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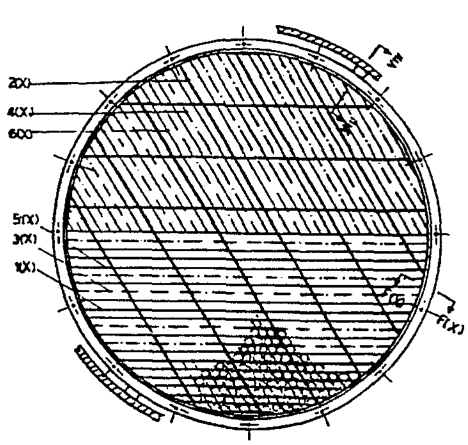
(54) Earthquake-proof tube support grid.

(57) An earthquake-proof support grip for supporting tubes in a steam generator, heat exchanger or the like, particularly for use in P.W.R. nuclear plants and for special heat exchangers for use in petro-chemical plants, comprising a reticular structure formed of main [1(x), 2(x)] and secondary [3(x), 6(x)] intersecting strips and an annular frame enclosing said reticular structure, said frame [30(a), 30(a')] being formed of material having the same coefficient of thermal expansion of the strips or said frame comprising an internal frame [30(b), 30(b')] formed of material having the same coefficient of thermal expansion of the strips and an external frame [40(b), 40(b')] formed of material having a lower coefficient of thermal expansion than that of the strips. Said reticular structure is characterized in that all said secondary strips or only some thereof [3(x), 4(x)] have interengaging slots (21) with portions of said main strips, at the intersecting zone therebetween, and that all strips or only some thereof have the ends [7(x), 8(x)] shaped in the form of a hammer-head profile or a dovetail profile or the like, and that said strip ends are received and blocked without clearance in grooves [23(x), 24(x)] formed in the frame body [30(a), 30(a'); 30(b), 30(b')], said grooves being shaped also respectively in the form of a hammer-head profile or a dovetail profile or the like, in order to prevent the relative movement or the sliding between said strip ends and the said frame enclosing the same. Said hammer-head connections or dovetail connections or the like between the said strip ends and the said frame body being provided to resist severe forces acting on said tube support grid, at all operative temperatures, and caused by the highest grade seismic event together with the greatest accident, such as the burst of a pipe of the primary circuit of a steam generator for use in a nuclear power plant.



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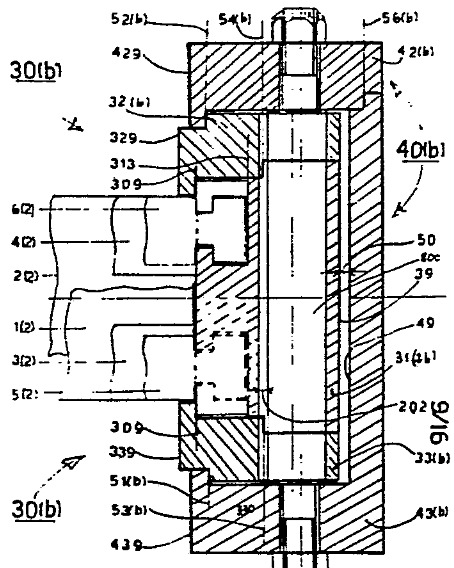

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52(b)
54(b)
56(b)
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42(b)
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40(b)
6(2)
4(2)
2(2)
1(2)
3(2)
5(2)
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33(b)
51(b)
53(b)
439
43(b)
30(b)

FiG 9(2 b)

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EARTHQUAKE-PROOF TUBE SUPPORT GRID

BACKGROUND OF THE INVENTION

The invention proposes new and original technical solutions of the structure of a support grid for tubes of steam generators, heat exchangers and the like, as to solve the problem of the reliability and of the safety of such a support, problem which is acquiring more and more importance and which is urging more and more the manufacturers and the users of such supports, especially as concerns their use for the support of the tubes in nuclear steam generators of P.W.R. type, that is of pressure water reactor;

As well-known, the international rules, particularly the USA ones, concerning nuclear safety, prescribe that the apparatus used in a nuclear power plant have to be so designed as to withstand the dynamic stresses to which they can be subjected when occurs the highest grade seismic event together with the greatest accident, such as the burst of a pipe of the steam generator primary circuit.

Such contemporary events, the second as consequence of the first, cause the arising of local forces, amounting to some tens of tons, in the inside of the tube bundle and therefore inside the supports sustaining such tube bundle.

The said forces can stress a group of tubes of the local zone of the tube bundle, where the said forces burst out and by acting on the supports of the said tubes can cause the permanent deformation of the same and consequently the tube cracking and the burst of the same with the outflow of radioactive water and consequent heavy damages to the nuclear power plant and to the operation personnel.

As to eliminate these great troubles which may occur with the conventional support grids, the present invention proposes new and original solutions for the stiffening of the reticular structure, of the connection of the said reticular structure with the external frame and for the stiffening of the same external frame.

As the forces caused by the contemporary occurence of the seismic event and of the accident concerning the burst of a pipe in the steam generator primary circuit can act whether radially towards the outside of the said support grid, or in opposite direction that is towards the inside of the same, the present invention proposes the stiffening of the reticular structure through a non axially sliding coupling (that is according to the strip axis) between secondary strips and main strips, the stiffening of the strip-frame joint by adopting special mechanical blocking joints (that is of the non sliding type) between the ends of the said strips and the said frame, and the stiffening of the same frame by adopting original constructive solutions which greatly improve the stiffening of the above frame and of the support of the reticular structure on the said frame.

DESCRIPTION OF THE INVENTION

The present invention proposes different embodiments for the manufacturing of an earthquake-proof support grid principally used for the support of the tubes in nuclear steam generators type PWR, the said embodiments all having as aim the problem solution of the tearing or the extracting of the strips' ends from the external frame and of the deformation of this under the action of external forces acting inside the structure of the strips.

As concerns the support reticular structure, the invention proposes the increase of its stiffness by connecting with a non-sliding joint all secondary strips or only some of them (according to the stiffness requirements of the said structure) with portions of main strips, at the intersecting zones with the same. The said joining, according to the invention, is obtained with slots in above-said secondary strips at the said intersection zones, the above said slots having a height equivalent to about 1/5 or 1/6 of the strips height and adapted to receive without clearance portions of main strips. Different construction versions of the said reticular structure are possible with different quantity combinations of main strips with slots and of the secondary strips with or without joining slots.

According to the invention the reticular structure of the support grid can be stiffened in comparison with the well-known conventional ones (for example in comparison with the one described in the Canadian patent n. 1022410 allowed to the same applicant of the present invention) by adopting a combination which uses a quantity of main strips equal to 1/6 of the total amount of all strips and a quantity of secondary strips having interengaging slots with the main ones equal to 5/6 of the total amount in all those cases where the calculation of the reticular structure requires the maximum stiffness, obviously for particular dimensions of the strips.

Thickness and height already prefixed in the calculation.

In the cases in which for the same dimensions of the strips the structure calculation requires a lower stiffness, without changes in the quantity of the main strips, that is 1/6 of the total, the invention proposes a quantity of secondary strips with interengaging slots joining with the main ones equal to 2/6 of the strips total and a quantity of the secondary strips without the said slots equal to the remaining difference and i. e. equal to 3/6 of the strips total.

Combinations differing from the above mentioned ones are possible, according to the invention, for the quantities of main strips with slots and of secondary strips with or without slots for the same dimensions, fixed in the calculations, of the main and secondary strips, as well as for every single quantity combination of main and secondary strips it is possible to further stiffen, according to the invention, the reticular structure by increasing only the height of the secondary strips with slots and i. e. the height of the said slots and not the height of the secondary strips without slots so as not to reduce the strength of the main strips and the above naturally compatible with the load loss allowed by the secondary circuit in which are immersed the said support grids.

It is appropriate to point out that the height of the secondary strip with slots, according to the invention, is equal to the sum of the height of the secondary strip without slots and of the height of the slots.

As concerns the stiffness of the strips-frame joint the present invention proposes some construction versions which completely solve the problem of the tearing that is of the drawing out of the strips' ends from the frame under the action of external forces acting inside the structure of the said strips, either at room temperature, or at operative temperature.

The construction versions, according to the invention, are substantially as follows:
r) strips-frame joint of the dovetail type
s) strips-frame joint of the half-dovetail type
t) strips-frame joint of the hammer-head type
v) strips-frame joint of the half-hammer-head type
z) strips-frame joint of the pin type.

For every one of the first 4 types r - s - t - v - there are two construction embodiments:
- joint with constant thickness and variable height
- joint with variable thickness and constant height.

The choice between these two embodiments depends on the thickness of the strips.

For a thickness of the strips of about 3 - 5 mm., the invention proposes a joint with constant thickness and variable height.

For a thickness of the strips of about 6 - 10 mm. or more the choice, according to the invention, can fall on both construction types, that is either on the type with constant thickness and variable height, or on the type with variable thickness and constant height, according to the economic convenience of the pertinent mechanical machining and of the external frame machining.

Finally the present invention proposes some construction embodiments for the stiffness of the external frame, embodiments which confer a raised stiffness to the same, either cold or hot, in comparison with the well-known conventional solutions, either in the case that the said frame is formed of materials having the same coefficient of thermal expansion of the grid strips, or in the case that the said frame is formed of an internal frame formed of material having the same coefficient of thermal expansion of the strips and of an external frame formed of material having a lower coefficient of thermal expansion than that of the strips.

The increased stiffness of the support grid frame in comparison with the well-known conventional support grids (for example in comparison with the support described in the Canadian patent n. 1022410 already mentioned) is guaranteed, according to the present invention, by new and original solutions concerning the structure of the said frame, structure that is extending generally axially in order not to narrow the useful passage section of the tubes of the steam generator or heat exchanger through the grating of the support grid.

The stiffness of the external frame, according to the invention, can also be increased by the assembling with a tight fit of the various elements forming the same.

Substantially the frames built with materials having the same coefficient of thermal expansion of the strips, have a compact structure generally formed of three rings (two of which generally structurally alike) enclosing without clearance the strips-frame joints and an annular portion of the reticular structure adjacent to the joint itself as to transmit the external forces (which act in accordance with the axis of the tube bundle) directly to the external frame and not through the strips-frame joint, avoiding in this way the fatigue stresses of the said joint and assuring to the same a long life.

The frames built with materials having different coefficient of thermal expansion are formed, according to the present invention, of 5 rings, 3 rings of which for the compact internal frame enclosing without clearance the strips-frame joints and an annular external portion of the reticular structure adjacent to the joint itself and two rings for the external frame enclosing with radial clearance (as to allow the differential thermal expansion between the various elements) the internal frame.

For the above mentioned solution with 5 rings, the present invention proposes furthermore two construction versions, one solution with axial holes passing in all 5 rings (the said holes used, some for the passage of the peripheral tension rods of axial fixing of the grids' group to the tube plate of the steam generator, and others for the passage of the spacers and of the tension rods locking the external frame) and one solution with the said holes passing only through the two rings of the external frame.

The choice of one or of the other solution proposed by the invention depends on the results of the calculation of the stresses, to which the internal and the external frames can be submitted, and therefore on the requirement of having a more rigid internal frame and a less rigid external one or the contrary.

The advantages of the 5 rings version, in the case of earthquake-proof support grids built with materials having different coefficient of thermal expansion, in comparison with the well-known conventional solutions are essentially two:

- increased stiffness of the strips-frame joint and of the frame itself, guaranteed either with cold joint, that is at room temperature, or with hot joint, that is at operative temperature (200-300^{o} C and more)
- total elimination of the harmful fretting between the strips and frame and therefore total elimination of the wear of the strips' ends under the action of the said fretting due to the differential thermal expansion generally combined with the action of the external forces acting on the strips-frame contact zone. In fact being the internal frame built with materials having the same coefficient of thermal expansion of the strips material, the said contact parts expand and contract at the same rate under the effect of the temperature variations and therefore there is no relative movement of the said contact parts or the said movement results negligible, in the case of small inevitable differences of the coefficients of thermal expansion or of different temperature level of the said parts. The important relative movement which is obtained by effect of high temperature variations between the internal frame and the external frame does not result harmful for the grid support integrity, according to the present invention, as the said movement occurs between continuous surfaces in contact with sufficiently rigid structures forming the said frames.

The construction versions proposed by the present invention concerning the earthquake-proof support grid for steam generators, heat exchangers and like apparatus, take also into remarkable account, besides the stiffness requirements of the said support, the simplification of the mechanical machining and of the assembling operations of the different components and therefore the manufacture economy compatible with the requirements of highest stiffness of such a support which may be submitted, as already previously mentioned, to the strongest stresses caused by seismic events of the highest grade.

SUMMARY DESCRIPTION OF THE DRAWINGS

With reference to the drawings here enclosed, which are an integral part of the present descriptive paper, hereunder are described details and advantages of the present invention, which are clearly illustrated in the said drawings, which represent the illustrative, but not restrictive, embodiments of the earthquake-proof support grid.

Fig. 1 represents the schematic assembly in a plan view of the earthquake-proof support grid.

Fig. 2 represents in view a typical tern of three different types of lower and upper strips with the pertinent schematic connections, subject of the present invention.

Fig. 2(1), 2(1'), 2(2), 2(2') each represents a typical tern of three different types of lower and upper strips having at each end a non-sliding connection, according to the invention, with variable section, with constant thickness and variable height, respectively in the shape of dovetail fig. 2(1), half-dovetail fig. 2(1'), hammer-head fig. 2(2), half-hammer-head fig. 2(2').

Fig. 2(3), 2(3'), 2(4), 2(4') each represents a typical tern of three different types of lower and upper strips, having at each end a non-sliding connection, according to the invention, with variable section, with constant height and variable thickness, respectively in the shape of dovetail fig. 2(3), half-dovetail fig. 2(3'), hammer-head fig. 2(4), and half-hammer-head fig. 2(4').

Fig. 2(5) represents a typical tern of three different types of lower and upper strips, having at each end a non-sliding connection, with variable section, with constant thickness and constant height, with central hole for the insertion of a locking pin in the said connection.

Fig. 3 represents schematically a partial view of a nuclear steam generator of a P.W.R. reactor in a typical cross-section to which the present invention applies.

Fig. 4 represents in a larger partial plan view and in a partial horizontal section the upper and intermediate zone of the typical components of the annular frame of the earthquake-proof support grid.

Fig. 5 represents in a larger partial plan view and in a partial horizontal section the lower and intermediate zone of the said typical components of the annular frame of the earthquake-proof support grid.

Fig. 6(1), 6(1'), 6(2), 6(2') each represents the perspective exploded view of a typical pair, according to the invention, of lower and upper slots with variable section, with constant width and variable height, formed in the annular frame for the fitting respectively of the said connections of the strips with constant thickness and variable height, in the shape of dovetail fig. 6(1), half-dovetail fig. 6(1'), hammer-head fig. 6(2), half-hammer-head fig. 6(2').

Fig. 6(3), 6(3'), 6(4), 6(4') each represents the perspective exploded view of a typical pair, according to the invention, of lower and upper slots with variable section, with constant height and variable width, formed in the annular frame for the fitting respectively of the said connections of the strips, with constant height and variable thickness, in the shape of dovetail fig. 6(3), half-dovetail fig. 6(3'), hammer-head fig. 6(4), half-hammer-head fig. 6(4').

Fig. 7(1), 7(1'), 7(2), 7(2') each represents a perspective exploded view of a typical pair, according to the invention, of connections with variable section, with constant thickness and variable height, of the ends of the lower and upper strips, respectively in the shape of dovetail fig. 7(1), half-dovetail fig. 7(1'), hammer-head fig. 7(2), half-hammer-head fig. 7(2').

Fig. 7(3), 7(3'), 7(4), 7(4') each represents a perspective exploded view of a typical pair, according to the invention, of connections with variable section, with constant height and variable thickness, of the ends of the lower and upper strips having the profile respectively in the shape of dovetail fig. 7(3), half-dovetail fig. 7(3'), hammer-head fig. 7(4), half-hammer-head fig. 7(4').

Fig. 8 represents the exploded cross-section VIII-VIII of Fig. 1, in order to show the typical assembling between a tube support grid and the shell 500 wherein are mounted and spaced the various support grids. This figure 8 shows the well-known spacers 600 between any two grids for the axial positioning of the same and the well-known wedges 700 for the radial positioning of each support grid.

Fig. 8(1), 8(1'), 8(2') each represents a perspective view of a typical section, according to the invention, of the lower and upper annular chambers of the annular frame for the fitting of the said connections of the ends of the strips and of the spacers between the said connections, the said chambers having the profile of the vertical section respectively in the shape of dovetail fig. 8(1), half-dovetail fig. 8(1') and half-hammer-head fig. 8(2').

Fig. 9(1a) and 9(2a) each represents a typical section, according to the invention, F(x)-F(x) of Fig. 1 and refers to the execution of the annular frame of the 3 rings support grid with the said lower and upper inner annular chambers having the profile of the vertical section respectively in the shape of dovetail fig. 9(1a), half-dovetail according to the interrupted line of fig. 9(1a) and half-hammer-head fig. 9(2a).

Fig. 9(1b) and 9(2b) each represents a typical section F(x)-F(x) of Fig. 1 and refers to the execution of the annular frame of the 5 rings support grid, according to the invention, 3 intermediate rings of which forming the intermadiate frame and 2 external rings forming the external annular frame formed of material having lower expansion coefficient than the intermediate frame, the said intermediate frame having in the inner zone the said lower and upper annular chambers, – the vertical section of which has a profile respectively in the shape of dovetail fig. 9(1b), half-dovetail according to the interrupted line of fig. 9(1b) and half-hammer-head fig. 9(2b).

Fig. 9(1b') and 9(2b') each represents an alternative solution to the one illustrated respectively in the figures 9(1b) and 9(2b) and concerns the execution of the annular frame with 5 rings with axial holes (for the passage of the tension rod 200 fixing the support grid to the tube-plate of the steam generator and of the peripheral tension rods 800 locking the annular frame) formed in the two external rings instead in the 5 rings as in figures 9(1b) and 9(2b).

Fig. 9(1a') and 9(2a') each represents a typical section F(x)-F(x) of Fig. 1 and refers to the execution of the 3 rings annular frame with lower and upper milled axial slots, with variable section, with constant width and variable height, formed in the intermediate ring and having the profile respectively in the shape of dovetail fig. 9(1a'), half-dovetail according to the interrupted line of Fig. 9(1a'), hammer-head fig. 9(2a') and half-hammer-head according to the interrupted line of fig. 9(2a').

Fig. 9(3a') and 9(4a') each represents a typical section of the said intermediate ring in an execution in alternative to the one illustrated respectively in figures 9(1a') and 9(2a'), with lower and upper milled axial slots with variable section, with constant height and variable width, formed in the said intermediate ring and having the profile respectively in the shape of dovetail fig. 9(3a'), half-dovetail according to the interrupted line of fig. 9(3a'), hammer-head fig. 9(4a') and half-hammer-head according to the interrupted line of fig. 9(4a').

Fig. 10 represents a typical vertical section of the intermediate ring in the execution of the 3 rings annular frame of fig. 9(2a) as well as in the 5 rings execution of fig. 9(2b), 9(2b').

Fig. 11(3), 11(4) each represents a typical horizontal section M(x)-M(x) of the intermediate ring of Fig. 10 and refers to the execution of the annular frame in alternative to the one represented in fig 9(1a), 9(1b), 9(1b'), 9(2a), 9(2b) and 9(2b'), with lower and upper slots, delimited by spacers with variable section, with constant height and variable width, having the profile respectively in the shape of dovetail fig. 11(3), half-dovetail according to the interrupted line of fig. 11(3), hammer-head fig. 11(4) and half-hammer-head according to the interrupted line of fig. 11(4).

Fig. 11(5) represents a vertical section and a typical plan view of the annular frame containing the connections of the ends of the strips of the pin type represented in fig. 2(5), in variant to the execution with 3 and 5 rings represented in fig. 9(1a), 9(1b), 9(1b'), 9(2a), 9(2b), 9(2b'), the said variants referring only to the pin connection of the ends of the strips and to the type of spacers between the said connections.

Fig. 12(1a') and 12(2a') each represents a typical vertical section and a partial plan view of the intermediate ring represented respectively in fig. 9(1a') and 9(2a').

Fig. 13(1b), 13(1b'), 13(2b) and 13(2b') each represents the components of the earthquake-proof support grid, according to the invention, in an exploded view and refers to the 5 rings execution of the annular frame respectively represented in fig. 9(1b) for the fig. 13(1b); 9(1b') for the fig. 13(1b'); 9(2b) for the fig. 13(2b) and 9(2b') for the fig. 13(2b').

Fig. 25(1), 25(1'), 25(2), 25(2') represent in a vertical section according to a plan parallel to the strips and in a lateral view the shaped lower spacers between the connections with constant thickness and variable height of the ends of the lower strips, respectively fig. 25(1) represents the lower spacers of the dovetail type 25'(1); the fig. 25(1') the lower spacers of the half-dovetail type 25(1'); the fig. 25(2) the lower spacers of the hammer-head type 25'(2) and the fig. 25(2') the lower spacers of the half-hammer-head type 25(2').

