such as sugar solutions.

The present invention has been able to overcome the drawbacks associated with distributing means or devices for falling film evaporators in a simple but novel manner utilizing the natural flow characteristics of the fluids. This has been achieved by modifying the distributor device in a manner so that the liquid entering the tubes is made to swirl in a specific manner resulting in uniform distribution and formation of a uniform thin layer wetting the inner walls of the evaporator tubes. Apart from benefits of energy saving, another distinct advantages also results due to this simple but effective innovation viz. use of feed material with higher content of dissolved solids and suspended particulate matter becomes possible. This is because the areas prone to scaling and clogging leading to evaporator malfunctioning are totally avoided.

A search of Indian patent databases reveals that no patent as for the present invention has been described in the prior art.

OBJECT OF THE INVENTION:

The principal object of the present invention is to provide an improved distributor device for falling film evaporators which is energy efficient, cost effective, and has features which permit quick and easy maintenance. Another object of the
present invention is to provide a distribution device which is suitable for feed material which has higher content of dissolved solids and suspended particles.

SUMMARY OF INVENTION:

The present invention discloses an improved distributor for falling film evaporator in which the energy losses have been considerably reduced by substantially utilizing the natural flow characteristics of the feed material in a manner such that a natural vortex formation, which has both the axial and tangential components of flow, is imparted in an unhindered manner to the feed material. This has been made possible by use of a novel distribution device over each evaporator tube modified in a manner to whose single axial outlet is a hole with a circular cross section, concentric with the outer diameter of the distribution device. Another innovative feature of the invention is the use of thermoplastic material instead of metal in the construction of the distribution device, which has not been described in the prior art. The use of thermoplastic material results in several technical advantages viz. easy manufacture, reduced friction and weight, lower costs and easy maintenance. Further the distribution device is also suitable for feed material having high content of dissolved solids and suspended particulate matter.

STATEMENT OF INVENTION:

Accordingly the present invention provides an improved distributor for a falling film evaporator comprising a cylindrical body, upper inlet chamber, means to allow tangential entry into the said upper inlet chamber, means for imparting swirl to feed material, an outlet chamber, and a single axial outlet, wherein the said distributor imparts swirl to the feed material with minimal energy losses by utilizing natural fluid flow tendencies.
BRIEF DESCRIPTION OF THE DRAWINGS:

FIG.1: Isometric view of one form of the liquid distribution device for falling film evaporator of the present invention.

FIG.2: Side Elevation view of the liquid distribution device of Fig.1.

FIG.3: Longitudinal section of the liquid distribution device of Fig.1 taken along line A-A of Fig.2.

FIG.4: Cross sectional view of liquid distribution device of Fig.1 taken along line B-B of Fig.2.

FIG.5: Longitudinal section of an evaporator tube of a falling film evaporator showing liquid distribution device of the present invention.

DETAILED DESCRIPTION OF THE INVENTION WITH REFERENCE TO THE DRAWINGS:

It has been observed in the prior art that distributors play a vital role in falling film evaporators by providing uniform distribution and thin film formation of feed material on the inner surface of the into the tubes.

Fig.1 refers to the distribution device (1) of the present invention. The distribution device (1) has a cylindrical body (2), the lower portion (3) of which is of lesser diameter. It has a removable cap (4). A single inlet (5) for the feed material is provided tangentially in the side wall (6) of distributor device (1) and a single outlet (7) for the feed material is arranged axially. The lower portion (3) of the cylindrical body (2) extends below the level of the outlet (7).

Fig.2 is the side elevation view of the distribution device (1) of the present invention clearly showing its cylindrical shaped body (2), the lower portion (3) of which is of lesser diameter, tangential inlet (5) in the side wall (6) and a removable cap (4).

Fig.3. shows the longitudinal section of the distributor device (1) of the present invention. It comprises of an upper inlet chamber (8) and lower outlet chamber
(9). The upper and lower chambers are co-axial. Upper inlet chamber (8) is adapted for swirling the feed material. The removable cap (4) is provided with a threaded cavity (10) to facilitate easy cleaning and maintenance. The lower outlet chamber (9) has a flow-through channel converging in the flow direction with a cylindrical outlet (7). The outlet chamber (9) ends at some distance before the lower level of the cylindrical body (2).

