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An agency of Industry Canada

CA 2974436 A1 2016/08/04

(21) 2 974 436

(12) DEMANDE DE BREVET CANADIEN
CANADIAN PATENT APPLICATION

(13) A1

(86) Date de dépôt PCT/PCT Filing Date: 2016/01/25
(87) Date publication PCT/PCT Publication Date: 2016/08/04
(85) Entrée phase nationale/National Entry: 2017/07/19
(86) N° demande PCT/PCT Application No.: US 2016/014772
(87) N° publication PCT/PCT Publication No.: 2016/123038
(30) Priorités/Priorities: 2015/01/26 (US62/107,955); 2015/06/30 (US62/187,193)

(51) Cl.Int./Int.Cl. *E04C 2/32* (2006.01), *B31D 3/00* (2017.01), *E04B 9/00* (2006.01), *E04B 9/04* (2006.01), *E04C 2/22* (2006.01), *E06B 9/24* (2006.01)

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(54) Titre : PANNEAU EXTENSIBLE
(54) Title: EXPANDABLE PANEL

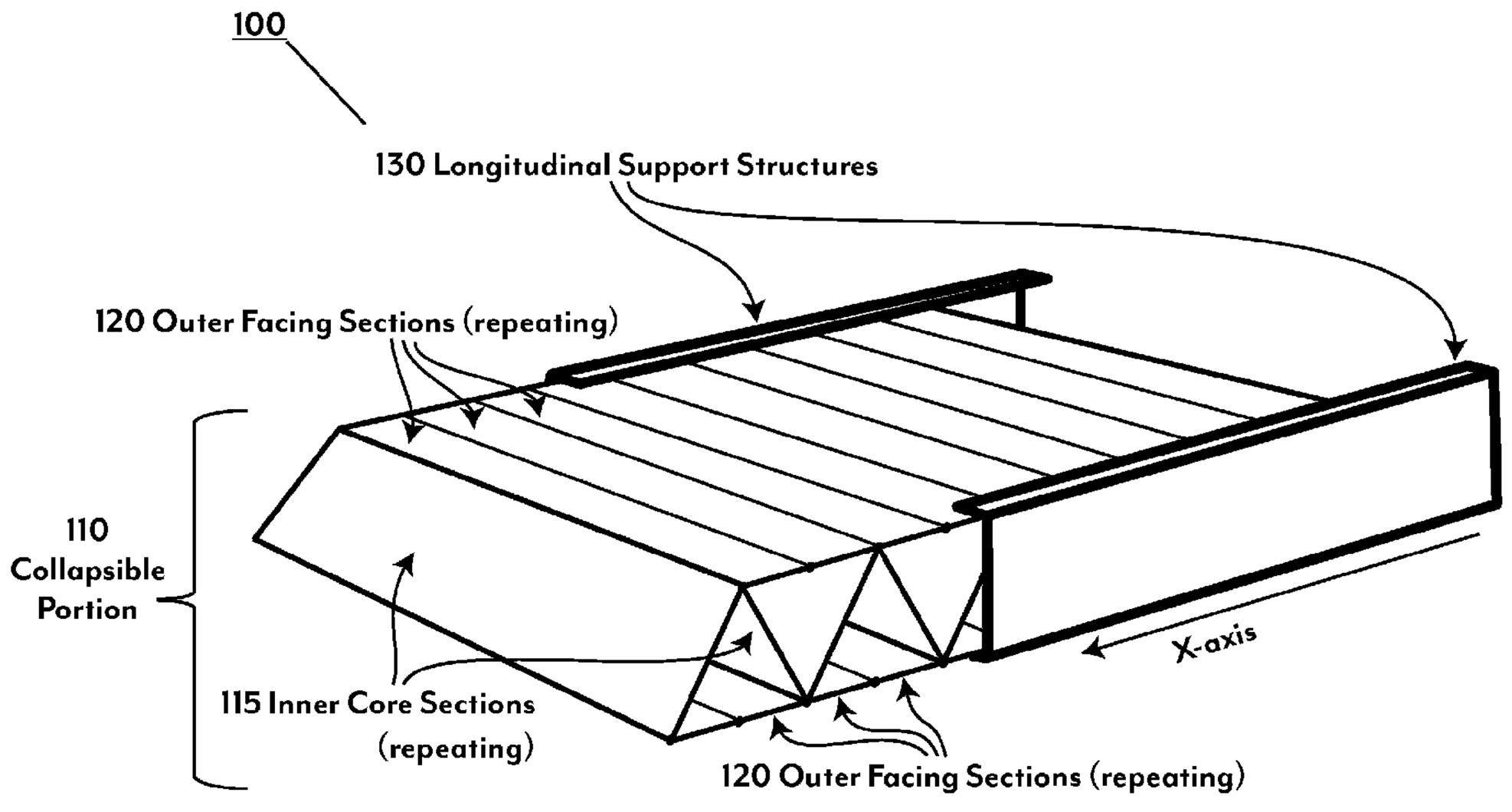

Fig. 1B

(57) Abrégé/Abstract:
A lightweight, compressible panel structure can include a collapsible portion that includes outer facing sections and inner core sections connected by hinge points and/or hinge assemblies. One or more longitudinal support structures can be included to hold the expandable panel structure in its expanded configuration. Methods and apparatus are described.

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
4 August 2016 (04.08.2016)

WIPO | PCT

(10) International Publication Number
WO 2016/123038 A1

(51) International Patent Classification:
E06B 9/24 (2006.01) *E04C 2/32* (2006.01)
B31D 3/00 (2006.01) *E04C 2/22* (2006.01)
E04B 9/00 (2006.01) *E04B 9/04* (2006.01)

(21) International Application Number:
PCT/US2016/014772

(22) International Filing Date:
25 January 2016 (25.01.2016)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
62/107,955 26 January 2015 (26.01.2015) US
62/187,193 30 June 2015 (30.06.2015) US

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(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report (Art. 21(3))*

— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))*

(54) Title: EXPANDABLE PANEL

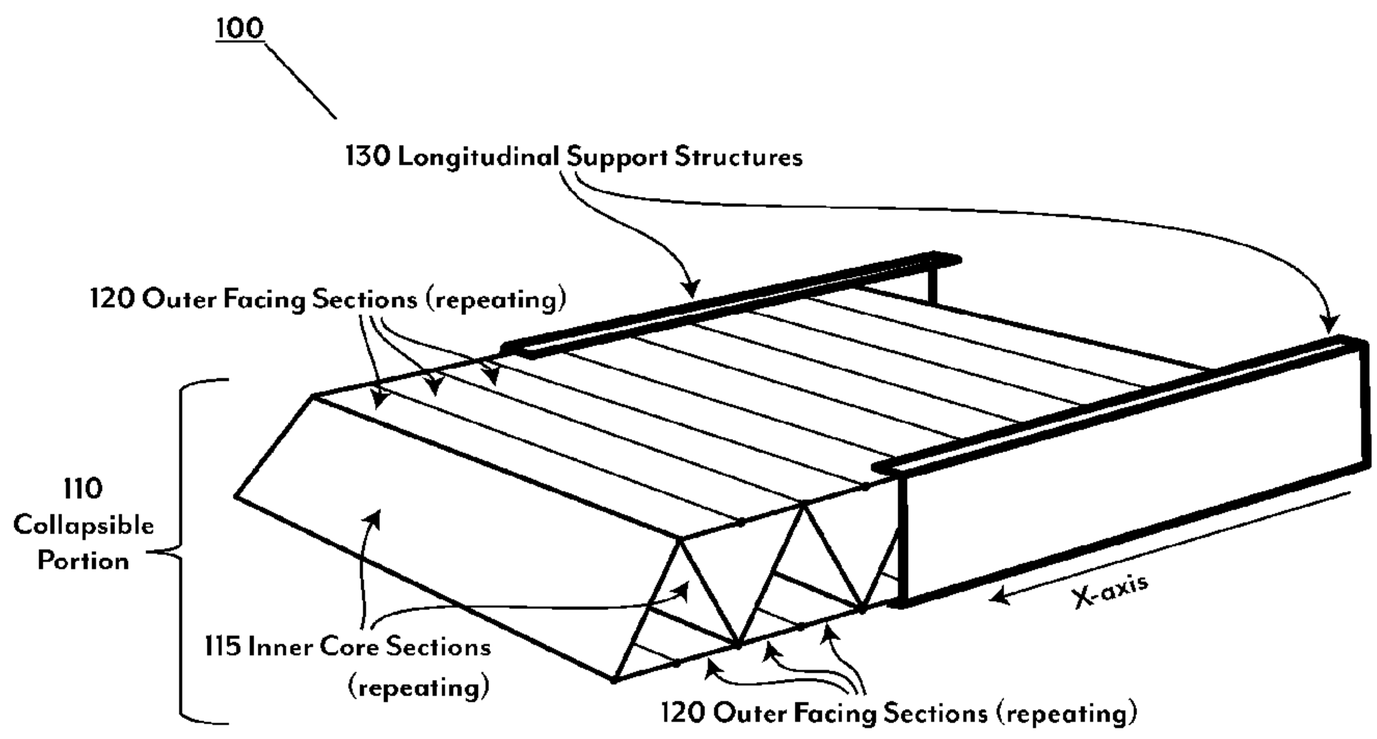

Fig. 1B

(57) Abstract: A lightweight, compressible panel structure can include a collapsible portion that includes outer facing sections and inner core sections connected by hinge points and/or hinge assemblies. One or more longitudinal support structures can be included to hold the expandable panel structure in its expanded configuration. Methods and apparatus are described.

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EXPANDABLE PANEL

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] The current application claims priority to U.S. Provisional patent application serial number 62/107,955 filed on January 26, 2015 and entitled "Expandable Panel" and U.S. Provisional patent application serial number 62/187,193 filed on June 30, 2015 and entitled "Expandable Panel," which are both incorporated by reference herein in their entirety.

TECHNICAL FIELD

[0002] The subject matter described herein relates to an expandable panel structure that includes a collapsible portion and, in some implementations, can further include one or more longitudinal support structures.

BACKGROUND

[0003] There may be instances where robust structures, such as for example shelters, temporary bridges, support platforms, or the like, need to be constructed quickly and inexpensively.

SUMMARY

[0004] Aspects of the current subject matter can include a compressible panel that has a collapsible portion and, in some implementations, can further include one or more longitudinal support structures.

[0005] In a first aspect, an apparatus includes a collapsible panel structure configured to form an expanded configuration and a collapsed configuration. The collapsible panel structure includes outer facing sections forming a first side and a second side of the

collapsible panel structure, and inner core sections arranged in a zig-zag manner between the first side and the second side with vertex hinge points pivotally coupling adjoining inner core sections. The first and second sides include facing pair hinge points that pivotally couple adjoining outer facing sections. The inner core sections and the outer facing sections form a series of adjoining triangular prisms when the collapsible panel structure is in the expanded configuration, and the inner core sections and outer facing sections form a series of adjoining quadrilateral prisms when the collapsible panel structure is transitioning into the collapsed configuration.

[0006] In a second, interrelated aspect, an apparatus includes a collapsible panel structure configured to form an expanded configuration and a collapsed configuration. The collapsible panel structure includes outer facing sections forming a first side and a second side of the collapsible panel structure, inner core sections arranged in a zig-zag manner between the first side and the second side with inner core hinge points that pivotally couple adjoining inner core sections, extensions that extend between each coupling of an inner core section and an inner core hinge point thereby offsetting the inner core hinge point from a longitudinal length of the inner core section, and supplemental hinge points that pivotally couple adjoining outer facing sections and inner core sections. The first and second sides include facing pair hinge points that pivotally couple adjoining outer facing sections. The inner core sections, the extensions, and the outer facing sections form a series of adjoining quadrilateral prisms when the collapsible panel structure is in the expanded configuration, and wherein the inner core sections, the extensions, and the outer facing sections form a series of adjoining six-sided prisms when the collapsible panel structure is transitioning into the collapsed configuration.

[0007] In a third interrelated aspect, a method includes expanding a collapsible portion of a collapsible panel structure along an axis perpendicular to faces of a plurality of

inner core sections of the collapsible panel structure; and completing the expanding of the collapsible portion upon planar alignment of two outer facing sections of the collapsible panel structure joined at a facing pair hinge point that is disposed opposite a vertex hinge point joining two of the inner core sections. The inner core sections are arranged in a zig-zag manner between a first side of outer facing sections and a second side of outer facing sections with vertex hinge points pivotally coupling adjoining inner core sections. A method can optionally include joining a longitudinal support structure to the expanded collapsible portion, subsequently removing the longitudinal support structures, and re-collapsing the collapsible portion.

[0008] In a fourth interrelated aspect, a method includes expanding a collapsible portion of a collapsible panel structure along an axis perpendicular to faces of a plurality of inner core sections of the collapsible panel structure and completing the expanding of the collapsible portion upon planar alignment of two outer facing sections of the collapsible panel structure joined at a facing pair hinge point that is disposed opposite an inner core hinge point joining two of the inner core sections. The inner core sections are arranged in a zig-zag manner between a first side of outer facing sections and a second side of outer facing sections with inner core hinge points pivotally coupling adjoining inner core sections and are offset from longitudinal lengths of the adjoining inner core sections by extensions. Supplemental hinge points pivotally couple adjoining outer facing sections and inner core sections. A method can optionally include joining a longitudinal support structure to the expanded collapsible portion, subsequently removing the longitudinal support structures, and re-collapsing the collapsible portion.

