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(54) **Asymmetric rod and neutron guide tube comprising asymmetric rods**

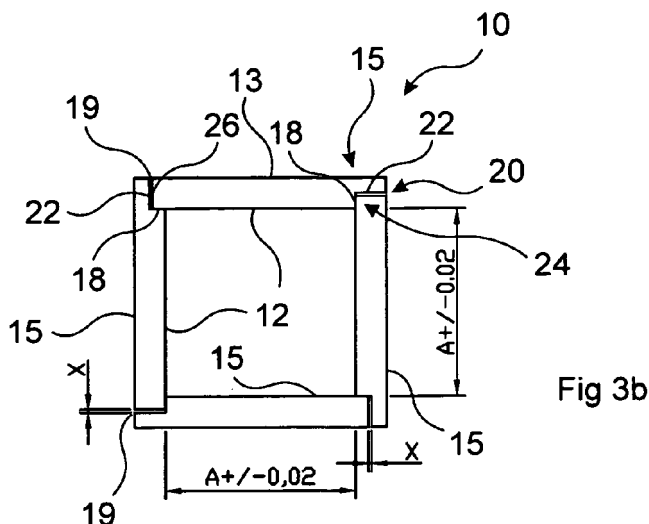
(57) The invention relates to an asymmetric rod (15) for forming a side of a neutron guide tube (10), the asymmetric rod (15) having:

- an inner side (12) for facing the inside of the neutron guide tube (10),
- an outer side (13) opposite the inner side (12),
- an end side (26) connecting the inner side (12) and the outer side (13),

characterised by further comprising a concave side (20)

connecting the inner side (12) and the outer side (13) opposite the end side (26), the concave side (20) having a base side (18) adjacent the inner side (12) and a closing side (22) forming a shoulder recess (24) with the base side (18), wherein the angle of the shoulder recess (24) corresponds to the angle formed between the inner side (12) and the end side (26).

The invention further relates to a neutron guide tube (10) comprising such an asymmetric rod (15) and a method for forming a multi-layered asymmetric rod structure (50).



Description

[0001] The present invention relates to an asymmetric rod for forming a side of a neutron guide tube, such a neutron guide tube and a method of forming multi-layered asymmetric rod structures.

[0002] Neutron guide tubes are generally formed as cuboid tubes, wherein the walls of the cuboid tubes are made up of two pairs of panels called rods and plates. Fig. 1 shows such a prior art neutron guide tube 100. The inner sides 102 of the rods 104 and the plates 106 are coated with a neutron reflecting coating to form an active surface for guiding a neutron beam within the neutron guide tube 100. The rods 104 are provided with two base sides 108 at each end of their inner side 102 which are perpendicular thereto. In the assembled position each base side 108 abuts the inner side 102 of the plates 106 thereby defining the w width of the tube 100. Consequently the tolerance of the w width of the neutron guide tube 100 cannot be less than the tolerance with which the base side 108 is manufactured. As neutron guide tubes 100 generally need to be relatively long, the tube 100 is generally made up of a plurality of tube sections each comprising a pair of rods 104 and plates 106. A variation in the inner w width of the neutron guide tubes 100 leads to a break (misaligned surfaces) where two tube sections meet, which will lead to neutron losses in such regions. Furthermore, the base side 108 of the rod 104 has to be affixed to the inner side 102 of the neighbouring plate 106 which is generally done by applying glue 109 between the two surfaces. The glue 109 will also have a certain X thickness which is impossible to control accurately, hence this leads to an even greater deviation from the desired tube-width. For example if the tolerance of the rod 104 is about 0/-0.02, the resulting tolerance of the w width of the tube 100 will be about +/-0.02 which will lead to undesirable neutron losses at the junction of two neighbouring tube sections as explained earlier. A further drawback of this solution is that the glue 109 is applied on the inner surface 102 of the plates 106, which is the active surface provided with the neutron reflecting coating hence in order not to apply glue on the coating (which would lead to the peeling off of the coating) a very precisely sized bordering region of the plates 106 needs to be left uncovered by the neutron reflecting coating. A further disadvantage is that the glue 109 is exposed to the neutron beam and neutron scattering within the neutron guide tube 100 as it is not separated from the inside of the tube 100 which will eventually lead to the deterioration of the glue 109. If the glue 109 is compromised it will not hold the rod 104 strong enough and the vacuum created within the neutron guide tube 100 may lead to the collapsing of the tube 100. A further disadvantage is that when the rods 104 and plates 106 are glued together they are pressed against each other whereby tensional forces arise, however the abutting surfaces correspond to the surfaces between which the glue 109 is applied, hence the rods 104 and plates 106 do not have any neu-

tral support with respect to each other. Since the rods 104 and the plates 106 are pressed against each other at certain regions (and not along the whole length of the neutron guide tube 100) the thickness X of the glue 109 will be smaller at the regions where the pressure is applied and greater in the other regions. The uneven glue thickness X may lead to minor torsions of the tube 100 which impairs the neutron guiding efficiency.

[0003] The latter problem is overcome by a second prior art neutron guide tube 200 illustrated in Fig. 2. As can be seen the rods 204 are formed with two concave sides 210 adjacent their inner side 202 and the base sides 208 are provided on the concave sides 210. The base side 208 is perpendicular to the inner side 202 and adjacent therewith. The concave side 210 further comprises a closing side 212 which is parallel with the inner side 202 of the rod 204 and spaced apart therefrom by the base side 208, thus forming a shoulder recess 214 together with the base side 208. The shoulder recess 214 is dimensioned such as to receive an end side 216 of a neighbouring plate 206 in the assembled position. This way the distance of the plates 206 abutting the shoulder recess 214, i.e. the inner w width of the neutron guide tube 200, is determined by the distance of the two base sides 208 formed at each concave side 210 of the rod 204. The glue 209 attaching the neighbouring rods 204 and plates 206 is applied on the two surfaces of the shoulder recess 214, i.e. on the base side 208 abutting the inner side 202 of the neighbouring plate 206 and on the closing side 212 abutting the end side 216 of the neighbouring plate 206. This has the advantage that even if the glue 209 weakens the rod 204 will not collapse into the neutron guide tube 200 as a result of the vacuum therein since the closing sides 212 of the shoulder recess 214 are supported on the end sides 216 of the plates 206. However, all the other aforementioned problems of the prior art neutron guide tube 100 illustrated in Fig. 1 remain to be a disadvantage of the present prior art neutron guide tube 200 as well. A further disadvantage of the prior art tube 200 is that the shoulder recess 214 needs to be manufactured with high precision otherwise the plates 206 cannot be fitted precisely between the two rods 204.

[0004] A further common disadvantage of the above prior art neutron guide tubes 100, 200 is that two different kinds of elements need to be manufactured, namely rods 104, 204 and plates 106, 206.

[0005] It is an object of the present invention to overcome the above problems associated with the prior art. In particular, it is an object of the invention to provide uniform elements which allow for the easy assembly of a neutron guide tube and which are free of all the above disadvantages of the prior art solutions.

[0006] In a first aspect of the invention an asymmetric rod for forming a side of a neutron guide tube is provided, the asymmetric rod having:

- an inner side for facing the inside of the neutron

guide tube,

- an outer side opposite the inner side,
- an end side connecting the inner side and the outer side,

characterised by further comprising a concave side connecting the inner side and the outer side opposite the end side, the concave side having a base side adjacent the inner side and a closing side forming a shoulder recess with the base side, wherein the angle of the shoulder recess corresponds to the angle formed between the inner side and the end side.

