The present invention relates to cross-corrugated packings. It applies particularly to air distillation columns on board floating oil platforms or barges.

As is well known, cross-corrugated packings are used in certain distillation columns in place of distillation plates to perform exchange of materials and heat between an upward stream of gas and a downward stream of liquid. These cross-corrugated packings consist of superposed sections. Each section is formed of a stack of corrugated strips each arranged in a vertical overall plane and one against the other. The corrugations are oblique and directed downwards in opposite directions from one strip to the next.

The strips generally comprise dense small-diameter perforations, with a degree of perforations of about 10%, to allow the liquid to pass right through the corrugated strips.

GB-A-1,004,046 and CA-A-1,095,827 describe such cross-corrugated packings.

A cross-corrugated packing is generally made from a flat product, namely metal sheets in the form of strips. The strips are first of all folded (or bent) so as to form a corrugated sheet in strip form, the corrugations of which are oblique with respect to the axis of the strip. The folded strips are then cut into sections, then stacked, inverting one strip in two, alternately. The packing sections thus obtained are often known as "packs".

WO-A-90/10 497 describes, among other things, a packing similar to the aforementioned cross-corrugated packings, but perforated in a different way. The term "cross-corrugated packing" as used here also comprises such a packing, as well as any similar packing.

Off-shore oil platforms produce residual gases. For economic and environmental reasons, it is becoming increasingly necessary to recover these gases. One method consists in converting them into heavier hydrocarbons, in liquid form, and which are therefore

easier to transport, using the Fischer-Tropsch process, which consumes large amounts of oxygen.

The basic problem that the invention sets out to solve consists in producing an air distillation column capable of operating under satisfactory conditions on board a platform or a barge, that is to say in the presence of oscillations due to the motion of the waves, and the amplitude of which is typically between 5° and 10° in all directions. An essential requirement is thus that the liquid distributed at the head of the column should wet the packing in a substantially uniform manner over the entire cross-section of the column, in spite of the aforementioned oscillations.

To this end, the subject of the invention is a corrugated strip for cross-corrugated packing, characterized in that it comprises, on its lower edge, when viewed face-on, at least one downwardly-projecting pattern, the contour of which is such that, if α_m and α_M denote the extrema of the algebraic value of the angle that the tangent to the contour makes with the horizontal direction, then

$$-\alpha_m > \alpha_0 \text{ and } \alpha_M > \alpha_0,$$

where α_0 denotes a predetermined angle at least equal to 5°.

The corrugated strip according to the invention may have one or more of the following features:

- the pattern repeats itself a number of times along the lower edge of the strip, the patterns being adjacent to one another or separated by essentially straight portions;

- each pattern is obtained by folding a flat strip into a corrugation of height H, of angle γ and of radius $\underline{r}$ at the crest of the corrugation, with the generatrices of the corrugations inclined by an angle δ, when viewed face-on, the parameters H, γ, $\underline{r}$ and δ being chosen such that

$$\frac{\sin\delta.\tan\mu.\sin\left(\frac{\gamma}{2}\right)+\cos\delta}{\sqrt{1+\tan^2\mu.\sin^2\left(\frac{\gamma}{2}\right)}} < \cos\ \alpha_0,$$

with $$\tan\mu=\tan\delta.\frac{\left[r.\sin\left(\frac{\gamma}{2}\right)+\frac{H}{2}-r\right]+\frac{\pi}{180}.\left(90-\frac{\gamma}{2}\right).\cos\left(\frac{\gamma}{2}\right)r}{\sin\left(\frac{\gamma}{2}\right).\left[r.\sin\left(\frac{\gamma}{2}\right)+\frac{H}{2}-r\right]+\cos^2\left(\frac{\gamma}{2}\right).r}$$

- each pattern is obtained by cutting two notches in the lower edge of the strip before folding it.

Another subject of the invention is a cross-corrugated packing section, comprising a stack of corrugated strips, at least one of which is as defined hereinabove, with their corrugations inclined in opposite directions alternately.