Fig.4. shows cross-section of the upper inlet chamber (8) of the distributor device (1) of the invention. The inlet chamber (8), having a tangential inlet (5), has a volute profile (11) comprising of a volute casing and a volute chamber, i.e. the flow path has a spiral form with a successively reducing cross-section.

Fig.5. refers to a distributor device (1) of the present invention mounted on a distributor plate (12) arranged at the top portion of a falling film evaporator. Each evaporator tube (13) is provided with its own distributor device (1). The lower portion (3) of the body (2) of the distribution device (1), which is of lesser diameter, affords adequate fixation into the distributor plate (12) and adjustment over evaporator tubes (13) fixed on the tube sheet (14).

Salient features of the invention are that the inefficiencies due to energy losses, malfunctioning due to scaling and clogging rampant in prior art distribution devices adapted to swirl the feed material have been considerably reduced.

Accordingly, the present invention provides a distributor device (1) in which the energy losses due to redirection, transformation and friction are reduced. This is brought about as follows:

The said distribution device (1) fixed on a distributor plate (12) is provided over each evaporator tube (13). It may also be fixed by inserting directly into the evaporator tube without the use of distributor plate. It conforms in its greater part to the natural fluid flow tendencies and assists the feed flow to cause swirling motion about the axis of the feed flow without additional energy inputs and in a completely unhindered manner. The feed enters the upper inlet chamber (8) of the said device (1) tangentially through a single inlet (5). The inlet may be
rectangular, round or of any other desirable shape. The inlet chamber (8) of the present distributor device (1) is adapted to swirl the feed material about its longitudinal axis by making it volute profile (11) and comprises of a volute casing and a volute chamber i.e. spirally curved with reducing cross-section.

The device of the present invention (1) is provided with a single axial outlet (7). The outlet chamber (9) of the device (1) may be cylindrical, preferably conical, more preferably multi-conical or most preferably bell-shaped. The volute profile of the inlet chamber along with the bell-shaped outlet chamber ensure transformation of potential energy of pressure into kinetic energy of feed flow with minimal energy losses to form a rotating hollow conical output of the feed material. To enhance the consistency of flow characteristics for a longer duration in case of conical, multi-conical and bell-shaped outlet chamber, the outlet is provided with a cylindrical portion (15) of up to 20% of the total length of the outlet chamber (9). The edge (16) of the outlet (7) is also chamfered at a critical angle.

The reducing area of the flow path in the flow direction of the feed material causes the increase in the velocity of the feed. Also the angular momentum of the swirling feed is conserved. The increase in angular velocity due to novel design of the distribution device produces centrifugal force and the feed issues from the outlet (7) of, the distributor device as a rotating hollow conical thin film distributing itself equally over the entire surface of the evaporator tube. The head is regulated to ensure that the feed material issuing from the outlet (7) as a rotating hollow conical thin film is never atomized or broken into droplets. The tangential component of the emerging feed material film enables it to adhere to the walls of the evaporator tubes (13).

In the present invention no additional means are required to assist the swirling feed material to form uniform thin film on the evaporator tube walls such as described in Patent No. US2545028 and Patent Application No. US2005042042. Grooves, conduits or the like, small slits or annular clearances used in the prior art distributors to form a uniform thin layer over the inner surface of evaporator tubes.
make them more prone to clogging in their application to feed material having high content of dissolved solids and suspended particles like sugar solutions in which the presence of bagasse particles cannot be ruled out completely. Also small amount of scaling in the grooves, conduits or the like, slit or clearance region in prior art distributors makes them malfunction repeatedly, thereby increasing the frequency of cleaning. Such grooves, conduits or the like, small slits or clearances are totally avoided in the present invention making the distributor device particularly suitable for feed material having higher content of dissolved solids and suspended particulate matter like sugar solutions.

Further the coefficient of discharge of the distribution device (1) of the present invention having a single outlet is lower as compared to that of tangential or helical outlets described in the prior art. As a result, to achieve the desired flow rate for required wetting of the evaporator tubes in similar operating conditions, the outlet size of the distribution device in the present invention has to be of greater diameter in comparison to tangential or helical outlets described in the prior art. This makes the device of the present invention particularly suitable for feed material having higher content of dissolved solids and suspended particulate matter.

Another feature of the present invention is that the redirection of the feed material is achieved without any significant energy loss since it takes place in the stage of low velocity. The feed material being processed is also supplied at pressure and velocity to ensure that the feed material issues from the outlet as a rotating hollow conical thin film.

