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[54] **DEVICE FOR SEPARATING TWO LIQUIDS OF DIFFERENT DENSITIES IN A TANK CONTAINING THESE TWO LIQUIDS**

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[30] **Foreign Application Priority Data**

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[51] **Int. Cl.** **B65d 1/24**

[58] **Field of Search** ...220/22, 18, 26 R, 26 S, 26 SA, 220/26 D, 93, 85 A, 13

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[57] **ABSTRACT**

A device for separating two liquids of different densities in a tank containing these two liquids one above the other which includes a separating element floating with clearance along the vertical wall of the tank between the two liquids, and a flexible sealing skirt of reduced thickness adapted to tangentially contact the vertical wall of the tank and to turn upwardly or downwardly along the tank wall without mixing of the two liquids when the tank is switched from a filling to an emptying operation or vice versa. The separating element may be provided with openings for passages of pipes, the edges of which are also provided with flexible sealing skirts, for filling or emptying the tank. Also, the separating element may include grooves for draining decanting products from the upper liquid toward the lower liquid.

6 Claims, 9 Drawing Figures

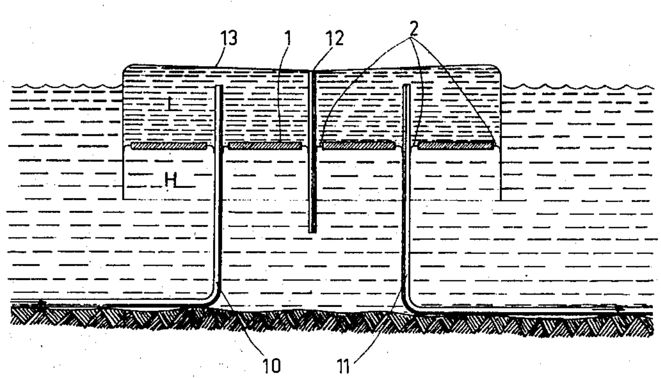

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FIG.1

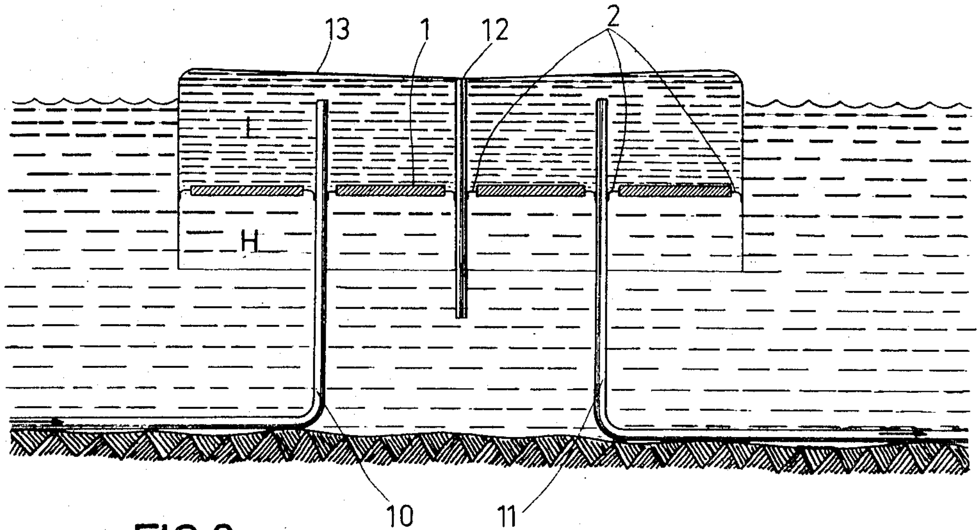


FIG.2

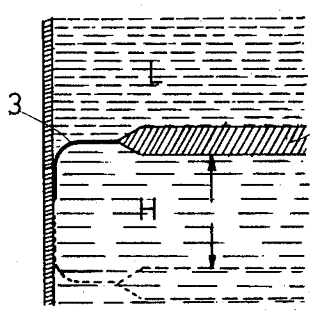


FIG.3

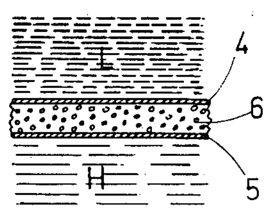


FIG.4

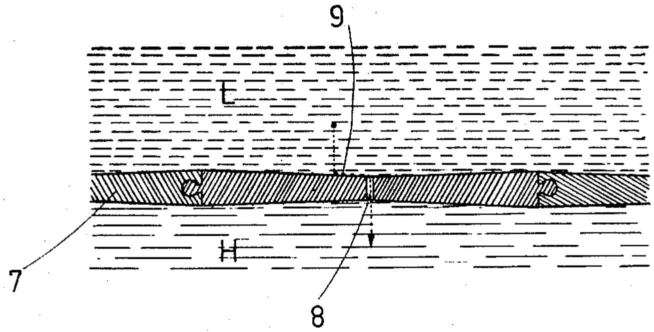


FIG.5

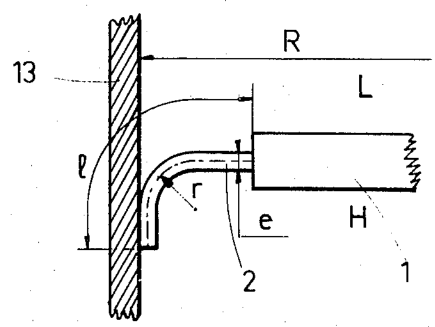


FIG.6

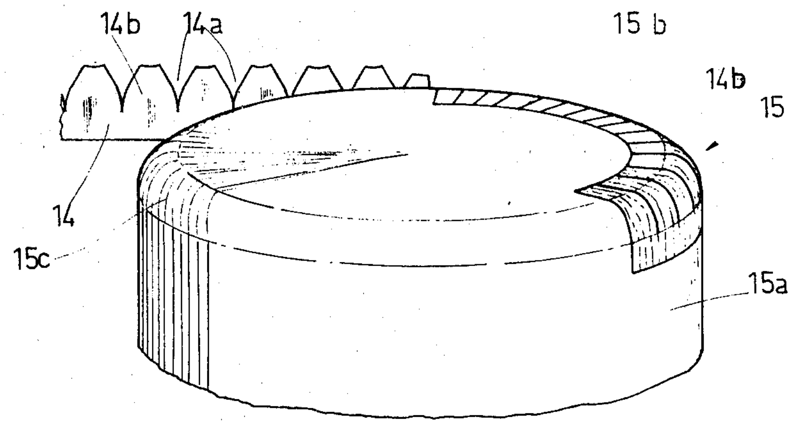


FIG. 6A

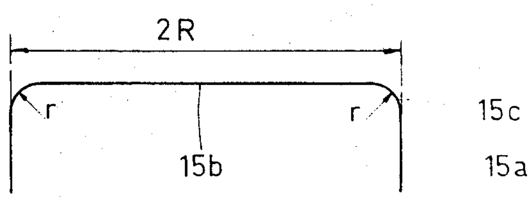


FIG.7

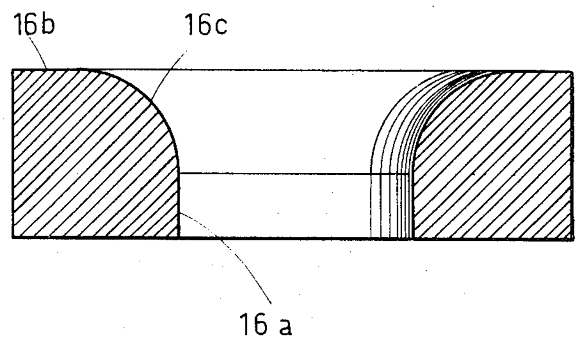
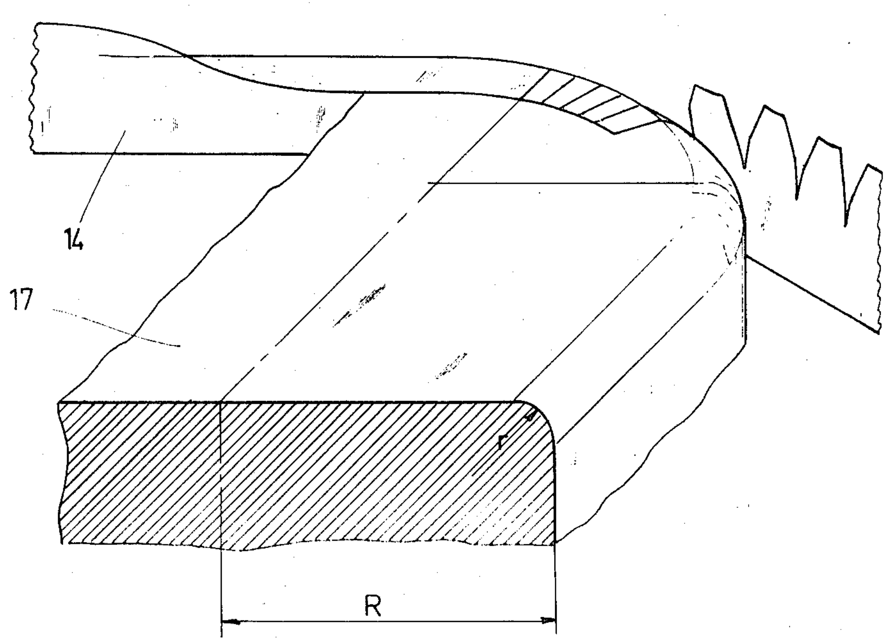


