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Boe et al.

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[54] **SUPPORTING PLATES FOR THE MEMBRANES OF A DIALYZER, PARTICULARLY FOR HEMODIALYSIS**

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[52] **U.S. Cl.** **210/321,** 210/541

[51] **Int. Cl.** **B01d 31/00**

[58] **Field of Search** 210/22, 321, 541; 23/258.5

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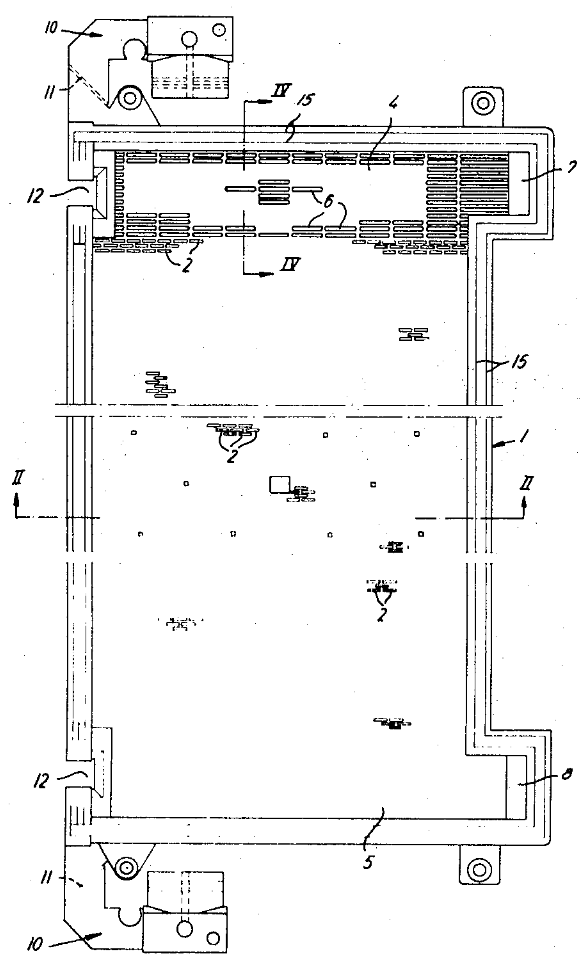
[57] **ABSTRACT**

For use in a dialyzer consisting of a stack of alternate pairs of membranes and supporting plates for these, a supporting plate is provided which has supporting projections arranged in a pattern such as to subdivide the path of flow from one end of the dialyzer to the other into a multitude of short longitudinal sections each connected at both ends through transverse flow paths with adjacent longitudinal sections at both sides thereof.

