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Office de la Propriété Intellectuelle du Canada

Innovation, Science and Economic Development Canada
Canadian Intellectual Property Office

CA 2974245 C 2021/09/28

(11)(21) **2 974 245**

(12) **BREVET CANADIEN**
CANADIAN PATENT

(13) **C**

(22) **Date de dépôt/Filing Date:** 2017/07/19
(41) **Mise à la disp. pub./Open to Public Insp.:** 2018/03/07
(45) **Date de délivrance/Issue Date:** 2021/09/28
(30) **Priorité/Priority:** 2016/09/07 (US15/258,919)

(51) **Cl.Int./Int.Cl.** *B64F 5/40* (2017.01), *B64C 1/00* (2006.01)

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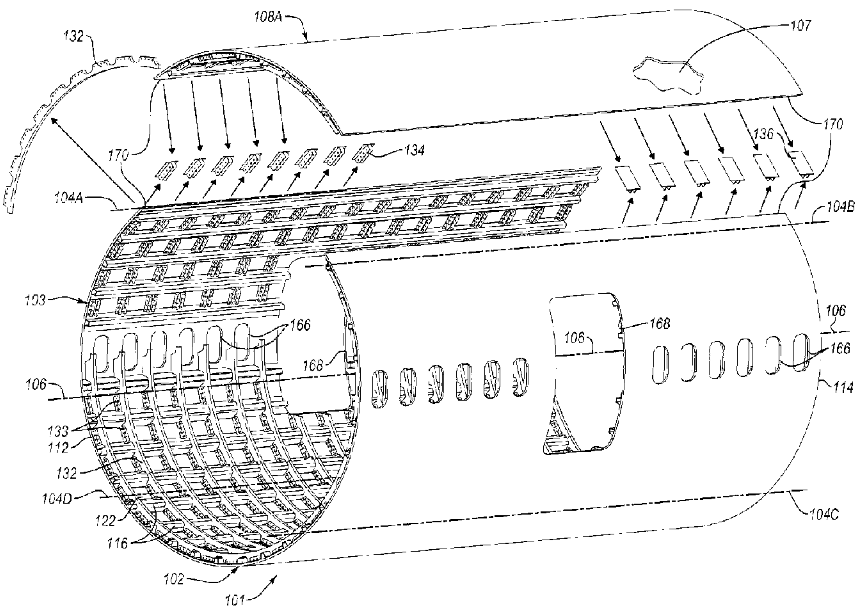
(54) **Titre :** METHODE DE REPARATION DE DOMMAGE AU CORPS DE FUSELAGE ET APPAREILLAGE ET SYSTEME ASSOCIES

(54) **Title:** METHOD OF REPAIRING DAMAGE TO FUSELAGE BARREL AND ASSOCIATED APPARATUS AND SYSTEM



(57) **Abrégé/Abstract:**

Disclosed herein is a method of repairing damage to a fuselage barrel, having a one-piece construction, of an aircraft. The method includes determining at least a first virtual splice line and a second virtual splice line along the fuselage barrel in a direction parallel to a longitudinal axis of the fuselage barrel. The method also includes detecting damage in a first section of the fuselage barrel between the first virtual splice line and the second virtual splice line. The method further includes cutting through the fuselage barrel along the first virtual splice line and the second virtual splice line to physically separate the first section from a main section of the fuselage barrel. The method also includes removing the first section from the main section of the fuselage barrel, and splicing a new section to the main section of the fuselage barrel in place of the first section.

ABSTRACT

Disclosed herein is a method of repairing damage to a fuselage barrel, having a one-piece construction, of an aircraft. The method includes determining at least a first virtual splice line and a second virtual splice line along the fuselage barrel in a direction parallel to a longitudinal axis of the fuselage barrel. The method also includes detecting damage in a first section of the fuselage barrel between the first virtual splice line and the second virtual splice line. The method further includes cutting through the fuselage barrel along the first virtual splice line and the second virtual splice line to physically separate the first section from a main section of the fuselage barrel. The method also includes removing the first section from the main section of the fuselage barrel, and splicing a new section to the main section of the fuselage barrel in place of the first section.

METHOD OF REPAIRING DAMAGE TO FUSELAGE BARREL AND ASSOCIATED APPARATUS AND SYSTEM

FIELD

This disclosure relates generally to fuselage barrels of aircraft, and more particularly to repairing fuselage barrels of aircraft made from fiber-reinforced polymers.

BACKGROUND

With typical aircraft having fuselage barrels made from metal, the fuselage barrels include multiple, pre-existing, interconnected segments. Often, the interconnected segments of a conventional fuselage barrel made from metal are coupled together at lap joints when the aircraft is initially assembled prior to first operation of the aircraft. When damage to such a conventional fuselage barrel occurs, the segment or segments of the interconnected segments containing the damage are separated along production splices, removed from the fuselage barrel, and replaced with an undamaged segment or segments. Because conventional fuselage barrels made from metal are initially manufactured to have a multi-piece construction, repair of damage to a conventional fuselage barrel made from metal can be accomplished with relative ease.