[0007] In a second aspect of the invention a neutron guide tube having at least four sides is provided. The neutron guide tube is characterised in that each side of the neutron guide tube comprises an asymmetric rod having:

- an inner side facing the inside of the neutron guide tube and preferably coated with a neutron reflecting coating,
- an outer side opposite the inner side,
- an end side connecting the inner side and the outer side, and
- a concave side connecting the inner side and the outer side opposite the end side,

the concave side having a base side adjacent the inner side and a closing side forming a shoulder recess with the base side, wherein the angle of the shoulder recess corresponds to the angle formed between the inner side and the end side.

[0008] In a third aspect of the invention a method is provided for forming a multi-layered asymmetric rod structure, characterised in:

- placing an asymmetric rod according to the invention onto a vacuum table surface with its inner side against the surface, the asymmetric rod having a first thickness
- affixing the asymmetric rod to the surface by vacuum suction,
- applying a support rod on the outer side of the asymmetric rod, the support rod having a second thickness being greater than the first thickness.

[0009] Further advantageous embodiments of the invention are defined in the attached dependent claims.

[0010] Further details of the invention will be apparent from the accompanying figures and exemplary embodiments.

Fig. 1a is a schematic cross sectional view of a prior art neutron guide tube.

Fig. 1b is a partial cross sectional view of the prior art tube according to Fig. 1a.

Fig. 2a is a schematic cross sectional view of another prior art neutron guide tube.

Fig. 2b is a partial cross sectional view of the prior art tube according to Fig. 2a.

Fig. 3a is a schematic cross sectional view of a first embodiment of an asymmetric rod according to the invention.

Fig. 3b is a schematic cross sectional view of a first embodiment of a neutron guide tube made up of four asymmetric rods according to Fig. 3a.

Fig. 3c is a partial cross sectional view of the tube according to Fig. 3b.

Fig. 4a - 4c are schematic cross sectional views illustrating the steps of assembling the tube according to Fig. 3b.

Fig. 4d schematically depicts an alternative way of assembling the four asymmetric rods to form the tube according to Fig. 3b.

Fig. 5a is a schematic cross sectional view of a second embodiment of a neutron guide tube according to the invention.

Fig. 5b is a schematic cross sectional view of an alternative to the second embodiment according to Fig. 5a.

Fig. 6a - 6e are schematic cross sectional views illustrating the steps of forming multi-layered rod structures and assembling the tube according to Fig. 5a.

Fig. 7a is a schematic cross sectional view of a further embodiment of a neutron guide tube according to the invention.

Fig. 7b is a partial cross sectional view of the tube according to Fig. 7a.

Fig. 8a is a schematic cross sectional view of a further embodiment of a neutron guide tube according to the invention.

Fig. 8b is a partial cross sectional view of the tube according to Fig. 8a.

Fig. 9 is a schematic cross sectional view of a further embodiment of a neutron guide tube according to the invention.

[0011] Fig. 3a depicts a preferred embodiment of an asymmetric rod 15 according to the invention. Fig. 3b and 3c shows a preferred embodiment of a neutron guide tube 10 according to the invention. The neutron guide tube 10 comprises four uniform asymmetric rods 15 according to Fig. 3a. Each asymmetric rod 15 comprises an inner side 12 which is coated with a neutron reflecting coating to form an active surface for guiding a neutron beam within the neutron guide tube 10 and an outer side 13 lying opposite the inner side 12. As can be seen the plates 15 are formed with a concave side 20 and an opposing end side 26 connecting the inner side 12 and the outer side 13 of the asymmetric rod 10. The concave side 20 of each asymmetric rod 15 comprises a base side 18 adjacent the inner side 12 and perpendicular therewith. The concave side 20 further comprises a closing side 22 forming a shoulder recess 24 with the base side 18. The shoulder recess 24 is dimensioned such as to receive at

least partly the end side 12 of a neighbouring asymmetric rod 15 when the neutron guide tube 10 is assembled. The α angle of the shoulder recess 24, i.e. of the angle formed between the base side 18 and the closing side 22 corresponds to the α angle formed between the inner side 12 and the end side 26 of the asymmetric rod 15. In the present embodiment this α angle is 90 degrees. When the four asymmetric rods 15 are assembled as illustrated in Fig. 1b to form the neutron guide tube 10 the base side 18 of each asymmetric rod 15 abuts the inner side 12 of the neighbouring asymmetric rod 10 in the proximity of its end side 26 while the closing side 22 of the asymmetric rod 15 reaches over the end side 26 of the neighbouring asymmetric rod 10 thereby forming a closed outer wall. The two asymmetric rods 15 can be affixed to each other for example by glue 19 which is preferably applied between the closing side 22 of the first asymmetric rod 15 and the end side 26 of the neighbouring asymmetric rod 15. This way the glue 19 does not need to be applied on the active inner side 12 of the asymmetric rod 15 as in the prior art, instead it is applied on the neutral surfaces of the closing side 22 of the shoulder recess 24 and the end side 26.

[0012] A further advantage of this construction is that the distance between the opposing asymmetric rods 15 is determined by the length of the portion of the asymmetric rod 15 which is inserted into the shoulder recess 24. Hence the inner width of the neutron guide tube 10 can be adjusted with greater precision than the manufacture of the individual asymmetric rods 15, for example if the asymmetric rods 15 are manufactured with a tolerance of 0/-0,1 a substantially smaller tolerance can be achieved, such as +/-0,02 for the inner width of the assembled tube 10 by precisely setting the distance between the closing side 22 of the shoulder recess 24 and the end side 26 of two neighbouring asymmetric rods 15 of the assembled tube 10. This way the costs of manufacturing the asymmetric rods 15 can be reduced. Furthermore, the X thickness of the applied glue 19 does not influence the precision of the fitting as the glue is not applied on the base side 18 which determines the actual inner cross section of the tube 10. The tensional and torsional forces are also eliminated as the supporting surface (the surface of the base side 18) and the fixing surface on which the glue 19 is applied (the surface of the end side 26 and the closing side 22) do not coincide.

[0013] The costs are further reduced by having to manufacture only one type of element, namely the uniform asymmetric rod 15 forming all four sides of the neutron guide tube 10 instead of the prior art rods 104, 204 and plates 106, 206.

[0014] A preferred way of assembling the neutron guide tube 10 according to Fig. 1b is illustrated in Figs. 4a - 4c. In the first step illustrated in Fig. 4a two neighbouring plates 15 are assembled and attached to each other. A gauge block 30 and an auxiliary plate 32 are used to set the position of a first asymmetric rod 15a and a second asymmetric rod 15b with respect to each other.

The cross section of the gauge block 30 determines the cross section of the neutron guide tube 10 as the asymmetric rods 15 are arranged on the external faces 34a, 34b, 34c, 34d of the gauge block 30. The auxiliary plate 32 is held against the fourth face 34d of the gauge block 30 such as to extend from this face 34d in the direction of the neighbouring first face 34a. The extending part of the auxiliary plate 32 serves as an abutment 36 for the first asymmetric rod 15 which is pressed against the first face 34a of the gauge block 30 in the direction indicated by I. At the same time the first asymmetric rod 15a is moved along the first face 34a of the gauge block 30 in the direction indicated by II so as to abut the abutment 36 of the auxiliary plate 32 extending beyond the fourth face 34d. When the first asymmetric rod 15a reaches the abutment 36 the end of the auxiliary plate 32 is at least partly received in the shoulder recess 24 and the base side 18 of the first asymmetric rod 15a abuts the abutment 36 thereby the base side 18 becomes coplanar with the first face 34a of the gauge block 30.

[0015] Once the first asymmetric rod 15a is arranged the second asymmetric rod 15b is placed in position by pressing it against the second face 34b of the gauge block 30 in the direction indicated by III and against the inner side 12 of the first asymmetric rod 15a in the direction indicated by IV. When the second asymmetric rod 15b reaches the first asymmetric rod 15a the base side 18 of the second asymmetric rod 15b abuts the inner side 12 of the first asymmetric rod 15a and the end side 26 of the first asymmetric rod 15a is received in the shoulder recess 24 of the second asymmetric rod 15b. In this position the width of the free surface of the inner side 12 of the first asymmetric rod 15a, i.e. the distance measured from the plane of the inner side 12 of the second asymmetric rod 15b and the plane of the base side 18 of the first asymmetric rod 15a, corresponds to the w' width of the gauge block 30 as indicated in Fig. 4a.

