US 20060091017A1

(19) **United States**

(12) **Patent Application Publication** (10) **Pub. No.: US 2006/0091017 A1**

Lam (43) **Pub. Date: May 4, 2006**

(54) ELECTROLYSIS PROCESS AND CELL FOR USE IN SAME

(75) Inventor: **Chung Ho Lam**, Croydon (AU)

Correspondence Address:
SEYFARTH SHAW LLP
55 E. MONROE STREET
SUITE 4200
CHICAGO, IL 60603-5803 (US)

(73) Assignee: **Intec Ltd**, Sydney, New South Wales (AU)

(21) Appl. No.: **10/531,862**

(22) PCT Filed: **Oct. 21, 2003**

(86) PCT No.: **PCT/AU03/01393**

(30) **Foreign Application Priority Data**

Oct. 21, 2002 (AU) 2002952181

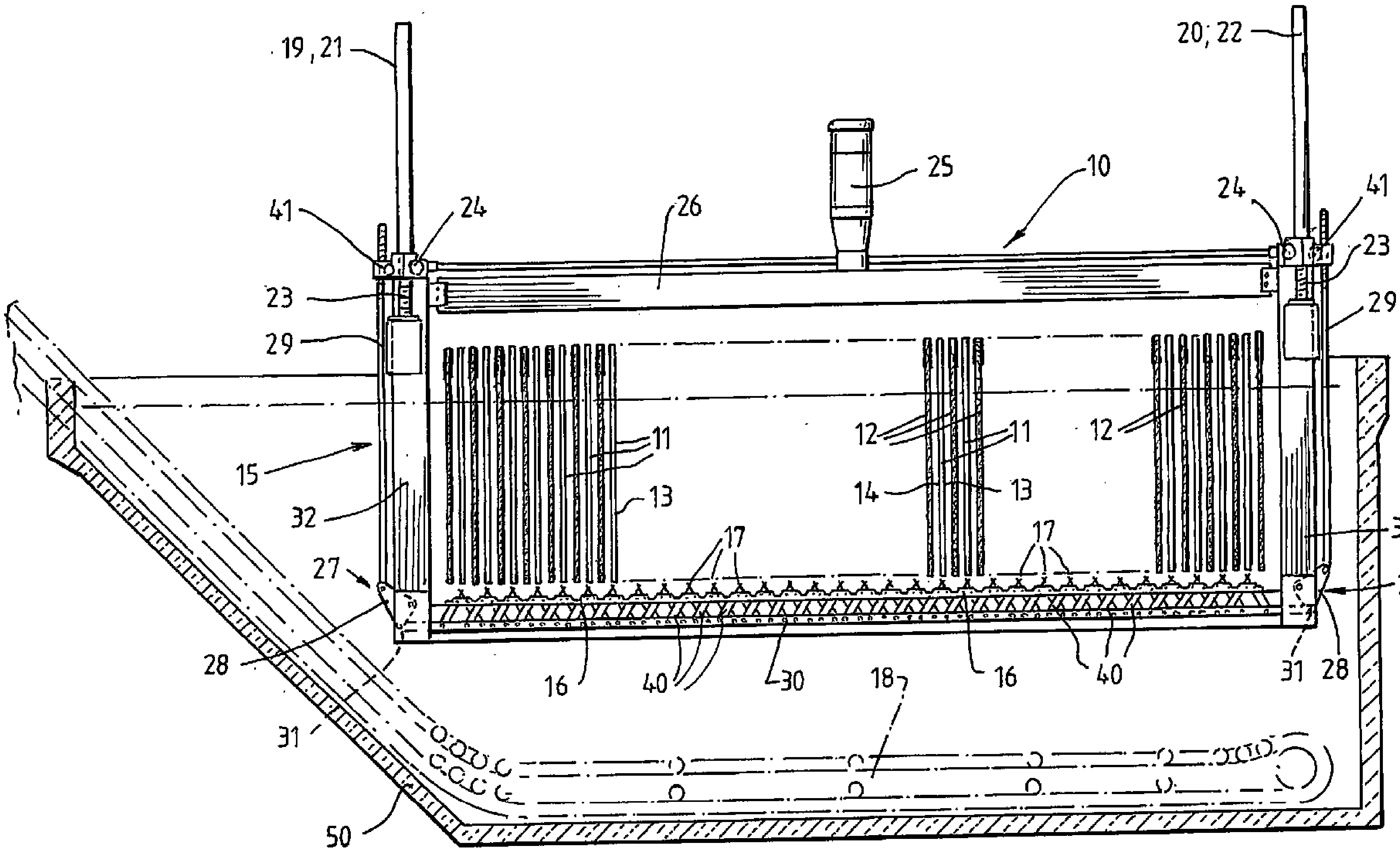
Publication Classification

(51) **Int. Cl.**
C25D 5/18 (2006.01)
C25C 7/02 (2006.01)

(52) **U.S. Cl.** **205/102**; 204/280

(57) ABSTRACT

An electrolysis process for the recovery of metal from an aqueous solution is defined. On electrolysing the solution metal is caused to deposit on a deposition surface of a cathode. The process includes the step of inducing a non-uniform current density across the deposition surface so as to form areas of high current density interspaced by areas of low current density. The difference between the areas of high current density and low current density is sufficient to cause metal deposition to be concentrated on the areas of high current density so as to promote non-uniform deposition of metal across the deposition surface. An electrolysis cell for the electro-recovery of metal from an aqueous solution is also defined. The cell includes a cathode which includes a deposition surface on which metal is deposited on electrolysing of the aqueous solution. In operation of the cell, the deposition surface has a non-uniform electrical field having areas of strong electrical field interspaced by areas of weak electrical field. The difference between the areas of strong electrical field and weak electrical field is sufficient to cause metal deposition to be concentrated on the areas of high electrical field so as to promote non-uniform deposition of metal on the surface.



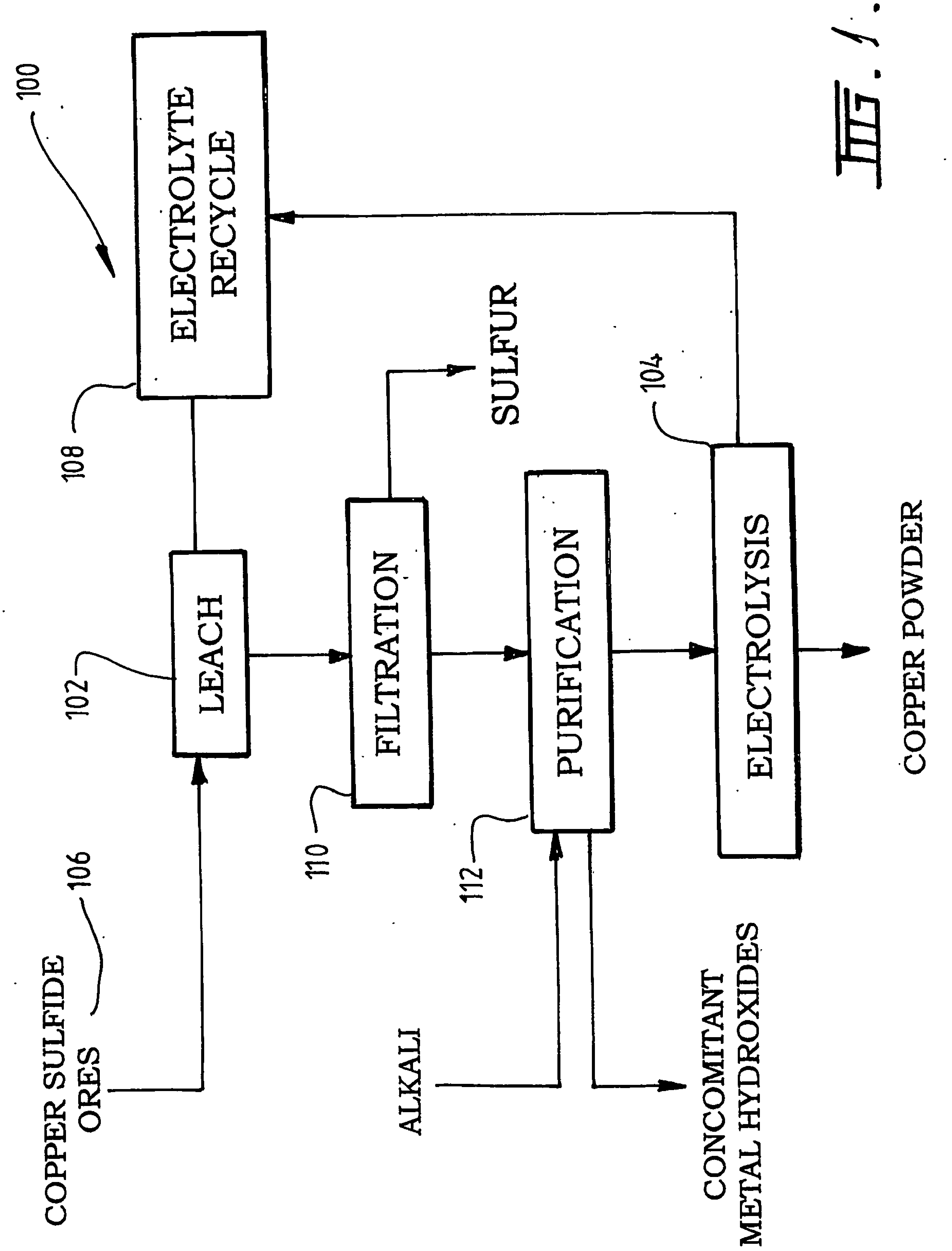

100
ELECTROLYTE RECYCLE
108
LEACH
102
FILTRATION
110
SULFUR
PURIFICATION
112
ELECTROLYSIS
104
COPPER POWDER
COPPER SULFIDE ORES
106
ALKALI
CONCOMITANT METAL HYDROXIDES

FIG. 1.

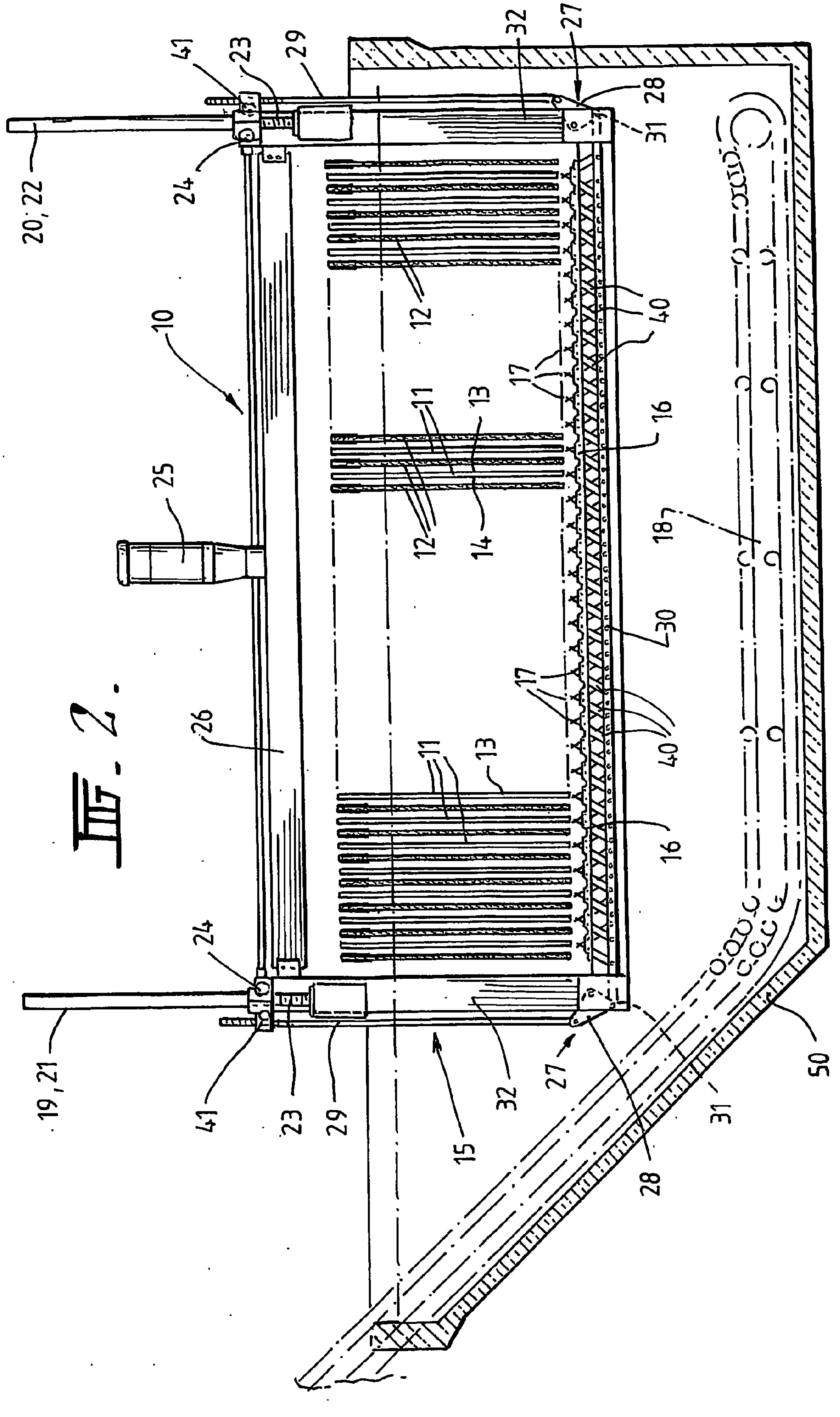

41
23
29
32
27
20, 22
24
28
31
10
12
11
13
17
40
16
25
14
18
30
26
40
16
19, 21
24
41
23
29
15
32
27
28
31
50

FIG. 2.

