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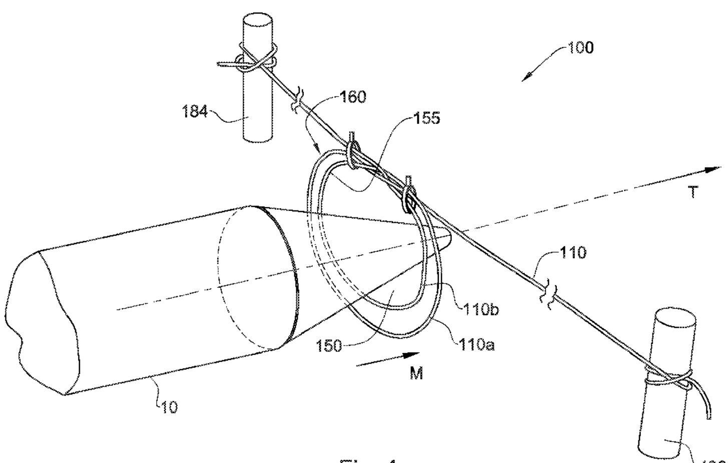

Fig. 4

(57) Abstract: A string assembly is provided defining at least one open cell. In at least some example, each cell includes one or more continuous primary string segment in open looped configuration forming a periphery of a respective open cell, and a retainer arrangement. The one or more primary string segment in such an open looped configuration operates to selectively lock onto an external object in response to the external object being selectively introduced into the open cell and into abutting contact with the periphery. The one or more primary string segment in such an open looped configuration operates to selectively unravel in the absence of such abutting contact and in the absence of the retainer arrangement being operational. Furthermore, the retainer arrangement, when operational, is configured for retaining one or more primary string segment in such an open looped configuration, at least in the absence of such abutting contact.

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STRING ASSEMBLY

TECHNOLOGICAL FIELD

The presently disclosed subject matter relates to string structures and string assemblies, in particular to string structures and string assemblies that form nets.

BACKGROUND

Nets and net-like structures/assemblies, collectively referred to herein as nets, are well known and have many uses, including capturing objects therein. Nets commonly have a number of strings arranged in the form of a 2-dimensional array of open cells, and comprising nodes where the strings intersect. Conventionally, permanent knots are formed at the nodes, for maintaining the form of the net array.

By way of non-limiting background, an intercept device for flying objects is disclosed in US 6,626,077. The device is made of a light-weight, packable structure made of a pliable, tear resistant material that can be expanded to a large web-like structure by means of a deployment device, into the path of a flying weapon. To capture, hold and reduce the velocity of intercepted flying objects, activatable resistance bodies are incorporated into uniformly distributed masses that are connected to the perimeter of the web like structure. Contractable sections of the web, made of cable-like structures, connected to perimeter masses, act as drawstrings upon collision with flying object. This causes closure of the web around the flying object as a result of the mass's inertia and added resistance from deployable resistance structures that place tension on drawstring structures of the web. The flying object is subsequently captured within the web, held secure and it's velocity rapidly reduced.

Also by way of non-limiting background, WO 2007/008960 discloses a system having a containment blanket, and a launcher configured to launch the containment blanket and logic configured to deploy the containment blanket. The containment blanket is configured to encompass an incoming projectile.

Also by way of non-limiting background, various nets or the like are disclosed in US 2004/0132362 and US 6,244,803.

GENERAL DESCRIPTION

According to a first aspect of the presently disclosed subject matter there is provided a string assembly defining at least one open cell, comprising;

at least one continuous primary string segment in open looped configuration forming a periphery of a respective said open cell, and further comprising a retainer arrangement, wherein:

(a) said at least one primary string segment in said open looped configuration is configured:

- for selectively locking onto an external object in response to the external object being selectively introduced into said open cell and into abutting contact with said periphery; and

- for selectively unraveling in the absence of such abutting contact and in the absence of said retainer arrangement being operational;

and wherein

(b) said retainer arrangement when operational is configured for retaining said at least one primary string segment in said open looped configuration at least in the absence of said abutting contact.

On the other hand, the retainer arrangement is considered to be “non-operational” when it is mechanically or otherwise incapable of retaining the primary string segment in the aforesaid open looped configuration at least in the absence of the aforesaid abutting contact between the external object and the periphery – for example the retainer arrangement can become non-operational by mechanically failing (e.g. breaking) or by becoming disassembled.

In at least some examples, the string assembly comprises a plurality of said open cells and a corresponding plurality of said primary string segments, each said open cell comprising a respective said primary string segment in a respective said open looped configuration, wherein said retainer arrangement is configured for retaining each said primary string segment in the respective said open looped configuration, independently from one another.

Additionally or alternatively, in said open looped configuration each respective said primary string segment is configured to lock onto the external object at least partially via frictional contact between overlapping parts of the respective said primary string segment.

Additionally or alternatively, in said open looped configuration the respective said primary string segment is configured to lock onto the external object at least partially via frictional contact between a portion of the respective said primary string segment and the external object.

For example, at least one said looped configuration has a form of a clove hitch knot or equivalents thereof, or a form resembling a clove hitch knot or equivalents thereof, or alternatively comprises any one of: a girth hitch knot, a rolling hitch knot, a constrictor knot, or equivalents thereof, or any knot arrangement that is self-locking onto said external object that is inserted thereinto.

Additionally or alternatively, said retainer arrangement comprises at least one mechanical retainer configured to become non-operational when a respective primary string segment is subjected to a load exceeding a predetermined load threshold, said load being induced in the respective primary string segment in response to the external object being selectively introduced into said open cell and into abutting contact with said periphery.

Additionally or alternatively, said retainer arrangement comprises at least one secondary string segment engaged to a respective said primary string segment; alternatively, said retainer arrangement comprises any one of: a cement or resin material engaged to a respective said primary string segment; or a plastic element or a metal element clamped onto, molded onto or heat shrunk onto respective said primary string segment.

Additionally or alternatively, at least one said primary string segment is provided excluding strength-reducing knots formed therein, such strength-reducing knots being self-locking and including bends of small-radius as compared with a thickness of the primary string segment.

Additionally or alternatively, each said open looped configuration excludes, i.e., has an absence of, strength-reducing knots formed by the respective primary string segment.

Additionally or alternatively, at least one said primary string segment in said open looped configuration is intertwined with respect to an adjacent said primary string segment in said looped configuration.

Additionally or alternatively, the string assembly comprises a string sub-assembly including a plurality of said primary string segments serially joined end-to-end forming a corresponding plurality of said looped configurations in adjacent serial relationship. In some examples, the string assembly comprises at least two said string sub-structures in juxtaposed relationship, or at least two said string sub-structures intertwined with respect to one another. For example, said at least two said string sub-structures are connected together via said retainer arrangement.

Additionally or alternatively, each of one, each of more than one, or each one of all of the primary string segments are extended to connect to a payload, for example a distant payload.

Additionally or alternatively, a continuous string element integrally comprises said plurality of said primary string segments in serial relationship.

Additionally or alternatively, said at least one primary string segment has a mechanical strength greater than a mechanical strength of the retainer arrangement.

Additionally or alternatively, said at least one primary string segment is configured for withstanding an impact from a body traveling at high velocity transverse to a longitudinal axis of the primary string segment. For example, said high velocity is a velocity greater than 400m/s, and/or greater than 500m/s, and/or greater than 600m/s, and/or greater than 700m/s, and/or greater than 800m/s, and/or greater than 900m/s.

Additionally or alternatively, said open cells are arranged in a general two-dimensional array and wherein said retainer arrangement is configured for retaining said plurality of primary string segments, each in corresponding said looped configuration, at nodes of said array. For example, said plurality of primary string segments that form at least one row of said open cells and/or that form at least one column of said open cells of said array is formed from a single continuous length of string. For example, the entire array is formed from a single primary string segment that is looped multiple times to form all the multiple open looped arrangements for the array. For example, each row of the array is formed from a single primary string segment that is looped multiple times to form all the multiple open looped arrangements for the respective row of the array. For example, each column of the array is formed from a single primary string segment that is looped multiple times to form all the multiple open looped arrangements for the respective column of the array.

In at least some examples, said cells of said array are generally polygonal. In at least some examples, said cells of said array are generally rectangular; optionally, said retainer arrangement comprises a secondary string segment co-extensive with a corresponding side of a plurality of said generally rectangular cells; optionally, said retainer arrangement comprises a pair of secondary string segments, each co-extensive with a corresponding side of a plurality of said generally rectangular cells.

Additionally or alternatively, the string assembly is configured for unraveling at least one said open looped configuration located adjacent to an impact cell while remaining mechanically connected hereto on impact of the external object with said impact cell.

Additionally or alternatively, some of said open looped configurations, located in a ring around and adjacent to an impact cell, are configured for unraveling while remaining mechanically connected thereto responsive to impact of the external object with the impact cell, said impact cell being chosen from said plurality of open cells. Additionally or alternatively, some of said open looped configurations, located in each of two or more concentric rings around an impact cell, are configured for unraveling while remaining mechanically connected thereto responsive to impact of the external object with the impact cell, said impact cell being chosen from said plurality of open cells. Optionally, said respective open looped configurations are configured for unraveling via mechanical failure or disassembly of the respective said retainer arrangements, wherein said mechanical failure of the respective said retainer arrangements being responsive to loading of the failed retainer arrangements beyond a failure loading limit due to said abutting contact between the external object and the respective said periphery of the impact cell.

Additionally or alternatively, said external object is a moving object.

Additionally or alternatively, said external object can comprise, for example, a projectile for example a missile or warhead, moving in the atmosphere, or moving through water, or moving in space. Alternatively, such an external object can comprise a satellite or spacecraft travelling in space. Alternatively, such an external object can comprise an aircraft or any air vehicle, manned or unmanned, travelling in the atmosphere. Alternatively, such an external object can comprise water borne craft, for example a surface water craft, or an underwater craft, for example a torpedo.

For example, said external object has a transverse cross-sectional profile that increases along a longitudinal direction generally orthogonal to a respective said cell. For example, the external object has a conical, frusto-conical or ogive shape.

Additionally or alternatively, said at least one primary segment is made from any one of Kevlar, Dyneema, Carbon fiber artificial spider web.

Additionally or alternatively, each said primary string segment comprises a plurality of strand elements.

Additionally or alternatively, each said primary string segment comprises at least a first strand element and a second strand element, and wherein said first strand element is configured for providing better performance than said second strand element with respect to said locking, and wherein said second strand element is configured for providing better performance than said first strand element with respect to said unraveling.

Additionally or alternatively, at least one said open cell comprises at least two said open looped configurations in general concentric relationship with one another and having respective said peripheries of different lengths one from another. Optionally, each said open looped configuration in said concentric relationship is configured for locking with the external object in succession with one another.

According to the first aspect of the presently disclosed subject matter there is also provided a net comprising a string assembly as defined above. Optionally, the net further comprises a payload. For example, said payload is one of:

- affixed to the net via a length of string section different from said at least one primary segment of a respective said open looped configuration, said length of string section having greater elasticity than that of the respective said at least one primary segment; and
- comprises a plurality of payload items distributed over the net.

In at least some examples, said payload is an explosive device; optionally, said payload is configured for detonating according to predetermined criteria after the external object establishes said abutting contact with said net. Additionally or alternatively, said payload is configured for selectively inducing a drag force to said net; for example, said payload comprises at least one parachute; additionally or alternatively, said payload is configured for deploying according to predetermined criteria after the external object establishes said abutting contact with said net. For example, said predetermined criteria include an elapsed time after the external object establishes said abutting contact with said net.

For example, the net is further configured for maintaining a particular spatial attitude with respect to the Earth, at least until the external object establishes said abutting contact with said net. For example, said spatial attitude includes a non-horizontal attitude of the net.

According to a second aspect of the presently disclosed subject matter there is provided a method comprising:

- providing a net as defined above for the first aspect of the presently disclosed subject matter;
- deploying said net at a location intersecting a projected path of the external object;
- allowing the external object to become introduced into any one said open cell and into abutting contact with a respective said periphery thereof to thereby lock said cell onto the external object.

According to a third aspect of the presently disclosed subject matter there is provided a method comprising:

- intercepting a moving object with at least one of a plurality of open looped elements of a net assembly, each said open looped elements being formed by respective primary string segments and configured for providing a friction lock when in contact with the external body therein, said looped elements having an absence of structural ties;
- frictionally locking the moving object with the respective at least one said open looped element.

Optionally, the method further comprises the step of allowing unraveling of at least one said open looped elements located in at least one concentric ring around the at least one said open looped element.

According to a fourth aspect of the presently disclosed subject matter there is provided a net assembly comprising a plurality of open cells, the net assembly comprising a plurality of primary string segments, each primary string segment being looped in an open looped configuration to define a respective said open cell, wherein said open looped configurations have an absence of a strength-reducing knot formed by the respective primary string segment, the net assembly further comprising a mechanical retainer arrangement configured for retaining said primary string segments in said looped configuration while the respective said primary string segments are subjected to loads below a predetermined threshold, each said cell being configured for locking therein an external object that is brought into abutting contact with a periphery of the respective cell to thereby load the respective said primary string segment to loads exceeding said threshold while being mechanically connected to a remainder of the net assembly via at least some of said primary string segments.

According to a fifth aspect of the presently disclosed subject matter there is provided a net assembly comprising an array of primary string segments defining a plurality of open cells and nodes, said primary string segments being in open looped configuration to define respective said open cells, wherein said primary string segment s have an absence of strength-reducing knot formed therein.

According to a sixth aspect of the presently disclosed subject matter there is provided a net assembly comprising open looped elements formed by respective primary string segments and configured for providing a friction lock when in contact with an external body therein, said looped elements having an absence of structural ties therein.

According to one or more of the above first through sixth aspects of the presently disclosed subject matter, and without being bound to theory, the impact between an external object and an open cell of a corresponding string assembly is considered to develop as follows.

First there is an initial contact between the external object and the respective open cell, and this is followed by close abutting contact between the full perimeter of the open cell and the external object.

In an ideal case, when the cross-section of the external object is circular and the trajectory of the external object is accurately centered so that the external object enters the respective open cell (which is also assumed to be circular) at its dead center, then such contact is made simultaneously over the full periphery of the open cell. Statistically, such a collection of circumstances is not considered to have a high probability of occurring in practice. Rather, in general such initial contact is often made at one point or area on the periphery, or perhaps a small number of points or areas.

In at least some examples of the presently disclosed subject matter, the respective open cells are formed as polygons. In cases in which the trajectory of the external object is centered with respect to the open cell, and the open cell is in the form of an equal-sided polygon (i.e., at sides of the polygon are equal to one another in length, such as a square or other regular polygon for example), such initial contact is nominally made on all the sides of the polygon simultaneously, with the number of contact points equal to the number of sides. Alternatively, in cases where the open cell is formed as a polygon with unequal sides, such as a rectangle (or another irregular polygon) for example, such initial contact is nominally made on the longer sides (which are closer to the center of the polygon or rectangle), and if there are a number of sides of equal length, such as the in a rectangle, then such initial contact can be made on these sides simultaneously.

Finite element simulations of an external object impacting on an open cell of string assembly indicate that the worst case in terms of the maximal stress buildup in the respective primary string segment after impact occurs when the impacting external object impacts the center of the cell, wherein several sides or points of the open cell are impacted simultaneously by the external object. Other such simulations also indicate that an open cell formed as a polygon shape with un-equal sides can withstand a higher velocity impact than an open cell formed as a polygon shape with equal sides.

It is considered that, emanating from each point of such initial contact, tensile shock fronts propagate in either direction along the respective primary string segment away from the initial impact point (also referred to interchangeably herein as the initial contact point). Without being bound to theory, it is further considered that the magnitude of the tensile shock fronts depends only on the relative velocity between the external object and the primary string segment of the open cell, and on some material properties of the string segment of the open cell. Again without being bound to theory, it is considered that the magnitude of the tensile shock fronts does not depend on the mass of the external object (with respect to which, the mass of the primary string element can be negligible), nor on the diameter of the primary string element (and thus the cross-sectional area thereof). Again without being bound to theory, it is considered that this non-dependence on the diameter or cross-sectional area of the primary string element is due to the nature of the impact which forces the primary string element to strain at the rate it is impacted onto by the external object; further, due to the large differences in mass between the primary string element and the external object (which is expected in many applications), the rate of strain is determined only by the relative velocity between the primary string element and the external object. Thus, even if a thin primary string element is replaced with a thicker primary string element, it will still be strained by the same amount, and the resulting stress (which is related to the aforesaid tensile shock fronts) is thus independent of the diameter or cross-sectional area of the primary string element.

The level of stress induced at the initial impact point determines whether or not the primary string segment can withstand the direct impact between the primary string element and the impacting external object. At very large relative impact velocities the stress induced at the point of contact can exceed the breaking stress of the material from which the primary string element is made, and the primary string element then breaks at the point of impact. In examples where this material is chosen from high tenacity materials, for example materials marketed under the name of Dyneema or Kevlar, breakage of the corresponding string segments at the contact point will occur at impact velocities much higher than 400m/s, and even exceeding 800 m/s or 900 m/s.

In conditions under which the primary string segment does not break due to the initial impact stress, the primary string segment still has to withstand the interaction of tensile shock fronts emanating from each of the different points of contact. This interaction can be in the form of constructive interference, and the magnitude of the resulting tensile shock fronts depends on the geometry of the impacted open cell and the location of the points of contact along the periphery of this open cell. For example, if the open cell is in the form of a regular polygon such as a square, for example, and the cell is impacted directly at its center, tensile shock fronts emanate at each of the four initial contact points at the center of the four sides of the open cell. The geometrical symmetry of the open cell results in the nominally simultaneous arrival of tensile shock fronts from two adjacent contact points at half the distance between these initial contact points (which occurs at the location of the corner of the square cell). The time interval **t** to this arrival from the initial contact can be determined from the following relationship:

t = *ac/2*...(1)

where *a* is the length of the side of the square cell, and *c* the velocity of the stress front.

Depending on the actual geometry of the open cell, higher stress levels in the primary string segment can be induced due to superposition of the tensile shock fronts and the reflections from sharp bends along the periphery of the primary string (such as the corners of the square cell, or the rejoins of intersection of the loops forming a circular open loop cell). Clearly, the primary string segment will break under conditions in which such higher stress levels exceed breaking stress of the primary string segment.

Relationship (1) above indicates that the timing for arrival of two tensile shock fronts at a corner of the open cell can be staggered so that the overall superposed stress level at the corner is correspondingly reduced. Thus, if the open cell is formed as an irregular polygon with unequal sides, the arrival of each of the stress fronts from adjacent initial contact points at the corner is staggered, and the maximal stress level at the corner is thus lower than would be the case if the cell is formed as a similar polygon but with equal sides. Hence, providing the open cells as polygons with unequal sides, for example rectangles, provides advantages over other forms (such as for example regular polygons, equal sided polygons, or circles) for the open cell regarding its capacity to withstand the initial impact of an external object.

Furthermore, in cases where the trajectory of an external object is not accurately centered with respect to the respective open cell, the timing of the arrival of the shock fronts from adjacent initial contact points to corners of the polygonal open cell is similarly temporally staggered. Therefore, as indicate above, the highest stress induced in the primary string segment is when an eternal object strikes and impacts the respective open cell accurately centered with respect thereto rather than when the impact is off-center.

Following the initial stress that develops in the primary string immediately following impact, the primary string is gradually forced into full abutting contact with the external object while two secondary processes take place:

In the first secondary process, the open cell is forced onto the external object, the primary string segment of the respective open looped configuration eventually stretches over the perimeter (e.g. circumference) of the external object, and the primary string segment experiences a circumferential stress as the front section of the object thrusts forward to tighten the respective open looped configuration outward. Such a front section increases in cross-section in an aft direction, and can be, for example, conical in form.

In the second secondary process, tensile stress fronts propagate outward towards the ends of the respective string assembly. In some examples the string assembly comprises payload items connected to the string assembly via extended portions of the primary string segment of the string assembly, for example. In such examples, as the stress fronts reach these payload items they are reflected and proceed to accelerate each of the payload items. The outcome of this process depends on the elasticity of the respective primary string segment, the length of these extended portions, the elasticity of these extended portions of the primary string segment, and the mass of the payload items. For sufficiently long extended portions of the primary string segment, sufficiently elasticity of these extended portions, and sufficiently small object mass, the primary string segment is able to accelerate the payload items so that these eventual move at the same velocity of the external object. The extended portions of the primary string segment attached to the payloads can optionally be made from a separate string section with increased elasticity to optimize the process of accelerating the payloads.

Either of these two secondary processes can lead to a break of the primary string segment of the open looped configuration of the respective open cell, as further discussed below. Nevertheless, for an impact within a specified performance envelope, the respective string assembly remains intact, is attached to the external object, and is carried by the external object at the object's velocity, while the extended portions of the string assembly with their payload items are carried along.

In examples where the front section of the external object increases in cross-section in an aft direction (for example, the front section is conical), the external object impacts and makes abutting contact with the primary string segment of the respective open looped configuration via this front section. As the external object continues along its trajectory and the open looped configuration accelerates, the open looped configuration is displaced over the surface of the front section in an aft direction, effectively "climbing" up towards the base of the cone. As it progresses aft, the open looped configuration is forced to stretch to occupy a larger inner circle defined by the increasing cross-section of the external object. This increases the normal force, N acting on the respective primary string segment, which, in turn increase the contact friction force $F=\mu N$. Such increase in the normal force N continues until the resulting friction force F reaches a threshold preventing the open looped configuration from displacing further aft.