[0016] The first and the second asymmetric rods 15a, 15b can be affixed to each other using glue 19 between the end side 26 of the first asymmetric rod 15a and the closing side 22 of the shoulder recess 24 of the second asymmetric rod 15b. If the tolerance of the asymmetric rods 15a, 15b are substantially greater than the tolerance of the gauge block 30 which determines the precision of the assembly then in certain cases the end side 26 of the first asymmetric rod 15a and the closing side 22 of the second asymmetric rod 15b might be separated from each other by a small gap in which case other filling material such as stainless steel may be used apart from the glue 19 to fill out the gap. However, any such gap does not influence the achieved tolerance of the inner width of the assembled neutron guide tube 10. Furthermore, the glue 19 and/or other filling material is separated from the inside of the tube 10 by the abutting inner side 12 of the first asymmetric rod 15a and the closing side 22 of the second asymmetric rod 15b, thus the glue 19 and/or other filling material does not need to be resistant against the neutron beams transmitted within the tube 10 or any

neutron scattering and there is no risk of the glue 19 and/or other filling material deteriorating over the time due to the neutron scattering.

[0017] Once the first and the second asymmetric rods 15a, 15b are assembled with respect to each other and the gauge block 30, and affixed to each other the resulting L-shaped first asymmetric rod assembly 38a is removed and the first step is repeated with the third and fourth asymmetric rods 15b, 15c as illustrated in Fig. 4b. First the third asymmetric rod 15c is pressed against the first face 34a of the gauge block 30 in the direction indicated by V and against the abutment 36 of the auxiliary plate 32 extending beyond the fourth face 34d of the gauge block 30 in the direction indicated by VI, whereby the base side 18 of the third asymmetric rod 15c abuts the abutment 36 and the end of the auxiliary plate 32 is received in the shoulder recess 24 of the third asymmetric rod 15c. After this the fourth asymmetric rod 15d is placed in position and pressed against the gauge block 30 in the direction indicated by VII and against the inner side 12 of the third asymmetric rod 15c in the direction indicated by VIII. Thus the base side 18 of the fourth asymmetric rod 15d abuts the inner side 12 of the third asymmetric rod 15c and the end side 26 of the third asymmetric rod 15c is received in the shoulder recess 24 of the fourth asymmetric rod 15d. In this position the width of the free surface of the inner side 12 of the third asymmetric rod 15c, i.e. the distance measured from the plane of the inner side 12 of the fourth asymmetric rod 15d and the plane of the base side 18 of the third asymmetric rod 15c, corresponds to the w' width of the gauge block 30 as indicated in Fig. 4b.

[0018] The third and fourth asymmetric rods 15c, 15d are affixed to each other for example by applying glue 19 between the end side 26 of the third asymmetric rod 15c and the closing side 22 of the fourth asymmetric rod 15d. The resulting L-shaped second asymmetric rod assembly 38b is fitted against the first asymmetric rod assembly 38a as illustrated in Fig. 4c. The second asymmetric rod assembly 38b is pressed against the first asymmetric rod assembly 38a by pressing the side formed by the fourth asymmetric rod 15d in the direction indicated by IX. As a result, the base side 18 of the third asymmetric rod 15c abuts the inner side 12 of the second asymmetric rod 15b whereby the inner W_1 width of the tube 10 parallel with the third asymmetric rod 15c is set. Note that this W_1 width corresponds to the w' width of the gauge block 30, since the second asymmetric rod assembly 38b assumes the same position with respect to the second asymmetric rod 15b as previously during assembly with respect to the auxiliary plate 32. The desired W_2 width of the tube 10 parallel with the second and fourth asymmetric rods 15b, 15d (which is preferably equal to the W_1 width) can be set by pushing the second asymmetric rod assembly 38b against the first asymmetric rod assembly 38a in the direction indicated by X to the desired position. The same gauge block 30 is preferably used for setting this distance at least at the two

ends of the neutron guide tube 10. However, other known means can be used to position the second asymmetric rod assembly 38b with respect to the first asymmetric rod assembly 38a as well.

[0019] The asymmetric rods 15 can be assembled in various other ways, for example an external adjusting frame 40 with adjusting screws 42 may be used to set the desired position of the asymmetric rods 15 as illustrated in Fig. 4d. The adjusting screws 42 can be screwed in to reach inside the frame 40 for setting the distance of the asymmetric rods 15 from the sides of the adjusting frame 40 and thereby setting the outer cross section of the tube 10. The asymmetric rods 15 as assembled in Fig. 4c are placed within the adjusting frame 40, the screws 42 are screwed in so as to determine the desired position of the outer sides 13 of the asymmetric rods 15, and the asymmetric rods 15 are forced against the screws 42 in the directions indicated by A, B, C, D (e.g. by applying vacuum suction on the outer sides 13 of the asymmetric rods 15 and pulling the asymmetric rods 15 in the directions A, B, C, D) until the outer sides 13 of the asymmetric rods 15 abut the screws 42. Preferably, the use of the gauge block 30 and the use of the adjusting frame 40 are combined: in the proximity of the two ends of the neutron guide tube 10 the L-shaped asymmetric rod assemblies 38a, 38b are set with respect to each other using the gauge block 30, while at the middle section of the tube 10 the position of the asymmetric rods 15a, 15b, 15c, 15d is corrected by using the external adjusting frame 40. Another gauge block 30 having a width corresponding to the desired external W_3 width of the neutron guide tube 10 may also be used to set the position of the screws 42 of the adjusting frame 40. This way an extremely precise alignment can be achieved along the whole of the asymmetric rods 15 and the tube 10 itself.

[0020] Fig. 5a illustrates another preferred embodiment of the neutron guide tube 10 according to the invention. The neutron guide tube 10 comprises multi-layered rod structures 50 having an inner asymmetric rod 15 and an outer support rod 75 which is preferably of the same asymmetric construction as the inner asymmetric rod 15. The inner side 12 of the inner asymmetric rod 15 faces the inside of the neutron guide tube 10 and is coated with a neutron reflecting coating. The outer side of the asymmetric rod 15 is attached to the support rod 75 preferably by glue 19. The inner asymmetric rod 15 is preferably a thin glass of about 2 - 6 mm and of a flatness in the magnitude of 10^{-5} radian (0.00001 radian), while the support rod 75 is preferably a substantially thicker carrier layer of about 10 - 25 mm. The multi-layered rod structure 50 may be a glass-glass structure using float and/or borofloat glass, alternatively it may be a glass-metal structure, e.g. the inner asymmetric rod 15 may be of float/borofloat glass, while the support rod 75 may be of steel. Further possible multi-layered structures as well as their manufacture is disclosed in PCT/HU2007/00033. According to a preferred embodiment of the invention the multi-layered rod structure 50 is formed by assembling the inner asym-

metric rod 15 and the outer support rod 75, which is also in the form of an asymmetric rod, with respect to each other, a vacuum gauge block 54 and two spacers 56a, 56b as illustrated in Figs. 6a - 6e. The vacuum gauge block 54 has at least one vacuum table surface 58 on which the inner asymmetric rod 15 is placed. The two spacers 56a, 56b are placed against the two opposite faces 60a, 60c of the vacuum gauge block 54 bordering the vacuum table surface 58. The length of the first spacer 56a is such as to extend beyond the first face 60a by less than the length of height of the base side 18 of the inner asymmetric rod 15 in order to provide an abutment 62 for the base side 18. In the first step of the method illustrated in Fig. 6a the asymmetric rod 15 is placed on the vacuum table surface 58 so as to abut the abutment 62 of the first spacer 56a, then the vacuum gauge block 54 is turned on and the inner surface 12 of the asymmetric rod 15 is affixed to the vacuum table surface 58 by vacuum suction. The vacuum table surface 58 is preferably a surface of very high flatness, preferably at least about 10^{-5} radian, whereby the thin asymmetric rod 15 assumes the same flatness.