[0009] In optional variations, one or more of the following features can be included or incorporated into the aforementioned aspects in any feasible combination. A support structure can be included to extend along a length of the collapsible panel structure in the

expanded configuration. The support structure can include one or more of an open channel that is configured to cap a first end of the collapsible panel structure, a telescoping segment that allows the support structure to at least partially collapse, and a plurality of joinable segments. The support structure can extend through openings located along the inner core sections. The support structure can be curved.

[00010] In at least the first aspect, the vertex hinge points can optionally be located at an apex of each triangular prism of the series of adjoining triangular prisms when the collapsible portion is in the extended configuration. Two outer facing sections jointed at a facing pair hinge point can be aligned with an opposite vertex hinge point joining two inner core sections. When the collapsible panel structure is transitioning into the collapsed configuration, a facing pair hinge point of the facing pair hinge points is located at a top or a bottom of each quadrilateral prism of the series of adjoining quadrilateral prisms.

[00011] In at least the second aspect, two outer facing sections can optionally be in an alignment and jointed at a facing pair hinge point that is disposed opposite an inner core hinge point when the collapsible portion is in the extended configuration. When the collapsible panel structure is transitioning into the collapsed configuration, the facing pair hinge points and inner core hinge points can be alternately located at a top and a bottom of each hexagonal prism of the series of adjoining quadrilateral prisms.

[00012] The details of one or more variations of the subject matter described herein are set forth in the accompanying drawings and the description below. Other features and advantages of the subject matter described herein will be apparent from the description and drawings, and from the claims.

DESCRIPTION OF DRAWINGS

[00013] The accompanying drawings, which are incorporated in and constitute a part of this specification, show certain aspects of the subject matter disclosed herein and, together with the description, help explain some of the principles associated with the disclosed implementations. In the drawings,

[00014] FIG. 1A is a front elevation view of a compactable, light-weight panel according to some embodiments;

[00015] FIG. 1B is a partially exploded perspective view of the compactable, light-weight panel of FIG. 1A;

[00016] FIG. 1C is a front elevation view of a compactable, light-weight panel with a collapsible portion that can slide onto longitudinal support structures, according to some embodiments;

[00017] FIG. 1D is a partially exploded perspective view of the compactable, light-weight panel of FIG. 1C;

[00018] FIG. 2 is a cross-sectional view of the compressible portion of the panel of FIGs. 1A - 1D;

[00019] FIG. 3 is a view of the compressible portion of the panel of FIG. 2 when it is compressed;

[00020] FIGs. 4A-4C show a cross-sectional view of the compressible portion of a light-weight panel that is curved along its expansion length which is representative of some embodiments;

[00021] FIG. 5 shows a view of a compactable, light-weight panel that is expandable to form a curved structure;

[00022] FIG. 6 shows a process flow chart illustrating features of a method consistent with implementation of the current subject matter;

[00023] FIG. 7 shows a partially exploded perspective view of a compactable, light-weight panel including supplemental hinge points and inner core hinge points;

[00024] FIG. 8 shows a cross-sectional view of the compressible portion of the light-weight panel of FIG. 7;

[00025] FIG. 9 shows a partially exploded perspective view of a compactable, light-weight panel including vertex hinge links; and

[00026] FIG. 10 shows a cross-sectional view of the compressible portion of the light-weight panel of FIG. 9.

[00027] When practical, similar reference numbers denote similar structures, features, or elements.

DETAILED DESCRIPTION

[00028] The descriptions herein include methods, approaches, techniques, articles, and systems relating to light-weight structural panels or other structures that can be compacted into a small volume when not in use. In some aspects, implementations of the current subject matter can include a compactable part and one or more support parts, which can also be referred to as longitudinal support parts. Implementations of the current subject matter can be useful in many applications, including but not limited to situations involving assembling structures in areas where it would be prohibitive or unwieldy to bring in conventional building materials, as well as where it may be time intensive to construct shelters using conventional materials. Convenience of assembly, disassembly, transportation, and storage can all be improved relative to existing approaches.

[00029] The above-noted aspects and features may be implemented in systems, apparatus, methods, and/or articles depending on the desired configuration. The details of one or more variations of the subject matter described herein are set forth in the accompanying drawings and the description below. Features and advantages of the subject

matter described herein will be apparent from the description and drawings, and from the claims.

[00030] FIG. 1A is a front elevation view of an exemplary construction panel 100 that is lightweight, but that can be compacted into a small volume when not in use and expanded from this small volume to a usable form both quickly and conveniently. The panel 100 includes two types of components: a collapsible portion 110 and longitudinal support structures 130. The collapsible portion 110 may be an accordion-like structure that can compress down to a small volume or expand out to span a length that is significantly longer than the height of the collapsible portion when it is compacted for transportation or storage. In some examples, the collapsible portion 110 in its collapsed configuration can have a length that is approximately one tenth the length of the expandable panel when fully expanded. Furthermore, because of the open structure of the expandable panel when in the expanded configuration, such structures can be lightweight and readily portable (e.g. when collapsed) while providing excellent rigidity.

[00031] The longitudinal support structures 130 can in some implementations of the current subject matter have a fixed geometry (e.g. they need not be collapsible like the collapsible portion 110). In other implementations of the current subject matter, a longitudinal support structure 130 can include one or more telescoping segments or segments that are combinable in other manners such that the longitudinal support structure 130 can be at least partially collapsed for transportation and storage. In one example, a longitudinal support structure 130 can be formed of two or more segments that are joinable by any feasible mechanism (e.g. threaded connections, an insertable feature of a first segment that slides into a receiving feature of a second segment, etc.)

[00032] As seen in FIG. 1A, the collapsible portion 110 includes at least one inner core section 115 and outer facing sections 120 which are above and below the inner

core sections 115. The longitudinal support structures 130 can optionally be shaped like caps that fit over the ends of the collapsible portion 110. Other configurations of the longitudinal support structures 130 are also within the scope of the current subject matter, including but not limited to the other variations discussed below. The length of the support structures 130 can correspond at least approximately to the length of the collapsible portion 110 when it is extended to an appropriate, load-bearing length, as seen in FIG. 1B, but may extend further, depending upon the application.

[00033] FIG. 1B is a perspective view of the panel 100 of FIG. 1A. In the view of FIG. 1B, the collapsible portion 110 can be seen to have multiple inner core sections 115 that are sections or strips of material that are arranged in a zig-zag manner, connecting at the edge of each core section 115 to an adjacent core section and/or to an outer facing section 120, either connecting directly by a simple hinge, or by means of an intermediary hinge assembly or other jointed assembly or combination thereof. In some examples, the hinge, intermediary hinge assembly, or other jointed assembly (which are at times generally referred to herein as a "hinge") can include an assembly that is secured to one or more associated outer facing sections and/or inner core sections during assembly of a collapsible portion of a panel. In other examples consistent with implementations of the current subject matter, respective outer facing sections and/or inner core sections that join to form a hinge can be manufactured or otherwise formed to include appropriate parts of a structure that forms a hinge when joined with a complementary structure on another outer facing section and/or inner core section along a hinge point (e.g. a facing pair hinge point or a vertex hinge point as described below). In other words, the hinges of a collapsible assembly can be separate assemblies attached to associated panel sections, or the hinges can be formed as an integral part of respective panels, or some combination of these approaches can be used.

[00034] The inner core sections 115 can be shaped as rectangles as in the example shown in FIGs. 1A to 1D or alternatively as other shapes as discussed in greater detail below. The inner core sections 115 make up sides of similar size of a series of adjoining triangular prisms that, with the outer facing sections 120, make up the collapsible portion 110. The outer facing sections 120 complete the triangular prisms of an extended collapsible portion 110. As used herein, the term "prism" refers to a three-dimensional volume having a cross section that is of a similar shape along an axis of the volume. For example, a triangular prism has a triangular cross-section along an axis passing from one end of an outer facing section to an opposite end of the outer facing section. The term "similar shape" indicates that the relative dimensions of the sides of the cross-sectional shape are constant although the size of the cross-sectional shape can vary along the length of the axis. In an example in which the outer facing sections are not rectangular (e.g., in which the expandable panel curves along its expanded length), the cross section of the resulting triangular prisms formed by one outer facing section 120 and two inner core sections 115 is a triangle of similar relative dimensions along an axis parallel to the plane of the outer facing section 120.

[00035] The pattern of inner core sections 115 can bear loads applied perpendicular to the outer facing sections 120 as well as provide some torsional rigidity to a completed panel 100. The bracing provided by the inner core sections 115 to the outer facing section 120 when the collapsible portion 110 is extended, combined with the added rigidity of the support structures 130 allow the panel 100 to be load bearing. The collapsible portion 120 extends out along a direction, labeled as the X-axis in FIG. 1B. The longitudinal support structures 130 attach to the extended collapsible portion 115 and outer facing sections 120 along the X-axis. It will be understood that the view of FIG. 1A is effectively a cross-sectional or end view taken along the X-axis.

[00036] In still other implementations of the current subject matter, the collapsible portion 110 can slide onto the longitudinal support structures 130. In other words, rather than the open channel configuration of a longitudinal support structure 130 discussed above, in which longitudinal support structures 130 are configured to attach over outer ends of the collapsible portion 110 once it is extended, one or more longitudinal support structures 130 can be formed as members that pass through holes or the like formed in the inner core sections 115.

[00037] FIG. 1C is an elevation view of a collapsible panel with an inner core section 115 which can slide onto longitudinal support structures 130. FIG. 1D is a perspective view of the panel shown in FIG. 1C. The panel shown in FIGs. 1C and 1D has similar components to the panel 100 of FIGs. 1A and 1B. The panel shown in FIGs. 1C and 1D has the same two types of components: a collapsible portion (110 in FIG. 1A) with an inner core section 115 and outer facing sections 120, as well as longitudinal support structures 130. The longitudinal support structures 130 of FIGs. 1C and 1D are shown as poles or tubes with a circular cross-section. In some implementations, the longitudinal support structures 130 can have other cross-sections that can allow for greater flexibility in the overall configuration of the panel. Though the longitudinal support structures 130 in FIGs. 1C and 1D are shown near the edges of the panel, the location of the longitudinal support structures 130 can vary. Additionally, though two longitudinal support structures 130 are shown, a panel can have more than two longitudinal support structures 130 or alternatively a single longitudinal support structure 130, for example one that is positioned approximately near the horizontal center of the inner core sections 115. The configuration of the panel shown in FIGs. 1C and 1D, with longitudinal support structures 130 through the inner core section 115 of the collapsible portion, may allow for panels that have fan-like

shapes, panels that are curved, and for panels that are otherwise not planar, as shown in FIG. 5 and described in greater detail below.

[00038] FIG. 2 shows a cross-sectional view 200 taken along a plane perpendicular to the X-axis of just the collapsible portion 110 of the panel seen in FIGs. 1A and 1B. In the cross-sectional view 200, the points at which each segment or section of material of the inner core sections 115 and outer facing sections 120 meet are shown as dots. The triangular prisms of FIG. 1B, when seen on-edge, appear as triangles in FIG. 2, illustrating the collapsible portion 110 when it is extended. When collapsed or collapsing, as in the bottom portion of FIG. 2, the triangles are collapsed as the angle between two adjoining inner core sections 115 is reduced and the part of the outer facing section 120 spanning between the ends of those two adjoining inner core sections 115 folds outwardly. When the collapsible portion 110 is extended, the vertices of the triangles are where two portions of the inner core sections 115 meet. These vertices are referred to as vertex hinge points 240. At the points where two segments or sections of the outer facing section 120 meet, there is also a hinge point, referred to herein as a facing pair hinge point 235. As seen in FIG. 2, in the extended configuration, each vertex hinge point 240 on a first outer facing section 120 is directly across from a facing pair hinge point 235 on the opposite outer facing section 120. As the collapsible portion 110 contracts or collapses, each facing pair hinge point 235 becomes the top or bottom point of a collapsing quadrilateral (e.g. a four-sided polygon), and each vertex hinge point 240 becomes a side point of this quadrilateral.

[00039] FIG. 3 shows the collapsible portion 110 of FIGs. 1A-2 when it is nearly or fully collapsed. The facing pair hinge points 235 can be seen to be the outer most points, each of those points connected to a segment of the outer facing sections 120. A vertex hinge point 240 is located between adjacent sections of outer facing section 120 and inner core sections 115.

[00040] While the explanation of the example implementation presented in reference to FIGs. 1A-3 above relates to an apparatus that expands to form a flat (e.g. planar) panel, this is not meant to be limiting. Consistent with some implementations of the current subject matter, the expanded structure can form a curved panel. FIGs. 4A-4C show cross-sectional views of an example of the collapsible portion 410 of such a curved structural panel 400. As shown in these figures, the collapsible portion 410 includes inner core sections 115 and outer facing sections 420A and 420B. Each segment of the first outer facing section 420A is slightly longer than each segment of the second outer facing section 420B. This difference in length of the individual segments that make up the outer facing sections 420A, 420B creates the curvature of the panel 400 as each triangular cross-sectional sub-structure formed by two adjoining inner core sections 115 and two expanded, planarly oriented first outer facing sections 420A opposite the vertex where the two adjoining inner core sections 115 meet has an at least slightly longer base than the adjacent and oppositely oriented triangular cross-sectional sub-structure formed by adjoining inner core sections 115 and two expanded, planarly oriented second outer facing sections 420B. When fully extended, the inner core sections 115 provide the bracing to the collapsible portion 410 that greatly contributes to the rigidity and load-bearing abilities of the panel. Though not shown, the longitudinal support structures 130 may have a suitable degree of curvature to correspond to that of the fully extended collapsible portion 410.

