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(54) Title: IMPROVEMENTS TO EQUIPMENT OF UREA PLANTS

(57) Abstract: A urea stripper or evaporator provided with fittings in the bottom liquid holder to reduce gas carryover wherein said fittings may include one or more of: perforated screens horizontally arranged or vertically in the bottom liquid holder; a sealed chamber arranged in the liquid holder to reduce the liquid collection volume in the liquid holder; a plurality of blades and/or vertical plates projecting from the inner surface of a bottom domed end of the apparatus to reduce speed of the liquid flow.

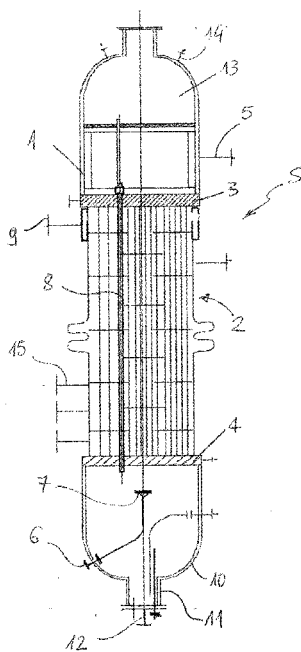


FIG. 1



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Improvements to equipment of urea plants

DESCRIPTION

Field of application

- 5 The invention relates to improvements of certain equipment of a urea production plant. Particularly the invention relates to an improved design applicable to urea strippers and evaporators.

Prior art

10 Urea is produced industrially by reacting ammonia and carbon dioxide under suitable urea-forming conditions, which typically include a high pressure of 100 to 200 bar and a high temperature around 200 °C. An overview of the industrial processes for the synthesis of urea can be found in Meessen, "Urea", Ullmann's Encyclopedia of Industrial Chemistry, Wiley-VCH Verlag, 2010.

15 The reaction mixture that can be obtained from a synthesis reactor is an aqueous solution including urea and a significant amount of unconverted reagents, typically in the form of ammonium carbamate. In a urea stripping process, the reaction mixture is processed in a urea stripper wherein ammonium carbamate contained in the mixture is thermally decomposed to obtain a purified urea solution and a gaseous stream including ammonia and
20 carbon dioxide removed from the mixture.

The purified urea solution still contains some carbamate and is normally sent to one or more recovery sections operating at a lower pressure to further decompose and remove the ammonium carbamate; the ammonia and carbon dioxide emerging from the stripper are normally condensed and recycled to
25 the reactor.

The stripping process may be performed with the help of a stripping medium.

The known CO₂ stripping process uses gaseous CO₂ as a stripping medium. In the alternative ammonia-stripping process, the reaction mixture contains excess of ammonia so that ammonia can act as a stripping aid.

5 The urea stripper is normally a vertical shell-and-tube apparatus wherein the reaction mixture flows downwards inside the tubes of a tube bundle, usually in a falling-film regime. The tube bundle is heated by hot steam traversing the shell side to provide the heat for decomposition of carbamate. The stripping medium, if used, is generally fed counter-current to the solution.

10 The urea solution effluent from the tubes, i.e. after the stripping process, is collected in the lower part of the stripper. Particularly, the known strippers have a bottom liquid holder wherein the purified urea solution is collected. The bottom liquid holder is directly in communication with a liquid outlet port of the stripper. The ammonia and CO₂ vapours on the other hand are generally withdrawn from top of the stripper.

15 The bottom holder is usually equipped with a vortex breaker to avoid the formation of a vortex in proximity of the outlet nozzle.

The applicant has noted that urea strippers suffer from a problem of gas carry-over. This term denotes the undesired occurrence that some process gas contained in the stripper (predominantly ammonia and/or carbon dioxide) is carried by the liquid effluent. It is desirable to maintain a good separation between the liquid phase and the gaseous phase to avoid said gas carry-over. However the applicant has noted the bottom part of the stripper, wherein the processed liquid is collected and directed towards the liquid outlet, is particularly exposed to the risk of gas carryover.

25 The applicant has further noted that gas carryover may occur in the evaporators of urea plants. An evaporator is provided to remove water from the aqueous solution produced in a recovery section. Said aqueous solution contains urea, water and unavoidable impurities. By removing water, the

solution is converted into a more concentrated solution or a urea melt, for example a urea melts suitable for a finishing process like prilling or granulation. The urea melt may have a concentration greater than 96 wt% of urea or greater than 98 wt% or greater than 99 wt% according to the use. For a prilling process
5 a purity greater than 99.5 wt% may be required. The applicant has noted that the concentrated solution or urea melt may entrain some process gas, predominantly ammonia and carbon dioxide or inert gas.

Summary of the invention

The invention addresses the technical problem of how to avoid or reduce the
10 drawback of gas carryover in a urea stripper or urea evaporator, as above disclosed. Accordingly the invention aims to increase the separation between the liquid effluent and process gas contained in the stripper or evaporator. This separation is also termed phase disengagement. Accordingly the patent aims to improve the phase disengagement at the liquid outlet of the stripper or of
15 the evaporator.

The applicant has realized that a common feature of urea strippers and evaporators is that the volume of the liquid holder (hold up volume) is comparatively small to reduce the residence time of the liquid (typically around 5 to 20 seconds) and related problems of formation of undesired by-products
20 such as biuret. This is particularly true for large items designed for a large capacity, wherein the size of the main pressure vessel is comparatively larger. As a consequence the liquid flow entering the holder has a high velocity and momentum which may promote the carry-over of process gas, typically of ammonia, carbon dioxide and inert gases. The idea underlying the invention is
25 to provide the bottom of the apparatus, particularly the liquid holder, with fittings adapted to oppose this effect.

