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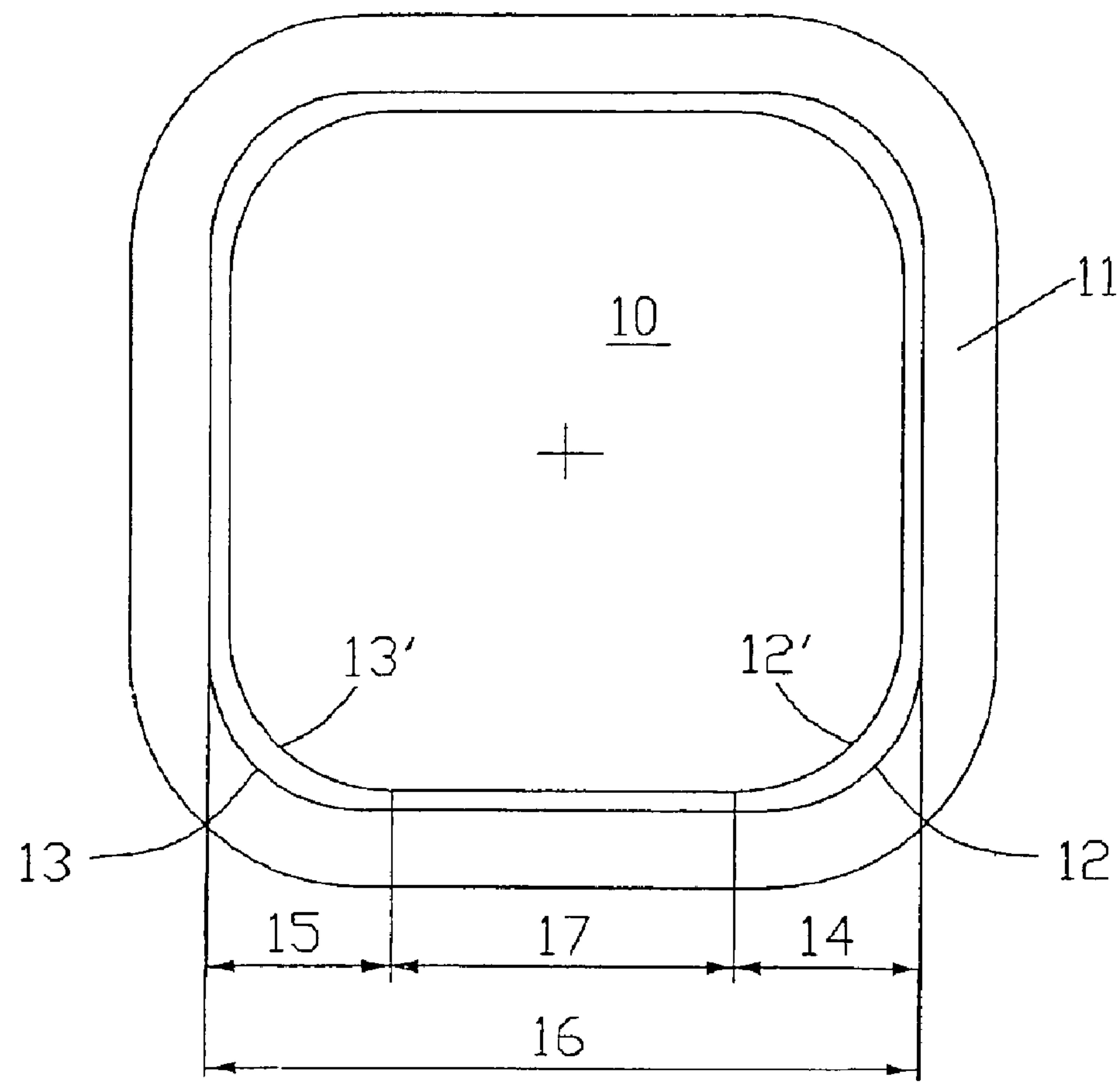
(54) Titre : INSTALLATION DE COULEE CONTINUE D'ACIER POUR FORMATS DE BILLETTE ET DE BLOOM
(54) Title: CONTINUOUS STEEL CASTING INSTALLATION FOR BILLET AND BLOOM FORMATS



(57) Abrégé/Abstract:
The invention relates to a continuous steel casting installation for billet and bloom formats that have a substantially rectangular cross-section. The aim of the invention is to improve the strand structure in the corner areas, to avoid rhomboidity, cracks and

(57) Abrégé(suite)/Abstract(continued):
dimensional imperfections of the strand cross-section and to achieve a high throughput capacity per strand while reducing investment and running costs. For this purpose, the fillets of the groove curvatures (12, 12', 13, 13') in the die cavity amount to at least 10 %, preferably 15 % or more of the length of the side (16) of the strand cross-section. The degree of curvature 1/R of the groove curvatures (12, 12', 13, 13') decreases in the direction of the strand at least along a partial length of the entire casting die, thereby allowing to control a targeted gap elimination between the casting shell and the casting die wall or a targeted casting shell shaping in the area of the groove curvature. The continuous casting installation, directly downstream of the casting die, is provided with a strand support-free secondary cooling zone or a supporting guide in the secondary cooling zone that is reduced in its supporting width and/or supporting length.

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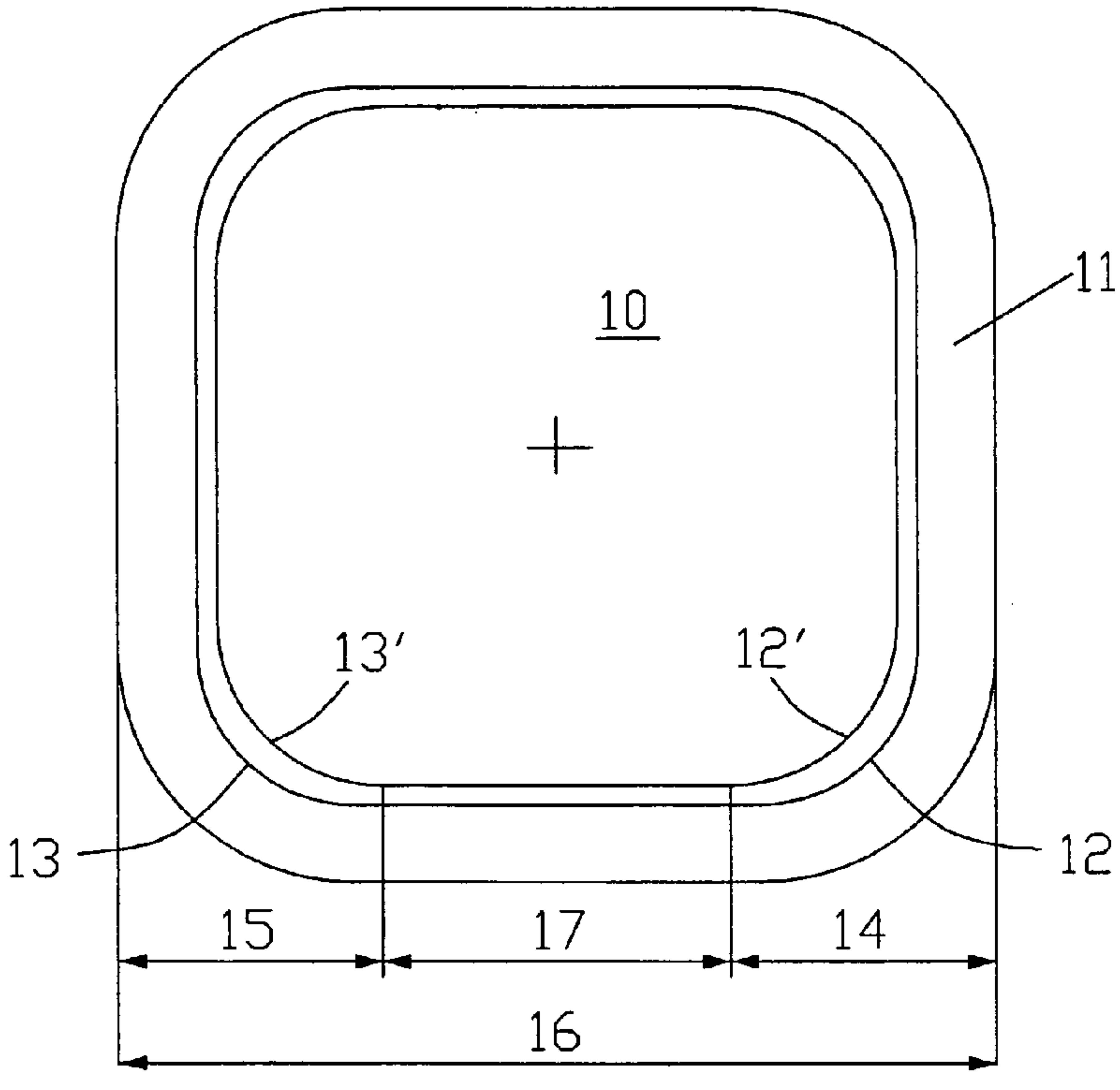
(54) Title: CONTINUOUS STEEL CASTING INSTALLATION FOR BILLET AND BLOOM FORMATS

(54) Bezeichnung: STAHLSTRANGGIESSANLAGE FÜR KNÜPPEL- UND VORBLOCKFORMATE



(57) Abstract: The invention relates to a continuous steel casting installation for billet and bloom formats that have a substantially rectangular cross-section. The aim of the invention is to improve the strand structure in the corner areas, to avoid rhomboidity, cracks and dimensional imperfections of the strand cross-section and to achieve a high throughput capacity per strand while reducing investment and running costs. For this purpose, the fillets of the groove curvatures (12, 12', 13, 13') in the die cavity amount to at least 10 %, preferably 15 % or more of the length of the side (16) of the strand cross-section. The degree of curvature 1/R of the groove curvatures (12, 12', 13, 13') decreases in the direction of the strand at least along a partial length of the entire casting die, thereby allowing to control a targeted gap elimination between the casting shell and the casting die wall or a targeted casting shell shaping in the area of the groove curvature. The continuous casting installation, directly downstream of the casting die, is provided with a strand support-free secondary cooling zone or a supporting guide in the secondary cooling zone that is reduced in its supporting width and/or supporting length.