FIG.8



DEVICE FOR SEPARATING TWO LIQUIDS OF DIFFERENT DENSITIES IN A TANK CONTAINING THESE TWO LIQUIDS

It is known that a substantial cost reduction can be obtained in the building of large diametered and very high tanks, when the stored product is immiscible or only slightly miscible with water and higher than water, by giving these tanks substantially the shape of a cup turned upside down and at least partly immersed in water . The hydrostatic stresses exerted on the periphery of the tank are then reduced substantially and, consequently, the thickness of the tank walls can be substantially reduced.

It is also known that savings are achievable in the field of hydrocarbons delivery on shore by using a fluid under pressure, such as, for example, water, for permanently replenishing the volume which is left free in the tanks by hydrocarbons and for providing the displacement of the hydrocarbons which are to be delivered.

One of the main difficulties encountered is however that microbial colonies rapidly develop at the surface separating the two phases, specially when these two phases respectively consist of crude oil and sea water. Some of these colonies include bacteries whereby the sulfates which are normally present in water can be reduced and converted to hydrogen sulfide (H_2S), the latter being dissolved into the crude oil and being capable of developing an important corrosive action on the tank itself, when this tank is made of ordinary non-protected steel or of any other material which can be attacked by H_2S, and of corroding all the elements made of attackable material with which the crude oil may subsequently come into contact, such as pipes, ship tanks, onshore tanks, heat exchangers and boiler piping, before the first distillation of the crude oil.

Furthermore this dissolution phenomenon increases the sulphur content of the crude oil, which has preferably to be reduced.

Moreover, when there is a free interface between two liquids there are risks of the building of emulsions which may be stable under certain conditions, since the crude oil and the refined products may contain tensoactive materials which are likely to stabilize these emulsions.

Furthermore, when it is wished to store fuels containing water soluble materials, as this is the case for ternary fuels, the portion of these fuels which is soluble in water will be dissolved therein, thereby changing the characteristics of this fuel.

It is possible to separate the two liquids which for example consist of crude oil and sea water, by means of a flexible membrane tightly secured to the periphery of the tank, thereby avoiding any contact between the two liquids, this membrane being of course resistant to sea water and to the stored products, and flexible enough to be able to follow, without being subjected to any substantial stress, the variations in the level of the interface during the filling and emptying periods of the tank. If however there is produced a stress, even only a small one, due to a differential pressure between water and the stored product, there would be a possibility, in case of an accidental piercing of the membrane, that one liquid should flow into the other and this would lead back to the afore-mentioned problems of bacterial corrosion, of risks of emulsions and of dissolution.

It has been proposed, prior to the present invention, to build a rigid floating roof, similar to the metal floating roofs, which are currently used at the surface of the tanks, but which would have a specific gravity comprised between the respective specific gravities of the two liquids to be separated.

Such a solution has however never been used industrially to the best of our knowledge, since it requires in order to permit the free vertical displacement of said floating roof, a large peripheral clearance, this clearance leaving a non-negligible free interface between the two fluids to be separated, which results in the above-mentioned drawbacks: bacterial corrosion, risks of emulsions and of a dissolution of a fraction contained in one phase and soluble in the other.

The main object of the invention is accordingly to provide in a tank containing two fluids a separation between these fluids which introduces in the separating elements no stress or at most only a negligible one, due to the differential pressure between the two fluids, avoiding any fixation of the separating element to the periphery of the tank and leaving only an absolutely negligible interface between the two fluids.

This result is obtained, according to the invention, by inserting a floating, rigid or flexible, separating element between the stored product and the other fluid, said separating element being displaceable along the vertical wall of the tank with some peripheral clearance, compensated for by means of a very flexible sealing skirt fixed to said floating element at its periphery, this skirt being of reduced thickness so that it presses itself tightly against the tank wall and is capable of turning upwardly or downwardly along the tank wall, without any mixing of the two liquids when one proceeds from an emptying to a filling period of the tank and vice versa.