[00041] As seen in FIG. 3, the collapsible portion 410 shown in FIGs. 4A-4C have hinge points that are illustrated as points or dots. Facing pair hinge points 235 are located at the interface of two portions of an outer facing section, either 420A or 420B, while vertex hinge points 240 are located at the interface of two portions or segments of the inner core sections 115. FIG. 4B shows the collapsible portion 410 as it is being compressed or collapsed, and FIG. 4C shows a fully or nearly fully collapsed collapsible portion 410. As in

FIG. 3, the triangles of the fully extended view seen in FIG. 4A are supplanted by the quadrilaterals of FIG. 4C. In FIG. 3, these quadrilaterals at the top have the same dimensions as those at the bottom of collapsible portion 110. In FIG. 4C, since the segments of the top outer facing section 420A are longer than those of the bottom outer facing section 420B, the top-most quadrilaterals shown in FIG. 4C will have different dimension than the bottom-most shapes of the collapsible portion 410.

[00042] FIG. 5 is a view of a compactable, lightweight panel 500 that is expandable to form a curved structure. In the panel 500 shown in FIG. 5, the inner core sections 115 can slide onto the longitudinal support structures 130 (or alternatively, one longitudinal support structure), as in the panel shown in FIGs. 1C and 1D. In FIG. 5, the collapsible portion of the exemplary panel 500 is shown partially expanded along two longitudinal support structures 130. The longitudinal support structures 130 are curved, and as the compressible portion is expanded along the support structures 130, the resulting panel 500 is curved. The collapsible portion can be adapted for the curvature of the longitudinal support structures 130. Adaptations of the compressible portion can include inner core sections 115 and outer facing sections 120 made of materials that can accommodate the curvature of the longitudinal support structures 130, which can have shapes and dimensions (as in FIGs. 4A-4C) that accommodate the curvature of the longitudinal support structures 130 in one or more axes, and the like. Adaptations of the compressible portion can also include facing pair hinge points 235 and vertex hinge points 240 formed of materials that can accommodate the curvature of the longitudinal support structures 130, that are configured to expand and/or contract to accommodate the curvature of the longitudinal support structures 130, and the like.

[00043] The parts of a panel as described herein may be constructed of one or more materials, which can be selected according to the intended use and/or desired properties

of the panel. For example the outer facing sections of the collapsible portion may include a first material selected for compatibility with an external environment in which the panel will be placed as well as tensile strength, while the inner core sections may include a second material that is chosen for compressive strength with less concern for the external environment. The longitudinal support structures may be formed of even another material that is perhaps more rigid than the outer facing sections. Alternatively, any or all of the parts of a panel may be constructed of the same material.

[00044] FIG. 6 shows a process flow chart 600 illustrating features of a method consistent with implementations of the current subject matter. At 610, a collapsible portion can be expanded along an axis (which can be a curved axis) that is approximately perpendicular to faces of a plurality of collapsed inner core sections. At 620, the expanding can be completed when two outer facing sections joined at a facing pair hinge point disposed opposite a vertex hinge point joining two of the inner core sections are aligned in a plane. At 630, at least one longitudinal support structure can be joined to the expanded collapsible portion. Optionally, at 640, the at least one longitudinal support structure can be removed, and the collapsible portion can be re-collapsed.

[00045] FIGs. 7 and 8 show perspective and side views, respectively, of another implementation of a collapsible panel structure 700 including a collapsible portion 110 having inner core hinge points 740 that link adjacent inner core sections 115 together. The inner core hinge point 740 can include one or more extensions 745 that extend between the inner core hinge point 740 and a side of an adjacent inner core section 115. As such, each extension 745 can offset the inner core hinge point 740 from the longitudinal length of an inner core section 115 to which the inner core hinge point 740 is connected. The collapsible portion 110 of the panel 700 can also include facing pair hinge points that link two outer facing sections, such as described above.

[00046] In addition, the collapsible portion 110 of the panel 700 can also include supplemental hinge points 710 that connect an outer facing section 120 to an adjacent inner core section 115. As such, a first inner core section 115 can be linked to a second inner core section 115 via an inner core hinge point 740, as well as linked to an outer facing section 120 via the supplemental hinge point 710. Therefore, an inner core section 115 can have a total of four linking points, with two separate links disposed near each end of the inner core section: one to an outer facing section 120 via a supplemental hinge point 710 and a second to another inner core section 115 via an inner core hinge point 740.

[00047] As shown in FIGs. 7 and 8, when collapsed or collapsing the collapsible portion 110 of the panel 700, each facing pair hinge point 235 and inner core hinge point 740 becomes the top or bottom point of a collapsing six-sided polygon (when the collapsible portion of the expandable panel is viewed along an axis parallel to an outer facing section 120, and each supplemental hinge point 710 becomes a side point of this six-sided polygon. In the fully expanded configuration (e.g. on the left side of FIG. 8), the inner core sections 115, outer facing sections 120, and extensions 745 form linked trapezoids (again, when viewed along an axis parallel to the outer facing sections 120) in which two inner core sections 115 form the angled sides of the trapezoid, while two outer facing sections 120 (including a facing pair hinge point 235) form a base of the trapezoid, and the oppositely disposed extensions 745 (including a inner core hinge point 740) form the top of the trapezoid.

[00048] As shown in FIG. 8, for example, when the collapsible portion 110 is in the fully expanded configuration, the supplemental hinge points 710 can align such that the outer facing sections 120 form a substantially flat configuration (e.g., an extended wall). In addition, the supplemental hinge points 710 can align such that a minimal gap is formed between adjacent supplemental hinge points 710. As such, in the substantially flat

configuration of the outer facing sections 120 minimal (or even zero) spacing or gaps can be formed between adjacent outer facing sections 120. Such a structure can be useful in applications such as video displays, solar panels, touch screen input displays, optical components, antenna arrays, radiator panels, or the like, in which a continuous or nearly continuous surface without gaps is desirable.

[00049] FIGs. 9 and 10 show perspective and side views, respectively, of another implementation of a collapsible panel structure 900 including vertex hinge links 910 that include four joints 915a-915d, with each joint having its own axis of rotation. For example, each vertex hinge link 910 can include a first joint 915a and a second joint 915b that pivotally links a first outer facing section 120a and second outer facing section 120b, respectively, to the vertex hinge link 910. In addition, the vertex hinge link 910 can include a third joint 915c and a fourth joint 915d that pivotally links a first inner core section 115a and second inner core section 115b, respectively, to the vertex hinge link 910. Each of the joints 915a-915d can include an axis of rotation that allows each of the linked collapsible portion 110 sections (e.g., outer facing sections 120a, 120b and inner core sections 115a, 115b) to independently pivot relative to each other and/or to the vertex hinge link 910. In addition, the vertex hinge link 910 can allow all of the linked collapsible portion 110 sections (e.g., outer facing sections 120a, 120b and inner core sections 115a, 115b) to all simultaneously pivot relative to each other and/or to the vertex hinge link 910.

[00050] The joints 915a-915d can be positioned relative to each other such that they allow the collapsible portion 110 to form a compact collapsed configuration. For example, in a collapsed configuration, at least the inner core sections 115 can be positioned approximately parallel to each other and spaced apart from each other by a distance defined by the space between two joints, such as the third joint 115c and fourth joint 115d of an

adjacent vertex hinge link 910. The collapsible portion 110 of the panel 900 can also include facing pair hinge points 235 that link two outer facing sections, such as described above.

[00051] As shown in FIGs. 9 and 10, when collapsed or collapsing the collapsible portion 110 of the panel 900, each facing pair hinge point 235 becomes the top or bottom point of a collapsing quadrilateral and each vertex hinge link 910 becomes a side point of this quadrilateral (as above, references to the shapes taken on by the various components of the collapsible portion as it is expanded, collapsed, or is in transition between expanded and collapsed states or vice versa refer to the shapes as viewed "end-on" to the collapsible portion 110, which is also referred to herein as "along an exist parallel to the outer facings sections). In the expanded configuration, the inner core sections 115 and outer facing sections 120 form the sides of linked triangular shapes (e.g. three-sided polygons) where the outer facing sections 120 (including facing pair hinge points 235) form the bottom side of the triangular shapes, and the inner core sections 115 form the sides of the triangular shapes.

[00052] In this implementation, the vertex hinge links 910 can allow for improved simplicity in manufacturing and assembly. As discussed above, a single vertex hinge link 910 can allow for the independent pivoting of four separate sections of the collapsible portion 110. As such, reductions in materials use as well manufacturing and assembly complexity can be realized. Additionally, this implementation can allow for greater structural loads and larger applications such as bridges, ramps, temporary piers and docks, and other uses.

[00053] Non-limiting examples of materials that may be used for the outer facing sections 120 include carbon fiber, polymers, fiber reinforced polymers, plastics, metal, ceramics, polymer reinforced ceramics, metal reinforced ceramics, composite materials, platelet material, chain link or chain mail material, mesh, woven fabric, wood, cardboard, paper, woven natural materials, honeycombed and other cored composites, and the like,

including any combination thereof. Polymers may include natural polymers, such as rubber, cellulose, and silk, and synthetic polymers, such as polyethylene, polystyrene, phenol formaldehyde resin, nylon, polyvinyl chloride, polylactic acid, acrylonitrile butadiene styrene, polypropylene, polyacrylonitrile, and the like. Fiber reinforced polymers may include polymers reinforced with glass fibers, aramid fibers, graphite fibers, carbon fibers, polymer fibers, boron fibers, hemp fibers, natural material fibers, and the like. Metals may include aluminum, aluminum alloys, nickel, nickel alloys, steel, iron, titanium alloys, cobalt-chromium alloys, and any other metal or metal alloy sufficiently strong and/or resistant to the environment in which the panel will be used. A treatment may be applied to the outer facing sections, particularly the portions of the outer facing sections that will be exposed to the environment. Exemplary treatments include paint or a coating that may allow the panel to blend in with its surroundings, a reflective coating, and the like. In some implementations of the current subject matter, one or more outer facing sections can include elements or the like applied or attached to the outer facing sections, such as for example, one or more electronic components (e.g. solar cells, antenna elements, LED screen components, lighting sources, sensor arrays, touch screens, sound generating devices, transducers, or the like), printed material (e.g. signs, fabrics, wall coverings, or the like), etc. When used as a support for a display screen, an expandable panel consistent with implementations of the current subject matter can be rapidly deployable (e.g. to provide a display screen of a desired scale – which can vary from screens sized for personal computer displays or smaller to theater-sized or larger – merely by expanding panel structure as described herein from a fully collapsed configuration to a fully expanded configuration and affixing one or more longitudinal support structures 130).

[00054] Materials used for the inner core sections 115 may also include those used for the outer facing sections, described above. The inner core sections may require that

the material selected also be strong in compression, so that the inner core sections resist collapse, buckling, or other failure when the panel is fully extended and a load is applied perpendicular to the outer facing sections. Similarly, the longitudinal support structures may be made from the same materials as those listed above for the outer facing sections. However, the longitudinal support structures may require additional characteristics, such as, for example, increased rigidity compared to the outer facing sections, increased friction against the ground, and/or malleability to enable the edges of the panel to conform to a roof or ceiling layer.

[00055] The outer facing sections, inner core sections, and longitudinal support structures may be made by conventional machining, hot-pressing, injection molding, extrusion, roller-pressing, conventional reinforced polymer composite lay-up, foaming, 3D printing, spraying, and the like. The components of a panel may be made as lattices or as solid bodies with strategically placed openings (e.g. holes or voids) to reduce weight while maintaining strength. For example, the components may include foamed materials, including foamed polymers, ceramics, and/or metals. Other possible materials can include honeycomb core composites, foam core composites, and optionally "built-up" structures for larger assemblies. For example, a welded truss assembly can be used for the inner core components for larger-scale panels (e.g. for use in temporary bridges, ramps, or the like). The outer facing sections, inner core sections, and longitudinal support structures may or may not have reinforcing shapes to provide additional stiffness as required by applications (e.g. ribbed or corrugated sections, or the like).

[00056] The vertices of the panel sections, optionally including but not limited to the vertex hinge points, the facing pair hinge points, the supplemental hinge points, the inner core hinge points, and the vertex hinge links, and the like, may be of any suitably strong and pliable material. For example, thin flexible hinges such as fabric or living hinges may be

used at the hinge points or hinge links to connect inner core and/or outer facing sections depending on application loads. In other implementations of the current subject matter, the hinge points or hinge links can be joined by molded or machined polymer hinges, machined metal hinges, metal injection molded hinge components, combinations thereof, or by any suitable hinging material or design consistent with the other teachings herein. The vertex hinge points 240, the facing pair hinge points 235, the supplemental hinge points 710, the inner core hinge points 740, and/or the vertex hinge links 910 may be simple hinges or assemblies of one or more hinges, hinging mechanisms, jointed assemblies, or other combinations thereof which connect two or more adjacent inner core sections 115 and/or outer facing sections 120 such that the centers of the hinge points or assemblies retain their arrangement as described above.

