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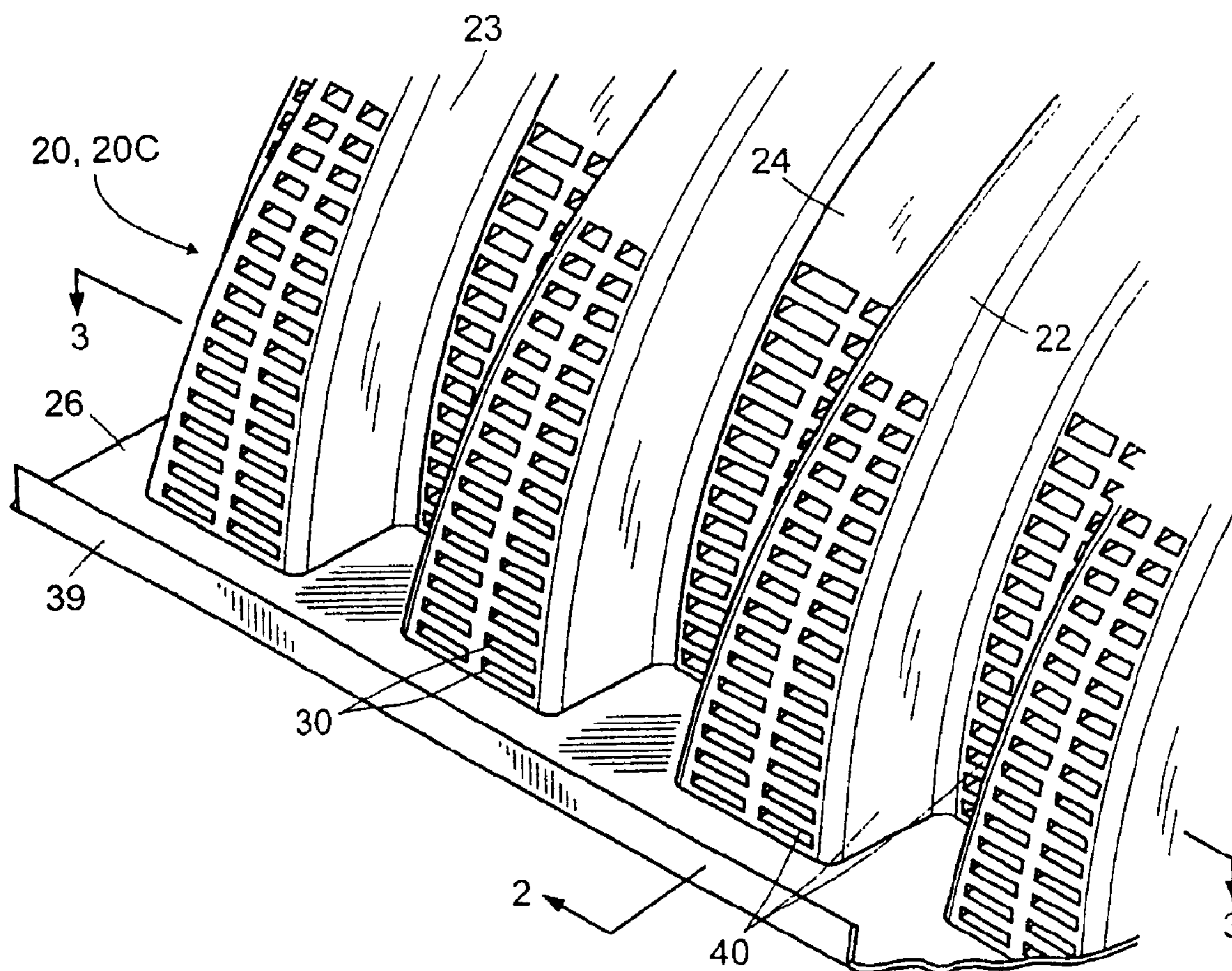
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(54) Title: CORRUGATED LEACHING CHAMBER



(57) Abrégé/Abstract:

A continuous curve arch shape cross section leaching chamber (20) made of molded thermoplastic has closely spaced corrugations (22, 24) and sidewalls (40) which are perforated with slots (30) which slope downwardly, from interior to exterior of the

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chamber. The slot height and or wall thickness vary with slot elevation from the base, so that a desired Soil Threshold Angle, which is the shape that resists entry of surrounding soil, is achieved for all slots. Slotted wall thickness is less than about 2 times the thickness of the basic chamber wall thickness elsewhere. The chamber has properties and performance approximating prior art chambers, but has substantially less normalized weight and total weight.

ABSTRACT

A continuous curve arch shape cross section leaching chamber (20) made of molded thermoplastic has closely spaced corrugations (22, 24) and sidewalls (40) which are perforated with slots (30) which slope downwardly, from interior to exterior of the chamber. The slot height and or wall thickness vary with slot elevation from the base, so that a desired Soil Threshold Angle, which is the shape that resists entry of surrounding soil, is achieved for all slots. Slotted wall thickness is less than about 2 times the thickness of the basic chamber wall thickness elsewhere. The chamber has properties and performance approximating prior art chambers, but has substantially less normalized weight and total weight.

CORRUGATED LEACHING CHAMBER

This application is a division of Canadian Patent Application Serial No. 2,535,017 filed September 30, 2004 which has been filed as the Canadian National Phase application of International Application No. PCT/US2004/033039, filed September 30, 2004.

TECHNICAL FIELD

The present invention relates to leaching chambers, for receiving and dispersing wastewater when buried in soil.

BACKGROUND

Most prior-art thermoplastic leaching chambers have a number of design characteristics in common, both for functional and manufacturing reasons. Typically, chambers have slotted, inwardly sloped, planar sidewalls, which run up to a curved arch top. They have arch-shape cross sections, and wide peak and valley corrugations running up over the arch. For example, see United States Patent No. 5,017,041 of Nichols et al.

Slotted sidewall perforations provide open area, for infiltration of wastewater through the sidewall into the soil surrounding the chamber. Prior art chambers have relatively few corrugations, typically about one peak per foot, because that makes more area available for slot opening in peaks and in valleys which are usually the only areas with perforations. In use, leaching chambers must resist the loads from both overlying soil, and from vehicles and other things traveling along the soil surface, as well as lateral load of soil on the sidewall. Since the slots or other perforations weaken the sidewall, the sidewall is substantially thickened in vicinity of the slots, and ribs and other structures are provided for strength.

During use soil should not enter the chamber through the sidewall perforations. Some prior art devices simply have holes in thin walls, and geotextile, or porous fabric, laid over the sidewall prevents entry of soil. But that approach is undesired by many persons, because of cost and nuisance. The present invention is concerned with the class of chambers, which have perforations that are intended to inhibit soil entry by shape, without use of geotextile. The intent is that dimensions of the perforations, typically horizontal slots, themselves inhibit soil entry. Commonly, the portions of sidewall which are just above and below any slot are referred to as louvers. Louvers project from the basic sidewall and make slots deep compared to what their depth would be otherwise. But doing that increases wall thickness, which increases chamber weight and cost. In a typical chamber, the through-wall length of a slot might be increased to about 0.5 inch (1.27 cm) by louvers, where the basic wall thickness of the chamber

elsewhere is about 0.13 inch (0.33 cm). However, louvers increase the amount of material in a chamber, and requires substantial attention to get proper feeding during molding.

Leaching chambers must be reliably and economically fabricated, and nested for shipment. When injection molding is used, feeding of different regions, particularly louvers near slots, is accomplished by flowing plastic along ribs, which also strengthen the structure. Ribs usually run lengthwise and transversely on the interior and or exterior of a chamber. However, the presence of ribs lessens the ability to stack chambers in closely nested fashion. See U.S. Pat. No. 5,511,903 for information relating to chamber parameters and nesting. The result of the various trade-offs has been that a typical commercial slotted wall leaching chamber made of high density polyethylene is about 6 feet (183 cm) long, about 3 feet (92 cm) in width at the base, about 12-18 inch (30-46 cm) high. And it has five or six peak corrugations, louvers, ribs, and weighs 25-40 pounds (11.4-18 kg) or more.

The prior art chambers work well and have enjoyed commercial success. But there is a constant aim to improve chambers, so effectiveness or performance can be increased for the same cost, or so that cost can be reduced while maintaining effectiveness. One of the ways to reduce costs is to reduce the weight of plastic in a given size chamber, thereby reducing material and manufacturing cycle costs. Progress has been obtained in some prior art chambers by using gas assisted injection molding, wherein some interior portions are made hollow. See U.S. Pat. No. 5,716,163. Further improvements are desired.

DISCLOSURE OF INVENTION

An object of the invention is to provide a leaching chamber which has reduced cost per unit of leaching area. Another object is to provide a chamber which has slots or other perforations in the sidewall, but which does not use heavy louvers to resist inward migration of soil. A further object is to provide a continuous curve arch shape leaching chamber with perforations which have substantially uniform Soil Threshold Angles, regardless of perforation elevation from the base. A still further object is to provide chambers which are lighter, stronger and easier to handle, and which nest well for shipment.

In accord with the invention, a continuous curve arch shape chamber has a sidewall of substantially constant thickness. Perforations, such as slots, are run on a downward slope at angle SA, from the interior to the exterior of the chamber. In this embodiment, the vertical height of perforation opening increases with perforation distance from the base. Preferably, the slots all have the same Soil Threshold Angle (STA). STA is a geometric measure of the ability

of a slot to inhibit soil infiltration into the chamber during use. STA is preferably less than RA, the repose angle of soil that surrounds the chamber. STA is preferably less than 30 degrees, more preferably 26 degrees or less.

In further accord with the invention, another embodiment of a continuous curve arch shape leaching chamber has a sidewall with perforations, such as slots, which have substantially constant height from one slot to the next; and, sidewall thickness decreases with elevation. The perforations run downwardly toward the exterior, as in the foregoing embodiment and preferably all have the same Soil Threshold Angle (STA).

In still further accord with the invention, combining the two foregoing features, another curved arch shape cross section leaching chamber has a wall thickness which decreases with elevation, together with slot height which increases with elevation, preferably so that STA for all slots is above a critical threshold, preferably greater than RA, and preferably 26 degrees or less.

In a preferred embodiment in accord with the invention, a chamber has a continuous curve arch shape, downward sloping perforations, preferably substantially identical inwardly flaring slots, and perforation height increases with elevation. The slot interior and exterior edges are rounded, which has the effect of significantly increasing STA for slots at high elevation, compared to what STA would otherwise be. . Thus, in the invention, chamber sidewall is thicker at higher elevation than it is near the base, to the extent that STA for all the slots may be equal or less than a critical STA, for instance 26 degrees.

In still further accord with the invention, a continuous curve leaching chamber is made of polypropylene and has peak and valley corrugations on a pitch which is 6-7 inch (15-18 cm), preferably about 6.5 inch (16.5 cm). That compares with the about 12 inch (30 cm) pitch common in the prior art. Sidewall slots sidewall slope downwardly, preferably at about 12 degrees from horizontal, and flare inwardly with an about 12 degree included angle.

In further accord with the invention, an arch shape cross section corrugated leaching chamber is made of a thermoplastic, having a specific gravity in the range of 0.033-0.034 lb per cu inch (0.91-0.94 gm per cu cm), for instance high density polyethylene or polypropylene. The chamber has a base width of about 34 inch (86 cm). The sidewall is slotted but free of louvers. The corrugated body is smooth and free of ribs. The chamber wall in regions away from the slotted sidewall is substantially thinner than at the slotted sidewall. The chamber has a leaching area to weight ratio of greater than about 100 square inch per pound (0.145 sq meter per kilogram), preferably about 125 square inch per pound (0.181 sq meter per kilogram). The

chamber has a leaching area per unit length of at least 30 square inch per inch (76 sq cm per cm). The chamber weighs less than about 4 pounds per foot (6 kg per meter) of chamber length, preferably less than about 3 pounds per foot (4.5 kg per meter). An exemplary chamber has in is about 4 ft (122 cm) long, and weighs about 12 pounds (5 kg).

In still further accord with the invention, the thickness of the perforated chamber sidewall, namely, the peaks and valleys of the corrugated sidewall, is less than about 2 times the thickness of the rest of the chamber wall, called the basic thickness, which is un-perforated. The walls are free of what have been characterized as louvers in the past, and substantially thinner, while still obtaining a Soil Threshold Angle in the perforations which is at least comparable to the prior art chambers and which inhibits entry of soil during use.

Chambers made in accord with the invention have leaching area per unit length which is in the range of the prior art chambers. They have strength in resisting loads imparted through the soil which is at least comparable to prior art chambers. Yet they have dramatically reduced weight per unit length and leaching area per pound of material. Thus, they are much more efficient in use of material. They are easy to handle and economic to make.

In one aspect, the present invention resides in an arch shape cross section corrugated leaching chamber, made of a plastic, the plastic of the chamber is polyethylene or polypropylene or a thermoplastic having a density in a range of 0.033-0.034 pounds per cubic inch, having at least 1.5 cu ft interior volume per foot of chamber (0.0192 cu meter per meter), a slotted sidewall which is free of louvers, and a leaching area to weight ratio of greater than about 100 square inch per pound (0.142 sq meter per kilogram).

In another aspect, the present invention resides in a corrugated arch shape cross section plastic leaching chamber adapted for burial within soil during use, to receive and contain waste water and to provide chamber leaching area for flow of said water into the soil surrounding the chamber, the chamber having a multiplicity of corrugations comprised of alternating peaks and valleys running transversely across the arch of the chamber cross section, which comprises: a base; a top; and opposing sidewalls, running upwardly from opposing sides of the base to the top; the sidewalls and top shaped so that the chamber has a continuous curve arch shape cross section; the chamber having an interior cavity contained within the arch shape cross section, for receiving and holding waste water; the chamber having a total chamber leaching area, for infiltrating waste water received within the interior cavity into soil surrounding the

chamber; wherein the total leaching area is comprised of a first fraction and a second fraction; the chamber having an open bottom, characterized by the area lying between said opposing sides of the base, said open bottom area providing said first fraction of chamber leaching area; portions of said sidewalls having a plurality of upwardly spaced apart horizontally-extending slots for flow of water from the interior of the chamber and through the thickness of the walls and into the surrounding soil; each slot having a slot leaching area which is the smaller of the interior or exterior slot opening area; wherein the summation of said slot leaching areas provide a second fraction of said chamber leaching area; wherein other portions of said sidewalls and portions of the top are free of slots; said other portions having an average thickness which is the basic thickness of the chamber; the chamber having an interior volume of at least 1.5 cubic feet per foot of chamber length; the chamber having a chamber leaching area to weight ratio of greater than 100 square inches per pound of chamber weight, wherein chamber leaching area is comprised of said first and second fractions; and, the chamber having a weight to length ratio of less than 4 pounds per linear foot.

