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(19)

(54) IMPROVEMENTS IN OR RELATING TO EVAPORATORS, PARTICULARLY WIPED FILM EVAPORATORS

(71) We, HENRY BALFOUR & COMPANY LIMITED, a British Company, of Leven, Fife, Scotland, Great Britain, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement: —

The present invention relates to wiped-film evaporators, and especially to such evaporators for use with corrosive liquids.

In one known form of wiped-film evaporator a thin film of liquid to be evaporated is formed on the internal wall of an upright cylindrical evaporation vessel by means of wiping elements carried by a rotary vertical shaft in the vessel, and heating means cause evaporation of the film. Such an evaporator is shown in British Patent Nos. 1288431 and 1038204 (Henry Balfour & Co. Limited). The wiping elements provide a rapidly changing film by fluid friction, and good heat transfer rates are maintained over the entire length of the evaporator because the wiper elements effectively wipe the entire heating surface irrespective of the film thickness. Dry spots and channelling are eliminated and nucleate (bubble) boiling is substantially reduced thus minimising high localised heat fluxes into the process liquor which, with heat sensitive chemicals and fodstuffs, can be detrimental to quality, taste and flavour. The wiped film evaporator can be used for evaporation of organic compounds, concentration of aqueous solutions, solvent recovery, stripping of aqueous solutions, and concentration of viscous products.

To enable the evaporator to handle corliquids, parts of the evaporator coming into contact with the corrosive liquids and/or products of the process have at least their outer surface of corrosion resistant material. Such parts include the vessel, shaft and wiping element support means: the wiping elements themselves can be made of a plastics material. A problem can arise in the provision of a wiped film on the internal wall of the vessel if irregularities are present in this wall, and this problem can particularly arise where a corrosion resistant layer is provided on this wall. It is a principal object of the present invention to provide improved wiping means in a wiped-film evaporator.

According to the present invention there is provided a wiped-film evaporator for corrosive liquids comprising a vertically orientated cylindrical evaporation vessel; the internal surface of which has a corrosion resistant glass lining thereon, rotary shaft means extending within the vessel and being supported in bearing means and connectible to a drive; the rotary shaft means having its outer surfaces of corrosion resistant material, an inlet for delivery of liquid to be evaporated into the cylindrical vessel; an outlet for vapour; a plurality of wiping units for wiping the internal surface of the cylindrical vessel for the formation of a liquid film on the internal surface, each wiping unit comprising an axial series of outwardly extending individual wiper elements and a corrosion resistant spindle, on which the wiper elements are individually pivotable, and a plurality of wiper support means carried by the rotary shaft means and each comprising a pair of axially-spaced socket devices serving to receive and support a respective spindle of a wiping unit, the socket devices and wiper elements being made from a corrosion resistant fluorocarbon, and the wiper elements each being engageable with the internal surface of the vessel so as to have a trailing configuration relativte to the radius from the shaft axis to the pivot point of the element so that the element is pivotable by irregularities on the internal surface of the vessel.

In the present specification and appended claims the term "glassing" or "glass lining" covers the bonding of a vitreous or partially devitrified inorganic coating to a substrate particularly a metallic substrate at a suitable elevated temperature.

Embodiments of the present invention will now be described by way of example with reference to the accompanying drawings in which: —

Fig. 1 is a cross-sectional elevational view of a wiped-film evaporator according to one embodiment of the present invention;

Fig. 2 is a cross-sectional elevational view of a detail of Fig. 1 to a larger scale;

Fig. 3 is a plan view of the evaporator distributor of Fig. 2;

Fig. 4 is a plan view of the evaporator of Fig. 1 through section X-X in Fig. 1 and showing the mounting of the demister plate;

Fig. 5 is a schematic plan view of the evaporator, with a modified form of wiper element tip, and showing the movements of the wiper elements;

Figs. 6 and 7 show various forms of sealing connection between the parts of the evaporator vessel;

Fig. 8 shows a cross-sectional plan view of the evaporator along line B-B in Fig. 1 but with a modified liquid distribution system; and

Fig. 9 shows a cross-sectional elevation of a wiped film evaporator according to a second embodiment of the present invention.