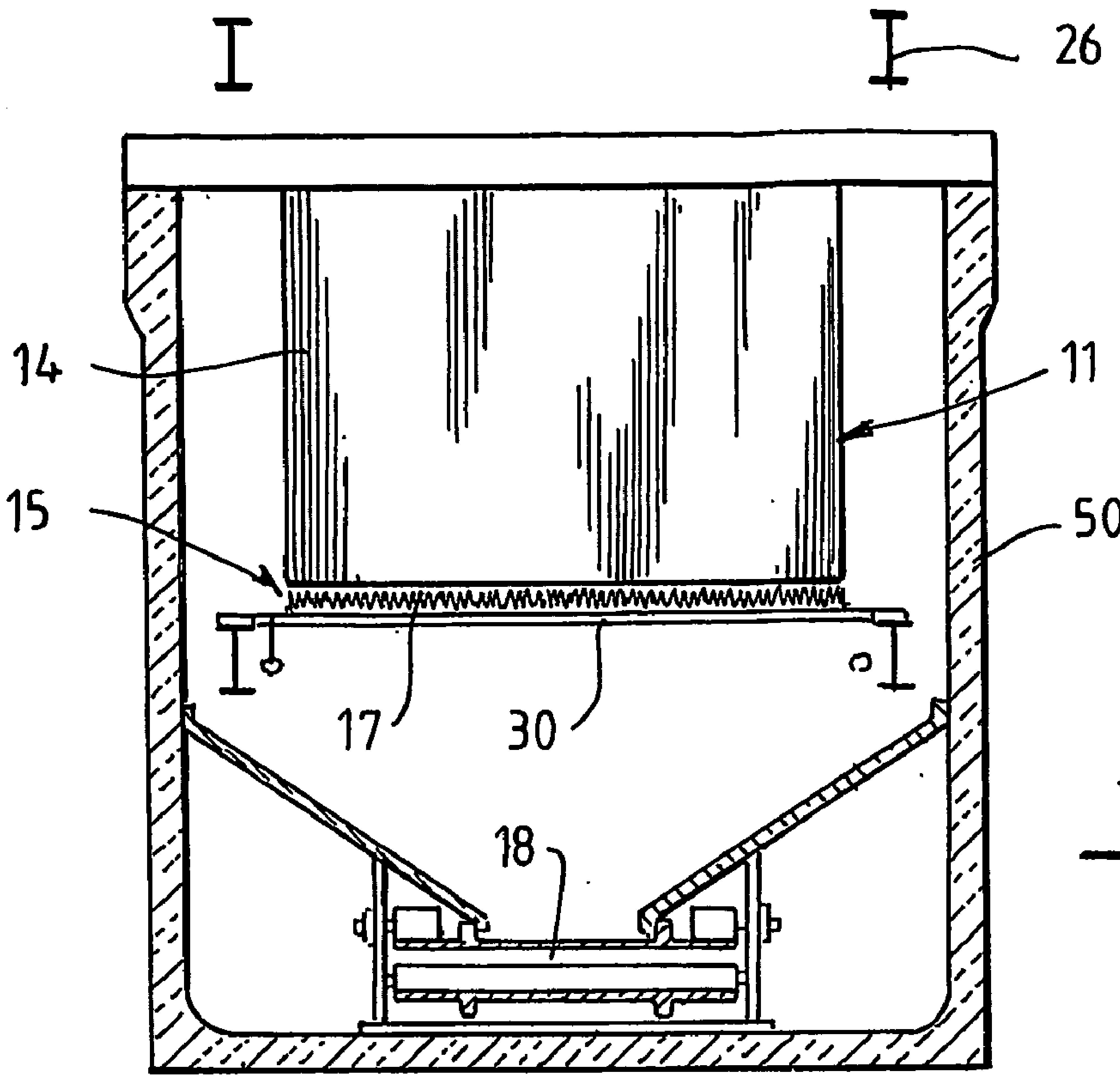


FIG. 3.

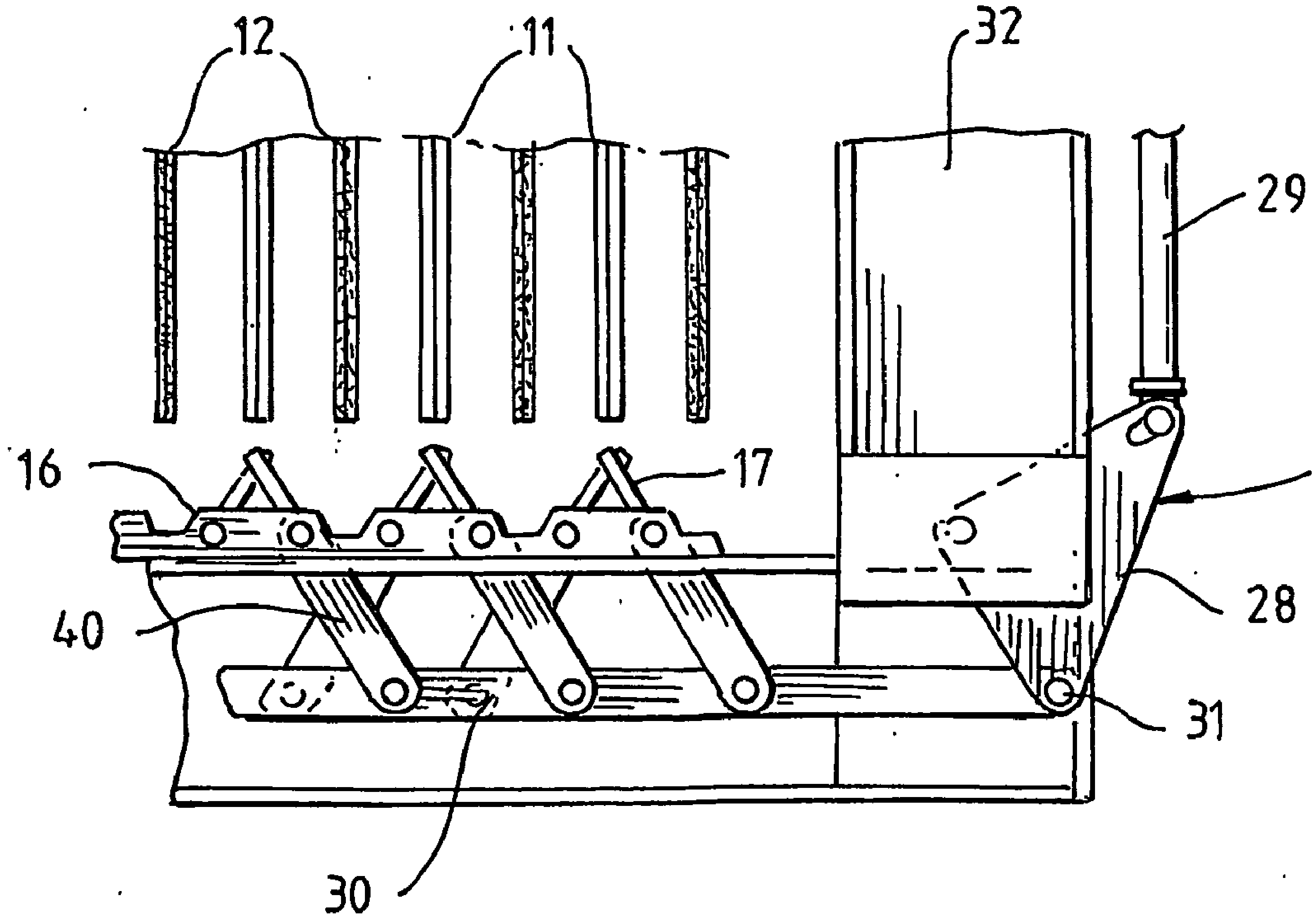


FIG. 5.

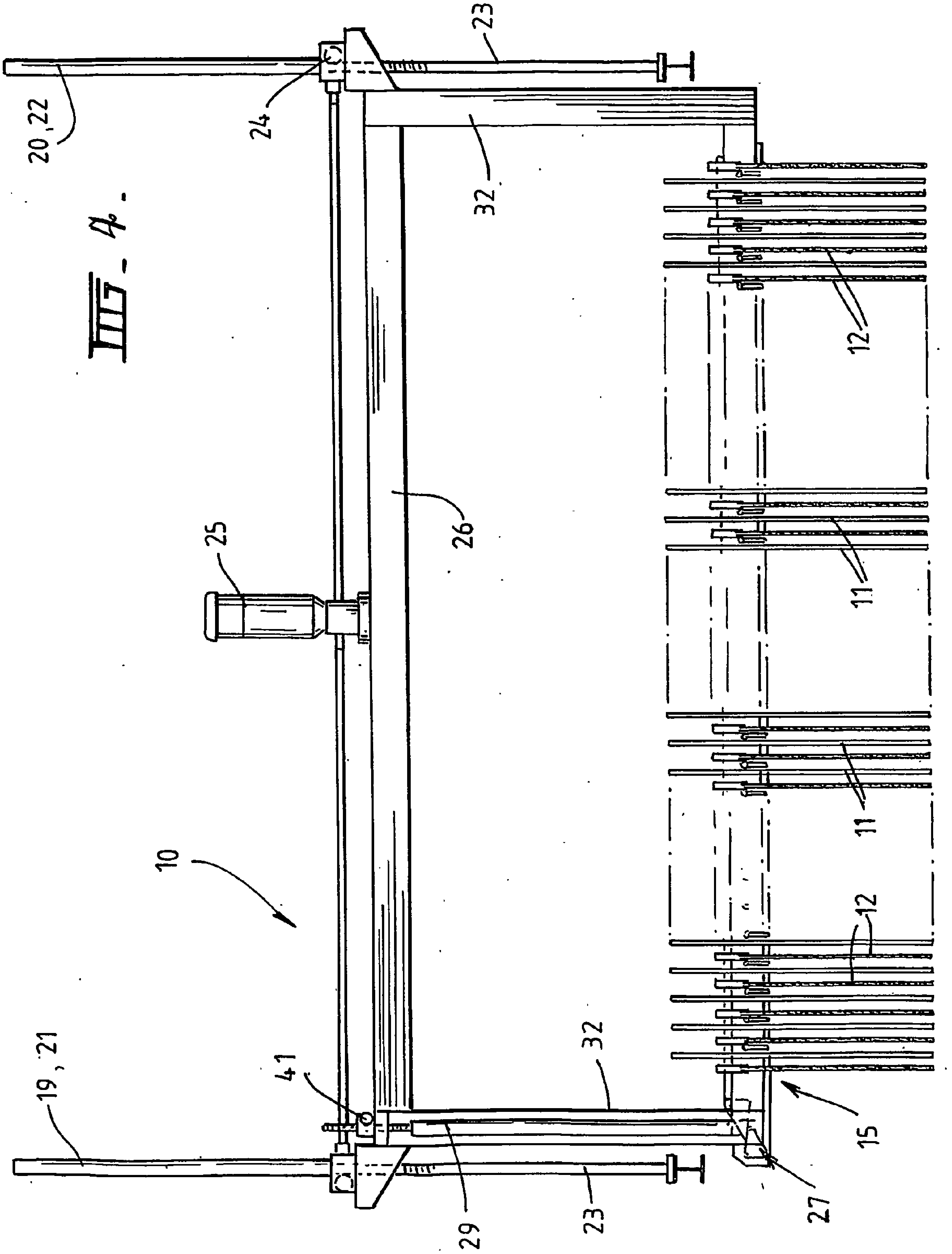


FIG. 4.