In another aspect, the present invention resides in a corrugated arch shape cross section plastic leaching chamber, for burial within soil during use, to receive and contain waste water and to provide chamber leaching area for flow of waste water into the soil surrounding the chamber, which comprises: a base, for supporting the chamber on soil during use, comprised of opposing sides running lengthwise along the chamber, wherein the space therebetween defines an open bottom of the chamber; a top, for supporting soil above the chamber when the chamber is buried for use; and, opposing sidewalls, running upwardly from the opposing sides of the base to the top, for supporting the top and for providing regions where water can flow from the interior to the exterior of the chamber; the sidewalls and top shaped so that the chamber has a continuous curve arch shape cross section; wherein the chamber has a multiplicity of corrugations comprised of alternating peaks and valleys running transversely across the arch of the chamber cross section; wherein, the chamber is substantially free of strengthening ribs; and wherein the center-to-center pitch of peak corrugations is substantially less than 12 inches; the chamber having an interior cavity extending upwardly from the base to the top and along the length of the chamber; the chamber having a total chamber leaching area, for infiltrating waste water received within the interior cavity into soil surrounding the chamber; wherein the total leaching area is comprised of a first fraction and a second fraction; and wherein said first fraction is provided by said open bottom; said sidewalls having portions with a plurality of upwardly spaced apart and horizontally-extending slots, for flow of water from the interior of the chamber and through the thickness of the walls and into the surrounding soil during use; each of said slots having a slot leaching area, wherein the summation of

said individual slot leaching areas is said second fraction of said chamber leaching area; said chamber having a basic thickness which is the average thickness of (a) any other portions of the sidewall where there are no slots and (b) the top; wherein the plastic of the chamber is a thermoplastic; wherein the chamber has (a) a leaching area to weight ratio of greater than 90 square inches per pound and (b) an interior cavity volume per unit length of at least 1.5 cubic feet per foot.

In a further aspect, the present invention resides in a corrugated arch shape cross section plastic leaching chamber, for burial within soil during use, to receive and contain waste water and to provide chamber leaching area for flow of waste water into the soil surrounding the chamber, which comprises: a base, for supporting the chamber on soil during use, comprised of opposing sides running lengthwise along the chamber, wherein the space therebetween defines an open bottom of the chamber; a top, for supporting soil above the chamber when the chamber is buried for use; and, opposing sidewalls, running upwardly from opposing sides of the base to the top, for supporting the top and for providing regions where water can flow from the interior to the exterior of the chamber; the sidewalls and top shaped so that the chamber has a continuous curve arch shape cross section; wherein the chamber has a multiplicity of corrugations comprised of alternating peaks and valleys running transversely across the arch of the chamber cross section; wherein, the chamber is substantially free of strengthening ribs; and wherein the center-to-center pitch of peak corrugations is substantially less than 12 inches; the chamber having an interior cavity extending upwardly from the base to the top and along the length of the chamber; the chamber having a total chamber leaching area, for infiltrating waste water received within the interior cavity into soil surrounding the chamber; wherein the total leaching area is comprised of a first fraction and a second fraction; and wherein said first fraction is provided by said open bottom; said sidewalls having portions with a plurality of vertically spaced and horizontally-extending slots, for flow of water from the interior of the chamber and through the thickness of the walls and into the surrounding soil during use; each of said slots having a slot leaching area, wherein the summation of said individual slot leaching areas is said second fraction of said chamber leaching area; the chamber having a basic thickness which is the average thickness of (a) any other portions of the sidewall where there are no slots and (b) the top; wherein the plastic of the chamber is a thermoplastic; wherein the chamber has (a) an interior volume per foot of length of at least 1.5 cubic feet per foot and (b) a weight per linear foot of 4 pounds or less.

In yet a further aspect, the present invention resides in a continuous curve arch shape cross section corrugated plastic leaching chamber comprised of a top, a base, and opposing sidewalls running

upwardly from opposing sides of the base to the top, wherein the plastic of the chamber is polyethylene or polypropylene or a thermoplastic having a density in the range of 0.033-0.034 pounds per cubic inch; wherein the base has a width of about 34 inches; wherein said opposing sidewalls comprise a multiplicity of horizontally spaced apart slots; wherein the chamber has a leaching area per unit length of more than 100 square inches per inch of length, and a weight of less than 4 pounds per foot of chamber length.

In another aspect, the present invention resides in an arch shape cross section corrugated leaching chamber having a base, a top, and opposing sidewalls running upwardly from the base to the top, comprising: a portion of sidewall, having a substantially constant thickness, running along a curved path upwardly from proximity of the base toward the top of the chamber; a plurality of perforations in said sidewall portion, spaced apart upwardly along the sidewall, running at substantially the same angle (SA) to the horizontal plane of the base; wherein, the vertical height of perforation opening increases with perforation elevation from the base.

In another aspect, the present invention resides in an arch shape cross section corrugated leaching chamber having a base, a top, and opposing sidewalls running upwardly from the base to the top, comprising: a portion of sidewall running along a curved path upwardly from proximity of the base toward the top of the chamber; a plurality of substantially constant height perforations in said sidewall portion, spaced apart upwardly along the side wall, the plurality of perforations running at substantially the same angle (SA) to the horizontal plane of the base; wherein, the thickness of the perforated sidewall decreases with elevation from the base.

In further aspect, the present invention resides in an arch shape cross section leaching chamber having a base, a top, and opposing sidewalls running upwardly from the base to the top, comprising: a portion of sidewall running along a curved path upwardly from proximity of the base toward the top of the chamber; a plurality of perforations in the sidewall portion, spaced apart upwardly along the side wall; wherein, perforation height varies with elevation from the base; and, wherein sidewall thickness varies with elevation from the base.

In yet another aspect, the present invention resides in an arch shape cross section leaching chamber having a base, a top, and opposing perforated sidewalls running upwardly from the base to the top, the method of providing all the perforations with a Soil Threshold Angle (STA) greater than a

predetermined value, which comprises: varying the wall thickness and height of the perforations with elevation from the base of the chamber.

In yet another aspect, the present invention provides an arch shape cross section corrugated leaching chamber having a base, a top, and opposing sidewalls running upwardly from the base to the top, the chamber which comprises: a sidewall having a portion which runs curvingly upwardly and inwardly toward the top of the chamber, the portion having a thickness and a plurality of upwardly spaced apart horizontally-extending slots for flowing water from within the interior of the chamber to the exterior of the chamber through the thickness of said sidewall portion; each slot having an opening height proximate the exterior surface of the sidewall, which height is the vertical distance between the horizontally-extending surfaces which define the slot; wherein, one or more of said plurality of slots which are at the upper part of the sidewall portion have opening height(s) which are greater than the opening height(s) of one or more of said plurality of slots which are at the lower part of the sidewall portion.

In another aspect, the present invention provides an arch shape cross section leaching chamber made of molded thermoplastic comprising: a base; a top; and, opposing sidewalls running upwardly from the base to the top, having portions which run curvingly inwardly and upwardly toward the top; said portions having horizontally-extending slots spaced apart upwardly along the sidewall portion, wherein the slots have opening heights proximate the exterior surface of the sidewall which vary progressively with increasing elevation from the base, wherein slot opening height is the vertical distance between horizontally-extending surfaces which define the slot proximate the exterior surface of the sidewall.

In another aspect, the present invention provides a method for constructing a portion of the sidewall of an arch shape cross-section leaching chamber, wherein the chamber has a base, a top, and opposing sidewalls running upwardly from the base to the top, which comprises: (a) forming a portion of the sidewall to run curvingly upwardly and inwardly from the base toward the top of the chamber, the portion having a thickness; and (b) forming a plurality of upwardly spaced apart horizontally-extending slots in said sidewall portion, wherein each slot has an opening height which is the vertical distance between horizontal surfaces which define the slot so that the opening heights proximate the exterior surface of the sidewall of said plurality of slots varies as a function of slot elevation from the base of the chamber, and so that each slot has a Soil Threshold Angle (STA) which is substantially equal to a predetermined value, wherein Soil Threshold Angle is the angle between a horizontal line and a straight line running from the top outside edge of a slot to the bottom inside edge of the slot.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is an isometric view of a portion of a leaching chamber.

Fig. 2 is vertical plane cross section of the chamber of Fig. 1.

Fig. 3 is a horizontal plane cross section through of a portion of the perforated sidewall of the chamber of Fig. 1.

Fig. 4 is an elevation view of a portion of the exterior sidewall of a chamber.

Fig. 5 is a vertical cross section through a portion of sidewall having varying thickness and having inwardly flared slots which increase in height with elevation.

Fig. 6 is a vertical cross section through a sidewall, to illustrate parameters associated with perforations, such as slots.

Fig. 7 is like Fig. 6, showing how soil lies within a slot.

Fig. 8 is a vertical cross section through a portion of chamber sidewall having constant slot perforation height and wall thickness which decreases with elevation.

Fig. 9 is a vertical cross section through a portion of chamber sidewall having constant wall thickness and slot perforation height which increases with elevation.

Fig. 10 is a vertical cross section through the sidewall, to show the effect of rounding of the edges of the slot entry and exit on Soil Threshold Angle STA.

Fig. 11 is a view like Fig. 10, showing a slot which flares outwardly.

Fig. 12 is a view like Fig. 10, showing a slot which flares inwardly.

Fig. 13 is a bar graph, showing how chambers compare with respect to weight per linear foot.

Fig. 14 is a bar graph, showing how chambers compare with respect to leaching area per unit weight.

Fig. 15 is an isometric view of a chamber of the present invention.

Fig. 16 is a cross section through a chamber wall showing a runner for distributing plastic during injection molding.

Fig. 17 is like Fig. 16, showing a rib, used for stiffening a chamber wall.

BEST MODES FOR CARRYING OUT THE INVENTION

The preferred embodiment of the present invention shares cross section shape and corrugation characteristics with chambers described in two U.S. patents to Krueger et al., namely U.S. Patent No. 7,118,306, filed May 4, 2001, and issued on October 10, 2006, and U.S. Patent No. 7,052,209, filed March 28, 2003, and issued May 30, 2006. Reference may also be made to a commercial product, the SC 310 stormwater chamber (StormTech LLC, Wethersfield, Connecticut, U.S.). The aforementioned storm chambers are characterized by freedom from ribs. However, because of their different use, storm chambers lack a multiplicity of small perforations in the sidewall, which necessarily characterize leaching chambers and weaken a sidewall. The chamber of the present invention preferably has an end which is shaped for swivel connection, as described in U. S. patent Publication No. US 2003-0219310

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to Burnes et al., filed May 20, 2003, and published November 27, 2003.

During use, a leaching chamber receives relatively small and continuous quantities of high organic-content wastewater, and disperses the water into surrounding soil, so it can be acted on microbiologically. Leaching chambers are typically buried directly in a soil trench, although they may be immediately surrounded by sand or crushed rock. They also may be used to gather liquids from surrounding media. A reference herein to soil, in addition to the common soil of the earth, means any granular water-permeable media into which leaching chambers may be placed for use.

Fig. 1 is an isometric view of a portion of a leaching chamber 20, an embodiment of the present invention. The chamber has horizontal slot perforations 30 in sidewall 40, which are exaggerated in height for better illustration. Fig. 2 is a vertical cross section through chamber 20. The chamber has a continuous curve semi-ellipse arch shape of minor radius R , the pivot point C of which is beneath the plane of the base. Chamber 20 has alternating peaks 22 and congruent valleys 24, which together comprise corrugations running along the arch shape cross section which defines chamber interior 21. Perforations 30 are closely spaced apart along the upward curve of the sidewall 40 at the peak and valley parts thereof. Un-perforated webs 23 connect the peaks and valleys.

Fig. 3 is a horizontal plane cross section through a portion of the sidewall of chamber 20. Pitch U of the peaks (valleys) in the new leaching chamber is less than the pitch of comparable slotted leaching chambers in the prior art. Exemplary chamber 20 has peaks which are pitched, or spaced apart, a distance U of about 6 inches (15 cm), center to center, which compares with the typical about 12 inch (30 cm) pitch in the prior art. Thus, the number of peaks/valleys per unit length is about doubled, compared to prior art chambers. The closely spaced corrugations, the continuous arch curve cross section and engineered slot perforation pattern combine to provide a lightweight and strong chamber.

Chamber 20 has a height h of about 12 inch (30 cm), a width w at the base of about 34 inch (86 cm), and an actual overall length of about 53 inch (135 cm). When installed, chamber 20 is overlapped by a like chamber at the joint by about 5 inch (13 cm). The basic wall thickness of the chamber in un-slotted locations is about 0.090 inch (0.23 cm). The chamber is injection molded from commercial grade polypropylene, such as Fortilene TG6801 Polypropylene (BP Amoco Co., Naperville, Illinois, U.S.) or other comparable performance material.

Opposing sidewalls 40 rise, along a curve, up to top 42 from each opposing side base flange 26, which has vertical strengthening fin 39 along its outer edge. Preferably, the whole useful elevation of the sidewall is perforated, at the peaks and at the valleys. When the arch has a continuous curve, such as the semi-ellipse shown in Fig. 2, the point at which the arch surface ceases being sidewall and starts being top is somewhat arbitrary, compared to a planar sided chamber of the prior art, where there is a break or discontinuity in the arch shape of the sidewall at the point where perforations end. In one definition applicable to the invention, the top is that portion of the chamber which lies within angle TA shown in Fig. 2, where TA is about 80 degrees. Alternatively, the top may be considered that part of the chamber which is above the elevation of the invert (i.e., the bottom of the interior opening) of an influent pipe. Typically, that height is determined by the configuration of the endplate and the diameter of the inflow pipe, usually nominally 4 inch (10 cm). Unless special endplates are used, the maximum invert height for a chamber is usually 4.5 inch (11.4 cm) below the elevation of a peak corrugation.

The radius of the minor axis of the preferred semi-elliptical arch curve has a point of rotation C, which is just below the plane of the base flange. See said U.S. Patent No. 7,118,306 to Krueger et al., issued on October 10, 2006. The combination of close pitch corrugations, continuous arch shape, and polypropylene material provides chamber 20 with superior specific strength, section modulus, and other specific structural properties, compared to prior art chambers. The arch curve is continuous, from one base flange to the other. For example, the arch shape is nominally a curve selected from the group consisting of a semi-circle, semi-ellipse, and parabola or other surface of revolution. Approximations are contemplated. For instance, sidewall thickness may vary; the sidewall may comprise a multiplicity of small steps or panels, following an essential curve; there may be a small vertical skirt near the base; or there may be a small flat or peaked portion at the top.