In accordance with the above, the invention may include at least one of the following:

- a) one or more perforated screens horizontally arranged in the bottom liquid holder;
 - b) one or more perforated screens vertically arranged in the bottom liquid holder;
 - 5 c) a sealed chamber arranged in the liquid holder to reduce the volume of an internal chamber of the liquid holder wherein the urea solution or melt can be collected;
 - d) a plurality of blades and/or vertical plates projecting from the inner surface of a bottom domed end connected to the liquid holder.
- 10 The above items represent fittings adapted to reduce the velocity of the liquid stream inside the bottom liquid holder and to limit the undesired formation of liquid-gas recirculation. More precisely the above items can break the liquid flow and reduce its velocity and momentum in the lower part of the apparatus and particularly at the liquid outlet. The applicant has found that breaking the
- 15 liquid flow and reducing its velocity and momentum can greatly reduce the undesired gas carryover.

Further aspects of the invention are a urea plant including the inventive urea stripper and/or the inventive evaporator, and a method for revamping such items. Particularly the various embodiments of the invention can be applied to

20 the provision of a new stripper or evaporator as well as to the modification of an existing stripper or of an existing evaporator.

The stripper is normally included in a high-pressure synthesis loop including a reactor and a condenser and optionally a scrubber.

The modification of an existing item is an interesting embodiment of the

25 invention. A relatively inexpensive modification of the lower part of the apparatus may give a significant improvement in terms of performance. For example referring to the modification of a stripper, the invention gives a better

separation of phases thus improving the recycle of the gaseous phase to the condenser and the operation of the recovery section downstream, where the liquid effluent of the stripper is processed.

Description of the invention

5 The above options a) to d) are now elucidated in a greater detail.

The option a) may include a plurality of perforated screens arranged at different elevation in the bottom liquid holder. The plurality of perforated screens may include disc-shaped screens and/or ring-shaped screens. Said screens may be stacked one above the other.

10 In an embodiment each of the perforated screens has a surface area substantially equal to the cross section of the liquid holder.

In an interesting embodiment, the plurality of perforated screens includes screens with a surface area smaller than the cross section of the liquid holder and the screens are arranged to cover different portions of the cross section.

15 Particularly, at least two consecutive screens may be staggered or offset to provide a sort of labyrinth path for the liquid stream flowing into the liquid holder.

In another interesting embodiment the option a) includes a horizontal screen proximal to a liquid outlet duct of the liquid holder. Said horizontal screen has preferably an unperforated central region adapted to act as a vortex breaker and a perforate annular region around said central region. Said screen may be spaced apart from the outlet duct by suitable supports so that the liquid flows into the outlet duct through passages between the supports. The supports may be substantially shaped like blades.

25 In an interesting embodiment, one or more perforated screen may be integral with a vortex breaker installed in the liquid holder. A vortex breaker is usually provided in the bottom liquid holder of a stripper.

The option b) may include a perforated cylindrical wall placed in the bottom liquid holder, so that the inside of the bottom liquid holder is divided into an annular chamber around said wall and a central chamber inside said wall. Said chambers are communication through the perforations of said wall and only
5 the central chamber is in communication with the liquid outlet. The liquid stream (e.g. aqueous solution from a stripper) is collected predominantly in the annular chamber; from here it passes into the central chamber through the perforated wall and eventually into the liquid outlet.

In a further embodiment the option b) includes a vertically arranged perforated
10 cylindrical wall extending downward from an unperforated horizontal screen. Said vertically arranged perforated wall may be realized with the known technique of Johnson screens or equivalent. In some embodiments it can be a slotted wall with a number of slots providing a suitable passage area.

According to yet another embodiment the option c) includes a closed
15 cylindrical chamber placed in the bottom liquid holder, so that the only region of the bottom liquid holder where liquid can be collected is an annular region around said sealed chamber. Said closed chamber may be delimited by a section of tube fitted in the liquid holder.

Said closed chamber reduced the volume available to the liquid in the bottom
20 holder, so that for a given amount (flowrate) of liquid a higher level will form in the holder. A higher liquid level improves the phase disengagement.

The option d) may include a plurality of blades of a suitable shape and/or vertical plates projecting from the inner surface of a bottom domed end of the apparatus.

25 Said option d) is particularly interesting for a stripper. In operation, the solution effluent from the tubes flows over the inner surface of the domed end towards the bottom liquid holder. The provision of a suitable number of blades or vertical plates reduces the velocity and momentum of the liquid flow travelling

towards the bottom holder.

The invention is applicable to all kinds of urea strippers. The urea stripper may be adapted to operate according to any of: the self-stripping process, the ammonia-stripping process, the CO₂ stripping process. A stripper for the CO₂ stripping process includes a CO₂ inlet and a CO₂ distributor in the lower part. The CO₂ distributor is adapted to provide an uprising flow of gaseous CO₂ in the tubes of the tube bundle, counter-current relative to the falling film of liquid.

The urea stripper is generally part of a high-pressure synthesis section or high-pressure synthesis loop. Said loop may include, in addition to the stripper, a urea synthesis reactor and a high-pressure condenser. The high-pressure condenser typically receives the gaseous stream from the stripper and a recycle carbamate solution from a recovery section. The loop may also include a high-pressure scrubber when vapours and inert gas withdrawn from top of the reactor are scrubbed with a carbamate solution.

The evaporator to which the invention is applied may be part of an evaporation section comprising more than one evaporator.

A further aspect of the invention is a method for revamping a stripper or an evaporator of a urea plant according to the claims.

A particularly interesting embodiment provides the modification or replacement of the vortex breaker. A urea stripper is normally equipped with a vortex breaker which includes unperforated screen positioned above the entrance of the liquid outlet and a suitable number (e.g. four) of lateral blade supports. The liquid flowing from above can enter the liquid outlet only by flowing laterally between the support blades as the screen prevents the liquid from falling vertically and directly into the liquid outlet.

According to the invention said vortex breaker can be modified or replaced providing a perforated horizontal annular screen around said unperforated

vortex-breaker screen. As a result, a first horizontal screen is provided with a unperforated central region surrounded by a perforated annular region. In some embodiments, one or more additional perforated screens, horizontally arranged, may be placed above said first screen.

- 5 Some embodiments of the inventive method of revamping can be put into practice by a modification or replacement of the existing vortex breaker. A vortex breaker can be modified for example by adding one or more perforated screen(s) to the conventional structure of the vortex breaker, as will be elucidated below with some examples.
- 10 In another embodiment a modified vortex breaker includes an unperforated horizontal first screen and a vertically arranged annular perforated screen extending down from said first screen.