Referring to Fig. 1, a wiped-film evaporator 1 for use in handling corrosive liquids in chemical processes comprises a cylindrical steel vessel, housing a rotor assembly 3, a drive unit 8 for the rotor assembly 3, wiper blade assemblies 4 carried by the rotor assembly 3 for the formation of a liquid film on the inner wall surface 5 of the vessel 2, an inlet feed system 6 (which will be described in greater detail below) for liquid to be evaporated delivering on to the inner wall 5, an outlet 7 for vapour, a heating jacket 9 for the vessel, and a discharge 10 for non-vaporised products. The wiper blade assemblies 4 are axially and circumferentially staggered for complete and effective wiping of a lower portion of the wall surface 5 adjacent the jacket 9. As can be seen in Fig. 1, the wiper assemblies 4 extend above the zone of the heating jacket 9 so that the liquid film is formed on the wall by the assemblies 4 prior to the heating zone.

The vessel 2 is located vertically and comprises main elongate cylindrical portion 2A, a domed top cap 2B and a generally frusto-conical bottom 2C. The vessel 2 is intended for operation under vacuum (e.g. 1 mm mercury abs) and the top cap 2B and bottom 2C are joined to the main portion 2A by peripheral air-tight connections 11 (two alternatives are shown in detail in Figs. 6 and 7) each comprising annular flanges 12, 13 having axial male-and-female interfitting parts, a sealing gasket 14 and one or more sealing O-rings 15, the flanges being tightly coupled by clamping means (not shown). A peripheral sealing sleeve 16 for the flange interface can also be provided.

The inner wall surface 5 has a corrosion resistant glass lining thereon, which lining can be formed using conventional glassing techniques. 7A is a demister plate and a lower heating jacket 9B serves to maintain product outflow. Referring to Fig. 4, the plate 7A is supported by a lower P.T.F.E. stud 75 carried by glassed bar 74 removably located in a radial bore 72 of the vessel 2, and a glassed rod 70 extending between P.T.F.E. plugs 71 in opposed bores 72 serves for upper support of the plate 7A. Flange plates 73 close the outer ends of bores 72.

The rotor assembly 3 includes a shaft 17 which extends through an opening 18 of the vessel 2 and a coupling 21 connects the shaft 17 to the motor drive-unit 8 which is supported on cap 2B by means of stool 8A. Axial support bearings 19A, 19B are provided in the drive unit 8, at least one bearing 19B being a radial thrust bearing, and the shaft 17 hangs in the vessel 2, with the lower end of the shaft 17 within the vessel 2. The upper end of the shaft 17 is journalled in a radial seal bearing 19C located in housing 20 and a corrosion resistant (ceramic) shaft seal is located at the vessel nozzle 18.

By virtue of the substantial axial spacing of the bearings 19A, 19B and 19C and by having the rotor assembly 3 constructed with suitable dimensions, the hung rotor assembly 3 can be provided with suitable rigidity and freedom from excess lateral deflection to permit satisfactory operation of the rotor assembly 3 and wiper assemblies 4. Consequently the normal internal lower bearing for the rotor assembly can be dispensed with and this greatly facilitates the provision of an evaporator suitable for handling corrosive liquids since an internal bearing is subject to rapid wear due to the corrosive environment in the vessel.

The rotor assembly 3 has an axial and circumferential series of radial arms 22 and this assembly 3 is glass coated (3A) to resist corrosive attack. It is a characteristic feature of this evaporator that all the edges 23 of the rotor assembly 3 are substantially radiused or rounded; this permits satisfactory glassing of the rotor assembly. The glass coating 3A on the shaft 17 extends substantially to the upper end of the shaft 17, so that all portions of the rotor assembly 3 within the vessel 2 have a lining of corrosion resistant glass. A radially extending plate 24 (Figs. 2 and 3) is welded to each straight arm 22, and has a removable fender member 24A, the plate 24 including an axial through-bore 33. The glass coatings 3A on arms 22 and plates 24 are shown in Fig. 2, and the substantial radius-

ing or rounding of the edges will be evident in this Figure. The through-bores 33 receive socket members 25 which include a tubular part 35 insertable into the bore 33 and a shouldered part 26 engageable with the plate 24 to locate the member 25. The members 25 are of glass-filled P.T.F.E. and a blind bore 37 of each member 25 receives the respective end of wiper rod 28 of the wiper assemblies.