If the cone angle of the front section of the external object (or at least the slope of the front section at the point of contact, taken on a longitudinal cross-section of the front section – such a slope is referred to herein as “local slope”) increases, then so does the strength of the corresponding normal force N, and of the resulting friction force F. For small cone angles (or small local slopes) the friction is lower and the external object continues to stretch the open looped configuration for longer. Therefore for small cone angles, the more likely failure is by stretching the primary string, whereas for larger cone angle (or large local slopes) if the primary string segment survives the initial impact, it will remain intact when subject to the circumferential stressing by the conical projectile. Similar considerations apply to other external object forms - the larger the slope of the surfaces of the front section, the more likely it is for the failure mode to be related to the direct impact stresses (and will occur at higher relative velocities). In as much as the design of the open cells of the string assembly can accommodate the external object geometry, a higher maximum limiting value for the impact velocity can be achieved with external objects that form larger sloping surfaces at the points of contact with the primary string segment than is the case with external objects that form shallower sloping surfaces at the points of contact with the primary string segment.

Furthermore, it is suggested that, as the process of stretching of the open looped configuration differs from the process of impact in that the stretching process introduces a stress boundary condition, while the latter corresponds to a strain boundary condition, it can be possible to increase the resilience of an open cell of a string assembly to stretch over the increasing cross-section of an impacting external object by correspondingly increasing the cross-sectional area of the primary string segment thereof. As noted above such increase in the cross section of the primary string does not improve the resilience of the string to the initial impact.

The maximal stress developed after impact with a rectangular-shaped open cell is thus considered to be less than the maximal stress developed after impact with a square-shaped open cell, when impacted by a similar external object, such as a missile for example, of circular cross-section. On the other hand, for an impacting external object having elliptical cross-section, a square form for the open cells can better ensure that the impact on adjacent sides of the open cell is staggered, depending on the aspect ratio of the elliptical cross-section.

A feature of at least one example of the presently disclosed subject matter is that the respective string assembly avoids any permanent knots, which could otherwise significantly reduce the overall strength of the respective primary string segments in the string assembly and thereby reduce the loading limit of the string assembly to well below the loading limit of the individual primary string segments of the string assembly. This feature ensures that the strength of the string assembly is not compromised by the presence of permanent knots, or at least minimizes the risk of such strength being compromised, while concurrently allowing the external object to be captured by the string assembly.

Two other features of this and/or at least one other example of the presently disclosed subject matter are that part of the string assembly, for example one open cell thereof, locks onto the impacting external object via the respective open looped configuration, while another part of the string assembly, comprising other, non-impacted, open cells, unravels. The locking feature ensures that the string assembly locks on to the external object after impact and stays affixed thereto, or at least minimizes the risk of the string assembly separating from the external object after impact. The unraveling feature ensures that the non-impacted open cells of the string assembly are minimally loaded after impact, and thus minimizes the risk of reducing the impact resilience of the string assembly.

BRIEF DESCRIPTION OF THE DRAWINGS

In order to understand the disclosure and to see how it may be carried out in practice, examples will now be described, by way of non-limiting example only, with reference to the accompanying drawings, in which:

Figs. 1(a), 1(b), 1(c) are, respectively, an isometric view, a plan view and a side view, of a string assembly according to a first example of the presently disclosed subject matter.

Figs. 2(a), 2(b), 2(c) schematically illustrate various stages in forming the string assembly of Figs. 1(a), 1(b), 1(c).

Fig. 3 illustrates, in isometric view, the string assembly of Figs. 1(a), 1(b), 1(c) in relation to the trajectory of an incoming object.

Fig. 4 illustrates, in isometric view, the string assembly of Fig. 3 just prior to impact with the respective incoming object.

Fig. 5 illustrates, in isometric view, the string assembly of Fig. 4 after impact with the respective incoming object.

Figs. 6(a) and **6(b)** schematically illustrate forces between the impacted object and the string assembly, where the object has a relatively large and relatively small cone angle, respectively.

Figs. 7(a), 7(b) are, respectively, a plan view and a side view, of a string assembly according to a second example of the presently disclosed subject matter.

Figs. 8(a), 8(b) are, respectively, a side view and a plan view, of the string assembly of Figs. 7(a) and 7(b) just prior to impact with an incoming object; **Fig. 8(c)** identifies various rings of open looped configurations of the string assembly of Figs. 8(a) and 8(b) with respect to the projected impact zone.

Figs. 9(a), 9(b) are, respectively, a side view and a plan view, of the string assembly of Figs. 8(a) and 8(b) just after impact with the respective incoming object at the projected impact zone.

Figs. 10(a), 10(b) are, respectively, a side view and a plan view, of the string assembly of Figs. 8(a) and 8(b) after impact with the respective incoming object at the projected impact zone and unraveling of a first ring of open looped configurations of the string assembly around the impact zone.

Figs. 11(a), 11(b) are, respectively, a side view and a plan view, of the string assembly of Figs. 8(a) and 8(b) after impact with the respective incoming object at the projected impact zone and unraveling of a second ring of open looped configurations of the string assembly around the impact zone.

Fig. 12 is a plan view of a string assembly according to a third example of the presently disclosed subject matter.

Figs. 13(a), 13(b) are, respectively, a plan view and a side view, of the string assembly of Fig. 12, illustrating further details thereof.

Fig. 14 is a plan view of a string assembly according to a variation of the example of Fig. 12.

Fig. 15 is a plan view of a string assembly according to another variation of the example of Fig. 12.

Fig. 16 is a plan view of a string assembly according to another variation of the example of Fig. 12.

Fig. 17 is a plan view of a string assembly according to another variation of the example of Fig. 12.

DETAILED DESCRIPTION

Referring to Figs. 1(a), 1(b), 1(c), a string assembly (also referred to interchangeably herein as a “string structure”) according to a first example of the presently disclosed subject matter, generally designated **100,** comprises a primary string segment **110** and a retainer arrangement **120.**

The primary string segment **110** is a continuous length of flexible, high tensile material, typically of generally uniform cross-section along its length, such as, but not limited to, a string. The primary string segment **110** is arranged in a continuous, single, open looped configuration **160** to define an opening **151** having a periphery **155.** This opening **151** and the corresponding open looped configuration **160** thereof are collectively referred to herein as an open cell, or simply as a cell **150** of the string assembly **100,** the open cell **150** having a characteristic peripheral length CL along the periphery **155.** For example, in examples where the open cell **150** is disk-shaped or circular, the peripheral length **CL** is a circumference length and is related to the diameter of the open cell **150.**

As shall become clearer below, the primary string segment **110** in the open looped configuration **160** is configured:

- for locking with respect to an external object in response to the external object being selectively introduced into the open cell **150** and into abutting contact with the periphery **155;** and

- for unraveling in the absence of such abutting contact (i.e., for unraveling under conditions of zero abutting contact) and in the absence of the retainer arrangement **120** being operational.

As shall also become clearer below, the retainer arrangement **120,** is configured for retaining the primary string segment **110** in the aforesaid open looped configuration **160** at least in the absence of the aforesaid abutting contact between the external object and the periphery **155.** The retainer arrangement **120** is considered being "operational" when retaining the primary string segment **110** in the aforesaid open looped configuration **160** at least in the absence of the aforesaid abutting contact between the external object and the periphery **155.** Conversely, the retainer arrangement **120** is considered to be "non-operational" when it is mechanically or otherwise incapable of retaining the primary string segment **110** in the aforesaid open looped configuration **160** at least in the absence of the aforesaid abutting contact between the external object and the periphery **155** – for example the retainer arrangement **120** can become "non-operational" by mechanically failing (e.g. breaking) or by becoming disassembled.

In this example, the open looped configuration **160** is in a form resembling a clove hitch knot. The string segment **110** thus comprises two consecutive loops **110a**, **110b**, overlaid on one another, the string segment **110** extending to respective ends **111a**, **111b** along generally opposite directions. One overlying section **112** of the string segment is overlaid over corresponding sections **113, 114** of the loops **110a**, **110b** to form an overcross.

For example, and referring to Figs. 2(a), 2(b) and 2(c), such an open looped configuration **160** can be formed starting with the primary string segment **110** in general elongate form, i.e. in an essentially unlooped configuration in Fig. **2**(a), double-looping the string segment **110** as illustrated in Fig. **2**(b) to form consecutive loops **110a**, **110b**, and bringing the two loops **110a**, **110b** in overlying relationship such as to provide the overcross of overlying section **112** over sections **113, 114** of the loops **110a**, **110b**, as illustrated in Fig. 2(c). Alternatively, open looped configuration **160** can be formed by manipulating and moving one end of the string segment **110** along a trajectory defined by the final form of the open looped configuration **160** illustrated in Fig. 2(c).

It is thus evident that the open looped configuration **160,** in this example in the form of a clove hitch knot, avoids, i.e., excludes, any permanent knots formed by the primary string segment **110** that can otherwise reduce the strength of the string segment **110.**

Herein, "permanent knot" (interchangeably referred to herein as structural ties), in contrast to a clove hitch knot for example, refers to any type of fastening knot that fastens on a string segment by forming a loop around (and in load-bearing contact with) a circumferential periphery of the general cross-section of a part of the string segment, for example at least partially helically, such that application of tension to the string of the fastening knot locks the loop around the full periphery of the aforesaid part of the string segment, thereby significantly weakening the strength of the string segment. In other words, a "permanent knot" is locked by the string itself and is characterized by having loops of large curvature (small radius) in relation to the thickness or diameter of the string segment itself on which the permanent knot is tied. Thus, a "permanent knot" is a type of knot that results in the respective string segment having a relative knot strength significantly less than 100% in the vicinity of the permanent knot, and more precisely the relative knot strength is less than 80%, or less than 70%, or less than 60%, or less than 50%. Relative knot strength, also known as knot efficiency, is conventionally defined as the breaking strength of a knotted string in proportion to the breaking strength of the string without the knot.

Referring again to Figs. 1(a), 1(b), 1(c), the retainer arrangement **120** is engaged to the open looped configuration **160,** and in this example retainer arrangement **120** comprises a pair of secondary string segments **122,** distinct, i.e. different from or separate from, the primary string segment **110.** Each secondary string segment **122** is tied to the open looped configuration **160** at a respective one of two positions **P1, P2,** which are spaced from one another. At each position **P1, P2,** the respective secondary string segment **122** is looped around and engages the primary string segment **110** at corresponding parts of the loop **110a**, loop **110b** and overlying section **112** retaining the open loop cell structure of cell **150.** Thus, overlying section **112** is fully or partially defined between the two positions **P1, P2.** In this manner, retainer arrangement **120** (in this example in the form of the string segments **122)** prevents the primary string segment **110** in the open looped configuration **160** from unraveling. In alternative variations of this example, the retainer arrangement **120** can comprise one such secondary string segment **122** (for example located at a position intermediate between **P1** and **P2)** or more than two such secondary string segments **122.** In this example, each secondary string segment **122** is affixed to itself in its looped configuration, in which it is engaged to the primary string segment **110** at corresponding parts of the open looped configuration **160** in any suitable manner – for example the respective secondary string segment **122** can be tied to itself, or can be welded, mechanically affixed, or be formed as an integral loop (such as for example a ring).

It is evident that the retainer arrangement **120,** when thus engaged to the open looped configuration **160,** is operational to maintain the spatial relationship that defines the open looped configuration (even though there is, as yet, an absence of any external body in abutting relationship with the periphery **155** of the cell **150)**, in particular the spatial relationship between the loops **110a**, **110b** and overlying section **112.**

In alternative variations of this example, the retainer arrangement **120** can comprise cement or resin or equivalents thereof, placed onto and around the primary string segment **110,** securing the same in place. Additionally or alternatively, the retainer arrangement **120** can comprise pressed strips of metal or other metal elements, or equivalents thereof, used to hold the primary string in place. Additionally or alternatively, the retainer arrangement **120** can comprise plastic retainers or equivalents thereof, clamped onto, molded onto, or heat shrunk onto the primary string segment **110.**

The retainer arrangement **120** is configured on the one hand to maintain the form of the open looped configuration even in the absence of any external body being in abutting relationship with the periphery **155** of the open cell **150.** On the other hand the retainer arrangement **120** does not itself apply significant loads on the string segment **110,** such as could otherwise reduce relative knot strength of the primary string segment **110** to significantly less than 100% in the vicinity of the secondary string segments **122,** and more particularly such as could otherwise reduce relative knot strength of the primary string segment **110** to significantly less than 80%, or less than 70%, or less than 60%, or less than 50%. In addition, and as will become clearer below, the retainer arrangement **120** is configured for becoming non-operational, for example mechanically failing (for example breaking or disassembling), at a predetermined load level, allowing the primary string segment **110** to unravel if it remains without a locking external body in abutting contact therewith. As will also become clearer herein, the retainer arrangement **120** can optionally become non-operational once an external locking body is inserted into the open cell **150** in abutting contact therewith, and thus the primary string segment **110** in the aforesaid open loop configuration remains locked onto the external body irrespective of whether or not the retainer arrangement is still intact.

In this example, the ends **111a**, **111b** of the string segment **110** each extend to a length considerably longer than the peripheral length **CL** of the cell **150.** For example, such a length can be at least **10** times the peripheral length **CL**.

Referring to Fig. 3, the string assembly **100** further comprises a payload **180,** which in this example includes two payload items **182, 184,** spaced from one another. Each end **111a**, **111b** of the string segment **110** being affixed to a respective one of the items **182, 184** (together with the string assembly **100**) are supported suspended in mid-air via lighter-than-air balloons or the like (not shown), or alternatively are following a particular trajectory in the atmosphere following deployment from a carrier projectile or an aircraft, for example, suspended by a pair of parachutes, for example. In alternative variations of this example, the items **182, 184** can be seated or supported on the ground (or on another structure such as for example a pair of spaced towers), such as to suspend the open looped configuration **160** above the ground (or above the other structure). In any case, the open looped configuration **160** is spaced between the two items **182, 184.**

Such long lengths are considered to delay and/or dampen the impact experienced by the string segment **110** of the open looped configuration **160** originating from reflection of impact stress wavefronts from the inertia of the payload **180.**

In an alternative variation of this example, the payload **180** comprises one such item or equivalents thereof affixed at one end **111a** of the string segment **110,** while the other end **111b** is seated or supported on the ground or on a static structure.

Referring again to Fig. 3, in operation of the string assembly **100,** the string assembly **100** and in particular the open cell **150** is positioned to intersect the projected trajectory **T** of an external object **10** that is moving towards the open cell **150.** In particular the projected trajectory **T** intersects the cell **150** generally orthogonal thereto, i.e., at least sufficiently orthogonal thereto such as to allow the external object **10** to at least partially penetrate into the cell **150** and to subsequently become locked therein. Of course the converse can instead be the case, in that the external object **10** can be static and the string assembly **100** can be moving towards the external object **10**; or indeed both the external object **10** and the string assembly **100** can both be moving in the same or different directions but with a relative velocity towards one another.

Referring to Fig. 4 and Fig. 5, as the object **10** follows trajectory **T**, the object **10** eventually impacts the primary string segment **110,** in particular the parts of the primary string segments **110** forming the loops **110a**, **110b** as the external object **10** becomes introduced into the open cell **150** and comes into abutting contact with the periphery **155.** As a result, the open looped configuration **160** of open cell **150** locks onto the object **10** in a manner similar to what would have been the case if the primary string segment **110** in general elongate form (i.e. in an essentially unlooped configuration in Fig. **2**(a)) would have been manipulated to form the open looped configuration directly on the external object **10**, i.e., while being supported by the object **10**. In this example, the open looped configuration **160** is in the form resembling a clove hitch knot that locks onto external object **10** in a manner similar to what would have been the case had a general elongate length of primary string segment **110** been directly tied onto the object **10** in the form similarly resembling a clove hitch knot. As is well known in the art, a string segment that is tied over an object (e.g. a rod) as a clove hitch knot, such that the object is engaged within the loops of the clove hitch knot, is self supporting once sufficient tension is applied to the string segment. In this example, the aforesaid sufficient tension in the primary string segment **110** is induced responsive to the abutting contact between the external object **10** and the periphery **155.** Such a sufficient tension (referred to herein as the load threshold for the open looped configuration **160)** is induced in the open looped configuration **160** of cell **150** by virtue of the impact and the subsequent loading of the primary string segment **110** as a result thereof.

Without being bound by theory, the inventor suggests that frictional forces are induced at the overcross between overlying section **112** and sections **113, 114** in the zone **Z** (see Fig. 1(b), Fig. 1(c) and Fig. 5) between overlying section **112,** and/or, frictional forces are induced between the loops **110a**, **110b** and the external object **10**, when the object **10** is engaged in the open cell **150** and is in abutting contact with the periphery **155,** in particular where such abutting contact applies the aforesaid predetermined tension to the primary string segment **110.** Without being bound by theory, the inventor further suggests that these frictional forces lock the open looped configuration **160** onto the object **10**, and prevent the string segment **110** unraveling from the open looped configuration.

As the external object **10** impacts and becomes engaged with the string segment **110,** the external object **10** carries the open cell **150** with it (and thus also payload items **182, 184**) along its trajectory **T**. Accordingly, the external object **10** carries with it the string assembly **100,** at least directly after impact.

The payload items **182, 184** in this example each comprise at least one of an explosive charge and a velocity retardant mechanism, at least one of which is configured to become activated either via external control (for example by remote control) or in response to predetermined set of conditions (for example via sensors in the payload items that determine that the external object **10** has been locked by the string segment, for example by sensing a sudden acceleration or velocity that accompanies the impact of the external object on the string segment **110**).

In further operation of the string assembly **100,** the payload items **182, 184** can be activated to disrupt the original trajectory **T** of the external object **10**, in particular by destroying or damaging the external object **10** via the explosive charge that is thus selectively detonated, and/or by significantly reducing the velocity of the external object via the velocity retardant mechanism. The velocity retardant mechanism can comprise, for example, one or more parachutes, balloons or other aerodynamic drag inducing devices or structures, that can be selectively deployed when the payload items **182, 184** are activated, which thereby induce a significant drag force and/or instability to the external object **10**, forcing the external object **10** away from the trajectory **T**.

Referring again to Fig. 5, when the primary string segment **110** in the open looped configuration **160** of cell **150** is locked onto the external object **10**, the retainer arrangement **120** is no longer necessary for maintaining the open looped configuration **160.** Thus, optionally, the secondary string segments **122** can be configured to become non-operational (e.g., mechanically break or open or disassemble, etc) when the external object **10** is in the aforesaid abutting contact with the periphery **155** of the open cell **150.** For example, the secondary string segments **122** can comprise weak bonds that hold the secondary string segments **122** in ring-form, and that are, on the one hand, mechanically competent to maintain the open looped configuration while the string assembly **100** is being handled, but on the other hand become non-operational (e.g. break or otherwise open mechanically or disassemble), when said predetermined tension is induced in the primary string segment **110** as a result of the external object **10** being locked by the open cell **150.** Alternatively, the retainer arrangement **120** is no longer necessary, but nevertheless remains relatively intact and in place after the external object **10** is in the aforesaid abutting contact with the periphery **155** of the open cell **150,** and the secondary string segments **122** do not necessarily become non-operational (for example do not break or otherwise open mechanically or disassemble) nor significantly load the primary string segment **10**.

It is to be noted that the string segment **110** in general, and the open looped configuration **160** in particular, do not have any permanent knots therein. Thus, the ability of the string segment **110** to withstand a high velocity impact from the external object is not significantly diminished with respect to the ability of a datum string segment to withstand a lateral impact from the external object **10** under the same conditions. Such a datum string segment is a continuous length of high tensile material, identical to that of the primary string segment **110,** but excluding any loops, bends, or knots of any kind.

Referring again to Fig. 3, the external object **10** in this example comprises transverse cross-sections (i.e., cross-sections generally orthogonal to the direction of motion **M** or longitudinal axis **15** of the object **10**) that are generally circular and that monotonically increase from the tip **11** to a base **12** thereof, defining a generally conical (or alternatively frusto-conical) shape. Furthermore, the characteristic peripheral length **CL** of the open cell **150** (after allowing for the elongation of the primary string segment **110** under stress) is intermediate between the minimum peripheral length $\mathbf{CL_{min}}$ (in this case, the minimum circumferential length) and the maximum peripheral length $\mathbf{CL_{max}}$ (in this case, the maximum circumferential length) of these circular cross-sections.

In alternative variations of this example the external object **10** can instead comprise a non-circular cross-section (for example, oval, elliptical, super-elliptical, polygonal, or equivalents thereof, and so on). Additionally or alternatively, the cross-section of the external object **10** can increase from the tip to the base in a non-linear manner, for example having ogive, part elliptical, part super-elliptical, rounded, or otherwise curved cross-sections taken along planes orthogonal to the transverse sections and aligned with the longitudinal axis **15** of the external object **10**. While in this example the external object **10** is axisymmetric about the longitudinal axis **15**, in alternative variations of this example the external object **10** can be non-axisymmetric.

In any case the external object **10** comprises a transverse cross-section (i.e., cross-sections generally orthogonal to the direction of motion **M** of the external object **10**) that increases from the tip to a base thereof, and the perimeter of these cross-sections thus increases from a minimum perimeter to a maximum perimeter. Thus, and particularly for cases where the object does not have a circular cross-sections, the characteristic peripheral length **CL** of the open cell **150**, which is the length along perimeter **155**, is thus intermediate in value with respect to the aforesaid peripheral length $\mathbf{CL_{min}}$ and maximum peripheral length $\mathbf{CL_{max}}$ of these corresponding cross-sections of the external object **10**.