Fig. 26(1), 26(1'), 26(2), 26(2') represent the shaped upper spacers between the connections with constant thickness and variable height of the ends of the upper strips; respectively the fig. 26(1) represents the upper spacers of the dovetail type 26'(1); the fig. 26(1') the upper spacers of the half-dovetail type 26(1'); the fig. 26(2) the upper spacers of the hammer-head type 26'(2) and the fig. 26(2') the upper spacers of the half-hammer-head type 26(2').

Fig. 26(3), 26(4), 26(5) represent the vertical section V-V according to a plan parallel to the strips respectively of the lower spacers and of the upper spacers represented in the fig. 11(3), 11(4), 11(5); respectively the fig. 26(3) represents the spacers of the dovetail type, lower spacers 25(3), upper spacers 26(3) and of the half-dovetail type lower spacers 25(3'), upper ones 26(3'); the fig. 26(4) represents the spacers of the head-hammer type - lower ones 25(4), upper ones 26(4) and of the half-hammer-head type, lower ones 25(4'), upper ones 26(4'); the fig. 26(5) represents the spacers of double "I" type , lower ones 25(5) and upper ones 26(5), between the connections of the ends of the locking pin type strips.

Fig. 26(3'), 26(4') represent the horizontal section 0-0 of the spacers of the type respectively half-dovetail 25(3'), 26(3') and half-hammer-head 25(4'), 26(4') represented respectively in the fig. 26(3) and 26(4).

Fig. 27(5) represents in section and in view the locking pin 107 inserted in the hole 106 of the connection of the ends of the locking pin type strips.

The reticular structure of the earthquake-proof support grid has been diffusely illustrated at the beginning of the present description as concerns the stiffness of the said structure.

Fig. 2 clearly shows the different types of lower and upper strips forming the said reticular structure.

The main lower 1(x) and upper 2(x) strips have the main slots 19 equally spaced having a depth equal to the half of the strip height. The said slots 19 are necessary for the engagement of the main lower strips with the upper ones at the intersecting zones. Between the said main slots 19 are obtained the secondary slots 20 equally spaced for the fitting of the secondary lower 3(x), 5(x) and upper 2(x), 4(x) strips. The said slots 20 have a depth generally equal to 1/3 - 1/4 of the height of the main strip.

The secondary lower 3(x) and upper 4(x) strips have also slots 21, according to the invention, equally spaced, with distance equal to the distance existing between the slots 19 of the main strips. The said slots 21 have a depth equal to 1/4 - 1/6 of the height of the said secondary strip 3(x), 4(x) and are provided for the engagement of the said strips with corresponding portions of main strips, at the intersecting zones therebetween, according to the invention, in order to stiffen considerably the reticular structure. The height of the said secondary strips 3(x) and 4(x) with slots 21 is equal, according to the invention, to the sum of the height of the secondary strips 5(x), 6(x) without slots and of the depth of the said slots 21.

Hereunder are described the main characteristics of the earthquake-proof support grid, according to the invention, as concerns the stiffness of the strips-frame joint and of the frame itself.

Furthermore are listed the typical supports and the pertinent main characteristics, by individualizing every typical support with a number and/or a letter which states the construction type of the said support, according to the invention:

- EARTHQUAKE-PROOF SUPPORT GRID WITH CONNECTIONS OF THE ENDS OF THE STRIPS WITH VARIABLE SECTION, WITH CONSTANT THICKNESS 110 AND VARIABLE HEIGHT, greater height 142 and therefore greater section, at the free end 13, 14 of the said connections and lower height 141 and therefore smaller section, at the root 9, 10 of the said connections:

1. - connections in the shape of dovetail 7(1) and 8(1) respectively of the ends of the lower strips 1(1), 3(1), 5(1) and of the upper strips 2(1), 4(1), 6(1);

1'. - connections in the shape of half-dovetail 7(1'), 8(1') respectively of the ends of the lower strips 1(1'), 3(1'), 5(1') and of the upper strips 2(1'), 4(1'), 6(1');

2. - connections in the shape of hammer-head 7(2), 8(2) respectively of of the ends of the lower strips 1(2), 3(2), 5(2) and of the upper strips 2(2), 4(2), 6(2);

2'. - connections in the shape of half-hammer-head 7(2'), 8(2') respectively of the ends of the lower strips 1(2'), 3(2'), 5(2') and of the upper strips 2(2'), 4(2'), 6(2');

- EARTHQUAKE-PROOF SUPPORT GRID WITH CONNECTIONS OF THE ENDS OF THE STRIPS WITH VARIABLE SECTION, WITH CONSTANT HEIGHT 140 AND VARIABLE THICKNESS, greater thickness 115 and therefore greater section at the free end 13, 14 of the said connections and lower thickness 114 and therefore smaller section at the root 9, 10 of the said connections:

3. - connections in the shape of dovetail 7(3), 8(3) respectively of the

ends of the lower strips 1(3), 3(3), 5(3) and of the upper strips 2(3), 4(3), 6(3);

3'. - connections in the shape of half-dovetail 7(3'), 8(3') respectively of the ends of the lower strips 1(3'), 3(3'), 5(3') and of the upper strips 2(3'), 4(3'), 6(3');

4. - connections in the shape of hammer-head 7(4), 8(4) respectively of the ends of the lower strips (1(4), 3(4), 5(4) and of the upper strips 2(4), 4(4), 6(4);

4'. - connections in the shape of half-hammer-head 7(4'), 8(4') respectively of the ends of the lower strips 1(4'), 3(4'), 5(4') and of the upper strips 2(4'), 4(4'), 6(4');

- EARTHQUAKE-PROOF SUPPORT GRID WITH CONNECTIONS OF THE ENDS OF THE STRIPS WITH VARIABLE SECTION, WITH CONSTANT THICKNESS 110 AND CONSTANT HEIGHT 140 :

5. - connections (with central hole 106 and locking pin 107), 7(5) and 8(5) respectively of the ends of the lower strips 1(5), 3(5), 5(5) and of the upper strips 2(5), 4(5), 6(5).

Each of the first eight construction versions above mentioned can be combined, according to the invention, with any one of the following four construction versions of the annular frame enclosing the said connections of the support grid:

a. - EARTHQUAKE-PROOF SUPPORT GRID WITH ANNULAR FRAME 30(a) FORMED OF 3 RINGS, overlapped and enclosing the said connections of the ends of the strips and the spacers between the said connections;

a'. - <u>EARTHQUAKE-PROOF SUPPORT GRID WITH ANNULAR FRAME 30(a') FORMED OF 3 RINGS, THE INTERMEDIATE RING OF WHICH HAVING LOWER AND UPPER MILLED SLOTS</u>, for the fitting of the connections of the ends of the strips;

b. - <u>EARTHQUAKE-PROOF SUPPORT GRID WITH INTERMEDIATE ANNULAR FRAME 30(b) FORMED OF THREE RINGS</u> overlapped and enclosing the said connections of the ends of the strips and the <u>SPACERS BETWEEN THE SAID CONNECTIONS</u> and with <u>EXTERNAL ANNULAR FRAME 40(b) FORMED OF TWO RINGS</u> overlapped and enclosing the said intermediate annular frame with adequate clearance 50 for the differential thermal expansion between the materials with different coefficient of thermal expansion of the intermediate annular frame 30(b) and of the external annular frame 40(b). The spacers and tension rods 800 for the locking of the external frame and the tension rods 200 for the fixing of the grid to the tube plate 400 of the steam generator cross all five rings, being foreseen an adequate clearance 202 (for the differential expansion of the different materials) between the said tension rods and the holes made in the three inner rings.

b'. - <u>EARTHQUAKE-PROOF SUPPORT GRID WITH 5 RINGS</u>, as previously described at point b, with the only difference that the said tension rods 800 for the locking of the external frame and the said tension rods 200 for the fixing of the grid to the tube plate 400 cross only the two external rings and not all 5 rings as per the construction solution b.

The combination of any construction version of the connections 1, 1', 2, 2', 3, 3', 4 and 4' of the ends of the strips 1(x) - 6(x) with any construction version of the annular frame a, a', b, b', enclosing the said connections, leads to 4 different construction types of the earthquake-proof support grid.

For example, by combining the connection 1 with the annular frame a the support grid of type 1a is obtained; by combining the connection 1 with the annular frame a' the support grid 1a' is obtained and the same applies to the supports 1b and 1b'; the same for the connections 1' which in combination respectively with the annular frames of type a, a', b, b', leads respectively to the support grids 1'a, 1'a', 1'b, 1'b'. As the construction types of connections of the ends of the strips, except the locking pin type, are 8 and the alternative solutions of the annular frame are 4, it is possible to get 32 different construction types for the earthquake-proof support grid.

Furthermore by combining the connection type 5 of the end of the strips with the central hole 106 and locking pin 107 with the three construction solutions of the annular frame a, b and b' enclosing the said connections and the spacers therebetween, it is possible to obtain three other different types 5a, 5b, and 5b' of the earthquake-proof support grid and therefore in all it is possible to get n. 35 different construction types of the support grid. These 35 different support grids, if adequately dimensioned, will be all suitable to withstand, in more or less measure, according to the project requirements, the intense mechanical stresses, which can be caused by seismic event, combined with mechanical stresses that can be caused by localized overpressures which are contemporaneous and consequent to the said seismic event.

The choice of any one of the 35 different construction types of the earthquake-proof support grid depends on the different requirements of dimensioning and stiffening of the single components and on the support assembly, on the space availability, on the materials used, particularly as concerns the coefficient of thermal expansion of the same, as well as on the economy requirement of the manufacture in relation to the availability of adequate shop equipment and on the mounting requirements of the assembly of the said support grid.

In order to better illustrate the different construction types of the earthquake-proof support grid, the different components represented in the different illustrative figures have been indicated with a number followed by an index determinating the construction type; for example the connection of the end of the lower strips of the dovetail type 7(1) is indicated with the number 7 which refers to the connection of any lower strip followed by the index 1 in parentheses that specifies the connection type and i. e. the dovetail connection 1 and also for the connection 8(2) the number 8 indicates the connection of any upper strip and the number 2 in parentheses indicates the hammer-head type connection; as well as for the other construction components, for example for the central ring 31(1a) of the 3 rings annular frame, the number 31 indicates the central ring wherein are fitted the said connections of the ends of the strips, the number 1 in parentheses indicates the construction type of the said ring i. e. with inner central flange in dovetail shape and therefore suitable to receive a connection of type 1 and the letter a indicates that the said central ring is a component of the 3 rings annular frame 30(a) of type a, which encloses the said connections of the ends of the strips and the spacers therebetween. For the components marked with a number followed by x in parentheses, for example 7(x), the number 7 indicates the component i. e. the connection of any lower strip and the x in parentheses indicates any construction type of connection which can be 7(1), 7(2), 7(3), etc., the same applies, for example, for the ring 31(x), where the number 31 indicates a ring enclosing the connections of the ends of the strips and the x in parentheses indicates that the said ring can belong to any one of the 35 above mentioned cunstruction versions of the earthquake-proof support grid.

Besides indicating with a number followed by x in parentheses the support grid components, the same characterization criterion has been adopted as to designate the spaces or slots containing the said connections of the ends of the strips and/or the spacers therebetween. For example, 23(x) indicates the lower slots obtained by milling in any central ring 31(x) of any annular frame of type a' for the fitting of the connections 7(x) of the ends of the lower strips 1(x), 3(x), 5(x); furthermore the same marking 23(x) designates the lower closed slots delimited by the lower spacers 25(x), by the central ring 31(x) and by the lower ring 33(x) of any annular frame of the construction type a, b and b'; the said slots 23(x) are suitable to receive and to put in position the said connections 7(x) of the ends of the lower strips 1(x), 3(x), 5(x).

On the contrary, as concerns the individualization of some significant surfaces and significant diameters common to different construction components or of some significant dimensions (thickness, width, height) of typical components, it was preferred to designate them with a simple number not followed by any other index; for example the numbers 13 and 14 individualize the free ends of the connections respectively of the ends of the lower strips 7(x) and of the upper strips 8(x); a further example, the number 309 marks the inside diameter of any ring 31(x), the said diameter aligned with the roots 9 and 10 respectively of the connections of the ends of the lower strips 7(x) and of the upper strips 8(x) and the number 313 marks the intermediate or outside diameter of any ring 31(x) generally aligned with the ends 13 and 14 respectively of the connections of the ends of the lower strips 7(x) and of the upper strips 8(x).

It is appropriate to point out also that all support grid components in the numerous construction versions illustrated in the different figures and the significant characteristics of the said construction components, for example thickness, width, height, etc., are always indicated with the same reference number.

Hereunder are described more in detail the main characteristics of the different construction types, according to the invention, of the support grid.

The characteristics of the supports of type 1a, 1'a, 2a, 2'a, 3a, 3'a, 4a, 4'a, are illustrated respectively in the figures 9(1a), 9(2a), 11(3) and 11(4) .

It should be noted that the construction types 1'a, 2'a, 3'a, 4'a, are marked respectively in the figures mentioned with interrupted line only for those components, the geometric configuration of which is to be modified in order to adapt the profile of the said components to the profile of the connection respectively of half-dovetail type 7(1'), 8(1'), 7(3'), 8(3') and of half-hammer-head type 7(2'), 8(2'), 7(4'), 8(4') of the ends of the strips. In order to increase the stiffening of the annular frame enclosing the said connections 7(x), 8(x) of the ends of the strips, the invention proposes one sole central ring 31(1a), 31(2a) with an inner central flange 310, having smaller thickness 311 at the root 313 of the said flange and greater thickness 312 at the free end 309 of the said flange. The inner lower and upper surface of the said sole ring 31(1a), 32(2a) is shaped according to the profile of the outline delimited respectively by the sides 9, 11, 13 of the connection 7(x) of the ends of the lower strips and/or the profile of the spacers 25(x) therebetween and by the sides 10, 12, 14 of the connection 8(x) of the ends of the upper strips and/or the profile of the spacers 26(x) therebetween.

The annular frame 30(a) of the construction types above mentioned is substantially formed of 3 rings, the central one of which 31(1a) and 31(2a) has been already previously described.

The other two rings that, in order to be better distinguished, will be called cover-rings respectively lower one 33(a), 33(1a) and upper one 32(a), 32(1a), have a geometric configuration substantially equal.

The vertical section of the said assembled 3 rings of the construction types 1a, 1'a, 2a, is represented in perspective view respectively in the figures 8(1), 8(1'), 8(2). In the above mentioned figures 8(1), 8(1'), 8(2) are clearly visible the lower annular chambers respectively 315(1), 315(1') and 315(2) and the upper annular chambers respectively 316(1), 316(1') and 316(2). The said annular chambers are formed respectively of the spaces enclosed by the central ring 31(1a), 31(2a) and by the lower cover-ring 33(a), 33(1a) and by the upper cover-ring 32(a), 32(1a) overlapped to the said central ring and to external annular zones 17, 18 respectively of the lower and upper reticular structure adjacent respectively to the connection 7(x), 8(x). The said cover-rings 33(a), 33(1a) and 32(a), 32(1a) have the inside diameter respectively 339 and 329 smaller than the inside diameter 309 of the flange 310 of the said central ring 31(1a), 31(2a).

The said lower and upper annular chambers have the greater height 332 at the root 313 of the flange 310 of the said central ring 31(a), 31(2a) and the smaller height 331 at the free end 309 of the said flange 310. The opening of the said annular chambers having height 331 is facing the inside of the reticular structure.

The said annular chambers are suitable to receive and to put in position the different types of connections of the ends of the strips and the different types of spacers therebetween. As it is easy to understand, the slots 23(x), 24(x) for the fitting of the connections 7(x), 8(x) respectively of the ends of the lower and upper strips, are obtained by shaping (generally by turning) the surfaces of the central ring 31(1a), 31(2a) and the surfaces respectively of the lower cover-ring 33(a), 33(1a) and of the upper cover-ring 32(a), 32(1a) according to the profile delimited respectively by the sides 9, 11, 13, 15 of the connections 7(x) of the ends of the lower strips and by the sides 10, 12, 14, 16 of the connections 8(x) of the ends of the upper strips and by shaping (generally by milling) the surfaces respectively of the said lower spacers 25(x) and upper ones 26(x) according to the surfaces of the said central ring and respectively of the said lower and upper cover-rings and to the surface of the said lower connections 7(x) and upper connections 8(x) i. e. according to the profile of the said surfaces with which the said spacers will be in contact.

The said slots 23(x), 24(x) with variable section, can have constant width 100 and variable height, greater height 132 and therefore greater section at the root 313 of the flange 310 of the said central ring 31(1a), 32(2a) and smaller height 131 and therefore smaller section at the free end 309 of the flange 310 of the said central ring.

In the figures 6(1), 6(1'), 6(2), 6(2') are illustrated in an exploded perspective view typical pairs of lower slot 23(x) and upper slot 24(x); respectively in the figure 6(1) are represented the slots 23(1), 24(1), in the figure 6(1') the slots 23(1'), 24(1'), in the figure 6(2) the slots 23(2), 24(2), in the figure 6(2') the slots 23(2'), 24(2').

The said slots 23(x), 24(x) with variable section, can have constant height 130 and variable width, greater width 105 and therefore greater section at the root 313 of the flange 310 of the said central ring 31(1a), 32(2a) and smaller width 104 and therefore smaller section at the free end 309 of the flange 310 of the said central ring.

In the figures 6(3), 6(3'), 6(4), 6(4') are illustrated in an exploded perspective view typical pairs of the said lower slots 23(x) and upper ones 24(x) with constant height 130 and with variable width; respectively in the figure 6(3) are represented the slots 23(3), 24(3), in the figure 6(3') the slots 23(3'), 24(3'), in the figure 6(4) the slots 23(4), 24(4), and in the figure 6(4') the slots 23(4'), 24(4'). The different types of shaped spacers 25'(1), 26'(1), 25(1'), 26(1'), 25'(2), 26'(2), 25(2'), 26(2'), 25(3), 26(3), 25(3'), 26(3'), 25(4), 26(4), 25(4'), 26(4') between the connections 7(x), 8(x) of the ends of the strips are illustrated respectively in the figures 25(1), 26(1), 25(1'), 26(1'), 25(2), 26(2), 25(2'), 26(2'), 26(3), 26(3'), 26(4), 26(4').
It should be pointed out that the lower spacers 25'(1) and 25'(2) have lower lateral projecting portions respectively 250(1') and 250(2') with upper surface shaped according to the profile 15 of the lower surface respectively of the connection 7(1) and 7(2) of the ends of the lower strips and the spacers 26'(1) and 26'(2) have upper lateral projecting portions respectively 260(1') and 260(2') with lower surface shaped according to the profile 16 of the upper surface respectively of the connection 8(1) and 8(2) of the ends of the upper strips.

The spacers 25(1') and 25(2') have lower lateral projecting portions 250(o) with upper flat horizontal surface, i. e. according to the profile 15 of the lower flat surface respectively of the connection 7(1'), 7(2') of the ends of the lower strips and the spacers 26(1') and 26(2') have upper lateral projecting portions 260(o) with lower horizontal flat surface, i. e. according to the profile 16 of the upper flat surface respectively of the connection 8(1'), 8(2') of the ends of the upper strips. The above mentioned lateral projecting portions 250(x) and 260(x) have a depth 120 equal to the thickness 110 of the connections 7(x), 8(x) of the ends of the strips. Generally the said spacers 25(x), 26(x) which form the annular frames of the support grids above mentioned have the height 27 greater than the height 142 of the pertinent connections 7(x), 8(x) with which they are in contact, so that the said spacers 25(x), 26(x) result imprisoned in the annular chambers respectively 315(x) and 316(x) of the said annular frame 30(a). Generally the said spacers 25(x), 26(x) (also owing to the half-hammer-head profile 345 of the vertical section, according to a plan parallel to the strips, of the said spacers) have the function of transmitting the horizontal forces going towards the inside of the support grid and acting on the said connections 7(x), 8(x) of the strips 1(x) - 6(x) directly on the 3 rings forming the said annular frame 30(a), when the above mentioned forces, owing to the particular geometric configuration of the connections 7(x), 8(x) and of the spacers 25(x), 26(x), are not directly transmitted by the above connections 7(x), 8(x) to the said 3 rings forming the annular frame 30(a). It should be pointed out furthermore that the above mentioned construction solutions of the earthquake-proof support grid, besides conferring a considerable mechanical stiffness to the support assembly, have the advantage of being realized without the necessity of expensive and special work-shop equipment both for the mechanical machining and for the mounting of the support grid.

The turning operations of rings having diameters generally not greater than 3,5 meters, are normal operations that can be executed by any mechanical shop of middle dimensions.

The milling operations of the strips with the pertinent connections and of the spacers therebetween are also common operations which can be executed on milling machines of small and/or middle dimensions of normal type or with numerical control system, available generally in any average mechanical work-shop.

The assembly of the support grid does not require special and expensive mounting jigs as is necessary on the contrary for the conventional support grids, as that described in the Canadian patent n. 1022410.

In fact, the sole central ring 31(1a), 31(2a) is sufficiently rigid as to replace the conventional mounting jig.

The positioning marking of the main lower 1(x) and main upper 2(x) strips can be made directly respectively on the lower and upper surface of the flange 310 of the ring 31(1a), 31(2a).

The gauges themselves for the milling of the slots and of the connections of the ends of the strips, owing to the stiffness of the said central ring 31(1a), 31(2a) can be built by copying the profiles of the lower and upper surfaces of the said flange 310 and of the cylindrical surfaces 309 and 313 respectively of the free end and of the root of the said flange.