[00057] In use, a panel may be transported to and/or from its use destination with the collapsible portion fully compressed and the longitudinal support structures separate from the collapsible portion. In this way, when transporting more than one panel at a time, multiple collapsible portions may be stacked upon or against each other, and the longitudinal support structures may be bundled together in an efficient manner, as well.

[00058] At its destination location, a collapsible portion of a panel may be fully extended then held rigid with the longitudinal support structures. The volume between the inner core sections may be left empty. Alternatively, some or all of the volume between the inner core sections may be filled with material found at the destination location or with material transported with the panel for that purpose. For example, if the destination location is a desert or beach, the volume between the inner core sections may be filled with sand before completing the panel with the addition of the longitudinal support structures. In another example, an insulating material, such as for example a foaming insulating material, may be inserted into the volume between the inner core sections. At a destination location, a

panel may be constructed and used in conjunction with other panels and/or other construction materials to build a structure. Panels may be connected to each other and/or other construction materials using adhesives, tape, physical joining methods, or any combination thereof. In some example implementations, interlocking clips can be included as part of (or add-on components to) the longitudinal support structures. Alternatively or in addition, panels of straight and curving sections can be combined to form walls and roofs. Temporary or portable shelters, shade structures, walkways, bridges, or the like may be constructed which are light, easily portable, and reusable.

[00059] The subject matter described herein can be embodied in systems, apparatus, methods, and/or articles depending on the desired configuration. The implementations set forth in the foregoing description do not represent all implementations consistent with the subject matter described herein. Instead, they are merely some examples consistent with aspects related to the described subject matter. Although a few variations have been described in detail above, other modifications or additions are possible. In particular, further features and/or variations can be provided in addition to those set forth herein. For example, the implementations described above can be directed to various combinations and subcombinations of the disclosed features and/or combinations and subcombinations of several further features disclosed above. In addition, the logic flows depicted in the accompanying figures and/or described herein do not necessarily require the particular order shown, or sequential order, to achieve desirable results. Other implementations may be within the scope of the following claim.

CLAIMS

What is claimed is:

1. An apparatus comprising:

a collapsible panel structure configured to form an expanded configuration and a collapsed configuration, the collapsible panel structure comprising;

outer facing sections forming a first side and a second side of the collapsible panel structure, the first and second sides comprising facing pair hinge points that pivotally couple adjoining outer facing sections; and

inner core sections arranged in a zig-zag manner between the first side and the second side with vertex hinge points pivotally coupling adjoining inner core sections;

wherein the inner core sections and the outer facing sections form a series of adjoining triangular prisms when the collapsible panel structure is in the expanded configuration, and wherein the inner core sections and outer facing sections form a series of adjoining quadrilateral prisms when the collapsible panel structure is transitioning into the collapsed configuration.

2. An apparatus as in claim 1, further comprising a support structure that extends along a length of the collapsible panel structure in the expanded configuration.

3. An apparatus as in claim 2, wherein the support structure comprises at least one of an open channel that is configured to cap a first end of the collapsible panel structure, a telescoping segment that allows the support structure to at least partially collapse, and a plurality of joinable segments.

4. An apparatus as in claim 2, wherein the support structure extends through openings located along the inner core sections.

5. An apparatus as in claims 2 through 4, wherein the support structure is curved.

6. An apparatus as in any preceding claim, wherein in the extended configuration, the vertex hinge points are located at an apex of each triangular prism of the series of adjoining triangular prisms.

7. An apparatus as in any preceding claim, wherein two outer facing sections jointed at a facing pair hinge point are aligned with an opposite vertex hinge point joining two inner core sections.

8. An apparatus as in any preceding claim, wherein when the collapsible panel structure is transitioning into the collapsed configuration, a facing pair hinge point of the facing pair hinge points is located at a top or a bottom of each quadrilateral prism of the series of adjoining quadrilateral prisms.

9. An apparatus comprising:

a collapsible panel structure configured to form an expanded configuration and a collapsed configuration, the collapsible panel structure comprising;

outer facing sections forming a first side and a second side of the collapsible panel structure, the first and second sides comprising facing pair hinge points that pivotally couple adjoining outer facing sections;

inner core sections arranged in a zig-zag manner between the first side and the second side with

inner core hinge points that pivotally couple adjoining inner core sections,

extensions that extend between each coupling of an inner core section and an inner core hinge point thereby offsetting the inner core hinge point from a longitudinal length of the inner core section; and

supplemental hinge points that pivotally couple adjoining outer facing sections and inner core sections;

wherein the inner core sections, the extensions, and the outer facing sections form a series of adjoining quadrilateral prisms when the collapsible panel structure is in the expanded configuration, and wherein the inner core sections, the extensions, and the outer facing sections form a series of adjoining six-sided prisms when the collapsible panel structure is transitioning into the collapsed configuration.

10. An apparatus as in claim 9, further comprising a support structure that extends along a length of the collapsible panel structure in the expanded configuration.

11. An apparatus as in claim 10, wherein the support structure comprises at least one of an open channel that is configured to cap a first end of the collapsible panel structure, a telescoping segment that allows the support structure to at least partially collapse, and a plurality of joinable segments.

12. An apparatus as in claim 10, wherein the support structure extends through openings located along the inner core sections.

13. An apparatus as in claims 10 through 12, wherein the support structure is curved.

14. An apparatus as in claims 9 through 13, wherein in the extended configuration, two outer facing sections are in an alignment and jointed at a facing pair hinge point that is disposed opposite an inner core hinge point.

15. An apparatus as in claims 9 through 14, wherein when the collapsible panel structure is transitioning into the collapsed configuration, the facing pair hinge points and

inner core hinge points are alternately located at a top and a bottom of each hexagonal prism of the series of adjoining quadrilateral prisms.

16. A method comprising:

expanding a collapsible portion of a collapsible panel structure along an axis perpendicular to faces of a plurality of inner core sections of the collapsible panel structure;

completing the expanding of the collapsible portion upon planar alignment of two outer facing sections of the collapsible panel structure joined at a facing pair hinge point that is disposed opposite a vertex hinge point joining two of the inner core sections, wherein the inner core sections are arranged in a zig-zag manner between a first side of outer facing sections and a second side of outer facing sections with vertex hinge points pivotally coupling adjoining inner core sections.

17. A method as in claim 16, further comprising joining a longitudinal support structure to the expanded collapsible portion.

18. A method as in claim 17, further comprising removing the longitudinal support structures.

19. A method as in claims 16 through 18, further comprising re-collapsing the collapsible portion.

20. A method comprising:

expanding a collapsible portion of a collapsible panel structure along an axis perpendicular to faces of a plurality of inner core sections of the collapsible panel structure;

completing the expanding of the collapsible portion upon planar alignment of two outer facing sections of the collapsible panel structure joined at a facing pair hinge point that is disposed opposite an inner core hinge point joining two of the inner core sections, wherein

the inner core sections are arranged in a zig-zag manner between a first side of outer facing sections and a second side of outer facing sections with inner core hinge points pivotally coupling adjoining inner core sections and are offset from longitudinal lengths of the adjoining inner core sections by extensions, and wherein supplemental hinge points pivotally couple adjoining outer facing sections and inner core sections.

21. An apparatus as in claim 1, wherein in the extended configuration, the vertex hinge points are located at an apex of each triangular prism of the series of adjoining triangular prisms.

22. An apparatus as in claim 1, wherein two outer facing sections jointed at a facing pair hinge point are aligned with an opposite vertex hinge point joining two inner core sections.

23. An apparatus as in claim 1, wherein when the collapsible panel structure is transitioning into the collapsed configuration, a facing pair hinge point of the facing pair hinge points is located at a top or a bottom of each quadrilateral prism of the series of adjoining quadrilateral prisms.

24. An apparatus as in claim 2, wherein the support structure is curved.

25. An apparatus as in claim 9, wherein in the extended configuration, two outer facing sections are in an alignment and jointed at a facing pair hinge point that is disposed opposite an inner core hinge point.

26. An apparatus as in claim 9, wherein when the collapsible panel structure is transitioning into the collapsed configuration, the facing pair hinge points and inner core hinge points are alternately located at a top and a bottom of each hexagonal prism of the series of adjoining quadrilateral prisms.

27. A method as in claim 16, further comprising re-collapsing the collapsible portion.

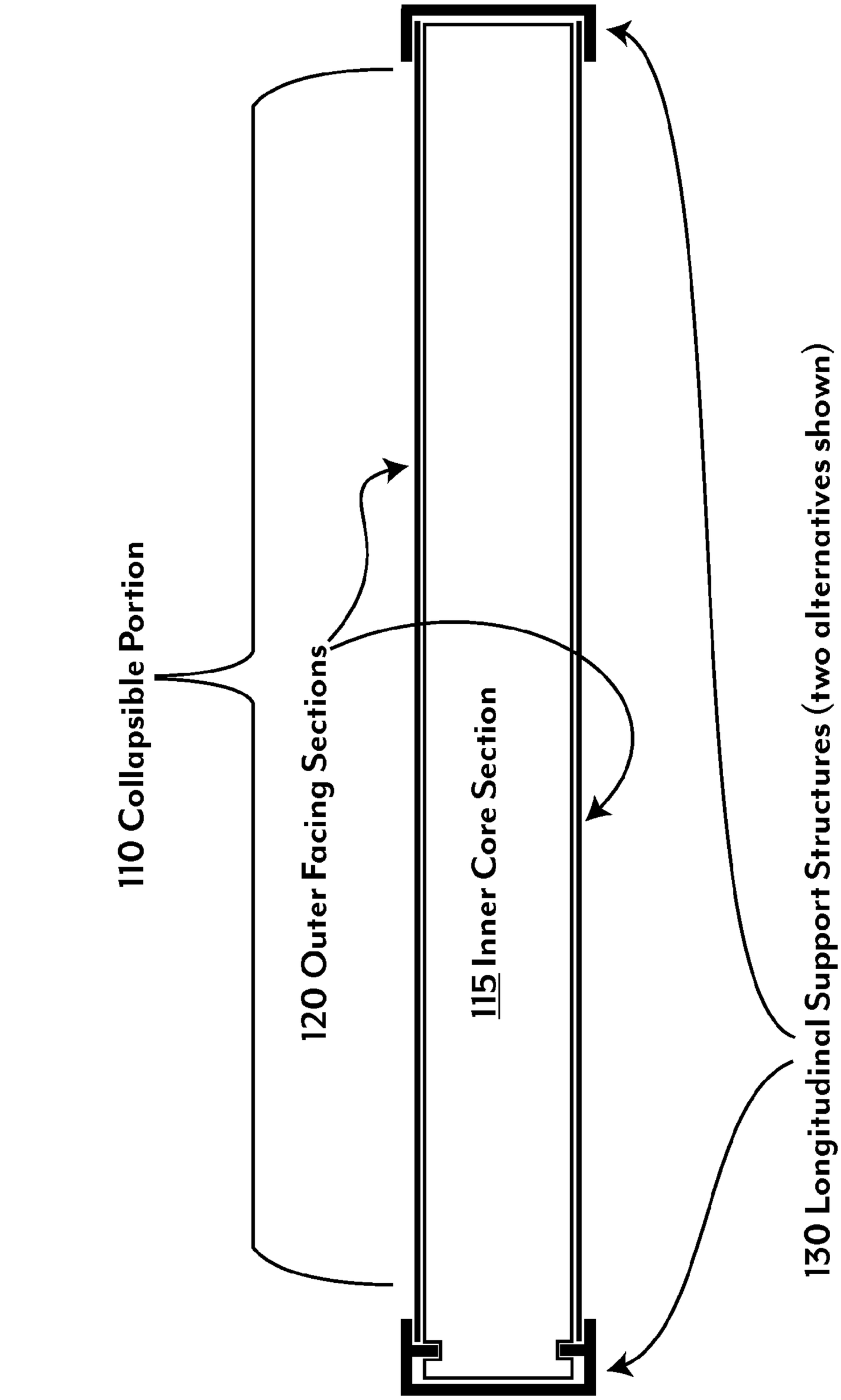
110 Collapsible Portion
120 Outer Facing Sections
115 Inner Core Section
130 Longitudinal Support Structures (two alternatives shown)
100