In yet other alternative variations of this example the external object **10** has a generally constant cross-section between the tip **11** and the base **12**, and the external object **10** can enter the open cell obliquely to the plane of opening **151,** for example.

In any case, the peripheral length **CL** of the open cell **150** can be designed to be smaller than the base periphery of the smallest external object **10**, that it is anticipated to be intercepted by the string assembly **100,** allowing for any elongation of the open cell **150** under its operational stress, thereby ensuring that the string assembly **100** can operate effectively with all anticipated external objects, for example in the form of projectiles.

In some cases, it is possible for the primary string segment **110** to mechanically fail after engagement with the object **10**, rather than become locked thereon. This can occur immediately following impact with the external object or at a later stage when the primary string is stretched over the circumference of the external object. In such cases, the primary string segment breaks and it is possible, though not necessarily certain, that the string assembly **100** becomes detached from the object **10**.

Without being bound by theory, the inventor suggests that there are at least two possible mechanisms for such mechanical failure, referred to herein as fail mechanisms (a) and (b) as follows:

(a) Buildup of stress in the string segment **110** due to the transverse loading of the object's impact. This is essentially the same load that would have been applied to a datum string segment, i.e., to the primary string segment **100,** had the string segment **110** not been part of the string assembly **100** and been impacted by the object under similar conditions, i.e. the load corresponds to the load that would have been applied transversely to the corresponding datum string segment under similar impact conditions. Again, without being bound by theory, the inventor suggests that this mechanism essentially poses a fundamental limitation on the strength and viability of the string assembly **100** that is a function of the material of the string segment and of the impact velocity between the object **10** and the string assembly **100.** In ordinary use of the string assembly **100** according to the presently disclosed subject matter, the material of the primary string segment **110** and the expected impact velocity are such as not to exceed this limitation. The inventor has found the high tenacity materials, such as marketed under the names Dyneema or Kevlar for example, can withstand impact at relative velocities of higher than 400m/s, and up to 800m/s or 900m/s or greater. Thus, in at least some examples of the presently disclosed subject matter, the respective string assembly is configured for maintaining mechanical integrity of the respective primary string segments for impact velocities greater than 400m/s, or greater than 500m/s, or greater than 600m/s, or greater than 700m/s, or greater than 800m/s, or greater than 900m/s.

A subset of the above limitation occurs due to the closed loop geometry of the primary string segment, in that the stress fronts from more than one impact point on periphery **155** can propagate to superpose on one another at different locations along the open loop configuration **160** of open cell **150.** This condition necessarily reduces the expected maximum allowable relative impact velocity relative to the theoretical limitation associated with a long, straight string segment where superposition of stress fronts is less likely.

(b) The stress that is induced in the primary string segment **110** along the periphery **155** that originates from the forces exerted on the primary string segment **110** tangentially by the circumferential force generated by the circular sections of a cone-shaped object having respective peripheries increasing (e.g., monotonically) in size from less than to greater than the characteristic peripheral length **CL** of the cell **150,** trying to force open the cell **150.**

Again, without being bound by theory, the inventor suggests that the slope of the contact surface on the object **10** with the periphery **155** determines which one of the two above mechanisms dominates in any given combination of the material from of at least the outer surface of external object **10**, and material from which the primary string segment **110** is made. Thus, in examples where the external object **10** has a conical or frusto-conical part that engages with the string assembly **100,** the corresponding cone angle determines which one of two above mechanisms can dominate in such cases. Referring to Fig. 6(a), if the cone half-angle, i.e., angle α_1 is relatively large, such that the resulting friction forces prevent the open cell from moving aft towards the base of the cone, the primary physical effect is that of a transverse impact on the string segment **110** at the open looped configuration **160.** In this case mechanism (a) dominates. Conversely, and referring to Fig. 6(b), if the cone half angle, angle α_2 is relatively small such that the resulting friction forces do not prevent the open loop cell from moving aft towards the base of the cone, the primary physical effect is that of a stretching of the primary string segment over the cone, generating large tensile stresses in the primary string segment, which acts to open the cell **150,** and mechanism (b) dominates. The actual magnitudes of the angles α_1 and α_2 depend on the material of the outer surface of the external object and the level of friction forces that are generated with the string material.

In any case, and as already referred to above, when such an object **10** having a conical, frusto-conical, or similar forward part that engages with the string assembly **100** by being inserted into the cell **160** into abutting contact with the periphery **155**, even a relatively small tensile force (the aforementioned load threshold) thereby applied to the string segment **110** of the open looped configuration **160** will lock and thus secure the external object **10** with respect to the string assembly **100.** On the other hand, in the absence of such abutting contact with the object **10**, and in the absence of the retainer arrangement **120** being operational, the open looped configuration **160** is unstable and will collapse or otherwise unravel when the smallest tensile force is applied to the string segment **110**, even a fraction of the aforementioned load threshold.

For example, the external object **10** can be a projectile (for example a missile or warhead) that it is wished to intercept and optionally neutralize using the string assembly **100.** In operation of the string assembly **100,** such a projectile having a projected trajectory **T** can be engaged by the open looped configuration **160** when the trajectory **T** intersects the cell **150,** and the projectile is locked by the string assembly **100.** In turn the payload **180** is dragged along with the string assembly **100,** and can selectively explode and/or induce significant drag and/or instability to the projectile, thereby causing the projectile to disintegrate or to at least veer significantly from the projected trajectory **T**, thereby becoming ineffective and/or missing an intended target at the end of projected trajectory **T**, for example.

In an alternative example, the external object **10** can instead be a probe of an aircraft, and the string assembly **100** can be used for enabling the aircraft to collect the payload **180** via the probe while airborne. Of course the payload **180** can be in this case any payload desired to be thus collected, and does not necessarily include an explosive charge or velocity retardant mechanism. In operation of the string assembly **100,** such an aircraft can travel with the aforesaid probe moving along projected trajectory **T**. The probe can then be engaged by the open looped configuration **160** when the trajectory **T** intersects the cell **150**, the probe becomes locked by the string assembly **100** and thus takes the payload **180** with it as the aircraft moves on. Such a payload can then be selectively released by the aircraft over a designated delivery area, whether the delivery is performed by low altitude dropping or with the aid of a parachute (which can be part of the payload). The release mechanism of the payload can be based, for example, on breaking the primary string segment mechanically (e.g. using a cutting tool) or by applying heat (for example the material Dyneema has a melting temperature of about 150°C, and thus a heating device capable of heating the primary string segment of cell

150 to temperatures higher than the melting temperature of the primary string segment can be used to effectively cut the primary string segment).

Alternatively, the external object **10** can be in the form of an aircraft or drone or other air vehicle, manned or unmanned, which it is desired to intercept and neutralize via the string structure.

Alternatively, the external object **10** can be in the form of a satellite or spacecraft travelling in space, which it is desired to intercept and neutralize via the string structure.

Alternatively, the external object **10** can be in the form of a surface or underwater craft, for example a torpedo, which it is desired to intercept and neutralize via the string structure.

As has already been discussed above, in this example the open looped configuration is in the form resembling a clove hitch knot. However, in alternative variations of this example the open looped configuration can include a form similar to or resembling, for example, any one of: girth hitch knot, rolling hitch knot, constrictor knot, or their equivalents, or any similar knot arrangements that are self-locking onto an external object that is inserted into them.

Referring to Figs. 7(a) and 7(b), a string assembly **200** according to a second example of the presently disclosed subject matter includes at least some of the elements and features as disclosed herein for the first example including alternative variations thereof as disclosed herein, *mutatis mutandis*, but with some differences, as will become clearer in the following disclosure.

String assembly **200** comprises an array of cells **250,** each cell being similar to cell **150** of the first example, *mutatis mutandis.* While in this example, the cells **250** are similar in size and shape to one another and arranged in a two-dimensional rectangular planar array, in alternative variations of this example the cells **250** can be arranged in any other manner, for example: in hexagonal-type arrays (in which each cell **250** is surrounded by six other cells **250**) or equivalents thereof,, and/or in which the cells **250** are arranged in a three-dimensional or non-planar array with respect to one another, and/or the cells **250** are not similar in size and/or shape to one another. Furthermore, while in the illustrated example there are four cells **250**, comprising two rows and two columns of cells **250,** in alternative variations of this example the array can include less than four cells, for example two or three cells **250,** or more than four cells **250**, *mutatis mutandis*.

String assembly **200** comprises a plurality of (in the illustrated example, two) string sub-assemblies, each string sub-assembly including a plurality of (in the illustrated example, two) primary string segments 210 serially joined end-to-end forming a corresponding plurality of looped configurations in adjacent serial relationship. Each primary string segment **210** is substantially similar to the primary string segment **110** as disclosed herein for the first example (or alternative variations thereof) of the presently disclosed subject matter, *mutatis mutandis*. In this example, each string sub-assembly corresponds to a row of the array of cells **250,** and comprises a plurality of (in the illustrated example, two) two primary string segments 210 forming respective open looped configurations **260,** each corresponding to a column of the array of cells **250.** Each open looped configuration **260** and corresponding open cell **250** are respectively substantially similar in structure and function to the open looped configuration **160** and open cell **150** as disclosed herein for the first example and alternative variations thereof, *mutatis mutandis*. Thus, in the second example, each open looped configuration **260** is in the form resembling a clove hitch knot, and the corresponding portion of the string segment **210** thus comprises two consecutive and contiguous loops **210a**, **210b**, overlaid on one another, the portion of string segment **210** extending to respective ends **211a**, **211b** along generally opposite directions, with one overlying section **212** of the portion of the string segment **210** being overlaid over corresponding sections **213, 214** of the loops **210a**, **210b** to form an overcross, similar to the corresponding components as disclosed above for the first example, *mutatis mutandis*, including: consecutive and contiguous loops **110a**, **110b**; ends **111a**, **111b**; overlying section **112;** sections **113, 114.** Also as for the first example, *mutatis mutandis*, in alternative variations of the second example each of the open looped configuration **260** can instead be in a form similar to or resembling, for example, any one of: girth hitch knot, rolling hitch knot, constrictor knot, or similar knot arrangements that are self-locking onto an external object that is inserted into them.

Furthermore, for each row of the array, the respective plurality of open looped configurations **260,** and thus the corresponding open cells **250,** are serially joined to one another, so that, for each pair of adjacent open looped configurations **260,** the end **211a** of one open looped configuration **260** is joined to the other end **211b** of the adjoining open looped configuration **260,** for example as indicated at "J" in Fig. 7(b). In this example, these adjoining ends are integrally joined to one another and are thus formed from same continuous string element that forms the respective string sub-assembly**.** In other words, the string assembly **200** is constructed from a number of string sub-assemblies (corresponding to the number of rows of the array), each being in the form of a continuous string element comprising a plurality of primary string segment **210,** and being used to successively form all the respective open looped configurations **260** of the respective row. Optionally, each of the separate string segments **210** can extend to reach and connect to the payload.

While in this example each of the rows of the array of the string assembly **200** is constructed with a respective single, continuous, string element, in alternative variations of this example each of the rows of the array of the string assembly **200** is made from a plurality of separate but contiguous primary string segments or equivalents thereof, joined serially to one another, each such primary string segments including a corresponding open looped configurations **260**.

In yet other variations of this example, the full array of the string assembly **200** is constructed with a single, continuous, string element, or equivalents thereof which integrally comprises all the respective primary string segments 210 in serial relationship, and which is used to successively form all the open looped configurations **260** of the array, for example forming each row or column of the array in succession.

In any case, and as seen in Fig. 7(a) but not shown in Fig. 7(b), in each string sub-assembly, the respective plurality of primary string segment **210,** the corresponding plurality of open looped configurations **260,** and thus the corresponding open cells **250,** are also intertwined serially to one another, such that for each pair of adjacent open looped configurations **260** thereof, the loops **210a**, **210b** of one open looped configuration **260** are also looped around the loops **210a**, **210b** of the other open looped configuration **260,** as generally indicated at "A". Furthermore, each pair of adjacent rows of the array (and thus the respective primary string segments thereof) are also intertwined in parallel with one another, such that for every pair of adjacent open looped configurations **260** (one open looped configuration **260** from each adjacent row), the loops **210a**, **210b** of one open looped configuration **260** are also looped around the loops **210a**, **210b** of the other open looped configuration **260,** as generally indicated at "B".

In alternative variations of this example, adjacent pairs of open looped configurations **260,** and thus the corresponding open cells **250,** are not intertwined with one another, but rather the loops **210a**, **210b** of one open looped configuration **260** are not looped around or otherwise connected in any direct manner to the loops **210a**, **210b** of the other open looped configuration **260** (except of course by virtue of being in adjacent primary string segments **210**). Additionally or alternatively, adjacent pairs of open looped configurations **260** one each from a pair of adjacent primary string segments **210** are not intertwined with one another, but rather the loops **210a**, **210b** of one open looped configuration **260** are not looped around or otherwise connected in any direct manner to the loops **210a**, **210b** of the other open looped configuration **260**. The entire string assembly **200** in this case is held together with retainer arrangements, **220,** which then serve a dual function: retaining the open loop configurations of the open cells intact; and connecting adjacent open loop cells together to form the net-like assembly.

In alternative variations of this example, the retainer arrangement **220** can comprise cement or resin or equivalents thereof securing the primary string. Alternatively pressed strips of metal can be used to hold the primary string in place. Alternatively plastic retainers can be clamped onto, or molded onto or heat shrunk onto the primary strings.

Furthermore, referring again to the plurality of open looped configurations **260** of the string assembly **200,** each open looped configuration **260** comprises a corresponding retainer arrangement **220,** similar to the retainer arrangement **120** as disclosed herein for the first example and alternative variations thereof, *mutatis mutandis*.

Thus, the plurality of open looped configurations **260** defines a corresponding plurality of respective cells **250**. In this example, the open loop configurations **260** are generally circular when viewed in plan view, as in Fig. 7(a), and thus in the respective rectangular array of cells **250** illustrated in this figure, the string assembly **200** further comprises relatively open nodal zones **290** defined at each node of the array by mutually-facing outsides of four mutually adjacent respective open looped configurations **260**.

A feature of at least the second example of the string assembly **200** is that it has the appearance of, and much of the functionality of, a net, a net assembly, a net-like assembly, or a net structure. Furthermore, each open looped configuration **260** is configured to operate in a similar manner to the open looped configuration **160** of the first example of the presently disclosed subject matter, *mutatis mutandis*. Thus, as external object **10** (for example in the form of a projectile, but can be any other object, for example as disclosed for the first example, *mutatis mutandis*) follows a trajectory **T** that intersects one of the cells **250,** the external object **10** eventually impacts the respective primary string segment **210** of the respective open cell **250.** In particular, as the external object **10** becomes introduced into the respective open cell **250** and comes into abutting contact with its periphery **255**, the external object **10** impacts the parts of the primary string segments **210** forming the respective loops **210a**, **210b** of the respective open looped configuration **260.** As a result, the respective open looped configuration **260** of the respective open cell **250** locks onto the external object **10** in a manner similar to that disclosed herein for the open looped configuration **160,** *mutatis mutandis*.

The net-like form of string assembly **200** of the second example of the presently disclosed subject matter, and in particular the inclusion of a plurality of open looped configurations **260** therein, increases the probability of aligning any one of the plurality of cells **250** with the trajectory **T**, as compared with attempting to align the cell **150** of the single open looped configuration **160** of the first example with trajectory **T**. At the same time, such increased probability is partly diminished by the statistical chance that such a trajectory **T** can instead intersect one of the open nodal zones **290**, rather than an open looped configuration **260**.

Thus, the greater the number of open cells **250** provided by the string assembly, **200,** the greater the probability of facilitating intersection of a particular trajectory **T** of external object **10** with one or another of the respective open looped configurations **260** thereof.

The string assembly **200** is thus configured for locking onto an external object **10**. Furthermore, the string assembly **200** can optionally be supported, suspended in mid-air, and/or can be configured for following a particular or random trajectory in the atmosphere, via lighter-than-air balloons or the like (not shown), and/or one or more parachutes, for example. Alternatively, the string assembly **200** follows a particular trajectory in the atmosphere following deployment from a carrier projectile or a carrier aircraft. Alternatively, the string assembly **200** can optionally be supported, for example suspended above the ground, for example on a structure, such that the structure is open and presents the plurality of cells **250** to enable at least one cell **250** to be intercepting an expected or desired trajectory **T**. In any case the string assembly **200** optionally carries a payload **280,** for example similar to payload **180** as disclosed herein for the first example of the presently disclosed subject matter, *mutatis mutandis.*

Whether the string assembly **200** is made from a single, continuous string element integrally comprising a plurality of primary string segments, or whether the string assembly **200** is made from a plurality of separate primary string segments, the string assembly **200** is configured such that the payloads **280,** remain attached to all primary string segments once they are completely unraveled.

The string assembly **200** operates to lock onto an approaching external object **10** with any one of the respective open cells **250.** Referring to Figs. 8(a) to 10(b), and for facilitating understanding this mode of operation, the string assembly **200** is shown as net structure comprising a 8×8 rectangular array of 64 open cells **250,** each defined by a respective open looped configuration **260,** though it is readily evident that this mode of operation can be applied to other designs of the string assembly **200,** including more than 64 open cells **250,** or less than 64 open cells **250,** and/or provided in symmetric or asymmetric arrays of any desired configuration, *mutatis mutandis.* Furthermore, the circular plan form of the open looped configurations **260** are depicted in these figures as octagons for easier comprehension.

The string assembly **200** operates in a similar manner to the string assembly **100** of the first example, *mutatis mutandis.* For example, and referring to Figs 9(a) and 9(b) the external object **10**, in the form of a projectile for example, having a projected trajectory **T** can be engaged by one of the open cells **250** when the trajectory **T** intersects the respective cell **250,** and the projectile is locked by the string assembly **200.** However, in this example the un-impacted open cells subsequently unravel, in a cascaded effect as described below, reducing the loading on the impacted open cell **250.**

In turn, the string assembly **200** drags the payload **280,** optionally via an additional flexible string segment connecting the payload **280** to the string assembly **200.** The payload **280** can selectively explode and/or induce a very significant drag and/or instability to the external object **10**, thereby causing the external object **10** to become damaged, to disintegrate, or to at least veer significantly from the projected trajectory **T**.

Optionally, for examples in which the payload **280** is explosive, the payload **280** can be distributed as a plurality of explosive charges at different locations in the string assembly **200,** ensuring or at least increasing the likelihood that at least some of charges are in direct contact with or close to the locked external object **10**, rendering the detonation of the payload more effective.

The external object **10** thereby becomes neutralized or ineffective by being damaged or destroyed, and/or by missing its intended target at the end of projected trajectory **T** due to the added drag/instability.

Thus, in this mode of operation the external object **10** first intercepts, impacts and becomes locked by the open looped configuration **260** of a particular open cell **250,** and thereafter causes a cascade effect in which successive concentric "rings" of open looped configurations **260,** around the impacted/locked cell **250,** unravel in succession as the stress fronts travel (from the point of impact of the eternal object on open cell **250A**) outwardly along the string assembly **200.**

In greater detail, and referring to Fig. 8(c), it can be clearly seen that in this example the string assembly **200** comprises a generally centrally disposed open looped configuration **260** (further designated with the reference numeral **260A**) corresponding to cell **250A**, surrounded or circumscribed by and connected to a first ring **R1** of looped configurations **260** (further designated with the reference numeral **260B** corresponding to open cells **250B**) adjacent to open looped configuration **260A**. Similarly, the first ring **R1** is surrounded or circumscribed by and connected to a second ring **R2** of open looped configurations **260** (further designated with the reference numeral **260C** corresponding to open cells **250C**) adjacent to open looped configurations **260B**, and the second ring **R2** is surrounded or circumscribed by and connected to a third ring **R3** of open looped configurations **260** (further designated with the reference numeral **260D** and corresponding to open cells **250D**) adjacent to open looped configuration **260C**.

In the example of Fig. 8(c), open cell **250A** is designated as the open cell **250** that is impacted by the external object **10**, e.g. a projectile. Nevertheless, a similar effect occurs in the string assembly **200** when any of the other open cells **250** in string assembly **200** is impacted by an external object. The stress fronts traveling outwards from the points of impact will cause successive open cells (surrounding the impacted open cell) to unravel, until the entire assembly is unraveled. The unraveling reduces the load of the adjacent open cells on the impacted cell, introduces a delay for the arrival of reflected stress front from the ends of the assembly and thereby improves the impact resilience of the string assembly **200.**

Each open cell **250** in the array of the string assembly **200** has a corresponding set (and pattern) of successive full (or partial) rings of other open cells **250** radiating therefrom to the outer edge **299** of the string structure **200,** and the details of such corresponding set (and pattern) of successive full (or partial) rings of other open cells **250** will of course depend the location of the particular open cell **250** within the string assembly **200.**

Thus, and referring in particular to Figs. 10(a) and 10(b), after the object **10** becomes locked with open looped configuration **260A** of open cell **250A**, the respective retainer arrangements **220** of at least some, and typically each one, of the open looped configurations **260B** in ring **R1** are configured to become non-operational, for example by mechanically failing, etc. Without being bound to theory, such mechanical failure is considered to be responsive to the loads induced in the parts of the respective primary string segments **210** that form the open looped configurations **260B**, these loads having been generated due to the impact and locking of the object **10** with open looped configuration **260A**. In this mode of operation the respective retainer arrangements **220** are thus configured for becoming non-operational, for example mechanically failing or disassembling, under such loads, after which the respective open looped configurations **260B** progressively unravel, while corresponding parts of the respective primary string segments **210** are still connected to the open looped configuration **260A**. At the same time, the unraveling open looped configurations **260B** (marked in the Fig. 10(b) as **260B'**) are also still connected to the open looped configurations **260C** of ring **R2,** but the unraveling of the open looped configurations **260B** provides a delay in, and in a reduction of the magnitude of, the load that is in turn applied to open looped configurations **260C** via the corresponding primary string segments **210** due to the original impact/locking of the object by the open looped configurations **260A**. Without being bound to theory, such an effect can be understood to originate from the fact that the respective lengths of primary string segments that were previously looped to form the respective are now unlooped and proceed to extend out in the general direction of motion of the object **10**, and in the meantime the remaining rings **R2, R3** have not yet been dragged due to the motion of the object **10**.