The mounting of the support grid can be executed in one phase only, as all support grid components, strips 1(x) - 6(x), spacers 25(x), 26(x), and rings 31(x), 32(x) and 33(x) are built beforehand with adequate tolerances, which can be more strict than those concerning a conventional grid, as the one described in the Canadian patent n. 1022410, in that the mounting is executed by assembling the different parts in a vertical position and by slightly pressing, if necessary, with a small hammer of hard-wood, the parts that have to come into contact.

The said vertical mounting of all strips presents two advantages in comparison with the traditional mounting system of the secondary strips in horizontal position described in the above mentioned Canadian patent. The first advantage is that of non-running the risk of scoring the surfaces of the strips, scorings which are possible with the old system of mounting the strips horizontally.

The second advantage is that of being in position to build the grid grating with null clearances between the coupled intersecting strips, owing to the vertical mounting of the said parts and therefore to obtain as a result a more compact and therefore more rigid grating. The mounting sequence proposed by the present invention, which is valid for all 35 different construction types of the support grid, is as follows:

Assembling of all main strips, for example the lower ones 1(x) on the central ring 31(x), according to the layout already preset on the said ring; rotation of 180 degrees of the said ring on proper rotation pins already preset; assembling of all upper main strips 2(x) by coupling the main slots 19 of these with the pertinent portions of lower main strips 1(x); subsequent assembling of all upper secondary strips 4(x), 6(x) by pressing them in the secondary slots 20 of the main lower strips 1(x) and by coupling the slots 21 with the pertinent portions of the said main lower strips; contemporaneous assembling to every upper strip of the pertinent spacer 26(x), if foreseen, in contact with the connection 8(x) of the said strip, by adapting, if necessary, the profile of the said spacer 26(x) to the profile of the said connection, especially to the upper surface 16 of the said connection. Subsequent assembling of the upper cover-ring 32(x), after having provided for the adequate heating of the partial support grid assembly, as to allow the mounting with a tight fit at the "L" shaped external annular zone 54(x) of the said ring 32(x) on the said ring 31(x). After having provided the blocking of the said upper cover-ring 32(x) on the said central ring 31(x), rotation of 180 degrees of the partially assembled support grid, mounting (following the same modalities above mentioned) of all lower secondary strips 3(x), 5(x) and of the pertinent spacers 25(x), if foreseen, between the connections 7(x) of the ends of the said strips, by adapting, if necessary, the profile of the said spacers to the profiles of the said connections, especially to the lower surfaces 15 of the said connections. Finally, assembling of the lower ring 33(x), after having adequately heated the support grid assembly as to allow the mounting with a tight fit at the "L" shaped external annular zone 53(x) of the said lower ring 33(x) on the said central ring 31(x). The above assembling sequence is completed for all construction types b and b' of the annular frame by proceeding to the assembling (after preheating of the support grid as to have a tight fit), first, of the lower ring 43(b), 43(b') on the lower ring 33(x) at the "L" shaped inner annular zone 51(x) and then of the upper cover-ring 42(b), 42(b') on the lower ring 43(b), 43(b') and on the upper cover-ring 32(x) at the "L" shaped annular zones respectively 56(x) and 52(x), in order to obtain a support grid assembly as rigid as possible.

Hereunder are now examined the construction types 1a', 1'a', 2a', 2'a', 3a', 3'a', 4a', 4'a', of the support grids represented respectively in the figures 9(1a'), 12(1a'), 9(2a'), 12(2a'), 9(3a') and 9(4a'). In the said drawings the construction types 1'(a'), 2'(a'), 3'(a') and 4'(a') are marked with interrupted lines for those components, the profile of which is to be modified according to the profile respectively of the connections 1', 2', 3', 4'.

The said construction types a' of the grid support are different from the construction types a previously described as concerns the structure of the central ring 31(x) and the structure of the lower ring 33(x).

The central ring 31(x) is a ring which has a plurality of milled lower slots 23(x), spaced and parallel to each other, suitable to receive the connections 7(x) of the ends of the lower strips 1(x), 3(x), 5(x) and a plurality of milled upper slots 24(x), spaced and parallel to each other, but forming a certain angle, generally 60°, with the plurality of lower slots; the said upper slots suitable to receive the connections 8(x) of the ends of the upper strips 2(x), 4(x), 6(x).

The said central ring 31(x) can be executed in 8 different construction types 31(1a'), 31(1'a'), 31(2a'), 31(2'a'), 31(3a'), 31(3'a'), 31(4a'), 31(4'a'), the rings of which have respectively a plurality of lower slots with constant width 100 and variable height 23(1), 23(1'), 23(2), 23(2'), with constant height 130 and variable width 23(3), 23(3'), 23(4), 23(4'), suitable to receive and to put in position, generally without clearance, respectively the connections 7(1), 7(1'), 7(2), 7(2'), 7(3), 7(3'), 7(4), 7(4') of the ends of the lower strips, and a plurality of upper slots with constant width 100 and variable height 24(1), 24(1'), 24(2), 24(2'), with constant height 130 and variable width 24(3), 24(3'), 24(4), 24(4'), suitable to receive and to put in position, generally without clearance, respectively the connections 8(1), 8(1'), 8(2), 8(2'), 8(3), 8(3'), 8(4), 8(4'), of the ends of the upper strips.

The lower ring 33(x) of the said construction a' of the support grid has a lower flange 330(a') facing the inside of the support and overlapped without clearance to the lower surface of the said central ring 31(x), to the surfaces 15 of the connections 7(x) of the ends of the lower strips and to an external annular zone 17 of the reticular structure adjoining the said connections 7(x), the said ring 33(x) having generally an axial inner length equal to the height of the said central ring 31(x).

The said lower ring 33(x) has the inner surface shaped in accordance with the different profiles of the external surface of the said ring 31(x), with the surface of which it is in contact.

The rings 33(1a'), 33(2a'), represented respectively in the figures 9(1a') and 9(2a') are used in the construction types respectively 1a', 2a' of the support grid, while the lower cover-ring type 33(a') is used in the construction types 1'a', 2'a', 3a', 3'a', 4a' and 4'a' of the support grid. The said lower ring 33(x) is mounted with a tight fit on the intermediate ring 31(x) at the "L" shaped external annular zone 53(a') adjoining the root of the flange 330(a') of the said lower ring. The upper cover-ring 32(x) in the different construction versions 32(a'), 32(1'a'), 32(2a') is overlapped without clearance to the external upper surface of the said intermediate ring 31(x), to the external upper surfaces 16 of the upper connections 8(x) of the upper strips 2(x), 4(x), 6(x) and an external annular zone 18 of the reticular structure adjoining the said connections 8(x).

The said upper cover-ring 32(x) is mounted with a tight fit on the said intermediate ring 31(x) at the "L" shaped external annular zone 54(a') of the said intermediate ring. The other construction solution 1b, 2b, of the earthquake-proof support grid are to be considered as construction solutions equivalent to the support grid types 1a, 2a, previously described as concerns the inner annular frame 30(b), which has the axial holes 203 (for the passage of the spacers and tension rods 800 for the locking of the external frame and the tension rods 200 for the fixing of the grid to the tube plate 400) increased by the quantity 202 in order to allow the free expansion of the different material making up the inner annular frame 30(b) and the external annular frame 40(b). Therefore for the description of the said inner annular frame 30(b), refer to the previous description of the annular frame 30(a) with 3 rings of the construction types 1a and 2a of the support grid.

Said support grids of type 1b and 2b, illustrated in the figures 9(1b), 9(2b), 13(1b) and 13(2b), are formed of the following components:

- inner central rings 31(1b), 31(2b) equivalent to the types already previously described 31(a), 31(2a);
- lower intermediate cover-rings 33(1b), 33(b) equivalent to the types 33(1a), 33(a);
- upper intermediate cover-rings 32(1b), 32(b) equivalent to the types 32(1a), 32(a);

(The abbular zones of coupling between the said rings are the lower zone 53(b) and the upper zone 54(b) both "L" shaped.)

- lower 25(x) and upper 26(x) spacers between the connections of the ends of the strips respectively 7(x) and 8(x), similar to the spacers already previously described;

- external annular frame 40(b), formed generally of a lower ring 43(b) having a lower flange 330 facing the inside of the support and having an inner height generally equal to the total height of the intermediate annular frame 30(b) and of an upper external cover-ring 42(b). The said lower ring 43(b) is generally mounted with a tight fit on the lower intermediate cover-ring 33(1b), 33(b) at the "L" shaped lower inner annular zone 51(b) of the said cover-ring.

Between the inner cylindrical surface 49 of the portion axially extending of the said external lower ring 43(b) and the external cylindrical surface 39 of the said intermediate annular frame 30(b) there is a sufficient clearance 50 in order to allow the free thermal expansion of the two adjacent annular frames formed of materials with different coefficient of thermal expansion.

The upper external cover-ring 42(b) is overlapped to the upper surface of the intermediate annular frame 30(b) generally with small axial clearance and with a tight fit at the "L" shaped inner annular zone 52(b) and to the upper surface of the lower ring 43(b) without axial clearance and with a tight fit at the "L" shaped external annular zone 56(b).

The support grids of type b' are different from the support grids of type b previously described for the different radial sizing (the axial one is substantially equal) of the inner annular frame 30(b') and of the external annular frame 40(b').

The supports of type b have an inner annular frame 30(b) having a total radial thickness such as to receive in the inner zone in the proper annular chambers 315(x) and 316(x) respectively the connections 7(x), 8(x) of the strips and in the external zone the said spacers and tension rods 800 and the said tension rods 200. The support grids of type b' have on the contrary an inner annular frame 30(b') with smaller radial thickness and are suitable to receive therefore only the said connections 7(x), 8(x) of the ends of the strips.

The contrary occurs as concerns the sizing of the external annular frame.

The support grids of type b' have an external annular frame 40(b') having a radial thickness such as to permit the passage of the tension rods 800 and of the tension rods 200.

The support grids of type b have on the contrary an external annular frame 40(b), having a smaller radial thickness sufficient only to permit an adequate fixing of the support grid by wedges to the external shell of the steam generator or heat exchanger.

For the supports of type b' the coupling with a tight fit between the external annular frame 40(b') and the inner annular frame 30(b') is assured by the "L" shaped inner annular zones respectively the lower one 51(b') and the upper one 52(b').

The coupling generally with a tight fit between the upper external cover-ring 42(b') and the lower ring 43(b') is assured by the "L" shaped upper external annular zone 56(b').

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CLAIMS

1. - An earthquake-proof support grid for tubes of steam generators, heat exchangers an the like, particularly for P.W.R. steam generators, comprising:

- a reticular structure formed of a plurality of main lower [1(x)] and upper [2(x)] intersecting strips, the said strips having interengaging main milled slots (19) equally spaced at the intersecting zones and secondary milled slots (20) equally spaced between the said main slots, and of a plurality of lower [3(x), 5(x)] and upper [4(x), 6(x)] secondary strips fitted in the said secondary slots, characterized by the fact that at least some secondary strips [3(x), 4(x)] have slots (21) equally spaced for the coupling with portions of the said main strips [1(x), 2(x)] at the intersecting zones and that all strips or at least some strips of the said reticular structure have at each end a non-sliding connection [7(x), 8(x)] with variable section, greater section at the free end of the said connection (13, 14) and smaller section at the root of the said connection (9, 10).

- an external annular frame [30(a), 30(a')] enclosing the said connections of the ends of the strips [7(x), 8(x)] and an external annular zone of the said reticular structure formed of portions (17, 18) of the strips adjoining the said connections, characterized by the fact that the inner central zone of the said annular frame has a plurality of lower slots [23(x)] and upper slots [24(x)] equally spaced, suitable to receive and to block in position, without clearance, respectively the said connections of the ends of the lower strips [7(x)] and upper strips [8(x)] , the said axially extending slots having a variable vertical transversal section, smaller section at the zone (309) wherein is fitted the root (9, 10) of the said connection of the end of the strips and greater section at the zone (313) wherein is fitted the free end (13, 14) of the said connection of the end of the strip, so that said connections may function in tension under the action of external forces (tending to separate the said strips from the said annular frame), in order to prevent the drawing out of the said connection [7(x), 8(x)] of the strip from the said external annular frame.

2. - An earthquake-proof support grid for tubes of steam generators, heat exchangers and the like, particularly for P.W.R. steam generators, comprising:

- a reticular structure formed of a first material and consisting of a plurality of main lower [1(x)] and upper [2(x)] intersecting strips, the said strips having interengaging main milled slots (19) equally spaced at the intersecting zones and secondary milled slots (20) equally spaced between the said main slots, and of a plurality of secondary lower [3(x), 5(x)] and upper [4(x), 6(x)] strips fitted in the said secondary slots characterized by the fact that at least some secondary strips [3(x), 4(x)] have slots (21) equally spaced for the coupling with portions of the said main strips [1(x), 2(x)] at the intersecting zones and that all strips or at least some strips of the said reticular structure have at each end a non-sliding connection [7(x), 8(x)] with variable section, generally greater section at the free end of the said connection (13, 14) and smaller section at the root of the said connection (9, 10);

- an intermediate annular frame [30(b), 30(b')] formed of a first material having substantially the same coefficient of thermal expansion of the material of the said strips, the said annular frame enclosing the said connections of the ends of the strips [7(x), 8(x)] and an external annular zone of the said reticular structure formed of portions (17, 18) of the strips adjoining the said connections, characterized by the fact that the inner central zone of the said annular frame has a plurality of lower slots [23(x)] and upper slots [24(x)] equally spaced, suitable to receive and to block in position, without clearance, respectively the said connections of the ends of the lower [7(x)] and upper [8(x)] strips, the said axially extending slots having a variable vertical transversal section, generally smaller section at the zone (309) wherein is fitted the root (9, 10) of the said connection of the end of the strip and greater section at the zone (313) wherein is fitted the free end (13, 14) of the said connection of the end of the strip, so that said connections may function in tension under the action of external forces (tending to separate the said strips from the said annular frame), in order to prevent the drawing out of the said connection [7(x), 8(x)] of the strip from the said intermediate annular frame [30(b), 30(b')];

- an external annular frame [40(b), 40(b')], formed of a second material having a coefficient of thermal expansion lower than the first material of the said strips [1(x), 6(x)] and of the said intermediate annular frame [30(b), 30(b')], the said external annular frame [40(b), 40(b')] enclosing substantially the said intermediate annular frame [30(b), 30(b')], characterized by the fact that the said external annular frame rigidly fits, at room temperature, with the annular "L" shaped inner lower [51(b), 51(b')] and upper [52(b), 52(b')] zones of the said intermediate annular frame [30(b), 30(b')], while at a certain operating temperature there is the free radial sliding of the said intermediate annular frame [30(b), 30(b')], being foreseen an adequate radial clearance (50) between the external cylindrical surface (39) of the said intermediate annular frame [30(b), 30(b')] and the central inner cylindrical surface (49) of the said external annular frame [40(b), 40(b')].

3. - An earthquake-proof support grid according to claim 1 or 2, characterized by the fact that the said connection [7(x), 8(x)] of the end of the main [1(x), 2(x)] and secondary [3(x), 4(x)] strips with slots (21) has a height (142) lower than the height of the strips and is placed at the opposite side to that wherein are the slots (19, 20, 21) of coupling with the other strips and that the height of the said connection [7(x), 8(x)] of the secondary strips [5(x), 6(x)] without slots is generally equal to the height of the strip.

4. - An earthquake-proof support grid according to claim 3, characterized by the fact that the said connection [7(x), 8(x)] with variable section has a constant thickness (110) generally equal to the thickness of the strip and variable height, greater height (142) at the free end (13, 14) of the said connection and lower height (141) at the root (9, 10) of the said connection.

5. - An earthquake-proof support grid according to claim 4,

characterized by the fact that the said connection [7(x), 8(x)] has a dovetail shaped profile [7(1), 8(1)] .

6. - An earthquake-proof support grid according to claim 4, characterized by the fact that the said connection [7(x), 8(x)] has a half-dovetail shaped profile [7(1'), 8(1')] .

7. - An earthquake-proof support grid according to claim 4, characterized by the fact that the said connection [7(x), 8(x)] has a hammer-head shaped profile [7(2), 8(2)] .

8. - An earthquake-proof support grid according to claim 4, characterized by the fact that the said connection [7(x), 8(x)] has a half-hammer-head shaped profile [7(2'), 8(2')] .

9. - An earthquake-proof support grid according to claim 3, characterized by the fact that the said connection [7(x), 8(x)] with variable section has a constant height (140) and a variable thickness, greater thickness (115) at the free end (13, 14) of the said connection and smaller thickness (114) at the root (9, 10) of the said connection.

10. - An earthquake-proof support grid according to claim 9, characterized by the fact that the said connection [7(x), 8(x)] has a dovetail shaped profile [7(3), 8(3)] .

11. - An earthquake-proof support grid according to claim 9, characterized by the fact that the said connection [7(x), 8(x)] has a half-dovetail shaped profile [7(3'), 8(3')] .

12. - An earthquake-proof support grid according to claim 9, characterized by the fact that the said connection [7(x), 8(x)] has a hammer-head shaped profile [7(4), 8(4)] .

13. - An earthquake-proof support grid according to claim 9, characterized by the fact that the said connection [7(x), 8(x)] has a half-hammer-head shaped profile [7(4'), 8(4')] .

14. - An earthquake-proof support grid according to claim 3, characterized by the fact that the said connection [7(x), 8(x)] with variable section has a constant thickness and that the smaller section is placed at the intermediate point between the free end (13, 14) of the said connection [7(x), 8(x)] and the root (9, 10) of the said connection.

15. - An earthquake-proof support grid according to claim 14, characterized by the fact that the said connection [7(x), 8(x)] has a central hole (106) wherein is fitted without clearance a blocking pin (107), [7(5), 8(5)] .

16. - An earthquake-proof support grid according to claims 1 or 2, characterized by the fact that the said annular frame [30(a), 30(b), 30(b ')] enclosing the said connections [7(x), 8(x)] of the ends of the strips [1(x), 6(x)] is formed of:

- an intermediate ring [31(x)] having an inner central annular flange (310) with smaller thickness (311) at the root (313) of the said flange and greater thickness (312) at the free end (309) of the said flange (310);

- a lower cover-ring [33(x)] completely overlapping the said intermediate ring [31(x)] and an external lower annular portion (17) of the said reticular structure adjoining the said connections [7(x)] of the strips, in order to form with the overhanging flange (310) of the said intermediate ring [31(x)] a lower annular chamber [315(x)] having variable height, greater height (332) at the root (313) of the said flange (310) and lower height (331) at the free end (309) of the said flange (310) ;

- an upper cover-ring [32(x)] completely overlapping the said intermediate ring [31(x)] and an external upper annular portion (18) of the said reticular structure adjoining the said connections [8(x)] of the strips in order to form with the flange below (310) of the said intermediate ring [31(x)] an upper annular chamber [316(x)] having variable height, greater height (332) at the root (313) of the said flange (310) and lower height (331) at the free end (309) of the said flange (310);

- a plurality of lower spacers [25(x)] between the said connections [7(x)] of the lower strips [1(x), 3(x), 5(x)] shaped according to the profile of the said connection [7(x)] and according to the profile of the said lower annular chamber [315(x)], in order to fill the spaces of the said annular chamber [315(x)] by delimiting the said slots [23(x)] for the fitting of the said connections [7(x)] and in order to block in position the said connections [7(x)] of the ends of the strips;

- a plurality of upper spacers [26(x)] between the said connections [8(x)] of the upper strips [2(x), 4(x), 6(x)], shaped according to the profile of the said connection [8(x)] and according to the profile of the said upper annular chamber [316(x)], in order to fill the spaces of the said annular chamber [316(x)] by delimiting the said slots [24(x)] for the fitting of the said connections [8(x)] and to block in position the said connections [8(x)] of the ends of the strips.

17. - An earthquake-proof support grid according to claim 16, characterized by the fact that the said lower [25(x)] and upper [26(x)] spacers have a height (27) generally greater than the height of the said connections [7(x), 8(x)] of the end of the strips.

18. - An earthquake-proof support grid according to claim 17, characterized by the fact that the said lower spacers [25(x)] have a lower lateral projecting portion [250(x)] having a depth (120) equal to the thickness (110) of the strips and having a shaped profile according to the profile of the lower surface (15) of the said connection [7(x)] of the lower strips [1(x), 3(x), 5(x)] and the said upper spacers[26(x)] have an upper lateral projecting portion [260(x)] having a depth (120) equal to the thickness (110) of the strips and having a shaped profile according to the profile of the upper surface (16) of the said connection [8(x)] of the upper strips.

19. - An earthquake-proof support grid according to claim 18, characterized by the fact that the said lateral projecting portions [250(x), 260(x)] of the said spacers [25(x), 26(x)] have a flat inner surface [250(o), 260(o)].

20. - An earthquake-proof support grid according to claim 18, characterized by the fact that the said lateral projecting portions [250(x), 260(x)] of the said spacers [25(x), 26(x)] have a half-dovetail shaped profile [250(1'), 260(1')].

21. - An earthquake-proof support grid according to claim 18, characterized by the fact that the said lateral projecting portions [250(x), 260(x)] of the said spacers [25(x), 26(x)] have a half-hammer-head shaped profile [250(2'), 260(2')].