Embodiments of the revamping method based on modified vortex breakers may be of particular interest due to easy and inexpensive implementation.

- 15 Particularly, the vortex breaker is relatively easy to access by opening the lower part of the pressure vessel and therefore the modification can be carried out on site in a relatively short time, which is a considerable advantage. Usually urea strippers and evaporators have a bottom manhole so that operation inside the lower part of its vessel is possible without complication.

20 Description of the figures

Fig. 1 is a sketch of a urea stripper for CO₂ stripping process according to the prior art.

Fig. 2 is a detail of the bottom of the stripper of Fig. 1, according to the prior art.

- 25 Figs. 3 to 7 illustrate embodiments of the invention.

Fig. 8 illustrate in detail a prior art vortex breaker of a urea stripper.

Figs. 9, 10 illustrate a modified vortex breaker according to some embodiments of the invention.

Fig. 11 illustrate a sketch of an evaporator of a urea plant.

Fig. 12 is a detail of the liquid holder of the evaporator of Fig. 11.

5 Fig. 13 illustrates a further embodiment of modified vortex breaker.

Detailed description

Fig. 1 illustrates a typical embodiment of a vertical shell-and-tube CO₂ stripper S with the following items.

- 1 Pressure vessel
- 10 2 Stripping section containing a tube bundle
- 3 Upper tubesheet
- 4 Lower tubesheet
- 5 Reaction mixture inlet
- 6 Gaseous CO₂ inlet
- 15 7 CO₂ distributor
- 8 Exemplary tube of the tube bundle
- 9 Steam inlet in communication with the shell side of the section 2 around the tubes
- 10 Bottom domed end
- 20 11 Bottom liquid holder
- 12 Liquid outlet (urea-carbamate solution after stripping)
- 13 Upper chamber for collection of gaseous ammonia and carbon dioxide
- 14 Gas outlet, e.g. to condenser

15 Steam/condensate outlets

The above features of a urea stripper are known to the skilled person and need not be described in detail.

5 Fig. 2 illustrates a detail of the lower part of the stripper, particularly the bottom end 10, the bottom liquid holder 11 and the liquid outlet 12. Fig. 2 further illustrates a vortex breaker 16 placed right above the inlet section 17 of the liquid outlet 12. Fig. 2 further illustrates the liquid level 18 inside the liquid holder 11.

10 The liquid holder 11 is basically a cylinder vessel with a diameter smaller than that of the stripper, i.e. smaller than the main pressure vessel 1.

In operation, the solution effluent from the tubes 8 flows over the inner surface 19 of the domed end 10 and is collected in the liquid holder 11 forming the liquid level 18. Flowing laterally around the vortex breaker 16, the liquid finally
15 enters the outlet 12 and leaves the stripper.

Fig. 3 illustrates a first embodiment of the invention wherein the stripper is fitted with horizontal perforated screens 20 placed in the liquid holder 11 above the vortex breaker 16. For example Fig. 3 illustrates an embodiment with three additional screens 20. The screens 20 are placed in the chamber 21 formed
20 by the liquid holder 11 and are preferably full-diameter screen extend over the entire cross section of the chamber 21.

Accordingly, the solution flows into the outlet 12 through the perforated screens 20 which reduce the velocity and momentum of the liquid flow and increase phase separation.

25 Fig. 4 illustrates an embodiment with multiple perforated screens 22 arranged to create a labyrinth path for the fluid along the chamber 21. Particularly the screens 22 include rings 23 and perforated discs 24. Preferably at least some

of the screens have a diameter smaller than the inner diameter of the chamber 21. A full diameter screen 24 is also provided in Fig. 4. Said full diameter screen may coincide with the screen of the vortex breaker 16, in a preferred embodiment.

5 Fig. 5 illustrates an embodiment where the liquid holder 11 is internally fitted with a perforated wall 25 so that the chamber 21 is divided by the wall 25 into a central chamber 26 and an annular chamber 27. The upper section 28 of the wall 25 opens into the lower chamber of the stripper. In this embodiment the urea solution is predominantly collected in the annular chamber 27, as it flows
10 over the surface 19 of the domed end. The solution collected in said annular chamber 27 reaches the outlet 12 through the perforated wall 25. A portion of the solution which flows directly into the central chamber 26 will flow around the vortex breaker 16.

Fig. 6 illustrates a variant wherein the liquid holder is fitted with a closed tube
15 29 so that only the chamber 27 is available to collect the liquid. Basically this embodiment reduces the volume of the chamber 21 to increase the liquid level in the chamber.

Fig. 7 illustrates an embodiment with blades 30 and/or vertical plates or screens distributed over the inner face 19 of the domed end 10. These fittings
20 slow down the urea solution before it enters the chamber 21.

The various embodiments of the invention are not mutually exclusive and can be combined. In principle, all embodiments described herein can be freely combined. For example some embodiments may include the screens or plates 30, 31 of Fig. 7 in combination with horizontal screens of Fig. 3 or Fig. 4 or in
25 combination with the vertical wall of Fig. 5 or with the closed chamber of Fig. 6.

Figs. 8 to 10 relate to an interesting embodiment wherein horizontal perforated screens made in accordance with the invention are integrated with the vortex

breaker 16.

Fig. 8 illustrates a typical embodiment of the vortex breaker 16 including an unperforated screen 32 over the inlet section 17 of the liquid outlet 12. The screen 32 is distanced from the inlet section 17 by blade-like supports 33.

- 5 Fig. 9 illustrates an embodiment of the invention wherein the screen 32 is replaced by a larger screen 34 having an unperforated central region 35 surrounded by a perforated annular region 36.

- Fig. 10 illustrates a further embodiment including, in addition to the screen 34, a second perforated screen 37 connected to the screen 34 by suitable supports
10 38. The second (upper) screen 37 may be perforated over the entire surface whilst the first (lower) screen 34 is only perforated in the region 35.

Embodiments of Figs. 9 and 10 can be obtained by means of a modification or replacement of the existing vortex breaker 16.