Unless this reduction in loading now applied to the open looped configurations **260C** at ring **R2** is such that the respective retainer arrangements **220** of these open looped configurations **260C** are still operational, then the unraveling effect will cascade to ring **R2.** In such a case, and referring to Figs. 11(a) and 11(b), the retainer arrangements **220** of the open looped configurations **260C** of ring **R2** will also become non-operational, similarly causing unraveling of open looped configurations **260C** (marked in the Fig. 10(b) as **260C'**), thereby providing a further delay in, and a further reduction of the magnitude of, the load that is in turn applied to open looped configurations **260C** of ring **R3** due to the original impact/locking of the object by the open looped configurations **260A**.

Similarly, unless this additional reduction in loading at ring **R3** is such that the respective retainer arrangements **220** of the open looped configurations **260D** are still operational, then the unraveling will also cascade to ring **R3.** In such a case (not shown), the retainer arrangements **220** of the open looped configurations **260D** of ring **R3** will also become non-operational, similarly causing unraveling of open looped configurations **260D**, thereby providing a further delay in, and a further reduction of the magnitude of, the load that is in turn ultimately applied to the payload **280** due to the original impact/locking of the object by the open looped configurations **260A**.

In alternative variations of this example in which the string assembly **200** has a very large array of open cells **250** (for example hundreds or thousands of open cells, or more), and that for at least some such open cells have a large number of successive, generally concentric rings of open cells, the unraveling cascade can stop one or more rings away from the periphery **299** of the string assembly **200,** in which the respective retainer arrangements **220** are still operational and conserve the open looped configurations. For example such a large string assembly **200** can be used for intercepting a plurality of spaced external objects (for example a barrage of projectiles) or the like, concurrently or in close succession.

In any case, after the last full or partial ring of respective open looped configurations **260** unravels, the string assembly **200** is dragged by the external object **10**, and at some point in the trajectory the payload **280** can be activated, rendering object **10** ineffective by being damaged or destroyed, and/or by missing its intended target at the end of projected trajectory **T** due to the added drag/instability, for example.

In at least some variations of this example, irrespective of the number of primary string segments used, the string assembly is designed such that the payloads **280,** remain attached to all such primary string segments once they are completely unraveled.

As will become clearer hereinbelow, the open nodal zones **290** are eliminated in other examples of the presently disclosed subject matter, essentially by reshaping the basic round shape of the open cell of the second example into other planar shapes, such as for example, rectangular shapes. Furthermore, such non-circular open cell shapes are maintained with the aid of retaining arrangements that are designed to break at sufficient loading, and once these retaining arrangements break, the open cell that is previously impacted by the external object is free to take the form of the cross-section of the impacting object, while surrounding cells that have not been impacted are allowed to unravel.

Referring to Fig. 12, a string assembly **300** according to a third example of the presently disclosed subject matter includes at least some of the elements and features as disclosed herein for the first example of the string assembly **100** and for the second example of the string assembly **200**, including alternative variations thereof as disclosed herein, *mutatis mutandis*, but with some differences, as will become clearer in the following disclosure.

String assembly **300** thus also comprises an array of open cells **350,** each cell being similar to open cell **150** of the first example (or alternative variations thereof) or open cell **250** of the second example (or alternative variations thereof), *mutatis mutandis*. Furthermore, string assembly **300** comprises a plurality of primary string segments **310,** each being similar to the primary string segment **110** as disclosed herein for the first example (or alternative variations thereof) or to the primary string segment

210 as disclosed herein for the second example (or alternative variations thereof) of the presently disclosed subject matter, *mutatis mutandis*. Thus, each primary string segment **310** comprises a corresponding open cell **350,** defined by a respective open looped configuration **360,** each open looped configuration **360** being substantially similar in structure and function to the open looped configurations **160** and **260** as disclosed herein for the first example and the second example (and alternative variations thereof), *mutatis mutandis*. Thus, and referring in particular to Figs. 13(a) and 13(b), in the third example each open looped configuration **360** is in the form resembling a clove hitch knot, and the corresponding portion of the string segment **310** thus comprises two consecutive and contiguous loops **310a**, **310b**, overlaid on one another, the portion of string segment **310** extending to respective ends **311a**, **311b** along generally opposite directions, with one overlying section **312** of the portion of the string segment **310** being overlaid over corresponding sections **313, 314** of the loops **310a**, **310b** to form an overcross, similar to the corresponding components as disclosed above for the first and second examples, *mutatis mutandis*, including: for example consecutive loops **110a**, **110b**; ends **111a**, **111b**; overlying section **112;** sections **113, 114**; or similar to: consecutive loops **210a**, **210b**; ends **211a**, **211b**; overlying section **212**; sections **213, 214.** Also as for the first and second examples, *mutatis mutandis*, in alternative variations of the third example each of the open looped configuration **360** can instead be in a form similar to or resembling, for example, any one of: girth hitch knot, rolling hitch knot, constrictor knot, or equivalents thereof, or similar knot arrangements that are self-locking onto an external object that is inserted into them.

Furthermore, for each row of the array, the respective plurality of open looped configurations **360**, and thus the corresponding open cells **350**, are serially joined to one another, and the corresponding loops **310a**, **310b** can optionally be intertwined with one another serially and/or in parallel with the open cells of adjacent rows of the array, for example at “E” and “F” respectively, similar to as disclosed above for the second example at “A” and “B”, *mutatis mutandis.*

In this example, the adjoining ends of adjacent open looped configuration **360** of each row of the array are integrally joined and the same continuous string element integrally includes the corresponding plurality of respective primary string segments **310.** In other words, the string assembly **300** is constructed from a number of string sub-assemblies (corresponding to the number of rows of the array), each string sub-assembly integrally comprising a plurality of primary string segments **310** and being used to successively form all the open looped configurations **360** thereof of the respective row. Optionally, each of the separate string segments **310** can extend to reach and connect to the payload.

However, while in this example each of the rows of the array of the string assembly **300** is constructed with a single, continuous, string element, in alternative variations of this example each of the rows of the array of the string assembly **300** is made from a plurality of separate primary string segments or equivalents thereof,, joined serially to one another, each such primary string segments including a respective open looped configurations **360**.

In yet other variations of this example, the full array of the string assembly **300** is constructed with a single, continuous, string element, or equivalents thereof, which is used to successively form all the open looped configurations **360** thereof, for example forming each row of the array in succession, and thus such a continuous, string element integrally comprises all the primary string segments of the array.

In any case, one difference between the string assembly **300** of the third example compared and the string assembly **200** of the second example is that the string assembly **300** at array nodes **390** eliminates, or at least minimizes the size of, the open nodal zones **290** of the string assembly **200.** In so doing, the statistical probability of an object **10** impacting the open cells **350** of the string assembly **300** rather than the array nodes **390** thereof is higher than for the string assembly **200.** Accordingly, string assembly **300** comprises a rectangular array of open cells **350,** in which the relatively round plan form of the corresponding open cells **250** of string assembly **200** are essentially "squared off" to the generally rectangular plan form of open cells **350,** as illustrated in Fig. 13(a) at "Q". The adjacent corners of each set of four adjacent open looped configurations **360** of string assembly **300,** marked "C", are thus located at the corresponding array node **390** of the array of open looped configurations **360.** As can be understood from Fig. 13(a), each cell **350** is rectangular, having a length dimension $\mathbf{L_2}$ greater than a width dimension $\mathbf{L_1}$**.** However, in alternative variations of this example, the rectangular cells **350** can be square, i.e., with the respective length dimension $\mathbf{L_2}$ being equal to the respective width dimension $\mathbf{L_1}$**.** In any case, and as for the first and second examples disclosed above, *mutatis mutandis*, the dimensions of the cell **350** can be chosen so that the perimeter **355** of the cell (= 2×**L1** + 2××$\mathbf{L_2}$) after it experiences the full elongation anticipated elongation by stretching over the impacted external object, is thus intermediate in value with respect to the aforesaid minimum perimeter and maximum perimeter of these corresponding cross-sections of the object **10**.

Furthermore, the corresponding retainer arrangement **320** for the open looped configurations **360** of the string assembly **300** are located at the array nodes **390,** and retainer arrangement **320** can be configured to concurrently retain the form of the four of the open looped configurations **360** that meet at the respective array node **390** (or of the two open looped configurations **360** that meet at the respective array node **390** where the array node **390** is at the periphery of the string assembly **300**). In this example, the retainer arrangement **320** comprises at each array node **390** a pair of secondary string segments **322,** distinct, i.e. different from or separate from, the primary string segments **310.** Each string segment **322** is tied to two different diagonally adjacent open looped configurations **360,** each respective secondary string segment **322** being looped around the corresponding parts of the loops **310a**, loop **310b** of each of the respective pair of open looped configurations **360**. Furthermore, and as can be seen from Fig. 13(a) at "C", the two looped secondary string segments **322** at the respective array node **390** cross one another when observed in plan view.

In this manner, retainer arrangement **320,** in this example in the form of the secondary string segments **322,** has a dual function: to prevent the primary string segments **310** that form the four open looped configurations **360** from unraveling; and to retain the rectangular form of the open cells **350.** In alternative variations of this example, the retainer arrangement **320** can comprise one such secondary string segment **322** that holds together the "corners" of two diagonally adjacent open cells **350,** and then extend in a contiguous manner to hold together the "corners" of the other two diagonally adjacent open cells. Alternatively, more than two such secondary string segments **322** can be used. In this example, each secondary string segment **322** is affixed to itself in its looped configuration, in which it is engaged to the primary string segments **310** at corresponding parts of the open looped configuration **360** in any suitable manner – for example the respective string segment **322** can be tied to itself, or can be welded, mechanically affixed, or be formed as an integral loop (such as for example a ring).

In alternative variations of this example, the retainer arrangement **320** can comprise cement or resin or equivalents thereof securing the primary string. Alternatively pressed strips of metal can be used to hold the primary string in place. Alternatively plastic retainers can be clamped onto, or molded onto or heat shrunk onto the primary strings.

It is evident that the retainer arrangement **320,** when thus engaged to the open looped configuration **360**, is operational to maintain the spatial relationship that defines the open looped configurations **360** (even though there is, as yet, an absence of any external body in abutting relationship with the periphery **355** of the respective cell **350**), in particular the spatial relationship between the loops **310a**, **310b** and overlying section **312** thereof.

The string assembly **300** can operate in the same manner as the disclosed above for the string assembly **200** according to the second example of the presently disclosed subject matter, *mutatis mutandis*, with the following main difference. Prior to impact of the object **10** with the string assembly **300,** the trajectory **T** of the object intersects one cell **350,** and as the object **10** enters the cell **350** it probably makes contact first with the longer sides of the periphery **355,** particularly if the object has a cross-section that is circular or near-circular. As the external object **10** continues penetrating the cell **350,** the open cell **350** is forced to deform and assume the shape of the cross-section of the object that is now abutting the full periphery **355.** In so doing, the open cell **350,** and thus the respective open looped configuration **360,** locks onto the object **10**, in a similar manner to that disclosed above for the first and second examples, *mutatis mutandis*. At the same time, the retainer arrangements **320** at the four corners of the respective open looped configuration **360** become non-operational, for example mechanically fail or otherwise break or otherwise disassemble. As the impacted open cell **350** is accelerated after impact by the external object **10**, this open cell **350** exerts tensile forces on the surrounding open cells **350,** which causes in turn their retainer arrangements to break or become disassembled, and their respective open looped configurations are, in turn unraveled.

Eventually, the now-unraveled string assembly **300** is dragged by the external object **10**, and at some point in the trajectory the payload **380** can be activated, selectively neutralizing or otherwise rendering object **10** ineffective by being damaged or destroyed, and/or by missing its intended target at the end of projected trajectory **T** due to the added drag/instability, for example.

An alternative variation of the third example of the string assembly **300** is illustrated in Fig. 14, wherein the particular retainer arrangement **320** comprises a plurality of continuous secondary string segments **322'**, distinct, i.e. different from or separate from, the primary string segments **310.** Each continuous string segment **322** follows a "row" of the rectangular array of the string assembly **300,** and is thus co-extensive with successive longer sides of the periphery **355** of respective cells **350** at the respective "row" of the array, while being tied around the array nodes **390** between the aforesaid longer sides of each successive pair of open cells **350.**

However, when the external object **10** first impacts the longer sides of a particular cell **350** it also impacts the part of the respective continuous secondary string segments **322'** thereby loading the same. However, since the retaining continuous secondary string segments **322'** are mechanically weaker than the primary string segments **310,** the continuous secondary string segments **322'** become non-operational (for example mechanically fail, for example break, or become disassembled), under the load, which thus precipitates unraveling throughout the remaining open cells. As a result the open cells adjacent to the impacted open cell unravel more quickly reducing the initial load of the impacted open cell.

Another alternative variation of the third example of the string assembly **300** is illustrated in Fig. 15, and while similar to the alternative example of Fig. 14**,** the particular retainer arrangement **320** now comprises a plurality of pairs of continuous secondary string segments **322'**, each string segment **322'** thereof being distinct, i.e. different from or separate from, the primary string segments **310.** Each pair of continuous string segments **322'** follows a "row" of the rectangular array of the string assembly **300,** and are thus co-extensive with successive longer sides of the periphery **355** of respective cells **350** at the respective "row" of the array, while being tied around the array nodes **390** between the aforesaid longer sides of each successive pair of open cells **350.** However, the continuous secondary string segments **322'** of each pair face the open cells **350** of adjacent open cells **350** along a "column" of the array assembly of the string assembly **300.** Furthermore, the continuous secondary string segments **322'** of each pair cross over one another at the array nodes **390.** Operation of this variation of string assembly **300** is similar to that illustrated in Fig. 12, *mutatis mutandis*.

Similar to the case of the cells of the second example of string assembly **200,** *mutatis mutandis*, in the third example and alternative variations thereof illustrated in Figs. 12 to 15, the respective primary string segments forming adjacent open cells can be intertwined (similar to the form shown in Fig 7(a), *mutatis mutandis*). Alternatively the open cells can be formed in a non-intertwined manner, i.e. separate from one another, and the respective string assembly is held together only with the retaining arrangements.

In yet a further alternative variation of the third example, each respective primary string segment is formed from a plurality of strands, and this feature can provide increased flexibility of the overall string assembly. Additionally or alternatively, such a multiple-stranded primary string can be formed from different materials so as to address different predicted situations. For example, the plurality of strands can comprise strands made from a relatively higher tensile material for high resilience at high impacts, combined with strands made from a relatively more flexible material for providing larger elongation. Such a combination of strands allows for different behaviors for the respective open cell, when impacted by an external object **10**, enabling the impacted open cell to withstand high impact and high levels of tensile stresses, compared with the surrounding unraveling open cells which provide a cushioning and dampening effect with a highly flexible material. The open cells surrounding the impacted open cell are subject to high tensile loads, and should the high tensile strands break as a result, the high flexibility strands will remain intact and maintain the entire string assembly functional.

Thus, in an alternative variation of the third example, illustrated in Fig. 16, includes a double-open loop cell configuration for the respective string assembly **300A**, where an inner open looped configuration **360a** (defining an inner open cell **350a**) is provided concentrically within an outer open looped configuration **360b** (defining an outer open cell **350b**). The inner open looped configuration **360a** (and thus inner open cell **350a**) has a relatively smaller peripheral length than the peripheral length of the outer open looped configuration **360b** (and thus of outer open cell **350b**). In this example, the inner open cell **350a** engages the impact of an external object **10** first. Should inner open cell **350a** fail due to the high impact, however, the second, outer open cell **350b** remains, and as the inner open cell **350a** has already engaged the external object and caused a certain acceleration of the string assembly, the outer open cell **350b** experiences a relative smaller impact velocity and can therefore survive the impact. Of course any number of concentric open cells can be provided, nested in one another with cascaded sizes can be provided to improve the resistance of the overall assembly to the impact. Otherwise, the string assembly **300A** comprises a retainer arrangement **320A** and payload as described for the third example, *mutatis mutandis*, and operates in a similar manner thereto, *mutatis mutandis*.

Another alternative variation of the third example of the string assembly **300** is illustrated in Fig. 17, in which the respective retainer arrangement **320B** is similar to that of the example illustrated in Figs. 14 and 15, *mutatis mutandis*. However, in the example of Fig. 17, each retainer arrangement **320B** is further partially looped around part of the respective peripheries **355** of the open cells **350.** Together, adjacent retainer arrangements **320B** form retainer arrangement loops **320C** around the periphery **355** of each respective open cell **350,** each retainer arrangement loop **320C** having a smaller periphery than the respective periphery **355.** This configuration ensures that the impinging object **10** in any particular cell **350** will first break the retainer arrangement loop **320C**, and thereafter the string assembly will operate in a similar manner to that disclosed above with reference to the examples illustrated in Figs. 14 and 15. Alternatively, the respective retainer arrangement **320** is configured to have smaller elongation (or smaller breaking strain) before breaking than the primary string segments **310,** and thus become non operational by mechanically breaking before the primary string segments **310** when subject to the same strain. In such a case, the retainer arrangement loops can have respective peripheries that are similar in size to respective peripheries **355** of the cells **350** (for example similar to the examples illustrated in Figs. 14 and 15, *mutatis mutandis*), but the retainer arrangement **320B** will nevertheless be first to become non-operational, for example by mechanically failing, when subject to the same stress as the primary string segment **310.**

In the method claims that follow, alphanumeric characters and Roman numerals used to designate claim steps are provided for convenience only and do not imply any particular order of performing the steps.

Finally, it should be noted that the word “comprising” as used throughout the appended claims is to be interpreted to mean “including but not limited to”.

While there has been shown and disclosed examples in accordance with the presently disclosed subject matter, it will be appreciated that many changes may be made therein without departing from the spirit of the presently disclosed subject matter.

CLAIMS:

1. String assembly defining at least one open cell, comprising;

at least one continuous primary string segment in open looped configuration forming a periphery of a respective said open cell, and further comprising a retainer arrangement, wherein:

(a) said at least one primary string segment in said open looped configuration is configured:

- for selectively locking onto an external object in response to the external object being selectively introduced into said open cell and into abutting contact with said periphery; and

- for selectively unraveling in the absence of such abutting contact and in the absence of said retainer arrangement being operational;

and wherein

(b) said retainer arrangement when operational is configured for retaining said at least one primary string segment in said open looped configuration at least in the absence of said abutting contact.

2. String assembly according to claim 1, comprising a plurality of said open cells and a corresponding plurality of said primary string segments, each said open cell comprising a respective said primary string segment in a respective said open looped configuration, wherein said retainer arrangement is configured for retaining each said primary string segment in the respective said open looped configuration, independently from one another.

3. String assembly according to claim 1 or claim 2, wherein in said open looped configuration each respective said primary string segment is configured to lock onto the external object at least partially via frictional contact between overlapping parts of the respective said primary string segment.

4. String assembly according to any one of claims 1 to 3, wherein in said open looped configuration the respective said primary string segment is configured to lock onto the external object at least partially via frictional contact between a portion of the respective said primary string segment and the external object.

5. String assembly according to any one of claims 1 to 4, wherein said looped configuration has a form of a clove hitch knot or a form resembling a clove hitch knot.

6. String assembly according to any one of claims 1 to 5, wherein at least one said looped configuration comprises any one of: a girth hitch knot, a rolling hitch knot, a constrictor knot, or any knot arrangement that is self-locking onto said external object that is inserted thereinto.

7. String assembly according to any one of claims 1 to 6, wherein said retainer arrangement comprises at least one mechanical retainer configured to become non-operational when a respective primary string segment is subjected to a load exceeding a predetermined load threshold, said load being induced in the respective primary string segment in response to the external object being selectively introduced into said open cell and into abutting contact with said periphery.

8. String assembly according to any one of claims 1 to 7, wherein said retainer arrangement comprises at least one secondary string segment engaged to a respective said primary string segment.

9. String assembly according to any one of claims 1 to 7, wherein said retainer arrangement comprises any one of: a cement or resin material engaged to a respective said primary string segment; or a plastic element or a metal element clamped onto, molded onto or heat shrunk onto respective said primary string segment.

10. String assembly according to any one of claims 1 to 9, wherein at least one said primary string segment is provided excluding strength-reducing knots formed therein such strength-reducing knots being self-locking and including bends of small-radius as compared with a thickness of the primary string segment.

11. String assembly according to any one of claims 1 to 9, wherein each said open looped configuration excludes strength-reducing knots formed by the respective primary string segment.

12. String assembly according to any one of claims 1 to 11, wherein at least one said primary string segment in said open looped configuration is intertwined with respect to an adjacent said primary string segment in said open looped configuration.