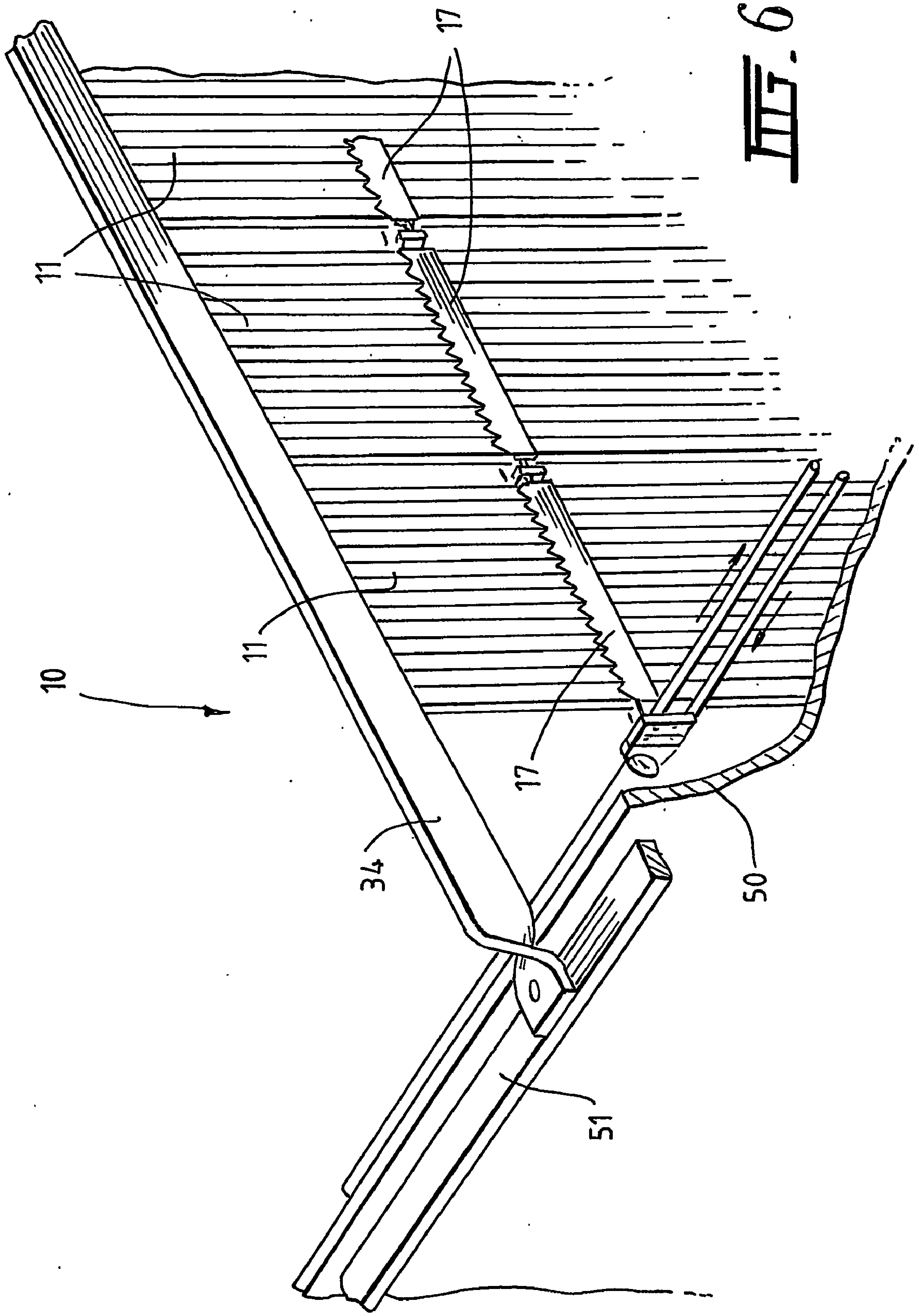
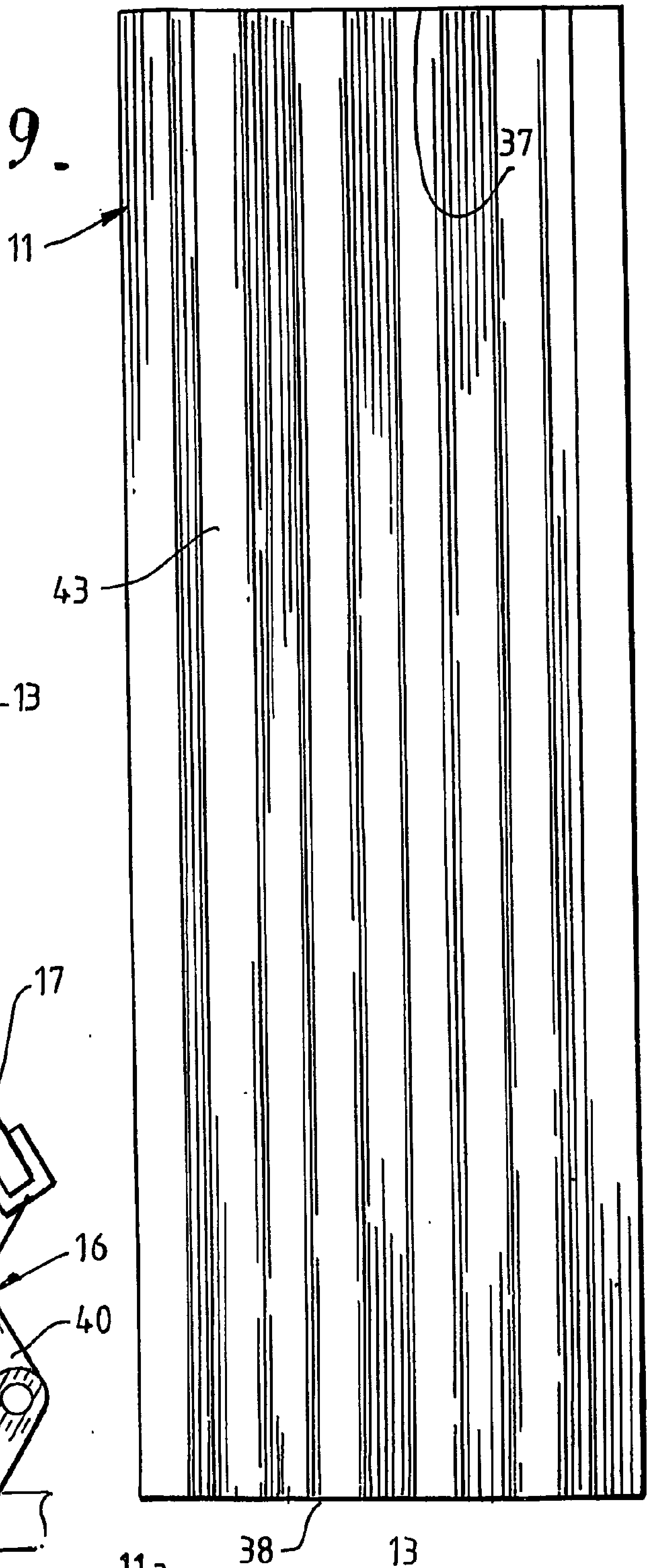


FIG. 6.

FIG. 9.



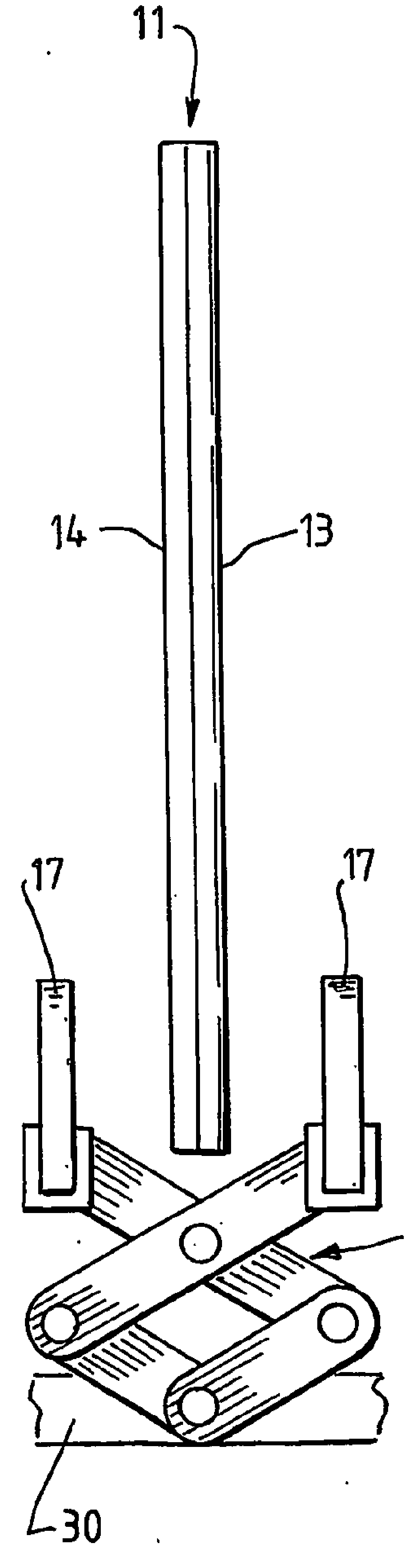


FIG. 7.

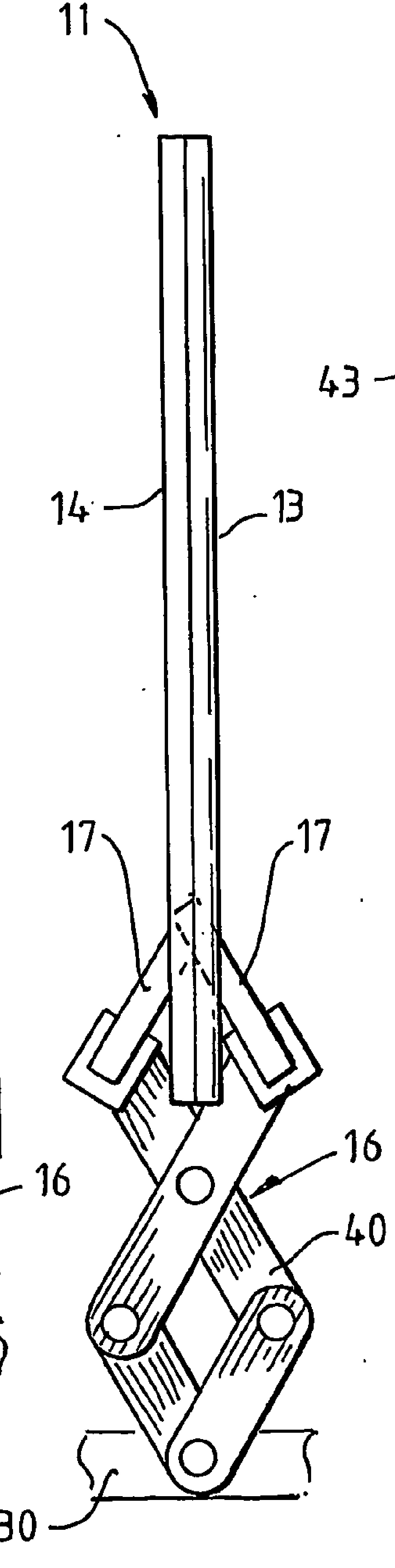


FIG. 8.