The floating element may be provided with orifices for the passage of filling or emptying pipes, the edges of said orifices being also provided with flexible sealing skirts.

The floating element and the skirt or skirts are so constituted as to have each an apparent density between d_1 and d_2, d_1 and d_2 being the respective densities of the two separate liquids.

In the case where these two liquids consist respectively of crude oil and sea water, this apparent density will be selected between 0.8 and 1.3 and preferably between 0.09 and 0.98.

Some non-limitative embodiments of the invention are illustrated in the attached drawings wherein :

FIG. **1** is a diagrammatic overall illustration of an embodiment of the invention;

FIG. **2** illustrates on a larger scale the peripheral portion of the floating element of FIG. **1**, showing in more detail the sealing skirt;

FIG. **3** illustrates an embodiment of the central part of this the element; decant;

FIG. **4** shows an improved embodiment of the central part of decant; floating element, in the case where the fluid stored in the tank contains suspended products, liable to decant.,

FIG. **5** is a partial enlarged view showing how the sealing between the two liquids is achieved; and

FIGS. **6**, **6A**, **7** and **8** illustrate processes for preforming the sealing skirt.

In the drawings, H designates the heavier fluid (for example sea water) and L the lighter one (for example crude oil).

In the overall diagrammatic illustration of an embodiment of the invention, shown in FIG. **1**, concerning for example a floating tank **13** used for offshore storage of crude oil, it is apparent that the floating element **1** may comprise as many sealing skirts **2** as required for the passage of vertical pipes, for example inlet and outlet pipes for the crude oil (pipes **10** and **11**) or pipes for discharging the rain water from the roof of the tank, if such a discharging device is used (pipe **12**).

FIG. **2** shows the detail of the periphery of the floating element, according to FIG. **1**, and particularly the flexible self-sustained skirt **3** separating the two liquids, the suitable density of which is obtained either by choosing a homogenous material like polyethylene or a polyvinylchloride (PVC)-polypropylene compound or any other aggregate of thermo-plastic materials and/or elastomers exhibiting the required properties of flexiblity, specific gravity and resistance to the separate fluids.

FIG. **3** shows an embodiment of the central part of the floating element, wherein a suitable average specific gravity, comprised between the above-indicated limits is obtained by using an aggregate of materials having a density respectively higher and lower than the selected average density, for example by constituting said floating element by two layers of glass resin stratified material **4** and **5** separated by a layer **6** of polyurethane foam, the specific gravity of which will be so selected as a function of the respective thicknesses of the different layers **4**, **5** and **6** and of the nature thereof, as to obtain the required average density.

The sealing skirt or skirts may be manufactured in a simple manner by extrusion using a flat drawing plate, by extruding and inflating the material constituting the skirt or by any other suitable means.The fixation of such a flexible skirt to the central part of the floating element may be effected by welding, sticking, or by any other suitable mechanical fixing means. This very flexible skirt of small thickness turns upwardly or downwardly along the tank wall when one proceeds from an emptying period of the tank (position shown in solid line in FIG. **2**) to a filling period of this tank (as shown in dotted line) and vice versa.

FIG. **4** shows a preferred but not limitative embodiment of the invention, wherein is used, by reason of the ease of manufacture, a homogenous material having the required specific gravity.

There can be used, for example, a high density polyethylene, when crude oil must be separated from sea water. Such a product having a density of 0.95 to 0.96, lying in the above-stated density range, has an excellent chemical resistance to oil products and to sea water, resists also very well to microbial colonies and may be employed economically using processes which are conventional in the art. It is possible, in particular, in the case of large sized floating elements to manufacture strips by extrusion, then join these strips together either by welding or sticking, or also, as in the illustrated embodiment, by mechanical assembling, using an extrusion drawing plate, these strips having profiled parts at their ends in the form of complementary male and female elements for the subsequent mechanical connection of the extruded strips with one another.

In some cases, it might be advantageous to give the profiled strips a variable thickness, so as to constitute in a way catch-drains which make it possible to drain the decanting products (for example sea water suspended in the crude oil) which might settle onto the separating element and enabling, by means of small openings through the bottom of the catch-drain, to return to the lower liquid the products suspended in the upper liquid which are heavier than this liquid.