13. String assembly according to any one of claims 1 to 12, comprising a string sub-assembly including a plurality of said primary string segments serially joined end-to-end forming a corresponding plurality of said looped configurations in adjacent serial relationship.

14. String assembly according to claim 13, comprising at least two said string sub-structures in juxtaposed relationship and/or comprising at least two said string sub-structures intertwined with respect to one another.

15. String assembly according to any one of claims 2 to 14, wherein a continuous string element integrally comprises said plurality of said primary string segments in serial relationship.

16. String assembly according to any one of claims 1 to 15, wherein said at least one primary string segment has a mechanical strength greater than a mechanical strength of the retainer arrangement.

17. String assembly according to any one of claims 1 to 16, wherein said at least one primary string segment is configured for withstanding an impact from a body traveling at high velocity transverse to a longitudinal axis of the primary string segment.

18. String assembly according to claim 16, wherein said high velocity is a velocity greater than 400m/s.

19. String assembly according to any one of claims 2 to 18, wherein said open cells are arranged in a general two-dimensional array and wherein said retainer arrangement is configured for retaining said plurality of primary string segments, each in corresponding said looped configuration, at nodes of said array.

20. String assembly according to claim 20, wherein said plurality of primary string segments forming at least one row of said open cells and/or forming at least one column of said open cells of said array is formed from a single continuous length of string.

21. String assembly according to claim 19 or claim 20, wherein said cells of said array are generally polygonal.

22. String assembly according to claim 19 or claim 20, wherein said cells of said array are generally rectangular.

23. String assembly according to claim 22, wherein said retainer arrangement comprises a secondary string segment co-extensive with a corresponding side of a plurality of said generally rectangular cells.

24. String assembly according to claim 22, wherein said retainer arrangement comprises a pair of secondary string segments, each co-extensive with a corresponding side of a plurality of said generally rectangular cells.

25. String assembly according to any one of claims 2 to 24, configured for unraveling at least one said open looped configuration located adjacent to an impact cell while remaining mechanically connected hereto on impact of the external object with said impact cell.

26. String assembly according to any one of claims 2 to 25, wherein some of said open looped configurations, located in a ring around and adjacent to an impact cell, are configured for unraveling while remaining mechanically connected thereto responsive to impact of the external object with the impact cell, said impact cell being chosen from said plurality of open cells.

27. String assembly according to any one of claims 2 to 26, wherein some of said open looped configurations, located in each a two or more concentric rings around an impact cell, are configured for unraveling while remaining mechanically connected thereto responsive to impact of the external object with the impact cell, said impact cell being chosen from said plurality of open cells.

28. String assembly according to any one of claims 25 to 27, wherein said respective open looped configurations are configured for unraveling via mechanical failure or disassembly of the respective said retainer arrangements, wherein said mechanical failure of the respective said retainer arrangements being responsive to loading of the failed retainer arrangements beyond a failure loading limit due to said abutting contact between the external object and the respective said periphery of the impact cell.

29. String assembly according to any one of claims 1 to 28, wherein said external object is a moving object.

30. String assembly according to any one of claims 1 to 29, wherein said external object is a moving projectile or an airborne aircraft.

31. String assembly according to any one of claims 1 to 30, wherein said at least one primary segment is made from any one of Kevlar, Dyneema, Carbon fiber artificial spider web.

32. String assembly according to any one of claims 1 to 31, wherein each said primary string segment comprises a plurality of strand elements.

33. String assembly according to any one of claims 2 to 31, wherein each said primary string segment comprises at least a first strand element and a second strand element, and wherein said first strand element is configured for providing better performance than said second strand element with respect to said locking, and wherein said second strand element is configured for providing better performance than said first strand element with respect to said unraveling.

34. String assembly according to any one of claims 1 to 33, wherein at least one said open cell comprises at least two said open looped configurations in concentric relationship with one another and having respective said peripheries of different lengths one from another.

35. String assembly according to claim 34, wherein each said open looped configuration in said concentric relationship is configured for locking with the external object in succession with one another.

36. A net comprising a string assembly as defined in any one of claims 1 to 35.

37. A net according to claim 36, further comprising a payload.

38. A net according to claim 37, wherein said payload is one of:

- affixed to the net via a length of string section different from said at least one primary segment of a respective said open looped configuration, said length of string section having greater elasticity than that of the respective said at least one primary segment; and
- comprises a plurality of payload items distributed over the net.

39. A net according to claim 37 or claim 38, wherein said payload is an explosive device.

40. A net according to claim 39, wherein said payload is configured for detonating according to predetermined criteria after the external object establishes said abutting contact with said net.

41. A net according to claim 37 or claim 38, wherein said payload is configured for selectively inducing a drag force to said net.

42. A net according to claim 41, wherein said payload comprises at least one parachute.

43. A net according to claim 41 or claim 42, wherein said payload is configured for deploying according to predetermined criteria after the external object establishes said abutting contact with said net.

44. A net according to any one of claims 40 and 43, wherein said predetermined criteria include an elapsed time after the external object establishes said abutting contact with said net.

45. A method comprising:

- providing a net as defined in any one of claims 36 to 44;

- deploying said net at a location intersecting a projected path of the external object;
- allowing the external object to become introduced into any one said open cell and into abutting contact with a respective said periphery thereof to thereby lock said cell onto the external object.

46. A method comprising:

- intercepting a moving object with at least one of a plurality of open looped elements of a net assembly, each said open looped elements being formed by respective primary string segments and configured for providing a friction lock when in contact with the external body therein, said looped elements having an absence of structural ties;
- frictionally locking the moving object with the respective at least one said open looped element.

47. Method according to claim 46 further comprising the step of allowing unraveling of at least one said open looped elements located in at least one concentric ring around the at least one said open looped element.

48. A net assembly comprising a plurality of open cells, the net assembly comprising a plurality of primary string segments, each primary string segment being looped in an open looped configuration to define a respective said open cell, wherein said open looped configurations have an absence of a strength-reducing knot formed by the respective primary string segment, the net assembly further comprising a mechanical retainer arrangement configured for retaining said primary string segments in said looped configuration while the respective said primary string segments are subjected to loads below a predetermined threshold, each said cell being configured for locking therein an external object that is brought into abutting contact with a periphery of the respective cell to thereby load the respective said primary string segment to loads exceeding said threshold while being mechanically connected to a remainder of the net assembly via at least some of said primary string segments.

49. A net assembly comprising an array of primary string segments defining a plurality of open cells and nodes, said primary string segments being in open looped configuration to define respective said open cells, wherein said primary string segment s have an absence of strength-reducing knot formed therein.

50. A net assembly comprising open looped elements formed by respective primary string segments and configured for providing a friction lock when in contact with an external body therein, said looped elements having an absence of structural ties therein.

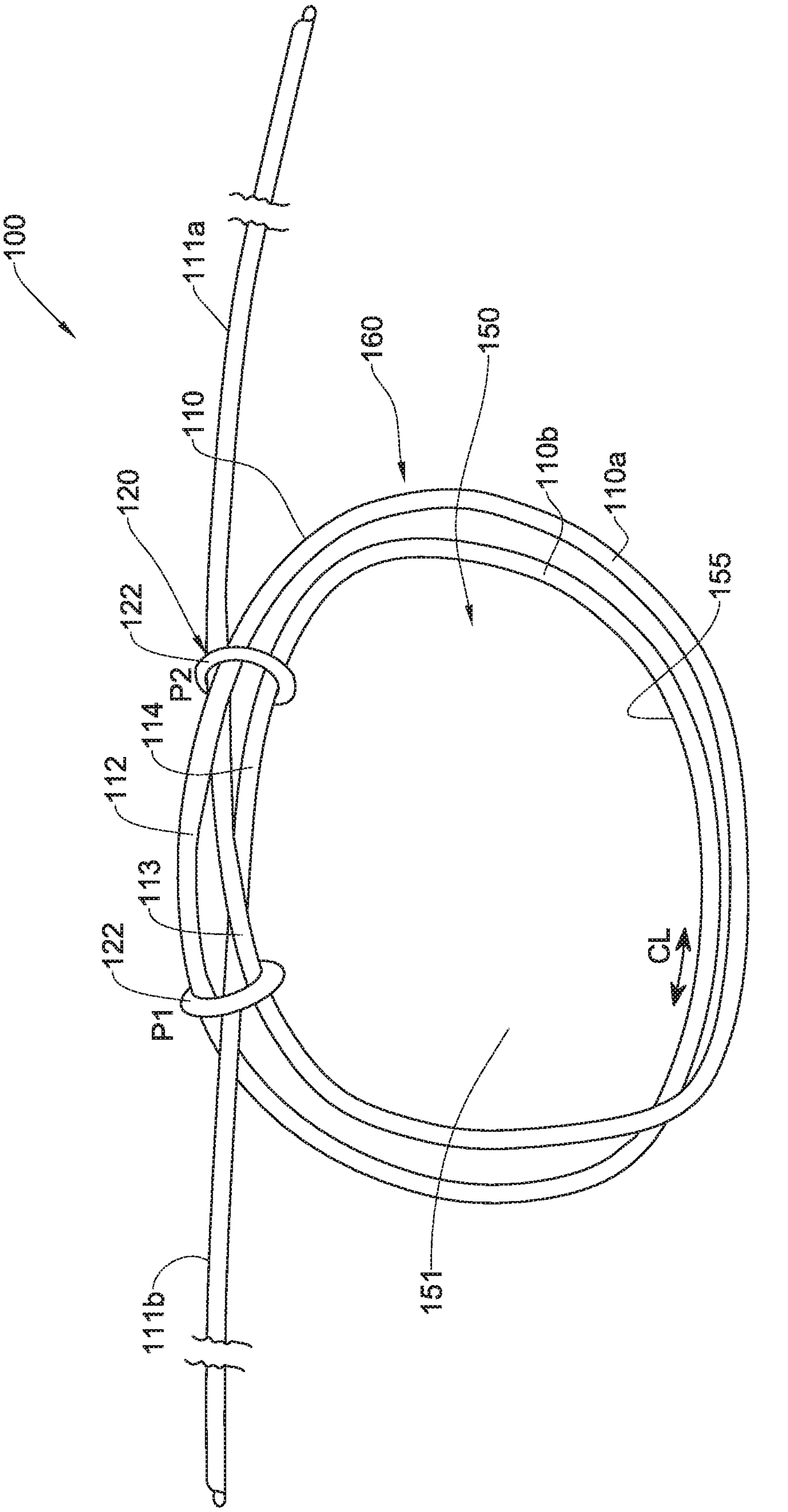
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Fig. 1(a)

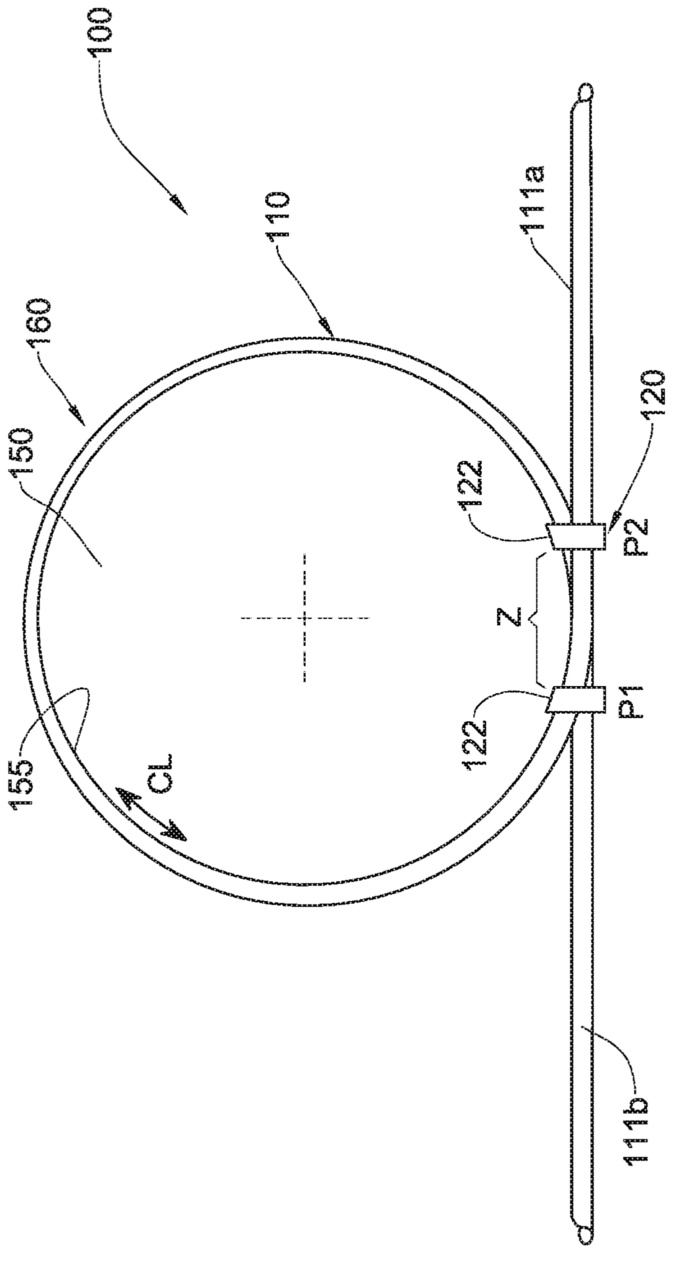
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Fig. 1(b)

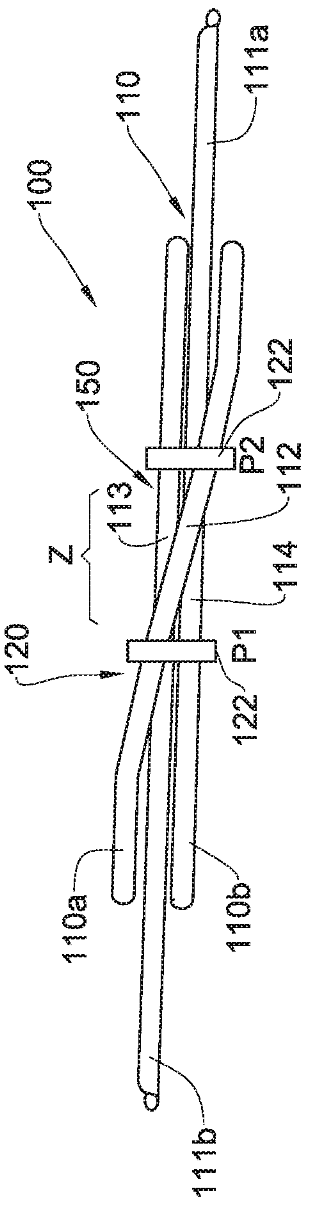
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Fig. 1(c)

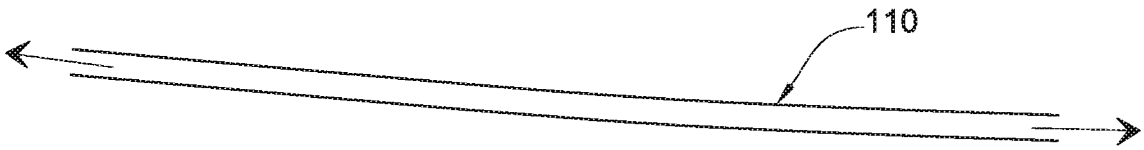


Fig. 2(a)

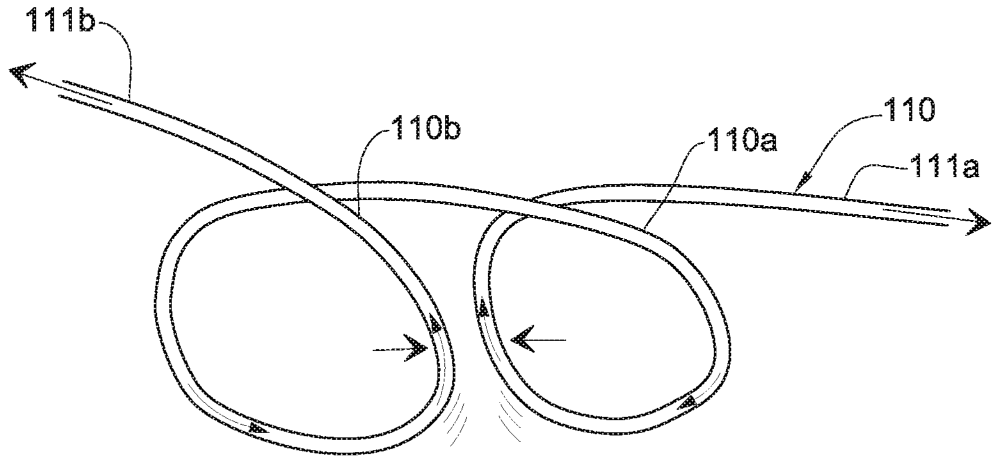


Fig. 2(b)

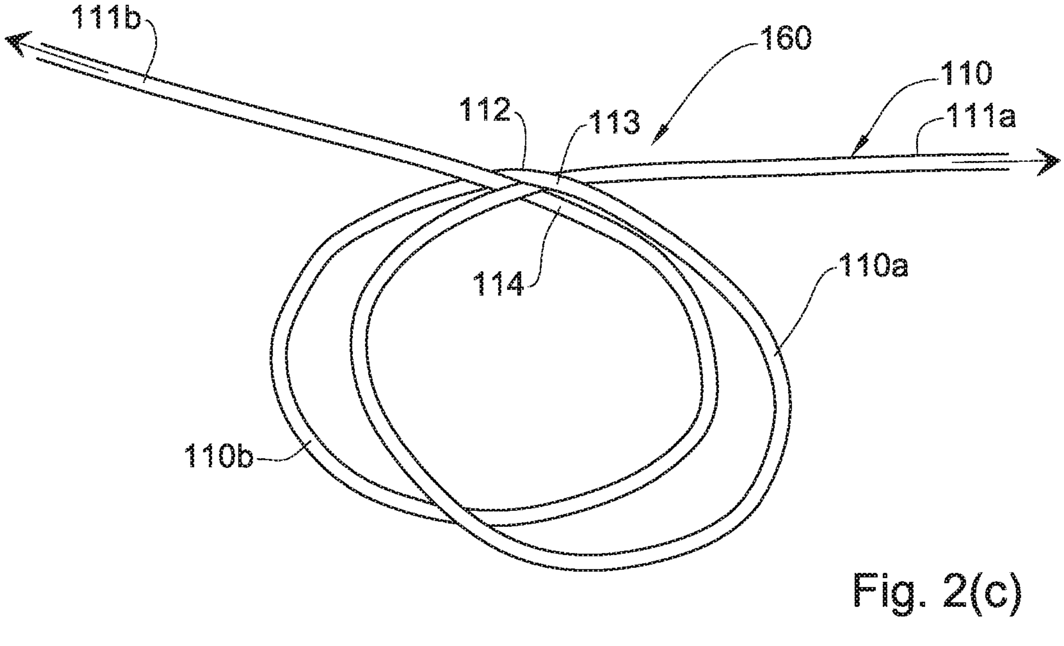
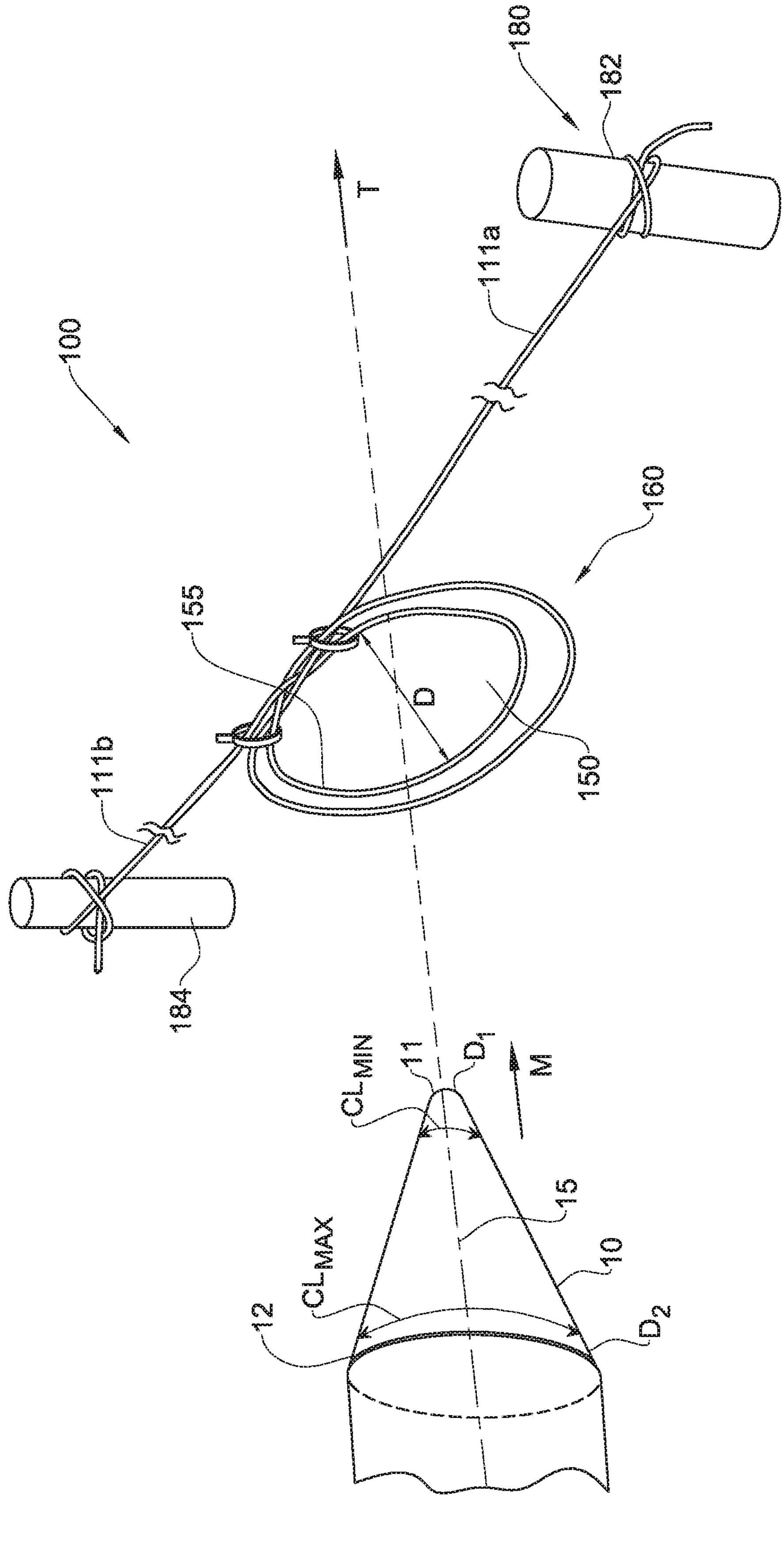