Technologically-advanced materials, such as fiber-reinforced polymers, allow for the construction of a one-piece fuselage barrel, which eliminates the need to interconnect numerous panels around the fuselage barrel. Conventional methods of removing and replacing fuselage panels are inadequate for a fuselage barrel made of a once-piece construction. For example, conventional methods of repairing damage to a fuselage barrel having a one-piece construction can be difficult, time-consuming, and expensive, and result in undesirable aesthetics.

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SUMMARY

The subject matter of the present application has been developed in response to the present state of the art, and in particular, in response to the problems and disadvantages associated with repairing damage to fuselage barrels having a one-piece construction, that have not yet been fully solved by currently available techniques. Accordingly, the subject matter of the present application has been developed to provide a method of repairing damage to a fuselage barrel having a one-piece construction that overcomes at least some of the above-discussed shortcomings of prior art techniques. More specifically, in one implementation, in order to utilize the structural and manufacturing efficiencies of a one-piece barrel design, a method is disclosed that helps to ensure that airframes involved in a large scale damage event can be rapidly repaired and returned to service.

In one embodiment, there is provided a method of replacing a portion of a fuselage barrel of an aircraft having a seamless construction. The method involves determining at least a first splice line and a second splice line along the fuselage barrel in a direction parallel to a longitudinal axis of the fuselage barrel. The method further involves, subsequent to determining at least the first splice line and the second splice line, detecting damage in a first section of the fuselage barrel between the first splice line and the second splice line and cutting through the fuselage barrel after detecting damage, along the first splice line and the second splice line to physically separate the first section from a main section of the fuselage barrel. The method further involves removing the first section from the main section of the fuselage barrel; and splicing a new section that is not co-formed with the main section of the fuselage barrel in place of the removed first section, wherein the splicing comprises forming a first butt joint along the first splice line and a second butt joint along the second splice line, parallel to the longitudinal axis, between the new section and the main section of the fuselage barrel.

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The fuselage barrel may extend longitudinally along the longitudinal axis from a first end to a second end and the first splice line and the second splice line both extend from the first end of the fuselage barrel to the second end of the fuselage barrel.

Splicing the new section to the main section of the fuselage barrel may further involve overlaying the first butt joint with a first splice plate, overlaying the second butt joint with a second splice plate, and fastening the first splice plate and the second splice plate to an interior surface of the main section of the fuselage barrel and an interior surface of the new section.

Removing the first section from the main section of the fuselage barrel may involve decoupling a frame element, extending circumferentially about the fuselage barrel, from a first shear tie coupled to the fuselage barrel over the first splice line and from a second shear tie coupled to the fuselage barrel over the second splice line, decoupling the first shear tie from the fuselage barrel; decoupling the second shear tie from the fuselage barrel. Splicing the new section to the main section of the fuselage barrel may involve coupling a first replacement shear tie to the first splice plate, wherein the first replacement shear tie is configured differently than the first shear tie, coupling a second replacement shear tie to the second splice plate, wherein the second replacement shear tie is configured differently than the second shear tie and coupling the frame element to the first replacement shear tie and the second replacement shear tie.

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The first splice plate may involve multiple first splice plate segments arranged substantially end-to-end along the first butt joint and the second splice plate may involve multiple second splice plate segments arranged substantially end-to-end along the second butt joint. Splicing the new section to the main section of the fuselage barrel may further involve intercoupling adjacent first splice plate segments with at least one coupler fixed to and spanning at least portions of the adjacent first splice plate segments and splicing the new section to the main section of the fuselage barrel further comprises intercoupling adjacent second splice plate segments with at least one coupler fixed to and spanning at least portions of the adjacent second splice plate segments.

A plurality of stringers, circumferentially spaced apart from each other may extend along the fuselage barrel parallel to the longitudinal axis of the fuselage barrel and may be coupled to the fuselage barrel. The plurality of stringers may be grouped into at least a first pair of stringers, comprising a first stringer, and a second pair of stringers, comprising a third stringer. The first splice line may extend between the first pair of stringers and the second splice line extends between the second pair of stringers.

Splicing the new section to the main section of the fuselage barrel may involve positioning a first filler between the first splice plate and the first butt joint and between the first stringer and a second stringer of the new section and positioning a second filler between the second splice plate and the second butt joint and between the third stringer and a fourth stringer of the new section.

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The fuselage barrel, first splice plate, second splice plate, and the plurality of stringers may be made from a fiber-reinforced polymer.

The aircraft may comprise multiple fuselage barrels coupled to each other in an end-to-end manner to form a fuselage of the aircraft and the method may involve removing the first section from the main section of the fuselage barrel comprises decoupling the first section of the fuselage barrel from adjacent fuselage barrels and splicing the new section to the main section of the fuselage barrel comprises coupling the new section to adjacent fuselage barrels.