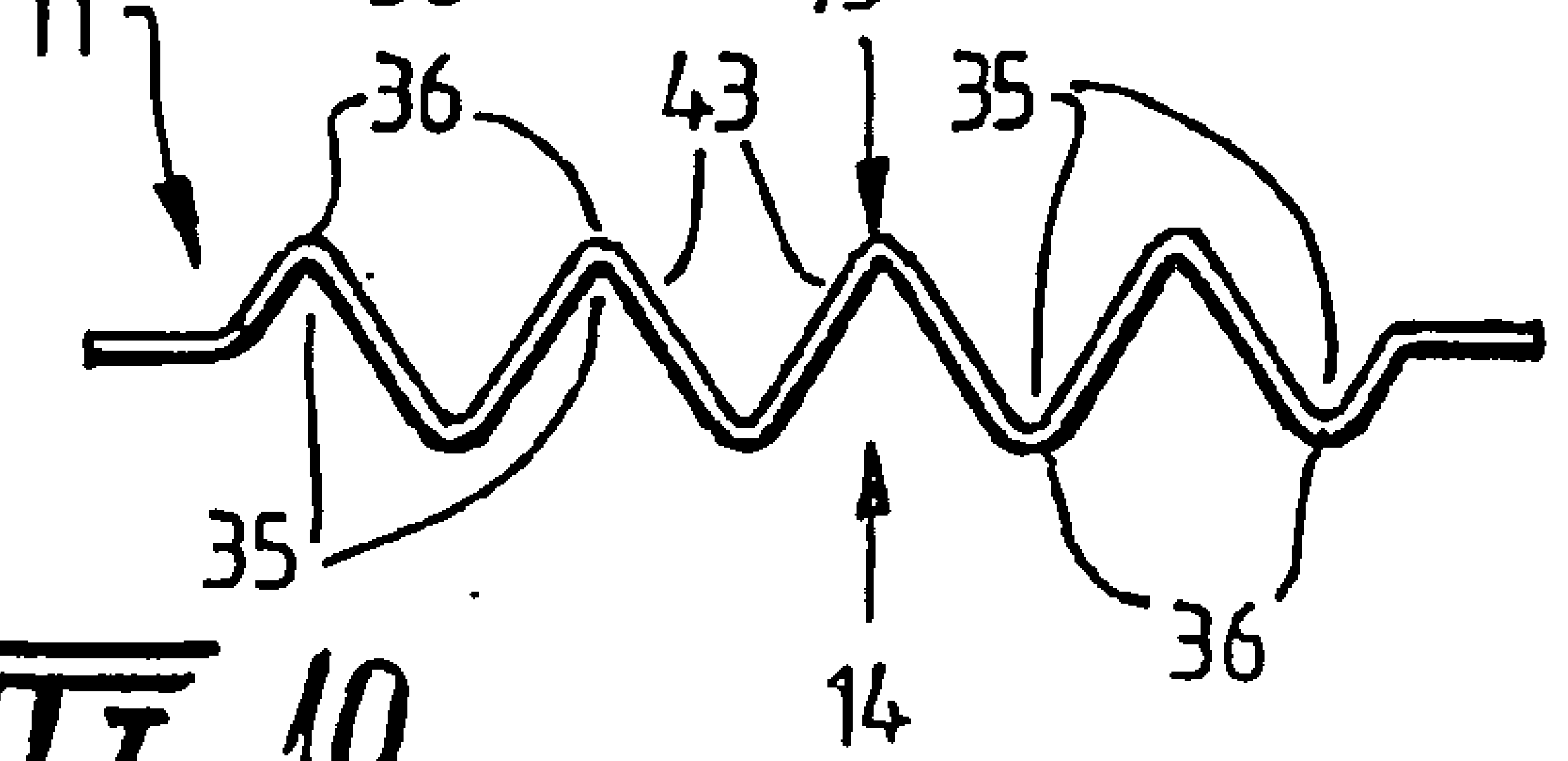


FIG. 10.

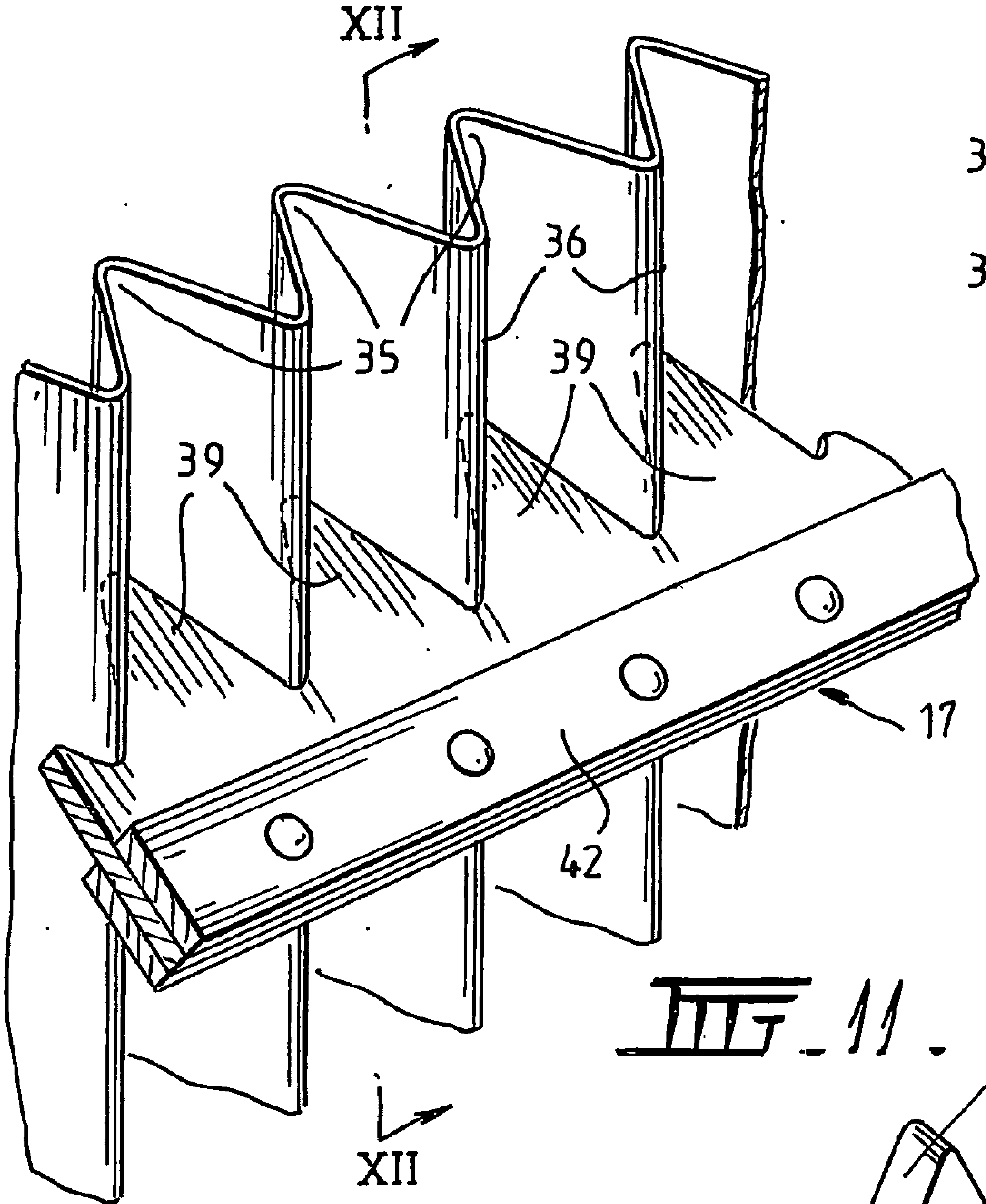


FIG. 11.

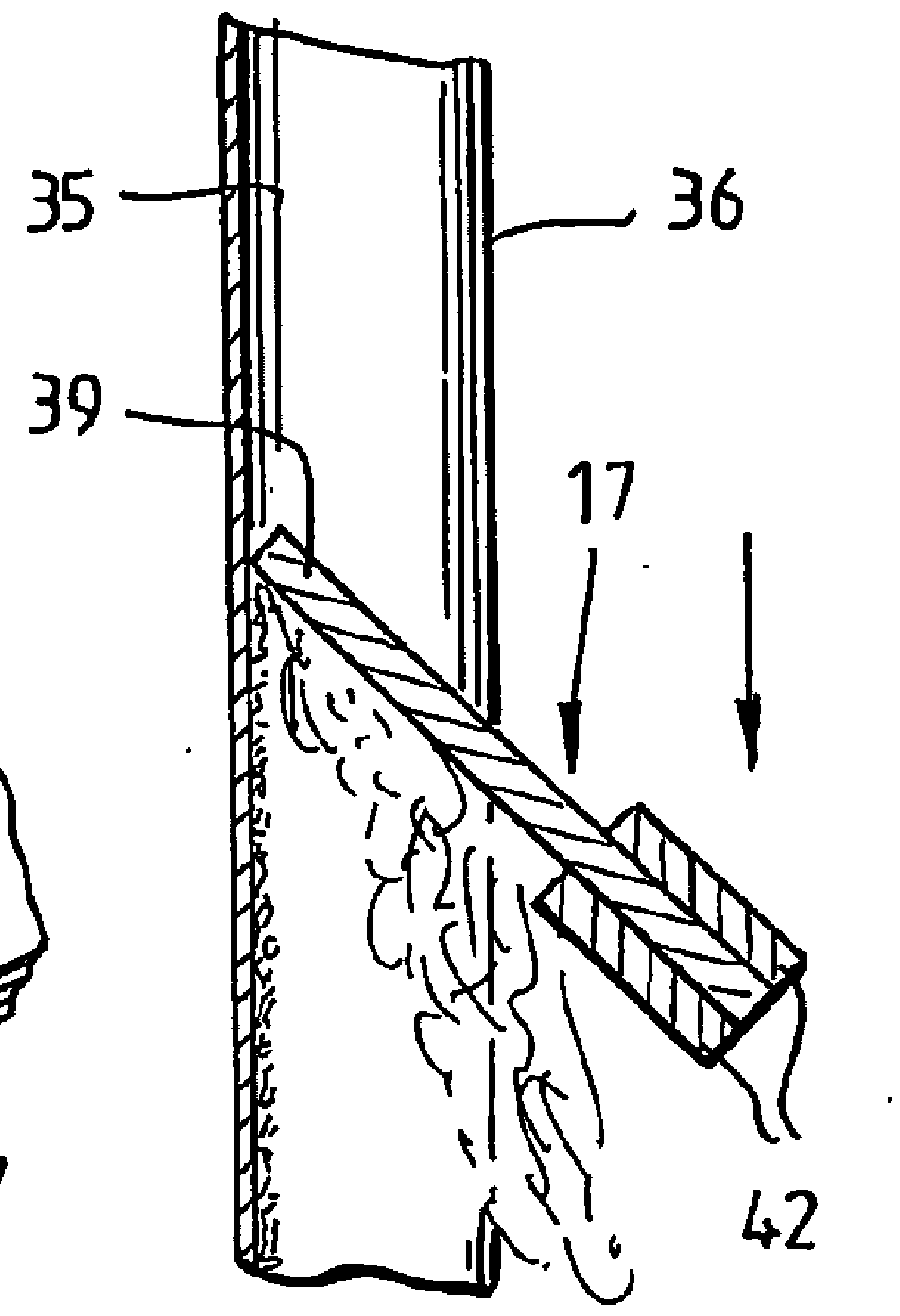


FIG. 12.