Each wiper assembly 4 comprises a steel wiper rod 28 having glass coating 28A, and an axial series of P.T.F.E. finger elements 29 pivotally carried by the rod 28, washers 30 serving to provide tip clearance (e.g. 1 mm) between adjacent elements 29. The tips of elements 29 are square ended and the side walls of each element 29 are recessed at 31 to provide greater clearance (4 to 5 mm) to resist any fouling between the elements. To fit a wiper assembly 4, the bore 37 of the top socket member 25 is in the open state (plug 27 removed) and the rod 28 is inserted through this top member 25. The fingers 29 and washers 30 and end washers 30A are fitted to the rod 28 prior to the rod being inserted in the lower socket member 25, and the bore 37 of the upper member 25 is closed by insertion of the plug 27 which can be a press fit in the bore 37 or alternatively can be fused to the member 25. As can be seen in Fig. 1, the wiper assemblies 4 have a staggered axial and circumferential relationship so that the portion of wall 5 adjacent heating jacket 9 is completely and effectively wiped. In particular and as shown in Fig. 2, it is preferable for the fingers 29 of the assemblies 4 at the same level to be staggered relative to each other so that a finger of one assembly wipes the gap between adjacent fingers of the other asssembly.

The glassing of the internal wall surface 5 of the vessel which involves a series of firing operations inevitably results in irregularities in the geometry of the vessel; in particular there occurs out-of-roundness distortion (Fig. 3) as can be assessed from transverse sections of the vessel and parallel or straightness distortion which can be assessed from longitudinal section of the vessel (Fig. 1). It is a particular feature of the present evaporator that these distortions are catered for by the wiper assemblies 4. Referring to Fig. 5, the wiper assemblies 4 are so arranged that the elements 29 adopt a trailing configuration relative to the radius line from the axis of shaft 17 to the through-bore 33 and the elements 29 which are urged into contact with the wall 5 by centrifugal force pivot to cater for out-of-roundness of the wall 5. Element 29A is in the normal position in Fig. 5 while elements 29B and 29C have pivoted to cater for maximum distortion on either side of the nominal radius, 29B to a maximum radius and 29C to a minimum radius. The pivotal elements 29 also permit discrepancies in the radial lengths of arms 22. The out-of-roundness distortion may be as much as 3% of the vessel's diameter. Straightness distortion is catered for by pivoting of the elements 29 of each assembly 4 relative to each other. The number of elements 29 in each assembly 4 can vary but will be dependent on the particular application of the evaporator and especially on the particular process requirements e.g. the chemical being processed with the degree of wiping to give good evaporation.

The inlet feed system 6 includes a rotary distributor as described and claimed in United States Patent 4173246 by E. Nunlist and J. Mitchell and entitled "Feed Distributor for Glassed Steel Wiped film Evaporator". The feed system 6 includes an annular open-topped housing 40 surrounding the shaft 17 and resting on the upper radial arms 22 of the uppermost wiper assemblies 4 and on a shorter pair of radial arms 42. The housing 40 is machined from a fluorocarbon block, such as P.T.F.E., and is clamped to the arms 22, 42 by means of a pair of P.T.F.E. half-rings 43, P.T.F.E. screws 44 linking the half-rings 43 and the housing 40. The housing 40 provides an annular chamber 45, and an inlet pipe 41 (Fig. 1) supplies liquid to be evaporated to the chamber 45.

An opposed pair of tubular conduits 46 of P.T.F.E. are screwed into bores 47 in the peripheral wall of the housing 40 and extend radially so that their outer ends lie closely adjacent the inner wall 5 of the vessel. Support rings 48 carrying pins 27 received in the upper sockets 25 serve for outer support of the conduits 46. The housing 40 has an inwardly inclined lip 49 to preclude splashing. The outer ends of the conduits 46 are of open-topped trough form 50: this form of conduit enables the feed system to handle particulate material.

In operation of the feed system the rotating conduits 46 discharge the liquid on to the vessel wall surface 5 ahead of the uppermost blade assemblies, by means of centrifugal force. It would be possible to have the conduits 46 inclined downwardly slightly so that liquid discharge is assisted by gravity. Additionally the housing 40 could be supported by the shaft 17 clear of the uppermost wiper assemblies 4 and the conduits 46 could wholly comprise open-topped troughs.