Fig. 1A

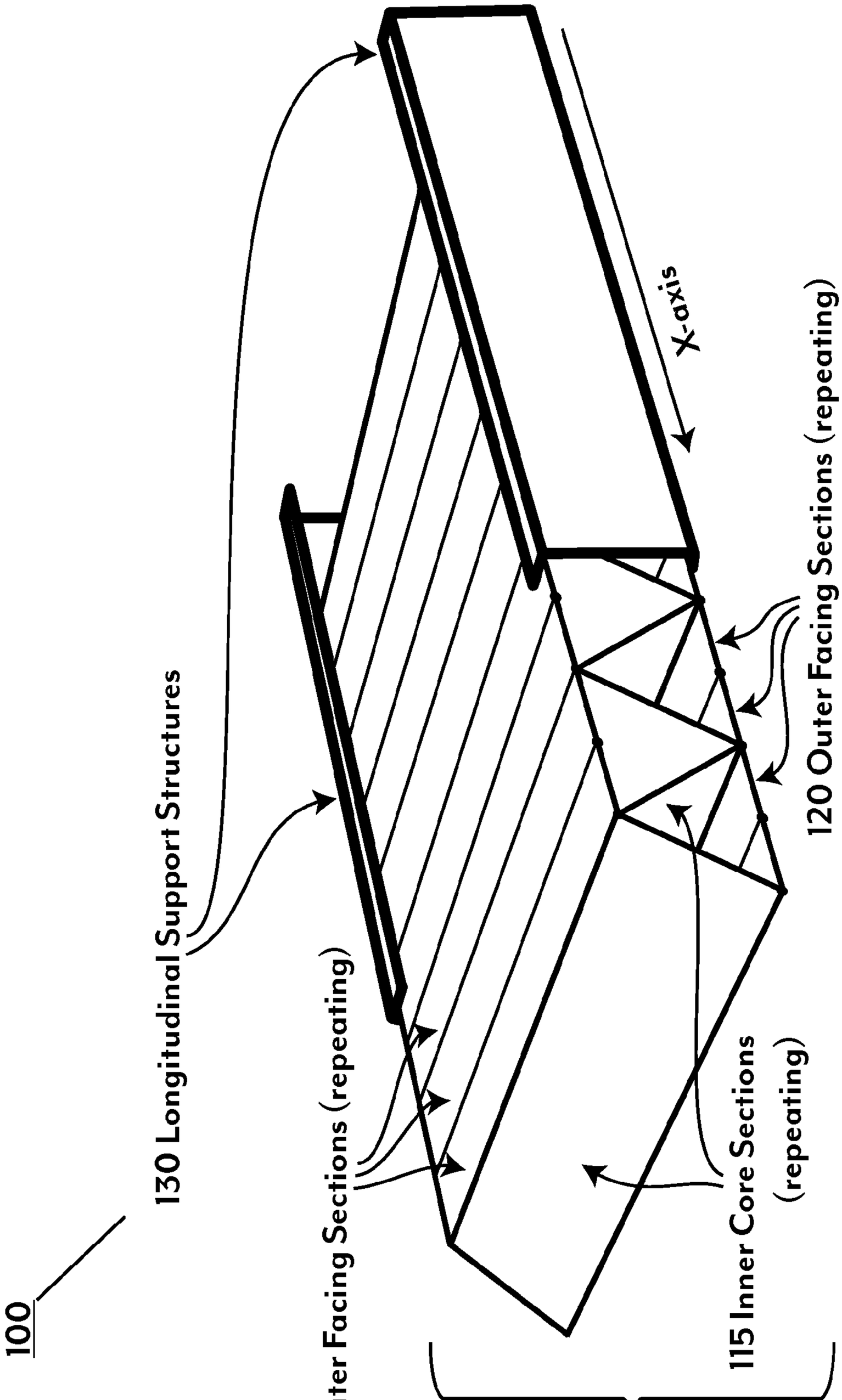
100
130 Longitudinal Support Structures
120 Outer Facing Sections (repeating)
115 Inner Core Sections (repeating)
120 Outer Facing Sections (repeating)
110 Collapsible Portion
X-axis

Fig. 1B

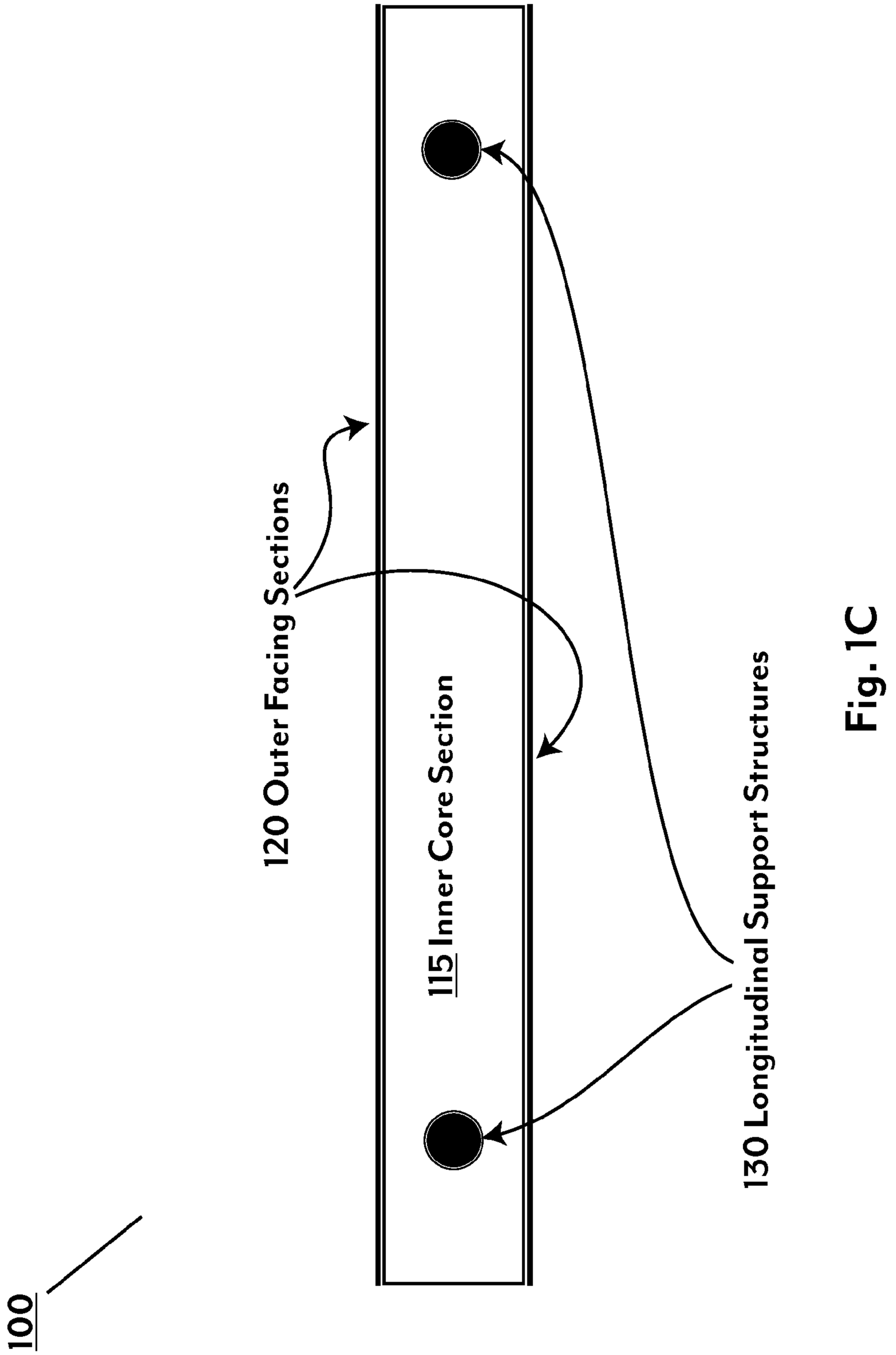
100
120 Outer Facing Sections
115 Inner Core Section
130 Longitudinal Support Structures

Fig. 1C

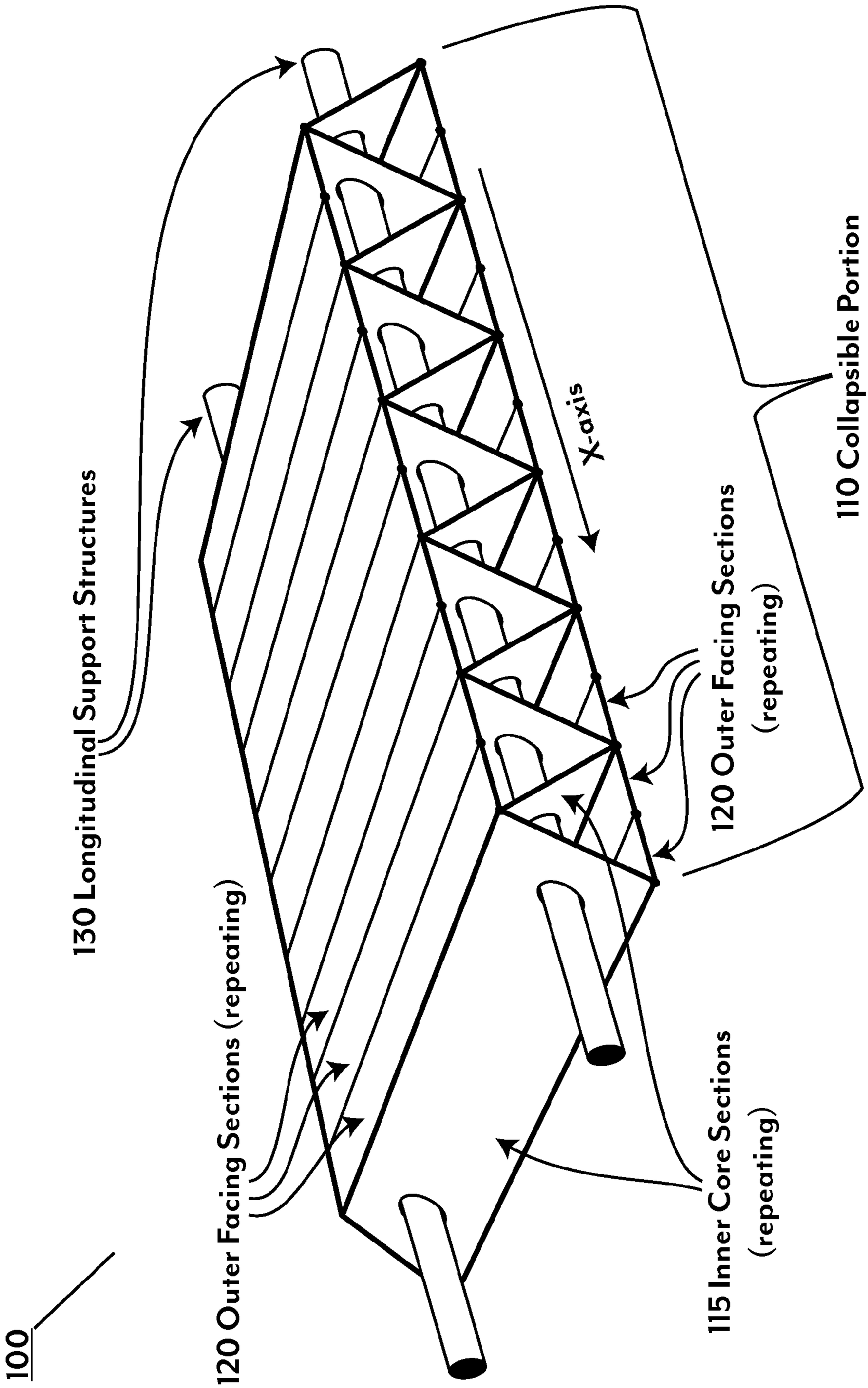
100
120 Outer Facing Sections (repeating)
130 Longitudinal Support Structures
115 Inner Core Sections (repeating)
120 Outer Facing Sections (repeating)
X-axis
110 Collapsible Portion

Fig. 1D

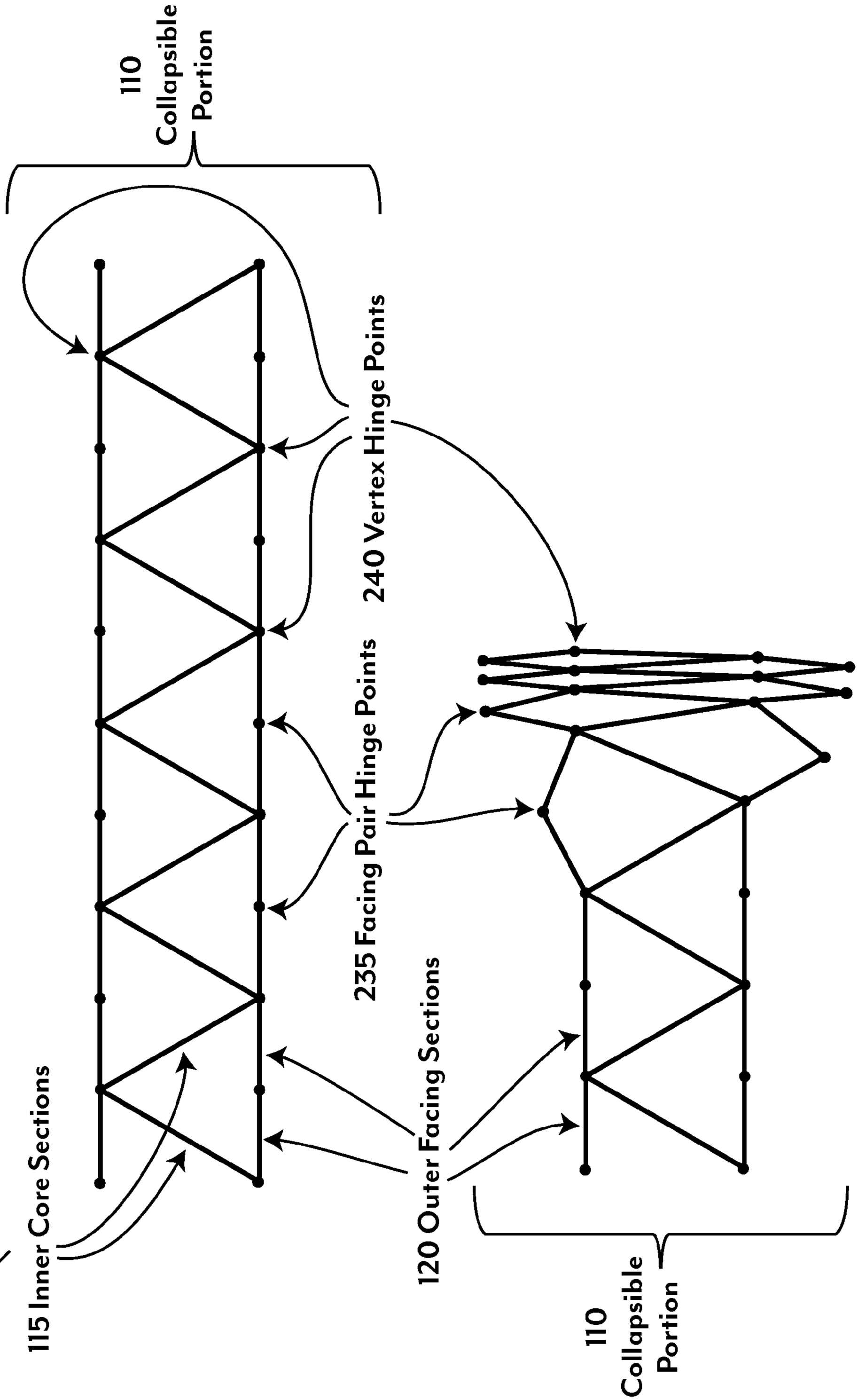
110 Collapsible Portion
240 Vertex Hinge Points
235 Facing Pair Hinge Points
115 Inner Core Sections
120 Outer Facing Sections
200
110 Collapsible Portion