- Fig. 11 discloses a vacuum evaporator E including a tube heat exchanger 41
15 and a pressure vessel 42. Fig. 11 illustrates a urea solution input line 43, a urea melt output line 44, a steam input line 45 and a steam/condensate output line 46, a vapour line 47. The pressure vessel 42 has a bottom liquid holder 11 for collection of the urea melt. The input line 43 may be connected to a first evaporator upstream the evaporator E.

- 20 In operation, the urea solution of line 43 traverses the tube side of the shell-and-tube exchanger 41, wherein the tubes are externally heated by steam 45 in the shell side. Water is then removed in the vessel 42 under vacuum and leaves the vessel via line 47.

- The above embodiments and combinations thereof for reducing the gas
25 carryover are applicable to the liquid holder of the evaporator E. This applies in particular to options a) to d) as above described and to embodiments of Figs. 3 to 10. The fittings as above described may be provided in the bottom liquid

holder of the evaporator E which is illustrated in Fig. 12.

Fig. 13 illustrates a further embodiment which may be realised upon modification of a vortex breaker. In this embodiment the modified vortex breaker includes an unperforated horizontal first screen 50 and a vertically
5 arranged annular perforated screen 51 extending down from said first screen 50. The perforated screen 51 may be realised with a slotted wall or a Johnson screen or equivalent.

CLAIMS

1. An apparatus of a urea production plant, wherein the apparatus is a urea stripper (S) adapted to process a urea-containing reaction mixture for decomposition of unreacted ammonium carbamate contained in the mixture into a gaseous mixture of ammonia and carbon dioxide, wherein:
- 5 the urea stripper includes a stripping section (2) wherein the stripping process is performed and a bottom liquid holder (11) arranged to collect urea-containing solution after the stripping process;
- the urea stripper further comprises at least one of the following:
- 10 a) one or more perforated screens (20) horizontally arranged inside the bottom liquid holder;
- b) one or more perforated screens (25) vertically arranged inside the bottom liquid holder;
- 15 c) a sealed chamber (29) arranged inside the liquid holder to reduce the size of an internal urea solution collection chamber (21) of the liquid holder;
- d) a plurality of blades (30) and/or vertical plates (31) projecting from the inner surface (19) of a bottom domed end (10) of the stripper, connecting the stripping section with the liquid holder.
- 20 2. An apparatus of a urea production plant, wherein the apparatus is an evaporator (E) adapted to process an aqueous urea solution to remove water and to obtain a concentrated solution or a urea melt, wherein:
- the evaporator includes a pressure vessel operated under vacuum and a bottom liquid holder (11) arranged to collect the concentrated solution or
- 25 the urea melt and the evaporator further comprises at least one of the following:

- a) one or more perforated screens (20) horizontally arranged inside the bottom liquid holder;
 - b) one or more perforated screens (25) vertically arranged inside the bottom liquid holder;
 - 5 c) a sealed chamber (29) arranged inside the liquid holder to reduce the size of an internal collection chamber (21) of the liquid holder;
 - d) a plurality of blades (30) and/or vertical plates (31) projecting from the inner surface (19) of a bottom domed end (10) of the evaporator connected to the liquid holder.
- 10 3. An apparatus according to claim 1 or claim 2 wherein option a) includes a plurality of perforated screens (20) arranged at different elevation inside the bottom liquid holder (11).
4. An apparatus according to claim 3 wherein said plurality of perforated screens includes disc-shaped screens (20, 24) and/or ring-shaped
15 screens (23) preferably stacked one above the other.
5. An apparatus according to claim 3 or claim 4 wherein said plurality of perforated screens includes screens (22) arranged so that at least two screens placed one above the other extend over different portions of the cross section of an internal chamber of the liquid holder.
- 20 6. An apparatus according to any of claims 1 to 5 wherein option a) includes a horizontal screen (34) proximal to a liquid outlet duct (12) of the liquid holder, said horizontal screen having an unperforated central region (35) adapted to act as a vortex breaker and a perforate annular region (36) around said central region.
- 25 7. An apparatus according to any of claims 1 to 6 wherein option a) includes that one or more horizontal screen(s) is/are integral with a vortex breaker

- (16) fitted inside the liquid holder (11).
8. An apparatus according to any of the previous claims wherein option b) includes a perforated cylindrical wall (25) placed inside the bottom liquid holder, so that the bottom liquid holder is divided into an annular chamber (27) around said wall and a central chamber (26) inside said wall, said chambers being in communication through the perforations of said wall (25).
 9. An apparatus according to any of the previous claims wherein option b) includes a vertically arranged perforated cylindrical wall (51) extending downward from an unperforated horizontal screen (50).
 10. An apparatus according to any of the previous claims wherein option c) includes a closed cylindrical chamber (29) placed in the bottom liquid holder, so that the only internal region of the bottom liquid holder where liquid can be collected is an annular region around said chamber (29).
 11. An apparatus according to claim 1 or any of the previous claims when depending on claim 1, the apparatus being a urea stripper adapted to operate according to any of: the self-stripping process, the ammonia-stripping process, the CO₂ stripping process.
 12. A urea production plant including at least one apparatus according to any of the previous claims.
 13. A method for revamping a urea stripper of a urea production plant wherein the urea stripper includes a stripping section wherein the stripping process is performed and a bottom liquid holder wherein urea-containing solution is collected after the stripping process, and the method comprises the provision of at least one of the following:
 - a) one or more perforated screens horizontally arranged in the bottom portion;

- b) one or more perforated screens vertically arranged in the bottom liquid holder;
 - c) a sealed chamber arranged in the liquid holder to reduce the volume in the liquid holder wherein the urea solution can be collected;
 - 5 d) a plurality of blades and/or vertical plates projecting from the inner surface of a bottom domed end of the stripper, connecting the stripping section with the liquid holder.
14. A method for revamping a vacuum evaporator of a urea production plant wherein the vacuum evaporator includes a vessel arranged to remove
- 10 water from an aqueous solution of urea for the production of a concentrated solution or of a urea melt, said vessel including a bottom liquid holder where the concentrated solution or urea melt is collected and the method comprises the provision of at least one of the following:
- 15 a) one or more perforated screens horizontally arranged in the bottom liquid holder;
 - b) one or more perforated screens vertically arranged in the bottom liquid holder;
 - c) a sealed chamber arranged in the liquid holder to reduce the volume in the liquid holder wherein the urea solution or melt can be collected;
 - 20 d) a plurality of blades and/or vertical plates projecting from the inner surface of a bottom domed end of the evaporator connected with the liquid holder.
15. A method according to claim 13 or claim 14 wherein option a) includes the provision of a plurality of perforated screens (20) arranged at different
- 25 elevation in the bottom liquid holder and preferably the plurality of perforated screens includes disc-shaped screens and/or ring-shaped

screens.