In the modification shown in Fig. 8, the inlet feed system 6 comprises at least one feed tray 60 (two diametrically opposed trays are used in this embodiment) with the

inlet pipe 41 discharging on to the tray 60 so as to mitigate splashing. The tray 60 which includes a base 62 and a peripheral wall 63 can be made of P.T.F.E., and a pair of steel support arms 64 carry the tray 60. The inner wall-facing edge 65 of the tray is profiled complementary to the wall 5, the edge 65 being spaced from the wall 5 to provide a liquid feed gap G. The portions of the steel support arms 64 within the vessel 2 are glass lined to resist corrosive attack, and it is a feature of the trays and support arms that they are removable from the vessel wall for repair. Specifically, the arms 64 are secured externally of the vessel to satisfy the design limitations resulting from the internal glassing. The tray 60 can be secured by pin or pins 69, which can be of suitable plastics material.

In the embodiment shown in Fig. 9, the rotor assembly 93 is upstanding from the bottom 2C of the vessel and is supported at the bottom in a thrust and journal bearing assembly 94, the uper end of the rotor assembly 93 being free within the vessel 2. Additionally, the motor 8 for the rotor assembly 93 is located below the vessel 2. Otherwise, like parts of the evaporator of Fig. 9 have the same reference numerals as in Fig. 1. The distributor 40 is located at the upper free end of the rotor assembly and is substantially similar to the distributor of the Fig. 1 embodiment: again the distributor is carried by the arms 22 (and 42). However, the housing 40 can be substantially cup-shaped, with the inlet feed pipe 41 discharging into the centre of the cup. In an alternative arrangement an axial vapour outlet is located at the top of the vessel, demister elements being provided to block liquid particle pasage to the axial outlet.

It is advantageous that the vapour discharge 7 is located transversely to the evaporator since this conveniences the positioning of a baffle (7A) to block the passage of liquid particles to the discharge. However, with the rotor supported in an upper external bearing as in the Fig. 1 arrangement, extra length of shafting is required for the distance between the upper bearing and the upper wiper assemblies. The Fig. 9 arrangement has the advantage of eliminating this extra shafting length, and this enables considerable economies to be achieved. Additionally, the arrangement and installation of the feed system 6 is made simpler and more satisfactory, particularly since a central through-bored hub is not required in the housing 40. The liquid outlet 10 is now axially off-set.

It is a feature of the above evaporators according to the present invention that the feed system 6 and also the rotor and wiper assemblies can be separated from the vessel to permit convenient repair where necessary, e.g. by re-glassing, and it is also possible to repair or replace the wiper assemblies by entering the vessel.

By the internal arrangement of the above evaporator, the glassing of the various evaporator parts can be readily achieved, which is advantageous to facilitate the production of a complete evaporator with glass lined internal parts, which evaporator can be satisfactorily used in chemical processes.

The glass lining in both embodiments can be of an acid/alkali corrosion resistant borosilicate glass and the lining preferably has a minimum thickness, for example 1 mm. The above described evaporators according to the present invention should find particular use in the chemical industry, where corrosive liquids are encountered, but it is envisaged that they would also be useful in hygenic applications (e.g. food industry) since there will be no metallic pick-up by the P.T.F.E. wipers due to their running on glass. In comparison with previous evaporators for use with corrosive liquids it is believed that the above evaporators according to the present invention will have a considerably longer life. The parts within the evaporator do not require to be made of expensive corrosion resistant material, and the number of radial wiper supporting arms can be reduced in comparison with previous arrangements.

Modifications are of course possible in the design. For example, the ends of arms 22 could be provided with a more tapering configuration as they blend to the portions 24.

WHAT WE CLAIM IS: —

1. A wiped-film evaporator for corrosive liquids comprising: a vertically orientated cylindrical evaporation vessel, the internal surface of which has a corrosion resistant glass lining thereon, rotary shaft means extending within the vessel and being supported in bearing means and connectible to a drive, the rotary shaft means having its outer surfaces of corrosion resistant material, an inlet for delivery of liquid to be evaporated into the cylindrical vessel; an outlet for vapour; a plurality of wiping units for wiping the internal surface of the cylindrical vessel for the formation of a liquid film on the internal surface, each wiping unit comprising an axial series of outwardly extending individual wiper elements and a corroson resistant spindle, on which the wiper elements are individually pivotable, and a plurality of wiper support means carried by the rotary shaft means and each comprising a pair of axially-spaced socket devices serving to

receive and support a respective spindle of a wiping unit, the socket devices and wiper elements being made from a corrosion resistant fluorocarbon, and the wiper elements each being engageable with the internal surface of the vessel so as to have a trailing configuration relative to the radius from the shaft axis to the pivot point of the element so that the element is pivotable by irregularities on the internal surface of the vessel.