Chamber 20 does not have any ribs on the interior or exterior of the corrugated body, which ribs are familiar in prior art chambers. The sidewall may be nominally constant in thickness about a typical perforation, although as described below, there optionally may be relatively small progressive change with elevation. Wall thickness t , is measured perpendicular to the nominal plane of the local wall portion. Basic wall thickness is the nominal wall thickness of the chamber wall, away from perforated areas, for instance, in the web, at the top, and in the base flange. The preponderance of an invention chamber has wall with the basic thickness, which can be visually appreciated from Fig. 15, and from the following data: The preferred embodiment chamber 20, described in more detail below, has a basic wall thickness of about

0.09 inch (0.23 cm). The average wall thickness for whole chamber is about 0.098 inch (0.25 cm), wherein the perforated sidewall thickness ranges from about 0.15 to about 0.18 inch (0.38 to about 0.46 cm). Wall thicknesses may be ascertained by direct measurement or by calculation, e.g., dividing the material volume by the surface area of the portion of interest.

In some prior art chambers, louvers are well defined lips above and below the perforations, and that is apparent where they laterally terminate. The sidewall adjacent the perforations will have the basic wall thickness. In other prior art chambers, louvers run into the adjacent sections, for instance into the web, and they are not so visually apparent as louvers. Typically, when viewed in cross section, and with respect to running toward the chamber exterior, the underside of a prior art louver might be horizontal or have a slight upward angle. And, the top side of a louver is down-sloped. Other designs might have both the underside and top sloping downward. The louver opening flares outwardly, reflective of slides which retract into the cavity (female) part of an injection molding die, and desire to have draft on the projections which form the perforations.

In a preferred chamber of the present invention, sidewall thickness varies from 0.15-0.18 inch (0.38-0.46 cm), and thus the ratio of perforated sidewall thickness to basic wall thickness 0.09 inch (0.23 cm) ranges from 1.72 to 1, and averages about 1.85 to 1. The foregoing ratio is called the sidewall thickness ratio. It compares with a ratio of about 4 to 1, characteristic of prior art chambers. Designers of prior art chambers had reasons for the thick sidewall, even though that increased weight and cost. The combination of technology that comprises the present invention achieves substantially lowered sidewall thickness ratios, while still achieving STA which is effective, e.g. 26 degrees

The corrugated body portion of chamber 20C, between the ends, has no strengthening ribs as such, but does have runners. Runners, or localized thickened sections of the chamber wall which are also called flow channels, are used as needed, to provide for flow of plastic from injection sprues, which are typically spaced apart near the chamber top. Runners are distinguished from ribs in being relatively squat, as shown in Fig. 16; the thickness (or total height) t_{fc} of a runner 90 is typically about 250 percent of basic wall thickness t . The purpose of the runner is to provide cross sectional area. In contrast, as shown in Fig. 17, a typical rib 92 is tall and thin. The wall thickness t_{rb} at the rib is typically 400-500% of the basic wall thickness t , to achieve its intended purpose, which is to provide stiffness, i.e., to substantially increase section modulus with economic use of material. Of course ribs, particularly those with thickened bases, may also serve as flow channels. See aforementioned U.S. Pat. No. 5,716,163 for other examples of such ribs. In chamber 20C, small drip ledges 43 run in parallel

lengthwise along the interior of the top. See Fig. 2. They drop down about 3/16 inch (0.47 cm), and are known in the prior art. When pressure-dosed wastewater is sprayed upwardly into interior of the top, ledges 43 inhibit the water from running down along the sidewalls. Any strengthening from such is incidental. Apart from the rib-free corrugated body portion of the chamber, there are small ribs 45 on the flange 26, running to fin 39. See Fig. 15. The ribs both strengthen the fin and provide support surfaces for an overlying stack of nested chambers.

Fig. 5 is a vertical cross section through a sidewall 40C of a preferred chamber 20C, which is generally like chamber 20. Fig. 4 is side elevation view of the same chamber. See also Fig. 10 and 11 for details of the slots, discussed further below. Slots 30C, 30 have central axes LL, which slope downwardly at angle SA of about 12 degrees from horizontal. Preferably, the slots are flared inwardly with an about 12 degree included angle, as described further below, and in co-pending U.S. patent application Publication No. US 2005-0074286 A1 to Swistak et al., entitled Leaching Chamber with Inward Flaring Sidewall Perforations, filed on October 1, 2003 and published on April 7, 2005. In chamber 20C, slot height h_x (i.e., height h which is measured at the sidewall exterior surface) becomes progressively larger with slot elevation from the base, increasing from about 0.070 inch (0.18 cm) at the bottom to about 0.090 inch (0.23 cm) at the top. The vertical edge-to-edge spacing of the slots is about 0.100 inch (0.254 cm), measured along the rise or curve of the sidewall. The basic wall thickness t of the chamber away from the perforated wall is about 0.090 inch (0.23 cm); and, that is the thickness at the top 42C. In Fig. 5, the thickness of the perforated chamber sidewall increases from to of about 0.150 inch (0.38 cm) at the bottom to t_b of about 0.175 inch (0.445), nominally 0.180 inch (0.46 cm), near the top. The preferred design will be further appreciated from the descriptions that follow. Fig. 15 is an isometric view of a whole chamber 20C having features of preferred embodiment. Fig. 15 illustrates the open ends of the chamber and how they are configured for connecting to other chambers.

Fig. 6 and Fig. 7 are used to define parameters. They show small segments of chamber sidewalls 40 having constant height perforations 30. Perforations 30 slope downwardly, running from the interior to the exterior of the chamber. Perforation 30 has a central axis LL, a depth SL and a height h , measured vertically as indicated in Fig. 6. Perforation length is measured horizontally in the direction of the longitudinal axis LX of the chamber. When the perforation is a slot, it has a width w which is greater than perforation height. Central axis LL of a perforation makes an angle SA with the horizontal plane, i.e., the plane of the bottom of the base of the chamber. A line drawn from the outside top edge 32 of a perforation to the bottom inner edge of the perforation, intersects the horizontal with angle STA. Angle STA,

also called Soil Threshold Angle, is a property of a chamber perforation. As further described STA is a function of slope angle SA, slot depth, slot height, and slot flare angle.

Fig. 7 shows how soil 36 lying against the exterior of a chamber wall 40 will tend to enter into the perforation 30 under the influence of gravity and the soil environment, such that the innermost end of the soil lies at an angle RA, also called Angle of Repose. Angle of Repose RA is a property of the soil material, typically measured in the dry state, according to familiar procedures, e.g. pouring material as a pile on a surface. Of course, for a leaching chamber in use, the situation is more complicated, since moisture and organic content affects angle of repose of soil media. Notwithstanding, a practical angle of repose can be determined by measurement of soil angle in a slot under typical field conditions.

Under normal quiescent conditions, soil will theoretically not enter the chamber through perforations if angle STA is less than angle RA. Thus, an angle STA, which is about equal to angle RA, is called the critical STA angle, STA_c . For the preferred chambers of the invention, all slotted perforations have angle STA which is equal or less than STA_c . From a certain sanitary engineering and regulatory viewpoint, the useful leaching area of a chamber is based on the soil which is exposed in the slot, namely that lying along the slope of the angle RA or angle STA, as may be attributed to be the limiting case. Leaching area for a chamber sidewall, is often based on the soil which lies along angle STA. (An alternate way is to calculate the total of perforation opening area; and for many prior art chambers the two modes don't vary greatly. Total leaching area for a chamber typically includes the area at the base of the arch.) STA angle for a chamber will typically be set according to the designer's estimation of field conditions, experience, and the aims for the product in the marketplace. In the invention STA is preferably less than 30 degrees, and in the range of 20-30 degrees. More preferably, STA is about 26 degrees or less.

Chamber perforations are preferably horizontal slots, wherein the opening at the exterior surface of the sidewall is rectangular. Perforations having other shape openings, such as square, round or elliptical may be used in the generality of the invention. Perforation height as defined in the invention has been shown in the illustrations; and, it will be measured in accord with good metrological practice. Generally, the slot height of interest in leaching chambers is the vertical plane slot height h_x measured at the outside of the chamber sidewall. The number and size of perforations on a sidewall, the spacing, and perforated sidewall thickness, will be a function of material properties, the loads that the chamber is designed to withstand, including loads carried by the perforated sidewall ligaments due to downward arch loads and lateral force from surrounding of soil, and other structural design factors.

Fig. 8 and 9 show portions of the sidewalls of two alternative embodiments of the invention. In each, the basic axes LL of downward sloping, essentially constant height, slots run at an angle SA, for example 12 degrees. In Fig. 8, chamber 20A has a curved sidewall 40A, with a plurality of upwardly spaced apart slots, all having the same height dimension h and angle SA. Sidewall 40A progressively decreases in thickness t with elevation e; from t_b at the lower part of the sidewall to t_a at the upper part. For comparison, phantom line 27A superimposes a constant thickness sidewall. If the sidewall 40A had such constant thickness, STA for slots at the lower part of the sidewall would be substantially greater than STA for slots at the upper part. Thus, the effect of thickening the lower wall of chamber 20A is to decrease angle STA, preferably so STA for all perforations is less than or equal to STA_c . In another way of characterizing this aspect of the invention, sidewall thickness is increased at more nearly vertical portions of the sidewall, i.e., the lower portions, to raise STA.

In the chamber 20B embodiment, shown in Fig. 9, thickness t of sidewall 40B is constant. The height h of the perforations is progressively increased with elevation, from small h_c near the base to larger h_a at the upper part of the sidewall. The decrease in height of the lower elevation perforations compensates for the decreased perforation depth, so that the desired STA is achieved.

Thus, in the generality of the invention, sidewall thickness is changed and or perforation height is changed with elevation of the perforation, to control (lower) STA, preferably so all perforations have STA equal or less than STA_c . Wall thickness may be varied in step function manner, to approximate a continuously varying thickness sidewall. Perforation height may likewise be varied in an incremental or step-function manner. The principles of the invention can be applied to chambers which have perforated sidewalls which may not be continuously curved, but which sidewalls have different slopes at different elevations. For example, a chamber may have a sidewall comprised of two or more planar sections, one above the other, or one adjacent the other. Similarly, the invention may be applied to only a portion of the vertical elevation of a sidewall, with the rest of the sidewall having different perforation features.

STA as defined and shown in drawings thus far assumes that the sidewall interior and exterior surfaces are perfectly formed, and the perforation edges are sharp edges. In practical parts, the sharp interior and exterior edges of the slots or other perforations are usually not present, either by design or because of manufacturing limitations. Typically, there will be a radius R or rounding on the edges, as shown in Fig. 10. For instance, in a chamber 20C, the upper and lower edges of the slots may have a radius of 0.010-0.030 inch (0.025-0.076 cm), preferably

about 0.020 inch (0.051 cm). As illustrated in Fig. 10, perfect or unrounded edges will produce a perfect or theoretical STA 80. When the edges have radii, a greater STA 82 results. The effect is more significant at the upper perforations. So, the chamber designer takes the edge radius effect into account when determining how wall thickness or slot height should vary. Thus, in chamber 20C, the perforated sidewall is thickened where it approaches top 42C, because the favorable effect on STA of the less vertical sidewall at such location is insufficient to achieve the desired STA.

Referring again to chamber 20C and Fig. 4 and 5, to seek to optimize design with respect to chamber strength, leaching area and material utilization, and to obtain essentially constant STA of about 26 degrees, slot height h_x is decreased for slots at the lower portion of the sidewall, compared to slots at the upper portion. To compensate for the edge radius effect, sidewall 40C is about 0.025 inch (0.064 cm) (or about 20%) thicker at the upper elevation than it is near the base. In the absence of an about 0.020 inch (0.051 cm) edge radius, the STA at the top slot would be about 16 degrees instead of the desired 26 degrees which is obtained.

In another variation, not pictured, chamber 20C is modified so that the slot height does not vary substantially from the lowermost slot height, irrespective of slot elevation. That would have the effect of reducing chamber leaching area somewhat. In another variation, also not pictured, the slots of chamber 20C are configured with varied height as first described, and the sidewall has a constant thickness t_b , characteristic of the upper sidewall. That which would mean that the lower part of the sidewall would be stronger than needed, but excessive in thickness from the standpoint of minimum STA.

Chambers in the present invention may have perforations which are essentially straight, which flare outwardly, or preferably, which flare inwardly. While in general perforations can be formed by machining, laser cutting, and possible other techniques, slots in prior art molded chambers have been predominately formed by molds having movable slide parts, typically located in the cavity part of the mold. Such slides move horizontally or at a downward angle, usually along the basic axis LL of the perforations, according to the particular maker. Even when slots or other perforations are intended to be straight, typically they will have a small flare or draft, for example 2 degrees or more. In other instances, flaring may be greater, for example, up to 12 degrees included angle.

Fig. 11 shows a typical slot 30 for which height h changes with slot depth (which also may be called the through-wall length), so the slot flares outwardly toward the chamber exterior. Fig. 12 shows preferred typical slot 30 which flares inwardly toward the chamber interior 21, so the

minimum height h of the slot, namely h_x , is at the exterior surface. The downward slope angle SA is preferably 12 degrees; and, the included angle FA of the flare is preferably about 12 degrees.

Chambers having slots 30 are formed by molds which have slides that retract into the core portion of the mold, that is, inwardly from the sidewall exterior, as detailed in the aforementioned Swistak et al. U.S. Patent application Publication No. US 2005-0074286 A1, filed October 1, 2003 and published April 7, 2005. The slots of preferred embodiment chamber 20C are shaped like those in Fig. 11. In the generality of the present invention, the other configurations of slots which have been described may be used.

The combination of curved arch shape, chamber corrugations, varied wall thickness and slot height, and material strength, enables the preferred chamber of the invention to be made free of substantial strengthening ribs which have characterized the chambers of the prior art, to provide strength. The chambers are thus lighter in weight than chambers in the prior art, and stack more compactly.

Comparing the invention chamber with a prior art same-company product for which it may substitute, the weight per linear foot of the new chamber is about 35% less than the comparable product. It has a leaching area per pound of chamber weight is about 35% greater, showing much greater efficacy of material utilization. Lighter weight and thinner wall chambers use less material and can be made with a quicker injection mold time cycle, thus achieving certain objects of the invention.

Chambers of the invention and prior art are made of high density polyethylene or polypropylene, or combinations of other thermoplastics. The lengths of the comparable prior art chambers are all around 75 inch (190 cm), while the invention chamber is preferably about 48 inch (122 cm). See prior discussion about actual length versus nominal length. The short length chamber is surprisingly easier to handle and install, economic to make, and provides better ability of a string of interconnected chambers to deviate from the straight line. Nonetheless, in the generality of the present invention, chambers may be made any length.