22. - An earthquake-proof support grid according to claim 16, characterized by the fact that the annular opening (331) at the inner annular zone (309) of the said lower annular chamber [315(x)] and of the said upper annular chamber [316(x)] is facing the inside of the said reticular structure and is aligned with the root (9, 10) of the said connections [7(x), 8(x)] of the strips.

23. - An earthquake-proof support grid according to claim 22, characterized by the fact that the vertical section of the said lower annular chamber [315(x)], formed of the said intermediate ring [31(1a), 31(1b), 31(1b')] and of the said lower cover-ring [33(1a), 33(1b), 33(1b')] and the vertical section of the said upper annular chamber [316(x)] formed of the said intermediate ring [31(1a), 31(1b), 31(1b')] and of the said upper cover-ring [32(1a), 32(1b), 32(1b')] have a dovetail shaped profile [315(1), 316(1)].

24. - An earthquake-proof support grid according to claim 22, characterized by the fact that the vertical section of the said lower annular chamber [315(x)], formed of the said intermediate ring [31(1a), 31(1b), 31(1b')] and of the said lower cover-ring [33(a), 33(b), 33(b')], and the vertical section of the said upper annular chamber [316(x)], formed of the said intermediate ring [31(1a), 31(1(b), 31(1b')] and of the said upper cover-ring [32(a), 32(b), 32(b')] have a half-dovetail shaped profile [315(1'), 316(1')].

25. - An earthquake-proof support grid according to claim 22, characterized by the fact that the vertical section of the said lower annular chamber [315(x)], formed of the said intermediate ring [31(2a), 31(2b), 31(2b')] and of the lower cover-ring [33(a),

33(b), 33(b')] and the vertical section of the said upper annular chamber [316(x)] , formed of the said intermediate ring [31(2a), 31(2b), 31(2b')] and of the said upper cover-ring [32(a), 32(b), 32(b')] have a half-hammer-head shaped profile [315(2'), 316(2')].

26. - An earthquake-proof support grid according to claims 5, 17, 20, and 24 or 6, 17, 19 and 24, characterized by the fact that the central vertical section of the said spacers [25(x), 26(x)], according to a plane parallel to the pertinent strips, has a half-dovetail shaped profile [25'(1), 26'(1)] [25(1'), 26(1')] .

27. - An earthquake-support grid according to claims 7, 17, 21 and 25 or 8, 17, 19 and 25, characterized by the fact that the central vertical section of the said spacers [25(x), 26(x)] , according to a plane parallel to the pertinent strips, have a half-hammer-head shaped profile [25'(2), 26'(2)] [25(2'), 26(2')] .

28. - An earthquake-proof support grid, according to claims 5 and 23, characterized by the fact that the vertical section of the said spacers [25(x), 26(x)] according to a plane parallel to the pertinent strips, has a dovetail shaped profile [25(1), 26(1)] .

29. - An earthquake-proof support grid, according to claims 10, 17 and 25, characterized by the fact that the horizontal section of the said spacers [25(x), 26(x)] has a dovetail shaped profile [25(3), 26(3)] .

30. - An earthquake-proof support grid, according to claims 11, 17 and 25, characterized by the fact that the horizontal section of the said spacers [25(x), 26(x)] has a half-dovetail shaped profile [25(3'), 26(3')] .

31. - An earthquake-proof support grid, according to claims 12, 17 and 25, characterized by the fact that the horizontal section of the said spacers [25(x), 26(x)] has a hammer-head shaped profile [25(4), 26(4)] .

32. - An earthquake-proof support grid, according to claims 13, 17 and 25, characterized by the fact that the horizontal section of the said spacers [25(x), 26(x)] has a half-hammer-head shaped profile [25(4'), 26(4')] .

33. - An earthquake-proof support grid, according to claims 15, 17 and 25, characterized by the fact that the horizontal section of the said spacers [25(x), 26(x)] has a double "I" shaped profile [25(5), 26(5)] .

34. - An earthquake-proof support grid, according to claims 29 or 30 or 31, or 32 or 33, characterized by the fact that the vertical section of the said spacers, according to a plane parallel to the pertinent adjacent strips, has a half-hammer-head shaped profile (345).

35. - An earthquake-proof support grid, according to claim 1, characterized by the fact that the said annular frame [30(a')] is formed of :

- an intermediate ring [31(1a'), 31(1'a'), 31(2a'), 31(2'a'), 31(3a'), 31(3'a'), 31(4a'), 31(4'a')] , having a plurality of lower [23(x)] and upper [24(x)] milled slots having a variable vertical transversal section, greater section at the external annular zone (313) and smaller section at the inner annular zone (309), the said slots suitable to receive and to block in position without clearance the said connections [7(x), 8(x)] of the strips;

- an external ring [33(a'), 33(1a'), 33(2a')] having a lower inner flange [330(a')] , the said flange having the inner diameter (339) smaller than the diameter (309) corresponding to the roots (9, 10) of the said connections [7(x), 8(x)] of the strips, the said external ring [33(a'), 33(1a'), 33(2a')] suitable to receive and to block with a tight fit at the "L" shaped inner annular zone [53(a')] , adjoining the root of the said inner flange 330(a') , the said intermediate ring [31(1a'), 31(1'a'), 31(2a'), 31(2'a'), 31(3a'), 31(3'a'), 31(4a'), 31(4'a')] , the said external ring having the inner shaped profile according to the external profile of the said intermediate ring;

- an upper cover-ring [32(a'), 32(1a'), 32(2a')] having the inner diameter (329) smaller than the diameter (309) corresponding to the roots (9, 10) of the said connections [7(x), 8(x)] of the strips, the said upper cover-ring [32(a'), 32(1a'), 32(2a')] having the inner shaped profile according to the external profile of the upper surfaces of the said intermediate ring [31(1a'), 31(1'a'), 31(2a'), 31(2'a'), 31(3a'), 31(3'a'), 31(4a'), 31(4'a')] and of the said external ring [33(a'), 33(1a'), 33(2a')] , the said upper cover-ring being mounted with a tight fit on the said intermediate ring at the "L" shaped inner annular zone [54(a')] of the said intermediate ring.

36. - An earthquake-proof support grid, according to claim 35, characterized by the fact that the said lower slots [23(x)] and upper slots [24(x)] have a constant width (100) equal to the thickness (110) of the said connections [7(x), 8(x)] of the ends of the strips and a variable height, greater height (132) at the

external diameter (313) of the said intermediate ring and lower height (131) at the inner diameter (309) of the said intermediate ring.

37. - An earthquake-proof support grid, according to claim 35, characterized by the fact that the said lower slots [23(x)] and upper slots [24(x)] have a constant height and a variable width, generally greater width (105) at the external annular zone (313) and smaller width (104) at the inner annular zone (309) of the said intermediate ring.

38. - An earthquake-proof support grid, according to claim 36, characterized by the fact that the vertical axial section of the said slots [23(x), 24(x)] has a dovetail shaped profile [23(1), 24(1)] .

39. - An earthquake-proof support grid, according to claim 36, characterized by the fact that the vertical axial section of the said slots [23(x), 24(x)] has a half-dovetail shaped profile [23(1'), 24(1')] .

40. - An earthquake-proof support grid, according to claim 36, characterized by the fact that the vertical axial section of the said slots [23(x), 24(x)] has a hammer-head shaped profile [23(2), 24(2)] .

41. - An earthquake-proof support grid, according to claim 36, characterized by the fact that the vertical axial section of the said slots [23(x), 24(x)] has a half-hammer-head shaped profile [23(2'), 24(2')] .

42. - An earthquake-proof support grid, according to claim 37, characterized by the fact that the horizontal section of the said slots [23(x), 24(x)] has a dovetail shaped profile [23(3), 24(3)] .

43. - An earthquake-proof support grid, according to claim 37, characterized by the fact that the horizontal section of the said slots [23(x), 24(x)] has a half-dovetail shaped profile [23(3'), 24(3')] .

44. - An earthquake-proof support grid, according to claim 37, characterized by the fact that the horizontal section of the said slots [23(x), 24(x)] has a hammer-head shaped profile [23(4), 24(4)] .

45. - An earthquake-proof support grid, according to claim 37, characterized by the fact that the horizontal section of the said slots [23(x), 24(x)] has a half-hammer-head shaped profile [23(4'), 24(4')] .

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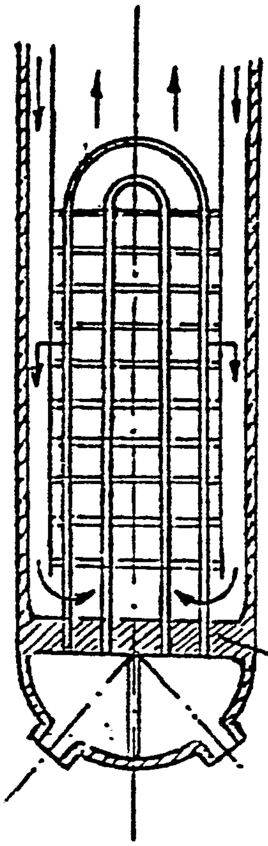


FiG.3

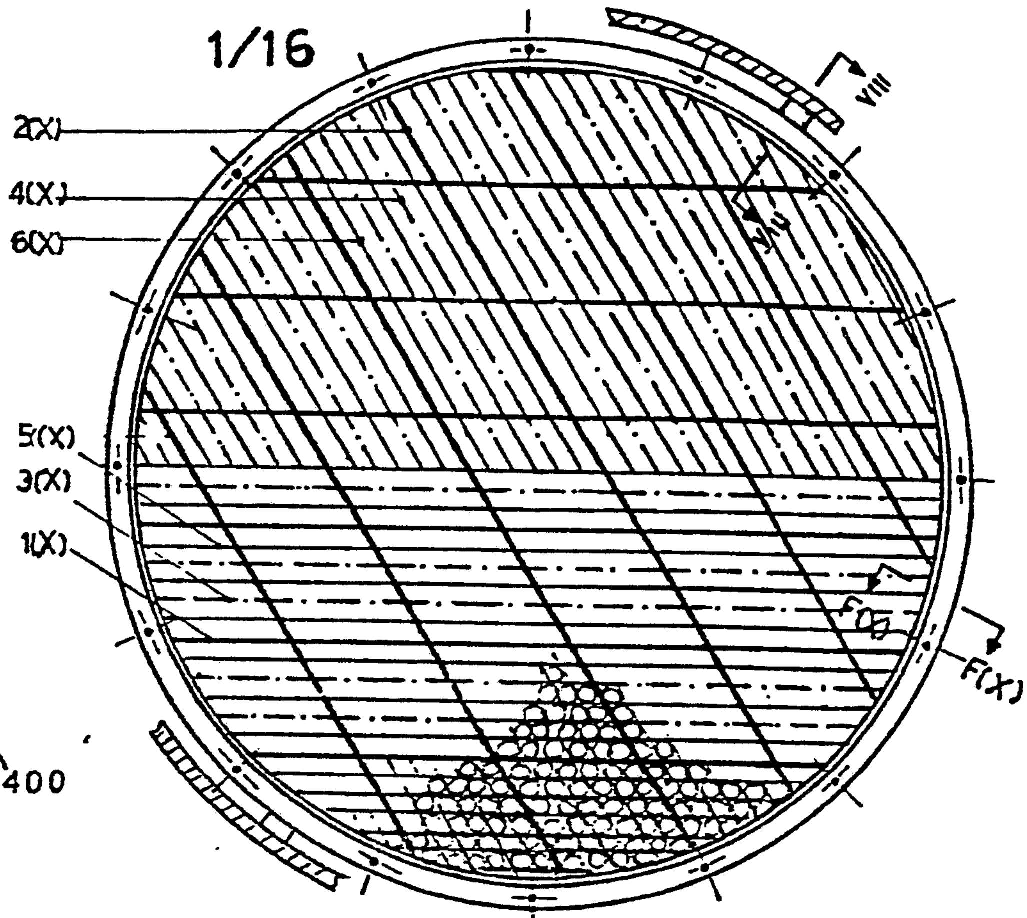


FiG.1

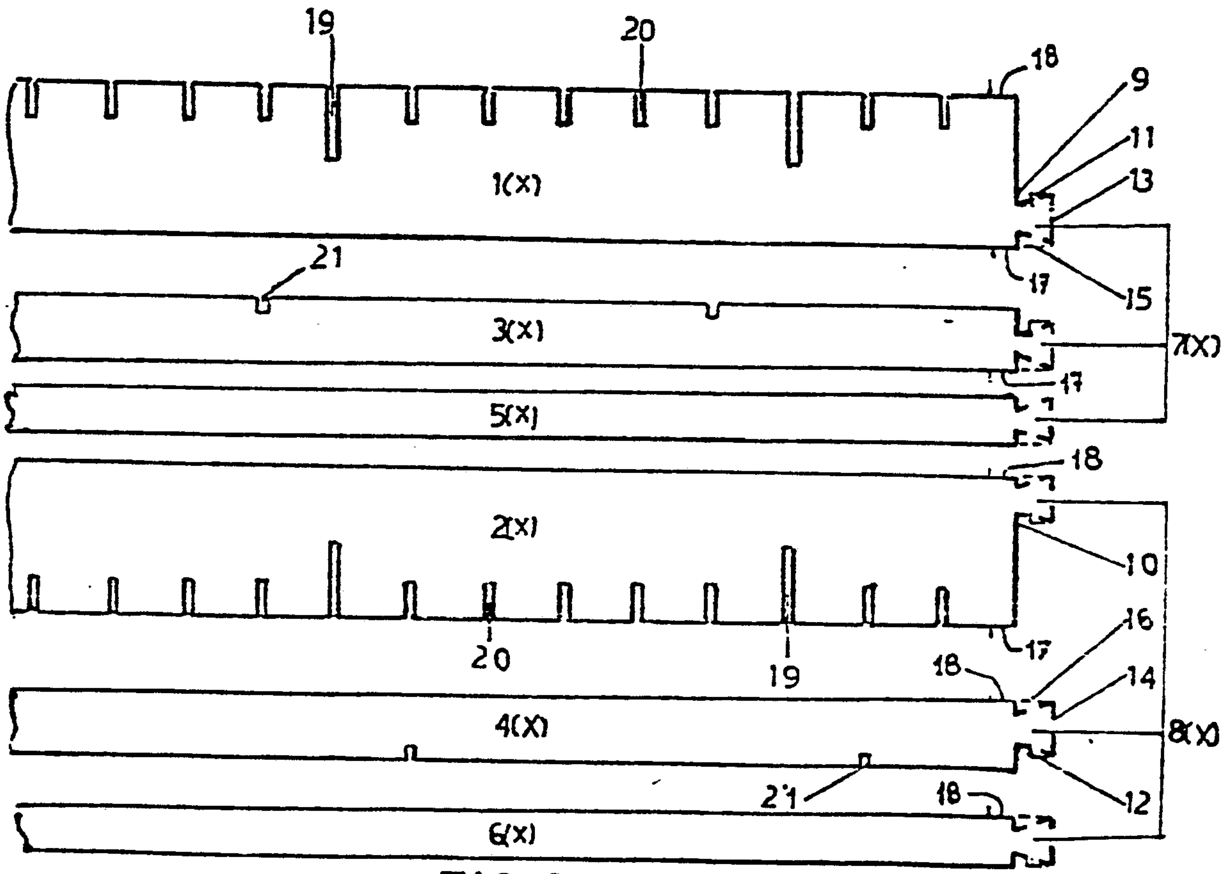
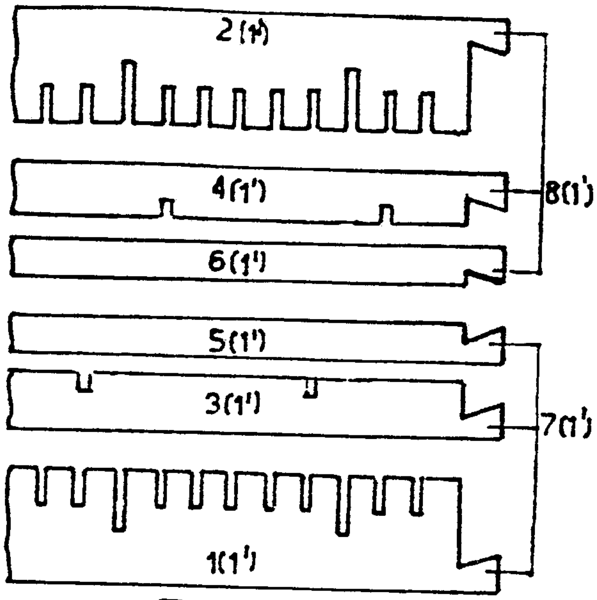


FiG.2



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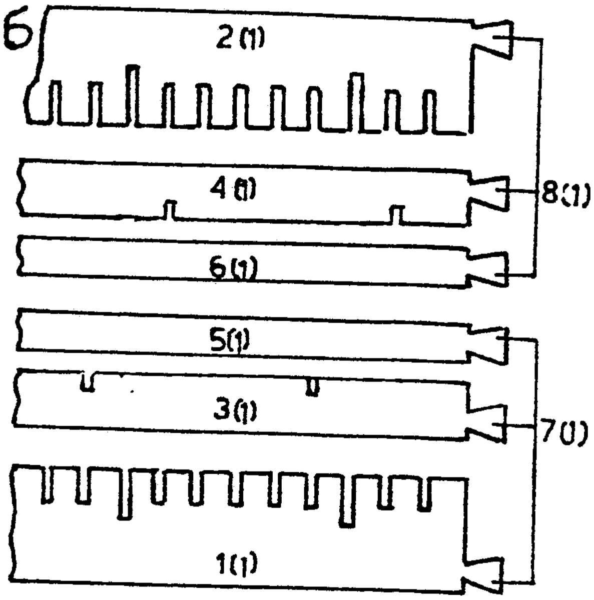

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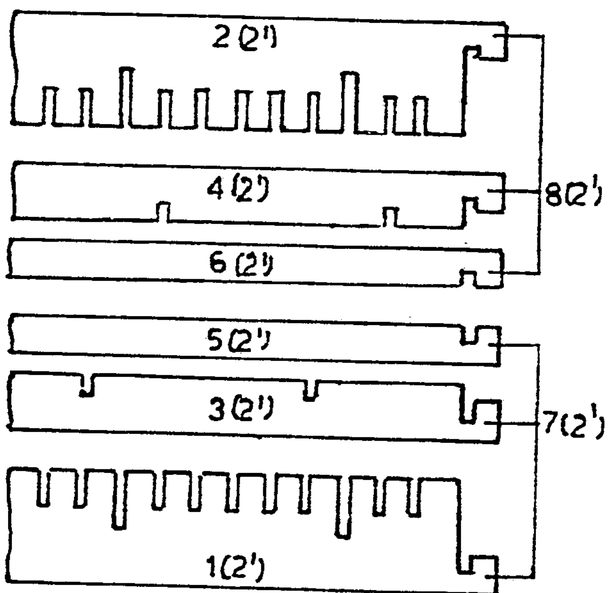

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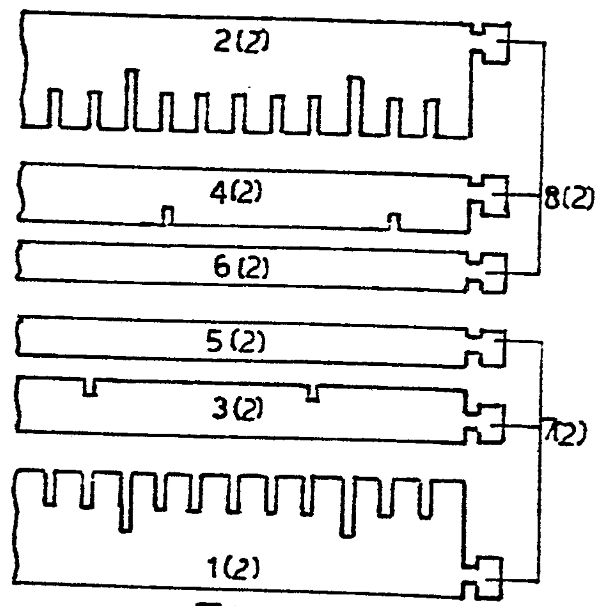

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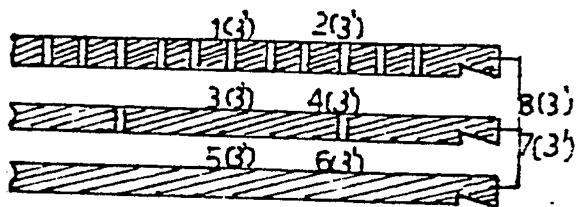

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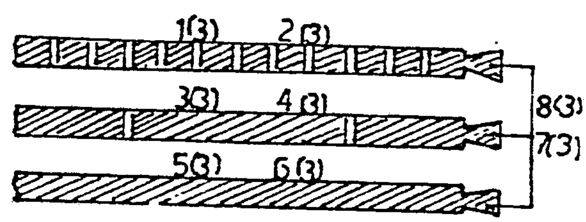

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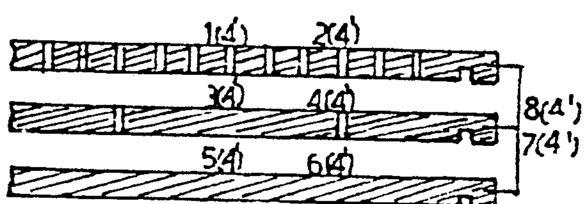