16. A method according to claim 15 wherein the option a) includes the provision of screens arranged so that at least two screens which are placed one above the other extend over different portions of cross section
5 of an internal chamber (21) of the liquid holder.
17. A method according to any of claims 13 to 16 wherein option a) includes the provision of a modified vortex breaker including:
- at least a first horizontal screen proximal to a liquid outlet duct of the liquid holder, said first horizontal screen having an unperforated central region
10 adapted to act as a vortex breaker and a perforate annular region around said central region;
- optionally at least a second perforated horizontal screen placed above said first screen.
18. A method according to claim 13 or 14 wherein option b) includes the provision of a modified vortex breaker including:
15
- an unperforated horizontal first screen;
- a vertically arranged annular perforated screen extending down from said first screen.
19. A method according to claim 13 or claim 14 wherein:
- 20 option b) includes the provision of a perforated cylindrical wall in the bottom liquid holder, so that the bottom liquid holder is divided into an annular chamber around said wall and a central chamber inside said wall, said chambers being in communication through the perforations of said wall,
- or
- 25 wherein option c) includes the provision of a closed cylindrical chamber

placed in the bottom liquid holder, so that the only region of the bottom liquid holder where liquid can be collected is an annular region around said sealed chamber.

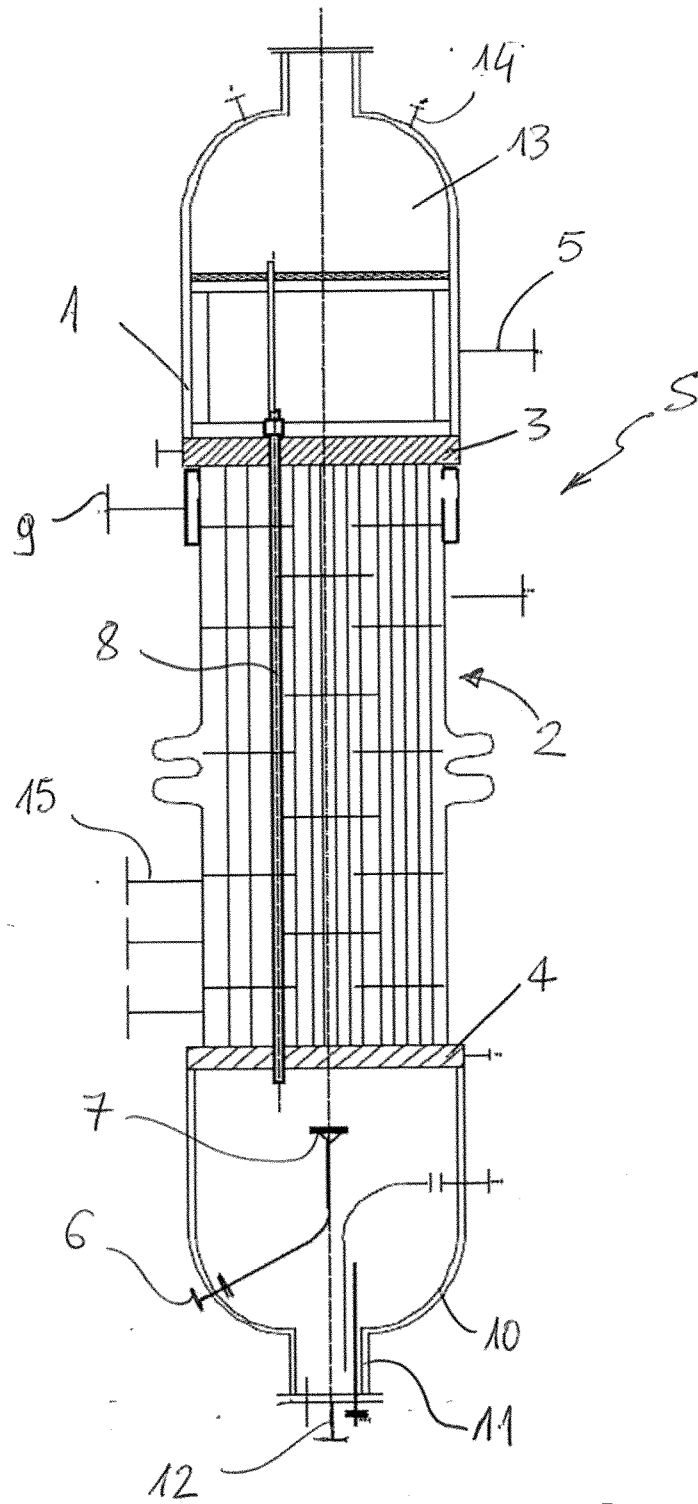


FIG. 1

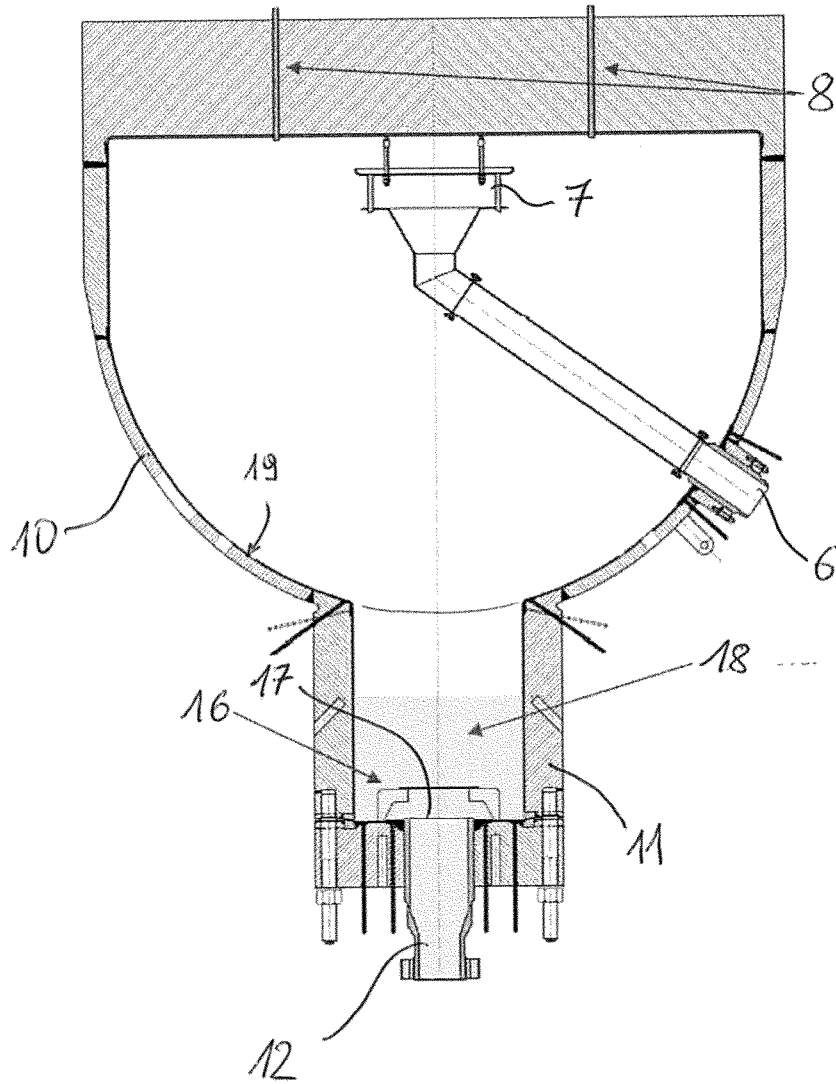


FIG. 2

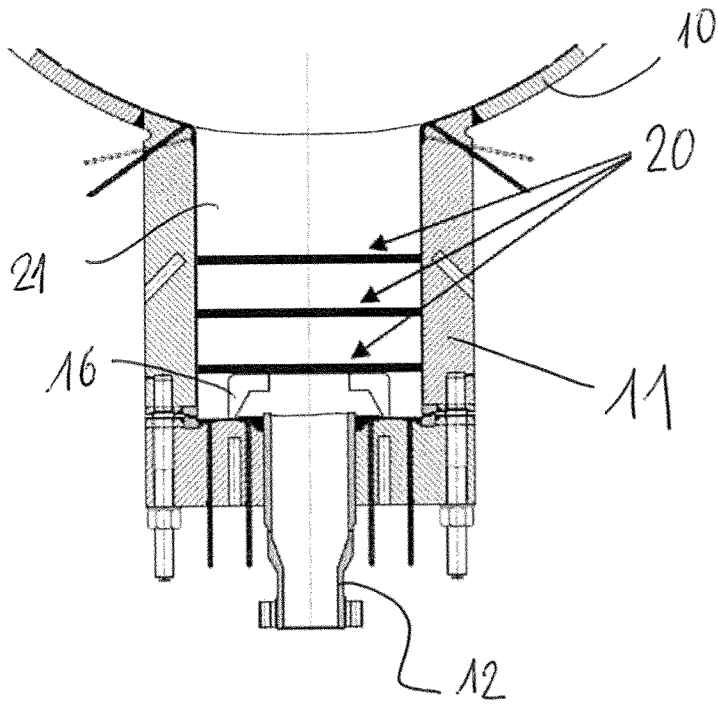


FIG. 3

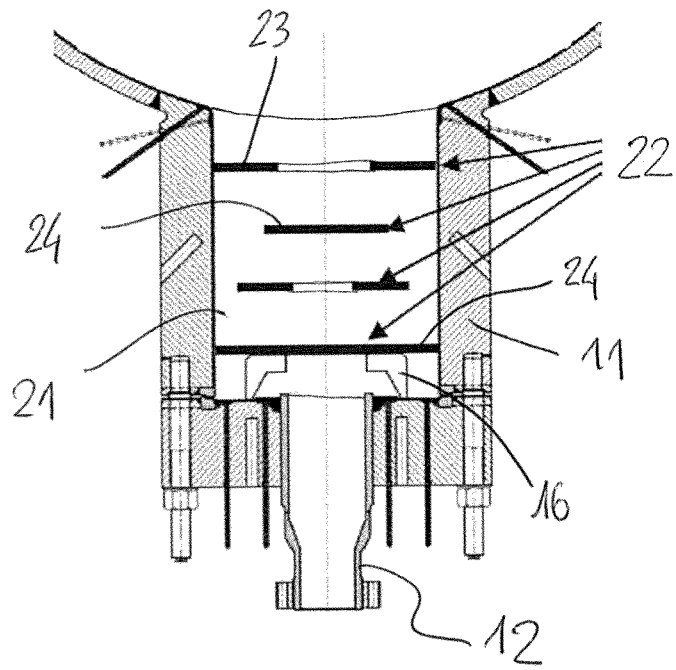


FIG. 4

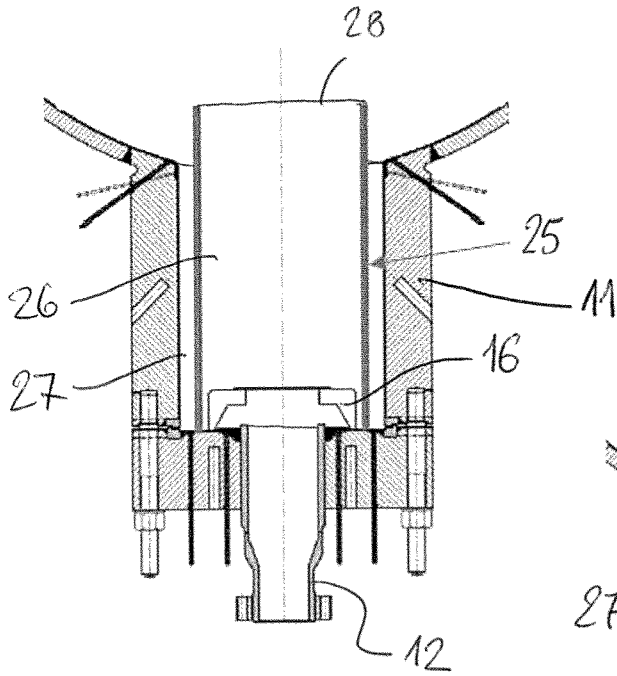


FIG. 5

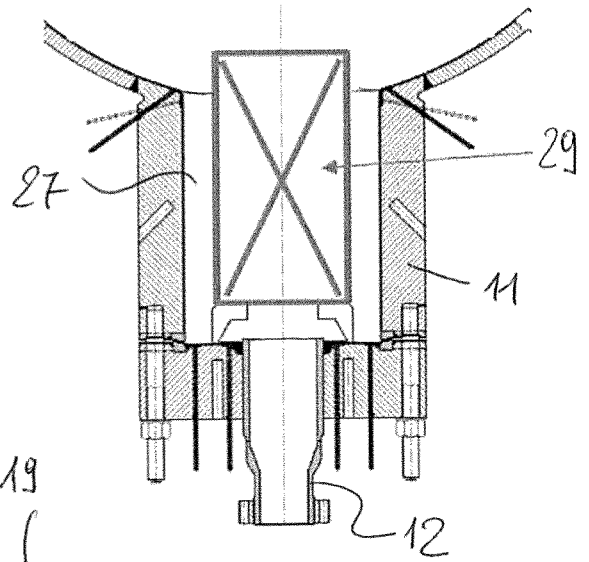


FIG. 6

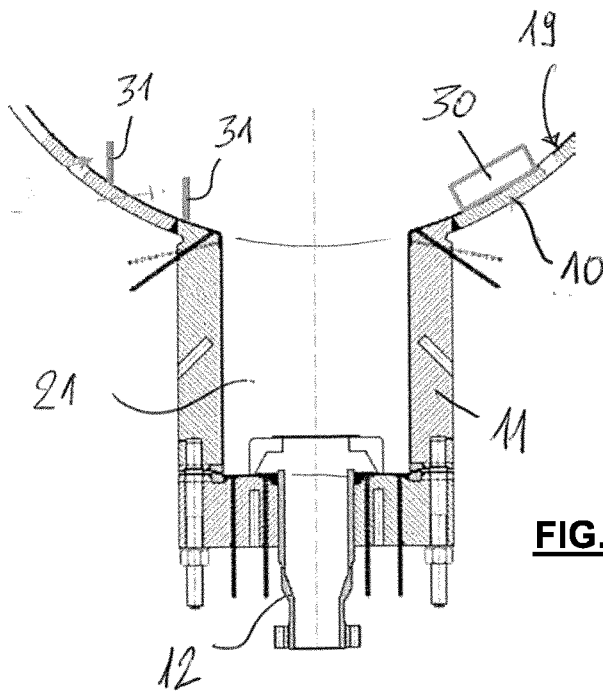


FIG. 7

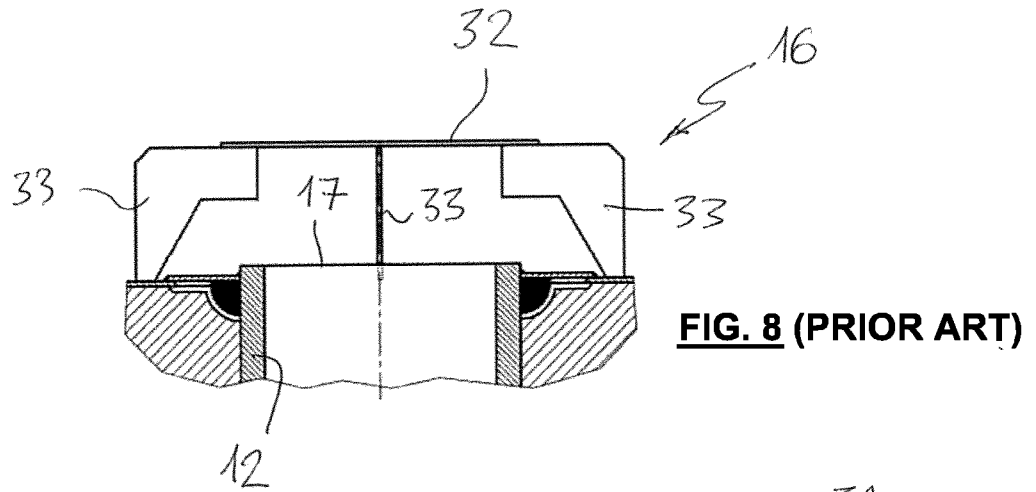


FIG. 8 (PRIOR ART)