The invention chamber has properties which are substantially different from the chambers of the prior art, due to the unique design features of the invention. Fig. 13 and 14 portray some of data in bar chart fashion. Fig. 13 illustrates how the weight per unit length of the invention is about 3 lb/ft (4.5 kg/m), substantially less than the nominal 4-6 lb/ft (6-9 kg/m) value in the prior art. Fig. 14 illustrates how the ratio of leaching area to weight is at about 120 sq inch/lb (0.174 sq m/kg), substantially greater than the nominal 70-90 sq inch/lb (0.121-0.156 sq m/kg) characteristic of the prior art. Thus, there is much improved material utilization. (Leaching area is a calculated measure of useful surface area of soil, including that at the bottom of the arch

shape cross section, which is exposed to wastewater during use. Due largely to the absence of ribbing, the invention chambers are adapted to nest well, with a stacking height of about 0.9 inch (2.3 cm) per chamber. Therefore, shipping is economical.

Obviously, for any embodiment that has been described, chamber wall may be thickened overall from what has been described as preferred, even though that would decrease the degree of advantage of the invention over the prior art. And, the end details, which are relatively compact and which do not add much weight, could be made more complex. So, taking these factors into consideration, a chamber of the present invention may have greater wall thickness and weight than the preferred embodiment chamber which has been described, while attaining a leaching area to weight ratio of greater than about 120 sq inch per pound (1.74 sq m/kg) and a weight per linear foot of less than about 4 lb/ft (6 kg/m). Despite the absence of ribs and the reduced amount of material, chambers 20, 20C will have section modulus and strength comparable to prior art chambers.

CLAIMS

1. An arch shape cross section corrugated leaching chamber having a base, a top, and opposing sidewalls running upwardly from the base to the top, comprising:
 - a portion of sidewall, having a substantially constant thickness, running along a curved path upwardly from proximity of the base toward the top of the chamber;
 - a plurality of perforations in said sidewall portion, spaced apart upwardly along the sidewall, running at substantially the same angle (SA) to the horizontal plane of the base;
 - wherein, the vertical height of perforation opening increases with perforation elevation from the base.
2. An arch shape cross section leaching chamber having a base, a top, and opposing sidewalls running upwardly from the base to the top, comprising:
 - a portion of sidewall running along a curved path upwardly from proximity of the base toward the top of the chamber;
 - a plurality of perforations in the sidewall portion, spaced apart upwardly along the sidewall;
 - wherein, perforation height varies with elevation from the base; and
 - wherein sidewall thickness varies with elevation from the base.
3. The chamber of claim 1 or 2 wherein a Soil Threshold Angle (STA) of said plurality of perforations is substantially similar.
4. The chamber of any one of claims 1 to 3 wherein a Soil Threshold Angle (STA) of said plurality of perforations is less than about 30 degrees.
5. The chamber of claim 2 wherein the perforations are slots having edge radii at interior and exterior surfaces of the sidewall; and, wherein the sidewall is thicker at an upper part of the perforated sidewall, then at a lower part of the sidewall, near the base.
6. The chamber of claim 5 wherein perforation height increases for slots at higher elevation from the base.
7. The chamber of claim 2 wherein perforation height increases and sidewall portion thickness decreases with elevation.

8. The chamber of claim 2, 6 or 7 wherein the perforation height and sidewall thickness change uniformly with elevation.
9. The chamber of claim 2, 6, 7 or 8 wherein the perforations are outward flaring slots.
10. The chamber of claim 2 wherein the thickness of said perforated sidewall portion is less than 2 times greater than a basic thickness of the chamber walls which are free of perforations.
11. For an arch shape cross section leaching chamber having a base, a top, and opposing perforated sidewalls running upwardly from the base to the top, the method of providing all the perforations with a Soil Threshold Angle (STA) greater than a predetermined value, which comprises: varying the wall thickness and height of the perforations with elevation from the base of the chamber.
12. The method of claim 11 wherein said predetermined value of STA is equal or less than a Repose Angle (RA) of soil for which the chamber use is intended.
13. An arch shape cross section corrugated leaching chamber having a base, a top, and opposing sidewalls running upwardly from the base to the top, the chamber which comprises:
 - a sidewall having a portion which runs curvingly upwardly and inwardly toward the top of the chamber,
 - the portion having a thickness and a plurality of upwardly spaced apart horizontally-extending slots for flowing water from within the interior of the chamber to the exterior of the chamber through the thickness of said sidewall portion;
 - each slot having an opening height proximate the exterior surface of the sidewall, which height is the vertical distance between the horizontally-extending surfaces which define the slot;
 - wherein, one or more of said plurality of slots which are at the upper part of the sidewall portion have opening height(s) which are greater than the opening height(s) of one or more of said plurality of slots which are at the lower part of the sidewall portion.
14. The chamber of claim 13 wherein said portion of sidewall has substantially constant thickness.
15. The chamber of claim 14 wherein said portion of sidewall comprises the substantial entirety of the slotted portion one of said opposing sidewalls.

16. The chamber of claim 14 wherein the slots are flared inwardly, so that the height of each slot at the exterior of the chamber is less than the slot height at the interior of the chamber.
17. The chamber of claim 13 wherein slot heights of slots in said portion increase progressively with increasing elevation.
18. The chamber of claim 17 wherein said portion comprises the substantial entirety of one of said opposing sidewalls.
19. The chamber of claim 13 wherein said portion of sidewall comprises the substantial entirety of the slotted portion one of said opposing sidewalls.
20. The chamber of claim 13 wherein the thickness of said sidewall portion decreases with increasing elevation.
21. The chamber of claim 13 wherein slot heights of slots in said portion and sidewall thickness of said portion change progressively with increasing elevation.
22. The chamber of claim 13 wherein said sidewall portion slots are outward flaring slots.
23. The chamber of claim 13 wherein said sidewall portion slots are inward flaring slots.
24. The chamber of claim 13 wherein the each of the slots in said sidewall portion has a downward sloping central axis.
25. The chamber of claim 13 wherein the Soil Threshold Angles (STA) of said plurality of slots is substantially similar;
wherein Soil Threshold Angle is the angle between a horizontal line and a straight line running from the top outside edge of a slot to the bottom inside edge of the slot.
26. The chamber of claim 25 wherein the Soil Threshold Angles (STA) are less than about 30 degrees.

27. The chamber of claim 25 wherein the Soil Threshold Angles (STA) are less than about 26 degrees.
28. The chamber of claim 13 wherein the basic wall thickness of the chamber is about 0.1 inch or less.
29. The chamber of claim 13 wherein the chamber has corrugations which comprise adjacent peaks and valleys running across the arch of the chamber cross section; and
wherein the pitch or spacing between adjacent peaks is between 6 and 8 inches.
30. An arch shape cross section leaching chamber made of molded thermoplastic comprising:
a base; a top; and opposing sidewalls running upwardly from the base to the top, having portions which run curvingly inwardly and upwardly toward the top;
said portions having horizontally-extending slots spaced apart upwardly along the sidewall portion, wherein the slots have opening heights proximate the exterior surface of the sidewall which vary progressively with increasing elevation from the base,
wherein slot opening height is the vertical distance between horizontally-extending surfaces which define the slot proximate the exterior surface of the sidewall.
31. The chamber of claim 30 wherein the average wall thickness for all the slotted portions of the sidewalls is less than about 2.5 times the average wall thickness of the un-perforated other portions of the chamber.
32. The chamber of claim 30 wherein substantially all the slots have substantially the same Soil Threshold Angle (STA),
wherein Soil Threshold Angle is the angle between a horizontal line and a straight line running from the top outside edge of a slot at the exterior of the chamber to the bottom inside edge of the slot at the inside of the chamber.
33. A method for constructing a portion of the sidewall of an arch shape cross-section leaching chamber,
wherein the chamber has a base, a top, and opposing sidewalls running upwardly from the base to the top, which comprises:

(a) forming a portion of the sidewall to run curvingly upwardly and inwardly from the base toward the top of the chamber, the portion having a thickness; and

(b) forming a plurality of upwardly spaced apart horizontally-extending slots in said sidewall portion,

wherein each slot has an opening height which is the vertical distance between horizontal surfaces which define the slot so that the opening heights proximate the exterior surface of the sidewall of said plurality of slots varies as a function of slot elevation from the base of the chamber, and so that each slot has a Soil Threshold Angle (STA) which is substantially equal to a predetermined value,

wherein Soil Threshold Angle is the angle between a horizontal line and a straight line running from the top outside edge of a slot to the bottom inside edge of the slot.

34. The method of claim 33 wherein said predetermined value of Soil Threshold Angle (STA) is 30 degrees.

35. The method of claim 33 wherein step (c) further comprises: keeping constant the wall thickness of the sidewall portion.

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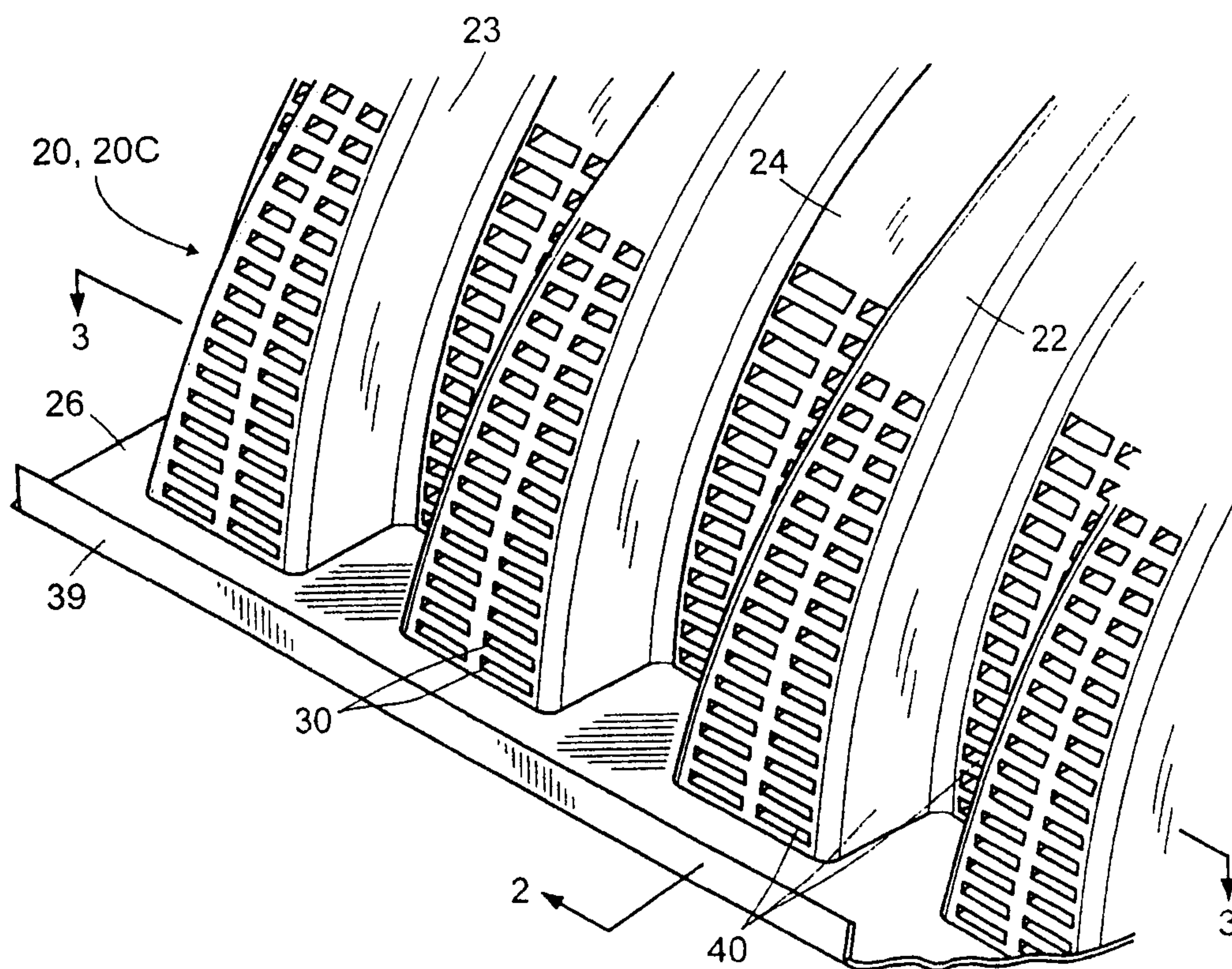