2. An evaporator according to claim 1 wherein the wiper elements and the socket devices are made from polytetrafluoroethylene (P.T.F.E.).

3. An evaporator as claimed in claim 1 or 2, wherein the rotary shaft means have a corrosion resistant glass coating thereon.

4. An evaporator according to any one of the preceding claims, wherein the bearing means for the rotary shaft means are located substantially outwith the cylindrical vessel.

5. An evaporator according to any one of the preceding claims wherein one of the ends of the rotary shaft means is free within the vessel.

6. An evaporator according to claim 5, wherein suport means are provided for the rotary shaft means at the upper end of the shaft means, said rotary shaft means being hung within the vessel by said support means with the lower end of the rotary shaft means free within the cylindrical vessel.

7. An evaporator according to claim 5, wherein support means are provided for the shaft means at the lower end of the shaft means, said shaft means being upstanding within the vessel with the upper end of the shaft means free within the vessel.

8. An evaporator according to any one of the preceding claims, wherein the wiping units have overlapping portions for complete and effective wiping of an extensive axial portion of the internal surface of the vessel.

9. An evaporator according to claim 8, wherein the wiping units are staggered axially and circumferentially.

10. An evaporator as claimed in any of the preceding claims, wherein two wiping units are located at substantially the same level, the pitch of the wiping element of one unit being staggered relative to the wiping elements pitch of the other unit whereby the wiped surface zone corresponding to the gap between adjacent elements of one unit is wiped by an element of the other unit.

11. An evaporator according to any one of the preceding claims, wherein tte rotary shaft means includes pairs of axially-spaced radially-extending arms for support of the socket devices of a wiping unit.

12. An evaporator according to claim 11, wherein each radial arm includes a through bore at its outer end and each socket device has an axial body portion insertable into a respective through-bore and a shoulder portion engageable with the arm to locate the socket device.

13. An evaporator according to any one of the preceding claims, wherein the spindle is a corrosion resistant glass coated metallic rod.

14. An evaporator according to any one of the preceding claims, wherein said inlet for delivery of liquid includes corrosion resistant liquid distributor means located above said wiping units, said corrosion resistant liquid distributor means serving to spread liquid on the internal surface of the cylindrical vessel.

15. An evaporator according to claim 14, wherein the liquid distributor means comprises a plurality of trays, each located closely adjacent the internal surface of the cylindrical vessel so as to provide a discharge clearance with said internal surface, and support members for the trays extending through the wall of the vessel.

16. An evaporator according to claim 7, wherein said inlet for delivery of liquid includes corrosion resistant liquid distributor means mounted on said rotary shaft means at the upper free end of said shaft means, said corrosion resistant liquid distributor means serving to spread liquid on the internal surface of the cylindrical vessel.

17. An evaporator according to any one of the preceding claims, wherein the cylindrical vessel comprises a main cylindrical portion the inner surface of which is wiped by said wiping units, and end cap portions joined to said main portion by sealing connections.

18. A wiped-film evaporator substantially as hereinbefore described with reference to and as illustrated in Figs. 1 to 7, or these Figs, as modified by Fig. 8, or to Fig. 9 of the accompanying drawings.

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Sheet 1

Fig.1.