A further subject of the invention is a distillation column, which comprises superposed sections of cross-corrugated packing with at least two different angular orientations, at least one of the sections in particular being as defined hereinabove, and in which there is at least one direction that is such that the mean of the cosines of the angles that all of the strips of the sections make with this direction, the cosines being considered in terms of absolute values, is below 0.5.

When the column is on board a floating structure which has a preferred direction of oscillation, which is generally the case with barges, the said direction is this preferred direction of oscillation.

In particular, in one embodiment, the superposed sections consist of sections with strips parallel to the preferred direction of oscillation and of sections with strips perpendicular to this direction, the number of the latter being between about

2/3 and 3/4 of the total number of the said superposed sections.

Embodiments of the invention will now be described with reference to the appended drawings, in which:

- Figure 1 schematically represents a distillation column according to the invention, in axial part section;
- Figure 2 represents in perspective part of a section of cross-corrugated packing;
- Figure 3 is a schematic perspective of an inclined distillation column;
- Figure 4 schematically depicts the arrangement of the column of Figure 1;
- Figure 5 schematically depicts an alternative form, in a similar way;
- Figure 6 represents the shape of the corrugation of the strips of the cross-corrugated packing of Figure 2;
- Figure 7 represents a corrugated strip of the packing, viewed face-on;
- Figure 8 represents, to a larger scale, the lower edge of a strip of the packing; and
- Figures 9 and 10 schematically represent two alternative forms.

Figure 1 schematically represents an air distillation column 1 fixed to a barge 2 anchored to the sea bed. This barge, under the action of the wave motion, oscillates with a preferred direction of oscillation, illustrated by the double-headed arrow F and contained within the plane of the figure. The angle of inclination to the vertical of the axis X-X of the column may reach a predetermined maximum value α_0 at least equal to 5°, and typically of between 5 and 10°. In this range of oscillation, the column must provide satisfactory distillation.

Figure 1 schematically illustrates the internal arrangement of the upper part of the column 1. This upper part comprises superposed cross-corrugated packs

3, each of which has the shape of a cylindrical slab occupying the entire cross-section of the column.

Each pack 3 (Figure 2) is made up of a stack of corrugated strips 4 with oblique corrugations 5, these strips possibly being perforated over their entire surface area. Each strip 4 has a vertical general plane, all the strips are the same height, and the corrugations are inclined in one direction and in the other alternately from one strip to the next. Thus, the corrugations of the adjacent strips touch at a great many points of intersection.

There are two types of pack 3: packs 3A in which the strips 4A are oriented parallel to the preferred direction of oscillation F, that is to say to the plane of Figure 1, and packs 3B in which the strips 4B are oriented at right angles to the strips 4A.

All the packs 3 have the same number of strips 4, but the packs 3B are present in greater number than the packs 3A. In this example, there are twice as many packs 3B as there are packs 3A: the upper pack is a pack 3A, then, working downwards, there are two packs 3B, a pack 3A, two packs 3B, etc. Of course, this arrangement may repeat itself right along the length of the distillation column, that is to say the low-pressure column and the medium-pressure column when, as in this example, the device in question is a double air-distillation column.

In consequence, the liquid which flows down through the column, distributed at the head of the column over the entire cross-section thereof by a distributor 6, flows mainly over the strips that are perpendicular to the direction F, which strips effectively discourage the liquid from being deflected in the direction of inclination. The packs 3A discourage this deflection to a lesser extent but their presence is needed to ensure that the liquid is redistributed at right angles to the strips 3A at several levels down the column.

In general, the number of packs 3B may be between about 2/3 and 3/4 of the total number of packs.

The ability of the packing to resist the deflection of the liquid under the effect of the oscillation may be characterized by a magnitude known as the "liquid deflection factor", equal to d/i, where d denotes the mean angle of deflection of the liquid with respect to the axis X-X of the column while i denotes the angle of inclination of this axis to the vertical (Figure 3).