[0021] The outer support rod 75 comprises an inner side 72 which is placed on the outer side 13 of the asymmetric rod 15. The support rod 75 further comprises an outer side 73 opposite its inner side, an end side 86 connecting its inner side 72 with its outer side 73 and a concave side 80 connecting its inner side 72 with its outer side 73 opposite its end side 86. The concave side 80 of the support rod 75 has a first side 78 adjacent the inner side 72 and a second side 82 forming a shoulder recess 84 with the first side 78. The angle of the corner formed within the shoulder recess 84 corresponds to the angle formed between the inner side 72 and the end side 86 of the support rod 75, which is 90 degrees in the present embodiment.

[0022] The dimension of the shoulder recess 84 of a first support rod 75a is designed such as to receive the end side 86 of a second support rod 75b of a neighbouring multi-layered rod structure 50b when the base side 18 of the second asymmetric rod 15b is abutted against the inner side 12 of the first asymmetric rod 15a adjacent the end side 82 of the first asymmetric rod 15a as illustrated in Fig. 6c.

[0023] As can be seen in Fig. 6a the thicker support rod 75 is placed on the outer side 13 of the asymmetric rod 15 such as to abut the second spacer 56b. The second spacer 56b is provided with an abutment 64 extending beyond the third face 60c of the vacuum gauge block 54 when fitted against this third face 60c. The abutment 64 is dimensioned such as to assume the required position of the neighbouring support rod 75 of the neighbouring multi-layered rod structure 50 when the neutron guide tube 10 is assembled. Thus the abutment 64 extends over the inner asymmetric rod 15 and into the shoulder recess 84 of the support rod 75 whereby the first side 78 of the support rod 75 can be abutted against the abutment 64. The inner asymmetric rod 15 and the outer support

rod 75 are affixed to each other by glue 19 applied between the outer side 13 of the asymmetric rod 15 and the inner side 72 of the support rod 75. After the binding of the glue 19 has taken place the vacuum can be turned off and the multi-layered rod structure 50 can be removed from the vacuum table surface 58. This step is repeated three more times in order to fabricate three more multi-layered rod structures 50 for forming the neutron guide tube 10. It should be noted that it is also possible to prepare the multi-layered rod structures 50 on any conventional vacuum table using similar spacer elements which are arranged on the vacuum table with the desired spacing to provide the required abutments 62, 64 for positioning the outer support rod 75 with respect to the inner asymmetric plate 15.

[0024] In the fifth step the second spacer 56b is removed and the first multi-layered rod structure 50a is placed on the surface 58 of the vacuum gauge block 54 such as to abut the abutment 62 of the first spacer 56a with the base side 18 of the inner asymmetric rod 15 whereby the base side 18 becomes coplanar with the surface 58 of the vacuum gauge block 54.

[0025] In the sixth step a second multi-layered rod structure 50b is fitted against the third face 60c of the gauge block 54 and the first multi-layered rod structure 50a such as to abut the inner side 12 of the first multi-layered rod structure 50a with the base side 18 of its inner asymmetric rod 15b. The end side 82 of the support rod 75b of the second multi-layered rod structure 50b is received in the shoulder recess 84 of the support rod 75a of the first multi-layered rod structure 50a. The first and second multi-layered rod structures 50a, 50b are affixed to each other in this position e.g. using glue 19 which can be applied between the end side 26 of the first asymmetric rod 15a and the closing side 22 of the second asymmetric rod 15b and/or between the end side 86 of the second support rod 75b and the second side 82 of the shoulder recess 84 of the first support rod 75a. Note that the first side 78 of the shoulder recess 84 of the first support rod 75a does not need to abut the inner side 72 of the second support rod 75b since the position of the two multi-layered rod structures 50a, 50b with respect to each other is determined by the two inner asymmetric rods 15a, 15b and in particular by the base side 18 of the second asymmetric rod 15b and the inner side 12 of the first asymmetric rod 15a. Once this step is completed the resulting L-shaped multi-layered rod assembly 90a is removed and the sixth step is repeated in the seventh step in order to produce a second L-shaped multi-layered rod assembly 90b.

[0026] In the eighth and ninth step the two L-shaped multi-layered rod assemblies 90a, 90b are fitted against each other such that first the second L-shaped multi-layered rod assembly 90b is pressed against the first L-shaped multi-layered rod assembly 90a in the direction indicated by I in order to achieve the desired inner w_1 width of the neutron guide tube 10 by setting the distance between the fourth multi-layered rod structure 50d of the

second multi-layered rod assembly 90b and the second multi-layered rod structure 50b of the first multi-layered rod assembly 90a. The gauge block 54 can be used to set the desired W_1 distance corresponding to the cross sectional w' width of the gauge block 54.

[0027] In the ninth step the distance between the third multi-layered rod structure 50c of the second multi-layered rod assembly 90b and the first multi-layered rod structure 50a of the first multi-layered rod assembly 90a (i.e. the w_2 width which is preferably equal with the w_1 width) is set by pressing the second L-shaped multi-layered rod assembly 90b against the first L-shaped multi-layered rod assembly 90a in the direction indicated by II. Again, the gauge block 54 may be used to set the desired distance.

[0028] The two L-shaped multi-layered rod assemblies 90a, 90b can be affixed to each other e.g. by glue 19 which can be applied between the end side 26 of the fourth asymmetric rod 15d and the closing side 22 of the first asymmetric rod 15a and/or between the end side 86 of the first support rod 75a and the second side 82 of the shoulder recess 84 of the fourth support rod 75d. Similarly, the glue 19 is preferably applied between the end side 26 of the second asymmetric rod 15b and the closing side 22 of the third asymmetric rod 15c and/or between the end side 86 of the third support rod 75c and the second side 82 of the shoulder recess 84 of the second support rod 75b.

[0029] Note, that in the described arrangement the glue 19 is never applied on a surface adjacent the inner side 12 of the inner asymmetric rod 15 and the thickness of the glue 19 does not influence the inner w width of the resulting neutron guide tube 10 since this is determined by the abutting surfaces of the base sides 18 and the inner sides 12 of the inner asymmetric rods 15.

[0030] The above described construction wherein the support rod 75 is of an asymmetric structure is particularly advantageous from the point of view of stable fitting, however the support rods 75 could be made with two straight end sides 86 as well since the inside of the guide tube 10 is formed by the inner asymmetric rods 15 in this embodiment as well. In this case the support rods 75 are preferably manufactured by a tolerance of 0/-0.02. Such a construction is illustrated in Fig. 5b.

[0031] It is also conceivable to form a multi-layered rod structure 50 with more than two layers, for example applying a support rod 75 on the outer side 13 of the asymmetric rod 15 is carried out by interposing a thin intermediate layer between the inner asymmetric plate 15 and the outer support rod 75, or further layers are provided outside of the support rod 75. The neutron reflecting coating on the inner side 12 of the asymmetric plate 15 may be regarded as a thin layer as well.