FIG. 1

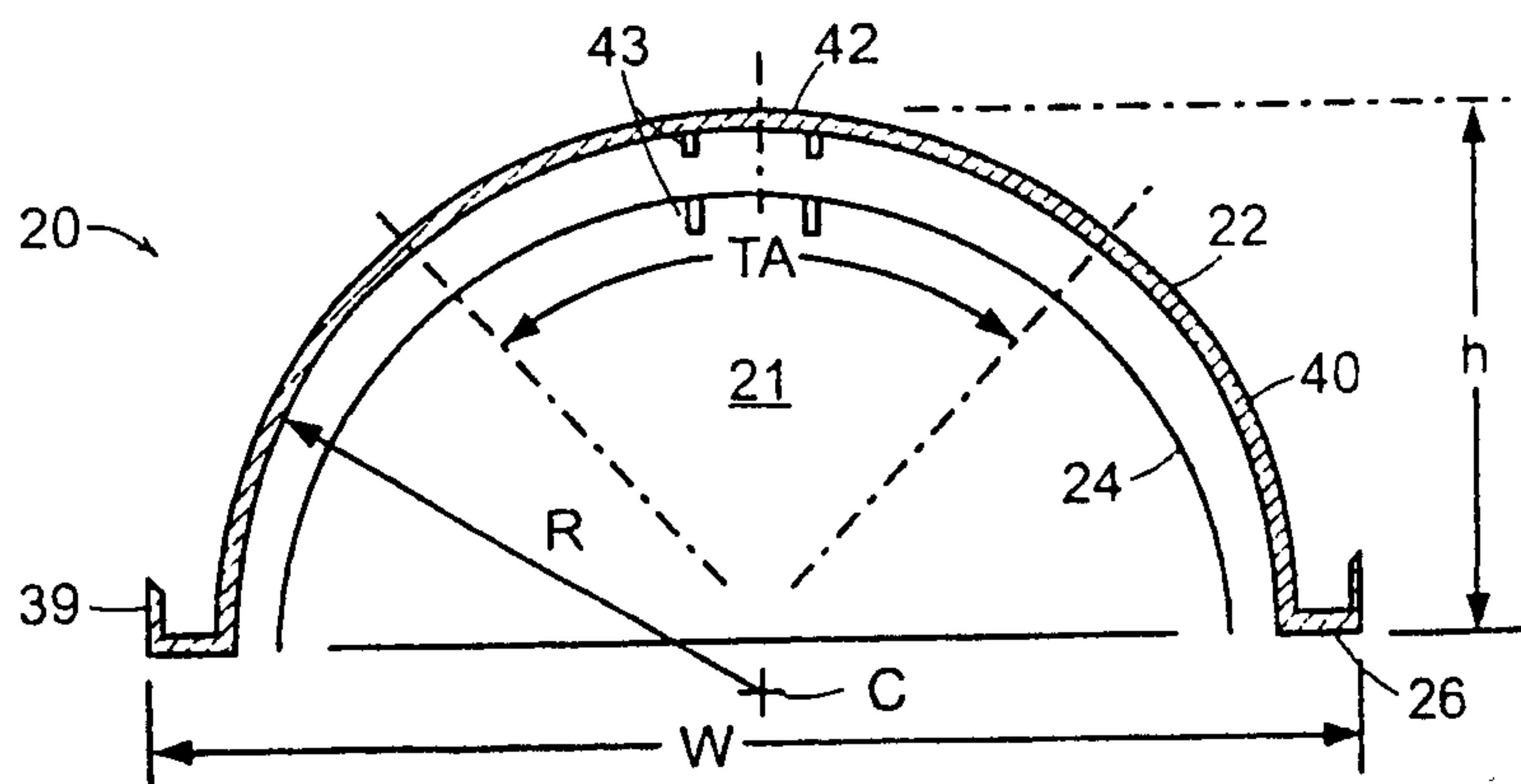


FIG. 2

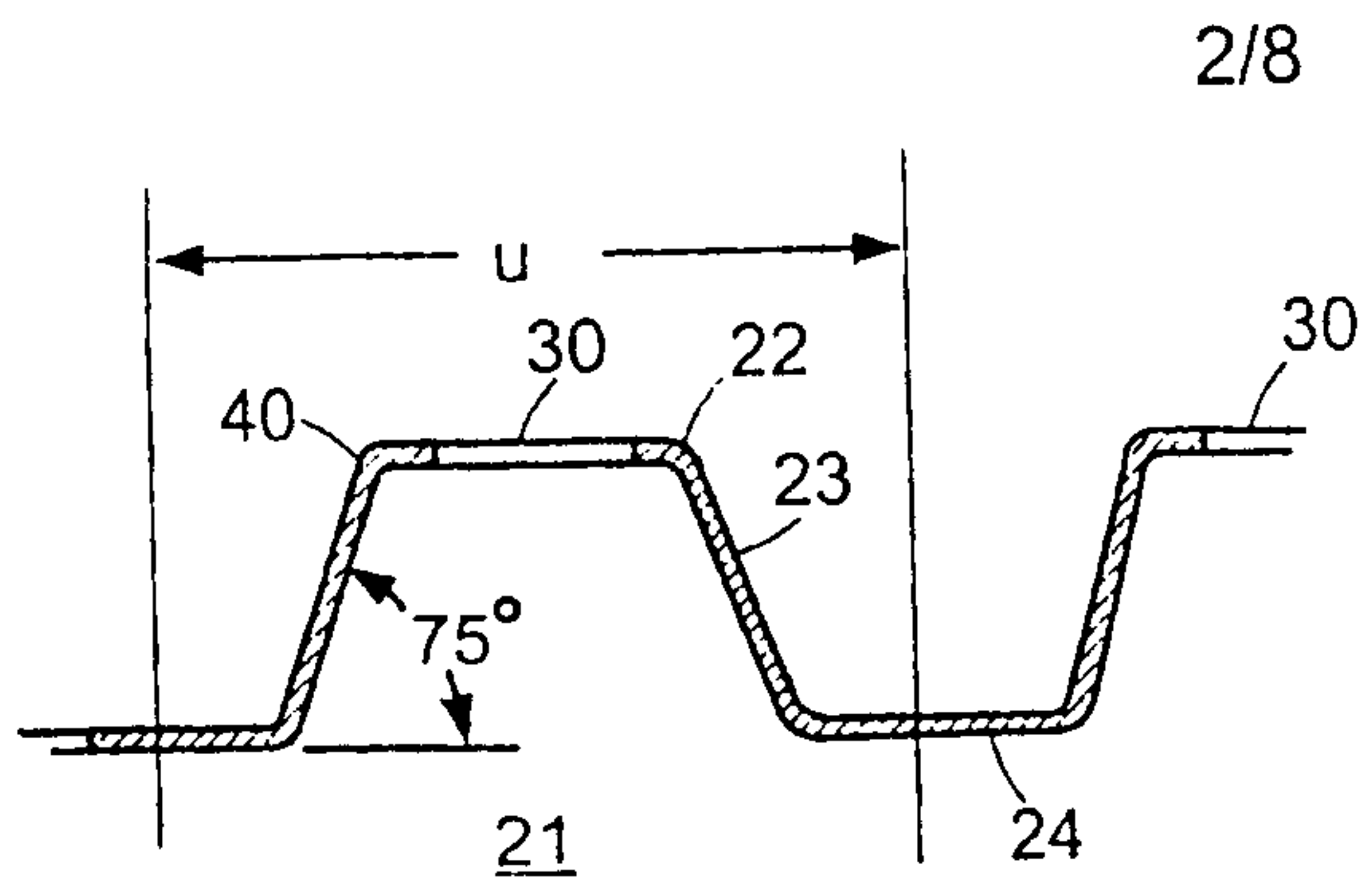


FIG. 3

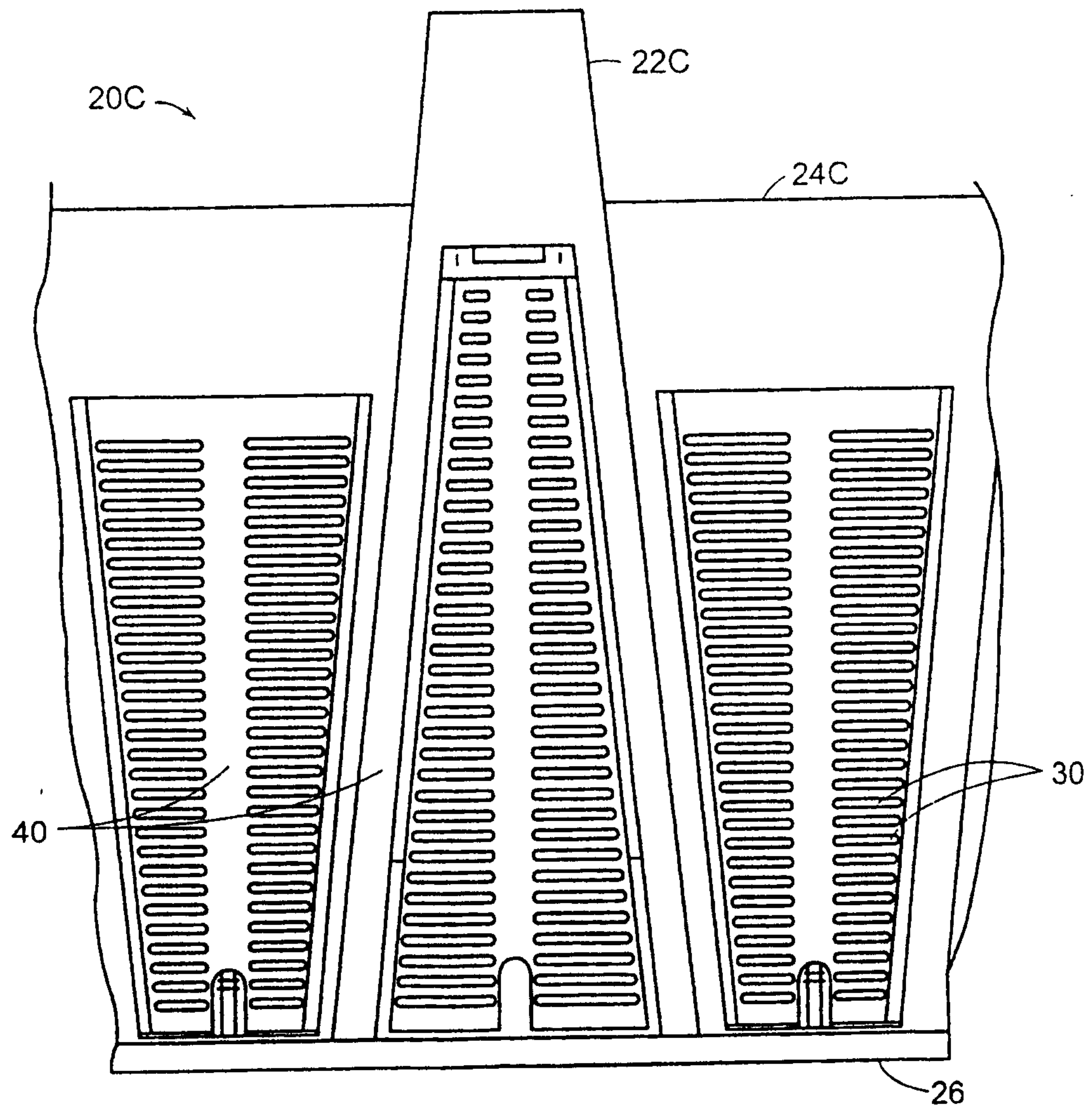


FIG. 4

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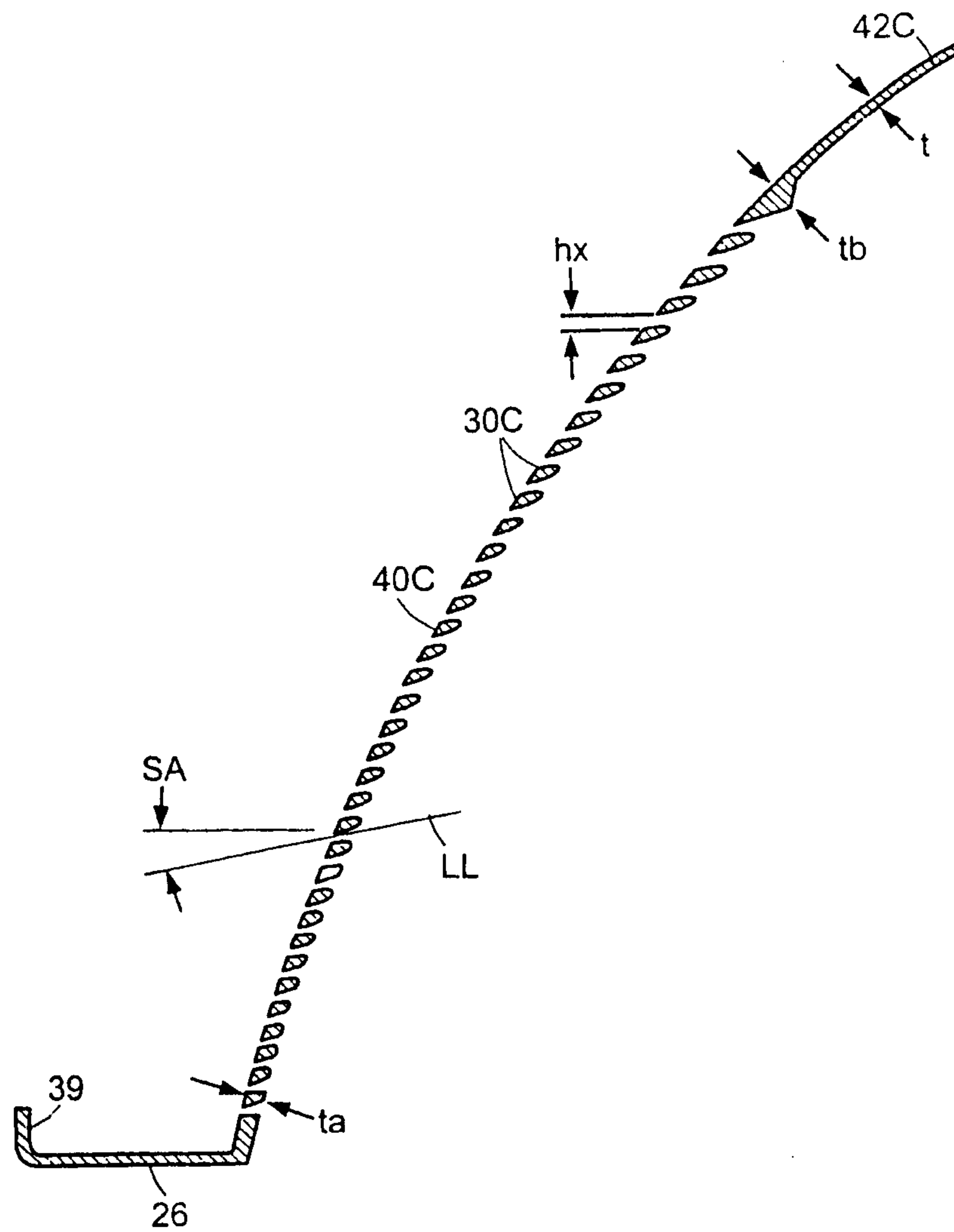