10 Claims, 8 Drawing Figures



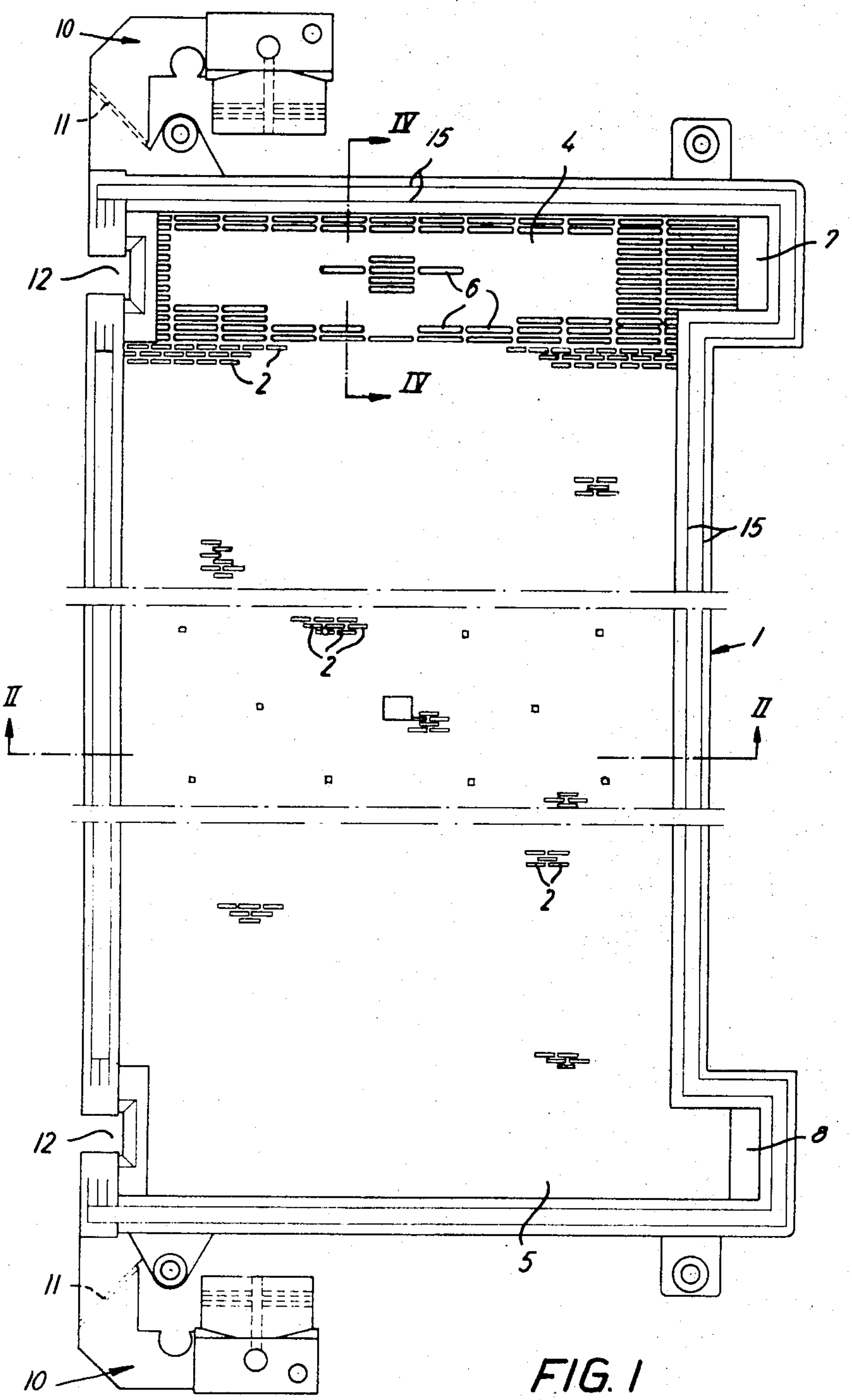


FIG. 1

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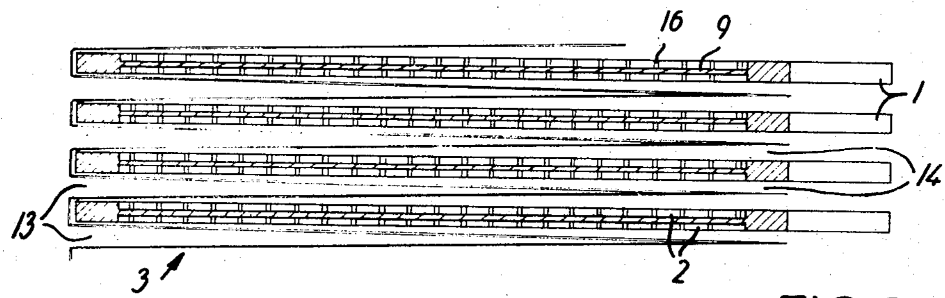