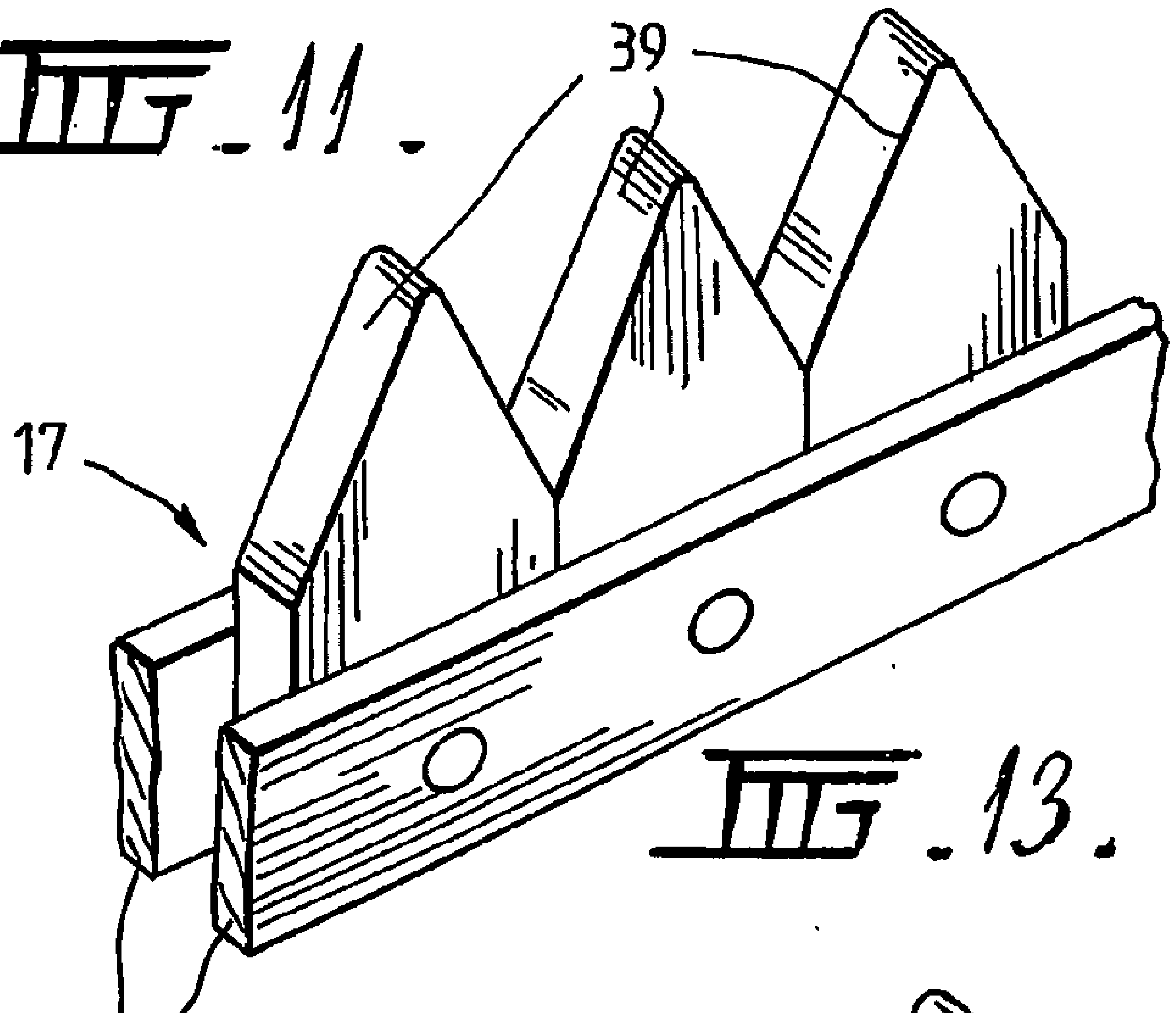


FIG. 13.

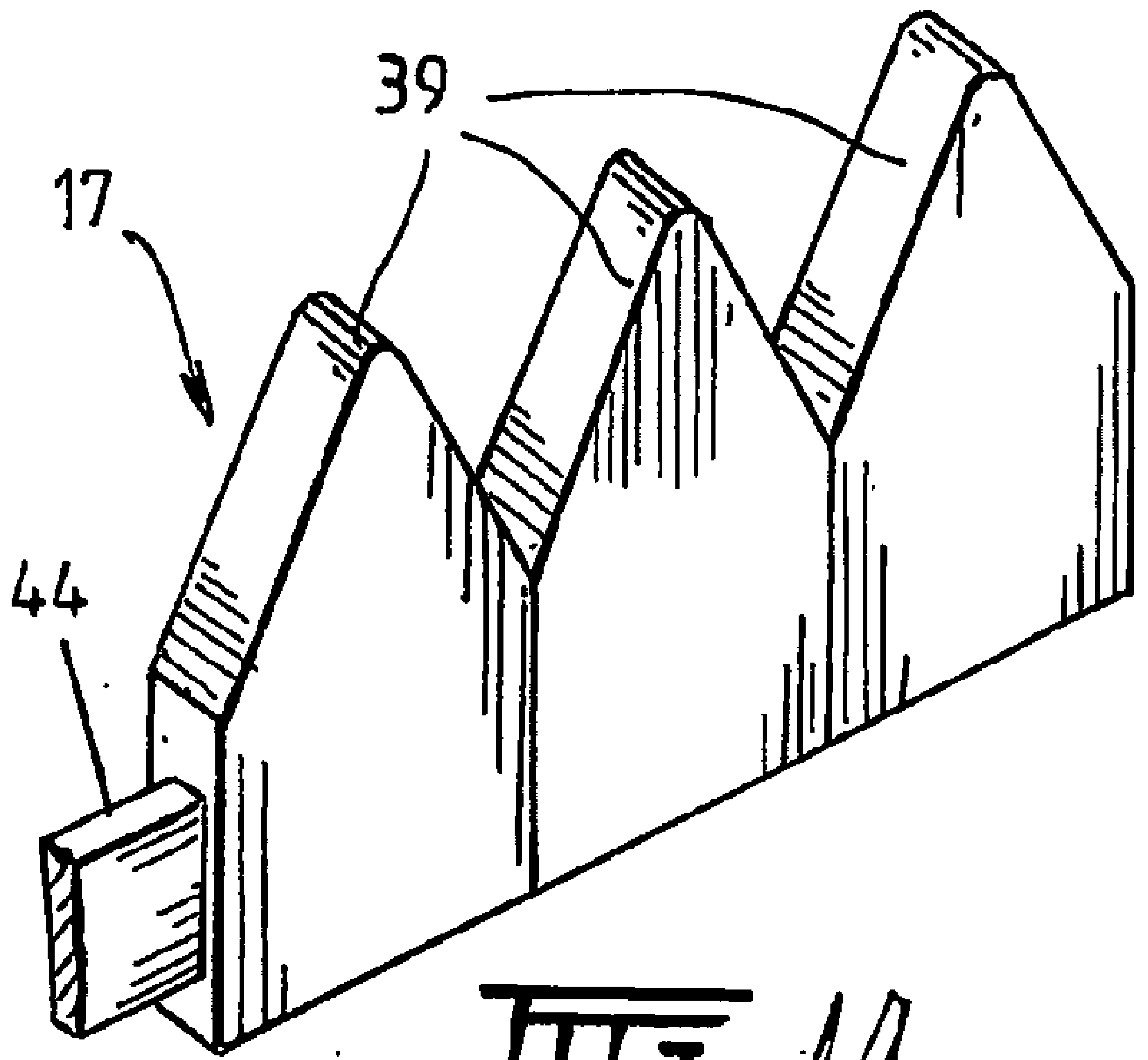


FIG. 14.

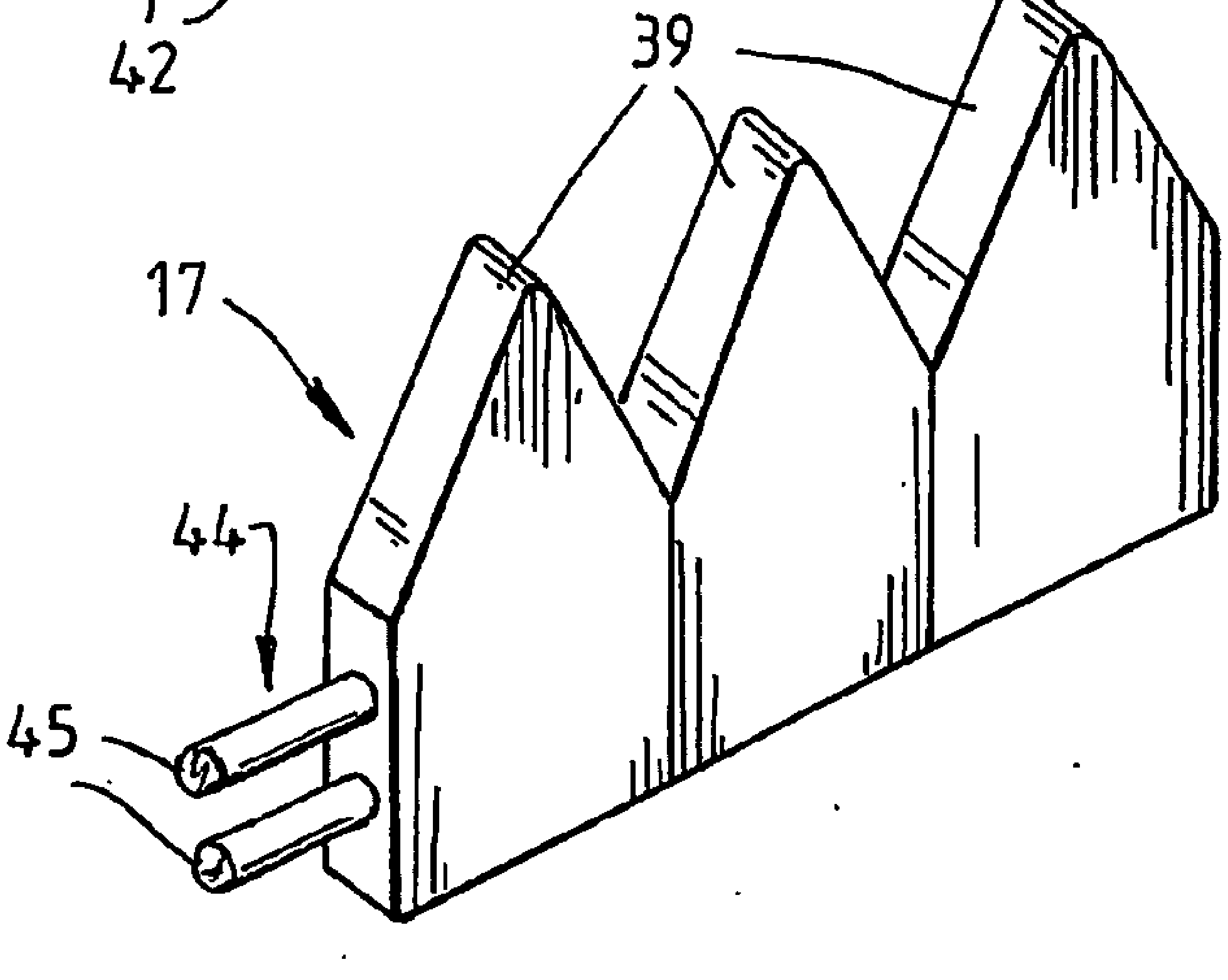


FIG. 15.

