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Description

This invention relates to a travelling wave induction heater comprising a plurality of primary windings and associated core means, and means to connect successive windings to successive phases of a multi-phase electric supply to provide the primary of the travelling wave induction heater, whereby, in use, a travelling magnetic field is produced and there being an electrically conductive member, in which eddy currents are induced by the magnetic field, and which acts as a secondary of the heater and is thereby heated. Such a heater is referred to hereinafter as being of the kind specified. US—A—4 321 444 discloses a heater of the kind specified in which the secondary has areas of different electrical conductivity in a plane containing the direction of travel of the travelling magnetic field.

In such heaters, the heating of the secondary may not be uniform for a uniform primary winding distribution and the object of the invention is to overcome this problem.

According to one aspect of the present invention, this problem is overcome by providing a heater of the kind specified wherein the primary is arranged to cause current flow in surface layers of the secondary in loops parallel to the surface of the secondary and the distribution of said areas of different electrical conductivity is such as to provide a desired distribution of heating in the secondary.

The secondary may comprise at least part of a workpiece to be heated.

Alternatively, the secondary may comprise a heating member which, in use, heats a workpiece by heat transfer.

The secondary may comprise an element of ferro magnetic material, such as cast-iron, soft-iron, or steel, having at least one opening therein and/or area of different thickness.

The secondary may comprise a component of a relatively high electrical conductivity material such as copper or aluminium or zinc or brass, having at least one opening therein and/or area of material of lower conductivity and/or area of different thickness.

The component may comprise a single element or be fabricated from a plurality of elements.

The secondary may also comprise an element of ferro magnetic material such as cast-iron, soft-iron or steel alone or in combination with said component of relatively high electrical conductivity.

The component may be formed separately from the remainder of the secondary and may be secured thereto. Alternatively it may comprise a coating applied to the remainder of the secondary, for example by spraying.

Alternatively the component may comprise the whole of the secondary, particularly where the secondary comprises said heating member.

In one application of the invention the secondary comprises a mould of a moulding apparatus.

The mould may be positioned between a pair of relatively movable press members for the application of pressure to the mould.

According to another aspect of the invention we provide a method of providing a predetermined pattern of heating in a secondary of a heater of the kind specified in which the primary is arranged to cause current flow in surface layers of the secondary in loops parallel to the surface of the secondary and comprising the steps of providing a secondary having areas of different electrical conductivity in a plane containing the direction of travel of the travelling magnetic field, the distribution of said areas being such as to provide said predetermined pattern of heating in the secondary.

Examples of the invention will now be described, with reference to the accompanying drawings, wherein:—

Figure 1 is a diagrammatic perspective view of a primary of a heater embodying the invention;

Figure 2 is a diagrammatic perspective view of a secondary of a heater embodying the invention;

Figure 3 is a diagrammatic cross-section through another embodiment;

Figure 4 is an underneath plan view of the secondary of Figure 3;

Figures 5 to 8 are diagrammatic perspective views of the primary of other embodiments;

Figure 9 is a diagrammatic side elevation of moulding apparatus embodying the invention; and

Figure 10 is a cross-section through a still further embodiment.

Referring to Figures 1 and 2, a travelling wave induction heater embodying the invention comprises a primary core P having a plurality of iron laminations 10 which may be insulated to reduce eddy current effects and clamped together by nut and bolt fasteners 11 to provide a series of adjacent teeth 12 having coplanar pole faces 13. The teeth 12 are insulated in conventional manner and copper wire windings W are formed around the teeth with successive windings being connected to successive phases of a multi-phase supply. In the present example, the multi-phase supply is three-phase. If desired, the supply may be of other than three phase, although three phase supply is preferred as it is readily available. Also if desired, the winding may be any other pattern that produces a travelling field.

The thus formed primary is then embedded in epoxy resin (not shown) in conventional manner and a terminal box (not shown) is provided for connection to the multi-phase supply.