In contrast, as described in Patent Application No. US2005042042, first whole of the axial component of feed material is converted into tangential component by passing through tangential conduits in the sidewall. Thereafter spurts of feed material emerging from the tangential outlets at an increased velocity stage are again redirected to form thin a film, adding to energy losses. In other cases the
axial and tangential components are imparted to the feed material at a stage of high velocity resulting in energy losses or increased energy inputs.

Such sudden and repeated redirection or redirection at a stage of high velocity of feed material is totally avoided in the distribution device of the present invention making it further energy efficient. The feed material is imparted a swirling motion at a stage of low velocity resulting in formation of a vortex, which has both the axial as well as tangential components, with minimal energy losses by utilizing the natural fluid flow tendencies. There is no sudden or repeated redirection of the feed material resulting in energy saving.

The experiments were conducted on a distributor device having 6 mm X 10 mm inlet and 7.89 mm internal diameter. It was fitted on a 32 mm internal diameter evaporator tube. It was observed that the emerging feed retained its film characteristics in the range of 1m to 6m head. The coefficient of discharge varied from 0.18 to 0.21. The cone angle varied from 75 deg. to 89 deg. Best results were obtained with 3 m head when the cone angle was 89 deg. and coefficient of discharge was 0.2.

The distributor (1) of the present invention while avoiding or reducing the energy losses associated with the prior art further has another innovative feature which result in several technical advantages viz. reducing the frictional losses, manufacturing cost and time and also reducing weight of the distributor as compared to conventional distributor devices facilitating quick and easy maintenance. Unlike conventional devices which are made of cast iron or stainless steel, the device in the present invention is made of engineering thermoplastics, resulting in reduced friction losses and lesser tendency to scale.

The cost and time to manufacture the distribution device (1) of the present invention is also much less.
Moreover, the efforts required to maintain consistency in dimensional accuracy in the manufacture of the distribution device (1) of the present invention are less as compared to that of prior art distribution devices.

The overall weight of the distributor comprising of distributor plate (12) and distribution device (1) of the present invention is also reduced considerably. The much reduced cost and weight enable easy and quick replacement of the distributor with another one either for cleaning or treating another type of feed material.

Due to overall reduction in energy losses, lesser energy in the form of pumping requirements is required to maintain the desired flow rate of the feed material. Also by completely eliminating regions prone to clogging and reducing malfunctioning of the evaporator due to scaling, the distribution device of the present invention makes itself particularly suitable for feed material having higher content of dissolved solids and suspended particles. The frequency of cleaning is also decreased. All these factors result in substantial cost, time and energy savings.

Although the invention has been described with reference to specific embodiments, this description is not meant to be construed in a limiting sense. Various modifications of the disclosed embodiments, as well as alternate embodiments of the invention, will become apparent to persons skilled in the art upon reference to the description of the invention. It is therefore contemplated that such modifications can be made without departing from the spirit and scope of the present invention as described.
CLAIMS:

1. A distributor for falling film evaporator, comprising of:
   a cylindrical body,
   upper inlet chamber,
   means to allow tangential entry into the said upper inlet chamber,
   means for imparting swirl to feed material,
   an outlet chamber, and
   a single axial outlet,

wherein the said distributor imparts swirl to the feed material with minimal energy losses by utilizing natural fluid flow tendencies.

2. A distributor as in claim 1 wherein the said distributor has a low coefficient of discharge in the range of 0.17 to 0.22 necessitating large diameter outlet.

3. A distributor as in claim 1 wherein the single axial outlet is a hole with a circular cross-section concentric with the outer diameter of the distributor.

4. A distributor as in claim 1 wherein the upper inlet chamber has a substantially volute profile comprising of a volute casing and a volute chamber.

5. A distributor as in claim 1 wherein the outlet chamber is cylindrical, preferably conical, more preferably multi-conical and most preferably bell-shaped.

6. A distributor as in claim 5 wherein the outlet is provided with a cylindrical portion of upto 20% of the total length of the outlet chamber.

7. A distributor as in claim 5 wherein the outlet chamber ends at some distance before the lower level of the cylindrical body.
8. A distributor as claimed in claim 1 wherein the edge of the single axial outlet is chamfered at a critical angle.