FIG. 5

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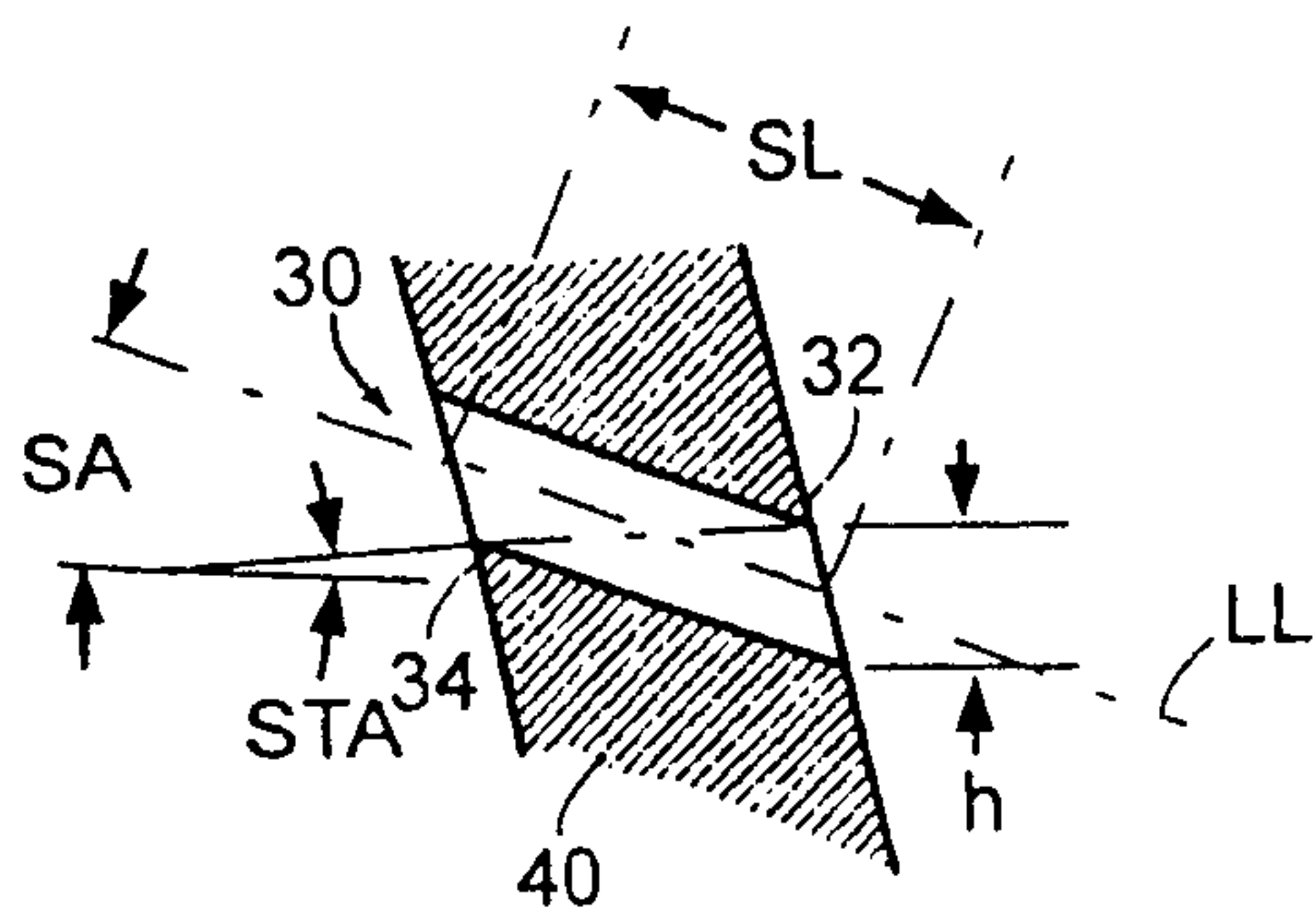