[0032] Fig. 7a and 7b depict another preferred embodiment of the asymmetric rod 15 and the neutron guide tube 10 according to the invention. The neutron guide tube 10 has a regular hexagonal cross section comprising six uniform asymmetric rods 15. The asymmetric rod

15 is similar to the previously described embodiments, the only difference being that the shoulder recess 24 at the concave side 20 is formed at an angle with the inner side 12 of the asymmetric rod 15, i.e. the base side 18 is not perpendicular to the inner side 12, instead the α angle between the base side 18 and the inner side 12 is 60 degrees. The angle of the shoulder recess 24, i.e. the angle between the base side 18 and the closing side 22 is 90 degrees, in order to receive the end side 26 of a neighbouring asymmetric rod 15 (which is perpendicular to the inner side 12) when the plates 15 are assembled to form the neutron guide tube 10 as illustrated in Fig. 7a. The asymmetric rods 15 are preferably affixed to each other by glue 19, which is applied between the end side 26 and the closing side 22 of the neighbouring asymmetric rods 15. This way the inner cross sectional dimension of the tube 10 is determined by the base sides 18 abutting the inner sides 12 of the neighbouring asymmetric rods 15 whereby the glue 19 is sealed off from the inside of the tube 10 on the one hand and on the other hand the X thickness of the glue 19 does not affect the precise fitting of the asymmetric rods 15 as the inner length of each side of the regular hexagon tube 10 (i.e. the w width of the inner side 12 exposed to the inside of the tube 10) can be set by adjusting the L length of the base side 18 which abuts the inner side 12 of the neighbouring asymmetric rod 15.

[0033] Fig. 8a and 8b depict another preferred embodiment of the asymmetric rod 15 and the neutron guide tube 10 according to the invention. In this embodiment the neutron guide tube 10 has a regular octagonal cross section comprising eight uniform asymmetric rods 15. The asymmetric rods 15 according to this embodiment differ from the previous embodiment in that the α angle between the base side 18 and the inner side 12 is 45 degrees. The angle of the shoulder recess 24 i.e. the angle between the base side 18 and the closing side 22 is 90 degrees in order to receive the end side 26 of a neighbouring asymmetric rod 15 which is perpendicular to the inner side 12.

[0034] Generally, if the neutron guiding tube 10 has a regular n -sided polygonal cross section, and the end side 26 to be received by the shoulder recess 24 of the asymmetric rod 15 forms a right angle with the inner side of the plate 15 as in the previously described embodiments than it is easy to calculate that the α angle between the base side 18 and the inner side 12 is:

$$\alpha = \frac{360}{n}.$$

[0035] It is also conceivable to form the end side 26 and the inner side 12 of the asymmetric rod 15 with a smaller or greater α angle than 90 degrees, in which case the shoulder recess 24 is formed with a corresponding α angle in order to receive the end side 26 of a neigh-

bouring asymmetric rod 15 as illustrated in Fig 9, wherein four asymmetric rods 15 make up the four walls of another neutron guide tube 10 according to the invention.

[0036] However, an α angle of 90 degrees between the base side 18 and the closing side 22 of the shoulder recess 24 is particularly advantageous from the point of view of manufacture, as the right angle shoulder recess 24 can be simply formed by a rotating cylindrical grinding tool as known in the art, and the end side 26 can be simply cut perpendicular to the inner side 12 and outer side 13 of the asymmetric rod 15 in this case.

[0037] The above-described embodiments are intended only as illustrating examples and are not to be considered as limiting the invention. Various modifications will be apparent to a person skilled in the art without departing from the scope of protection determined by the attached claims.

Claims

1. Asymmetric rod (15) for forming a side of a neutron guide tube (10), the asymmetric rod (15) having:

- an inner side (12) for facing the inside of the neutron guide tube (10),
- an outer side (13) opposite the inner side (12),
- an end side (26) connecting the inner side (12) and the outer side (13),

characterised by further comprising a concave side (20) connecting the inner side (12) and the outer side (13) opposite the end side (26), the concave side (20) having a base side (18) adjacent the inner side (12) and a closing side (22) forming a shoulder recess (24) with the base side (18), wherein the angle of the shoulder recess (24) corresponds to the angle formed between the inner side (12) and the end side (26).

2. Asymmetric rod according to claim 1, wherein the angle formed between the inner side (12) and the end side (26) and the angle between the base side (18) and the closing side (22) are both right angles.
3. Asymmetric rod according to claim 2, wherein the asymmetric rod (15) is for forming the side of a neutron guide tube (10) having a regular polygon cross-section of n sides and the angle between the base side (18) and the inner side (12) is:

$$\alpha = \frac{360}{n}.$$

4. Asymmetric rod according to any of claims 1 to 3, wherein the inner side (12) of the asymmetric rod

(15) is coated with a neutron reflecting coating in order to form an active surface of the neutron guide tube (10).

5. Asymmetric rod according to any of claims 1 to 4, wherein the outer side (13) of the asymmetric rod (15) is attached to a support rod (75) and forms a multi-layered asymmetric rod structure (50) therewith.
6. Asymmetric rod according to claim 5, wherein the support rod (75) comprises:
 - an inner side (72) facing the outer side (13) of the asymmetric rod (15),
 - an outer side (73) opposite its inner side (72),
 - an end side (86) connecting its inner side (72) with its outer side (73), and
 - a concave side (80) connecting its inner side (72) with its outer side (73) opposite its end side (86),

the concave side (80) of the support rod (75) having a first side (78) adjacent the inner side (72) and a second side (82) forming a shoulder recess (84) with the first side (78), wherein the angle of the shoulder recess (84) corresponds to the angle formed between the inner side (72) and the end side (26) of the support rod (75), and the dimension of the shoulder recess (84) is designed such as to receive at least partly an end side (86) of a support rod (75) of an identical multi-layered rod structure (50) when the base side (18) of an asymmetric rod (15) of the identical multi-layered rod structure (50) is abutted against the inner side (12) of the asymmetric rod (15) in the proximity of the end side (26) of the asymmetric rod (15).

7. Neutron guide tube (10) having at least four sides **characterised in that** each side of the neutron guide tube (10) comprises an asymmetric rod (15) having:
 - an inner side (12) facing the inside of the neutron guide tube (10) and preferably coated with a neutron reflecting coating,
 - an outer side (13) opposite the inner side (12),
 - an end side (26) connecting the inner side (12) and the outer side (13), and
 - a concave side (20) connecting the inner side (12) and the outer side opposite the end side,

the concave side (20) having a base side (18) adjacent the inner side (12) and a closing side (22) forming a shoulder recess (24) with the base side (18), wherein the angle of the shoulder recess (24) corresponds to the angle formed between the inner side (12) and the end side (26).

8. Neutron guide tube according to claim 7, wherein the asymmetric rods (15) are arranged such that the base side (18) of each asymmetric rod (15) abuts the inner side (12) of the neighbouring asymmetric rod (15) in the proximity of the end side (26) of the neighbouring asymmetric rod (15), whereby the end side (26) of the neighbouring asymmetric rod (15) is at least partly received within the shoulder recess (24) of the asymmetric rod (15) and the end side (26) of the neighbouring asymmetric rod (15) is attached to the closing side (22) of the receiving shoulder recess (24).

9. Neutron guide tube according to claim 8, wherein the angle formed between the inner side (12) and the end side (26) and the angle between the base side (18) and the closing side (22) of each asymmetric rod (15) are both right angles.

10. Neutron guide tube according to claim 9, having a regular polygon cross-section of n sides, each side comprising an asymmetric rod (15) and the angle between the base side (18) and the inner side (12) of each asymmetric rod (15) is:

$$\alpha = \frac{360}{n}.$$

11. Neutron guide tube according to any of claims 7 to 10, wherein the outer side (13) of each asymmetric rod (15) is attached to a support rod (75) and forms multi-layered asymmetric rod structure (50) therewith.