FIG. 2

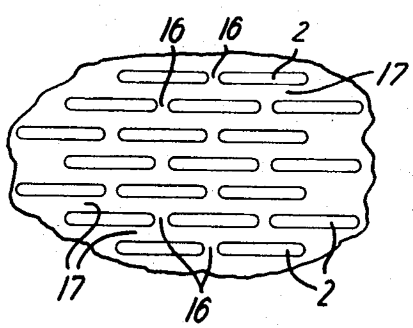

FIG. 3

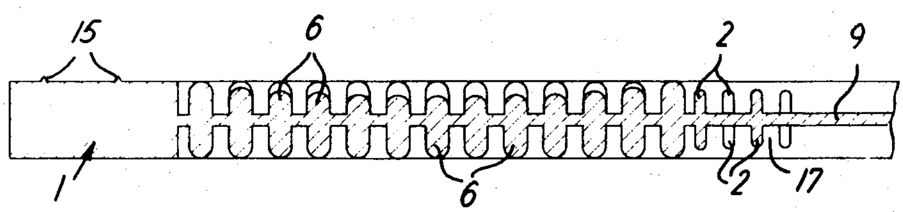

FIG. 4

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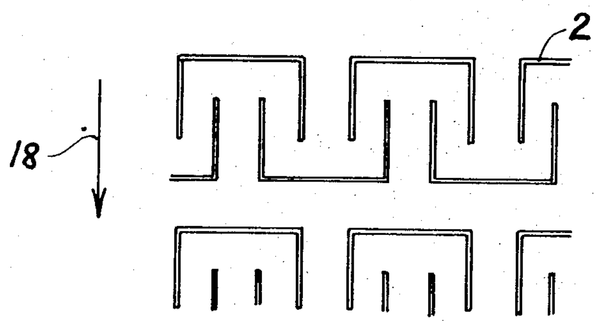

FIG. 5

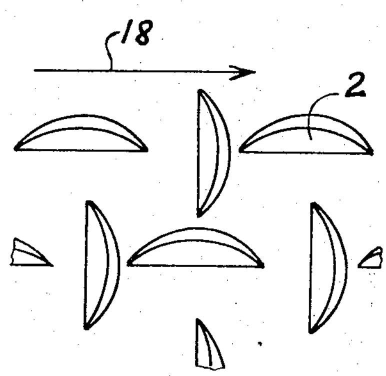

FIG. 6

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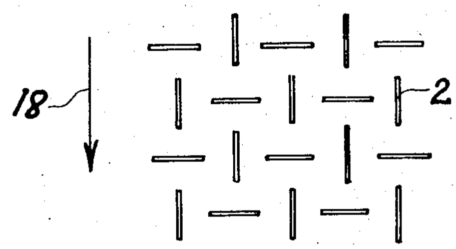

FIG. 7

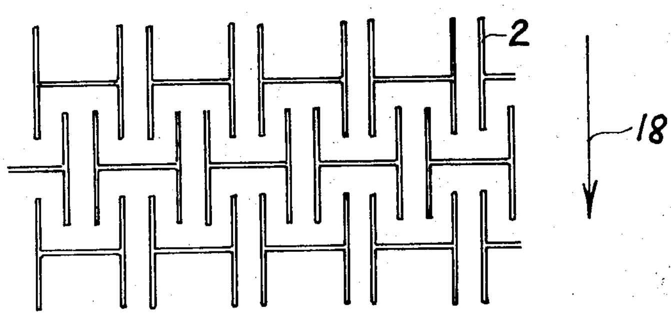

FIG. 8

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SUPPORTING PLATES FOR THE MEMBRANES OF A DIALYZER, PARTICULARLY FOR HEMODIALYSIS

BACKGROUND OF THE INVENTION

The invention relates to a supporting plate for the membranes of a dialyzer, particularly for hemodialysis, said plate being provided on both sides with projections adapted to support a membrane and in conjunction with such membrane to form flow paths for the dialysis liquid from one end of the sheet to the other, the blood flowing on the opposite side of the membrane in the same direction as the dialysis liquid or in the opposite direction.

Dialyzers of this kind usually comprise a plurality of membranes which are arranged in pairs between the said supporting plates so that the blood flows in a relatively thin layer between the two membranes of each pair. The dialysis liquid flows on the opposite side of the membranes in passages formed by the projections which at the same time support the membrane, the latter being slightly deformed between the projections and thereby forming corresponding passages for the flow of blood. The membranes may either be separate sheets or may be formed by a continuous length of suitable semipermeable material folded in zigzag between and around the edges of the supporting plates. The assembly of the stacked membranes and plates may be clamped together by means of bolts placed outside the periphery of the plates and the membranes.

In the known dialyzers, the projections of the plate are so constructed as to form continuous flow passages from one end of the plate to the other for both the dialysis liquid and the blood, the latter flowing in the passages formed by the bulging of the membranes between the projections. In the known dialyzers some of the passages may be sinuous, and parallel passages may be mutually connected.

SUMMARY OF THE INVENTION

According to the invention, in a dialyzer of the kind described, the projections of the supporting plates are constructed and arranged in a pattern subdividing each of the flow paths of the dialysis liquid into a multitude of short longitudinal path sections, each being obstructed at either end by a projection and communicating with a laterally offset longitudinal path section through a transverse path section.