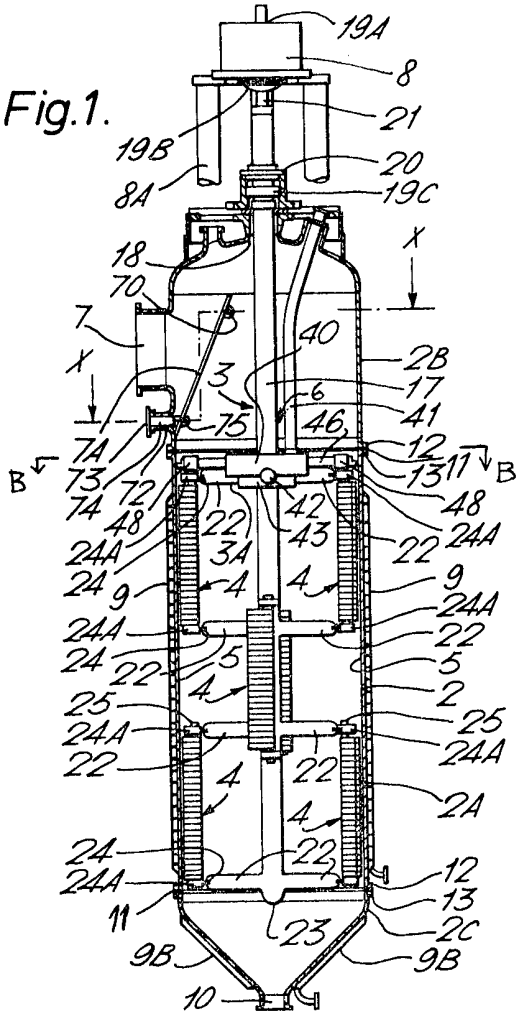

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Fig.2.

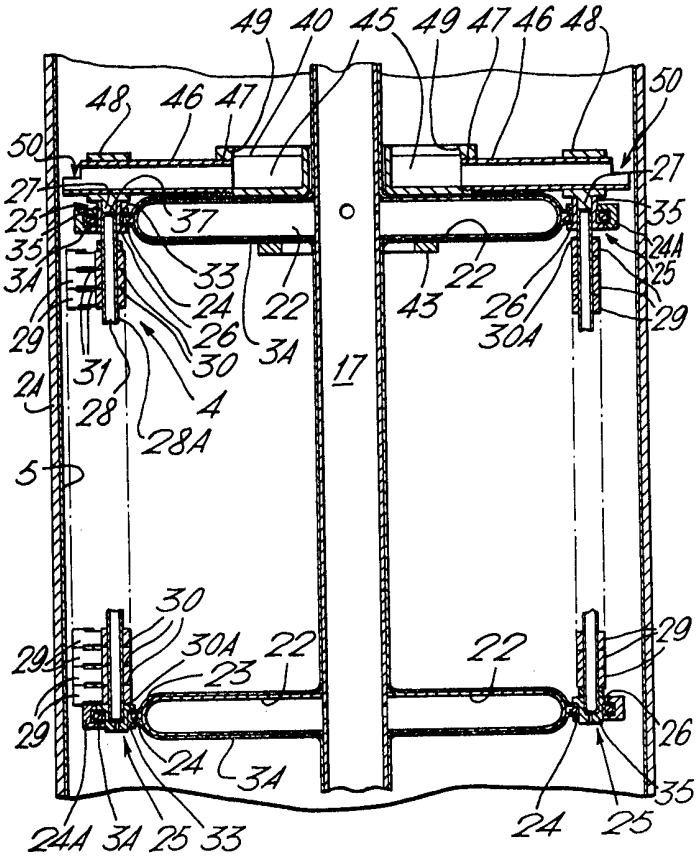

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Fig.3.

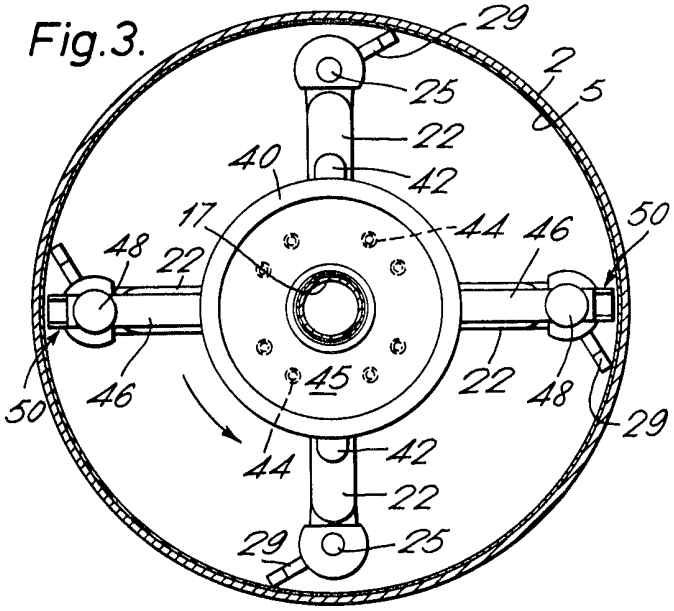

Fig.4.