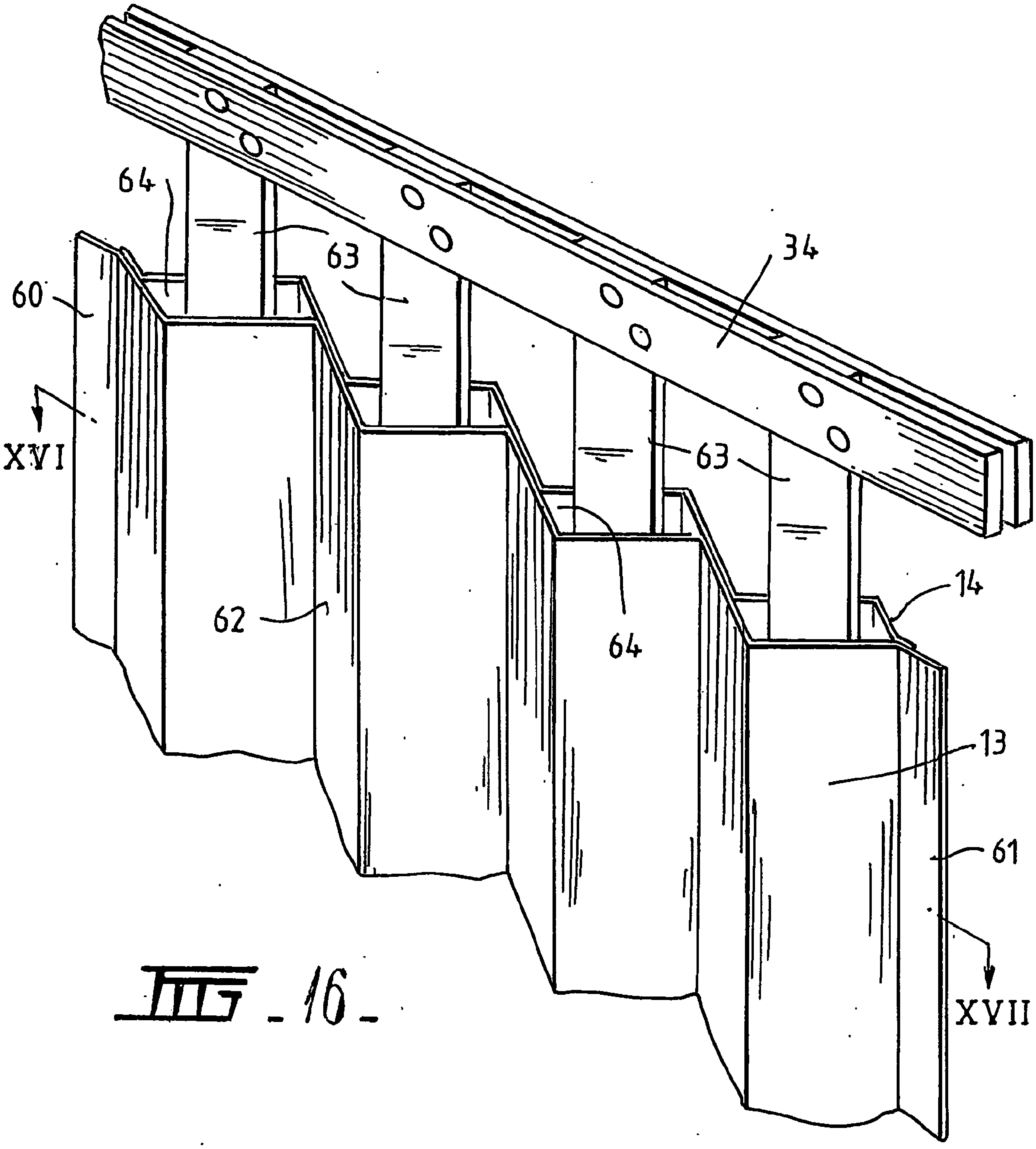


FIG. 16

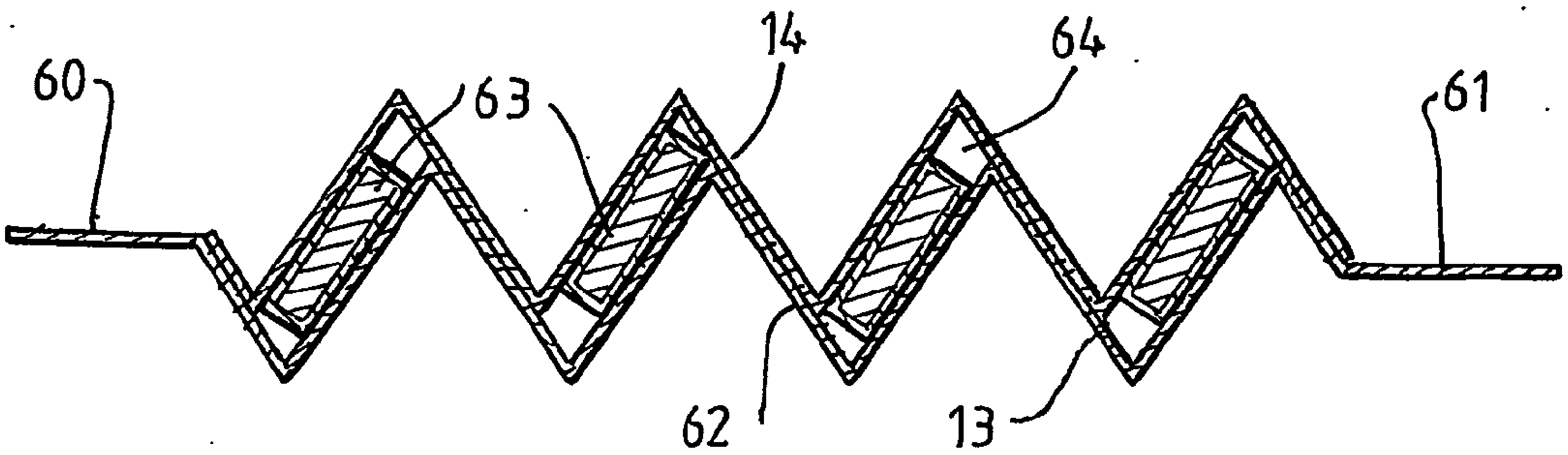


FIG. 17.

ELECTROLYSIS PROCESS AND CELL FOR USE IN SAME

FIELD OF THE INVENTION

[0001] The present invention relates generally to an electrolysis process for the recovery of metals from an aqueous solution and to an improved cathode for use in such a process. The primary application of the invention disclosed herein is in relation to the recovery of copper, although the invention finds equal application with electro-recovery of other metals such as nickel, lead, zinc etc.

BACKGROUND ART

[0002] Processes for leaching base metals from ores and concentrates with subsequent recovery of the base metal in electrolytic cells are known in the field of the hydrometallurgy. One example is disclosed in Australian Patent Application No. 42999/93 (669906). This process is multi-stage and produces a pregnant liquor stream following leaching of the mineral in a chloride medium. The pregnant liquor stream is electrolysed in an electrolysis cell to recover the metal from the solution which deposits on a cathode of the cell. Under high current densities, dendritic copper of high purity is produced on the cathode . In the past it has been necessary to regularly remove the cathodes to strip the plates of the metal deposits so as to maintain current efficiency in the cell.

[0003] Optimisation of the electrowinning operation is a function of the purity of the pregnant liquor stream, and general cell parameters such as current density, stripping cycle, cell configuration and the degree of agitation. Accordingly, an aim of the present invention is to improve the efficiency of the electrowinning operation. In particular, an aim is to provide an electrolysis process and cell configuration which is able to better control current density across the deposition surface of the cathode so as to assist in both formation and removal of the metal deposit.

SUMMARY OF THE INVENTION

[0004] In a first aspect the present invention provides an electrolysis process for the recovery of metal from an aqueous solution wherein on electrolysing the solution metal is caused to deposit on a deposition surface of a cathode, the process including the step of

> **[0005]** inducing a non-uniform current density across the deposition surface so as to form areas of high current density interspaced by areas of low current density, the difference between the areas of high current density and low current density being sufficient to cause metal deposition to be concentrated on the areas of high current density so as to promote non-uniform deposition of metal across the deposition surface.

[0006] In the context of the invention, the deposition surface may be of unitary structure or alternatively may be formed from discrete elements which may be spaced apart or in direct contact with one another.

[0007] Providing a non-uniform current density across the deposition surface provides a mechanism by which the deposition of metal on that surface can be controlled. In particular, it allows the metal deposition to be concentrated in certain areas (i.e. the areas of high current density) so as to promote non-uniform deposition across the surface. Non-uniform deposition of the metal is beneficial as it is easier to remove from the cathode which assists in the metal recovery process.

[0008] Preferably, the metal deposition is heavily concentrated on the areas of high current density so that the metal deposition is effectively discontinuous across the deposition surface. Preferably, the concentration of metal deposition in operation of the cell is greater than 80% in the areas of high current density and more preferably greater than 95%.

[0009] Preferably, the areas of high current density and low current density extend along the surface in one direction and alternate across the surface in an opposite direction. With this arrangement, the metal deposits in a series of generally linear bands which is ideally suited for removal using a wiping action as will be described in more detail below.

[0010] Preferably, the electrolysis process induces a non-uniform current density across the deposition surface by providing a cathode which in operation of the cell, creates a non-uniform electrical field having areas of strong electrical field and weak electrical field. With this arrangement, the areas of strong electrical field induce the areas of the high current density and the areas of weak electrical field induce the areas of low current density.

[0011] The non-uniform electrical field can be created through numerous mechanisms, including the geometry of the surface, and by varying the electrical resistance between the cathode and anode along the deposition surface, or by a combination of both these mechanisms.

[0012] The geometry of the surface influences the electrical field and is related to its surface curvature. Electrical fields are always parallel to the surface so that, sharp edges, or peaks at the deposition surface induce areas of high electrical field as compared to areas of flat surface, or valleys. The electrical resistance can be varied by using different materials along the deposition surface (e.g. providing sections with insulating material) or by changing the current path length between the cathode and the anode.

[0013] In a preferred form, the non-uniform electrical field is induced at the deposition surface by the geometry of the surface and in particular by forming a series of alternate ridges and valleys across the surface. By virtue of this geometry, in operation of the cell, there is a higher electrical field along the ridges as compared to the valleys. In addition, the current path length at the ridges is shorter as compared to the valleys thereby creating a situation where there is less resistance at the ridges as compared to the valleys.

[0014] The variation in current density across the deposition surface may be such that there is a sharp demarcation between the areas of high current density and low current density, or alternatively there may be a more gradual transition between the areas of highest current density and lowest current density.

[0015] The applicant has found that inducing a gradual transition between the areas of highest and lowest current density still provides good deposition patterns so as to promote substantially discontinuous growth across the deposition surface. In particular, the applicant has found that using a cathode which includes a deposition surface having ridges and valleys which do not include a sharp transition between the ridge and valleys so that there is a more gradual change between the highest current density and the lowest current density provides excellent performance. This arrangement induces secondary effects which assist in concentration of the metal deposition at the ridges as described in more detail below and also provides for easier removal of the metal as it allows easier access to the entire deposition surface in contrast to a sharp transition between the ridge and the valley may provide areas which are difficult to access.

[0016] In a preferred form, where the cell is operative to remove copper from an aqueous solution, the current density in the areas of high current density is in the range of 500 to 2,500 A/m^2 and more preferably 1,000 A/m^2. Preferably, the areas of low current density is in the range of 0 to 2,050 A/m^2 and more preferably 0 to 500 A/m^2.

[0017] Where there is a gradual transition between the areas of highest current density and lowest current density, the demarcation between an area of "high current density" and "low current density" is somewhat arbitrary. In this arrangement, the transition region may be regarded as an area of moderate current which in turn is located between areas of adjacent "high current density" and areas of "low current density".

[0018] Preferably, the process further includes the step of removing deposited metal from the deposition surface by passing an element over the surface.

[0019] Preferably, in the arrangement where the areas of high current density and low current density extend along the surface in one direction and alternate across the surface in an opposite direction, the element is moved in the direction in which the areas of high and low current density extend.

[0020] Preferably, the deposited metal is removed by the element whilst maintaining current flow in the aqueous solution. In this way, the process can be substantially continuous.

[0021] In yet a further aspect, the present invention relates to an electrolysis cell for the electrorecovery of metal from an aqueous solution, the cell including a cathode which includes a deposition surface on which metal is deposited on electrolysing of the aqueous solution, wherein in operation of the cell, the deposition surface has a non-uniform electrical field so as to have areas of strong electrical field interspaced by areas of low electrical field, the difference between the areas of high electrical field and low electrical field being sufficient to cause metal deposition to be concentrated on the areas of high electrical field so as to promote non-uniform deposition of metal on the surface.

[0022] Preferably, the areas of high electrical field and low electrical field extend along the surface in one direction and alternate across the surface in an opposite direction. In a particularly preferred form, the deposition surface of the cathode includes an array of alternate ridges and valleys, with the ridges forming areas of high electrical field and the valleys forming the areas of low electricalfield.

[0023] Profiling the deposition surface to have an array of alternate ridges and valleys has significant benefit in promoting substantially discontinuous metal deposition on the cathode. Typically such profiling promotes metal deposition as a dendrite growth on each of the ridges. Advantageously, the resulting dendrites are easy to remove (as described below). Not only does the profile provide, in the initial operation of the cell, the appropriate non-uniform current density to concentrate metal deposition as dendrites on the ridges, but it also assists in maintaining discontinuous growth as the process continues. As will be appreciated, once metal deposits on the deposition surface, the deposited metal forms an extension of a deposition surface. An advantage of having an arrangement of ridges and valleys is that as the dendrites grow on the ridges, they tend to "shadow" the valleys which further inhibits metal deposition in the valleys. In addition, the aqueous solution tends to stagnate in the valleys which further inhibits deposition of metal in the valleys. In tests conducted by the applicant, using a profile of alternate ridges and valleys, more than 98.8% of metal was deposited on the ridges of the deposition surface.