Fig. 2

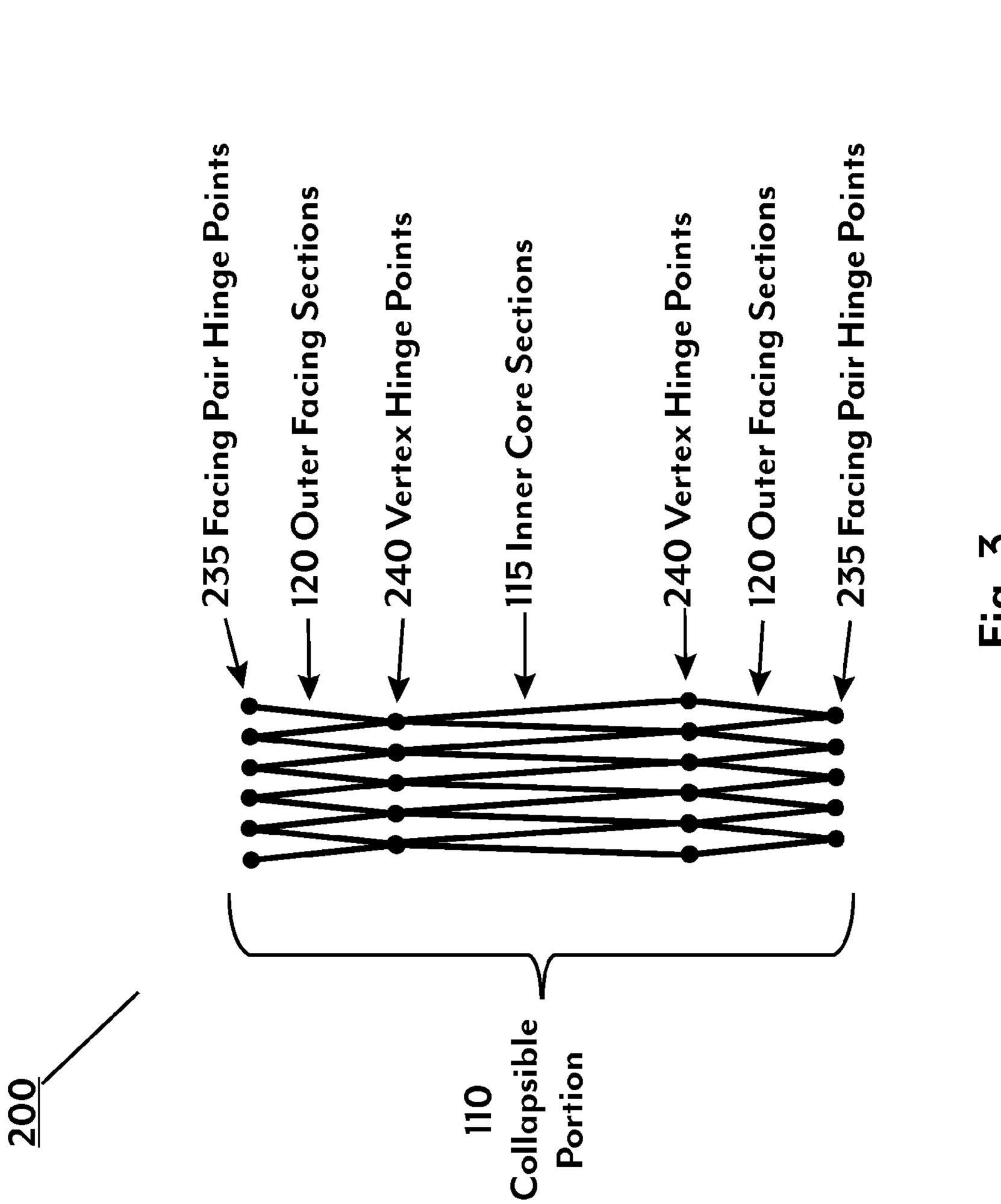
200
110
Collapsible
Portion
115 Inner Core Sections
120 Outer Facing Sections
235 Facing Pair Hinge Points
240 Vertex Hinge Points
120 Outer Facing Sections
235 Facing Pair Hinge Points
240 Vertex Hinge Points

Fig. 3

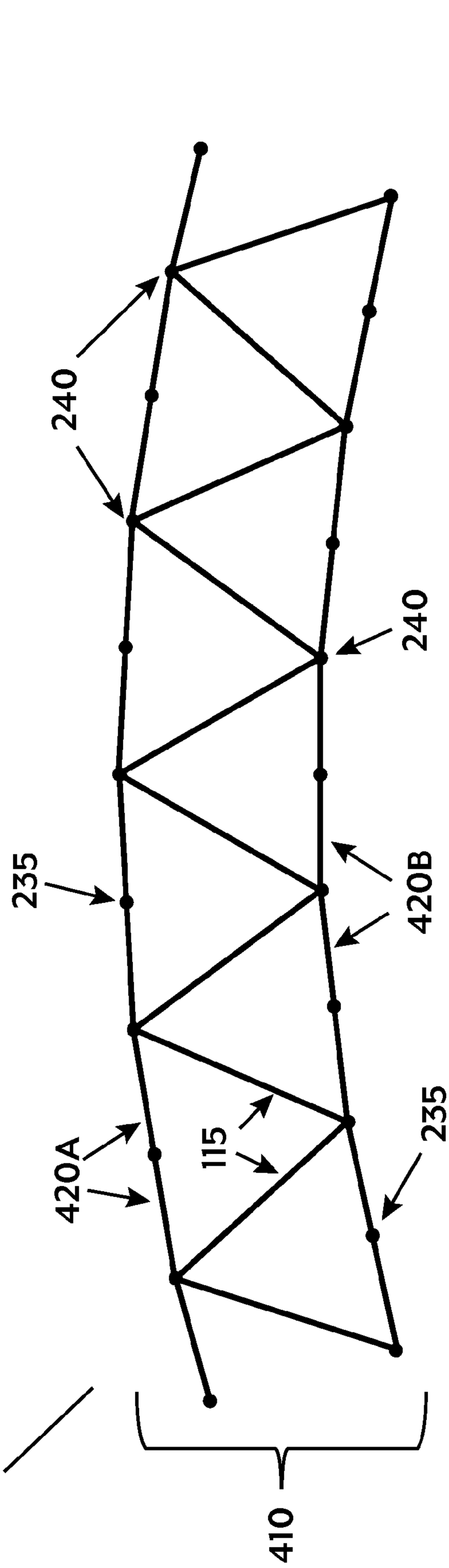

Fig. 4A

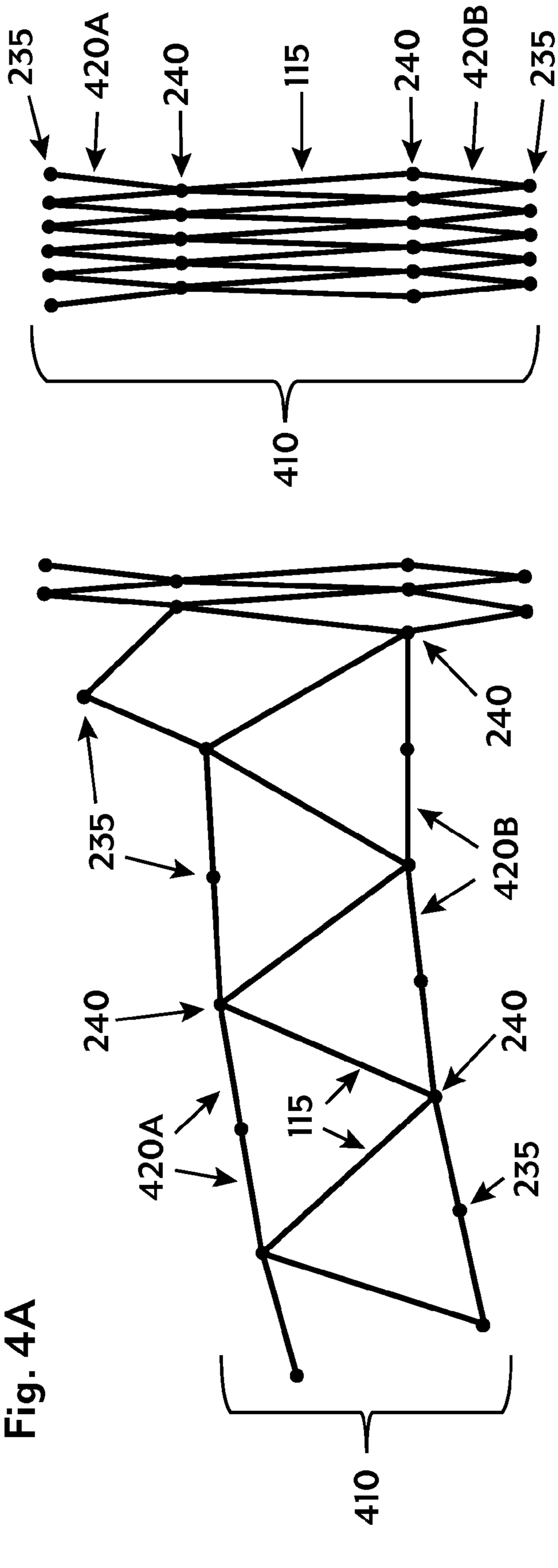

Fig. 4C

Fig. 4B

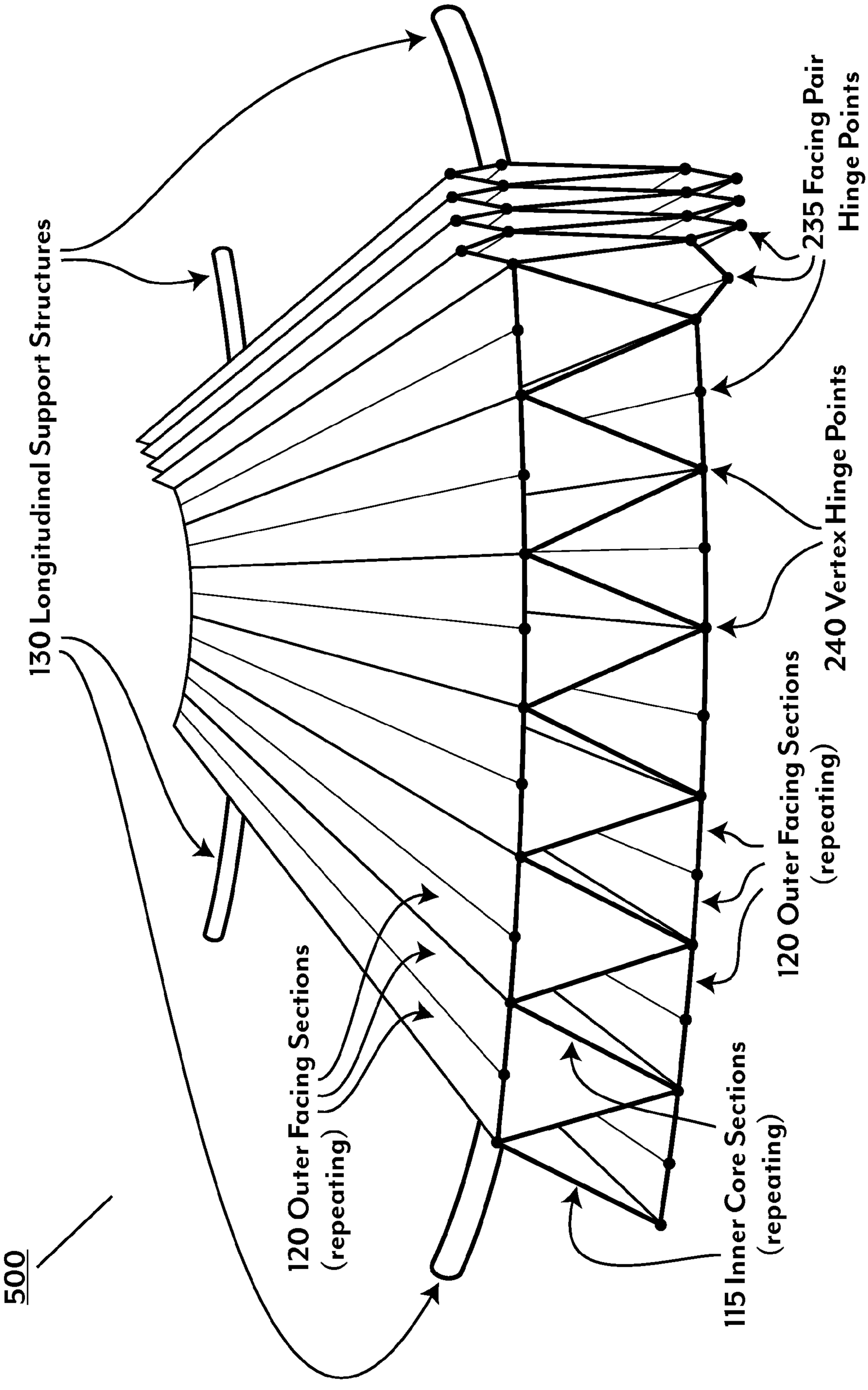
130 Longitudinal Support Structures
235 Facing Pair Hinge Points
240 Vertex Hinge Points
120 Outer Facing Sections (repeating)
120 Outer Facing Sections (repeating)
120 Outer Facing Sections (repeating)
115 Inner Core Sections (repeating)
500