A workpiece is indicated at 20 and, in the present example, comprises a block of steel to be heated. In order that the block of steel is heated uniformly, a sheet of copper is secured to the under surface of the block 20 as indicated at 21. The sheet 21 may be secured to the under surface of the block 20 by any desired means, such as by brazing. The sheet 21 thus provides a component of a secondary so that the sheet 21 and block 20 together comprise the secondary of the travelling

wave induction heater of which P is the primary core.

The sheet 21 has a series of rectangular openings 22 formed therein, the longer axes of which extend at right angles to the direction of motion of the field. In Figure 2 only a small number of openings is shown for clarity. It is found in practice, that by providing the sheet 21 with the openings 22 therein, that the heating of the block 20 is more uniform.

Instead of providing the sheet component 21 with the openings 22, the sheet 21 could be of composite construction comprising a relatively high conductivity copper in a region corresponding to the unapertured parts of the sheet 21 and a material of lesser conductivity, such as iron, in a region corresponding to the apertures 22.

Further alternatively, the sheet 21 could be of different thickness in regions corresponding to the unapertured parts of the sheet 21 and the aperture parts of the sheet 21 to achieve the desired variation in conductivity.

Another embodiment is shown in Figures 3 and 4 in which the primary P is as described above. The secondary is formed in two components 24 and 25 in facial contact, the component 25 having a relatively low conductivity such as iron or steel as described above, and the component 24 having a relatively high conductivity such as copper, aluminium etc. as described above. Grooves 26 extending at right angles to the direction of motion of the field are formed in the component 24. Moreover, the edges of the component 24 are provided with copper or other low resistivity areas 27 which extend in the direction of motion of the field. These three features can be used singly or in any combination.

The above described embodiments have a primary core in which the pole faces 13 are arranged in a plane and in which the field travels along the plane at right angles to the teeth 12.

Other primary and secondary configurations are possible.

Figure 5 shows another arrangement in which the primary P₁ is annular and has annular laminations L, and there being coils C lying in radial slots Q₁ together with an annular secondary not shown. Such a configuration provides a field which travels around the circumference of the annulus. The operation is the same as in the example described above, and one or more of the refinements shown in Figures 3 and 4 can be incorporated in the arrangements of Figure 5.

Figure 6 shows a further arrangement in which the primary P₂ is a generally cylindrical configuration with the teeth Q₂ extending parallel to the central axis of the cylinder and disposed side by side around the cylindrical surface thereof. The secondary (not shown) is of complementary configuration and the field travels around the circumference of the cylinder.

Figure 7 shows a further arrangement in which the primary P₃ is again of generally cylindrical configuration but with the teeth Q₃ extending circumferentially of the cylinder and being dis-

posed axially side by side around the cylindrical surface thereof. The secondary is of complementary configuration and the field travels along the axis of the cylinder.

Figure 8 shows a still further arrangement in which the primary P₄ is of annular configuration but with the teeth Q₄ also being annular so that the field travels radially. For clarity, only a segment of the circular cone is shown. Again a secondary of complementary configuration is provided.

The primaries of the embodiments illustrated in Figures 5 to 8 may extend around only part of a circle instead of the full circle as illustrated. Other primary and secondary configurations are possible other than those illustrated and a primary configuration is selected which is most suitable for the application concerned. For example, to heat tubes for example in an extrusion operation, the configuration shown in Figure 6 or Figure 7 would be selected. In all cases the secondary has a configuration complementary to that of the primary and may, for example, be provided with a series of grooves extending parallel to the pole pieces of the primary and perpendicular to the direction of movement of the field to provide a desired distribution of heating.

In another arrangement (not shown), the construction is similar to that of a motor with a cylindrically extending stator, but the rotor is replaced by a body part again formed from electrically conductive material and within which the eddy currents are generated. One end of the body part can be closed, so that the arrangement can be used to heat a liquid contained within the body part.