Such an embodiment is illustrated in FIG. **4**, the floating element **7** being formed of strips having a regularly decreasing thickness from the edge to the center of the strip and being provided with central openings **8** which are or not regularly spaced from one another, enabling the decanting products **9** to be drained toward the lower liquid phase.

Such openings enabling the decanting products to be drained could not be provided in a flexible wall separating the two fluids if this wall was fixed along the periphery of the tank, because of the pressure difference of the two fluids on both sides of this wall, which would lead, as already indicated, to a substantial pollution of one fluid by the other one.

On the contrary, it is possible to provide with draining openings a floating element according to the invention, since such a floating element neither introduces nor is subjected to a substantial stress resulting from a differential pressure.

Such openings will only introduces a negligible interface. For example, in a tank having a diameter equal to 10 meters, which is equiped with a floating element having no sealing skirt, according to the prior art, a distance of 4 to 5 cm must be left between the internal wall of the tank and the edge of the floating element, so as to permit free displacement of the latter.

The interface which is left free by such a floating element has an area of about 1. 56 m^2, for an overall cross sectional area of the tank of about 78.6 m^2 and the ratio of this free interval to the overall area will be of about 2 percent, which is far from negligible.

On the contrary, if this tank is equiped with a flexible skirt according to the invention, leaving at the tank periphery an interface which is about 0.1 mm broad, the area of the interface will only be 31.4 cm^2 which corresponds to only 40 millionth of the overall area and is absolutely negligible.

In the embodiment wherein the central part of the floating element itself is constituted, as illustrated in FIG. **4**, by 1-meter broad strips provided in their central part with openings having a diameter of 1 cm, separated by 1 meter intervals, which may be deemed quite sufficient, the additional interface thus introduced will be 0.78 10^{-4} m^2 for each m^2 of the tank section, i.e. 0.0078 percent of this tank section, which is again negligible.

FIG. **5** is an illustration on a larger scale showing how the flexible skirt provides for sealing between the two fluids H and L. The flexible skirt **2** according to the invention which exerts substantially no stress in the material constituting the floating element **1**, when the level of the interface between the two liquids is stationary, also exerts only a negligible stress on this floating element when there is proceeded from a stand-by to an emptying or filling period and vice-versa, which has in particular the advantage of avoiding any risk of a pollution of the fluids one by the other through the draining openings 8 (FIG. 4) as indicated above.

As pointed out hereinabove, this sealing skirt 2 thus turns upwardly or downwardly along the tank wall solely under the action of the hydrostatic forces when there is proceeded from an emptying to a filling period and vice versa, if this skirt is given a thickness which is small enough.

It has been discovered that these results were obtained if the thickness of the sealing skirt 2 was smaller than or at most equal to the value e_{maxi} defined by the following formula:

$$e_{\mathrm{maxi}} = k(10^{-5}E)^{-1/3} \cdot \frac{R}{R+1} \cdot r$$

In this formula, R is the radius of curvature, expressed in centimeters, of the tank 13 at the place where the skirt 2 provides for sealing, *r* is the maximum radius of curvature of this skirt, expressed in centimeters, E is the average value of the modulus of elastcity for the bending of the material constituting the skirt 2, this modulus of elasticity being expressed in Newtons/m^2, k is a coefficient equal to $d_2 - d_m$, wherein d_2 is the density of the liquid phase H located at the lower part of the tank and d_m is the average density of the flexible skirt 3, (densities relative to water).

Moreover, the length *l* (FIG. 5) of the skirt 2 must be selected sufficient so that this skirt still provides for a separation between the two fluids L and H when the floating element 1 has been subjected to a horizontal translation and is no more centered within the tank 13.

However, for a skirt fixed along the periphery of a floating element, there will generally be selected a value of *l* comprised between $\pi/2\ r$ and $5\ r$, the value of *r* being smaller than the above-defined value R and being generally comprised between 1 and 30 cm for storage tanks of usual sizes.

The sealing skirt 2 may be manufactured with a preforming on a matrix of suitable shape, as hereinunder indicated.

FIG. 6 illustrates a method for manufacturing the flexible skirt 1 surrounding the floating element 1.