Fig. 5

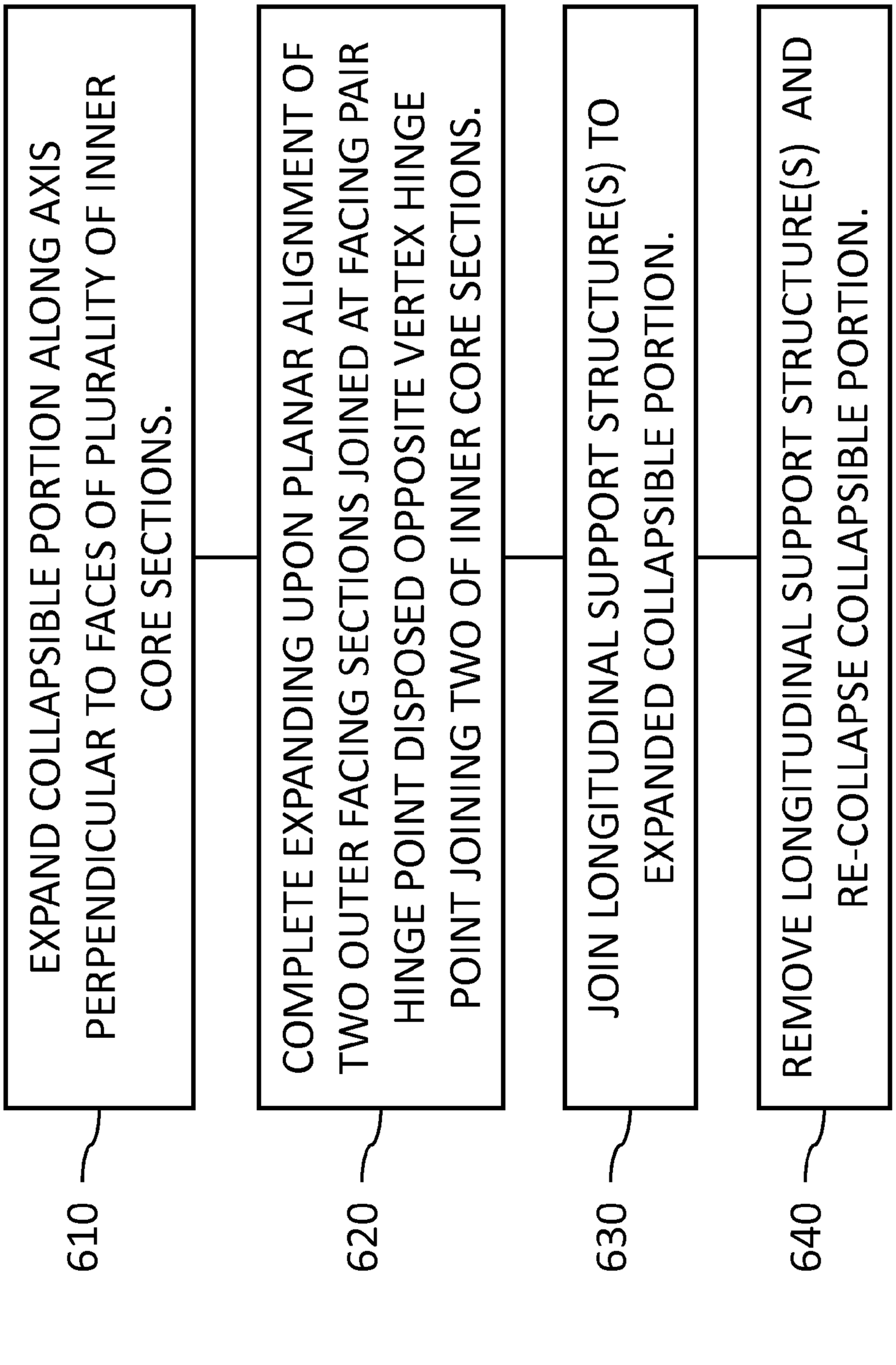
600
610
EXPAND COLLAPSIBLE PORTION ALONG AXIS PERPENDICULAR TO FACES OF PLURALITY OF INNER CORE SECTIONS.
620
COMPLETE EXPANDING UPON PLANAR ALIGNMENT OF TWO OUTER FACING SECTIONS JOINED AT FACING PAIR HINGE POINT DISPOSED OPPOSITE VERTEX HINGE POINT JOINING TWO OF INNER CORE SECTIONS.
630
JOIN LONGITUDINAL SUPPORT STRUCTURE(S) TO EXPANDED COLLAPSIBLE PORTION.
640
REMOVE LONGITUDINAL SUPPORT STRUCTURE(S) AND RE-COLLAPSE COLLAPSIBLE PORTION.

FIG. 6

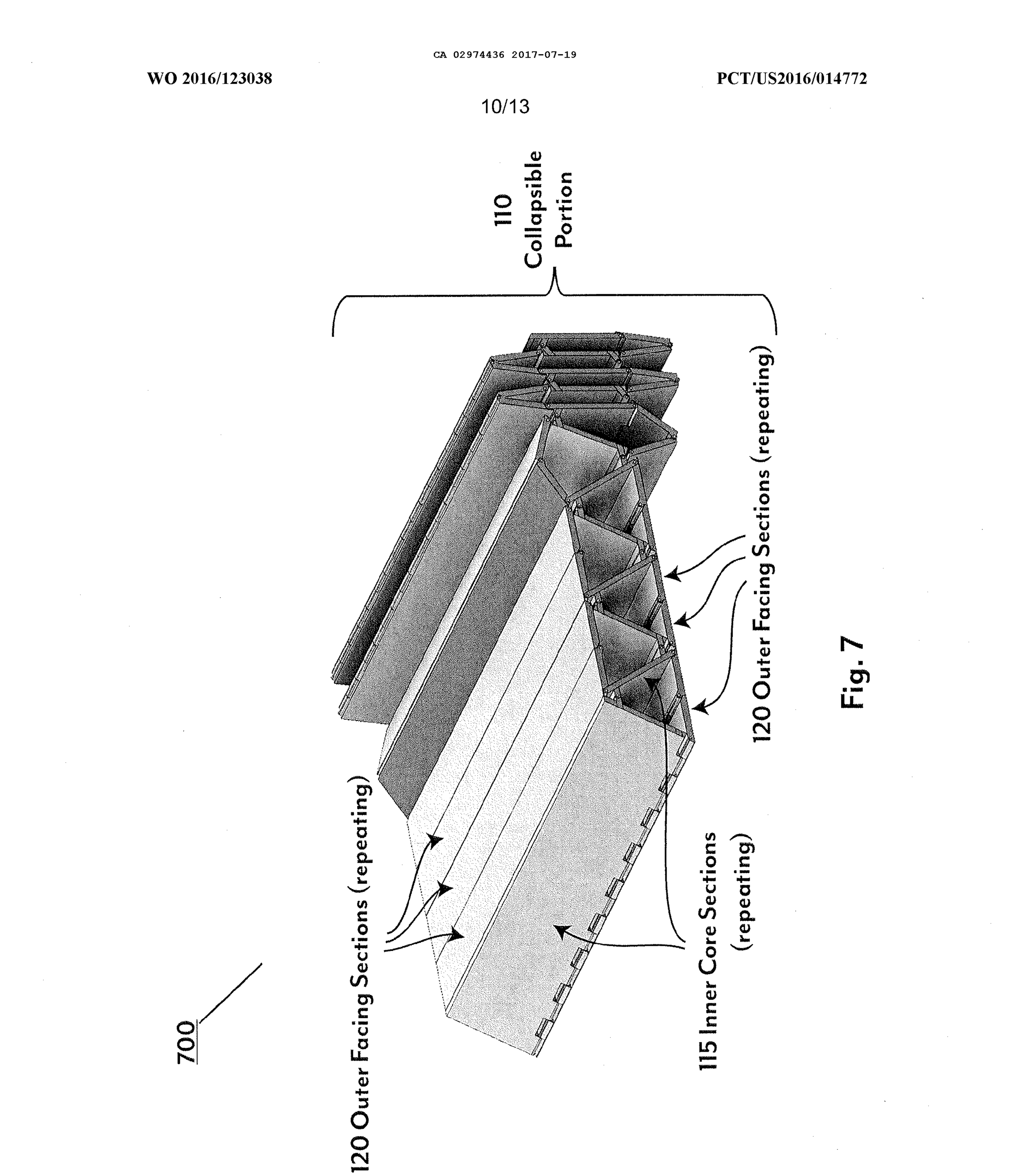
700
120 Outer Facing Sections (repeating)
115 Inner Core Sections (repeating)
120 Outer Facing Sections (repeating)
110 Collapsible Portion

Fig. 7

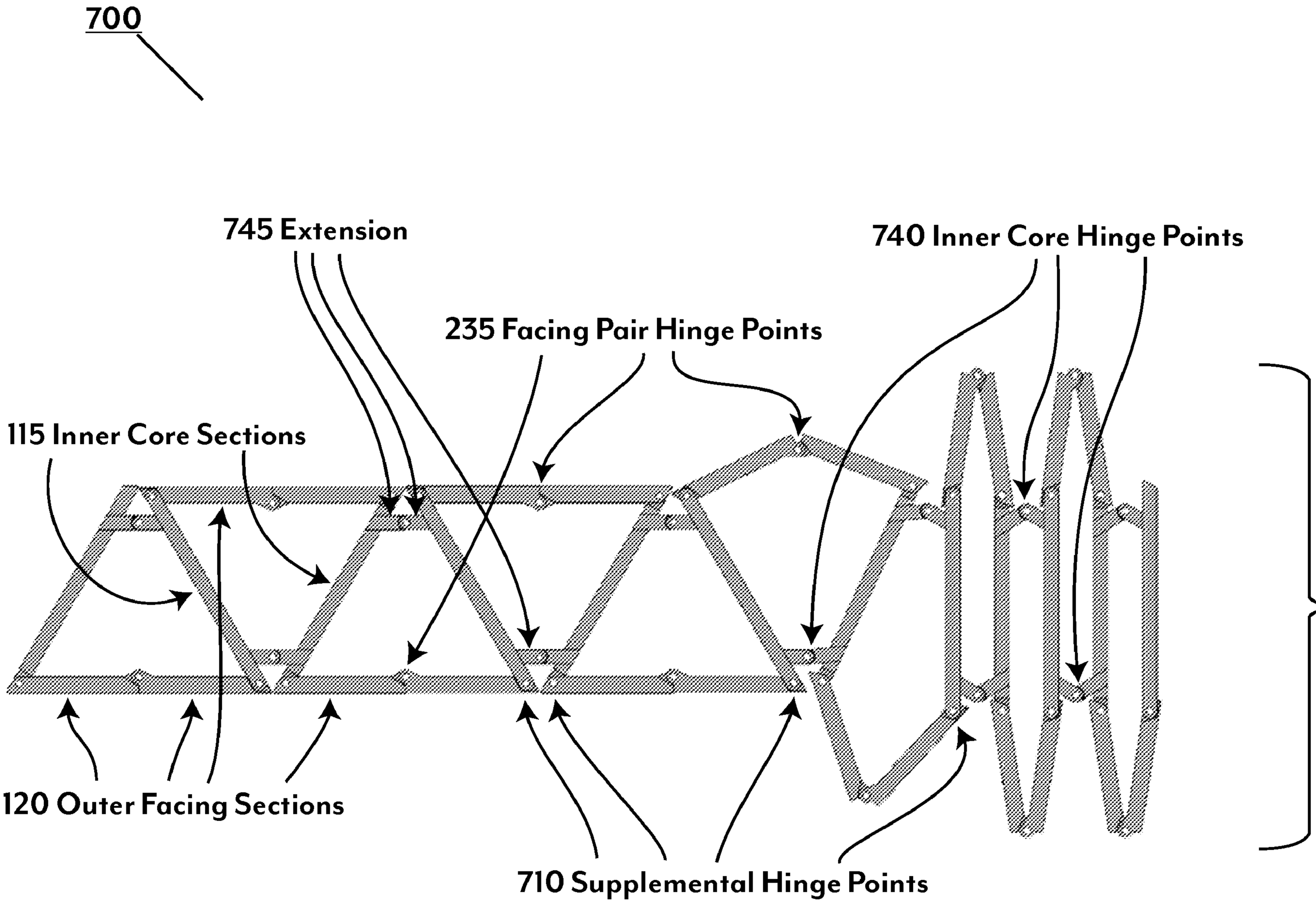
700
745 Extension
740 Inner Core Hinge Points
235 Facing Pair Hinge Points
115 Inner Core Sections
110
Collapsible
Portion
120 Outer Facing Sections
710 Supplemental Hinge Points