Referring now to Figure 9, a moulding press comprises a fixed press head 31 and a lower press head 32 movable vertically towards and away from the press head 31. The press head 31 has secured thereto a layer of electrically non-conductive and thermally insulating material 33 and a wear plate 34 of suitable material such as stainless steel. The primary windings of a heater, such as that described with reference to Figure 1, are mounted on the press head 32 as indicated at 35 and is also provided with a layer of electrically non-conductive thermal insulating material 33a, and a wear plate 34a similar to the wear plate 34.

A mould comprising a plurality of cavities for articles to be moulded is indicated at 36 and is removably engageable between the press heads 31 and 32. In use, the press head 32 is moved upwardly towards the press head 31 to apply pressure to the mould and the windings of the heater 35 are energised so that the mould acts as the secondary of the heater and is thereby heated.

In order that uniform heating of the mould is achieved, the lower surface 37 of the mould adjacent the heater primary 35 has sprayed thereon a layer of copper of high electrical conductivity to provide a component 38 of the secondary which defines a rectangular pattern having rectangular openings therein, similar to the openings 22 in the plate 21. This pattern of

high electrically conductive material ensures that a uniform heating of the mould is achieved.

If desired, instead of spraying the high electrically conductive material on the mould, the component 38 could be provided with a separately formed sheet of the same configuration which may be secured to the mould in any desired manner.

In a further embodiment of the invention illustrated in Figure 10, a heater comprises a primary 40 of the same construction as the primary 10 described with reference to Figure 1. Permanently mounted on the primary 40 is a secondary component 41 of copper and thermally insulated from the primary by a layer of non-electrically conductive thermally insulating material 42. The secondary component 41 is made as a sheet of high electrical conductivity material such as copper and is provided with rectangular openings 43. A wear plate, such as of stainless steel 44 is provided over the secondary component 41. In use, a workpiece to be heated is placed on top of the wear plate 44 and is heated primarily by heat transfer from the secondary component 41. By virtue of providing the openings 43 in the secondary component 41, a uniform heating effect is achieved in the workpiece. The secondary component 41 may be of any other configuration as described above in embodiments described with reference to Figures 1 to 4.

The secondary components may be of the same external configuration as described above but have a different pattern of opening or other region(s) of lower electrical conductivity therein, determined empirically to achieve a desired heating distribution. If desired, a secondary may be made of the same material, e.g. cast-iron, soft-iron, or steel, throughout its extent, the distribution of areas of different electrical conductivity being achieved by providing openings or regions of reduced thickness in the secondary, for example, of any of the configurations described hereinbefore in connection with the preceding embodiments.

The features disclosed in the foregoing description, or the following claims, or the accompanying drawings, expressed in their specific forms or in terms of a means for performing the disclosed function, or a method or process for attaining the disclosed result, or a class or group of substances or compositions, as appropriate, may, separately or any combination of such features, be utilised for realising the invention in diverse forms thereof.

Claims

1. A travelling wave induction heater comprising a plurality of primary windings (W) and associated core means (P), means to connect successive windings to successive phases of a multi-phase electric supply to provide the primary of the travelling wave induction heater, and an electrically conductive member which provides the secondary of the heater, the secondary (20,

21; 24, 25; 36, 38; 41) having areas of different electrical conductivity in a plane containing the direction of travel of the travelling magnetic field, characterised in that the primary is arranged to cause current flow in surface layers of the secondary in loops parallel to the surface of the secondary and the distribution of said areas of different electrical conductivity is such as to provide a desired distribution of heating in the secondary.

2. A heater according to Claim 1 wherein the secondary (20, 21; 24, 25; 38; 41) comprises at least part (21, 24, 38) of a workpiece (20, 25, 36) to be heated.

3. A heater according to Claim 1 wherein the secondary (41) comprises a heating member which, in use, heats a workpiece by heat transfer.