12. Neutron guide tube according to claim 11, wherein the support rod (75) comprises:

- an inner side (72) facing the outer side (13) of the asymmetric rod (15),
- an outer side (73) opposite its inner side (72),
- an end side (86) connecting its inner side (72) with its outer side (73), and
- a concave side (80) connecting its inner side (72) with its outer side (73) opposite its end side (86),

the concave side (80) of the support rod (75) having a first side (78) adjacent the inner side (72) and a second side (82) forming a shoulder recess (84) with the first side (78), wherein the angle of the shoulder recess (84) corresponds to the angle formed between the inner side (72) and the end side (86) of the support rod (75), and the dimension of the shoulder recess (84) is designed such as to receive at least partly an end side (86) of a support rod (75) of an identical multi-layered rod structure (50) when the

base side (18) of an asymmetric rod (15) of the identical multi-layered rod structure (50) is abutted against the inner side (12) of the asymmetric rod (15) in the proximity of the end side (26) of the asymmetric rod (15).

13. Method for forming a multi-layered asymmetric rod structure, **characterised in:**

- placing an asymmetric rod (15) according to any of the claims 1 to 4 onto a vacuum table surface (58) with its inner side (12) against the surface (58), the asymmetric rod (15) having a first thickness
- affixing the asymmetric rod (15) to the surface (58) by vacuum suction,
- applying a support rod (75) on the outer side (13) of the asymmetric rod (15), the support rod (75) having a second thickness being greater than the first thickness.

14. Method according to claim 13, **characterised in that** the support rod (75) comprises:

- an inner side (72) facing the outer side (13) of the asymmetric rod (15),
- an outer side (73) opposite its inner side (72),
- an end side (86) connecting its inner side (72) with its outer side (73), and
- a concave side (80) connecting its inner side (72) with its outer side (73) opposite its end side (86), the concave side (80) of the support rod (75) having a first side (78) adjacent the inner side (72) and a second side (82) forming a shoulder recess (84) with the first side (78), wherein the angle of the shoulder recess (84) corresponds to the angle formed between the inner side (72) and the end side (26) of the support rod (75),

the method further comprising the steps of:

- providing a first spacer (56a) and placing the asymmetric rod (15) onto the vacuum table surface (58) such as to abut the first spacer (56a) with its base side (18), and
- providing a second spacer (56b) and placing the asymmetric rod (15) onto the vacuum table surface (58) such as to abut the second spacer (56b) with the first side (78) of its concave side (20)

wherein the first and the second spacers (56a, 56b) are arranged at such a distance from each other that the resulting multi-layered asymmetric rod structure (50) is dimensioned such that:

- when an end side (26) of an identical asym-

metric rod (15) of an identical multi-layered rod structure (50) is at least partly received within the shoulder recess (24) of the asymmetric rod (15) then the end side (86) of the support rod (75) is at least partly received within a shoulder recess (84) of a support rod (75) of the identical multi-layered rod structure (50) and

● when the end side (26) of the asymmetric rod (15) is at least partly received within a shoulder recess (24) of the asymmetric rod (15) of the identical multi-layered rod structure (50) then an end side (86) of the support rod (75) of the identical multi-layered rod structure (50) is at least partly received within the shoulder recess (84) of the support rod (75).