FIG. 6

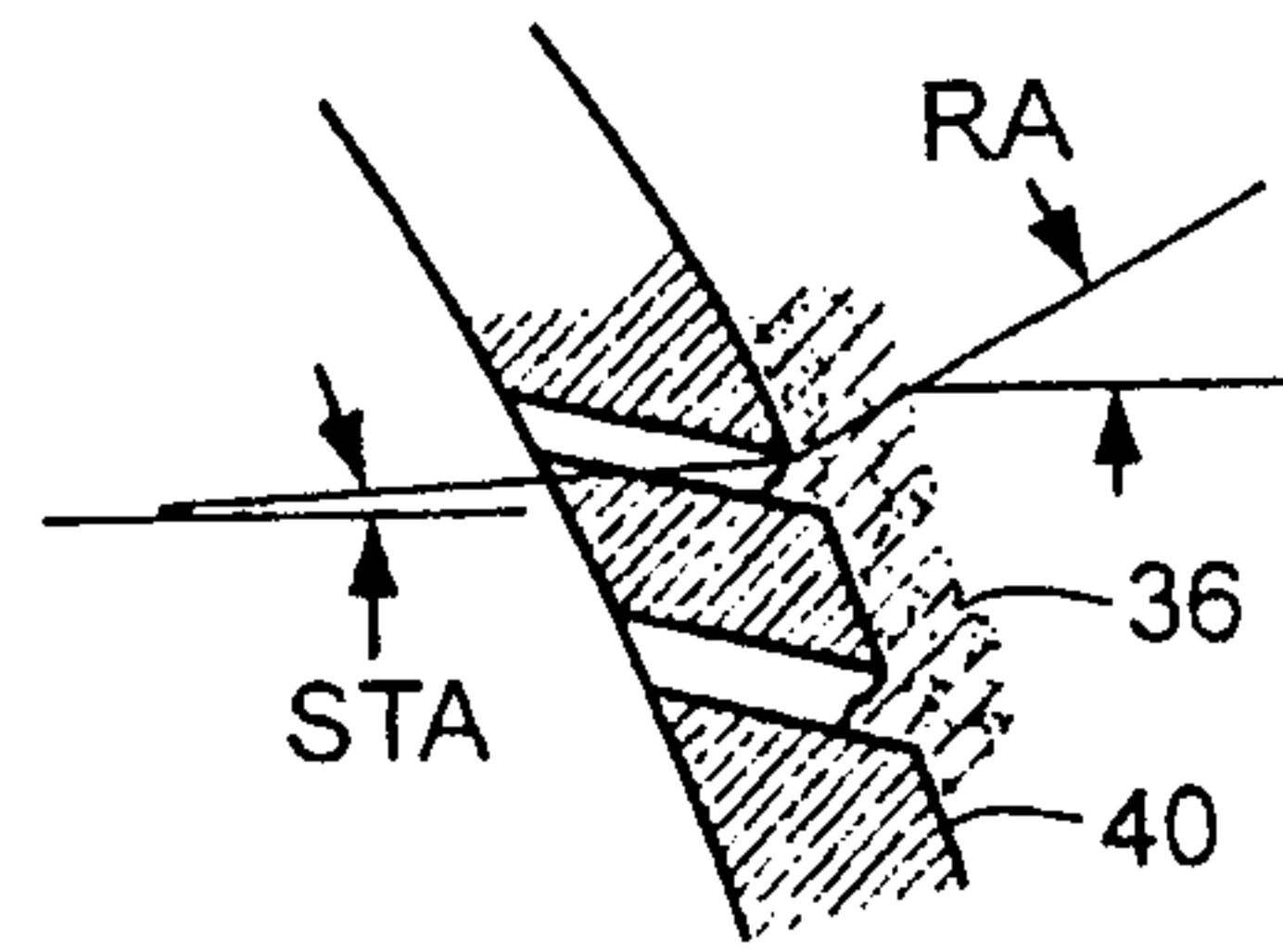


FIG. 7

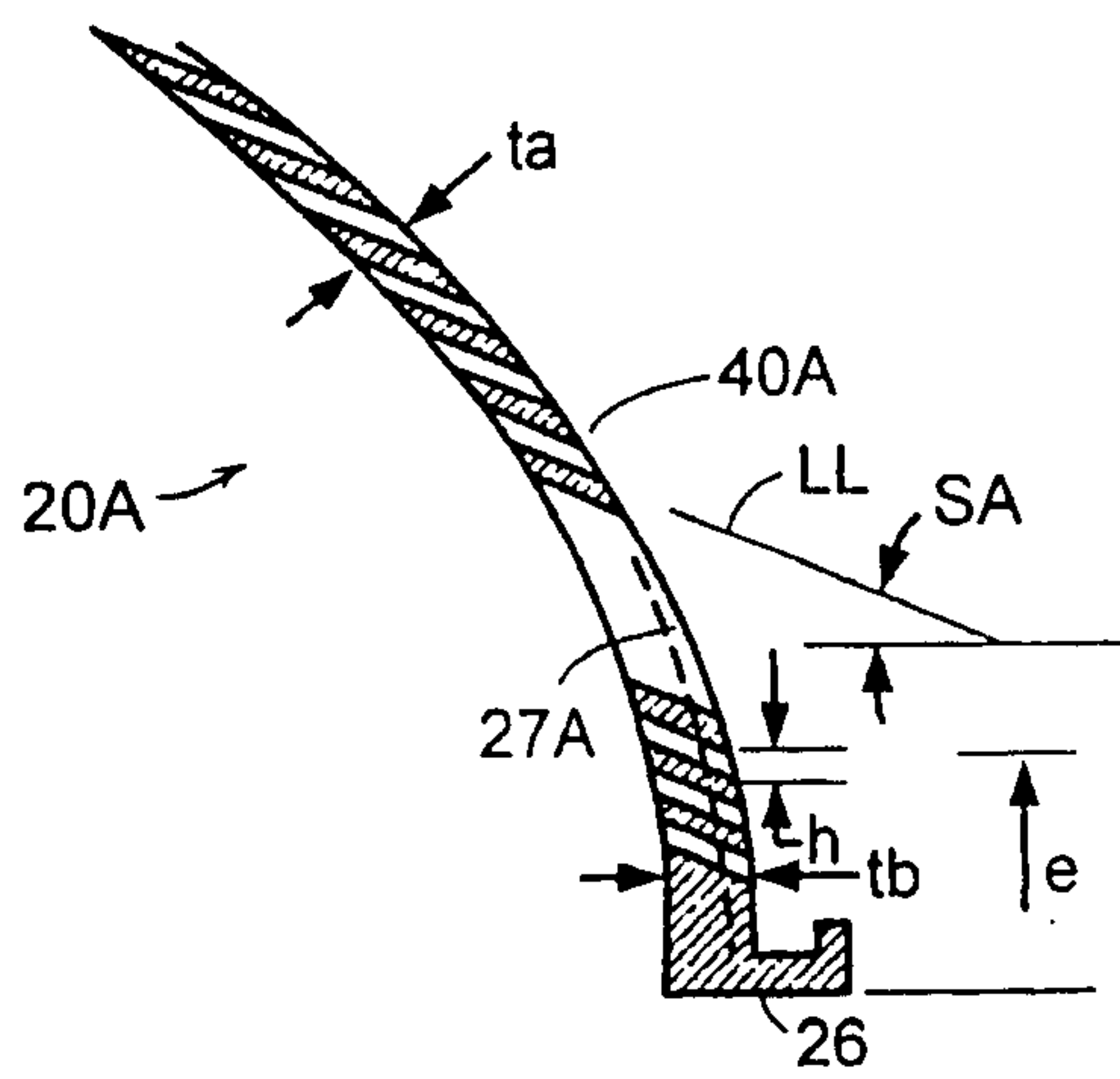


FIG. 8

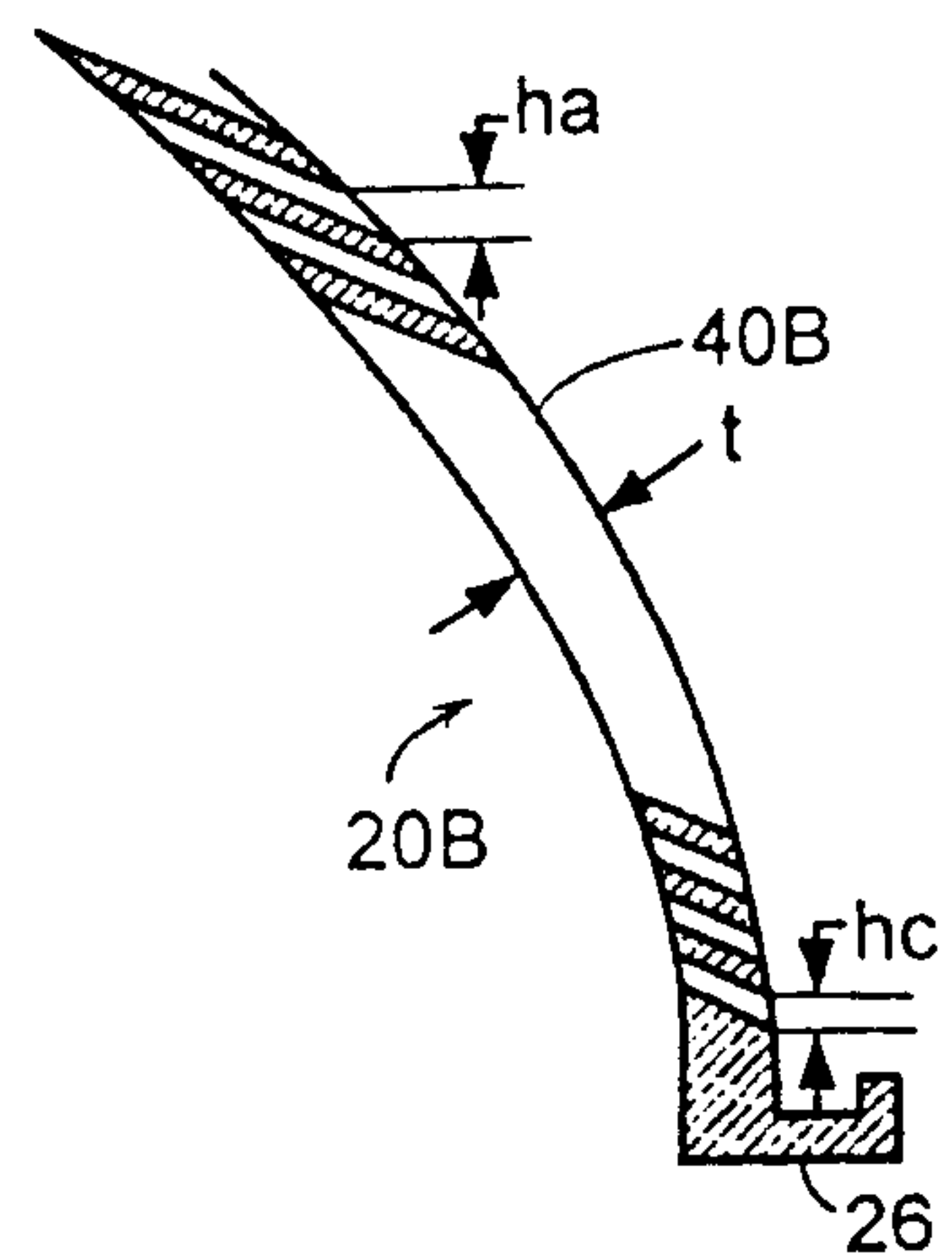


FIG. 9

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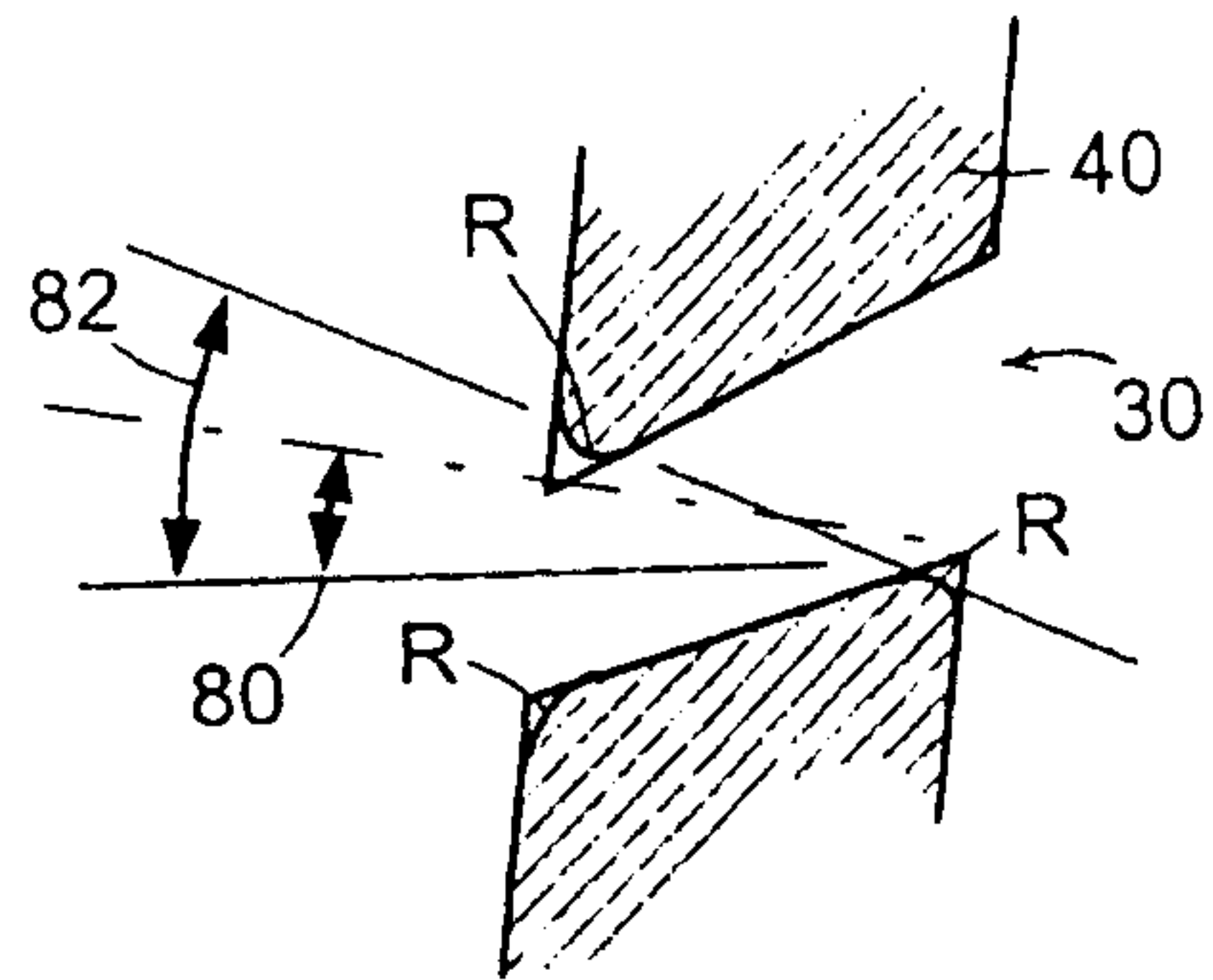


FIG. 10

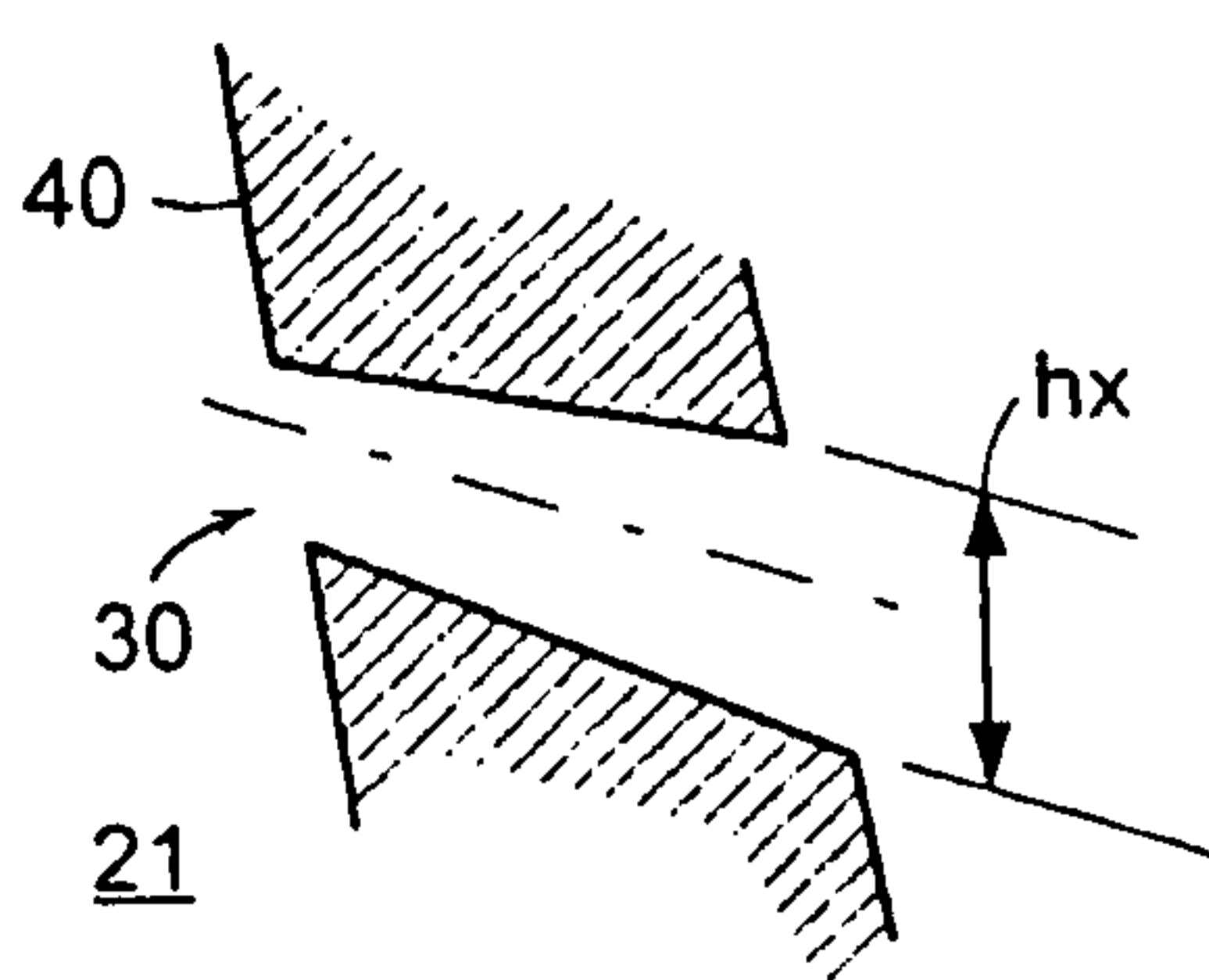


FIG. 11

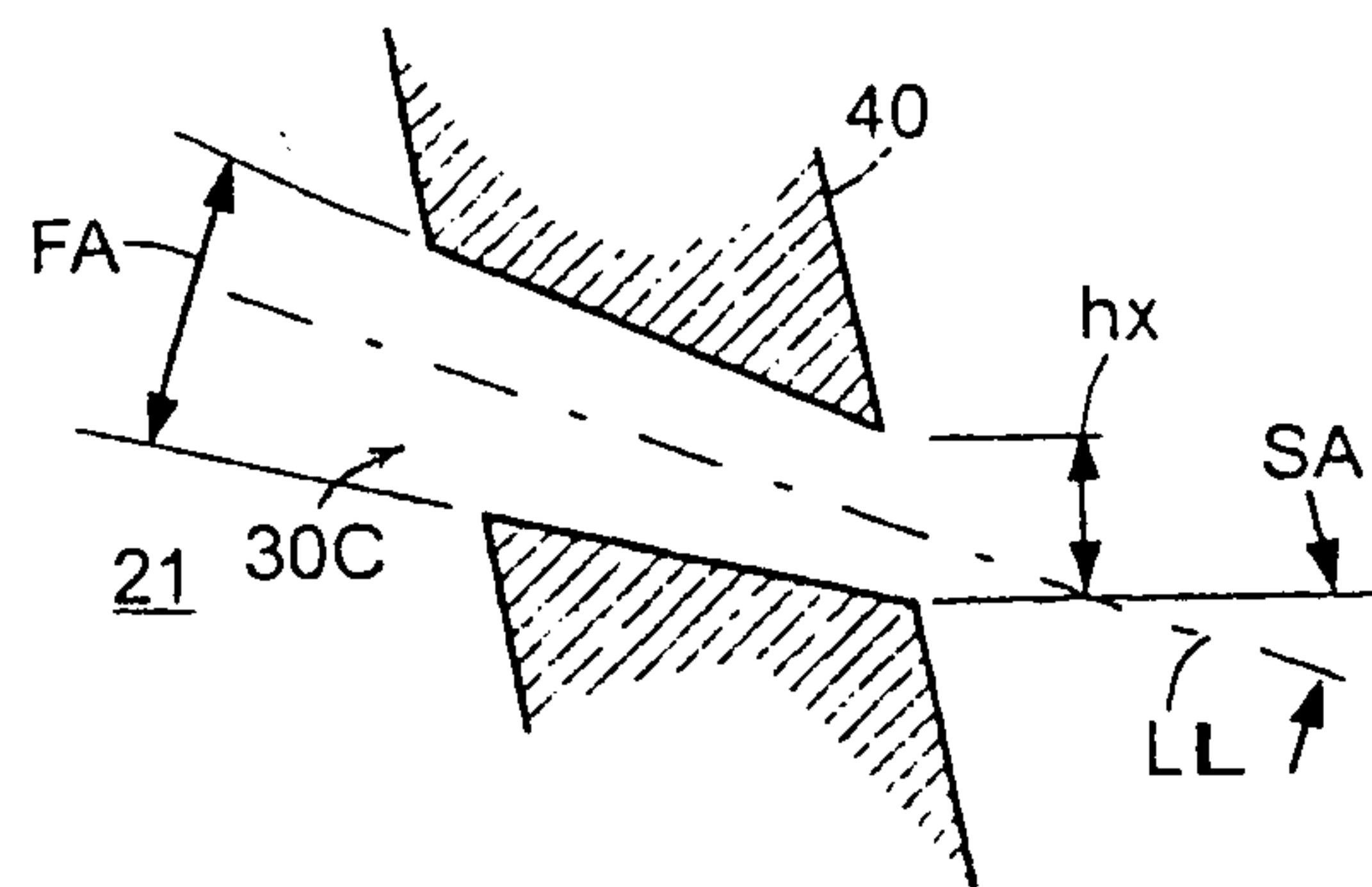


FIG. 12

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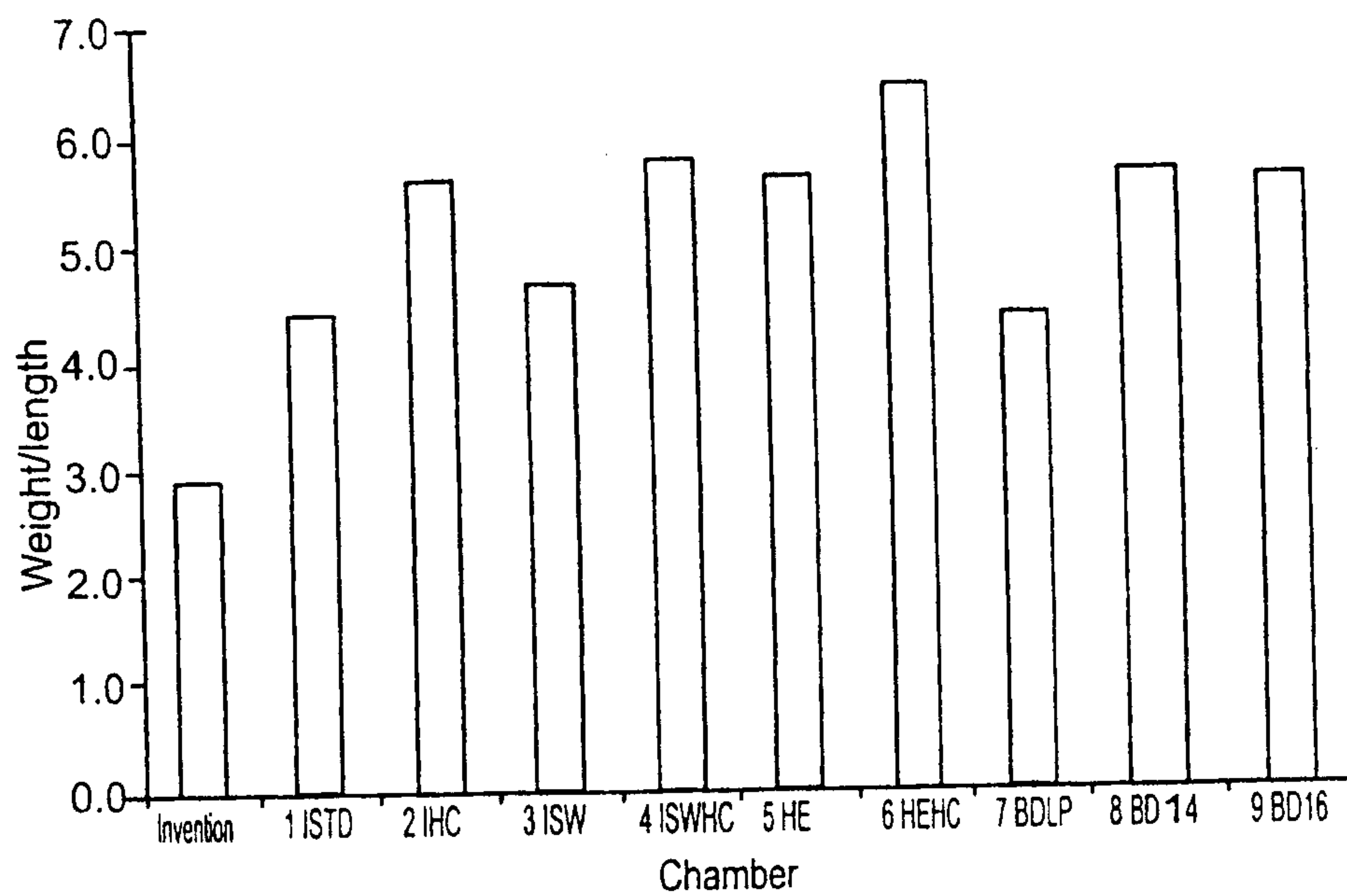