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Zur Erklärung der Zweibuchstaben-Codes und der anderen Abkürzungen wird auf die Erklärungen ("Guidance Notes on Codes and Abbreviations") am Anfang jeder regulären Ausgabe der PCT-Gazette verwiesen.

(57) Zusammenfassung: Die Erfindung bezieht sich auf eine Stahlstranggiessanlage für Knüppel- und Vorblockformate mit im wesentlichen rechteckigem Strangquerschnitt. Um das Stranggefüge insbesondere in den Eckbereichen zu verbessern, Spiesskantigkeit, Risse und schädliche Massabweichungen des Strangquerschnittes auszuschalten und um hohe Durchsatzleistungen je Strang bei niedrigen Investitions- und Betriebskosten zu erreichen, sollen die Ausrundungen der Hohlkehlbogen (12, 12', 13, 13') im Formhohlraum mindestens 10 %, vorzugsweise 15 % oder mehr der Seitenlänge (16) des Strangquerschnittes betragen. Im weiteren soll sich in Stranglaufrichtung mindestens entlang einer Teillänge der gesamten Kokillenlänge der Krümmungsgrad 1/R des Hohlkehibogens (12, 12', 13, 13') verkleinern. Dadurch soll eine gezielte Spaltaufhebung zwischen der Strangschale und der Kokillenwand bzw. eine gezielte Strangschalenumformung im Bereich des Hohlkehlbogens steuerbar sein. Die Stranggiessanlage soll im weiteren unmittelbar an die Kokille anschliessend eine strangabstützungsfreie Sekundärkühlzone oder eine in ihrer Stützbreite und/oder Stützlänge reduzierte Stützführung in der Sekundärkühlzone aufweisen.

CONTINUOUS STEEL CASTING INSTALLATION FOR BILLET AND BLOOM FORMATS

The invention relates to a continuous steel casting plant for billet and bloom formats.

Long continuous casting products are cast predominantly in tubular permanent moulds with a rectangular, in particular with an approximately square or round, cross-section. The billet and bloom slabs are then further processed by rolling or forging.

For producing continuous casting products with good surface and texture quality, in particular billet and bloom slabs, a uniform heat transition along the circumferential line of the slab cross-section between the slab being formed and the wall of the die cavity is of crucial importance. Many proposals are known for designing the geometry of the die cavity, in particular in the areas of the corner fillets of the die cavity, in such a way that no damaging air gaps arise between the slab shell being formed and the wall of the permanent mould, causing an uneven heat transition along a circumferential line of the slab cross-section and solidification defects and fractures.

Corners of the die cavity of tubular permanent moulds are rounded by fillets. The larger the configuration of the fillets in the die cavity of the permanent mould, the more difficult it is to achieve a uniform cooling between a slab shell being formed and the walls of the permanent mould, in particular over the circumference of the die cavity. The incipient solidification of the slab just below the bath level in the permanent mould proceeds differently on straight sections of the circumference of the die cavity from the fillet areas. The heat flow on the straight or substantially straight sections is quasi one-dimensional and follows the law of heat transmission through a flat wall. In contrast to this, the heat flow in the rounded corner areas is two-dimensional and it follows the law of heat transmission through a curved wall.

The resulting slab shell is normally thicker in the corner areas at the start of solidification below the bath level than on the straight surfaces and begins to shrink sooner and more intensely. The result of this is that even after about 2 seconds the slab shell lifts up irregularly from the wall of the permanent mould in the corner areas and air gaps form, which drastically impair the heat transmission. Not only does this impairment of the heat transmission delay the further growth of the shell, but it can even cause a re-fusion of already solidified inner layers of the slab shell. This fluctuating pattern of the heat flow - cooling and re-heating - leads to slab defects such as surface and internal longitudinal cracks at the edges or in areas near the edges, and also to mould defects such as rhomboidity, indents, etc. A re-fusion of the slab shell or larger longitudinal cracks can also lead to fractures.

The larger the fillets are dimensioned compared with the side length of the slab cross-section, in particular if the fillet radii amount to 10% or more of the side length of the die cavity cross-section, the more frequently such slab defects occur. This is one reason why the fillet radii are usually limited to 5 to 8 mm, although larger roundings at the slab edges would be more favourable for the subsequent rolling.

During casting at high casting speeds the dwell time of the cast slab in the permanent die cavity is reduced and the slab shell has overall less time to grow in thickness. Depending on the slab format chosen it is therefore necessary to support the slab shell with support rollers immediately after it leaves the permanent mould in order to avoid bulging of the slab shell or even fractures. Support roller stands of this kind directly beneath the permanent mould are exposed to great wear and can be restored to service after a fracture only with great expenditure of time and cost.

A permanent mould for continuous casting of billet and bloom slabs is known from JP-A-11 151555. In order to avoid rhomboid deformation of the slab cross-section when casting rectangular slabs and in order additionally to increase the casting speed, the fillets are specially shaped at the four corners of the die cavity as so-called corner cooling parts. On the pouring-in side the corner cooling parts are constructed as circular recesses in the wall of the permanent mould, which become smaller in the moving direction of the slab and re-form to a corner fillet towards the exit of the permanent mould. The degree of curvature of the circular recesses increases in the moving direction of the slab towards the exit of the permanent mould. This shaping is intended to ensure uninterrupted contact between the corner area of the slab shell and the specially shaped corner cooling parts of the permanent mould.

From JP-A-09 262641 a tubular permanent mould is known for the continuous casting of rectangular slabs, which in order to avoid longitudinal cracks at the slab edges and rhombus-shaped slab cross-sections in the die cavity, employs fillets with different corner radii at the upper and lower end of the permanent mould. The upper corner radius at the inlet side of the permanent mould is chosen to be smaller than the corner radius at the outlet side of the permanent mould. This measure is said to avoid an air gap between the slab shell and the wall of the permanent mould. No details are given or implied regarding the size of the fillets in relation to the side length of the slab cross-section and the absolute size of the slab cross-section, nor is any information given or implied concerning simplifying the support guidance adjoining the permanent mould.

The object of the invention is to create a continuous steel casting plant for billet and bloom formats preferably with a substantially rectangular slab cross-section, or one similar to rectangular, which achieves a combination of the following partial aims. It should ensure on the one hand a high casting capacity with as small a number of slabs as possible, and thereby minimum investment and maintenance costs, and on the other hand an improved slab quality. The improvement in the slab quality should in particular prevent slab defects in the corner areas, such as cracks, solidification defects and casting powder inclusions in the slab shell, but also deviations in dimensions, such as rhomboidity, bulges and indents. The continuous casting plant according to the invention should furthermore reduce investment and maintenance costs for support guide stands and additionally improve the profitability and slab quality when permanent mould stirring devices are used.

According to a first aspect of the present invention, there is provided a continuous steel casting plant for billet and bloom formats, with a substantially rectangular cross-section, wherein circumferential lines of a die cavity cross-section of a permanent mould are provided in the corners with fillet arcs and a secondary cooling device with spray nozzles is arranged adjoining the permanent mould, and a liquid steel can be fed substantially vertically into the die cavity, characterised in that rounded-out portions of the fillet arcs account for 20% or more of the side length of a slab cross-section, the rounded-out portions have a curvature course that increases to a maximum degree of curvature 1/R, R being a radius of curvature, and then decreases and that in the moving direction of the slab along the die cavity the maximum degree of curvature 1/R of the fillet arc is reduced continuously or discontinuously in such a way that a slab shell deforms in the region of the fillet arcs, and that the permanent mould with side lengths of the slab cross-section up to about 150 mm adjoins a secondary cooling zone without guide support, and with side lengths of the slab cross-section greater than about 150 mm, the secondary cooling zone adjoining the permanent mould is equipped with a support guide, a support width of which is restricted to roller lengths that correspond substantially to straight sections between the fillet arcs and the supporting length of which in the moving direction of the slab is reduced in the secondary cooling zone.

Other preferred aspects, embodiments, variants and/or resulting advantages of the present invention will be briefly described hereinbelow.