[0024] Whilst the beneficial effects of including the ridges and valleys may be achieved over a range of profiles, the applicants have found that a regular profile where the surfaces between the top of the ridge and the base of the valley is substantially linear and have an internal angle of approximately 60° between adjacent surfaces provides good results. Furthermore preferably the pitch distance between adjacent ridges is in the order of 10-40 mm, and more preferably 15-25 mm, and the depth between the ridge and the valley is in the order of 8-32 mm and more preferably in the range of 12-20 mm. A deposition surface having these characteristics has been found to produce substantially discontinuous metal deposits. A further advantage is that this profile enables the surface to be substantially cleaned without creating "hot spots" of current density which would lead to impure metal deposits. If the current density at a site is too high, as the deposition progresses, it leads to concentration polarisation (which takes place around the growing deposit). When this phenomenon occurs, a relative increase in impurity inclusions in the depositing metal (e.g. in copper) can occur. Thus it is important to control the current density at the site. The advantage of the profile mentioned above is that the areas of high current density where metal deposits still takes up a substantial part of the total area of the cathode. (i.e. in the vicinity of 25-35% of the total area of the deposition surface). With this arrangement, the current is able to be maintained at a substantially constant rate regardless of whether the surface is clean of metal deposits or whether deposition has already occurred. As such, there is no need to ramp up the current on initiating the cell as the profile itself does not tend to induce strong "hot spots" of current density which is likely to cause problems in initial metal deposition.

[0025] In a particularly preferred form, the cathode includes a sheet having at least one major surface which forms the deposition surface of the cathode, the sheet being preformed so as to incorporate the alternate ridges and valleys. The sheet may thus define a corrugated profile. Preferably, this preforming operation is achieved by folding of the sheet but it could be made by any other appropriate process such as a stamping, milling, swaging, casting process or combinations thereof.

[0026] In a particularly preferred form, the sheet is formed from titanium or similar oxidation resistant material. Whilst other oxidation resistant materials may be used, such as platinum, stainless steel, corrosion resistant metal alloys, titanium is most preferred because of its excellent oxidation resistance, its capacity to resist forming a metallurgical bond with metals such as copper, and because of its relative availability.

[0027] A further advantage of using a corrugated profile is that it assists in maintaining dimensional stability for the sheet. Such an arrangement can assist in overcoming the disadvantages of prior art arrangements where sheet cathodes had a tendency to flex and buckle. Further, when metal deposits on the sheet as a dendritic or crystalline growth, the dimensional stability of the sheet enables wiping methods to be used to easily remove the deposit from the sheet. The applicants have found that titanium sheets in the order of 1.6 mm thickness provide sufficient dimensional stability for this process.

[0028] Preferably, the sheet is adapted in use for attachment to a conductive header bar. This header bar supports the cathode in use and supplies electrons to it

[0029] In one form, the opposite major surfaces of the folded sheet are used as deposition surfaces in operation of the cathode.

[0030] In an alternative form, the cathode is made from a composite structure and further includes a conducting element which extends along the sheet. The conducting element is in electrocommunication with the sheet so as in use to supply the deposition surface with electrons in the electrolysis process. One advantage of using a conducting element which extends along the sheet is that it minimises ohmic drop which occurs when the electrons are supplied solely from one edge of the sheet. A second advantage of using a conducting element is that is may be of sufficient size to provide rigidity to the sheet to further assist in maintaining dimensional stability of the cathode. With the composite arrangement it may thus be possible to use thinner sheet structures for the deposition surface(s).

[0031] In a preferred form of this latter arrangement, the cathode includes a second sheet which is connected to the first sheet and which has a major surface which forms a second deposition surface of the cathode, the second sheet being preformed so as to incorporate the alternate ridges and valleys along that deposition surface. Preferably, the second sheet is connected to the first sheet of the cathode so as to form a plurality of pockets which extend in the direction of the alternate ridges and valleys. At least some of these pockets are operative to receive the conducting element of the cathode.

[0032] In a preferred form, the wiping device is operative to pass over a deposition surface of the cathode so as to remove deposited material from the deposition surface. In a particularly preferred form, where the cathode includes the ridge and valley profile, the wiping device includes a plurality of projections which are operative to locate within respective valleys of the deposition surface. In a preferred form, these projections are made from a ceramic material but can be made of any other corrosive resistant material.

[0033] In a preferred form, the projections are movable between a first and a second position and are operative to pass over the surface in either of these positions. In a first position, the element is in contact or in close proximity to the deposition surface so as to remove substantially all of the deposition material from that surface. In the second position, preferably the element is spaced from the deposition surface and is operative to remove deposited material which extends a predetermined distance from the deposition surface.

[0034] In yet a further aspect, the present invention relates to a cathode for use in a process or electrolysis cell as defined in any form above.

[0035] In yet a further aspect, the present invention relates to a wiping system for use in an electrolysis cell in any form as defined above.

[0036] In yet a further aspect, the present invention relates to a cathode for use in an electrolysis cell for the electrorecovery of metal from an aqueous solution, the cathodes including a deposition surface having a plurality of ridges which are interspaced by a plurality of valleys, the profile of the cathode being operative on operation of the cell to cause metal deposition to be concentrated on the ridges so as to promote non-uniform deposition of metal on that surface.

BRIEF DESCRIPTION OF THE DRAWINGS

[0037] Not withstanding any forms which may fall within the scope of the present invention, preferred forms of the invention will now be described, by way of example only, with reference to the accompanying drawings in which:

[0038] **FIG. 1** is a generalised flowchart for processing and recovery of copper;

[0039] **FIG. 2** is a sectional elevation of an electrolysis cell in accordance with one embodiment of the invention with wiper sets of the cell in a closed position;

[0040] **FIG. 3** is a sectional side view of the cell of **FIG. 2**;

[0041] **FIG. 4** is a sectional elevation of the cell of **FIG. 2** with the wipers in an open position;

[0042] **FIG. 5** is a detailed view of the linkage assembly in the cell of **FIG. 2**;

[0043] **FIG. 6** is a cut-away perspective view of the cell of **FIG. 2**;

[0044] **FIG. 7** is a schematic view to an enlarged scale showing the wipers located in an open position at the top of the cathode plates;

[0045] **FIG. 8** is a detailed view to an enlarged scale of the wipers in a closed position;

[0046] **FIG. 9** is a front elevation of a cathode panel used in the cell of **FIG. 2**;

[0047] **FIG. 10** is an end view of the panel of **FIG. 9**;

[0048] **FIG. 11** is a schematic perspective view of a wiper engaging a cathode in the cell of **FIG. 2**;

[0049] **FIG. 12** is a sectional view along section line XII-XII in **FIG. 11**;

[0050] **FIG. 13** is a detailed view of the blade construction of the wipers used in the cell of **FIG. 2**;

[0051] **FIGS. 14 and 15** are variations of the blade instruction shown in **FIG. 13**;

[0052] **FIG. 16** is a schematic perspective view of an alternative cathode designed for use in the cell of **FIG. 2**; and

[0053] **FIG. 17** is a cross sectional view along section line XVII-XVII of the cathode of **FIG. 16**.

MODES FOR CARRYING OUT THE INVENTION

[0054] In **FIG. 1**, a schematic representation of a combined process **100** including leach and electrorecovery **104** of metal is depicted. In a preferred form of this process, ground copper sulfide **106** is fed to a multistage counter current leaching process in which the metals are solubilised through oxidation by a lixiviant. In a preferred form, the lixiviant includes a complex halide species which is formed in the anode of the subsequent electrolysis stage and is fed back into the leach stage as part of the electrolyte recycle **108**.

[0055] Dissolved metals in desirable oxidation states are removed at various stages from the leach process in the leachate. The leachate is passed through filtration **110** to remove unwanted solids such as sulfur and ferric oxide. The leachate is then passed to purification **112** to remove metals which may otherwise contaminate subsequent electrolysis (such as silver and mercury). The contaminant metals may be precipitated as the metal oxide or carbonate form.

[0056] The purified leachate is then fed to the electrolysis stage **104** which may include a plurality of electrolysis cell groups in series and/or in parallel. In each group, a different metal may be produced, with typically copper metal being electrorecovered in a first cell group and metals such as zinc, lead and nickel being recovered in subsequent or parallel cell groups. The electrolysis process is typically operated such that a highly oxidising lixiviant (such as a complex halide species) is produced at the anode. The spent electrolyte (anolyte) is then recycled to the leaching stage and includes the highly oxidising lixiviant which participates in further counter current leaching. Thus, the process can operate continuously.

[0057] The present invention is concerned with optimising the electrorecovery of metals and relates to significant design improvements in the electrolysis process, including improved cathode design and geometry.

[0058] Referring now to **FIGS. 2-5** the electrolysis cell **10** for use in the process **100** includes a series of cathode plates **11** which are disposed within the electrolysis cell tank **50** and interspaced by anodes **12**. Electrolyte fed to the cell enables current flow between the anodes and the cathodes. The outer surfaces **13**, **14** of the respective cathodes form a deposition surface for the cell on which the metal to be recovered deposits in operation of the cell **10**. As will be described in more detail below, the cathode plates are formed from a generally corrugated profile having alternate ridges and valleys so as to influence the mode of deposition of the metal on the respective deposition surfaces **13** and **14**.

[0059] The cell **10** includes a wiper system **15** which includes a plurality of wiper sets **16** operative to interfit between respective cathodes and anodes with the wipers **17** of respective wiper sets **16** being operative to move across the deposition surfaces **13** and **14** of respective cathodes **11** so as to remove metal deposits from those surfaces. The wipers **17** are arranged to be wiped down the respective deposition surfaces **13** and **14** at predetermined intervals to cause the dislodged metal to drop to the bottom of the cell **10** wherein it is transferred to a conveyor **18** for removal from the cell.

[0060] To achieve this wiping action, the wiping system **15** includes two principle movements; the first being a vertical movement to allow the wiper sets **16** to move between the top and the bottom of the respective cathodes **11**, the second being to allow the wipers **17** in each set **16** to move from an open position (as best illustrated in **FIG. 7**) to a closed position (as best illustrated in **FIG. 8**).

[0061] The wiper sets **16** are mounted on a frame **32** which is secured at its upper end to four supporting struts **19**, **20**, **21** and **22**. Each of the struts include a helical track **23** which cooperates with a worm gear **24** connected to the frame **32**. In this way, the frame **32** moves relative to the struts. An electric motor **25** mounted on a cross beam **26** is operative to drive the worm gears **24** so as to achieve the vertical movement of the wiper sets relative to the deposition surfaces **13** and **14**. Under this action, the wipers are able to move between a lower position as disclosed in **FIG. 2** to an upper position as disclosed in **FIG. 4**.

[0062] The frame **32** supports a linkage assembly **27** which in turn is connected to the wiper sets **16**. The linkage assembly **27** includes a pair of link plates **28** at each end of the wiper sets **16** which are connected to respective link arms **29**. A crank **30** is pivotally connected to respective pairs of the link plates **28** through pivot points **31**. Crank arms **40** extend from the crank **30** to the wiper sets **16** so as to support each end of the wiper sets. The link arms **29** are capable of vertical movement through a second actuator **41**. In the illustrated form, the second actuator is in the form of worm gears which cooperate with helical tracks formed on the respective link arms. The worm gears rotate which impacts the rotation to the the link arms **29** to cause vertical displacement of those arms relative to the frame **18** which in turn drives the crank **30** so as to move the wipers between their open and closed positions. The second activator can be damped to prevent over-tightening and jamming of the wipers against the cathode. Damping can be provided by a spring-loaded coupling or by using a pneumatic cylinder in place of the worm gear.

[0063] As best illustrated in **FIG. 6** each line of cathodes in the cell **10** is formed from a plurality of cathode plates **11** which are connected to a header bar **34** so that the individual plates are suspended in the tank **50**. The header bar **34** is conductive and connected to a power source so as to supply electrons to the cathode.

[0064] Typically the electrolyte is highly corrosive, resulting from typically a 5 molar or greater concentration of alkali or alkaline-earth metal halides. To enable the components to be able to operate in this environment, the wiper system **15** is made from a corrosion resistant material which is preferably titanium. Other suitable materials include platinum, stainless steel, corrosion resistant metal alloys (such as Hastalloy C 22), or even some plastics. Also, titanium is most preferred for the cathode because of its excellent corrosion resistance and its capacity to resist forming a metallurgical bond with metal such as copper, and because of its relative availability (hence cost benefit). Its resistance to forming a metallurgic bond improves the ability of the plates to be stripped using the wiper system described above.