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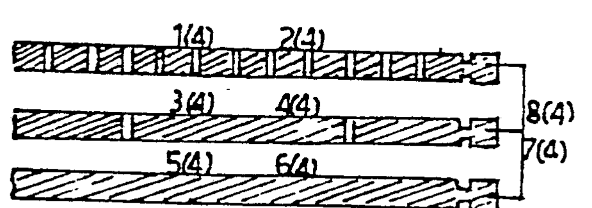


FiG.2(4)

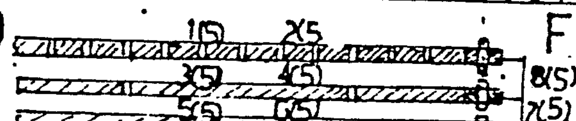


FiG.2(5)

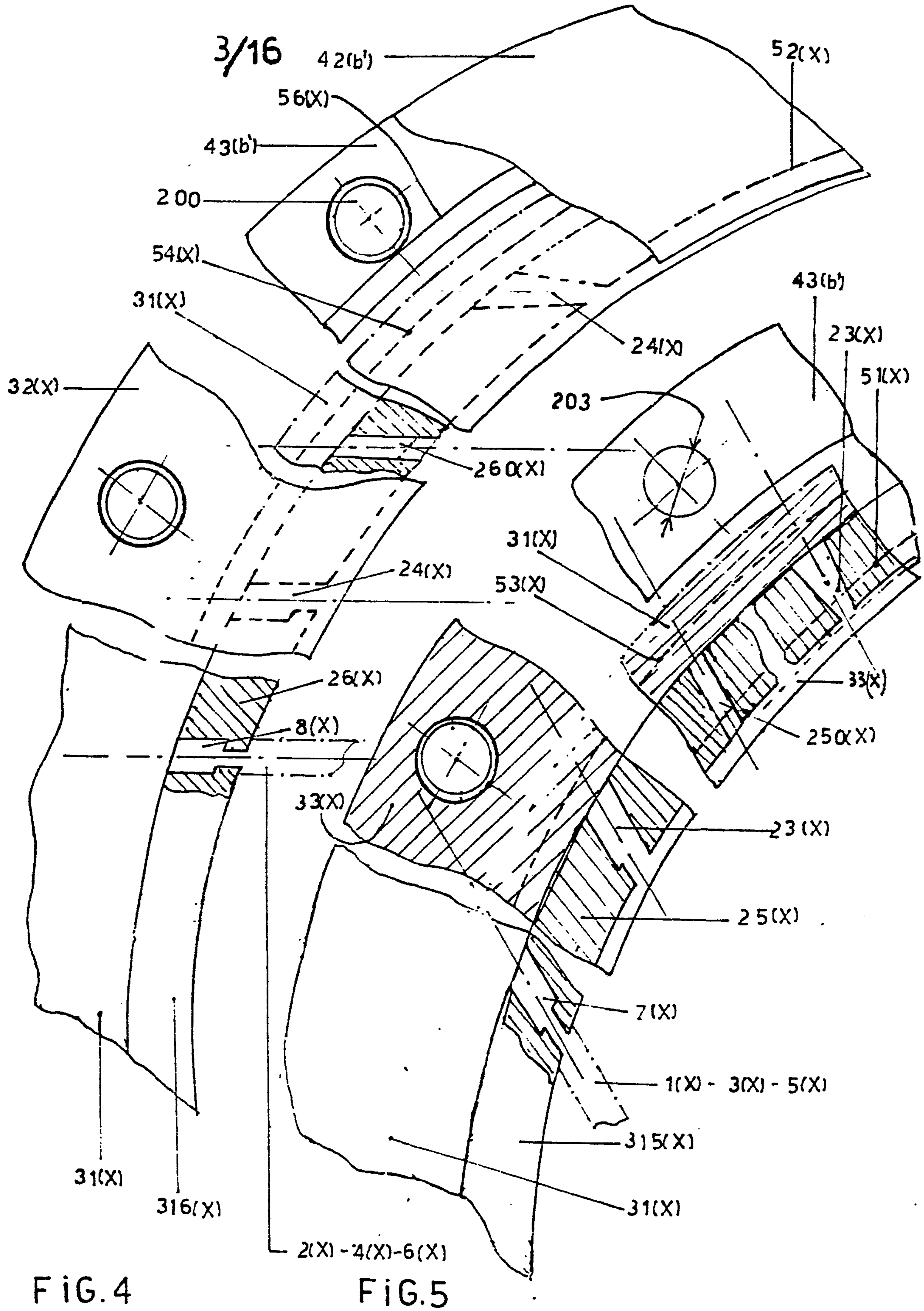

42(b')
52(X)
56(X)
43(b')
200
54(X)
31(X)
24(X)
43(b')
23(X)
51(X)
32(X)
203
260(X)
31(X)
24(X)
53(X)
26(X)
33(X)
8(X)
250(X)
33(X)
23(X)
25(X)
7(X)
1(X) - 3(X) - 5(X)
315(X)
31(X)
316(X)
31(X)
2(X) - 4(X) - 6(X)

FiG.4 FiG.5

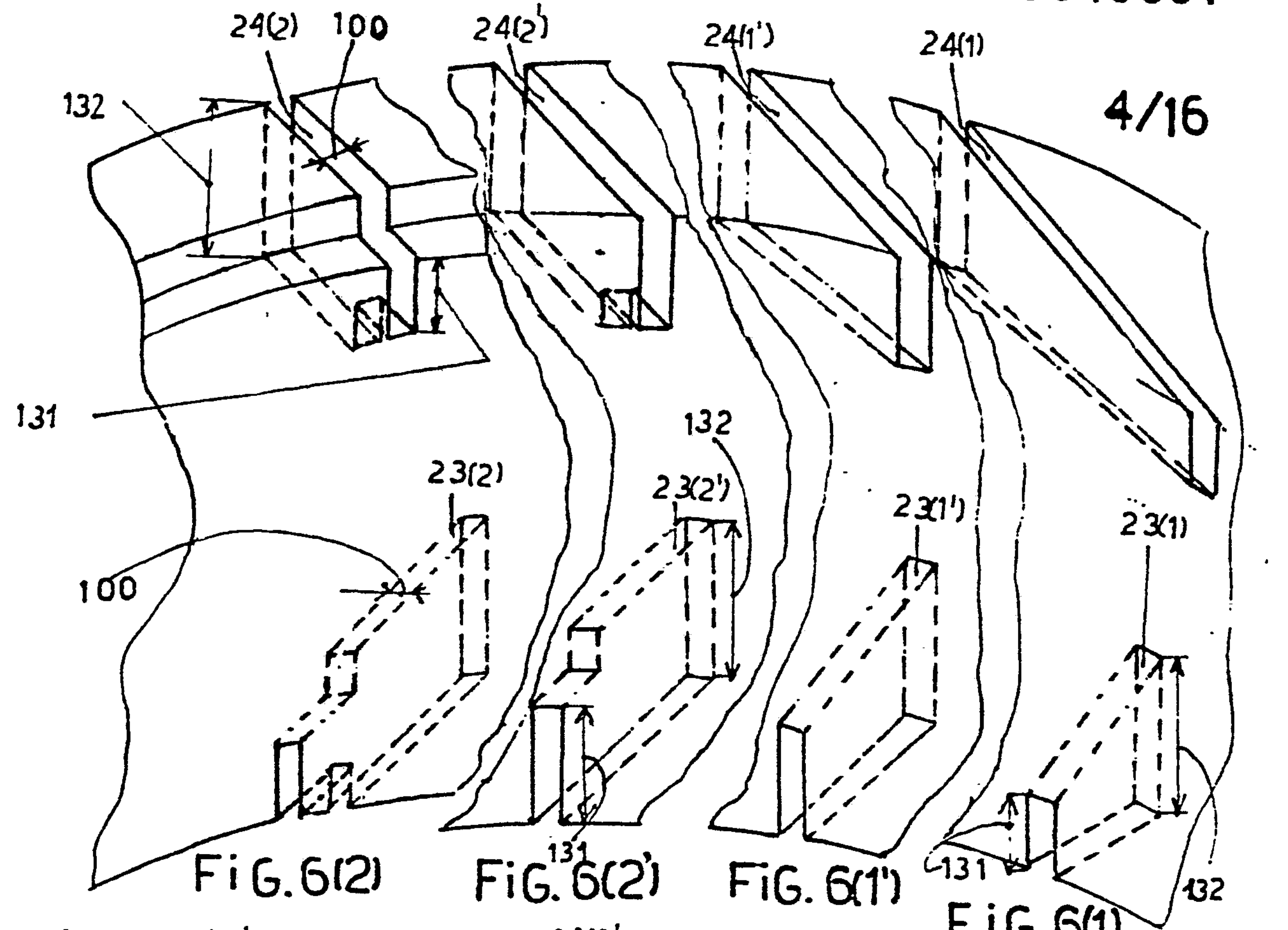


Fig. 6(2) Fig. 6(2') Fig. 6(1') Fig. 6(1)

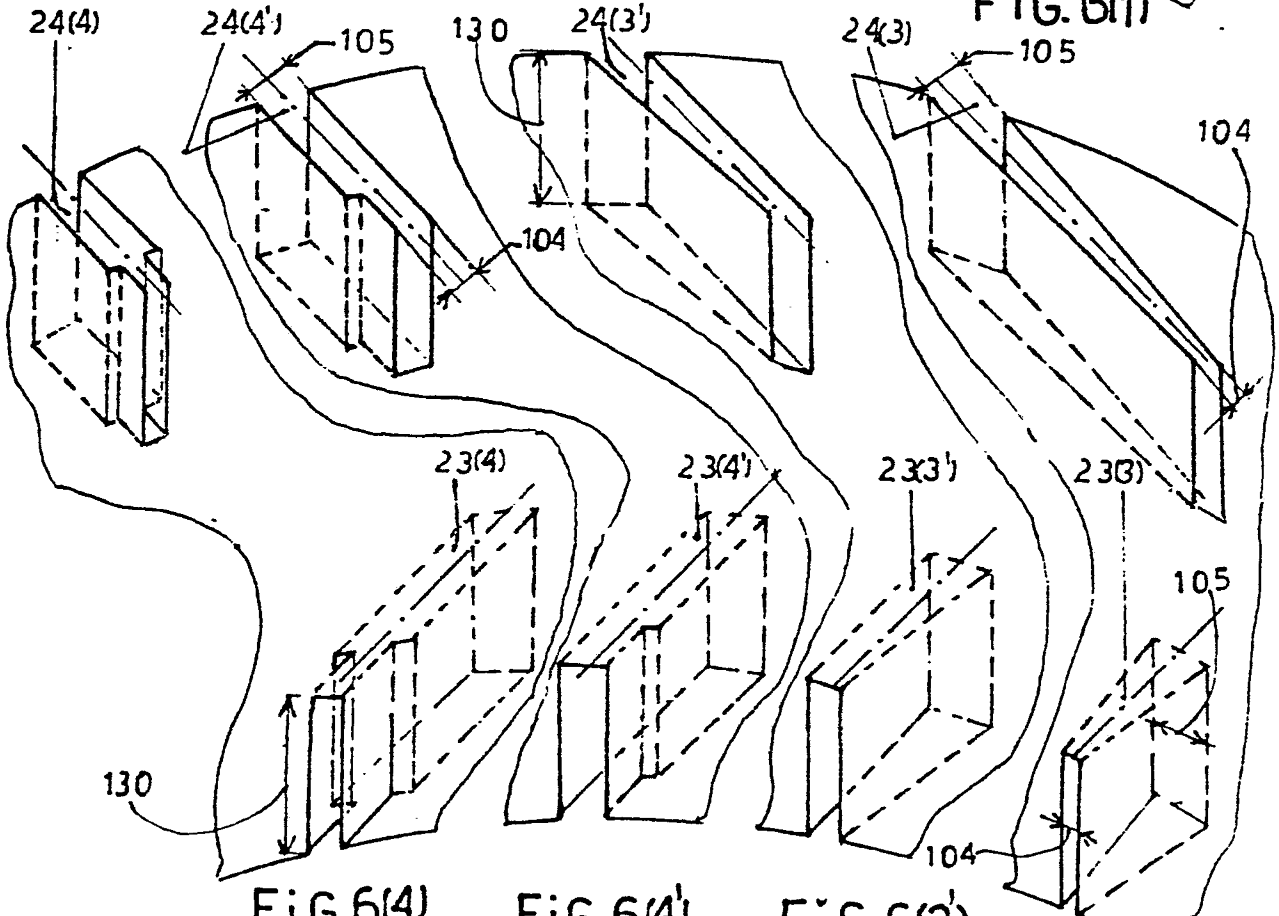


Fig. 6(4) Fig. 6(4') Fig. 6(3') Fig. 6(3)

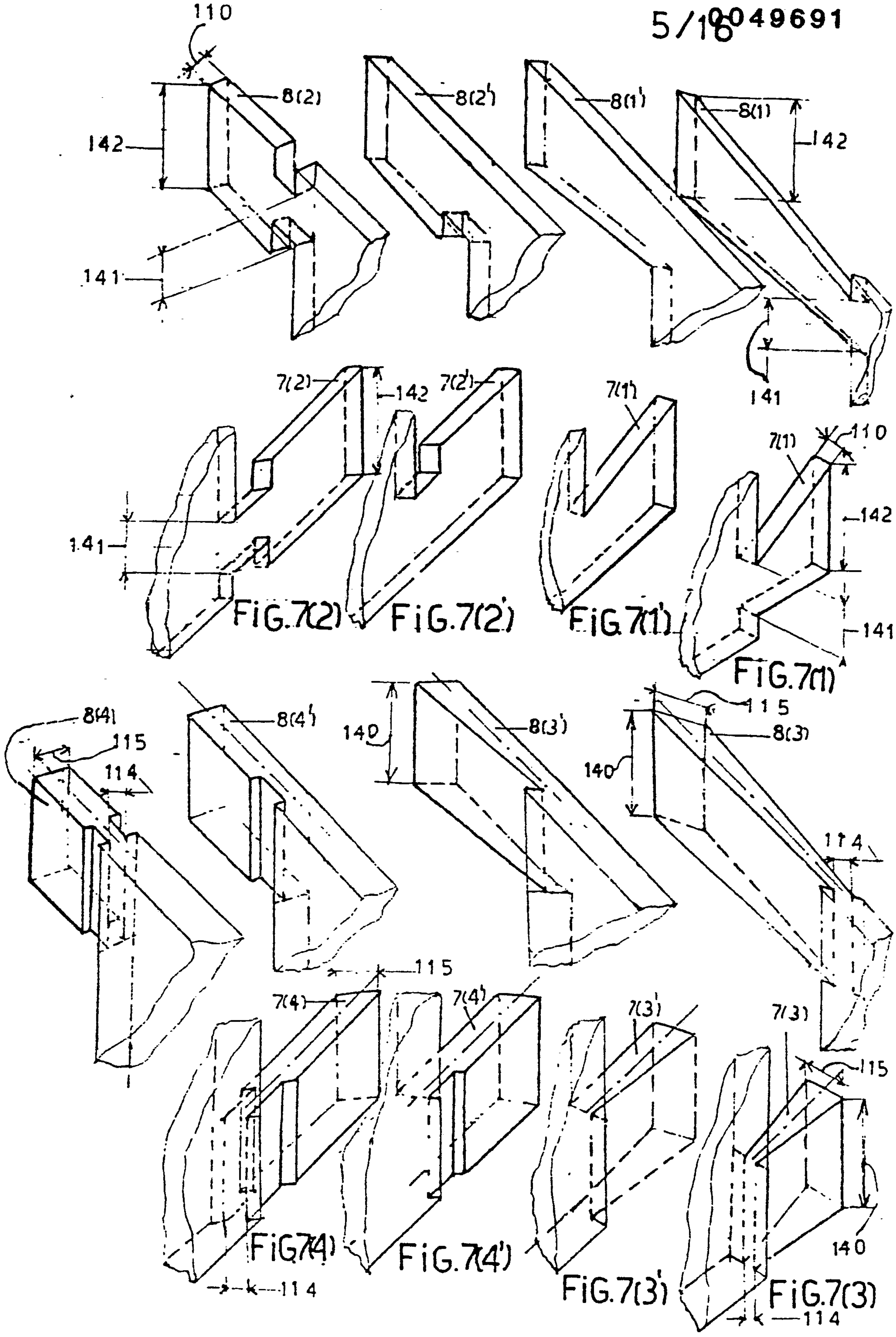


FiG.7(2) FiG.7(2') FiG.7(1') FiG.7(1)

FiG.7(4) FiG.7(4') FiG.7(3') FiG.7(3)

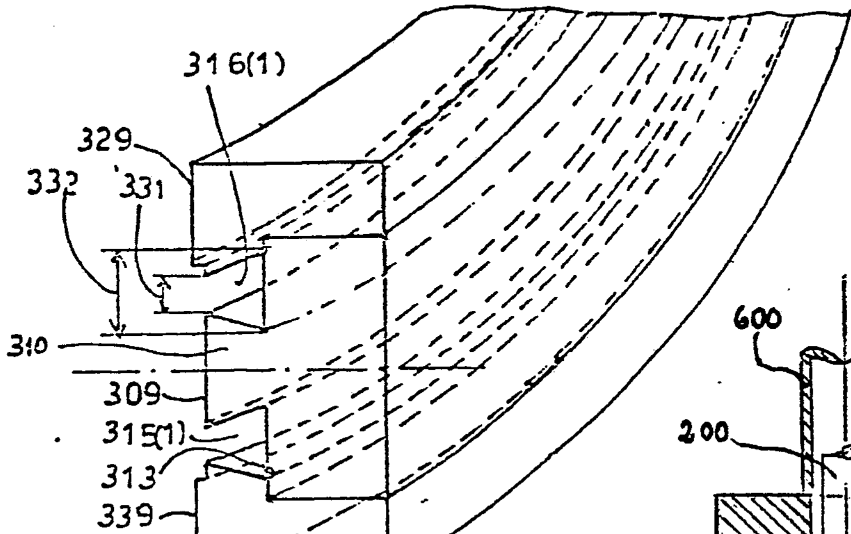


FiG.8(1)

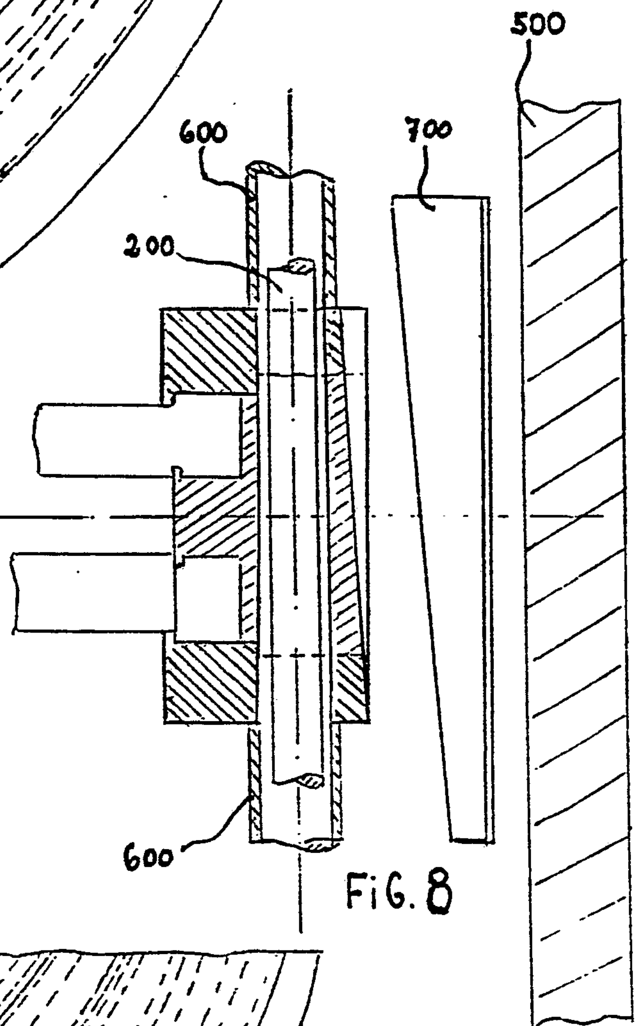
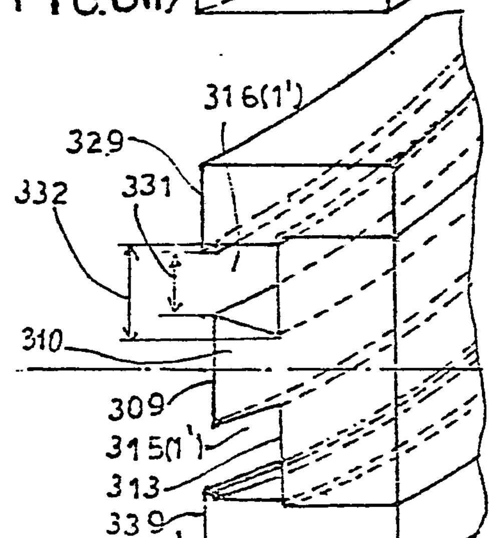