It has been found that by arranging the projections in the pattern described a substantial improvement of the efficiency of the dialyzer is obtained, the efficiency being measured e.g., as the reciprocal value of the time required at a predetermined flow of blood and dialysis liquid and with a certain membrane area for obtaining a predetermined change of the concentration in the blood of a chemical compound or ion to which the membrane is permeable. Consequently the total membrane area of the dialyzer and thereby the size of the dialyzer may be reduced which again means that the volume of blood in the extracorporal circulatory system and the time of stay of the blood in the dialyzer are reduced so that the treatment is gentle to the patient. The reduction of the size of the dialyzer also results in a reduction of the manufacturing expenses which is of particular importance in the case of a disposable dialyzer.

One probable reason for the increased efficiency of the dialyzer according to the invention is that the projections arranged in the pattern described will prevent the membranes from bulging in such a manner as to form dead pockets extending continuously in the direction of flow. Besides the dialysis liquid and the blood are forced continually to change direction of flow from longitudinal to transverse. Owing to these circumstances the danger of formation of deposits is reduced and both flows of liquids will become very homogenous and uniform. A further factor contributing towards homogeneity and uniformity is the continual mixing of the individual parallel flows of blood resulting from the transverse flow between offset longitudinal path sections. It has also been found that obstruction of the flow passages owing to the formation of bubbles of air is practically eliminated because any such bubbles will be caught and taken along by the flowing liquids instead of being trapped by the walls of the flow passages, thereby to obstruct the flow so that the corresponding portions of the membrane area are put out of action.

Advantageously, each longitudinal path section communicates at each end thereof with longitudinal path sections laterally offset therefrom in both transverse directions. By this arrangement the tendency towards intermixing of the individual flows of blood is increased.

In a preferred embodiment of the invention the projections are constructed in the form of transverse rows of ribs separated by gaps defining the longitudinal path sections, the gaps of two consecutive rows of ribs being laterally offset from one another. In such a pattern where all the projections are rectilinear and parallel there will be a smooth and rounded transition between the longitudinal and the transverse path sections and there will be no sharp edges or dead corners with stagnant blood which would according to experience result in a risk of clotting with precipitation of fibrin. The distance at which the gaps of two consecutive rows of ribs are laterally offset from one another is equal to one half of the spacing of two consecutive gaps of each row, whereby all liquid particles will be caused to travel from one end of the dialyzer to the other along paths of practically the same length which contributes towards uniform and thereby optimum utilization of the membrane area.

It has been found that a spacing of two consecutive gaps of each row amounting to approximately five times the width of each gap will be suitable for obtaining a favourable mutual proportion of the lengths of the transverse and longitudinal flow path sections and also of the supported and the non-supported membrane areas with a view to obtaining the advantages mentioned above.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 shows a plane view of a supporting plate according to one embodiment of the invention before the plate is stacked in a dialyzer,

FIG. 2 a section along the line II—II in FIG. 1 showing four plates and a continuous membrane sheet folded therebetween, such as these parts will be located in the finished dialyzer, the plates and the membrane sections being, however, drawn apart to improve the illustration,

FIG. 3 a plane view on a larger scale showing a fraction of the supporting ribs of the plate shown in FIG. 1,

FIG. 4 a section on a larger scale along the line IV—IV in FIG. 1, and

FIG. 5–8 views corresponding to FIG. 3 of four examples of alternative patterns of projections.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The figures of the drawings are in part diagrammatical.