The flexible skirt 2 is than constituted by a strip 14 previously cut out by any suitable means, so as to form regularly spaced indentations. This strip is then formed on a matrix 15. This matrix, which is diagrammatically illustrated in FIG. 6A, has a cylindrical part 15*a* having an external diameter equal to the internal diameter 2R of the tank 13. This cylindrical part is connected to the upper part 15*b* of the matrix through a part 15*c* of toroidal shape, i.e. through a curved portion, the radius r of which has in this embodiment a substantially constant value, defining the performing radius of the sealing skirt. After the strip 14 has been placed on the matrix 15, as illustrated by FIG. 6, the adjacent cut out parts 14*b* are soldered together, using any known process, such as for example an ultrasonic soldering process, with or without addition of soldering material between these cut out parts, according to the method which has been selected for cutting strip 14.

In order to achieve a preadaptation of the sealing skirt 2, which provide for sealing around pipes such as pipes 10, 11 or 12 (FIG. 1), to their profile of equilibrium in operation, it is possible to also preform these skirts in a similar manner using a preforming matrix of suitable shape, such as the one illustrated in cross-section in FIG. 7, which is constituted by a cylindrical part 16*a* connected to a plane face 16, perpendicular to the axis of this cylindrical part, through a toroidal part 16*c*.

In the case wherein the tank has a polygonal cross section, that part of the sealing skirt located at the connection of two adjacent faces may be preformed according to the above-indicated process,as illustrated by FIG. 8, by application onto a mold 17 which may be similar to matrix 15 of FIG. 6 or only constituted by an angular sector of matrix 15.

Other methods for preforming the flexible skirt may obviously also be used, such as the processes of hot forming of the skirt 2 on a matrix, or also casting or molding processes, for example by injecting the material constituting this skirt into a mold adapted to the shape of the tank.

What we claim is:

1. A device for separating two liquids of different densities in a tank containing these two liquid one above the other, comprising a separating element of a density less than the density of the lower liquid and greater than the density of the upper liquid floating between these two liquids, said separating element being displaceable with some peripheral clearance along the wall of the tank and being provided at its periphery with a sealing skirt of a radial length exceeding the distance between the separating element and the wall of the tank, wherein said sealing skirt is of small thickness and great flexibility and is constituted of a material having a specific gravity intermediate between those of said liquids so as to be self-sustained at the interface of said liquids and to tangentially engage without substantial frictional force the lateral wall of the tank, being capable of turning upwardly or downwardly along the tank wall without the mixing of the two liquids and also without any substantial force, when the tank is switched from a filling to an emptying operation or vice-versa.

2. A device according to claim 1, wherein said separating element is provided with grooves for draining decanting products toward the liquid located below said separating element.

3. A device according to claim 1, wherein said separating element is provided with a flexible sealing skirt which is preformed along at least a part of its periphery, so as to be adapted to the curvature of the tank wall whereagainst this skirt is applied.

4. A device according to claim 1, wherein said separating element is provided with at least one opening for the passage there-through of a vertical pipe, the edges of these openings being also provided with a sealing skirt of small thickness and great flexibility constituted of a material having a specific gravity intermediate between those of said liquids so as to be self-sustaining at the interface of said liquids and to tangentially engage without substantial frictional force the lateral wall of the pipe, being capable of turning upwardly or downwardly along the pipe wall without the mixing of the two liquids and also without any substantial force, when the tank is switched from a filling to an emptying operation or vice-versa.

5. A device according to claim 4, wherein the sealing skirts with which are provided said orifices for the passage of the pipes are preadapted to their profile of equalibrium in operation.

6. A device for separating two liquids of different densities in a tank containing these two liquids one above the other, at least one of which constitutes a stored product, including a separating element of a density less than the density of the lower liquid and greater than the density of the upper liquid floating between these liquids, said separating element being displaceable with some peripheral clearance along the vertical wall of the tank, wherein said separating element is provided at its periphery with a very flexible sealing self-sustained skirt of reduced thickness and a specific gravity between those of said liquids capable of applying itself tightly against the vertical wall of the tank and of turning upwardly or downwardly along the tank wall without mixing of the two liquids, when there is proceeded from a filling to an emptying period of the tank and vice versa, said sealing skirt having a thickness at most equal to the value given by the formula:

$$e_{max}=k(10^{-5}E)^{-1/3}\frac{R}{R+1}r,$$

wherein E represents the average value of the modulus of elasticity for the bending of the material constituting said sealing skirt expressed in Newtons/m^2. R is the radius of curvature of the tank wall and r the maximum radius of the skirt at the place where this skirt provides for sealing, the radii R and r being both expressed in centimeters and k is a coefficient equal to $d_2 - d_m$, d_2 being the density of the heaviest of the two liquids separated by said flexible sealing skirt and d_m being the average density of this skirt.

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