[0065] **FIGS. 9 and 10** illustrate the construction of the individual cathode plates **11**. In the illustrated form, the cathode plate **11** is formed from a titanium sheet having a thickness which is preferably about 1.6 mm. Sheets of this thickness have been found by the applicant to give adequate rigidity to the cathode plate to prevent buckling in use. The titanium sheet is folded to form a generally corrugated profile so as to provide on each deposition surface **13**, **14** alternate valleys and ridges **35**, **36** respectively. These corrugations run along the entire length of the cathode between its upper and lower edges **37**, **38**.

[0066] In the illustrated form, the distance between adjacent ridges **36** is 20 mm, whereas the depth between the top of the ridges **36** and the bottom of the valleys **35** is approximately 16 mm. The wall surfaces **43** formed on the corrugated sheet are generally linear and have an internal angle at the top at the ridges and bottom of the valleys of approximately 60°.

[0067] A primary purpose for incorporating the corrugations in the cathode is to influence the current density on the deposition surfaces **13**, **14** under operation of the cell. In particular, the corrugations on the deposition surface cause a non-uniform electrical field across that surface in operation of the cell.

[0068] The corrugated deposition surface on the cathode creates bands of high current density along the ridges of the cathode due to its corresponding high electrical field at those areas and relatively low current densities in the valleys. This causes metal deposition to be concentrated in the areas of high current density and promotes non-uniform deposition across the surface so that the vast majority of the deposition includes in the ridge regions **35** of the deposition surface. Creating substantially discontinuous deposition improves the ability to be able to remove recovered metal from the cathode using the wiping system **15**.

[0069] The profile of the deposition surface with the valleys and ridges causes the non-uniform electric field by two mechanisms. Firstly, in view of the geometry of the profile, the electrical field will be stronger at the ridges than the valleys because of its surface curvature. In general, the electric field lines are always parallel to the surface. Therefore, at each ridge there will be a concentration of a field along those points. Secondly, the current flow path at the ridges is less than the current flow path at the valleys. As a result, there is less resistance at the ridges than there is at the valleys.

[0070] In addition, the use of the corrugated profile of the cathode allows better control at the main sites of deposition (i.e. along the ridges). If the current density at a site is too high, as deposition progresses, it leads to concentration polarisation (which takes place around the growing deposit). When this phenomenon occurs, a relative increase in impurity inclusion in the depositing metal (e.g. in copper) can occur. With the corrugated profile, the main sites of deposition account for approximately 25-35% of the total surface area of the cathode. As a function of the mass transfer, ideally the current at the deposition surface should be in the vicinity of 1,000 A/m^2 or less. As the dendrites grow on the surface, the actual area of deposition surface increases as metal is deposited on the previously deposited metal. If the initial deposition sites on the cathode are too small, then there is a tendency that once the dendrite is removed from the cathode the current density at that site becomes too high. Through trials conducted by the applicant, using the corrugated profile, it is found that the current density at the deposition sites both on initial operation of the cell and after dendritic growth has occurred, it is able to be maintained in the vicinity of 1,000 A/m^2 so as to provide high quality metal deposition. As such, there is no need to vary the current during the process.

[0071] A further advantage of using the corrugated profile on the cathode is that it improves the rigidity of the cathode plate, as the corrugated profile is inherently stiffer than a flat plate along the direction of the ridges and valleys. In addition, the corrugated profile is ideally suited to be cleaned using the wiping blade system as is described in more detail below.

[0072] With reference to FIGS. **11** to **15**, the wipers **17** include fingers **39** which are mounted between a pair of rails **42**. In the illustrated form, each of the individual fingers are formed from a ceramic material with the rails being made of titanium. Each of the fingers is spaced along the rail **42** so that the wipers **17** conform generally to the shape of the corrugated cathode plate **11**, with the individual fingers locating within the valleys **35** of the deposition surface and over the associated ridges **36**.

[0073] As best illustrated in **FIG. 12**, the wiping system **15** is designed so that when the wiper sets **16** are in their closed position, the wipers **17** are angled to the cathode plate **11** so that the individual fingers **39** are in a trailing position relative to the line of movement of the wiper **17** down the cathode plate **11**. This arrangement is preferred as it inhibits jamming of the fingers in the valleys as may occur if the fingers **39** were in a leading position relative to the direction of movement of the wipers down the cathode plate.

[0074] As described above, in view of the configuration of the cathode plates **11**, the metal recovered from the electrolysis cell is concentrated on the ridges of the respective deposition surfaces of the cell. As such, when the wiper **17** is moved across the deposition surface the dislodged material from the ridges tends to move into the adjacent valleys of the deposition surface. This causes an accumulation of the metal within the valleys which tends to envelop the fingers **34** thereby protecting the ceramic fingers **39** from wear. In addition, there is a build up in frictional force as the mass of material is moved down the deposition surface thereby aiding removal of material as the material is dragged from the surface under this frictional force. It is not necessary that the fingers **39** are in direct contact with the deposition surface to ensure adequate cleaning of that surface.

[0075] Another advantage of the design of the wiping system **15** is that it enables different stages of cleaning of the cathodes. In particular, as described above, the wipers **17** can be operated to remove the bulk of the deposited material on the deposition surfaces by dragging across those surfaces when in their closed position. The wipers can also be moved across the deposition when in their open position. This is used not to fully clean the deposition surface but rather to ensure that there is no extended dendritic growth on part of the deposition surface which could otherwise grow to an extent that it contacts the anode and thereby causes short circuiting of the electrolysis cell. Also, this allows for more consistent growth across the ridges of the cathode, which aids in control of the current density along the deposition surface.

[0076] **FIGS. 14 and 15** illustrate some variations in the design of the wipers **17**. As in the arrangement of **FIG. 13**, each of the wipers **17** include ceramic fingers **39**. However, rather than using the rail arrangement **42** as disclosed in **FIG. 13**, the fingers **39** are interconnected by an internal connecting bar **44**. In the embodiment of **FIG. 14** the bar **44** is formed as a square section, whereas in **FIG. 15** the connecting bar is made up of two cylindrical bars **45**.

[0077] Referring now to **FIGS. 16 and 17**, an alternative cathode construction is depicted. In this embodiment the cathode is formed as a composite structure wherein the outer deposition surfaces **13**, **14** are defined by separate sheets which are fastened together along their respective lateral edges **60**, **61**, and which may optionally be fastened together at intermittent regions **62**.

[0078] In this embodiment, a plurality of conducting bars **63** form part of the construction and extend downwardly from the header bar **34**, the conducting bars typically also being formed from titanium (or a titanium coated copper bar to further improve conductively). Typically the conducting bars extend for the full length the plates **13**, **14** through each of the passages defined between a plate and are fastened thereto. Such an arrangement provides enhanced distribution of electrons through the assembly, thereby minimising ohmic drop which can occur when the electrons are supplied solely to one edge of the sheet. In addition, it has been found that the composite arrangement, including the arrangement of the conducting bars in the passages, enhances the dimensional stability of the sheet so that thin plate structures (e.g. as small as 1 mm) or alternatively wide plate structures can be employed for the cathode. Otherwise, the principles of operation of the cathode of **FIGS. 16 and 17** are described above.

[0079] Whilst the invention has been described with reference to a number of preferred embodiments, it should be appreciated that the invention can be embodied in many other forms.

1. An electrolysis process for the recovery of metal from an aqueous solution wherein on electrolysing the solution metal is caused to deposit on a deposition surface of a cathode, the process including the step of

inducing a non-uniform current density across the deposition surface so as to form areas of high current density interspaced by areas of low current density, the difference between the areas of high current density and low current density being sufficient to cause metal deposition to be concentrated on the areas of high current density so as to promote non-uniform deposition of metal across the deposition surface.

2. A process according to claim 1, wherein the areas of high current density and low current density extend along the surface in one direction and alternate across the surface in an opposite direction.

3. A process according to either claim 1, wherein the cell is operative to recover copper from the aqueous solution and the current density in the areas of high current density is in the range of 500-2500 A/m^2 and more preferably 1000 A/m^2.

4. A process according to claim 1, wherein the cell is operative to recover copper from the aqueous solution and the current density in the areas of lower current density is in the range of 0-1250 A/m^2 and more preferably 0-500 A/m^2.

5. A process according to claim 1, further including the step of removing deposited metal from the deposition surface by passing an element over said surface.

6. A process according to claim 5, wherein the element is moved in the direction in which the areas of high and low current density extend.

7. A process according to claim 6, wherein deposited metal is removed by the element whilst maintaining current flow in the aqueous solution.

8. A process according to claim 5, wherein the element is moveable between first and second positions, and is operative to be passed over the deposition surface in either of the first and second positions.

9. A process according to claim 8, wherein when in its first position, the element is in contact with, or in close proximity to, the deposition surface so as to remove substantially all of the deposition material from that surface.

10. A process according to claim 8, wherein when in its second position, the element is spaced from the deposition surface and is operative to engage and remove deposited material which extends a predetermined distance from the deposition surface.

11. An electrolysis cell for the electro-recovery of metal from an aqueous solution, the cell including a cathode which includes a deposition surface on which metal is deposited on electrolysing of the aqueous solution, wherein in operation of the cell, the deposition surface has a non-uniform electrical field having areas of strong electrical field interspaced by areas of weak electrical field, the difference between the areas of strong electrical field and weak electrical field being sufficient to cause metal deposition to be concentrated on the areas of high electrical field so as to promote non-uniform deposition of metal on the surface.

12. An electrolysis cell according to claim 11, wherein the areas of strong electrical field and weak electrical field extend along the surface in one direction and alternate across the surface in an opposite direction.

13. An electrolysis cell according to claim 11, wherein the deposition surface of the cathode includes an array of alternate ridges and valleys, with the ridges forming the areas of strong electrical field and the valleys forming the areas of weak electrical field.

14. An electrolysis cell according to claim 13, wherein the cathode includes a sheet having at least one major surface which forms the deposition surface of the cathode, the sheet being preformed so as to incorporate the alternate ridges and valleys.

15. An electrolysis cell according to claim 14, wherein the sheet has opposite major surfaces, each of which forms a deposition surface of the cathode.

16. An electrolysis cell according to claim 15, wherein the sheet is folded so as to form the valleys and ridges on the opposite deposition surfaces with the ridges on one deposition surface being directly opposite the valleys on the opposite deposition surface and vice versa.

17. An electrolysis cell according to claim 14, wherein the sheet is of generally uniform thickness.

18. An electrolysis cell according to claim 14, wherein the sheet is formed from titanium.

19. An electrolysis cell according to claim 14, further including at least one conducting element which extends along the sheet, the conducting element being in electro-communication with the sheet so as in use to supply the deposition surface with electrons in the electrolysis process.

20. An electrolysis cell according to claim 19, wherein the conducting element is of sufficient size to add rigidity to the sheet.

21. An electrolysis cell according to claim 19, wherein the cathode includes a second sheet which is connected to the first sheet and which has a major surface which forms a second deposition surface of the cathode, the second sheet being preformed so as to incorporate the alternate ridges and valleys along the deposition surface.

22. An electrolysis cell according to claim 21, wherein the second sheet is connected to the first sheet of the cathode so as to form a plurality of pockets which extend in the direction of the alternate ridges and valleys, the pockets being operative to receive a conducting element of the cathode.

23. An electrolysis cell according to **11**, further including a wiping device which is operative to pass over the deposition surface of the cathode so as to remove deposited material from that deposition surface.

24. An electrolysis cell according to claim 23, wherein the wiping device includes a plurality of projections which are operative to locate within respective valleys of the deposition surface.

25. A cathode for use in an electrolysis cell for the electrorecovery of metal from an aqueous solution, the cathode having a deposition surface including an array of alternate ridges and valleys.

26. A mechanism for removing metal deposited onto the deposition surface of the cathode of claim 25, the mechanism including a plurality of elements arranged to project into respective valleys and be moved therealong so as to dislodge deposited metal from the ridges and valleys.

27. A mechanism as claimed in claim 26, wherein the elements have a shape generally corresponding to the valleys.

28. A mechanism as claimed in claim 26, wherein the elements are formed from a ceramic material.

29. A mechanism as claimed in **26**, wherein the elements are pivotally operable between a first position in which the elements protrude into the valleys and a second position in which the elements do not so protrude.

30-33. (canceled)

* * * * *