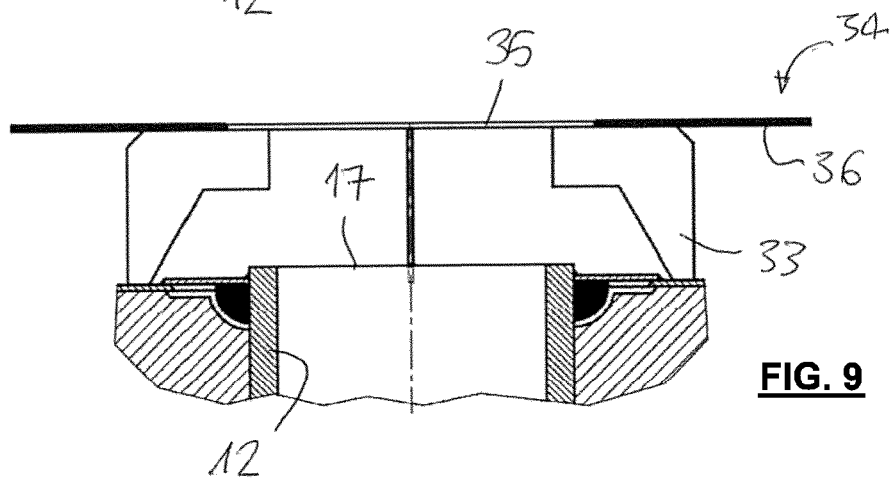


FIG. 9

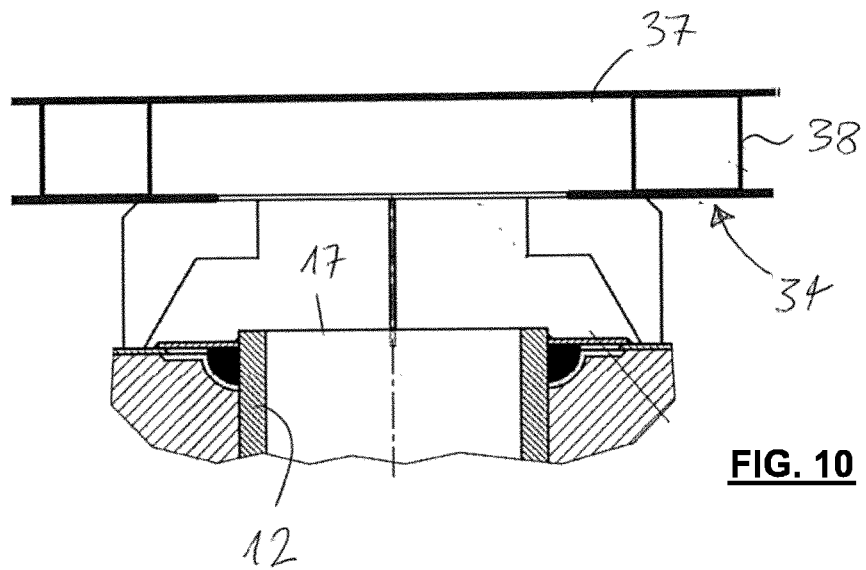


FIG. 10

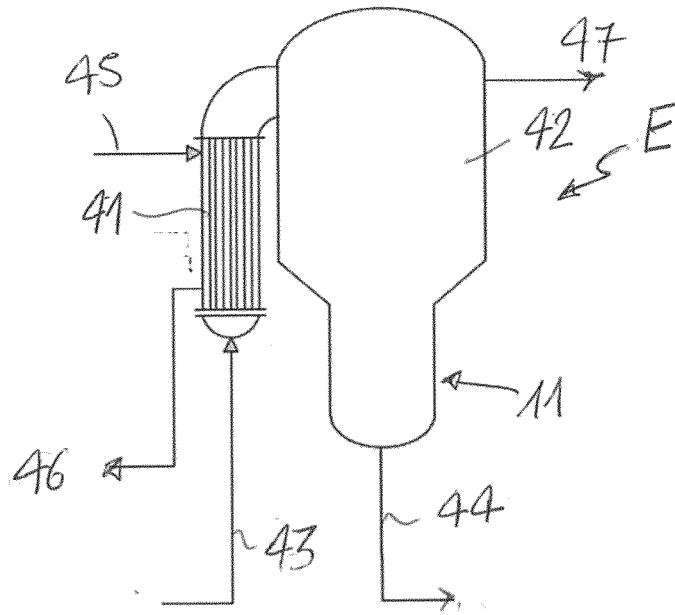


FIG. 11

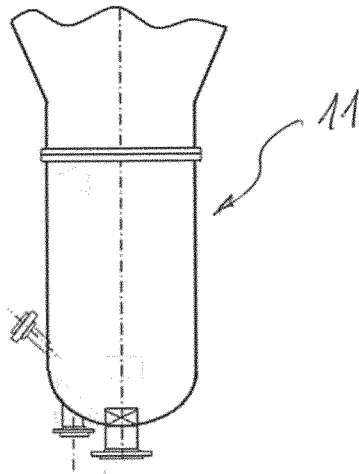


FIG. 12

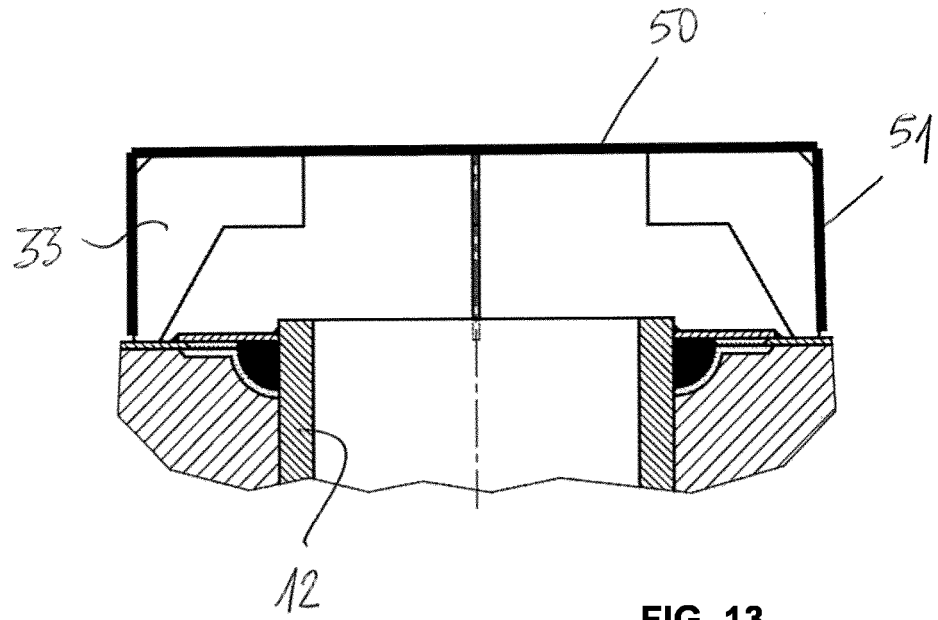


FIG. 13