Fig. 2(c)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CL_{MAX}
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12
D_2

Fig. 3

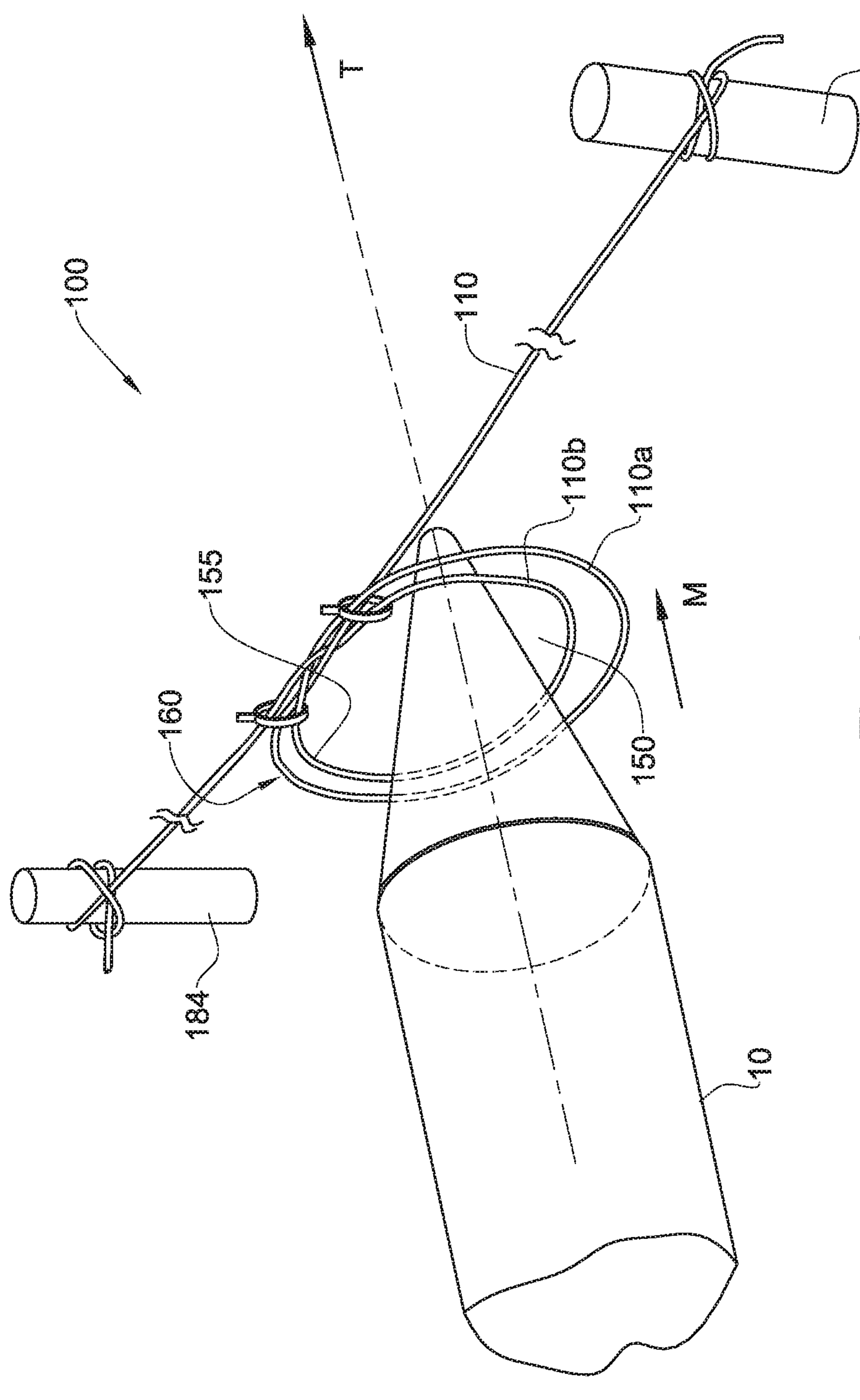

Fig. 4

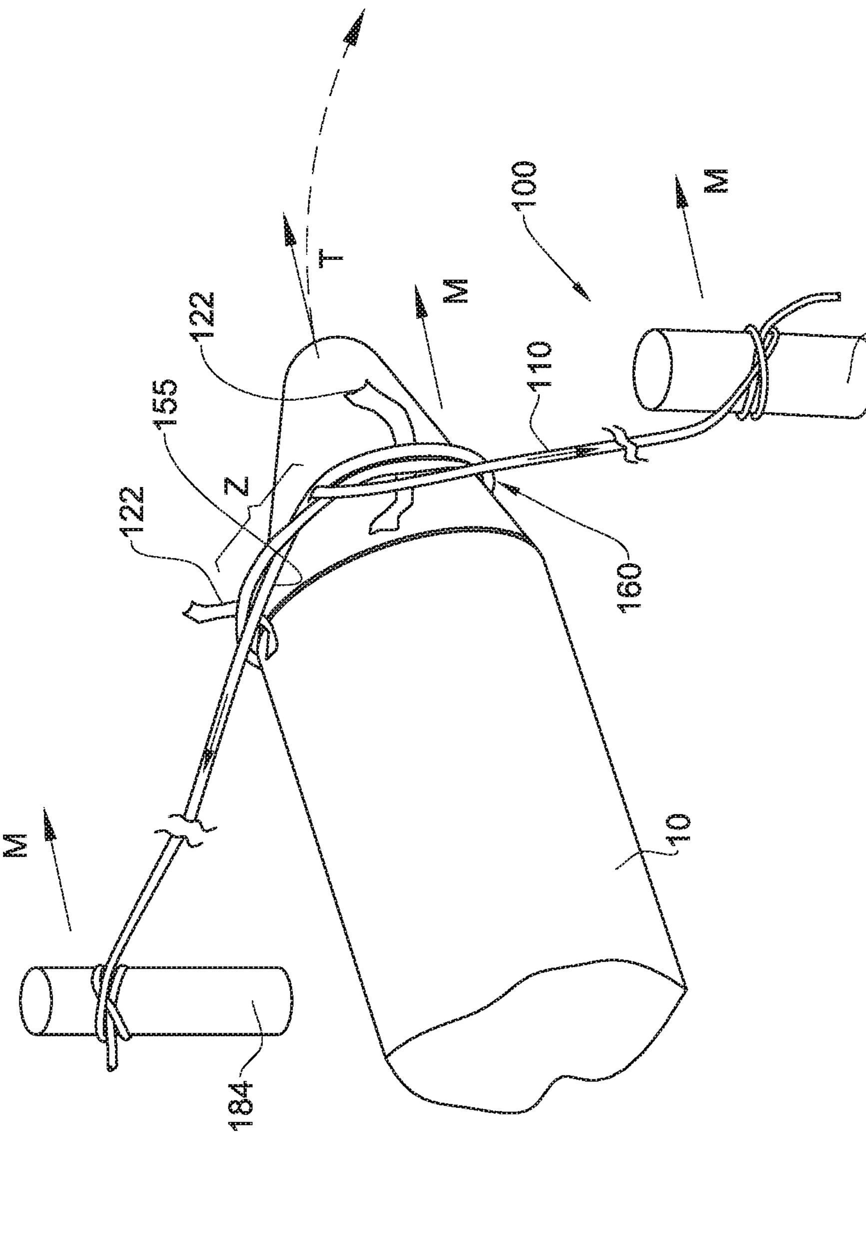

Fig. 5

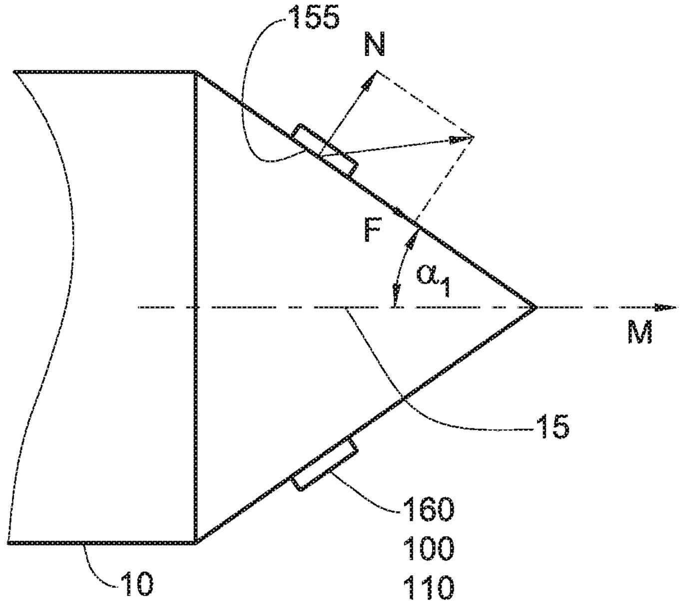
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Fig. 6(a)

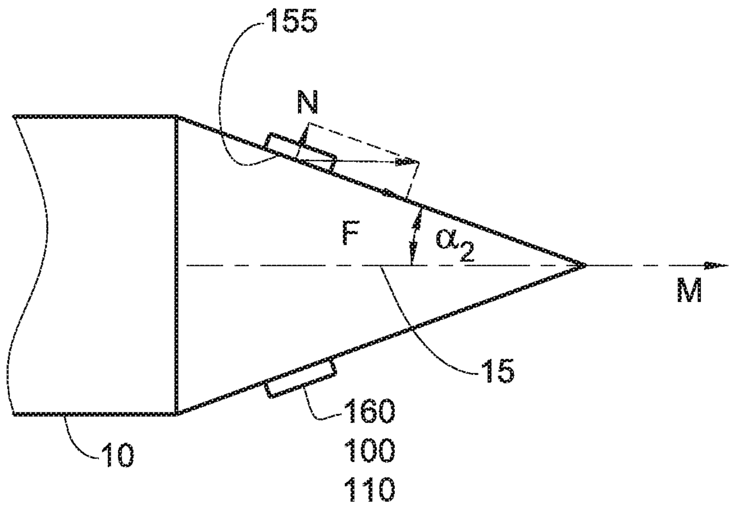
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Fig. 6(b)

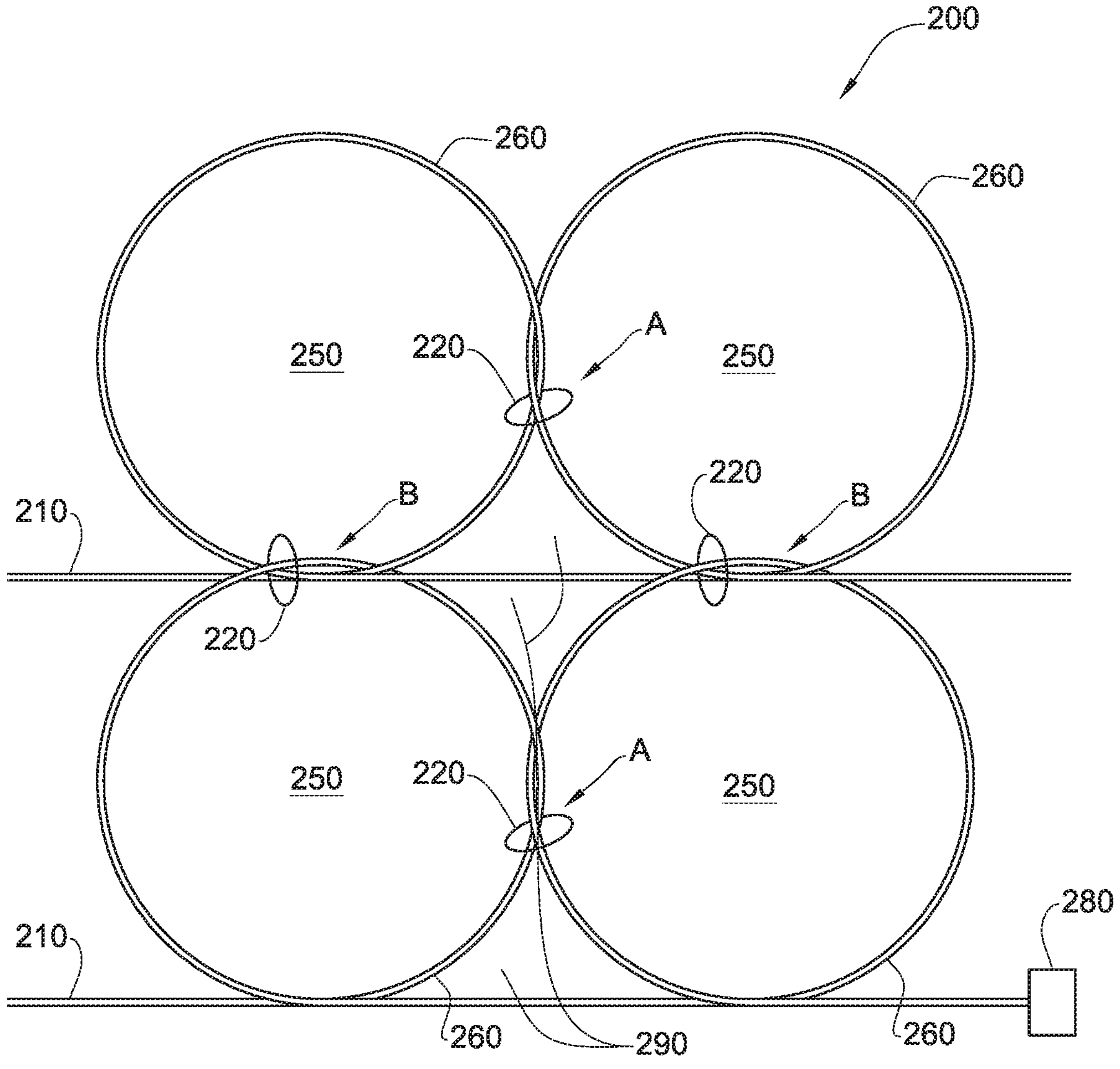
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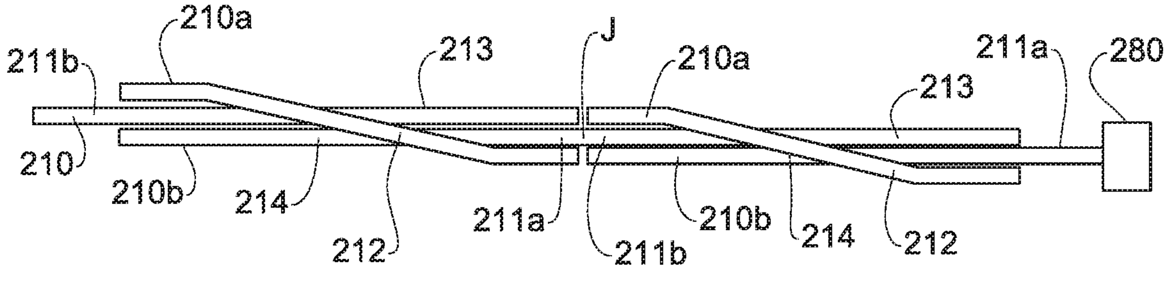
Fig. 7(a)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212

Fig. 7(b)

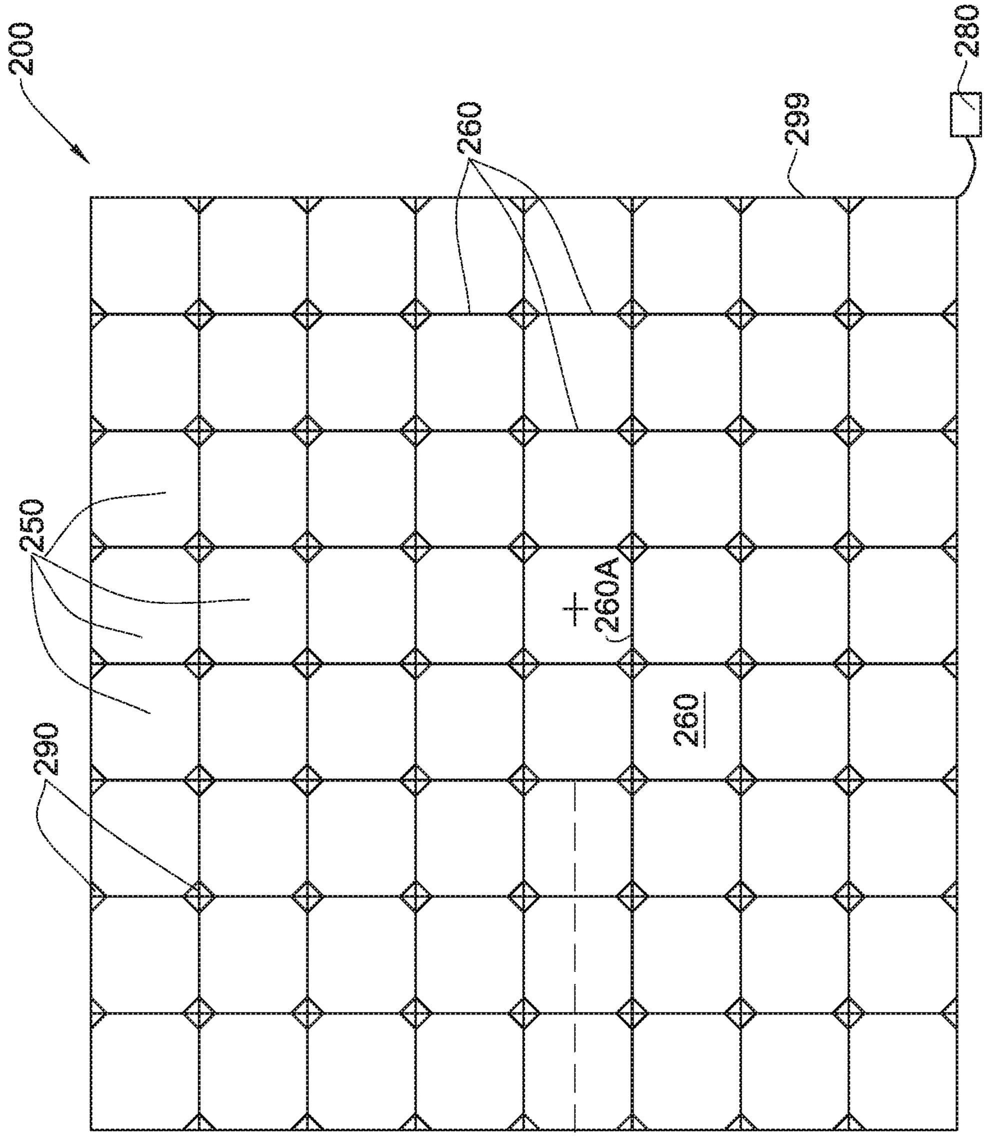

Fig. 8(b)

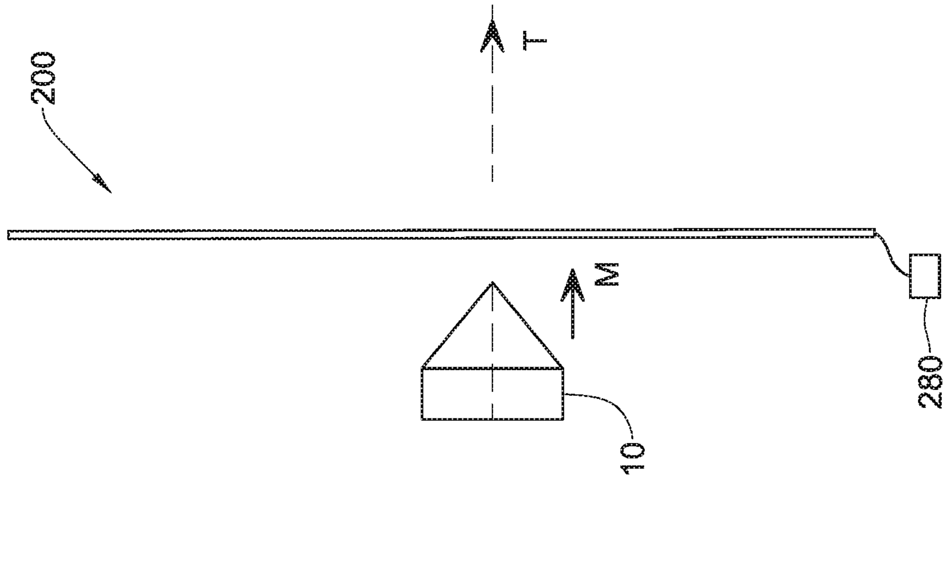

Fig. 8(a)