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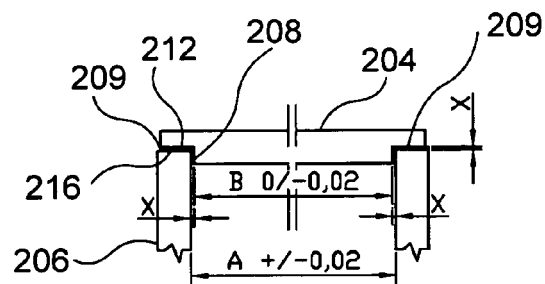
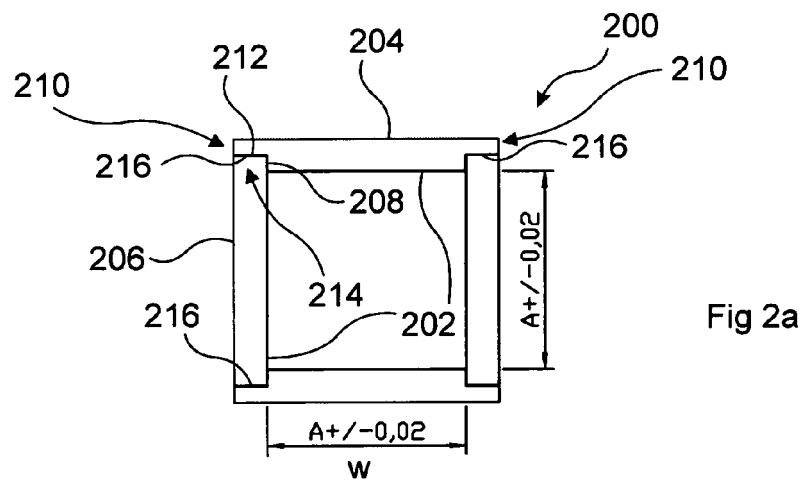
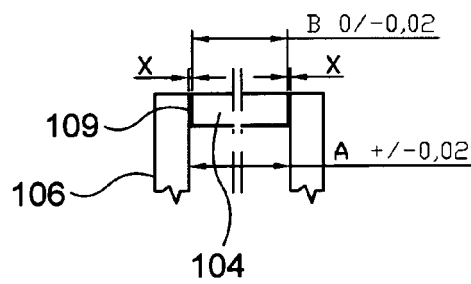
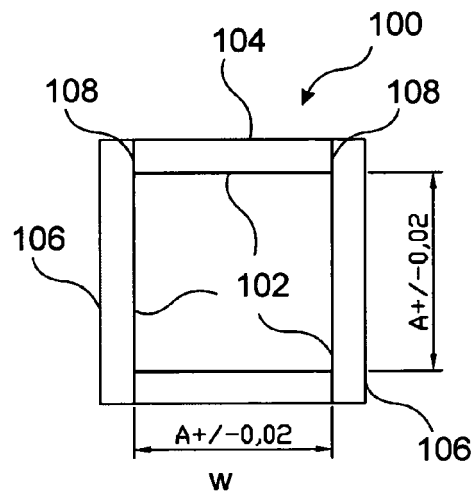
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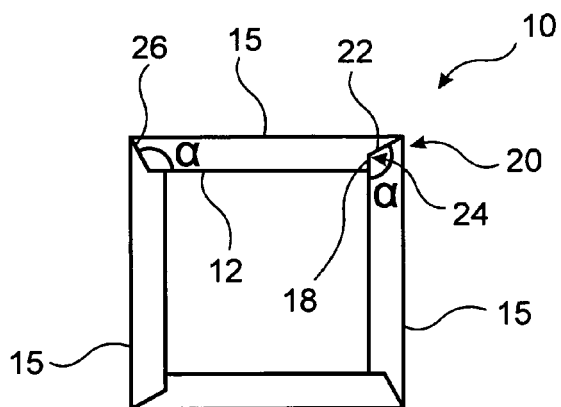
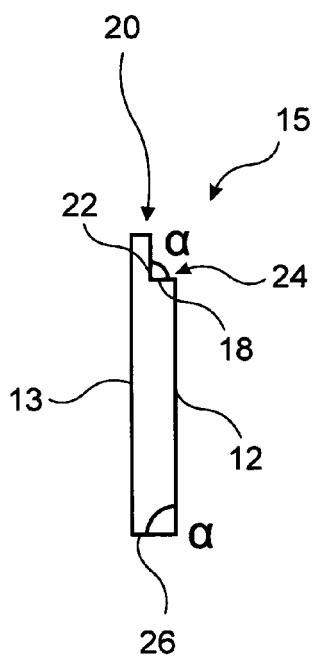
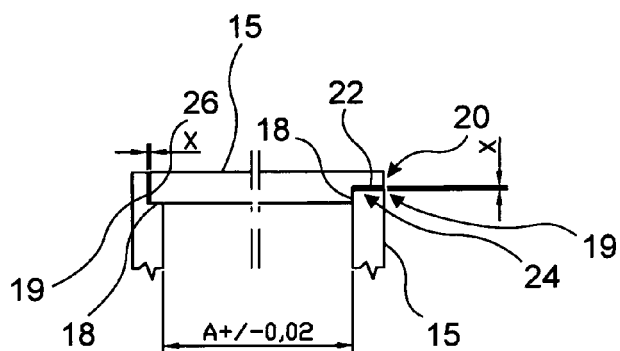
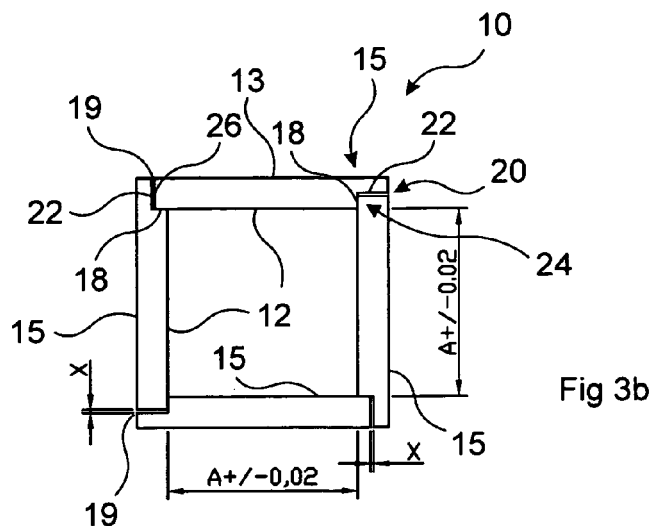
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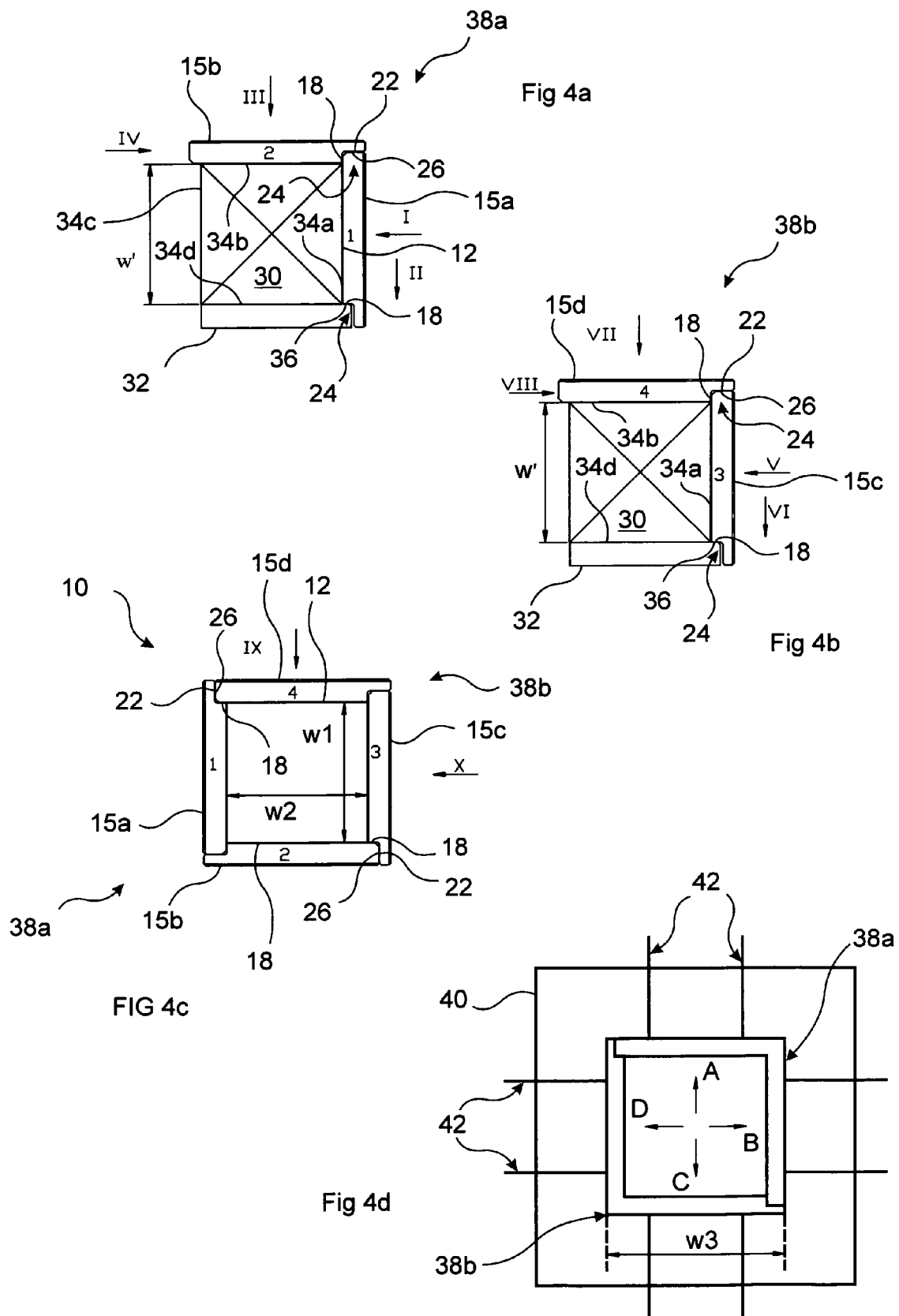
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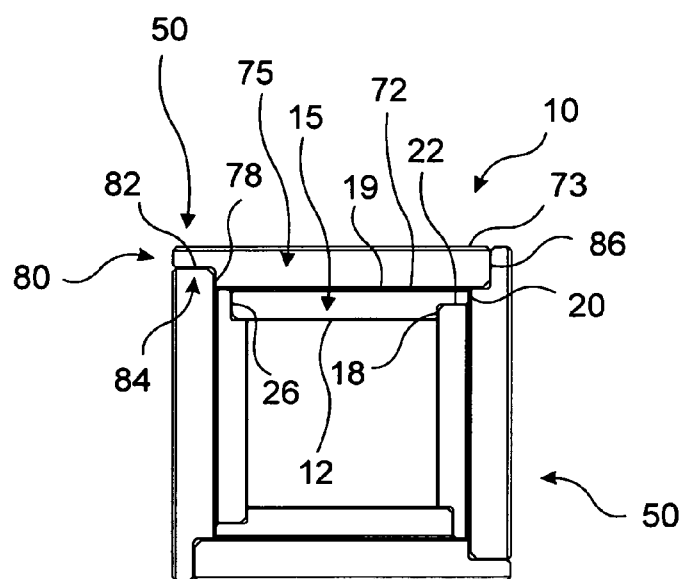