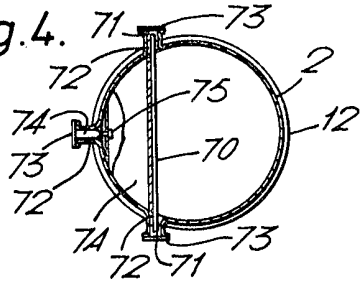

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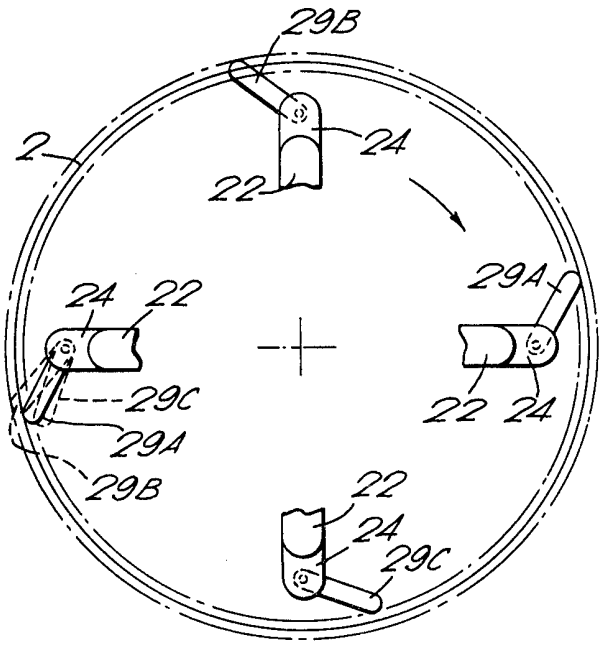
Fig.5.



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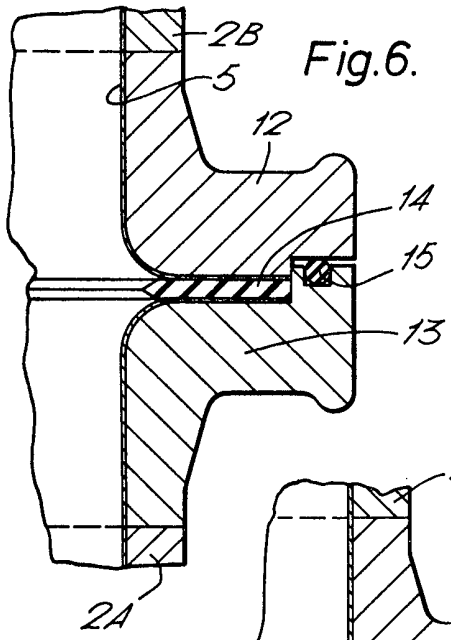

Fig.6.

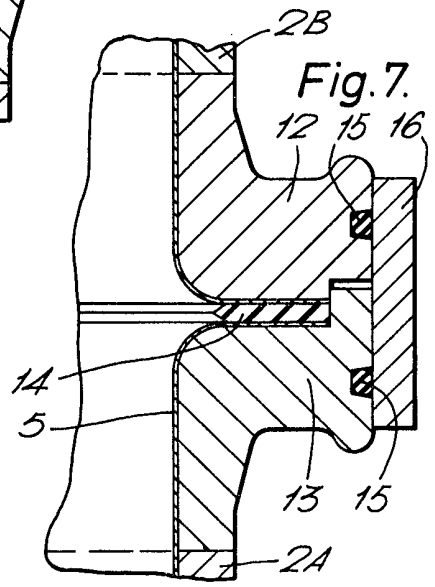

Fig.7.

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Fig.8.

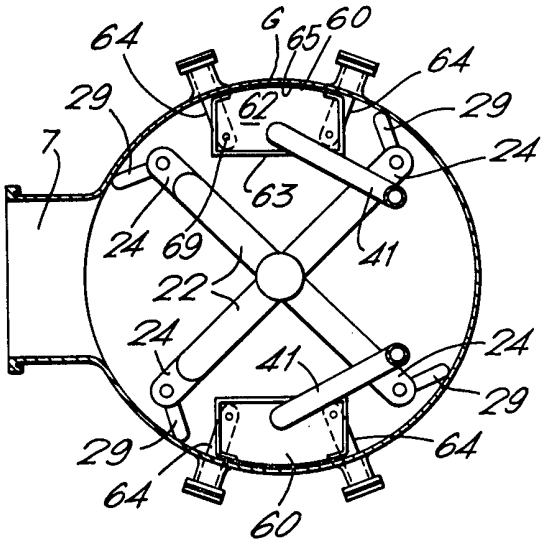

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Fig.9.