With the continuous casting plant according to the invention it is possible to cast larger billet and bloom formats and preform slabs at higher casting speeds and without a support guide, or with a guide of reduced support width and/or support length, immediately below the permanent mould. At a preset production capacity the number of slabs can thereby be reduced and investment costs saved. At the same time the maintenance costs of the plant are reduced both because of the smaller number of slabs and because of the omission or reduction of support guides for the cast slabs. By enlarging the edge roundings of the cast slabs critical stresses in the remaining flat slab shell, produced by the ferrostatic pressure of the liquid core, can be considerably reduced when the slab emerges from the permanent mould. A shortening of the straight sections of the circumference of the die cavity located between the rounded-out corners by 10%, for example, reduces the flexural stress in these sections, likely to cause a bulge, by approximately 20%.

Besides these economic advantages, the slab quality is additionally improved in a great many respects. By controlling a selective elimination of the gap between the slab shell and the wall of the permanent mould or selective reshaping of the slab shell in the area of the fillet arc, the growth of the slab shell is evened out over the circumference of the slab and over predetermined parts of the length of the permanent mould, thereby improving the slab structure and preventing slab defects such as cracks, etc., in the edge areas. Additionally, geometric slab defects such as rhomboidity, bulges, etc., can be reduced or eliminated. However, enlargement of the rounded-out corners also influences the flow ratios in the region of the bath level. If casting powder is used to cover the bath level, with increasing enlargement of the rounded-out corners an evening-out of the conditions for the re-fusion of the casting powder can be achieved on the entire circumference of the meniscus. This advantage is reinforced further in permanent moulds with stirring devices. Slab defects such as casting powder and slag inclusions, in particular in the edge areas, but also slab surface defects, can be reduced by evening-out the lubricating effect of the casting powder. Additional quality advantages are achievable by adapting the size of the rounded edges of the slab to the requirements of the subsequent rolling or forging operations.

The boundary between a support guide in the secondary cooling zone without a slab support and with a slab support of reduced support width and support length is determined by numerous parameters, in particular by the bulging behaviour of a cast slab. Besides the main parameters of format size and overall length of the rounded-out portions of the two fillet arcs associated with a slab side or the length of a straight section between the two fillet arcs associated with a slab side, the casting speed, length of the die cavity, steel temperature and steel analysis, etc. are also decisive. For tests to determine the boundary between a secondary cooling zone without support and a reduced support guide in the secondary cooling zone the following guideline values are proposed. With slab formats which are smaller than approximately 150 x 150 mm^2 and with an overall length of the two rounded-out portions of a slab side of approximately 70% or more of the dimension of the slab side, it is usually possible to cast without support. With slab formats which are larger than approximately 150 x 150 mm^2 and have a straight section between the two rounded-out portions of approximately 30% or more of the dimension of the slab side, a support guide of reduced support width and support length can be arranged in the secondary cooling zone. By means of the teaching according to the invention, on the one hand by enlarging the rounded-out portions, for example to 100% of the side length of the slab cross-section, and on the other hand by changing the degrees of curvature of successive fillet arcs in the moving direction of the slab, the bulging behaviour of the slab after leaving the permanent mould can be influenced in such a way that, compared with the prior art, considerably larger slab formats can be produced without a support guide or with a reduced support guide, even at higher casting speeds.

Fillet arcs in the circumferential line of the cross-section of the die cavity can be formed from circular lines, composed circular lines, etc. Additional advantages are achievable if the fillet arcs do not adjoin the straight sections of the circumferential line tangentially or in a punctiform manner. According to a further proposal, a curvature course along the fillet arc can be chosen which increases to a maximum degree of curvature 1/R and then decreases. The maximum degree of curvature 1/R in successive fillet arcs in the moving direction of the slab can reduce continuously or discontinuously. For producing the die cavity by means of NC-controlled cutting machine tools it is additionally advantageous if the circumferential lines of the slab cross-section have fillet arcs with curvature courses which follow a mathematical function and increase to a maximum degree of curvature 1/R and then decrease, such as for example mathematical functions such as a super circle or super ellipse.

With fillet arcs with fillet dimensions of 25% or more of the side length of the slab cross-section additional advantages can be achieved if the substantially rectangular die cavity cross-section consists of four bow lines, each enclosing approximately a quarter of the circumference of the cross-section, and the bow lines follow a mathematical function. The mathematical function

$$\left(\frac{|x|}{A}\right)^n + \left(\frac{|y|}{B}\right)^n = 1$$

fulfils this condition for example if an exponent "n" of between 3 and 50, preferably between 4 and 10, is chosen. A and B are the dimensions of the bow line.

The circumferential line of the slab cross-section can also be composed of several bow lines, the fillet arcs having a curvature course which follows a mathematical function, e.g. $|X|^n + |Y|^n = |R|^n$. Sections of the circumferential line arranged between the fillet arcs may have slightly curved bow lines, as described in EP patent specification 0 498 296. Seen in the moving direction of the slab, the degrees of curvature 1/R of both the fillet arcs and the relatively stretched bow lines located between them can decrease in such a way that at least on a partial length of the permanent mould the slab shell is slightly deformed, i.e. stretched, on traversing the entire circumference.

Depending on the casting format chosen and envisaged maximum casting speed, an optimum length for the permanent mould can be determined. Casting formats between 120 x 120 mm^2 and 160 x 160 mm^2 can optimally be cast at high casting speeds with a length of the permanent mould of approximately 1000 mm, omitting a slab support.

Large rounded corners in the die cavity create advantages not only in casting with a casting powder covering of the bath level. With increasing size of the rounded corner it is also possible to increase the stirring effect in the bath level and in the liquid sump with constant electrical stirrer power. This possibility of improving the stirring power by the geometric shaping of the die cavity creates additional structural freedoms in installing stirrers in the billet and bloom permanent moulds.

Embodiments of the invention are explained below using figures.

Fig. 1 shows a vertical section through part of a continuous casting plant.

Fig. 2 shows a plan view of a copper pipe of a bloom permanent mould.

Fig. 3 shows a plan view of a corner construction of a die cavity with fillet arcs.

Fig. 4 shows a plan view of a copper pipe with circumferential lines of the die cavity cross-section.

Fig. 5 shows a plan view of a copper pipe with circumferential lines of a further die cavity cross-section.

Fig. 6 shows a horizontal section through a half slab in the secondary cooling zone.

Fig. 7 shows a horizontal section through another example of a half slab in the secondary cooling zone.

Fig. 8 shows a horizontal section through a half preform slab in the secondary cooling zone.

In Fig. 1 liquid steel flows vertically into a permanent mould 4 through a discharge nozzle 2 of an intermediate vessel 3. The permanent mould 4 has a rectangular die cavity for a billet cross-section of for example 120 x 120 mm^2. A partially solidified slab is denoted by 5, a slab shell is denoted by 6 and a liquid core is denoted by 7. A height-adjustable electromagnetic stirring device 8 is illustrated schematically outside the permanent mould 4. It can also be arranged inside the permanent mould 4, for example in the water jacket. The stirring device 8 produces a horizontally circulating rotary movement in the region of the bath level and in the liquid sump. Immediately adjoining the permanent mould 4 is a first secondary cooling zone, without slab support and provided with spray nozzles 9.

In Fig. 2 a die cavity, denoted by 10, of a permanent mould pipe 11 is provided with fillet arcs 12, 12', 13, 13' in the corner areas. The rounded-out portion 14, 15 of the fillet arcs 12, 12', 13, 13' amounts in this example to approximately 20% each of a side length 16 of the slab cross-section. The degree of curvature 1/R of the pouring-in side fillet arc 12, 13 is different from the degree of curvature 1/R of the fillet arc 12', 13' at the exit of the permanent mould. At least along a partial length of the overall length of the permanent mould the degree of curvature 1/R of the fillet arc 12, 13 of for example 1/R = 0.05 decreases to a degree of curvature 1/R of the fillet arc 12′, 13′ of for example 1/R = 0.046. By choosing the size of the decrease in the degree of curvature, an elimination of the gap between the forming slab shell and the wall of the die cavity or selective deformation of the slab shell and therefore the heat flow between the slab shell and the die cavity wall can be selectively controlled. Besides the increased and, seen over the circumference, evened-out heat flow, the size of the rounded-out portions 14, 15 also contributes to the fact that, in spite of the high casting speed, the partially solidified slab can be guided through the secondary cooling zone immediately after leaving the die cavity without or with reduced slab support. With a preset format, by enlarging the rounded-out portions 14, 15 a straight section 17 between the rounded-out portions 14, 15 can be selectively decreased in such a way that damaging bulges in the slab shell can be avoided in spite of the secondary cooling zone having no slab support. With large formats or if for technical reasons the size of the rounded-out portions is limited, a slab support of reduced support width can be provided.