Fig 5a

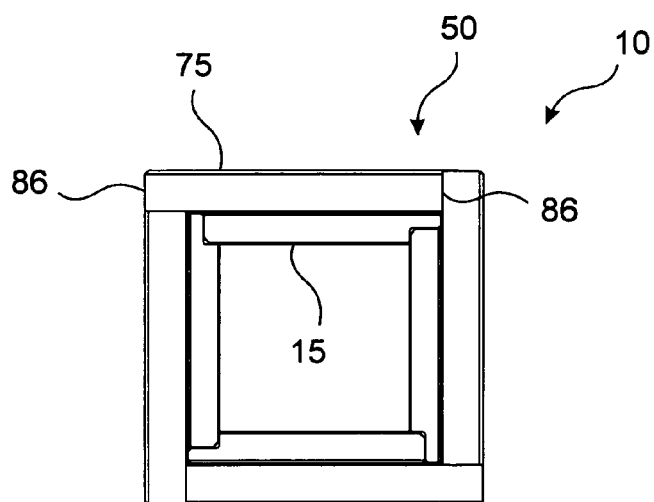
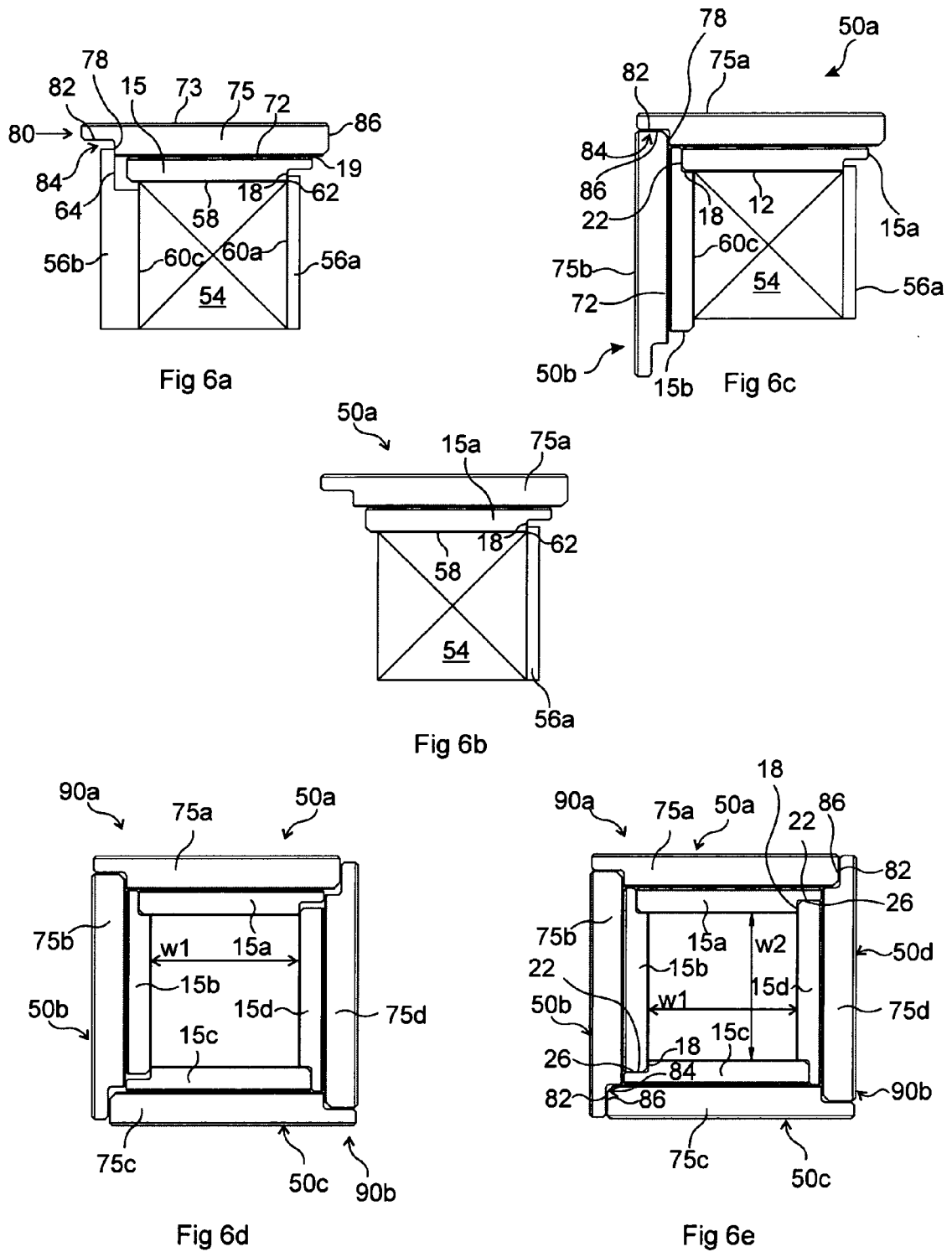


Fig 5b



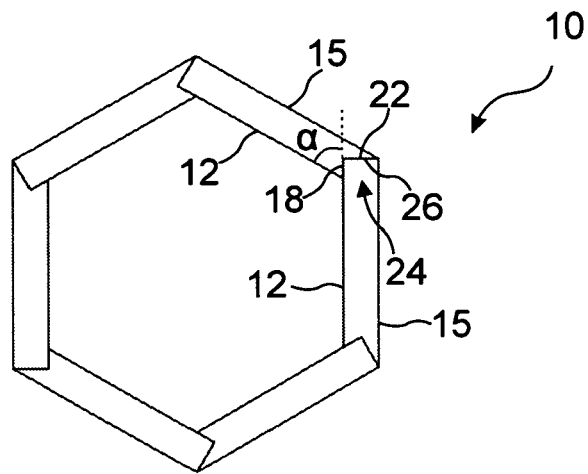


Fig 7a

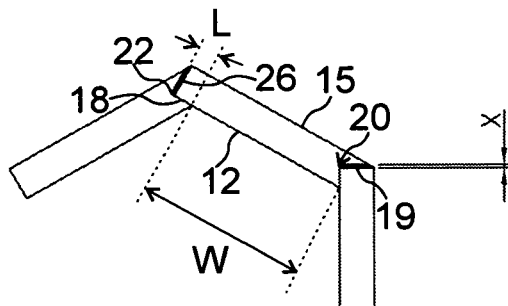


Fig 7b

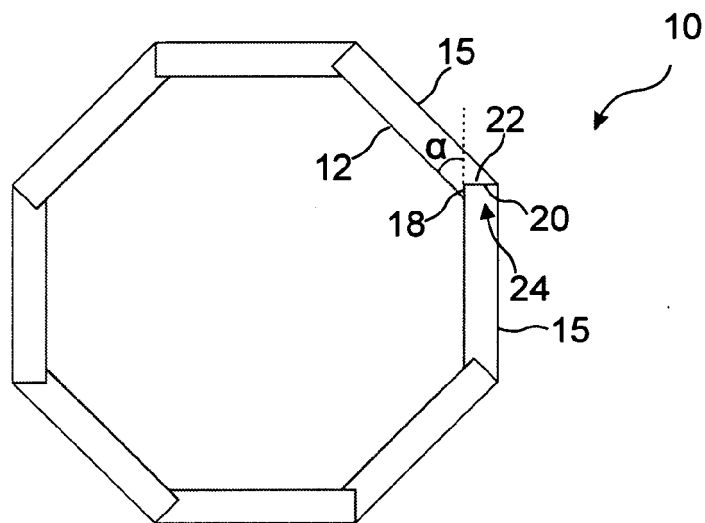


Fig 8a

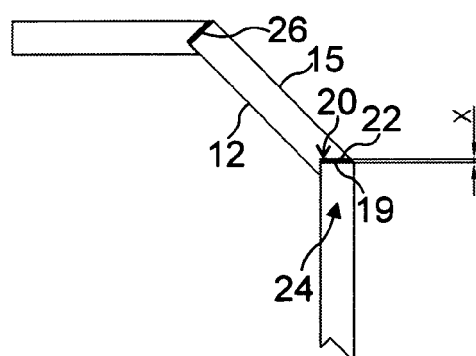


Fig 8b



EUROPEAN SEARCH REPORT

Application Number
EP 11 46 2002

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 5 949 840 A (GREENE GEOFFREY L [US]) 7 September 1999 (1999-09-07) * column 1, lines 32-39 * * column 2, lines 40-51; figure 1 * -----	1-4	INV. G21K1/06
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			G21K
The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 15 June 2011	Examiner Angloher, Godehard
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	

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15-06-2011

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