Fig. 8

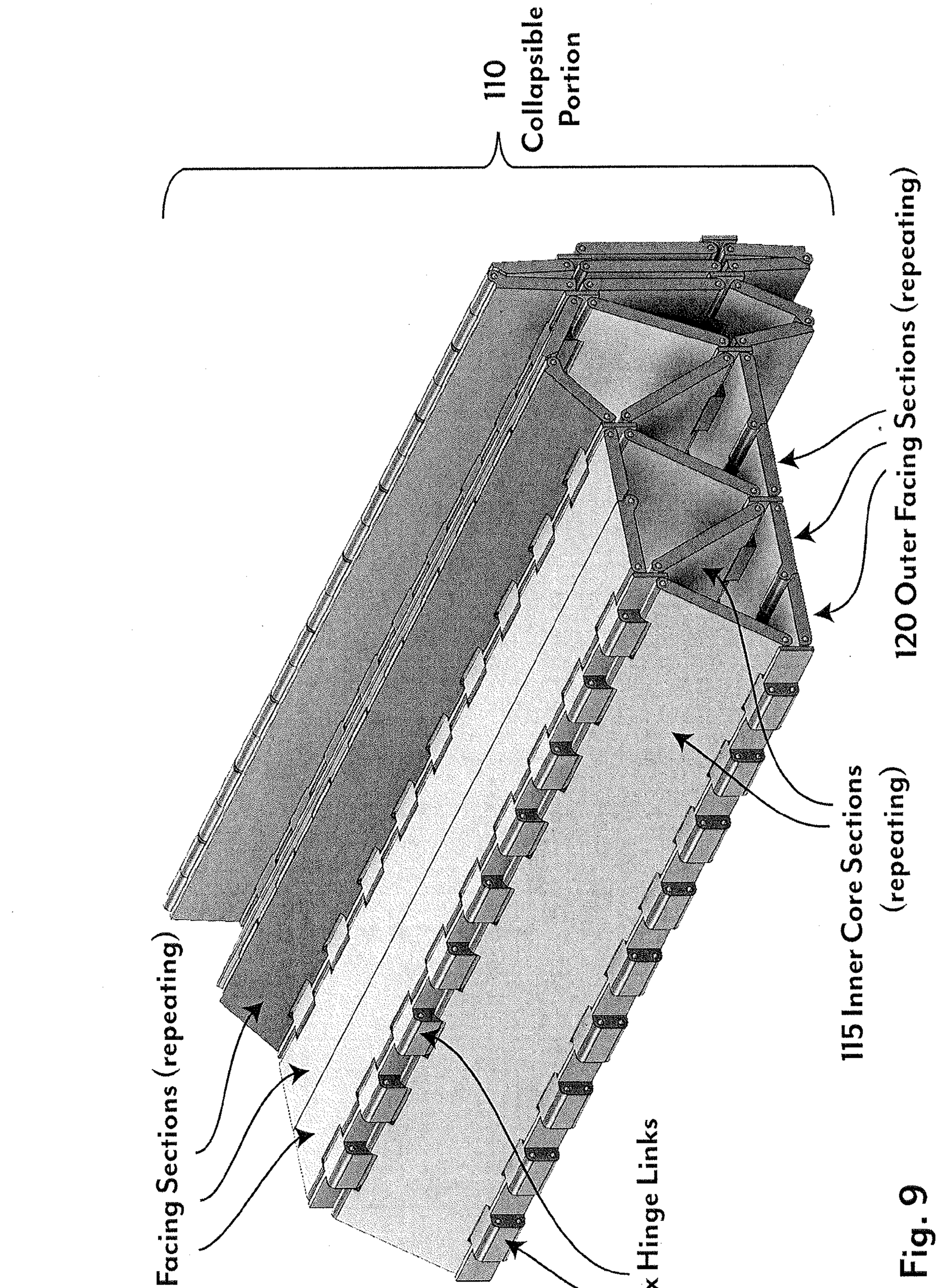
900
110 Collapsible Portion
120 Outer Facing Sections (repeating)
115 Inner Core Sections (repeating)
910 Vertex Hinge Links
120 Outer Facing Sections (repeating)

Fig. 9

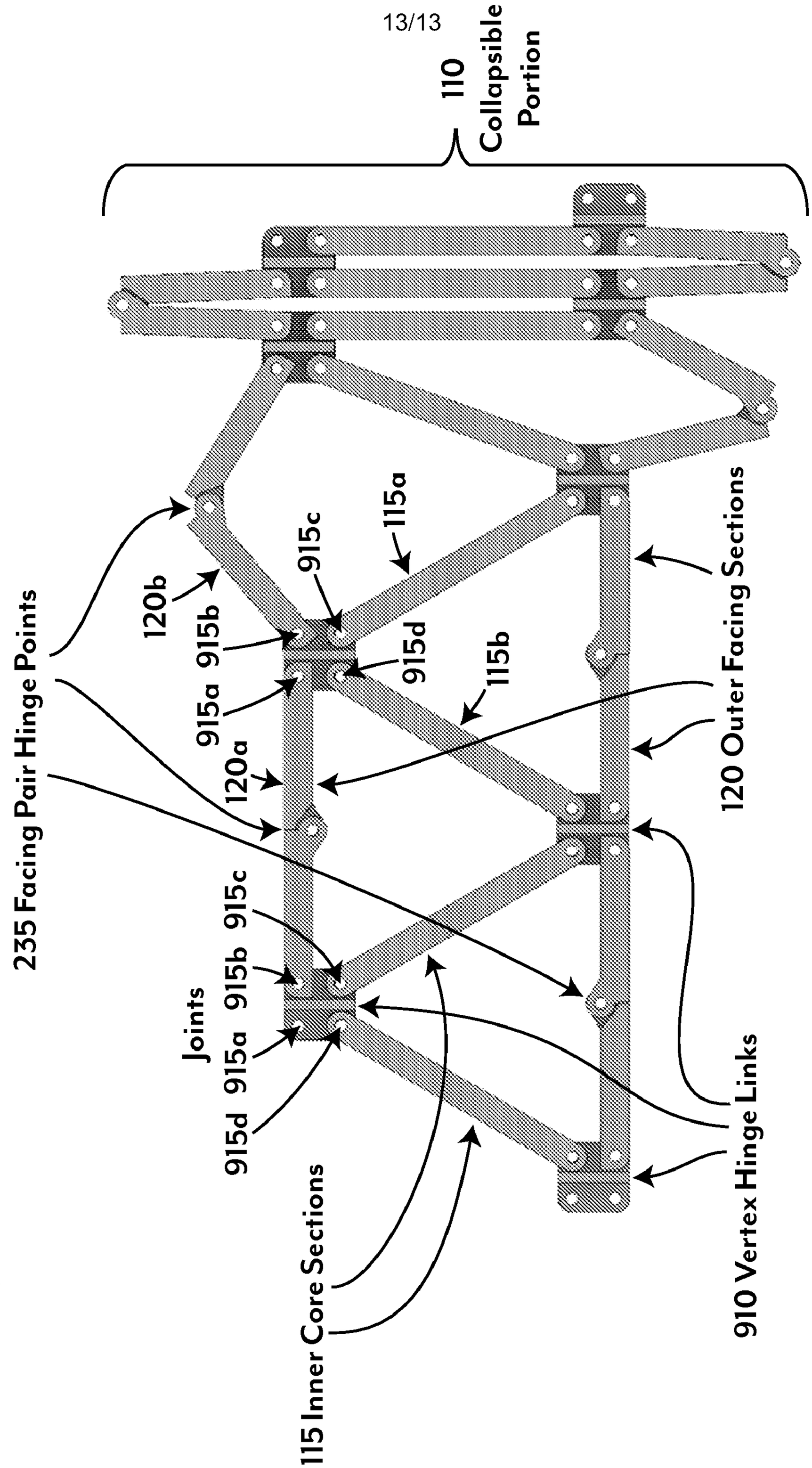
110 Collapsible Portion
120b
915b
915a
915c
115a
915d
115b
120a
235 Facing Pair Hinge Points
Joints
915d 915a 915b 915c
115 Inner Core Sections
120 Outer Facing Sections
910 Vertex Hinge Links
900

Fig. 10

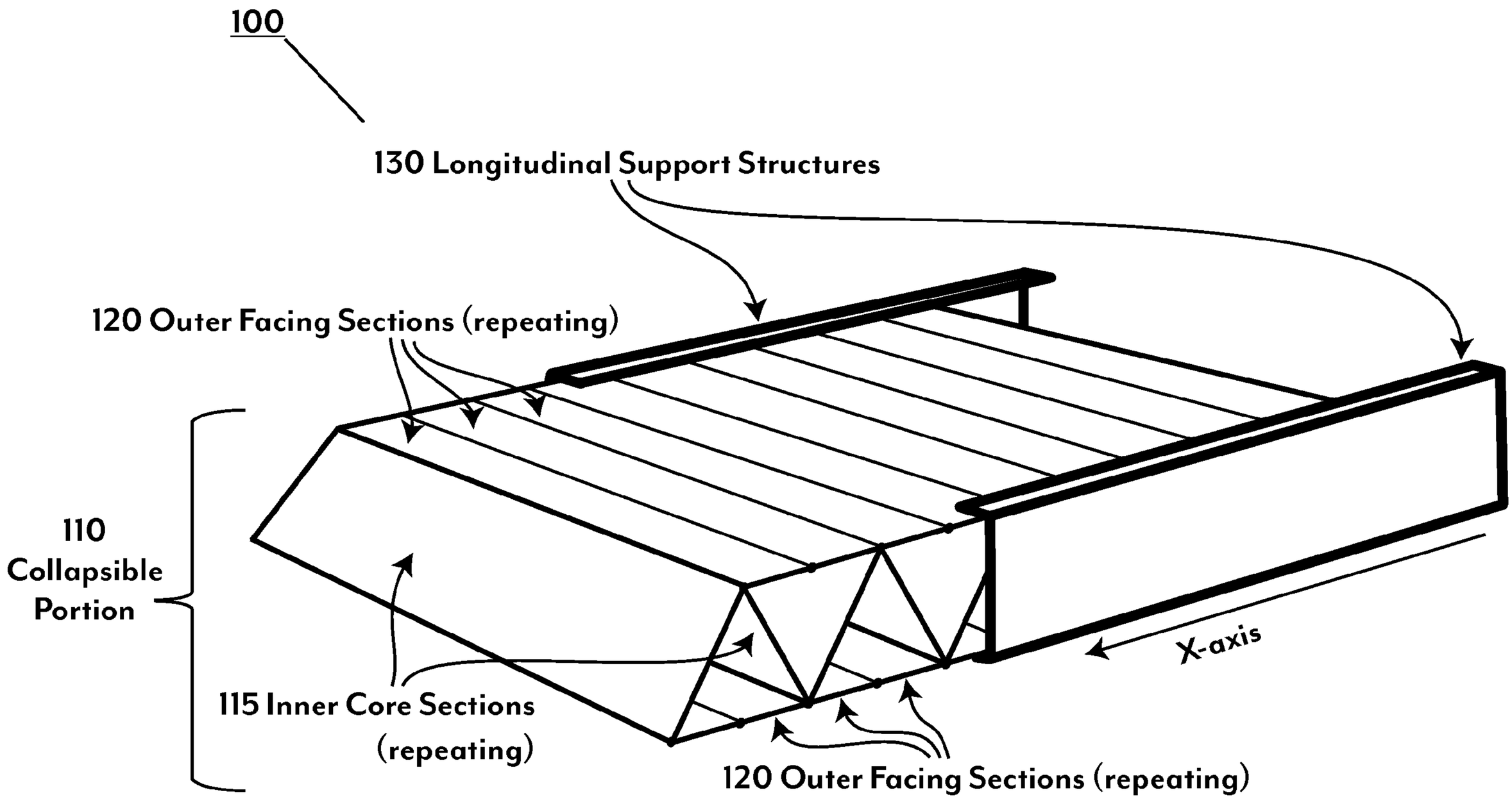
100
130 Longitudinal Support Structures
120 Outer Facing Sections (repeating)
110
Collapsible
Portion
115 Inner Core Sections
(repeating)
120 Outer Facing Sections (repeating)
X-axis

Fig. 1B