4. A heater according to any one of the preceding claims wherein the secondary comprises an element of ferro magnetic material, having at least one opening therein and/or area of different thickness.

5. A heater according to any of the preceding claims wherein the secondary (20, 21; 24, 25; 36, 38; 41) comprises a component (21, 24, 38, 41) of a relatively high electrical conductivity material such as copper or aluminium or zinc or brass, having at least one opening (22, 26, 43) therein and/or area of material of lower conductivity and/or area of different thickness.

6. A heater according to Claim 5 wherein the component (21, 24, 38, 41) comprises a single element.

7. A heater according to Claim 5 wherein the component (21, 24, 38, 41) is fabricated from a plurality of elements.

8. A heater according to any one of Claims 5 to 7, wherein the secondary (20, 21; 24, 25; 36, 38; 41) also comprises an element (20, 25, 36) of ferro magnetic material such as cast-iron, soft-iron or steel.

9. A heater according to any one of Claims 5 to 8 wherein the component (21, 24) is formed separately from the remainder of the secondary and secured thereto.

10. A heater according to any one of Claims 5 to 8 wherein the component (38) comprises a coating applied to the remainder (36) of the secondary (36, 38).

11. A heater according to any one Claims 5 to 8 wherein the component (41) comprises the whole of the secondary.

12. A heater according to any one of the preceding claims wherein the secondary (38, 36) comprises a mould of a moulding apparatus.

13. A method of providing a predetermined pattern of heating in a secondary (20; 21, 24; 25; 36; 38; 41) of a travelling wave induction heater in which the primary is arranged to cause current flow in surface layers of the secondary in loops parallel to the surface of the secondary and comprising the steps of providing a secondary having areas of different electrical conductivity in a plane containing the direction of travel of the travelling magnetic field, the distribution of said

areas being such as to provide said predetermined pattern of heating in the secondary.

Patentansprüche

1. Wanderwellen-Induktionsheizgerät, bestehend aus einer Mehrzahl von Primärwicklungen (W) und zugehörigen Kernen (P), Mitteln zum Verbinden aufeinander folgender Windungen mit aufeinanderfolgenden Phasen einer mehrphasigen elektrischen Versorgungsquelle zur Bildung der Primärseite des Wanderwellen-Induktionsheizgerätes und einem elektrisch leitfähigen Element, das die Sekundärseite des Heizgerätes bildet, wobei die Sekundärseite (20, 21; 24, 25; 36, 38; 41) Bereiche unterschiedlicher elektrischer Leitfähigkeit hat in einer Ebene, die die Bewegungsrichtung des wandernden magnetischen Feldes beinhaltet, dadurch gekennzeichnet, daß die Primärseite angeordnet ist zur Verursachung eines Stromflusses in Oberflächenschichten der Sekundärseite in Schleifen parallel zu der Fläche der Sekundärseite und die Verteilung der Bereiche unterschiedliche elektrische Leitfähigkeit derart ist, das eine gewünschte Wärmeverteilung auf der Sekundärseite bewirkt wird.

2. Heizgerät nach Anspruch 1, wobei die Sekundärseite (20, 21; 24, 25; 36, 38; 41) wenigstens einen Teil (21, 24, 38) eines zu erwärmenden Werkstücks (20, 25, 26) beinhaltet.

3. Heizgerät nach Anspruch 1, wobei die Sekundärseite (41) ein Heizelement aufweist, das, bei Verwendung, ein Werkstück durch Wärmetransfer erwärmt.

4. Heizgerät nach einem der vorangehenden Ansprüche, wobei die Sekundärseite ein Element aus einem ferromagnetischen Material aufweist, das mit wenigstens einer Ausnehmung und/oder einem Bereich unterschiedlicher Dicke versehen ist.