FiG.8



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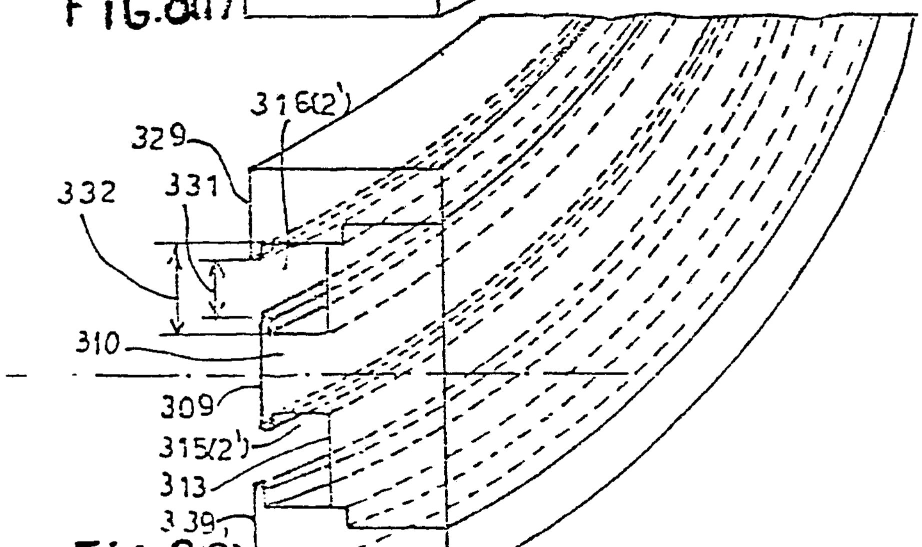

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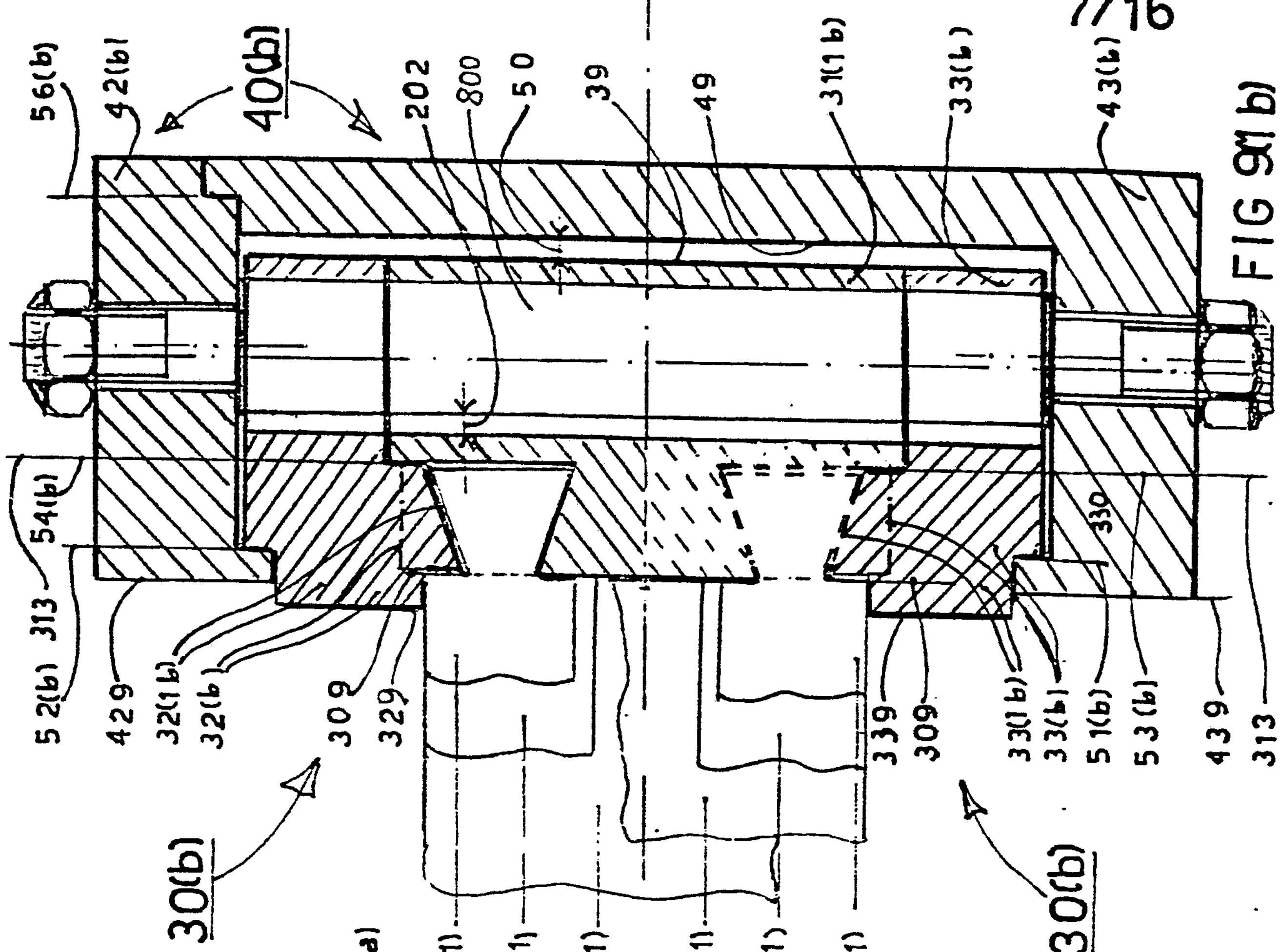


FIG 9(1b)

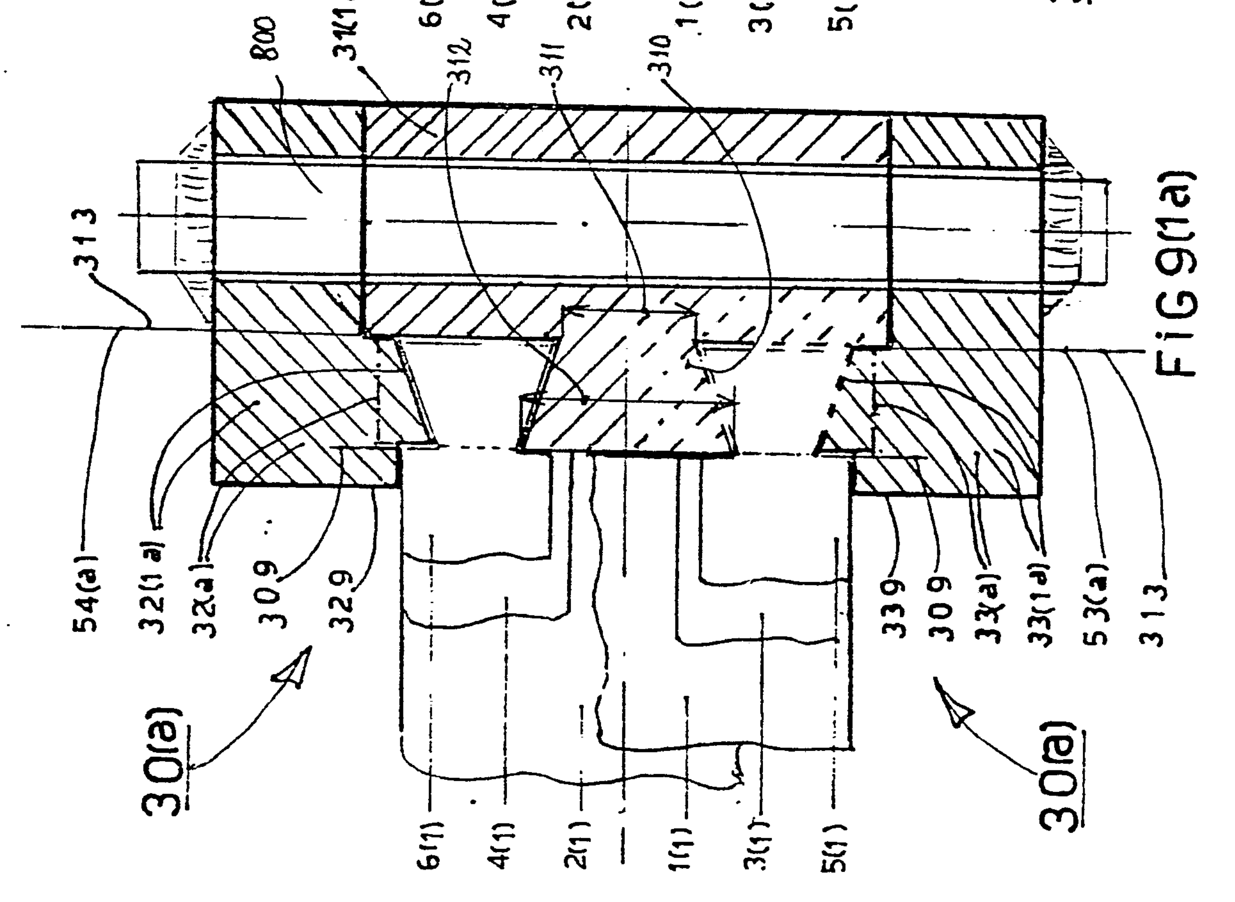


FIG 9(1a)

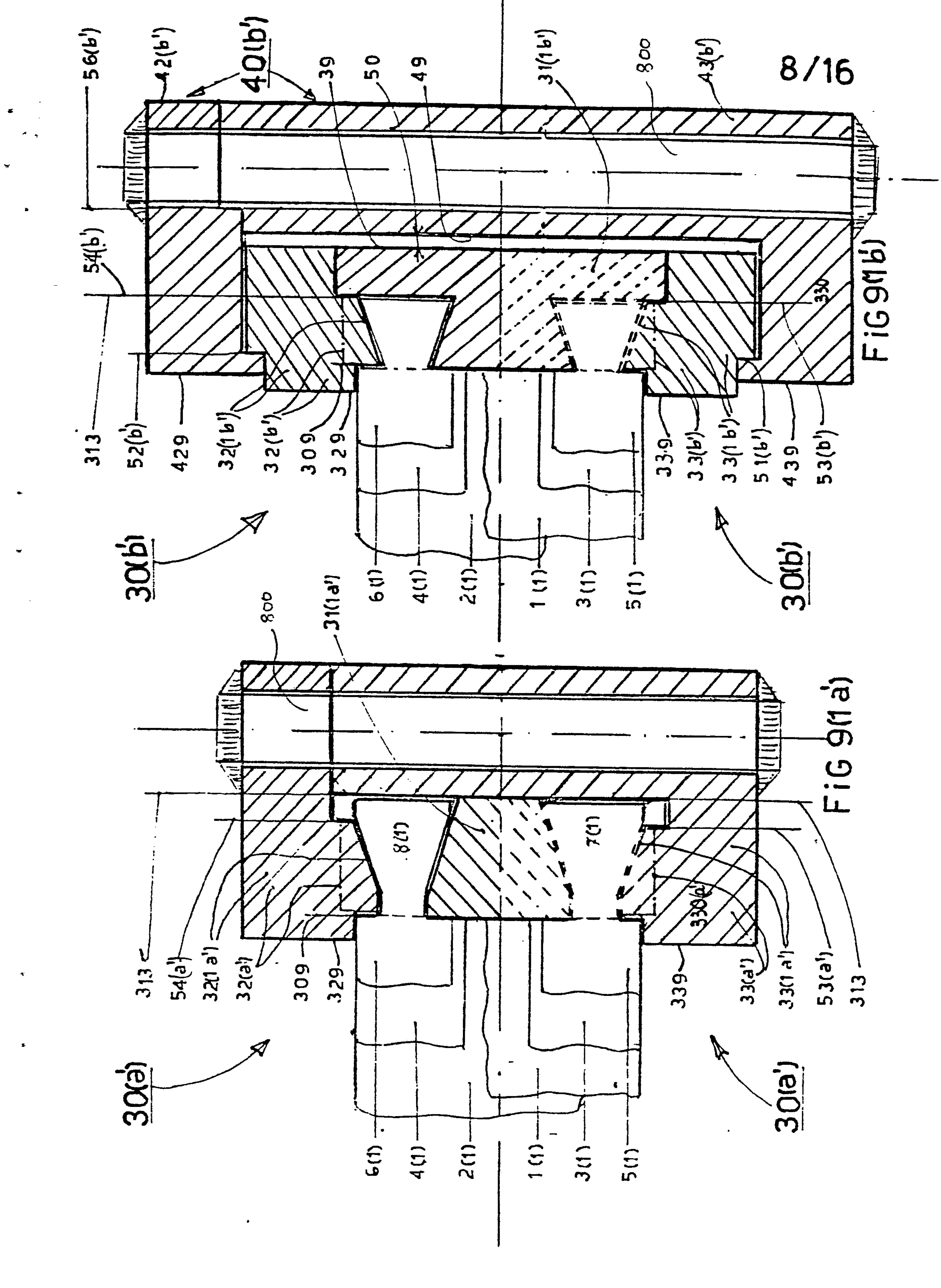


FIG 9(1b')

FIG 9(1a')

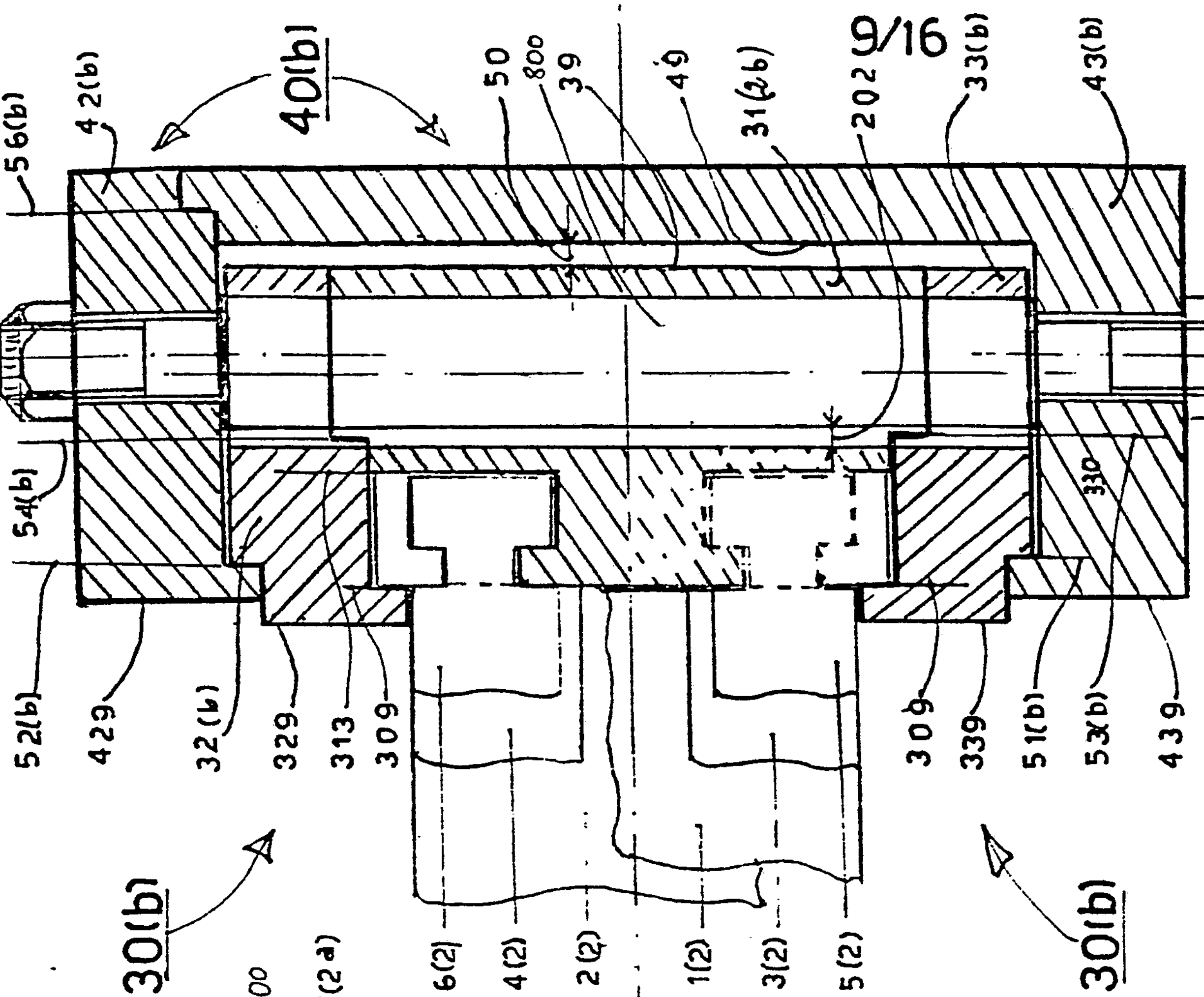


FiG 9(2 b)

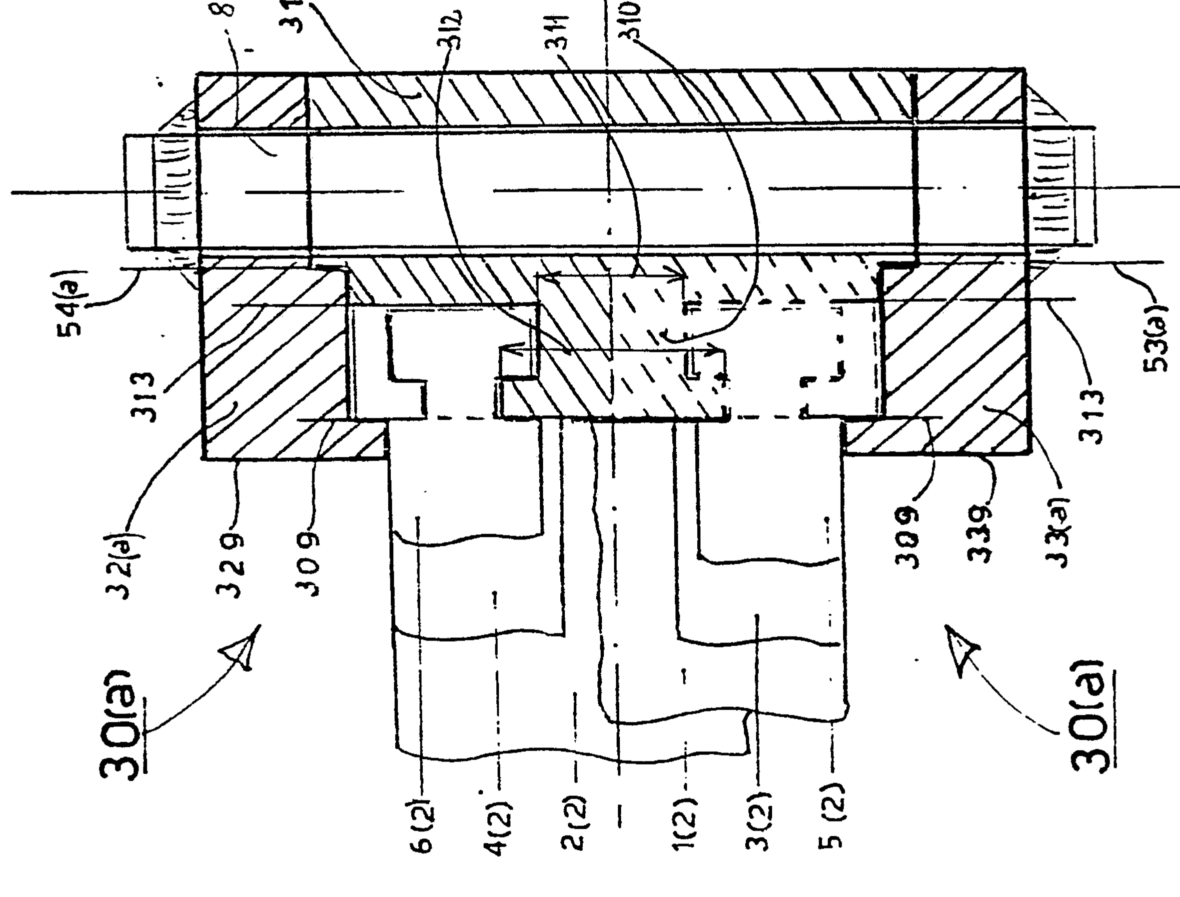


FiG 9(2 a)