FIG. 1 shows a substantially rectangular supporting plate 1 which is provided on both faces with a multitude of supporting ribs 2 for a semipermeable dialyzer membrane 3, see FIG. 2. At the ends of the supporting area formed by the ribs 2 the plate is constructed at both ends with chambers 4 and 5 serving to distribute the dialysis liquid supplied to the dialyzer, and to collect the individual flows of dialysis liquid to be discharged from the dialyzer, respectively. In both chambers 4 and 5 ribs 6 are provided which are similarly constructed as the ribs 2, but have greater dimensions and a correspondingly greater spacing. To simplify the illustration, only some of the ribs 2 and 6 are shown, but it is to be understood that these cover the whole of the relevant areas of the surface of the plate in the patterns illustrated. At each of the chambers 4 and 5 one side edge of the plate is cranked outwards, and between the edge and the ribs 6 openings 7 and 8 are provided extending through the whole thickness of the plate. When a number of plates are stacked in the finished dialyzer, as diagrammatically illustrated in FIG. 2, with membranes 3 therebetween, and are clamped tightly together, the openings 7 and 8 of the individual plates from vertical passages extending through the whole stack of plates and being connected through openings in bottom and top plates, not shown, to an inlet conduit and an outlet conduit for the dialysis liquid, respectively. As is apparent from FIGS. 2 and 4, the ribs 2 and 6 are produced integrally with a plane body 9, e.g., by injection moulding, said body extending to the edge of the plate 1, with the exception of the openings 7 and 8.

At the longitudinal edge of the plate 1 remote from the openings 7 and 8 a connector element 10 for the supply and discharge of blood, respectively, is provided at each corner. By means of a hinged connection 11 each element 10 can be folded from the position shown in FIG. 1 to a position on top of the plate 1, where the element will overlap an incision 12 of the edge of the plate. Details of the connector element 10 and the components belonging thereto for controlling the supply and discharge of blood to and from the dialyzer are described in further detail in a copending application filed simultaneously with the present application. The specification of the said co-pending application should be regarded as part of the specification of the present invention.

FIG. 2 shows how the dialyzer is assembled from a continuous membrane sheet 3 and a number of plates 1 whereby, as likewise described in more detail in the said co-pending application, a number of pockets 13 are formed for the flow of blood between consecutive membranes, as well as a number of pockets 14 for the flow of the dialysis liquid along the opposite surface of each membrane. In the chamber 4 the dialysis liquid supplied through the opening 7 is distributed across the width of the plate 1, the liquid flowing in paths between the individual ribs 6 on the upper edge of which the membrane 3 is supported. To facilitate the distribution in the transverse direction, the body 9 of the plate 1, which in the zone of the opening 7 is preferably located in the middle of the thickness of the plate, may be located below the middle of the thickness at the opposite edge of the plate, i.e., in the zone of the incision 12, the ribs 6 being then constructed with correspondingly decreasing height from the right to the left on both sides of the body 9. The vertical height of the blood inlet chamber which is delimited between two membranes supported on the ribs 6 on the upper and lower face respectively of two adjacent plates 1 will then decrease correspondingly from the left to the right side of the plate. To avoid excessively sharp bends of the membrane which at the ends of the plates 1 is clamped between the sealing ribs 15, illustrated in FIG. 4, and the next plate above, it is preferable, however, that at least the ribs 6 most adjacent to the edge of the plate have a constant height, the height then decreasing uniformly towards the middle of the chamber 4 or 5, and thereafter increasing towards the transition to the primary dialysis area where the ribs 2 support the membranes. This is illustrated in FIG. 4.

As seen in FIGS. 1 and 4, the ribs 2 are arranged in transverse rows, gaps 16 being provided between the individual ribs of each row. Thus, a passage 17 extending transversely of the principal direction of flow of the dialysis liquid and the blood is formed between each two consecutive rows of ribs, the said passage 17 extending continuously from one edge of the effective membrane area to the opposite edge. Moreover, the individual rows of ribs 2 are preferably mutually offset at a distance such that the gaps 16 of each row of ribs are located directly opposite the middle of the ribs in the two adjacent rows such as illustrated in FIG. 3. A great number of parallel flow paths for the dialysis liquid are formed between the ribs 2, the body 9 and the membrane 3, each such flow path being composed of alternate longitudinal and transverse sections formed by the gaps 16 and parts of the passages 17, respectively. Since the membrane 3 engages the rounded edge of the ribs 2 under the influence of a pressure of the flow of blood above that of the flow of dialysis liquid, flow paths of similar configuration are on principle formed in the layers of blood between the pairs of membranes 3 present between consecutive supporting plates, though the ribs 2 will not necessarily form an absolute barrier to the flow of blood, viz. if the ribs 2 of consecutive supporting plates are kept at a slight distance from one another by suitable spacing means. Both the blood and the dialysis liquid will therefore during their flow through the dialyzer be forced repeatedly to change direction and there will be a continual mixing and exchange between the individual parallel flows. As explained above these occurrences, which are caused by the construction and placing of the ribs 2, have been found to result in a very efficient utilization of the membrane area. The membrane area required for a certain yield will thereby be correspondingly reduced. Experiments indicate that it will be possible to reduce the total area of the membrane of a hemodialyzer cell by between 25 and 50 percent as compared with a dialyzer cell used up to now. As an example of the dimensions of the supporting pattern of the plates, very good results have been obtained with a length of the ribs 2 to 4 mm and a minimum width of the gaps **16** of 1 mm, i.e., one-fifth of the rib spacing of the transverse row. The width or thickness of the ribs in the principal direction of flow was about 0.5 mm and the spacing in this direction about 1.5 mm, the width of the passages **17** thus likewise being about 1 mm. The height of the ribs **2** was about 0.8 mm while the thickness of the body **9** of the plate was about 1.1 mm. The total thickness of the plate **1** was 3.0 mm so that the ribs **2** on either side were retracted about 0.15 mm whereby the height of the layer of blood between two membranes supported by the ribs was about 0.3 mm.