5. Heizgerät nach einem der vorangehenden Ansprüche, wobei die Sekundärseite (20, 21; 24, 25; 36, 38; 41) eine Komponente (21, 24, 38, 41) aus einem Material mit relativ hoher elektrischer Leitfähigkeit wie Kupfer oder Aluminium oder Zink oder Messing hat, mit wenigstens einer Öffnung (22, 26, 43) in dieser und/oder einem Material von geringerer Leitfähigkeit und/oder einem Bereich unterschiedlicher Dicke.

6. Heizgerät nach Anspruch 5, wobei die Komponente (21, 24, 38, 41) ein einzelnes Element aufweist.

7. Heizgerät nach Anspruch 5, wobei die Komponente (21, 24, 38, 41) aus einer Mehrzahl von Elementen hergestellt ist.

8. Heizgerät nach einem der Ansprüche 5 bis 7, wobei die Sekundärseite (20, 21; 24, 25; 36, 38; 41) weiter ein Element (20, 25, 36) aus einem ferromagnetischen Material wie Gußeisen, Weicheisen oder Stahl aufweist.

9. Heizgerät nach einem der Ansprüche 5 bis 8, wobei die Komponente (21, 24) gesondert von dem Restteil der Sekundärseite ausgebildet und an diesem befestigt ist.

10. Heizgerät nach einem der Ansprüche 5 bis 8,

wobei die Komponente (38) eine auf den Restteil (36) der Sekundärseite (36, 38) aufgebrachte Beschichtung aufweist.

11. Heizgerät nach einem der Ansprüche 5 bis 8, wobei die Komponente (41) die gesamte Sekundärseite beinhaltet.

12. Heizgerät nach einem der vorangehenden Ansprüche, wobei die Sekundärseite (38, 36) eine Gußform einer Gießvorrichtung beinhaltet.

13. Verfahren zur Bildung eines vorgegebenen Erwärmungsmusters auf der Sekundärseite (20, 21; 24, 25; 36, 38; 41) eines Wanderwellen-Induktionsheizgerätes, bei dem die Primärseite zur Verursachung eines Stromflusses in Flächenschichten der Sekundärseite in Schleifen parallel zu der Fläche der Sekundärseite ausgebildet ist und die Schritte der Schaffung einer Sekundärseite mit Bereichen unterschiedlicher elektrischer Leitfähigkeit in einer Ebene, die die Richtung der Bewegung der Wanderwellen beinhaltet, aufweist, wobei die Verteilung der Flächen derart ist, daß das vorgegebene Erwärmungsmuster auf der Sekundärseite erzeugt wird.

Revendications

1. Un dispositif de chauffage à induction à propagation d'ondes comportant une pluralité d'enroulements primaires (W) et des moyens de noyaux associés (P), des moyens pour connecter des enroulements successifs à des phases successives d'une alimentation électrique polyphasée pour constituer le primaire du dispositif de chauffage à induction à propagation d'ondes et un élément conducteur électrique qui constitue le secondaire du dispositif de chauffage, le secondaire (20, 21; 24, 25; 36, 38; 41) comprenant des surfaces de conductivité électrique différente dans un plan contenant la direction de propagation du champ magnétique se propageant, caractérisé en ce que le primaire est agencé de manière à induire une circulation de courant dans des couches superficielles du secondaire, en boucles parallèles à la surface du secondaire et en ce que la répartition desdites surfaces de conductivité électrique différente est prévue pour fournir une répartition souhaitée de la chaleur dans le secondaire.

2. Un dispositif de chauffage selon la revendication 1 dans lequel le secondaire (20, 21; 24, 25; 36, 38; 41) comporte au moins une partie (21, 24, 38) d'un ouvrage (20, 25, 36) devant être chauffé.

3. Un dispositif de chauffage selon la revendication 1 dans lequel le secondaire (41) comporte un élément de chauffage qui, à l'emploi, chauffe un ouvrage par transfert de chaleur.