It can be shown that this deflection factor is proportional to the mean M of the cosines of the angles that all of the strips 4A and 4B make with the direction F, these cosines being considered in terms of absolute values. The proportionality factor depends only on the type of packing used.

With the conventional arrangement with alternating packs 3A and 3B, the mean M is 0.5 when the direction F corresponds to one of the two orientations of the strips, and exceeds 0.5 for any other direction F. For example, M = 0.71 for an inclination whose plane makes an angle $\theta = 45°$ with the planes of the corrugated strips.

In Figures 4 and 5, θ denotes the angle that the plane of oscillation makes with a reference plane, the line of which is assumed to be horizontal.

Figure 4 corresponds to the arrangement of two packs 3B - one pack 3A described above. $\theta = 0$ is the direction of the strips 4A. In this case, for $\theta = 0$, M = 0.33; for $\theta = 45°$, M = 0.71; and for $\theta = 90°$, M = 0.67. Thus, the deflection factor is reduced when the preferred direction of oscillation F is chosen such that $\theta = 0$ or a similar direction.

As an alternative, other arrangements may lead to a reduced deflection of the liquid. Thus, in the example of Figure 5, the packs alternately make an angle $x = +60°$ and $x = -60°$ with the reference direction $\theta = 0$. In this case, $\theta = 0$ gives M = 0.5, $\theta = 30°$ gives M = 0.43 and $\theta = 90°$ gives M = 0.87. It can

be seen that the deflection factor is reduced when the preferred direction of oscillation F is chosen such that $\theta = 30°$ or a similar direction. In this case there are, of course, two symmetric directions F which are suitable.

The construction of the lower edge of the strips 4A and 4B will now be described with reference to Figures 6 to 10.

When viewed end-on (Figure 6), each corrugation has a triangular overall shape, with straight flanks 7 which are symmetric with respect to the vertical direction D and rounded portions 8 at the crests of the corrugations. The corrugation is defined by its total height H measured parallel to the direction D, by its angle γ at the crests, and by the radius r of the rounded portions 8.

When viewed face-on (Figure 7), each strip 4 is a rectangle, the corrugations 8 of which are inclined by an angle δ with respect to the horizontal.

When the flat starting sheet is folded at the angle δ, by wrapping it around an appropriate oblique mandrel, its upper and lower edges assume a sawtooth shape, as represented in Figure 8 in the case of the lower edge. There is thus, when viewed face-on, on the lower edge, a series of downwardly-projecting protrusions 9. Compared with the horizontal direction oriented towards the right, the tangent to the contour of the protrusions varies between a negative minimum α_m and a positive maximum α_M.

When the liquid which trickles along the corrugated strip reaches its lower edge, each protrusion 9 constitutes a low point which encourages the liquid to drip onto the lower pack and prevents it from travelling as far as the end of the strip. For this phenomenon to occur irrespective of the inclination of the axis of the column, in any direction whatsoever, up to the aforementioned angle α_0 ($\alpha_0 \geq 5°$), the parameters H, r, γ and δ are chosen such that:

$$-\alpha_m > \alpha_0 \text{ and } \alpha_M > \alpha_0.$$

This can be obtained if the following condition is satisfied:

$$\frac{\sin\delta.\tan\mu.\sin\left(\frac{\gamma}{2}\right)+\cos\delta}{\sqrt{1+\tan^2\mu.\sin^2\left(\frac{\gamma}{2}\right)}} < \cos\alpha_0 \ ,$$

with

$$\tan\mu = \tan\delta.\frac{\left[r.\sin\left(\frac{\gamma}{2}\right)+\frac{H}{2}-r\right]+\frac{\pi}{180}.\left(90-\frac{\gamma}{2}\right).r}{\sin\left(\frac{\gamma}{2}\right).\left[r.\sin\left(\frac{\gamma}{2}\right)+\frac{H}{2}-r\right]+\cos^2\left(\frac{\gamma}{2}\right).r}$$

As represented in Figures 9 and 10, the existence of low points along the lower edge of the strips 4 for the on-board column can also be achieved by making along this lower edge, before the sheet is folded, a series of notches 10 which have any appropriate profile: arc of a circle or of an ellipse as depicted, but also polygonal, etc. These notches 10, which delimit the protrusions 9 between them, may be separated from one another by straight portions (Figure 8) or may be adjacent to one another (Figure 9).