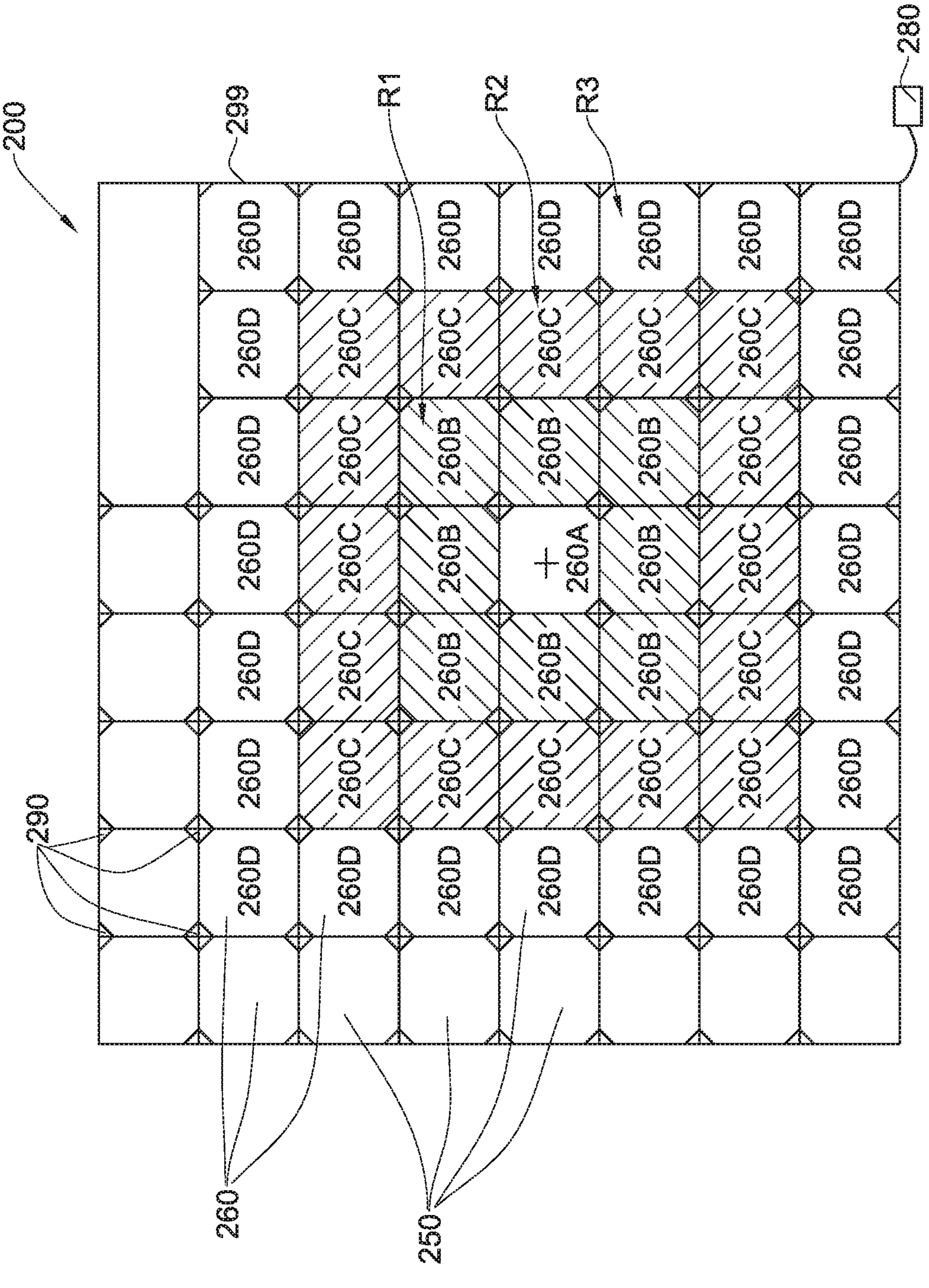

Fig. 8(c)

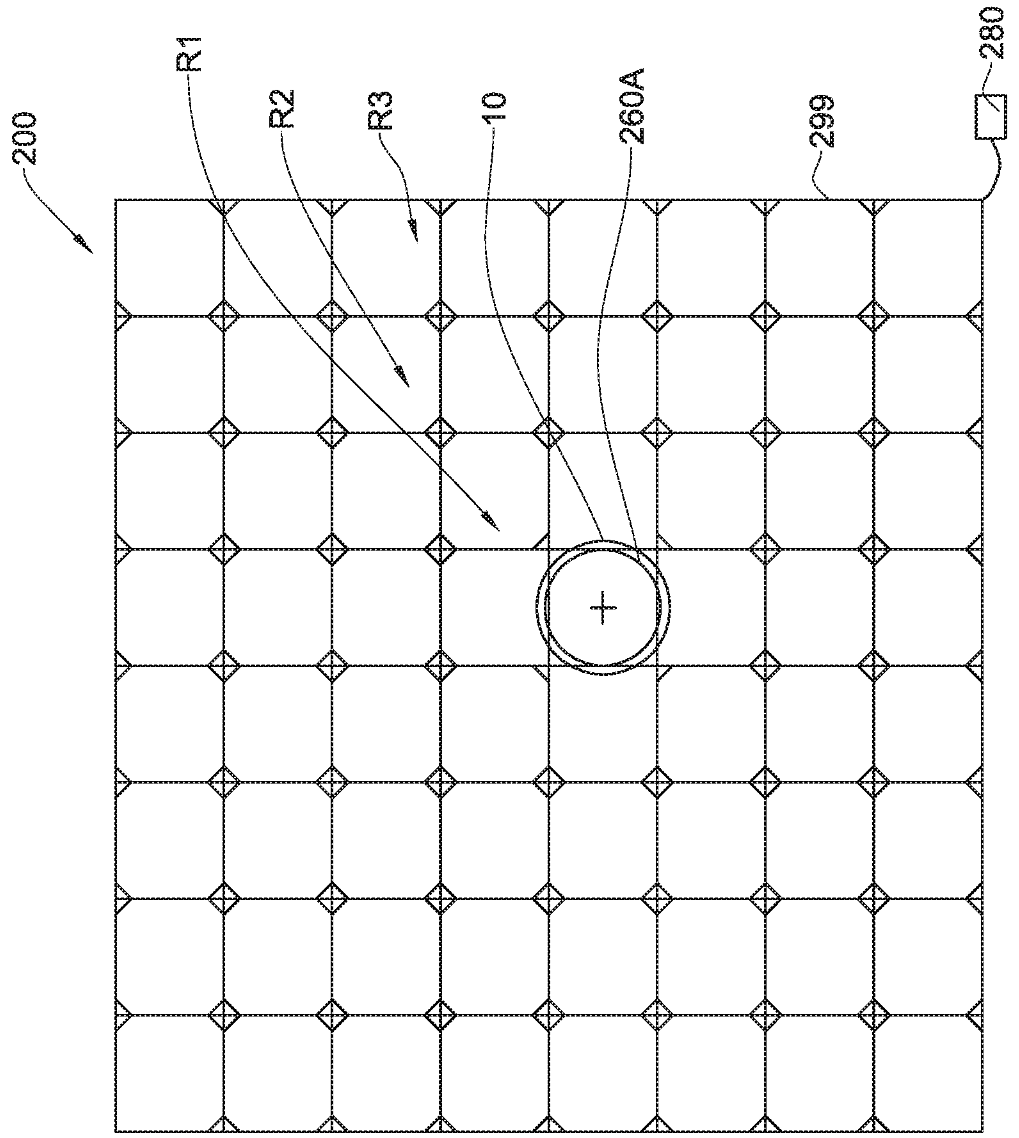

Fig. 9(b)

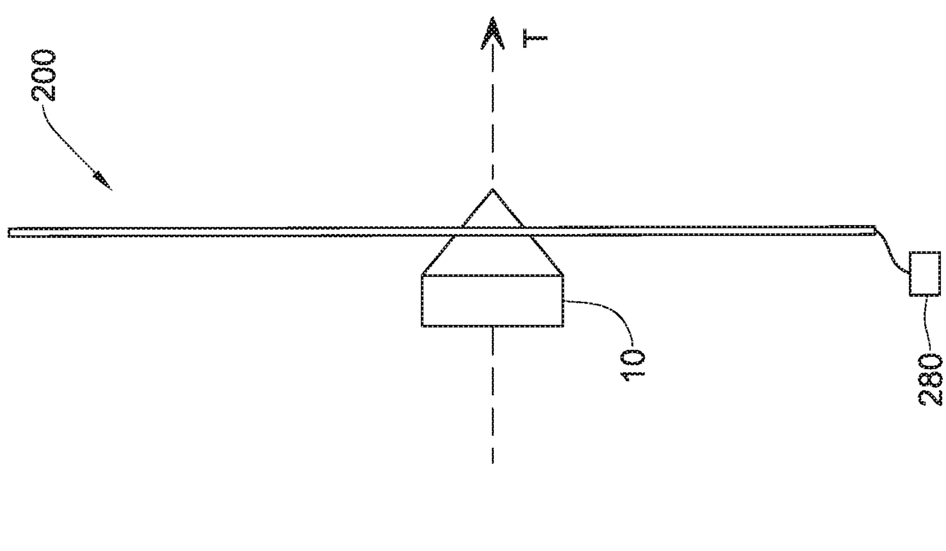

Fig. 9(a)

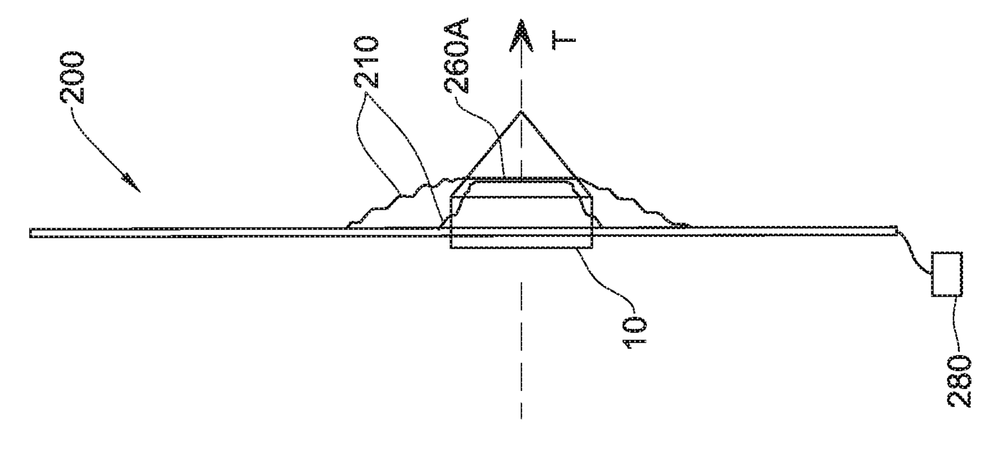

Fig. 10(a)

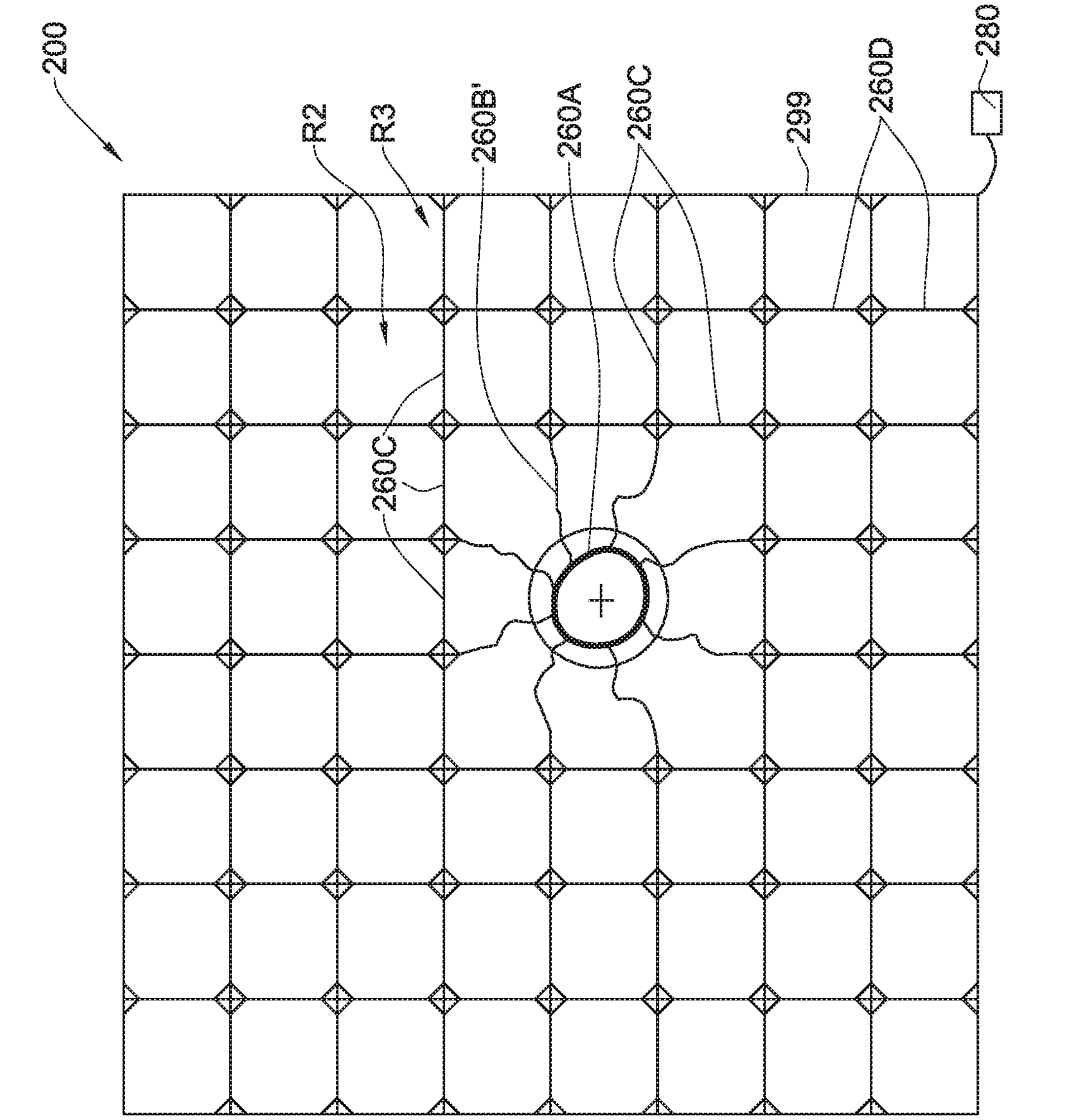

Fig. 10(b)

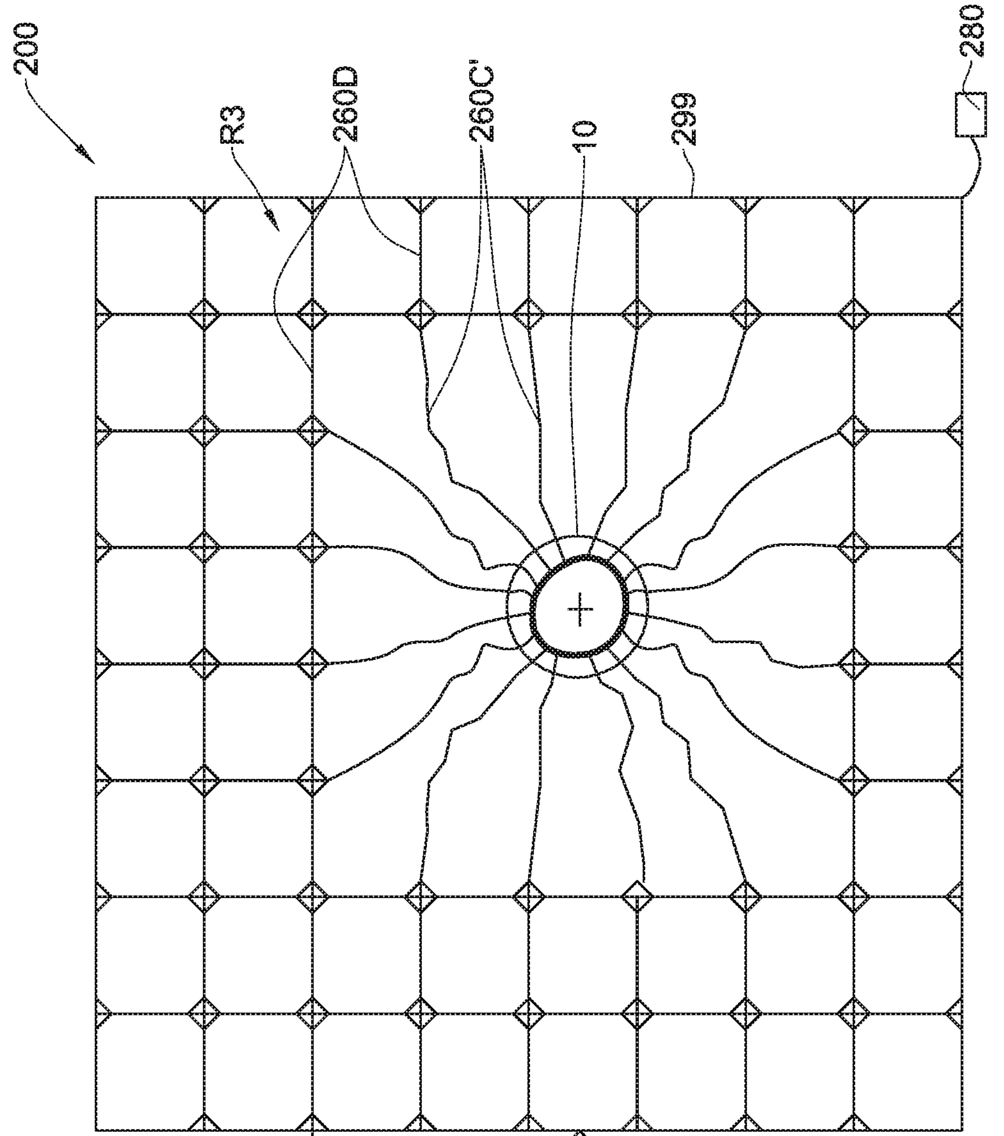

Fig. 11(b)

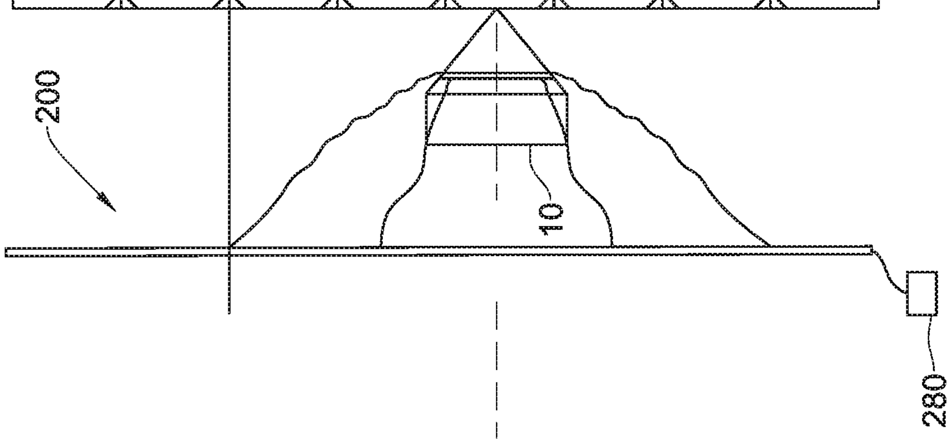

Fig. 11(a)