In Fig. 3 a corner 19 of a die cavity is illustrated on an enlarged scale. Five fillet arcs 23 - 23′′′′ represent the geometry of the corner construction by way of vertical curves. The contact points of the fillet arcs 23 - 23′′′′ with the straight sections 24 - 24′′′′ of circumferential lines of the cross-section of the permanent mould can be chosen along the lines R, R_4 or R_1, R_4. The distances 25 - 25′′′ in this example show a constant conicity along the straight side walls. The fillet arcs 23 - 23′′′′ are defined by a mathematical curve function $|X|^n + |Y|^n = |R|^n$, wherein, by choosing the exponent "n", different degrees of curvature can be fixed. The degree of curvature of the fillet arcs 23 - 23''' is different along the arc. It expands to a maximum degree of curvature at the point 30 - 30''' and then decreases. In the moving direction of the slab the maximum degree of curvature decreases from fillet arc to fillet arc. The fillet arc 23'''' is in this example a circular arc. The exponents of the fillet arcs are in this example chosen as follows:

fillet arc 23	exponent "n" = 4.0
fillet arc 23'	exponent "n" = 3.5
fillet arc 23''	exponent "n" = 3.0
fillet arc 23'''	exponent "n" = 2.5
fillet arc 23''''	exponent "n" = 2.0 (circular arc)

By the selection of the exponents the degree of curvature of the successive fillet arcs 23 - 23'''' in the moving direction of the slab is changed or decreased in such a way that an elimination of the gap between the slab shell and the wall of the permanent mould or a selective deformation of the slab shell in the area of the fillet arcs 23, 23'''' can be selectively controlled. This control of the elimination of the gap or slight reshaping of the slab shell allows the desired heat transmission to be controlled, and in particular an evening-out of the desired heat transmission along the fillet arcs is achieved in all corner areas of the slab when it passes through the die cavity.

In Fig. 4 only three successive circumferential lines in the moving direction of the slab with fillet arcs 51 - 51'' of a square die cavity 50 are illustrated, to give a clear view. The circumferential lines are each composed of four fillet arcs 51 - 51'', enclosing an angle of 90°.

For calculating the circumferential lines 51 - 51'' the following mathematical function was used: $|X|^n + |Y|^n = |R-t|^n$.

The following numerical values were used as the basis of this example.

Circumferential line	Exponent n	R-t	t
51	4	70	0
51'	5	66.5	3.5
51''	4.5	65	5

To achieve a deformation of the slab shell, in particular along the substantially straight side walls between the corner areas (convex technology) along a pouring-in side upper partial length of the permanent mould, an exponent "n" of 4 is chosen at bow line 51 and of 5 at bow line 51', following in the moving direction of the slab. In a lower partial length of the permanent mould the exponent 5 of the bow line 51' is decreased to 4.5 at the bow line 51'' and therefore an optimum corner cooling is achieved.

This enlargement of the exponent "n" from 4 to 5 indicates that in the upper partial length of the permanent mould a deformation of the slab shell takes place at the substantially straight side walls between the corner areas, and in the lower partial length of the permanent mould by decreasing the exponent "n" from 5 to 4.5 an optimum contact of the slab shell and possibly a slight deformation of the slab shell takes place in the corner areas of the die cavity.

Fig. 5 shows a tubular permanent mould 62 for the continuous casting of billet or bloom formats with a die cavity 63. The cross-section of the die cavity 63 is square at the exit of the permanent mould and corner areas 65 - 65''' are arranged between adjacent side walls 64 - 64'''. The fillet arcs 67, 68 are not circular lines but curves, according to the mathematical function $|X|^n + |Y|^n = |R|^n$, wherein the exponent "n" has a value between 2 and 2.5. In the upper part of the permanent mould part the side walls 64 - 64''' between the corner areas 65 - 65''' are concavely shaped on a partial length of 40% to 60% of the length of the permanent mould. On this partial length an arc height 66 decreases in the moving direction of the slab. A convex slab shell forming in the permanent mould is flattened along the upper partial length of the permanent mould. The bow line 70 may be formed by a circular line, a composed circular line or by a curve based on a mathematical function. In the lower partial length of the permanent mould the straight side walls 71 of the permanent mould are provided with a conicity of the die cavity corresponding to the shrinkage of the slab cross-section.

For simplification, all the mould cavities in Figs. 1 to 5 are provided with a straight longitudinal axis. However, the invention can also be applied to permanent moulds with a curved longitudinal axis for circular arc continuous casting plants. The configuration of the die cavity according to the invention is furthermore not restricted to tubular permanent moulds. It can also be applied to plate or block permanent moulds, etc.

In Fig. 6 half a substantially rectangular slab cross-section 60 is illustrated, with a solidified slab shell 61 and a liquid core 42. The circumferential line of the half slab cross-section 60 is composed of two partial curves 45, enclosing an angle of 90°, the shape of which corresponds to the initial cross-section of the die cavity of the permanent mould. The partial curves 45 follow the mathematical relation

$$\left(\frac{|x|}{A}\right)^n + \left(\frac{|y|}{B}\right)^n = 1$$

The length of each rounded-out portion 44 of the partial curves 45 amounts to 50%, or both rounded-out portions 44 together correspond to 100% of the dimension of the slab side 66. Arrows 48 indicate the ferrostatic pressure acting on the slab shell 61. The sum of the two rounded-out portions 44 of the partial curves 45 is greater than 70% of the dimension of the slab side 66 and a slab support in the secondary cooling zone is thus not necessary in this example.

In Fig. 7, compared with Fig. 6 the circumferential line of the half slab cross-section is composed of two circular arcs 75 with a rounded-out portion dimension 76 of 30% and straight sections 77 of 40% of the dimension of the slab side 78. The straight sections 77 between the circular arcs 75 are in this example more than 30% of the dimension of the slab side 78, and a support guide of reduced support width and support length can be arranged in the form of support rollers 79. A width of the support rollers corresponding to the length of the straight section or slightly smaller than this is usually sufficient. Arrows 79 indicate the ferrostatic pressure acting on the slab shell 71.

An example of a bloom slab in the shape of a preform section 80 for an H-steel is illustrated in Fig. 8. A die cavity for preform sections 80 also has corners 86, which are rounded out with fillet arcs 81. A slab side dimension 82 is composed of two fillet arcs 81 with rounded-out portions 83 of for example 40%, and a substantially straight section 84 of for example 20%. The ferrostatic pressure on the slab shell 86, indicated by arrows 85, generates a bulge in H-steel slabs according to the prior art, if the shaping is not arranged, as in this example, by special measures by choosing appropriate fillet arcs 81 or an appropriate support guide. In the illustrated example, by the choice of the length and geometry of the rounded-out portions 83 in the form of a super ellipse a slab shell is formed which withstands the ferrostatic pressure without support guide. With increasing slab side dimension 82, with appropriate dimensioning of the two rounded-out portions a reduced support guide in the secondary cooling zone may be sufficient.

In Figs. 6 to 8 the horizontal sections through the slabs are illustrated immediately after leaving the permanent mould. For simplification and a better view the spray nozzles arranged in a secondary cooling zone have been omitted.

WHAT IS CLAIMED IS:

1. Continuous steel casting plant for billet and bloom formats, with a substantially rectangular cross-section, wherein circumferential lines (51) of a die cavity cross-section of a permanent mould (4, 11, 62) are provided in the corners with fillet arcs (12, 13, 23, 51, 67, 68) and a secondary cooling device with spray nozzles (9) is arranged adjoining the permanent mould (4, 11, 62), and a liquid steel can be fed substantially vertically into the die cavity (10, 50, 63), characterised in that rounded-out portions (14, 15, 44, 76) of the fillet arcs (12, 13, 23, 51, 67, 68) account for 20% or more of the side length (16) of a slab cross-section, the rounded-out portions (14, 15, 44, 76) have a curvature course that increases to a maximum degree of curvature 1/R, R being a radius of curvature, and then decreases and that in the moving direction of the slab along the die cavity the maximum degree of curvature 1/R of the fillet arc (23, 51, 67, 68) is reduced continuously or discontinuously in such a way that a slab shell (61, 71) deforms in the region of the fillet arcs (12, 13, 23, 51, 67, 68), and that the permanent mould (4, 11, 62) with side lengths (16) of the slab cross-section up to about 150 mm adjoins a secondary cooling zone without guide support, and with side lengths (16) of the slab cross-section greater than about 150 mm, the secondary cooling zone adjoining the permanent mould (4, 11, 62) is equipped with a support guide, a support width of which is restricted to roller lengths that correspond substantially to straight sections (17, 84) between the fillet arcs (14, 15, 83) and the supporting length of which in the moving direction of the slab is reduced in the secondary cooling zone.

2. Continuous steel casting plant according to claim 1, characterised in that a secondary cooling zone without slab support is arranged in the case of an overall length of the rounded-out portions (14, 15, 64, 76) of the two fillet arcs (12, 13, 23, 51, 67, 68) associated with a slab side, of about 70% or more of the dimension of the slab side (16).

3. Continuous steel casting plant according to claim 1, characterised in that a support guidance, reduced as regards its support width and its support length in the moving direction of the slab, is arranged in the secondary cooling zone in the case of a length of the straight section (17) of more than about 30% of the dimension of the slab side between the two fillet arcs (12, 13, 23, 51, 67, 68) associated with a slab side.

4. Continuous steel casting plant according to one of claims 1 to 3, characterised in that the substantially rectangular die cavity cross-section consists of four fillet arcs (51), each of which encloses approximately a quarter of the circumference of the cross-section and in that the fillet arcs (51) obey the mathematical function

$$\left(\frac{|x|}{A}\right)^n + \left(\frac{|y|}{B}\right)^n = 1$$

wherein:

x is an x-coordinate value of a curvature profile,

y is a y-coordinate value of the curvature profile,

A and B are respective dimensions of a bow line, and

the value of the exponent "n" is between 3 and 50.