9. A distributor as in claim 1 wherein the lower portion of the cylindrical body has lesser diameter than upper portion.

10. A distributor as in claim 1 wherein the cylindrical body is fitted with a removable cap.

11. A distributor as in claim 10 wherein the removable cap is provided with a threaded cavity.

12. A distributor as in claim 1 wherein the head is regulated to ensure that the feed material issues from the outlet as a rotating hollow conical thin film.

13. A distributor substantially as herein described in the specification with reference to the accompanying drawings.
1. A distributor for falling film evaporator, comprising of:
   5 a cylindrical body,
   upper inlet chamber,
   means to allow tangential entry into the said upper inlet chamber,
   means for imparting swirl to feed material,
   an outlet chamber, and
   10 a single axial outlet,

   characterized by the fact that the upper inlet chamber has a substantially volute profile comprising of a volute casing and a volute chamber.

2. The distributor as in claim 1 wherein the said distributor has a low coefficient of discharge in the range of 0.17 to 0.22 necessitating large diameter outlet.

3. The distributor as in claim 1 wherein the outlet chamber ends at some distance before the water level of the cylindrical body.

4. The distributor as claimed in claim 1 wherein the edge of the single axial outlet is chamfered at a critical angle.

5. The distributor substantially as herein described in the specification with reference to the accompanying drawings.
STATEMENT UNDER ARTICLE 19 (1)

Amendment has been made in view of observation made by ISA/AU in Box No. V and VIII of its WO.

Amendment:
Pending claims 1 to 13 have been replaced by amended claims 1 to 5.

Explanation:
It has been pointed out by the learned examiner that claims 2, 4, 7, 8, 12 & 13 as submitted meet the novelty criteria. Accordingly, claims have been redrafted to retain only the claims which clearly define the novel aspects of the invention in concrete terms as indicated. This has been done by replacing the entire text of the original claims with new ones which are annexed separately with the response. The novel features of the distributor while minimizing the energy losses / requirements, have enabled the use of feed material with higher content of dissolved solids and suspended particulate matter because the areas prone to scaling and clogging, leading to malfunctioning of the evaporator frequently encountered in the prior art distributors (including the documents cited in the ISR), have been totally avoided.

To remove any doubts with respect to clarity of claim 12, the same is omitted.

Effect of Amendment:
With this explanation and amendment, the novelty & industrial applicability aspects of the present invention have been duly highlighted and also introduced in the claims. It now appears that the same qualify the criterion of novelty and industrial applicability.
INTERNATIONAL SEARCH REPORT

International application No.
PCMN2007/000296

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl.

BOID 1/06 (2006.01)  BOID 1/30 (2006.01)  F28D 3/04 (2006.01)
BOID 1/22 (2006.01)  C13G 1/04 (2006.01)  F28D 5/02 (2006.01)

According to International Patent Classification (IPC) or to both national classification and IPC

B. MINIMUM DOCUMENTATION SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Documented searched other than minimum included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

DWPI: IPC Marks- BOID 1/06, BOID 1/22, BOID 1/30, C13G 1/IC, F28D 3/04, F28D 5/02, F28F 1/00 With Key Words- FEED, DISTRIBUTE ADAPTOR+, ADAPTER+, SPIRAL+, TANGENT+, SWIRL+, ROTAT+, CIRCULAR, HELICAL, CYCLON+, AXIAL

GOOGLE PATENTS: Key Word Search

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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<th>Category*</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
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<tr>
<td>X</td>
<td>US 2545028 A (G. W. HALDEMAN) 13 March 1951 See abstract, figs. 1, 2, 4</td>
<td>1-12</td>
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<tr>
<td></td>
<td>US 340671 6 A (C. J. CORNILS ET AL.) 22 October 1968 See column 4 lines 26-47, figs 1-4</td>
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<tr>
<td>A</td>
<td>WO 2005/007297 A1 (MANGO MARTINI PTY LTD) 27 January 2005 See abstract, figs 1-6</td>
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☐ Further documents are listed in the continuation of Box C  ☒ See patent family annex

* Special categories of cited documents.
  *A* document defining the general state of the art which is not considered to be of particular relevance
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Y document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
K document member of the same patent family

Date of the actual completion of the international search
26 October 2007

Date of mailing of the international search report
30 OCT 2007

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Form PCT/ISA/2 10 (second sheet) (April 2007)
This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

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Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.

END OF ANNEX