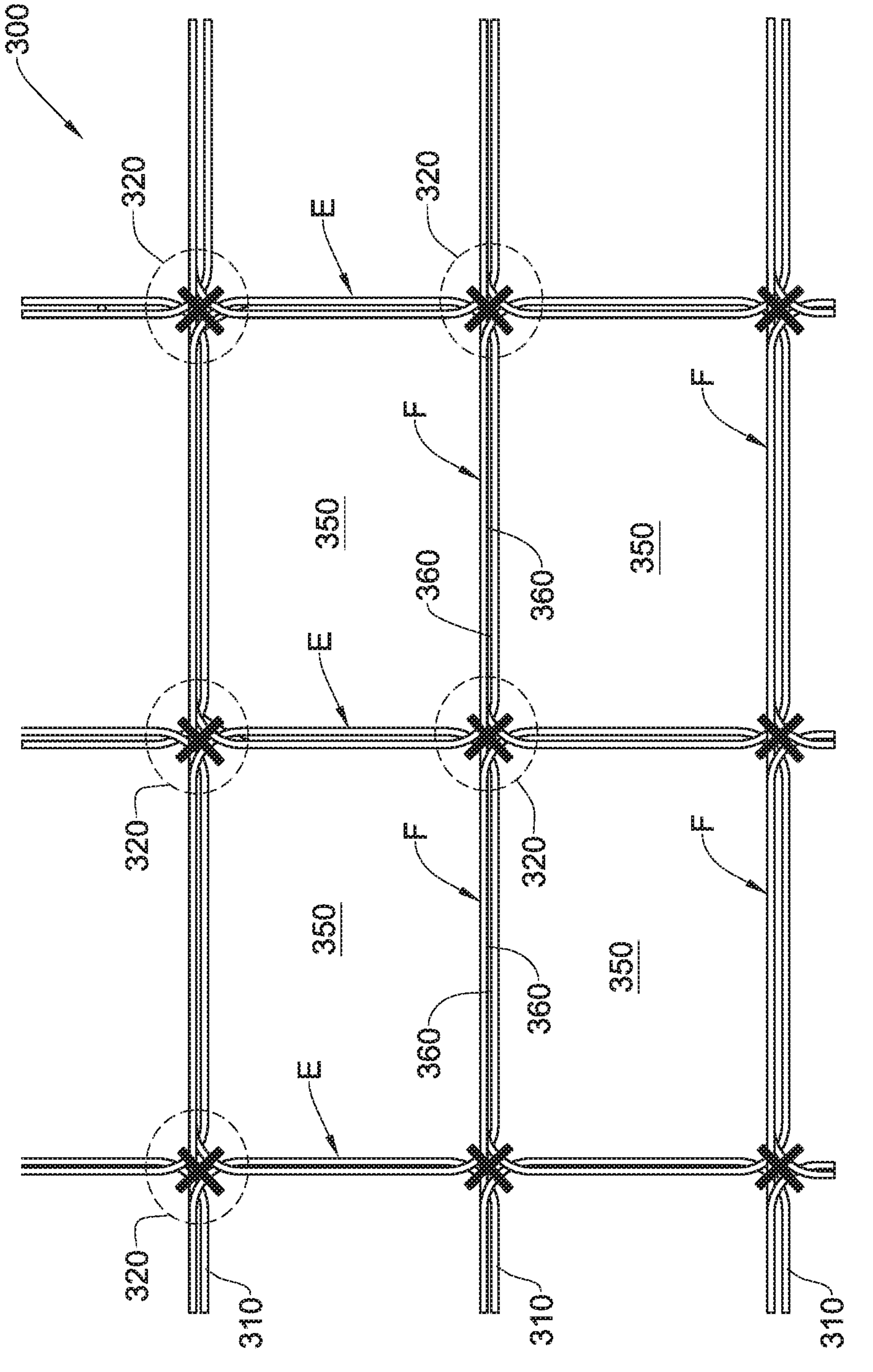
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Fig. 12

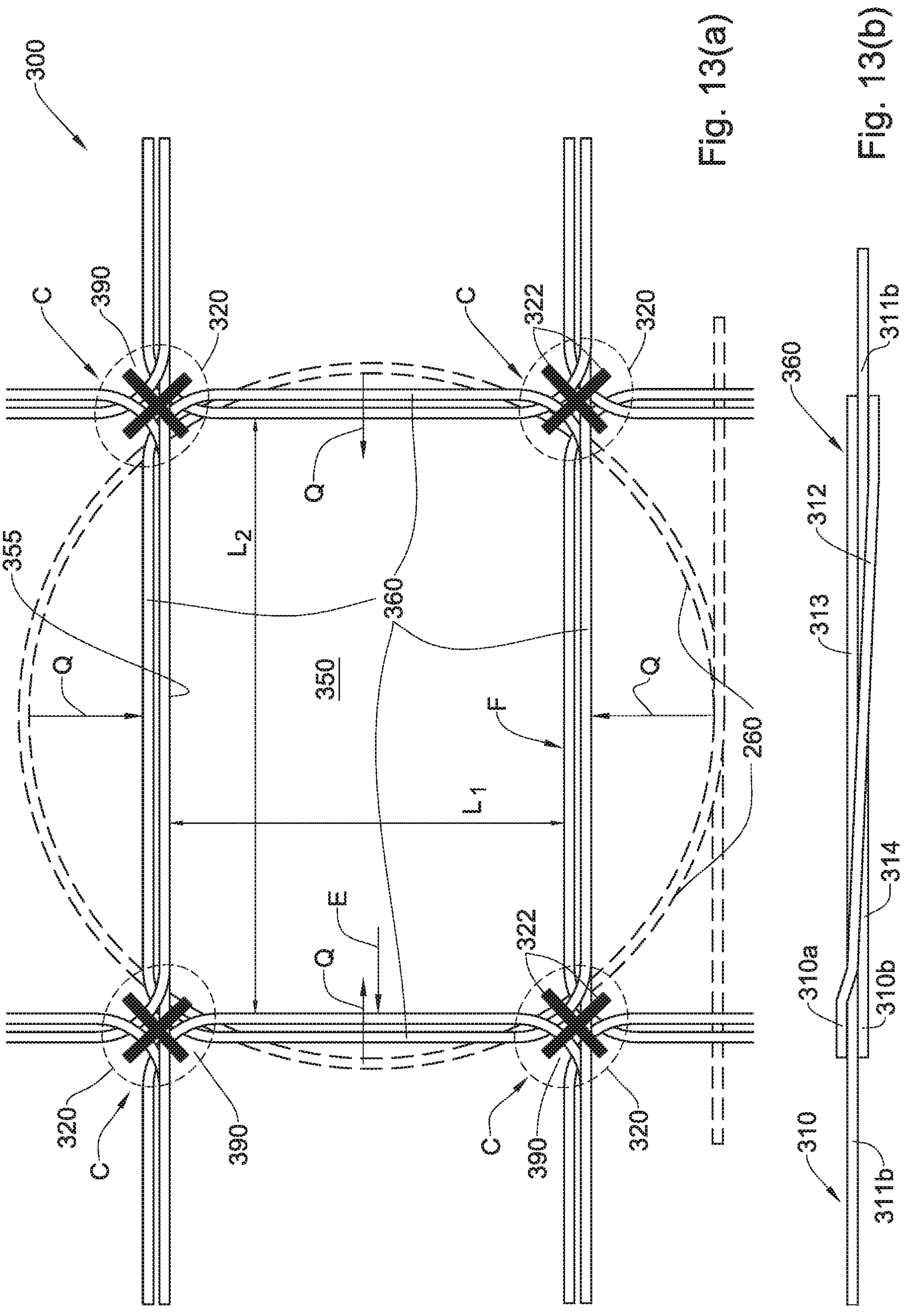

Fig. 13(a)

Fig. 13(b)

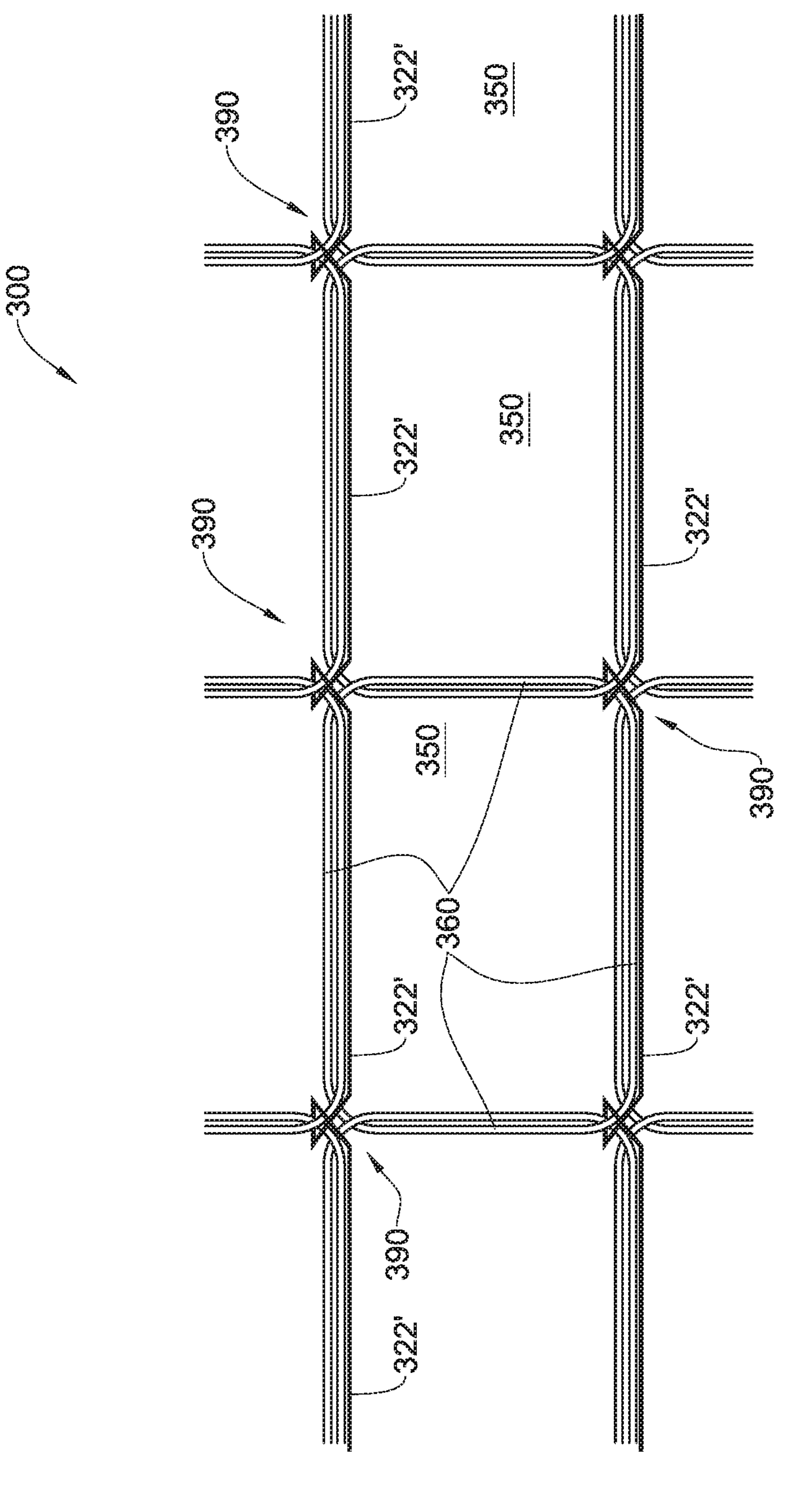

Fig. 14

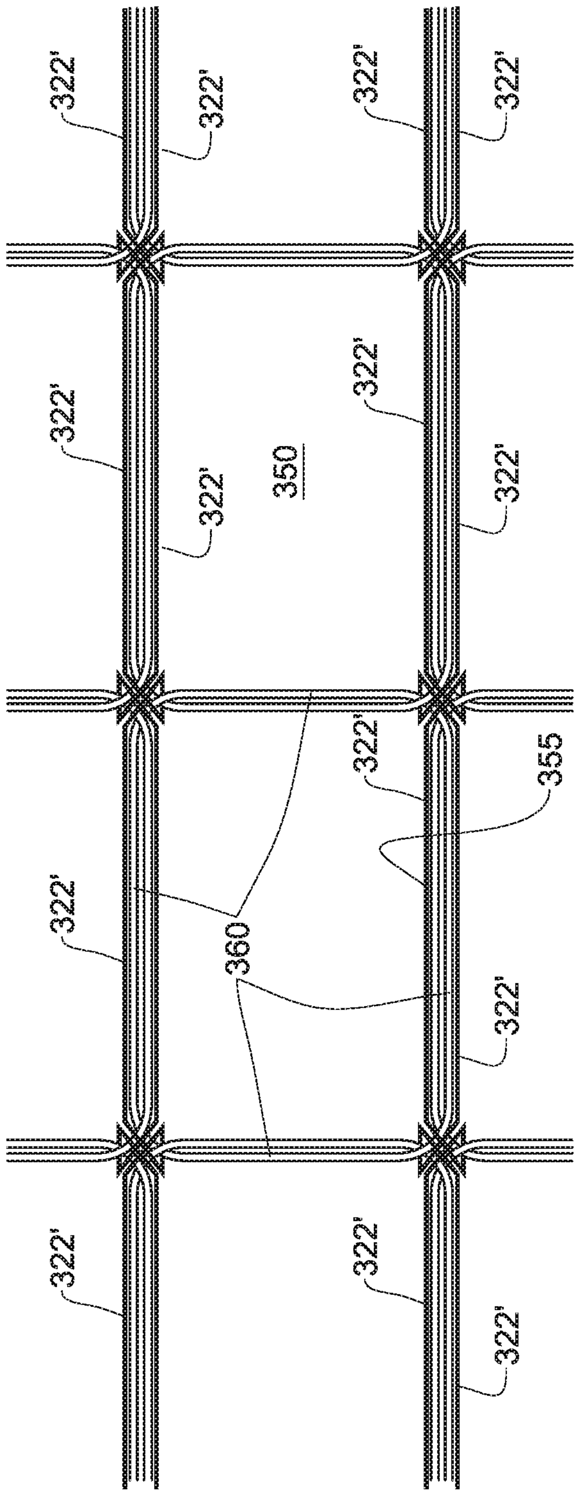

Fig. 15

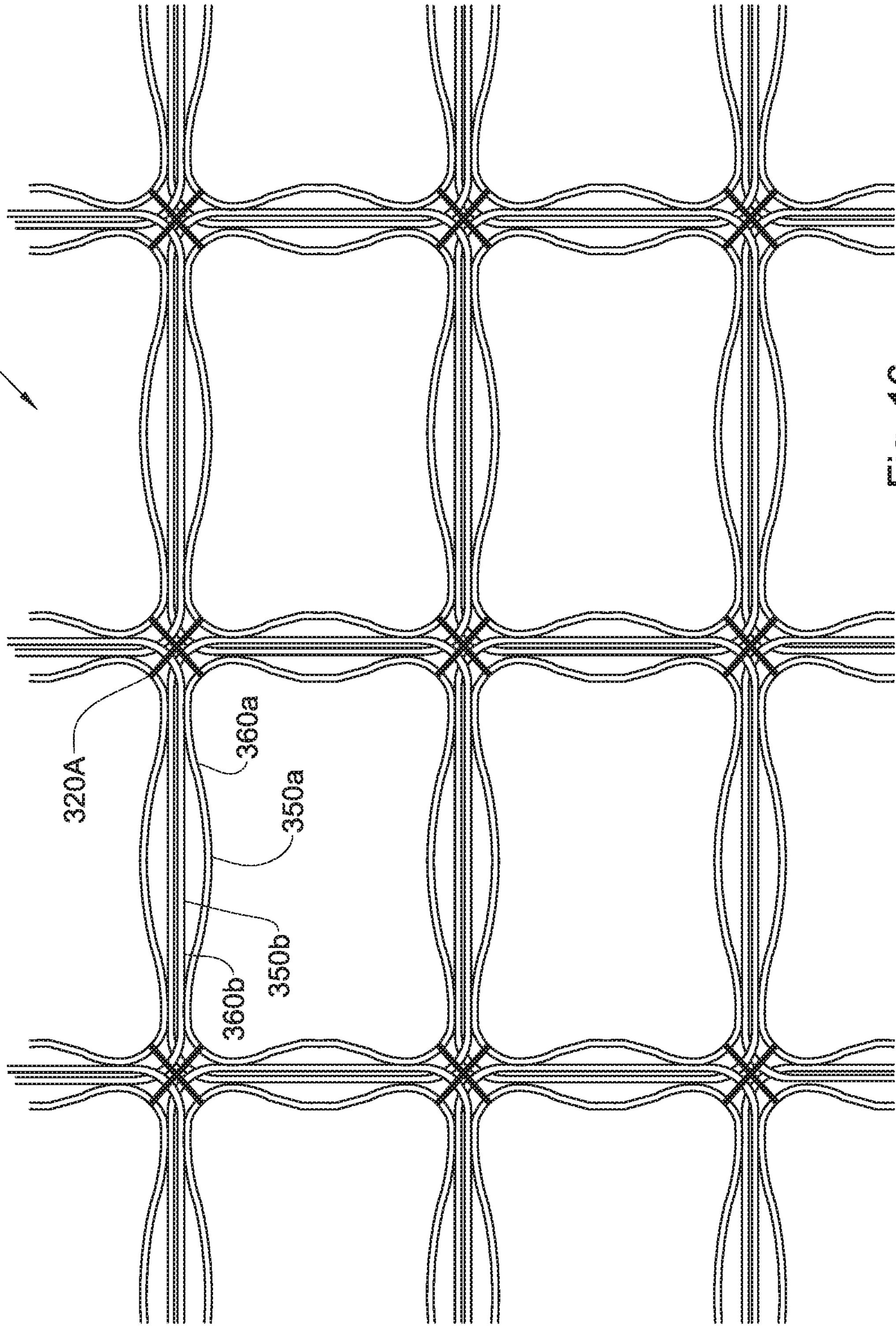

Fig. 16

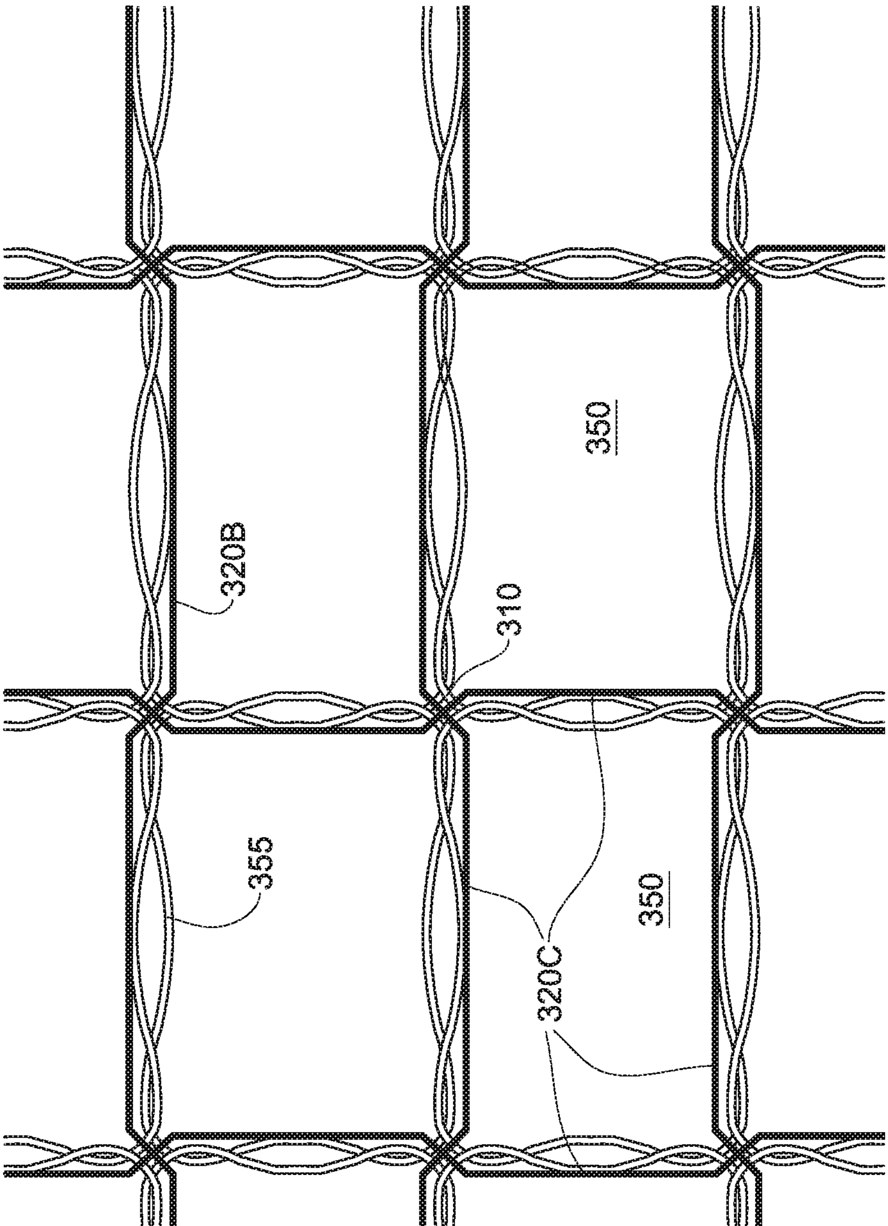

Fig. 17

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IL2013/050867

A. CLASSIFICATION OF SUBJECT MATTER
IPC (2013.01) F41H 1/04

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC (2013.01) F41H 11/04, F41H 11/05, F41H 13/00, F41H 5/00, B64C, A01M

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
See extra sheet.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 1240317 A CLARK EWEN A [US] 18 Sep 1917 (1917/09/18) All document	1-4,6,9-11,13,14,17, 29-32,36,37,41,45,46, 48-50
Y		37-40,42-44
Y	US 2010102166 A1 KONSTANTINOVSKIY ALEXANDR [RU] 29 Apr 2010 (2010/04/29) Figs 2-4; 16, 20 | ¶ [0039]	37-40
Y	US 6325015 B1 US NAVY [US] 04 Dec 2001 (2001/12/04) Col 4 rows 15-51 | Fig 2	42-44
A	US 2009035068 A1 TERAI JEFFREY B [US]; MCDOLE JAMES M [US] 05 Feb 2009 (2009/02/05)	1-50

☒ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
27 Jan 2014	28 Jan 2014

Name and mailing address of the ISA:	Authorized officer
Israel Patent Office Technology Park, Bldg.5, Malcha, Jerusalem, 9695101, Israel Facsimile No. 972-2-5651616	COHAY Matan Telephone No. 972-2-5651611

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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Search terms used: missile, projectile, rocket, shell, mortar, warhead, aircraft, drone, uav, trap, net, web, grid, lattice, mesh, retainer, ring, clamp, heat shrunk, mold, tie, hold, fastener, grommet, grummet, guide Loop, knot, loop

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