5. Continuous steel casting plant according to one of claims 1 to 3, characterised in that the fillet arcs (67) have curvature courses which obey the mathematical function $|X|^n + |Y|^n = |R|^n$ and in that sections of the circumferential line arranged between the fillet arcs (67) have slightly curved bow lines (70), the degree of curvature of which decreases at least on a partial length of the permanent mould in the moving direction of the slab and thereby deforms the slab shell as it passes through the partial length, wherein:

X is an x-coordinate value of a curvature profile, Y is a y-coordinate value of the curvature profile, and

n is an exponent selected to provide a degree of curvature.

6. Continuous steel casting plant according to one of claims 1 to 3, characterised in that the die cavity is provided towards an exit of the permanent mould with a casting conicity according to the mathematical formula $|X|^n + |Y|^n = |R - t|^n$, wherein:

X is an x-coordinate value of a curvature profile,

Y is a y-coordinate value of the curvature profile,

n is an exponent selected to provide a degree of curvature, and

t is a dimension for conicity.

7. Continuous steel casting plant according to any one of claims 1 to 6, characterised in that the cavity of the permanent mould (10, 50, 63) has a length of approximately 1000 mm.

8. Continuous steel casting plant according to any one of claims 1 to 7, characterised in that spray nozzles (9) are arranged immediately adjoining the permanent mould (4), which cool the slab uniformly.

9. Continuous steel casting plant according to any one of claims 1 to 8, characterised in that the permanent mould (4) is provided with electromagnetic stirring devices (8), in particular of a kind which cause the steel bath in the area of the permanent mould to execute a horizontally circulatory motion.

10. Continuous steel casting plant according to claim 4, wherein n is between 4 and 10.

Fig.1

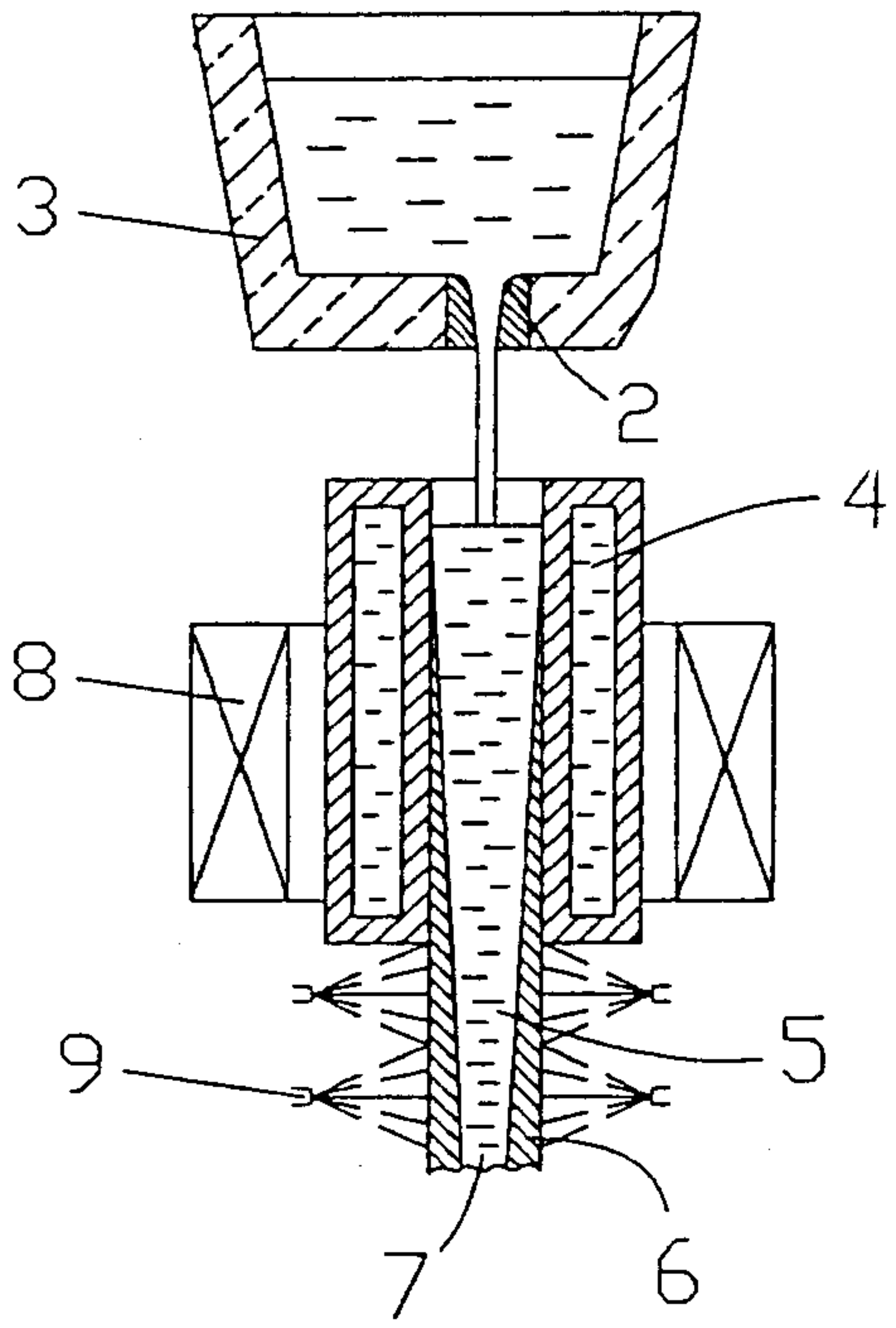
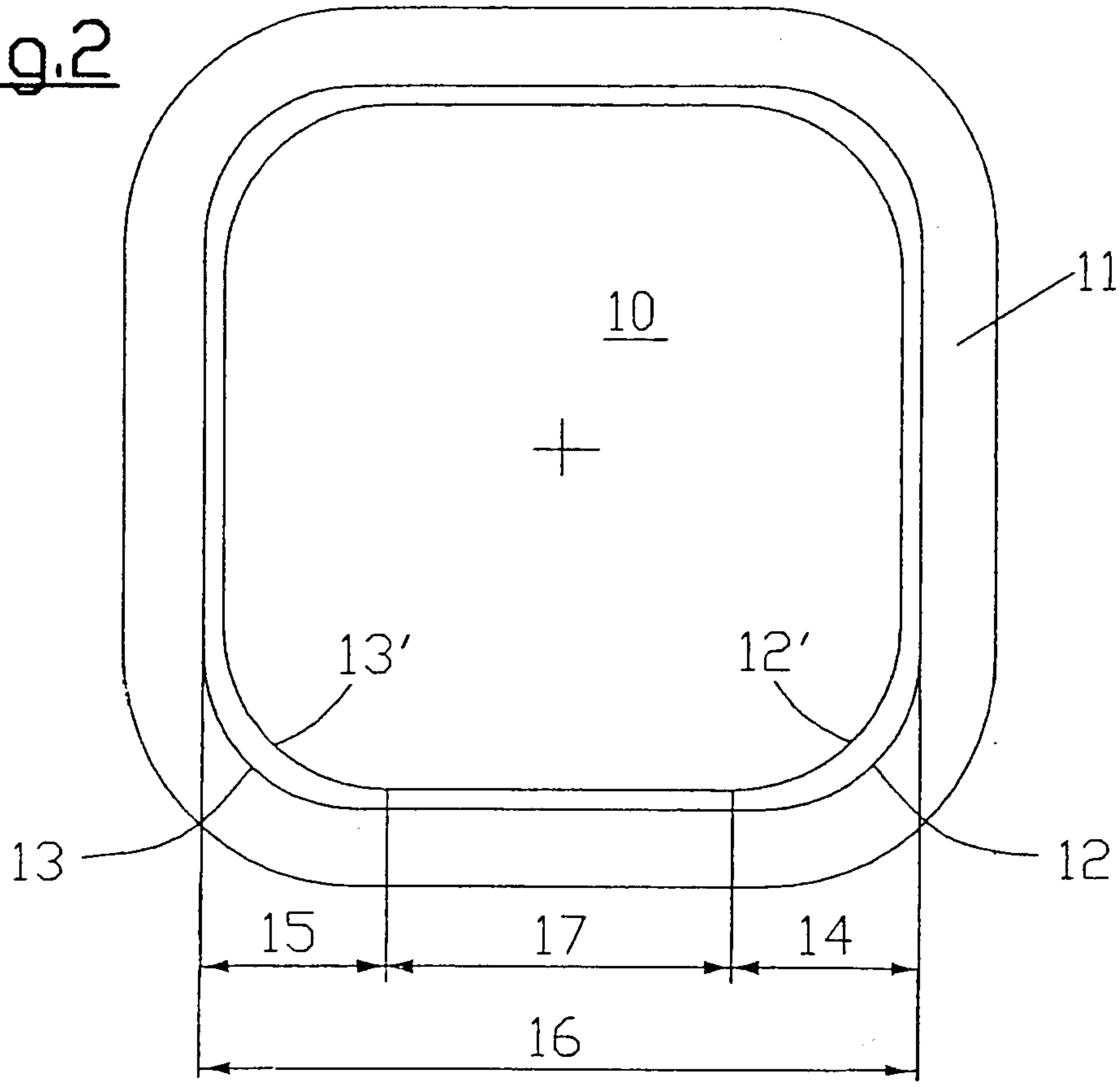