4. Un dispositif de chauffage selon l'une quelconque des revendications précédentes dans lequel le secondaire comporte un élément en matériau ferro-magnétique, sur lequel est aménagée au moins une ouverture et/ou une surface d'épaisseur différente.

5. Un dispositif de chauffage selon l'une quelconque des revendications précédentes dans lequel le secondaire (20, 21; 24, 25; 36, 38; 41)

comporte une composant (21, 24, 38, 41) en un matériau de conductivité électrique relativement élevée tel que du cuivre ou de l'aluminium ou du zinc ou du laiton, dans lequel est aménagée au moins une ouverture (22, 26, 43) et/ou une surface en un matériau de conductivité plus faible et/ou une surface d'épaisseur différente.

6. Un dispositif de chauffage selon la revendication 5 dans lequel le composant (21, 24, 38, 41) comporte un élément unique.

7. Un dispositif de chauffage selon la revendication 5 dans lequel le composant (21, 24, 38, 41) est fabriqué à partir d'une pluralité d'éléments.

8. Un dispositif de chauffage selon l'une quelconque des revendications 5 à 7 dans lequel le secondaire (20, 21; 24, 25; 36, 38; 41) comporte aussi un élément (20, 25, 36) en un matériau ferromagnétique tel que la fonte, le fer doux ou l'acier.

9. Un dispositif de chauffage selon l'une quelconque des revendications 5 à 8 dans lequel le composant (21, 24) est formé séparément du reste du secondaire et fixé à celui-ci.

10. Un dispositif de chauffage selon l'une quelconque des revendications 5 à 8 dans lequel le

composant (38) comporte un revêtement appliqué au reste (36) du secondaire (36, 38).

11. Un dispositif de chauffage selon l'une quelconque des revendications 5 à 8 dans lequel le composant (41) constitue l'ensemble du secondaire.

12. Un dispositif de chauffage selon l'une quelconque des revendications précédentes dans lequel le secondaire (38, 36) comporte un moule d'une appareil de moulage.

13. Un procédé pour produire une répartition prédéterminée de chauffage dans un secondaire (20, 21; 24, 25; 36, 38; 41) d'un dispositif de chauffage à induction à propagation d'ondes dans lequel le primaire est agencé pour induire une circulation de courant dans des couches superficielles du secondaire en boucles parallèles à la surface du secondaire et comprenant les étapes prévoyant un secondaire ayant des surfaces de conductivité électrique différente dans un plan contenant la direction de propagation du champ magnétique se propageant, la répartition desdites surfaces étant prévues pour fournir ladite répartition de chaleur dans le secondaire.