FIG. 13

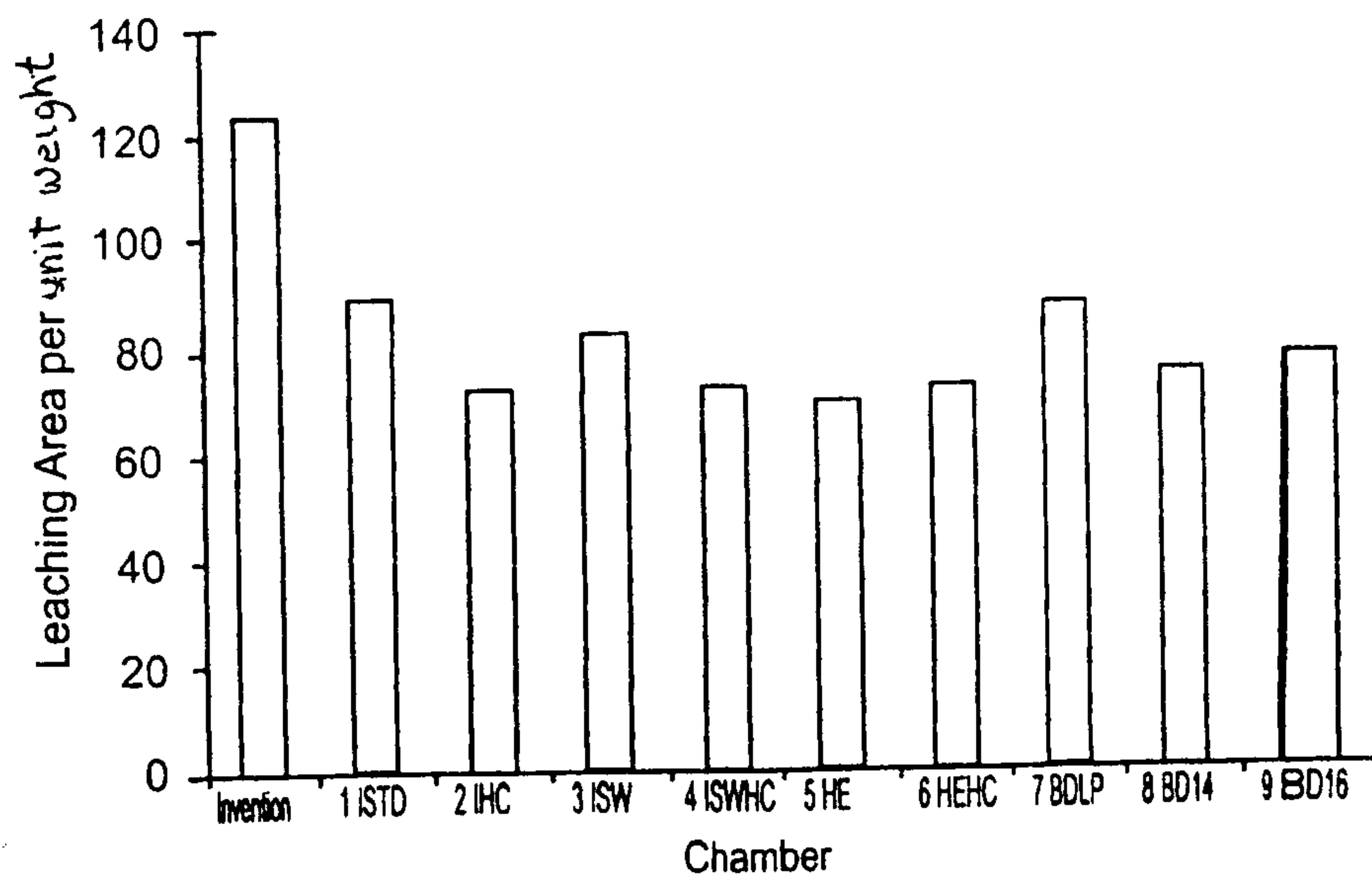


FIG. 14

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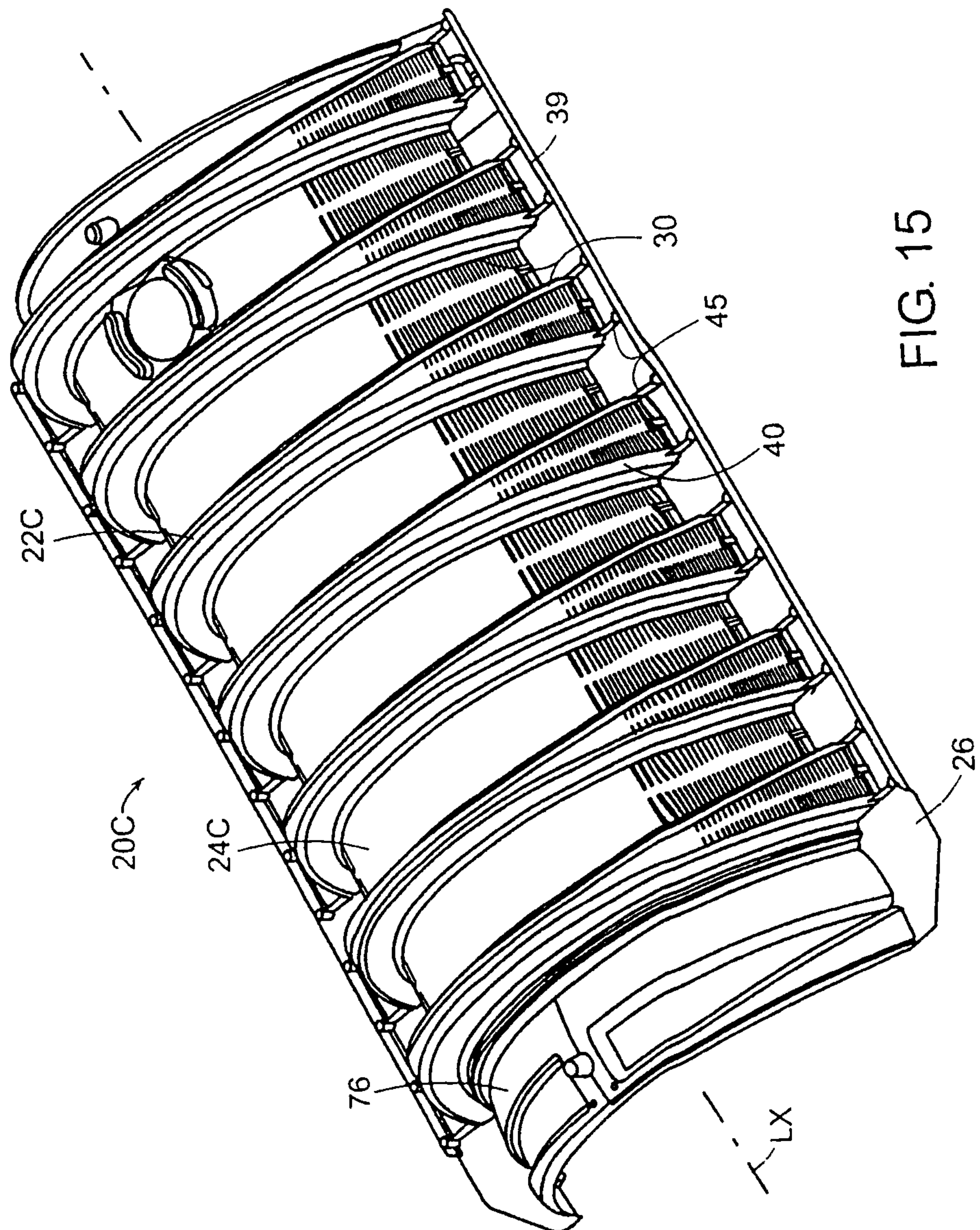


FIG. 15

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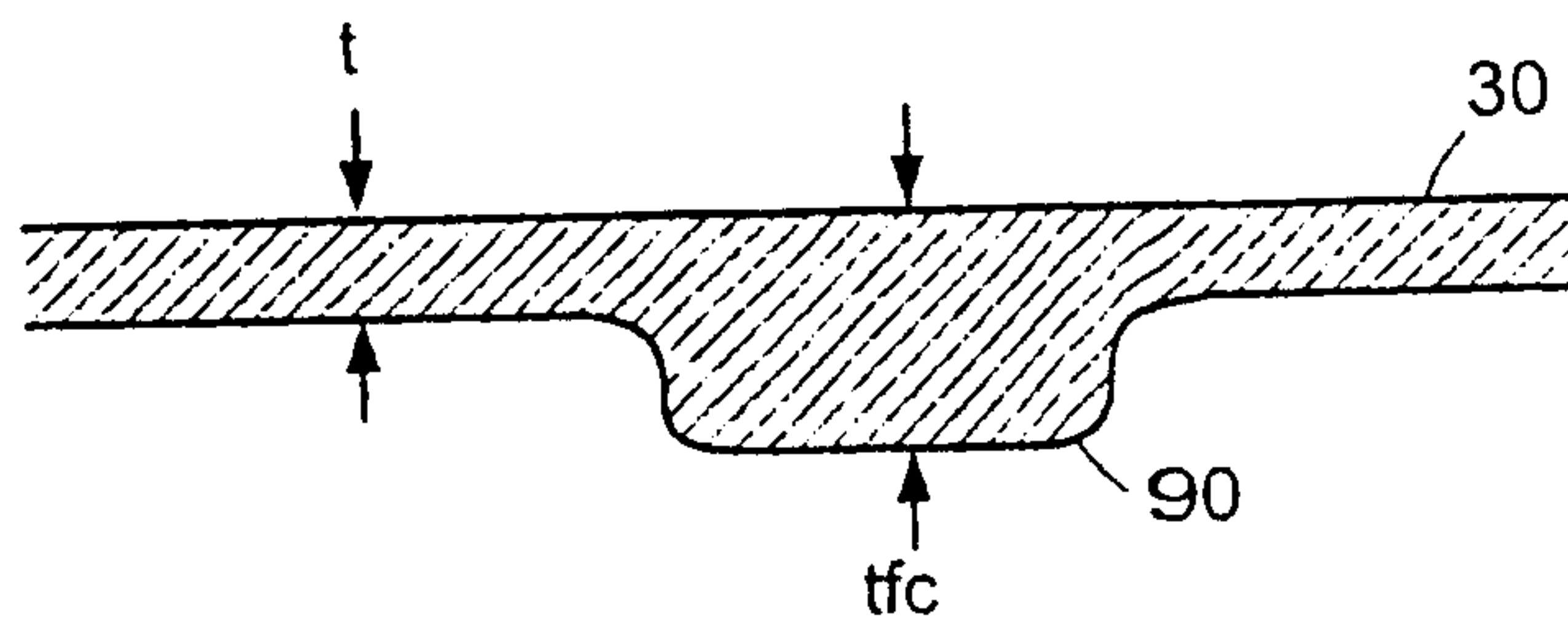


FIG. 16

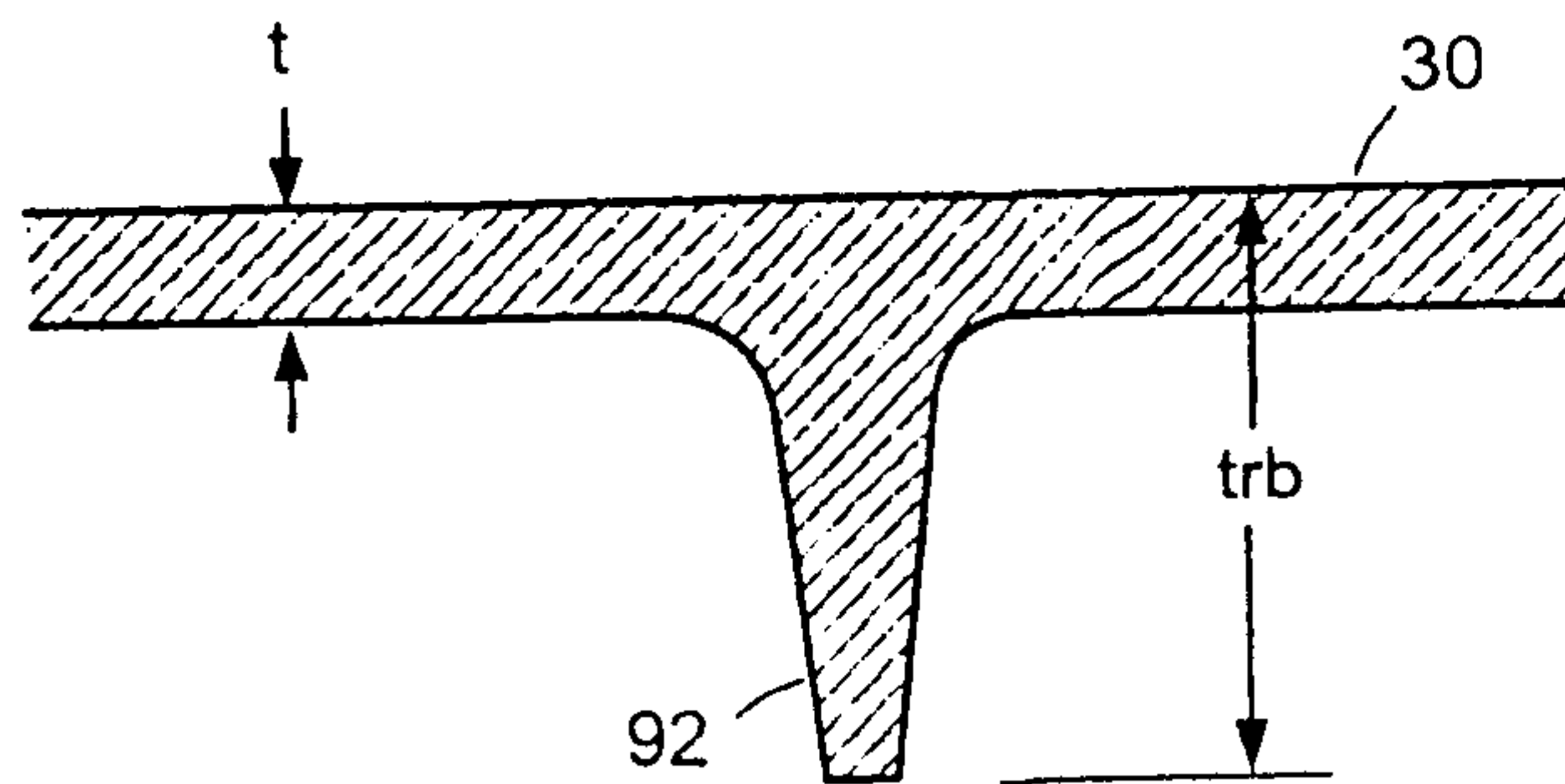


FIG. 17