Fig.2



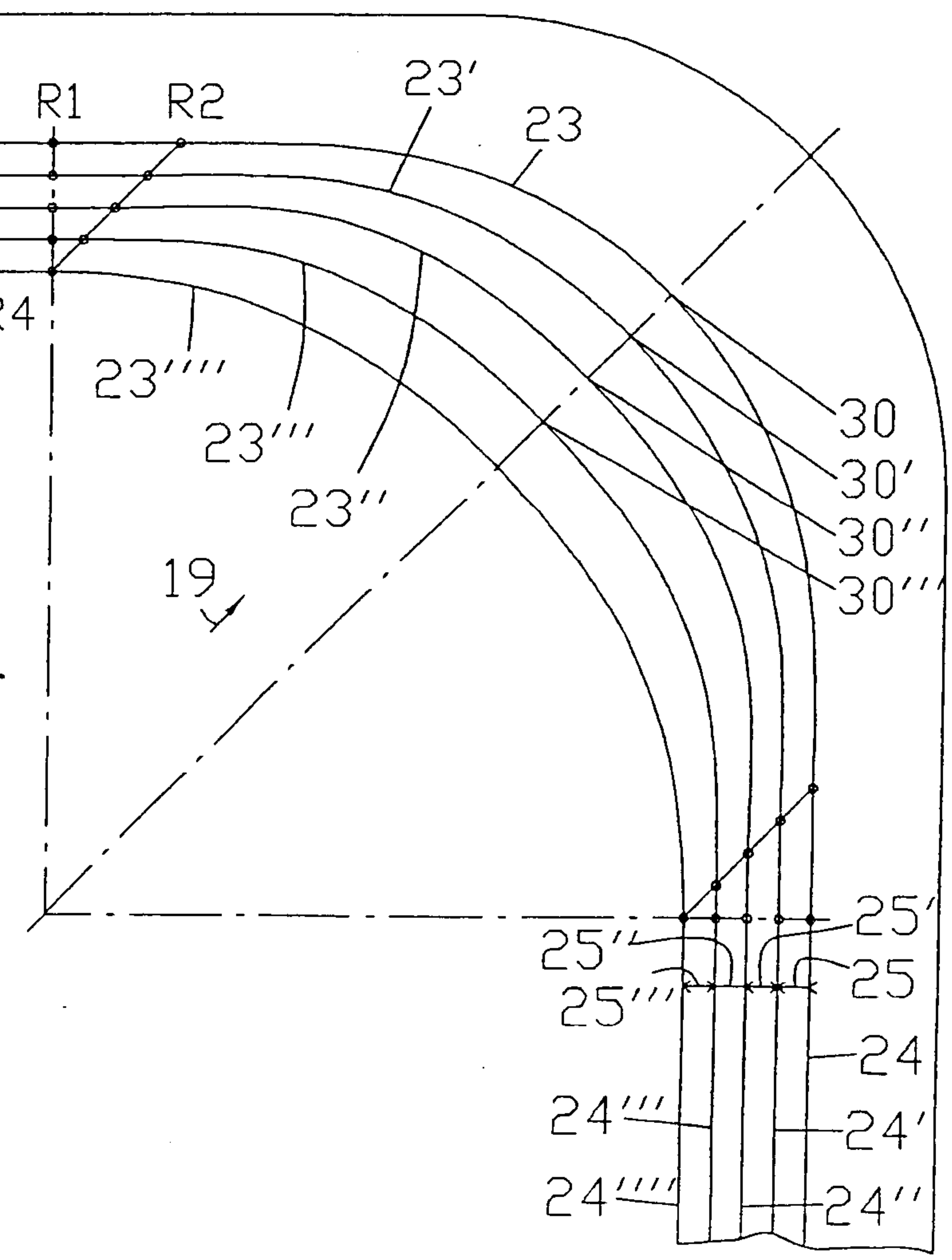


Fig.3

Fig.4

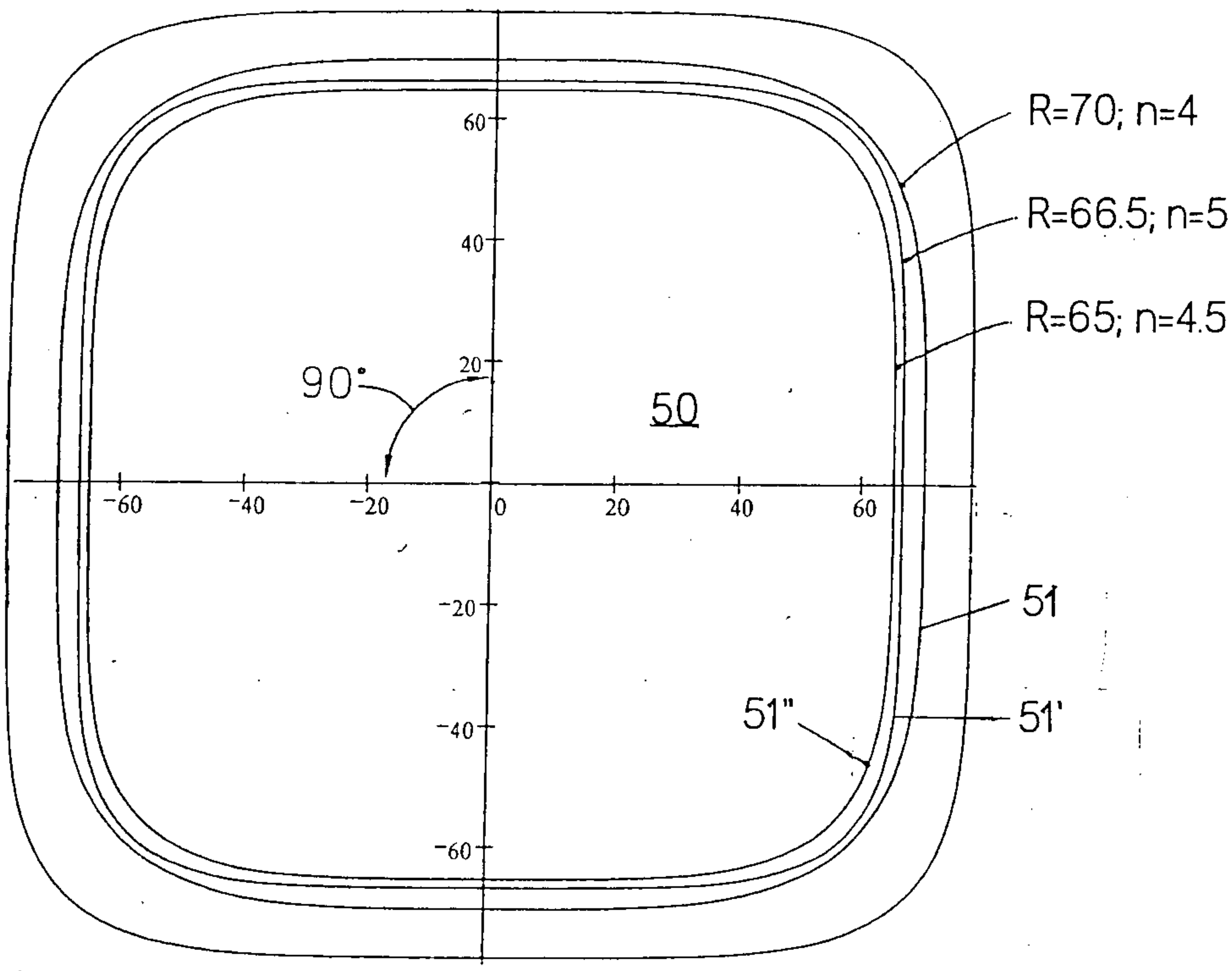
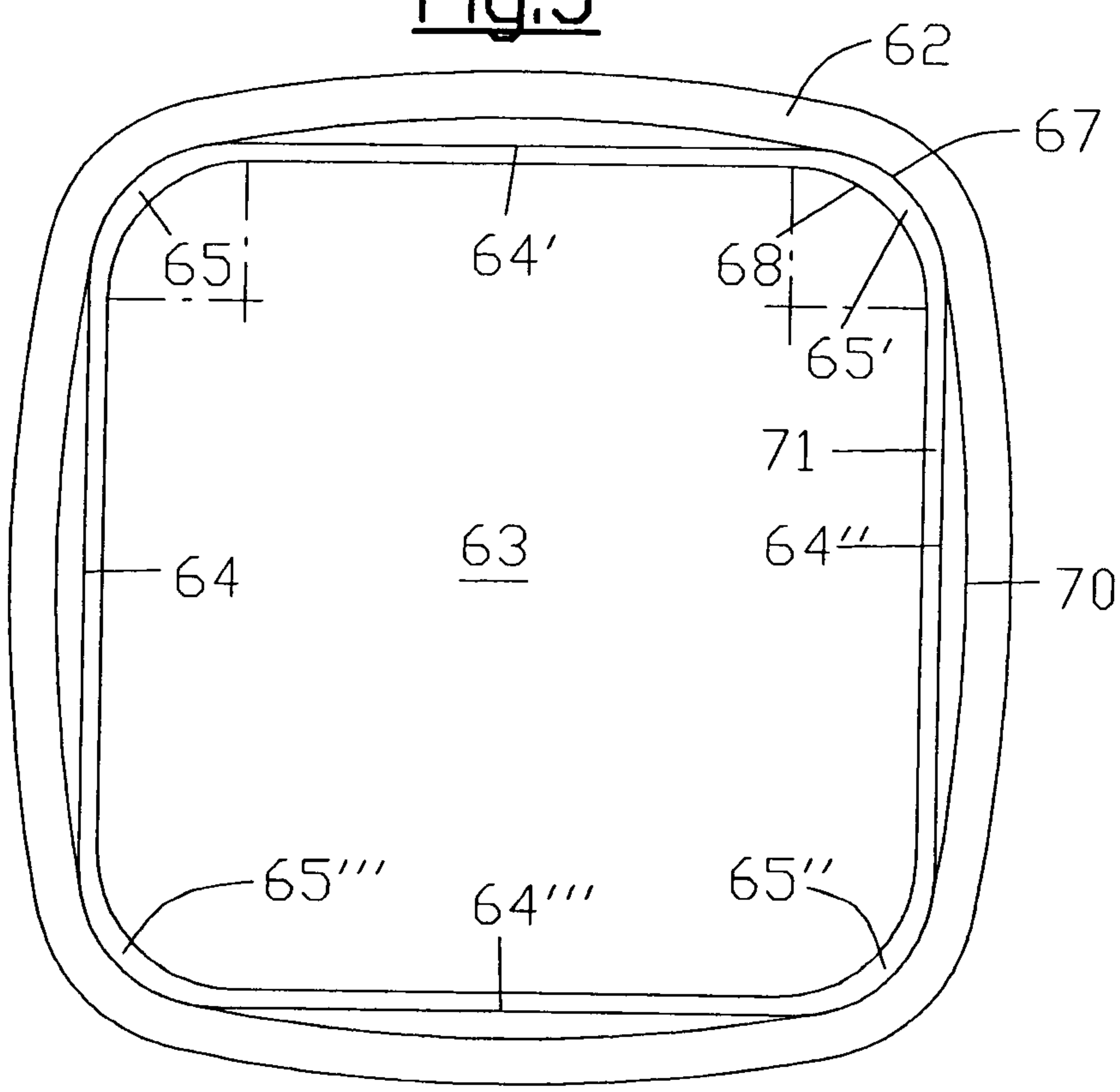