In the case of Figure 9, $-\alpha_m = \alpha_M = 45°$, and, in Figure 10 $-\alpha_m = \alpha_M = 90°$. These values change somewhat after the sheet has been folded, but remain very much greater than the recommended values α_0 for the application in question, which values are between about 5 and 10°, as mentioned earlier.

As will be understood, the invention also applies to distillation columns which are stationary, but whose axis is not perfectly vertical.

* C L M S *

CLAIMS

1. Corrugated strip for cross-corrugated packing, characterized in that it comprises, on its lower edge, when viewed face-on, at least one downwardly-projecting pattern (9), the contour of which is such that, if α_m and α_M denote the extrema of the algebraic value of the angle that the tangent to the contour makes with the horizontal direction, then

$-\alpha_m > \alpha_0$ and $\alpha_M > \alpha_0$,

where α_0 denotes a predetermined angle at least equal to 5°.

2. Corrugated strip according to Claim 1, characterized in that the pattern (9) repeats itself a number of times along the lower edge of the strip (4), the patterns being adjacent to one another or separated by essentially straight portions (11).

3. Corrugated strip according to Claim 1 or 2, characterized in that each pattern (9) is obtained by folding a flat strip into a corrugation of height H, of angle γ and of radius r at the crest of the corrugation, with the generatrices of the corrugations inclined by an angle δ, when viewed face-on, the parameters H, γ, r and δ being chosen such that

$$\frac{\sin\delta.\tan\mu.\sin\left(\frac{\gamma}{2}\right)+\cos\delta}{\sqrt{1+\tan^2\mu.\sin^2\left(\frac{\gamma}{2}\right)}} < \cos\alpha_0,$$

with

$$\tan\mu=\tan\delta.\frac{\left[r.\sin\left(\frac{\gamma}{2}\right)+\frac{H}{2}-r\right]+\frac{\pi}{180}.\left(90-\frac{\gamma}{2}\right).\cos\left(\frac{\gamma}{2}\right)r}{\sin\left(\frac{\gamma}{2}\right).\left[r.\sin\left(\frac{\gamma}{2}\right)+\frac{H}{2}-r\right]+\cos^2\left(\frac{\gamma}{2}\right).r}$$

4. Corrugated strip according to Claim 1 or 2, characterized in that each pattern (9) is obtained by cutting two notches (10) in the lower edge of the strip before folding it.

5. Cross-corrugated packing section, characterized in that it comprises a stack of vertical corrugated strips (4), at least one of which is in accordance with any one of Claims 1 to 4, with their corrugations (8) inclined in opposite directions alternately.

6. Distillation column (1), characterized in that it comprises superposed sections of cross-corrugated packing (3A, 3B) with at least two different angular orientations, at least one of the sections in particular being in accordance with Claim 5, and in that there is at least one direction (F) that is such that the mean of the cosines of the angles that all of the strips (4A, 4B) of the sections make with this direction (F), the cosines being considered in terms of absolute values, is below 0.5.

7. Distillation column according to Claim 6, characterized in that it is on board a floating structure (2) which has a preferred direction of oscillation (F), and in that the said direction (F) is this preferred direction of oscillation.

8. Distillation column according to Claim 7, characterized in that the superposed sections consist of sections (3A) with strips (4A) parallel to the preferred direction of oscillation and of sections (3B) with strips (4B) perpendicular to this direction, the number of the latter being between about 2/3 and 3/4 of the total number of the said superposed sections.