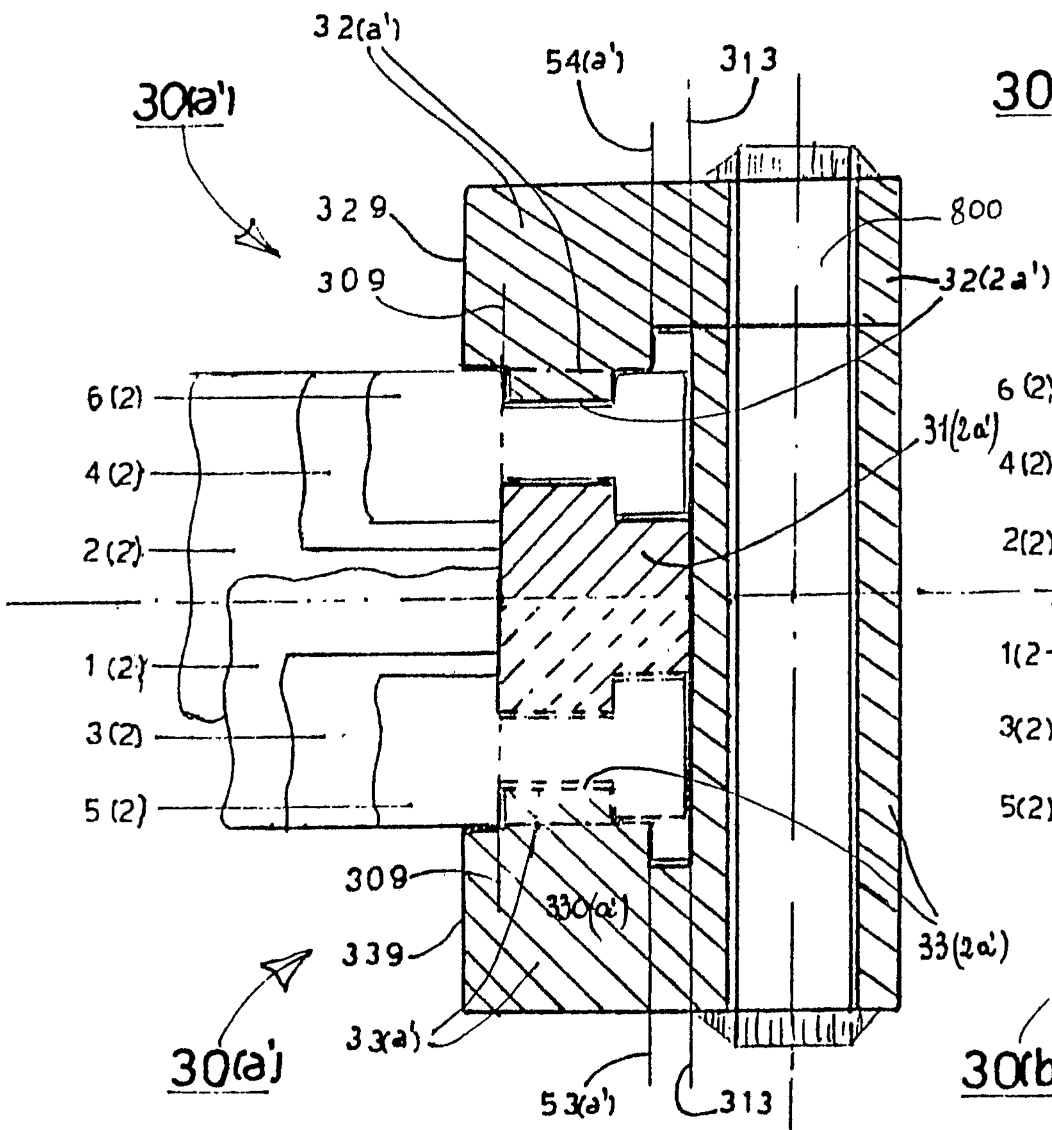


FiG 9(2a')

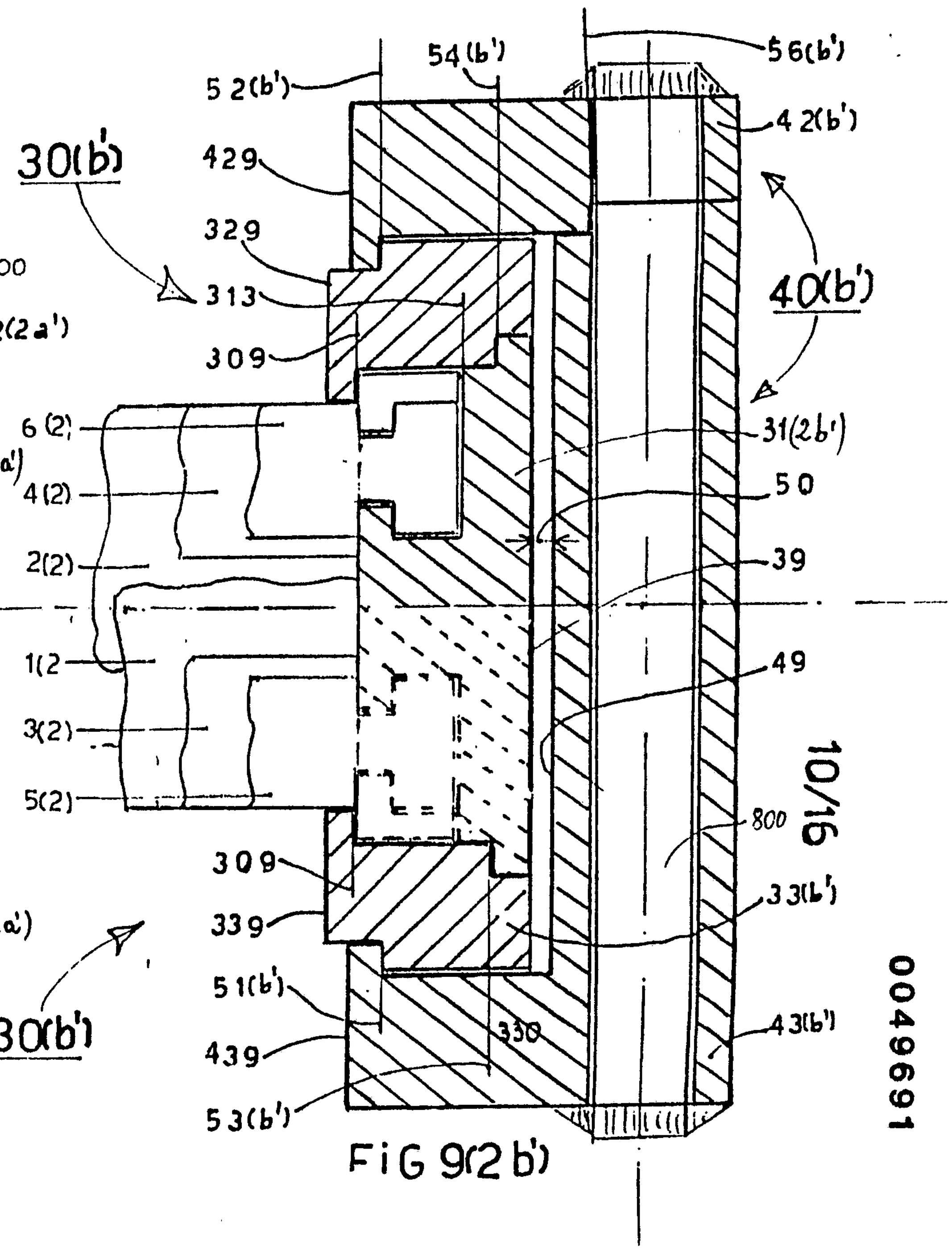


FiG 9(2b')

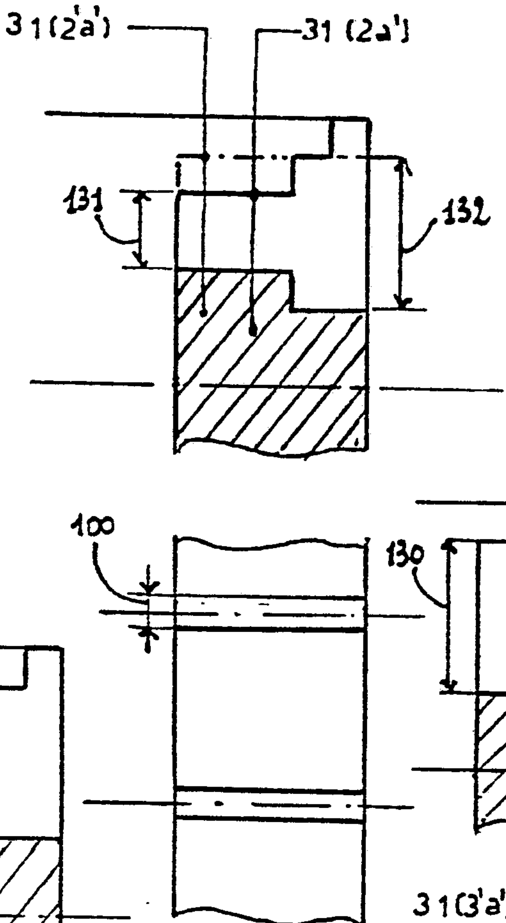


FIG.12(2a')

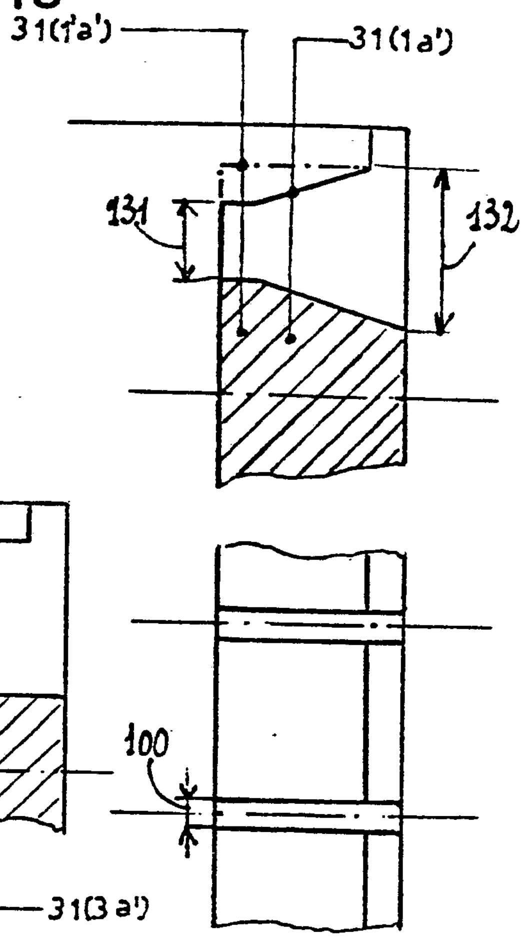


FIG.12(1a')

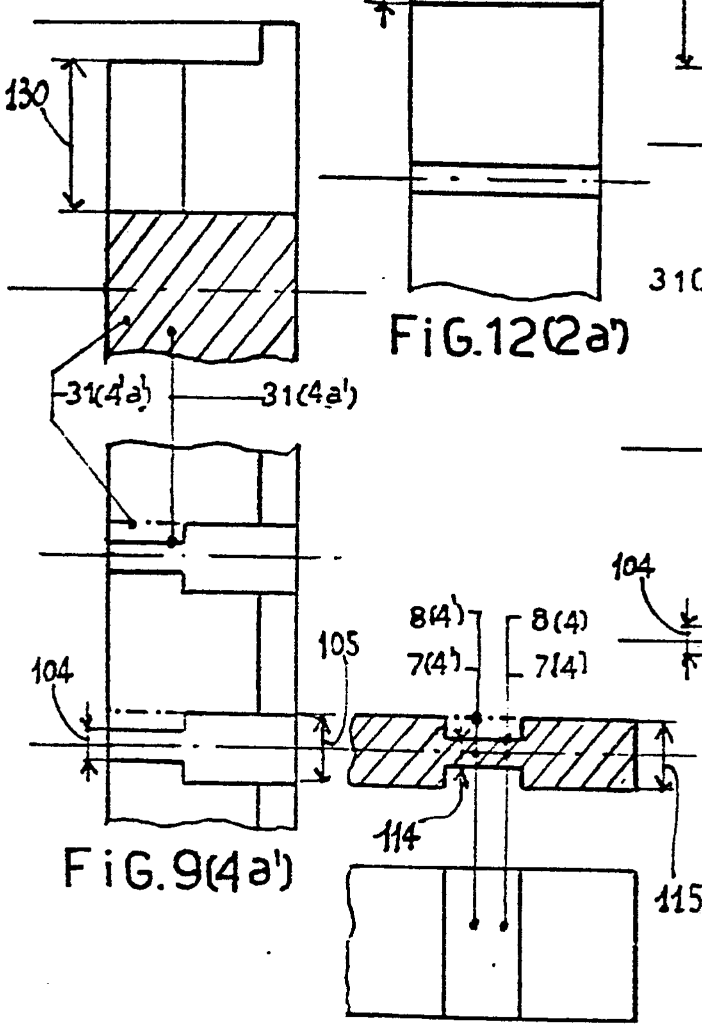


FIG.9(4a')

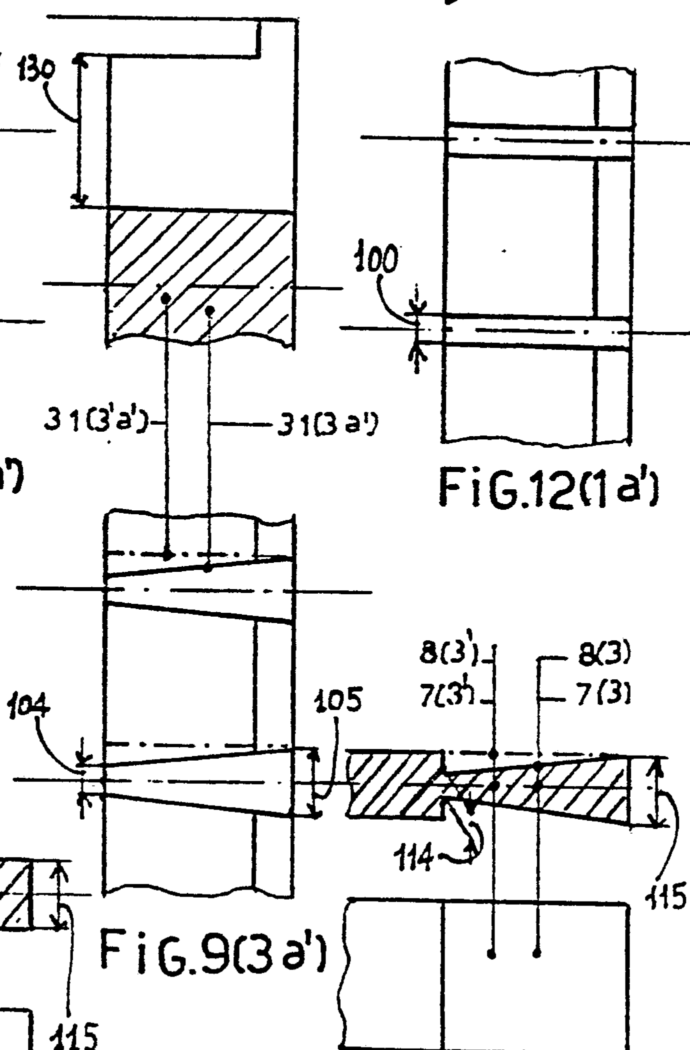


FIG.9(3a')

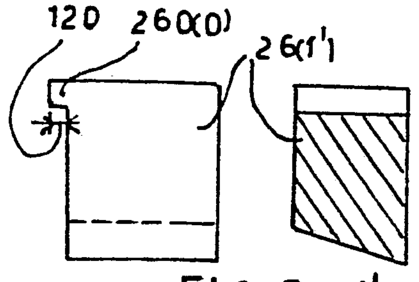
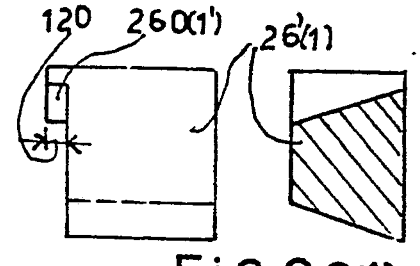


FiG. 26(1')



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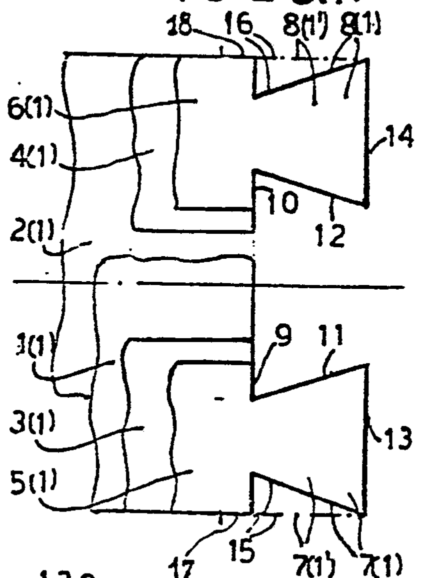


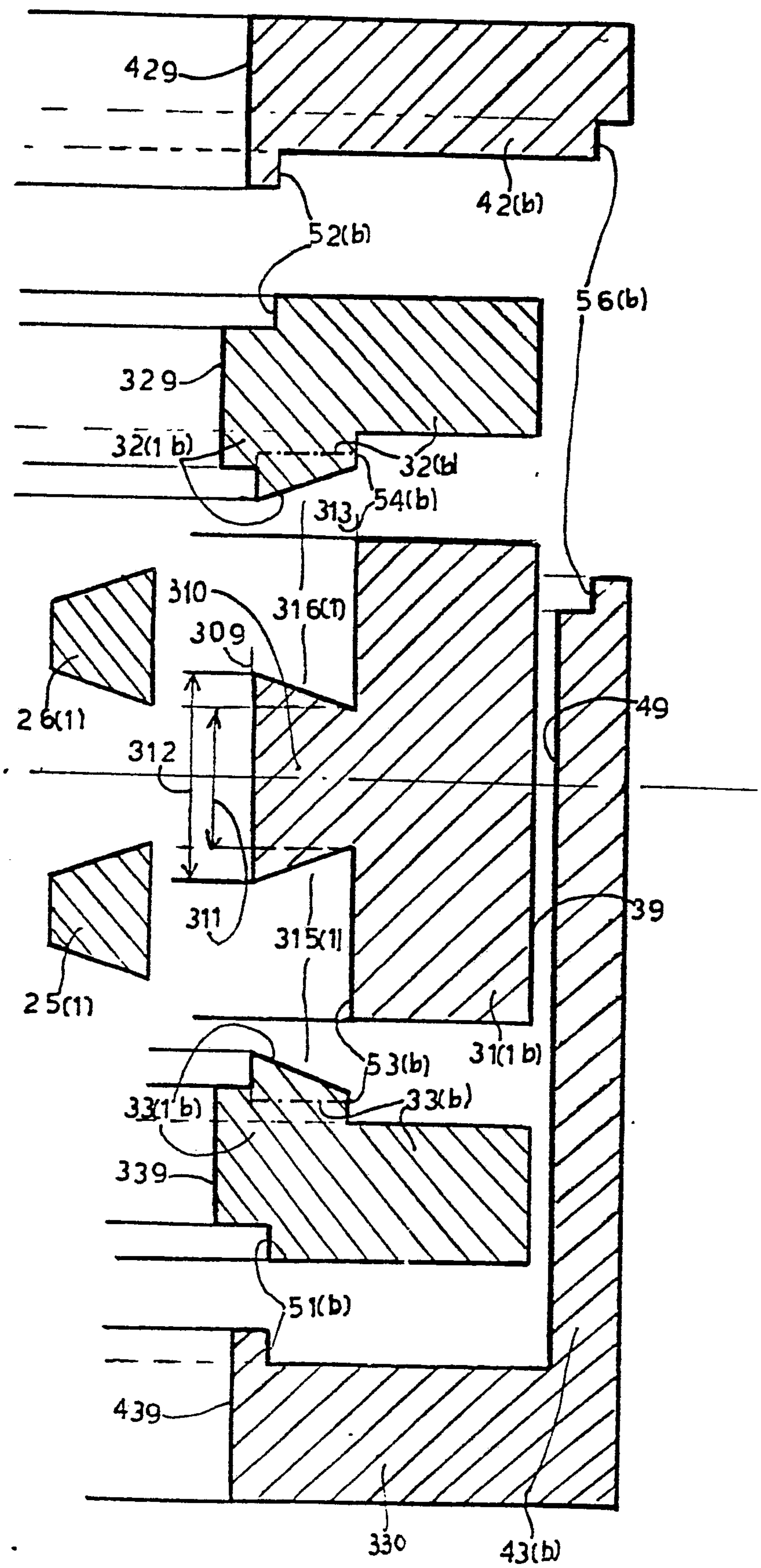


FiG.13(1 b)

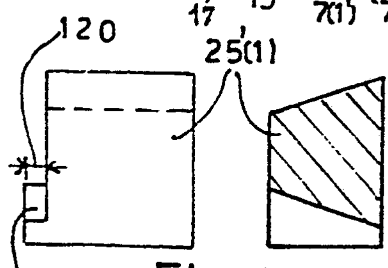


FiG. 25(1)