R=70; n=4
R=66.5; n=5
R=65; n=4.5
90°
50
51
51"
51'
60
40
20
-20
-40
-60

Fig.5


62
67
65'
64'
68
65'
71
63
64
64''
70
65'''
64'''
65''

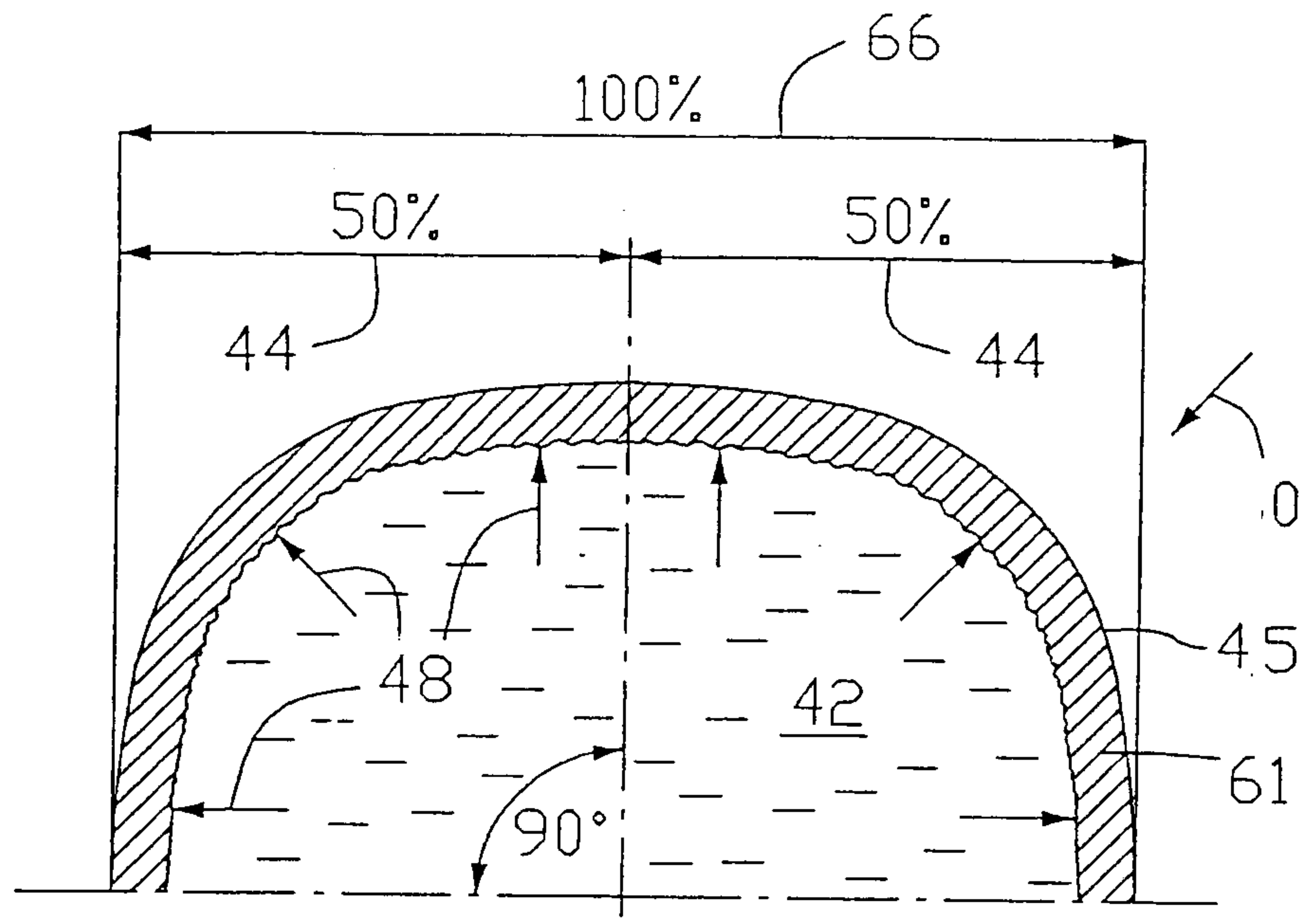