In a dialyzer constructed as above described the blood in the individual pockets may flow in the same direction as the dialysis liquid or in the opposite direction. Theoretically, counter flow dialysis is somewhat more efficient, but in practice flow of the two liquids in the same direction will frequently be preferred because it then becomes possible to have a practically constant pressure difference across the membrane in the whole area thereof.

FIGS. **5–8** illustrate other examples of patterns of supporting projections according to the invention. In the patterns of FIGS. **5**, **7** and **8** the projections **2** are in the form of ribs similar to those of the embodiment illustrated in FIG. **3**. In the embodiment of FIG. **6**, the projections **2'** are of rounded configuration with a generally triangular cross section. In each of FIGS. **5–8** the direction of flow is indicated by an arrow **18.**

We claim:

1. A supporting plate for the membranes of a dialyzer, particularly for hemodialysis, said plate being provided within the active part of the plate, and on both sides thereof with projections adapted to support a membrane and in conjunction with such membrane to form flow paths for the dialysis liquid from one end of the plate to the other, the blood flowing on the opposite side of the membrane in the same direction as the dialysis liquid or in the opposite direction, characterized in that the projections are divided into first and second groups of projections, the projections of said first group being substantially perpendicularly arranged with respect to the projections of said second group, said groups of projection are constructed and arranged in a pattern subdividing each of the paths through which the dialysis liquid flows from one end of the dialyzer to the other into a multitude of short longitudinally extending path sections, said path section being arranged for enabling the dialysis liquid to flow along both lateral sides of each of the projections, each of said path sections being obstructed at each end thereof by a projection and communicating with a laterally offset longitudinal path section through a transverse path section.

2. A supporting plate as in claim **1**, characterized in that the projections of said first group are constructed in the form of transverse rows of ribs separated by gaps defining the longitudinal path sections, the gaps of two consecutive rows of ribs being laterally offset from one another.

3. A supporting plate as in claim **2**, characterized in that the distance at which the gaps of two consecutive rows of ribs are laterally offset from one another is equal to one half of the spacing of two consecutive gaps of each row.

4. A supporting plate as in claim **3**, in which the spacing of two consecutive gaps of each row is approximately five times the width of each gap.

5. A supporting plate as in claim **2**, in which the spacing of two consecutive gaps of each row is approximately five times the width of each gap.

6. A supporting plate as in claim **1**, characterized in that each longitudinal path section communicates at each end thereof with longitudinal path sections laterally offset therefrom in both transverse directions.

7. A supporting plate as in claim **6**, characterized in that the projections of said first group are constructed in the form of transverse rows of ribs separated by gaps defining the longitudinal path sections, the gaps of two consecutive rows or ribs being laterally offset from one another.

8. A supporting plate as in claim **7**, in which the spacing of two consecutive gaps of each row is approximately five times the width of each gap.

9. A supporting plate as in claim **7**, characterized in that the distance at which the gaps of two consecutive rows of ribs are laterally offset from one another is equal to one half of the spacing of two consecutive gaps of each row.

10. A supporting plate as in claim **9**, in which the spacing of two consecutive gaps of each row is approximately five times the width of each gap.

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