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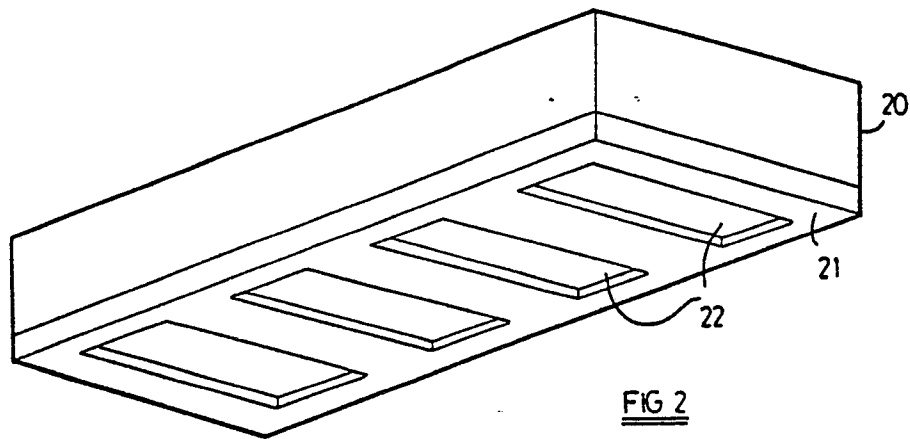
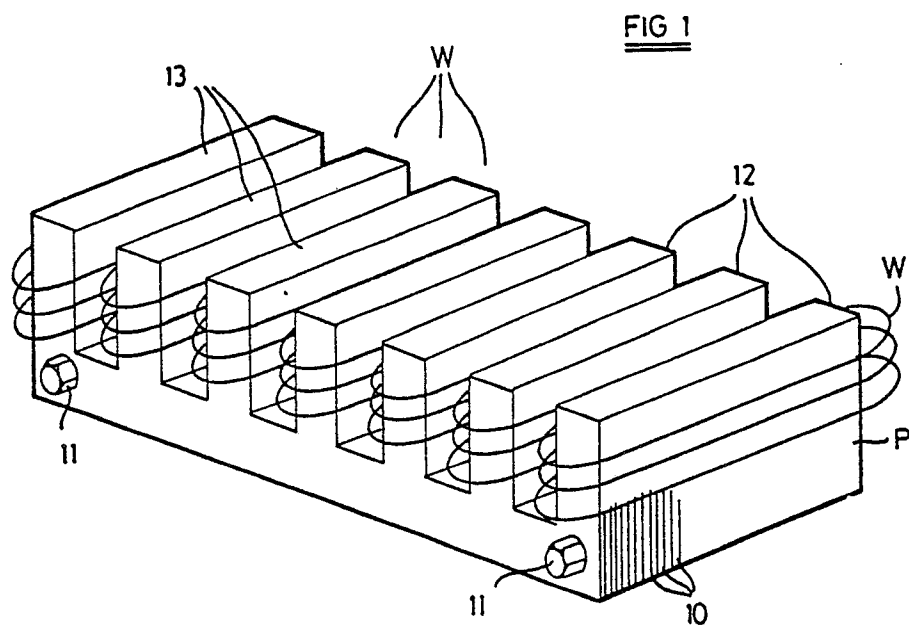
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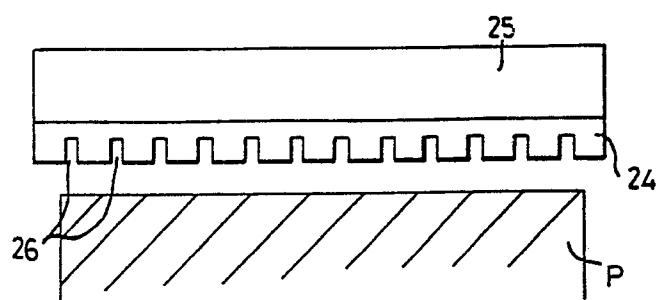


FIG 3

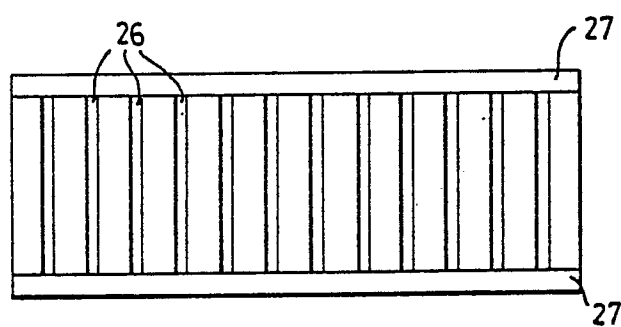


FIG 4

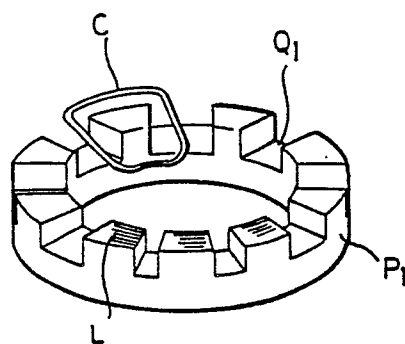


FIG 5