Fig.6

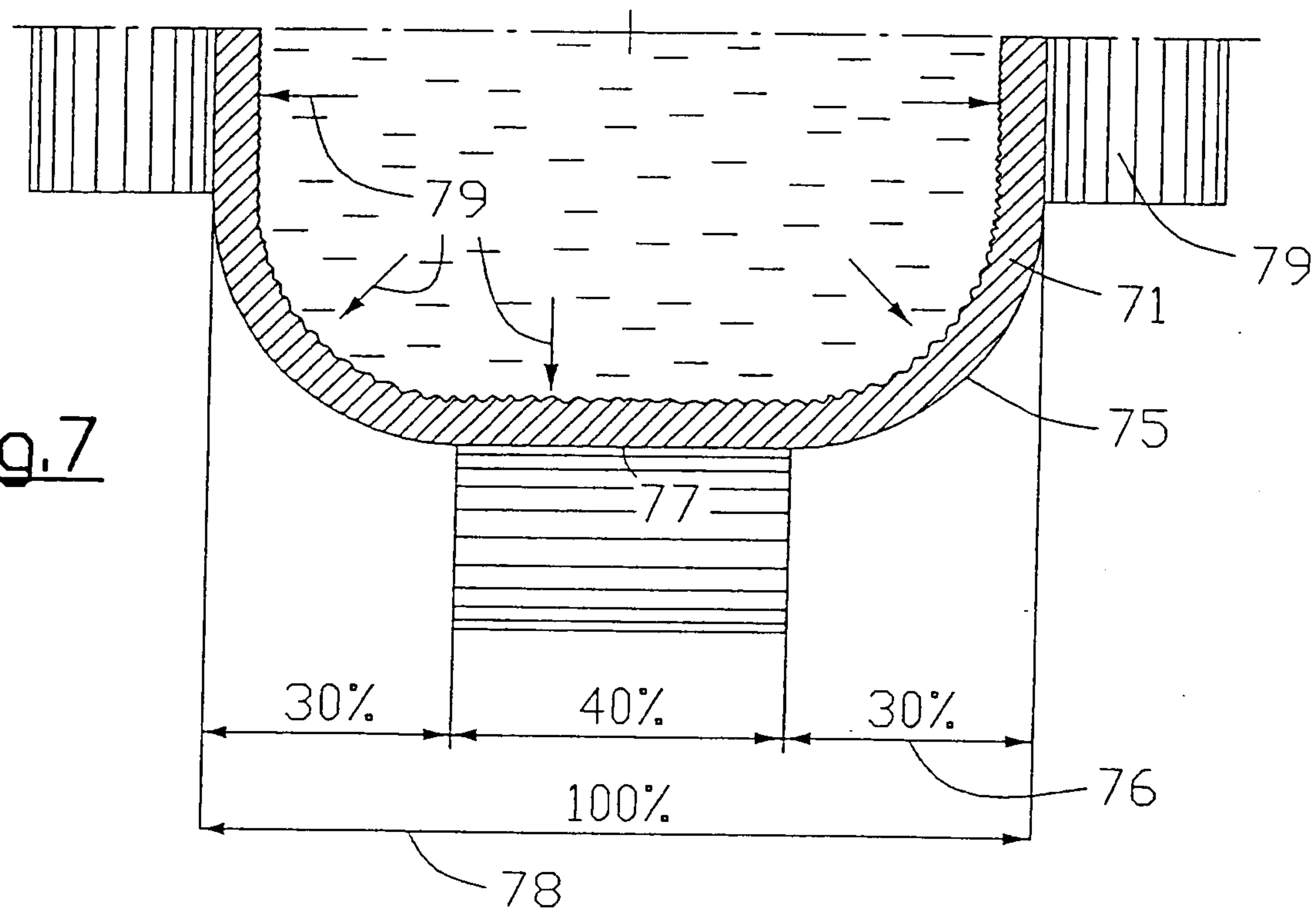


Fig.7

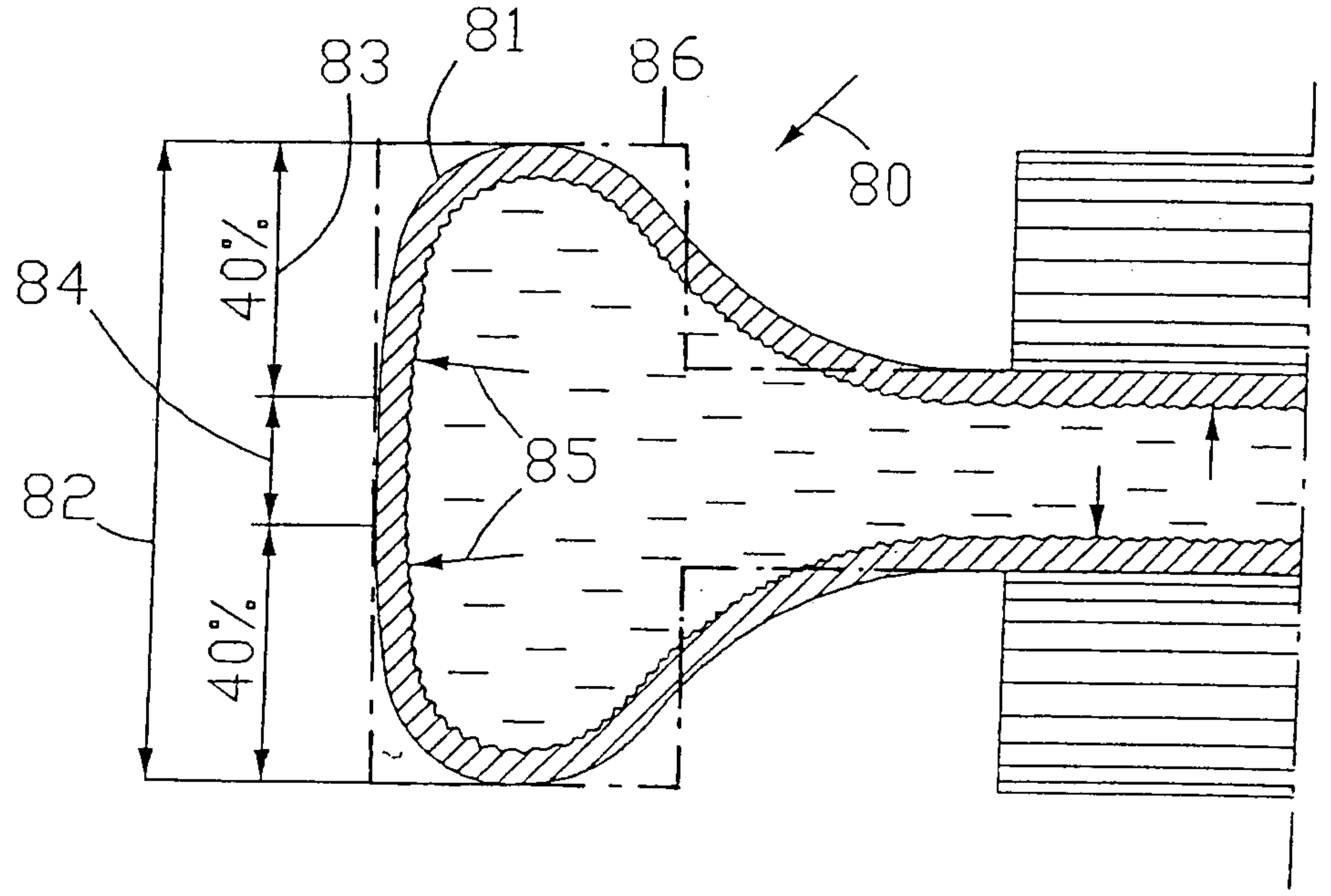
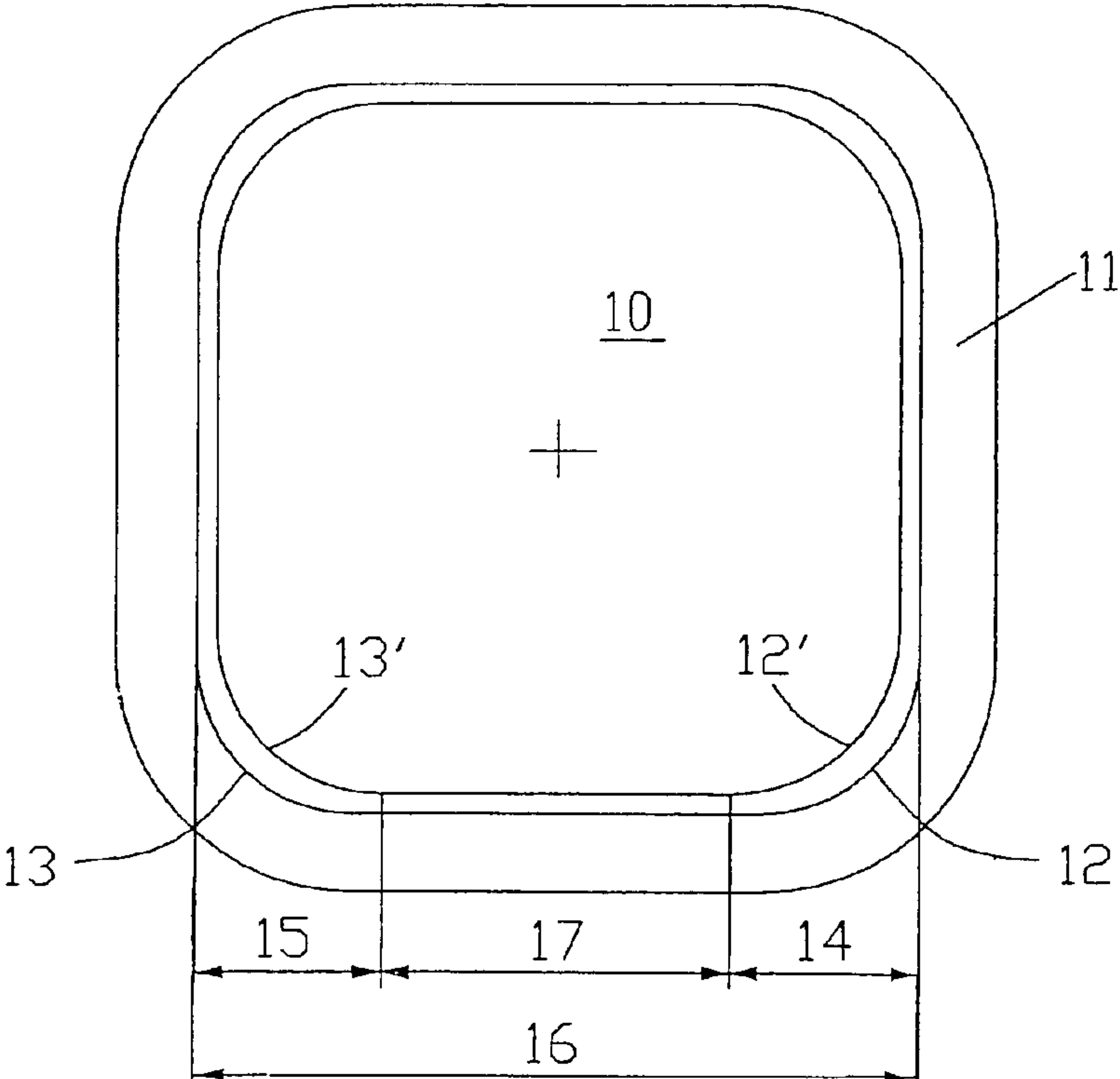


Fig.8



10
11
13'
12'
13
12
15
17
14
16