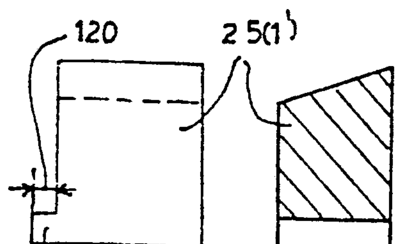
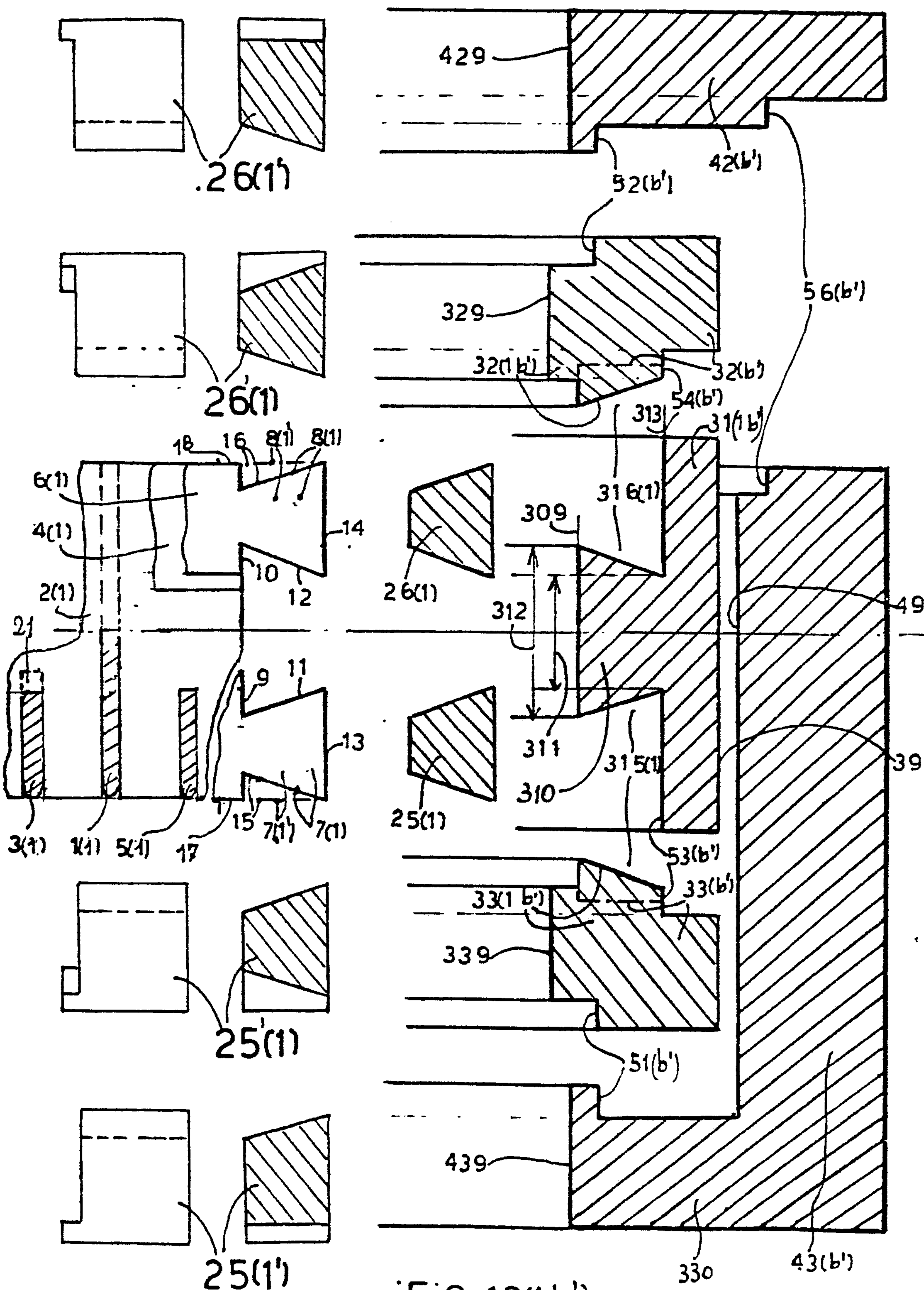


FiG. 25(1')

250(0)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42(b')
52(b')
56(b')
26(1')
26(1)
329
32(1b')
32(b')
54(b')
313
31(1b')
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8(1)
6(1)
4(1)
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316(1)
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2(1)
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315(1)
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25(1)
3(1)
1(1)
5(1)
17
15
7(1)
53(b')
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33(b')
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25'(1)
51(b')
439
25(1')
330
43(b')

FIG. 13(1b')

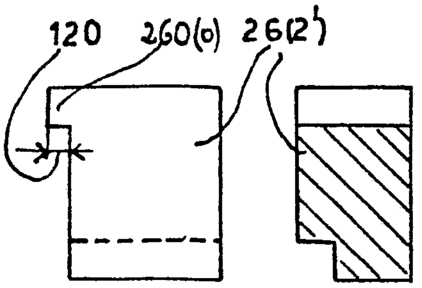
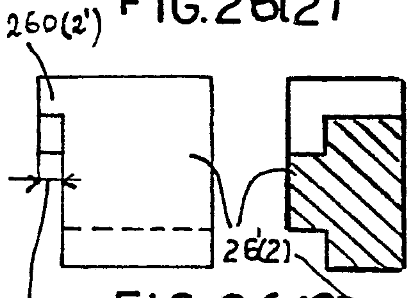


FiG.26(2')



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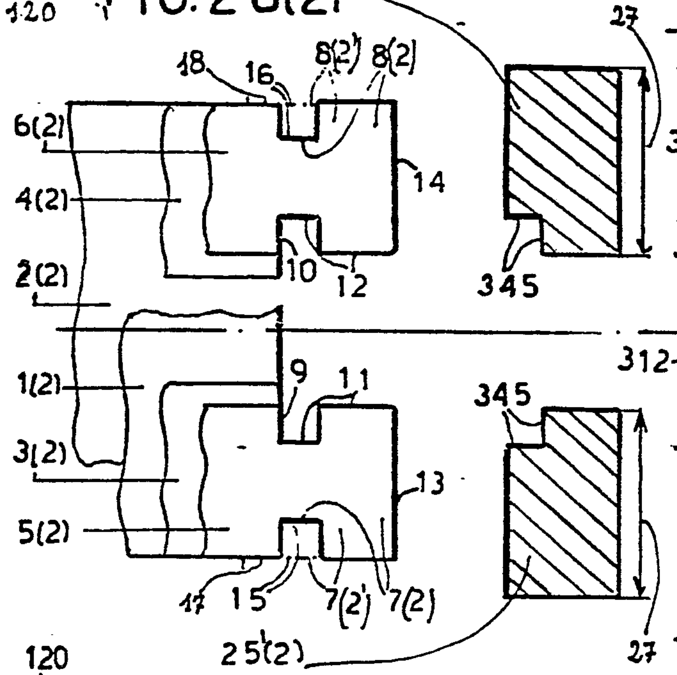


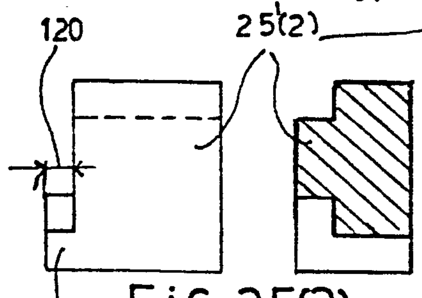
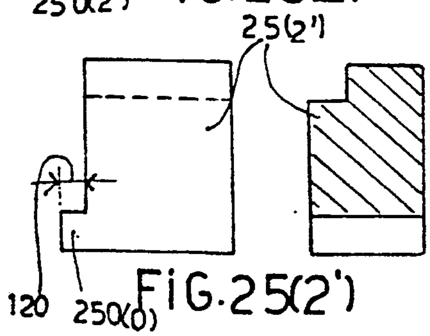


FiG.25(2)



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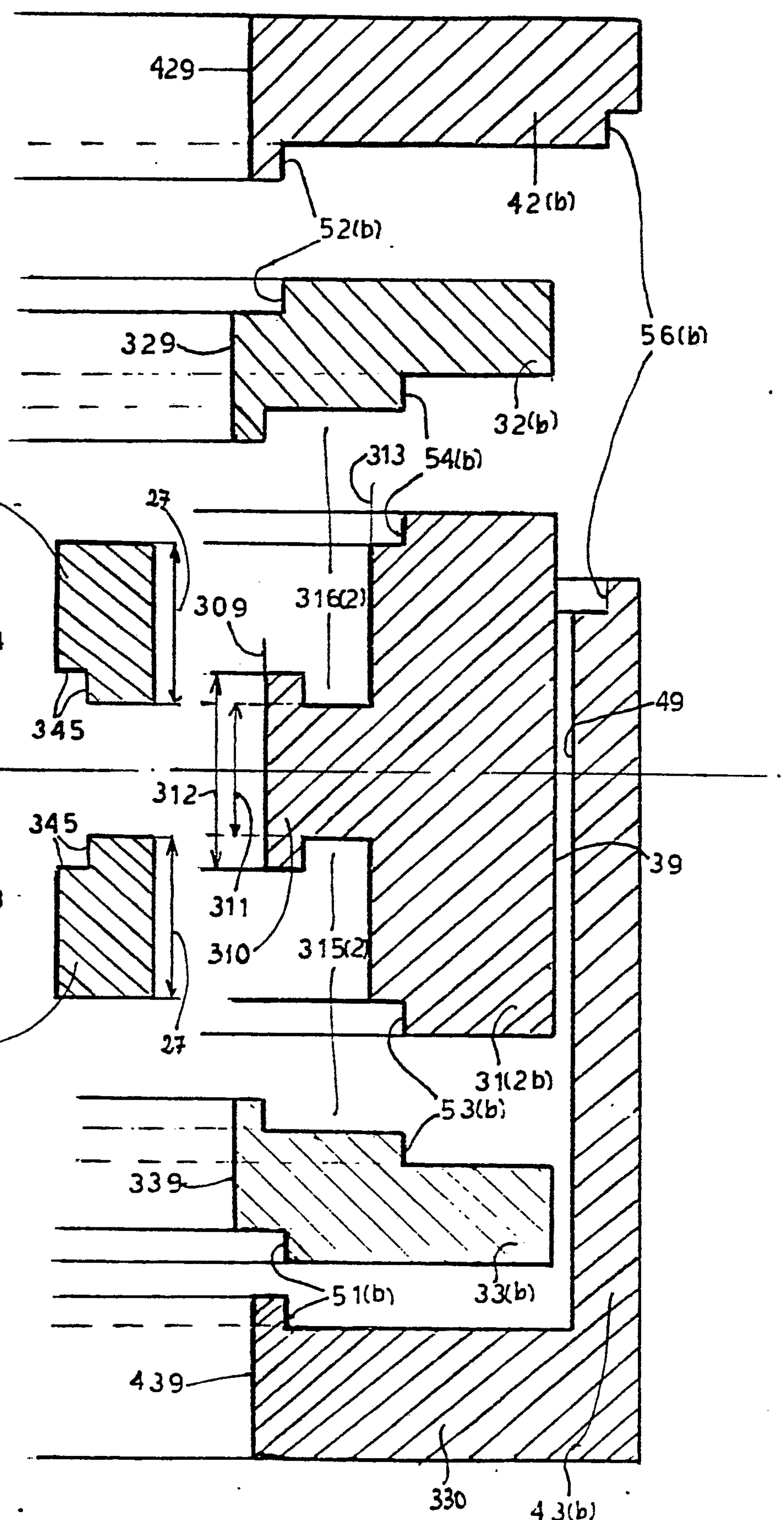
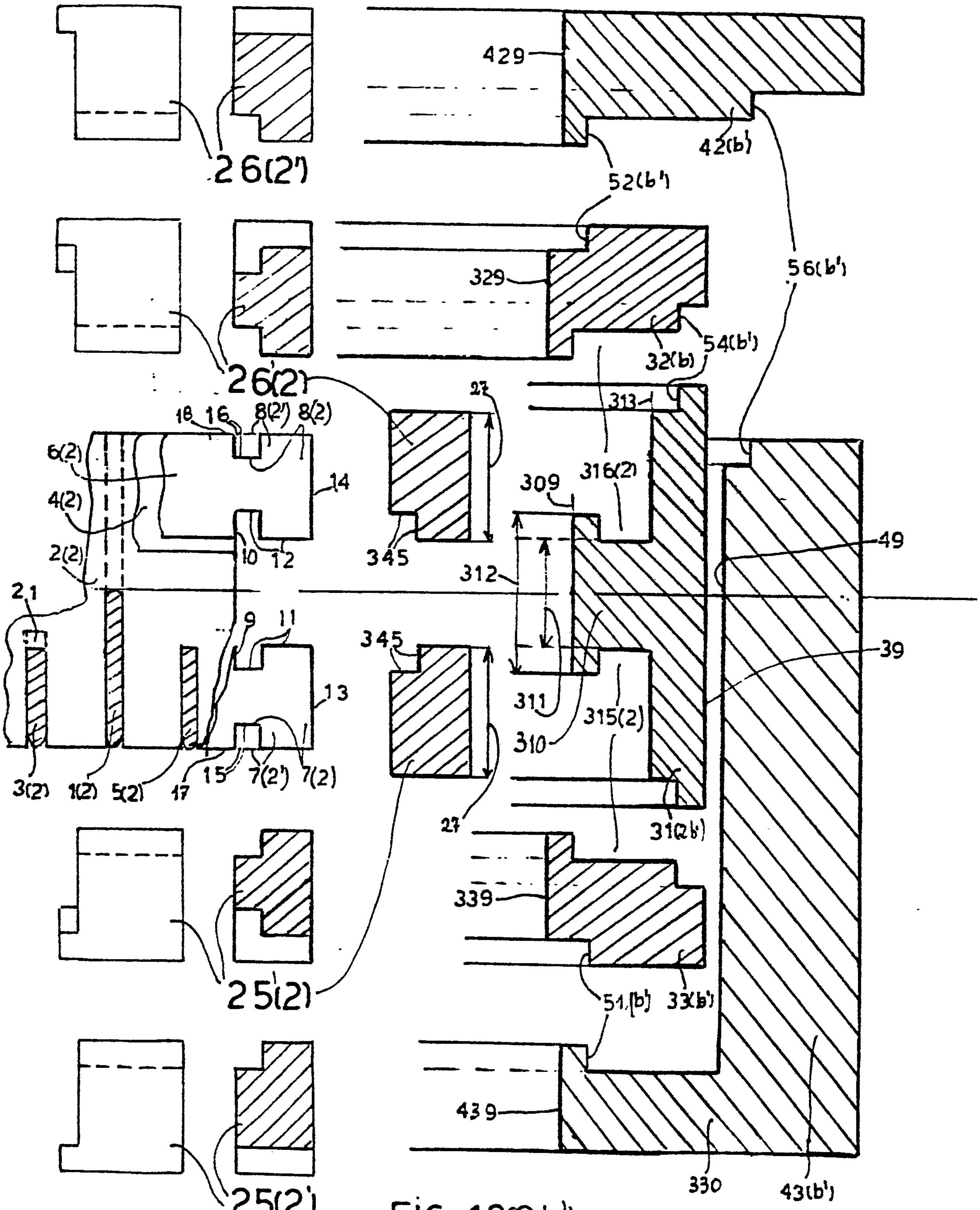


FiG.13(2b)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42(b')
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33(b')
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25(2')
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43(b')

FIG. 13(2b')

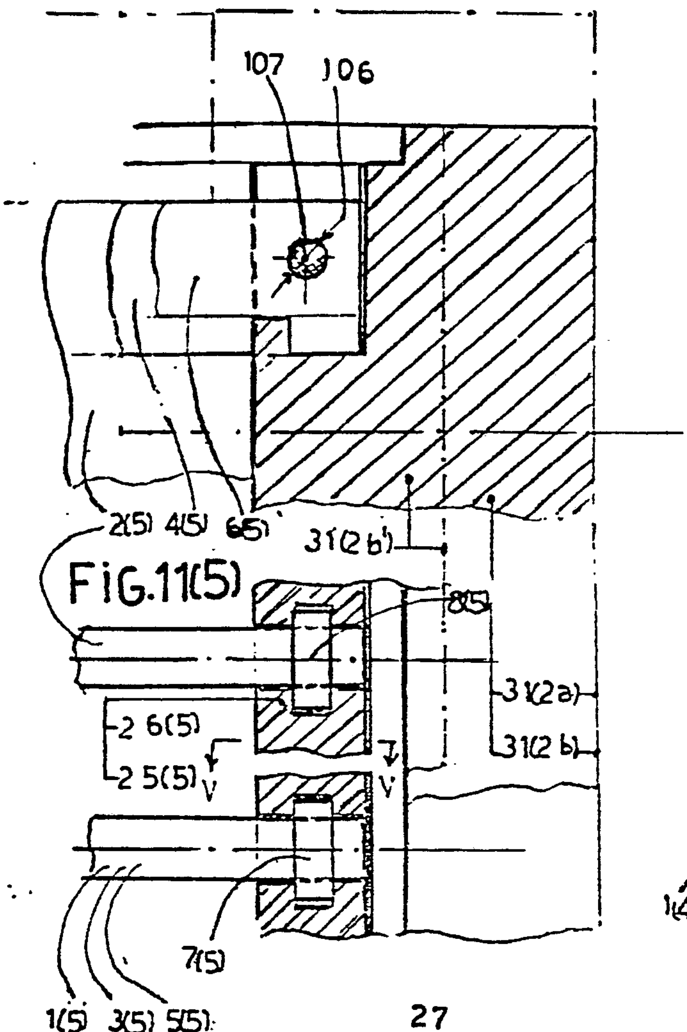


FiG.11(5)

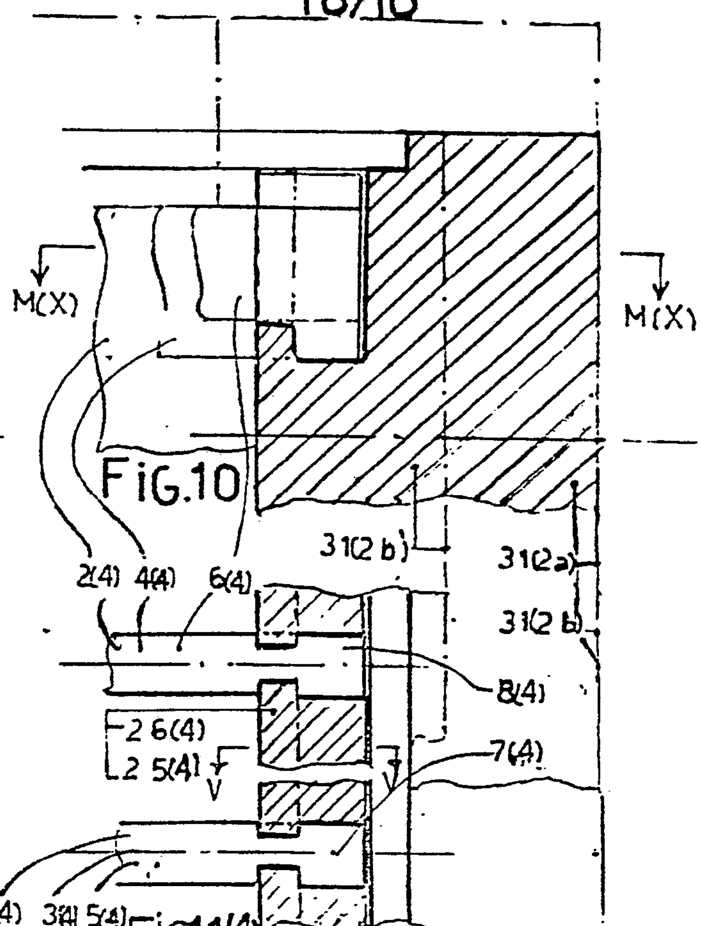


FiG.10

FiG.11(4)

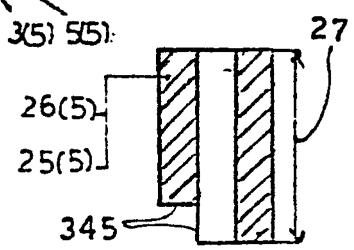
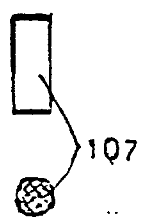


FiG.26(5)



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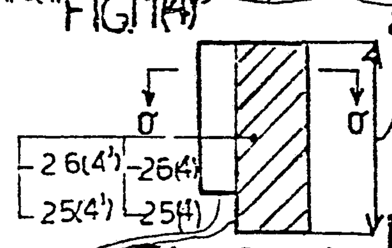
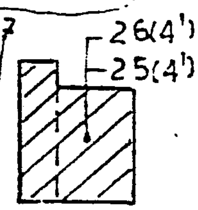


FiG.26(4)



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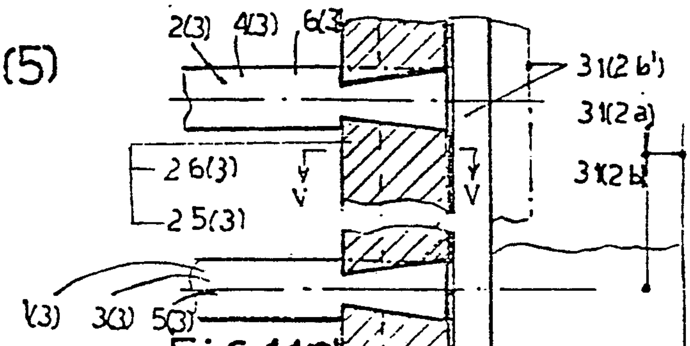

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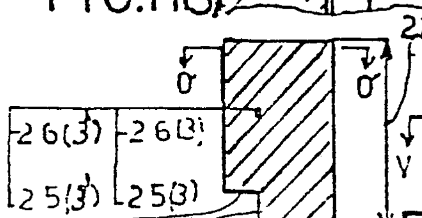

FiG.26(3)

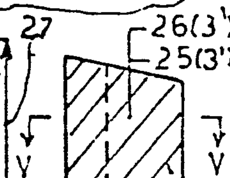

FiG.26(3')