The new section may be pre-manufactured, prior to damage of the fuselage barrel, responsive to a location on the fuselage barrel of the first splice line and the second splice line.

Determining at least the first splice line and the second splice line may involve detecting a path along an interior surface of the fuselage barrel having a line of sight from one end of the path to an opposite end of the path and locating one of the first splice line and the second splice line along the path.

Each of the first section and the new section may form at least a quarter of the fuselage barrel.

The method may further involve, prior to damage of the fuselage barrel, determining at least a third splice line along the fuselage barrel in a direction parallel to a longitudinal axis of the fuselage barrel.

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In another embodiment, there is provided a fuselage barrel assembly of an aircraft. The fuselage barrel assembly includes a main section of a fuselage barrel having a one-piece construction and includes a new section of the fuselage barrel having a one-piece construction and spliced to the main section along a first butt joint between the main section and the new section and along a second butt joint between the main section and the new section. The fuselage barrel assembly further includes a first splice plate fastened to the main section of the fuselage barrel and the new section over the first butt joint, and a second splice plate fastened to the main section of the fuselage barrel and the new section over the second butt joint. The fuselage barrel assembly additionally includes a first replacement shear tie coupled to the first splice plate, a second replacement shear tie coupled to the second splice plate, and a frame element coupled to both the first replacement shear tie and the second replacement shear tie.

The main section may include a first stringer extending parallel to the first butt joint, and a second stringer extending parallel to the second butt joint. The new section may include a third stringer extending parallel to the first butt joint, and a fourth stringer extending parallel to the second butt joint. The fuselage barrel further includes a first filler between the first splice plate and the first butt joint and between the first stringer and the third stringer, and a second filler between the second splice plate and the second butt joint and between the second stringer and the fourth stringer.

The main section may include a first stringer extending parallel to the first butt joint, and a second stringer extending parallel to the second butt joint. The new section may include a third stringer extending parallel to the first butt joint, and a fourth stringer extending parallel to the second butt joint. The first splice plate may be supported on and fastened to the first stringer, the third stringer, and the first filler. The second splice plate may be supported on and fastened to the second stringer, the fourth stringer, and the second filler.

The first butt joint and the second butt joint may be circumferentially spaced apart from each other. The first butt joint and the second butt joint may extend parallel to a longitudinal axis of the fuselage barrel. The first butt joint and the second butt joint may extend from a first end of the fuselage barrel to a second end of the fuselage barrel.

The main section, new section, first splice plate, and second splice plate may be made from a fiber-reinforced polymer.

The main section of the fuselage barrel may have a seamless construction.

The new section of the fuselage barrel may have a seamless construction.

The entirety of the main section of the fuselage may be circumferentially open and the entirety of the new section of the fuselage barrel may be circumferentially open.

An entire length of the new section of the fuselage barrel may be equal to an entire length of the main section of the fuselage barrel.

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The first butt joint and the second butt joint may extend an entire length of the main section of the fuselage barrel and an entire length of the new section of the fuselage barrel. The first splice plate may extend the entire length of the main section and the new section of the fuselage barrel and the second splice plate may extend the entire length of the new section of the fuselage barrel.

The fuselage barrel assembly may include a plurality of first replacement shear ties and a plurality of second replacement shear ties, wherein the plurality of first replacement shear ties are coupled to and spaced apart along the first splice plate and the plurality of second replacement shear ties are coupled to and space apart along the second splice plate.

The first splice plate may have a seamless construction and the second splice pate may have a seamless construction.

The first splice plate may have multiple first splice plate segments; and the second splice plate comprises multiple second splice plate segments.

The first splice pate segments may be interconnected in an end-to-end manner longitudinally along the first butt joint and the second splice plate segments may be interconnected in an end-to-end manner longitudinally along the second butt joint.

The fuselage barrel assembly may further include first couplers each fixed to and spanning at least portions of adjacent ones of the multiple first splice plate segments and second couplers each fixed to and spanning at least portions of adjacent ones of the multiple second splice plate segments.

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The first splice plate and the second splice plate may be made from the same material as the main section of the fuselage barrel and the new section of the fuselage barrel.

The first filler and the second filler may be made from a fiber-reinforced polymer.

The first stringer may include a first flange, the second string may include a second flange, the third stringer may include a third flange, he fourth stringer may include a fourth flange. The first splice pate mat sit flush against the first flange and the third flange, the second splice plate may sit flush against the second flange and the fourth flange, the first filler may be interposed between the first flange and the third flange and the second filler may be interposed between the second flange and the fourth flange.

The first splice plate and the second splice plate may sit flush against an interior surface of the main section of the fuselage barrel and an interior surface of the new section of the fuselage barrel.

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In another embodiment, there is provided an aircraft including a plurality of fuselage barrel assemblies interconnected to each other. At least one of the fuselage barrel assemblies includes a main section of a fuselage barrel having a one-piece construction and a new section of the fuselage barrel having a one-piece construction and spliced to the main section along a first butt joint between the main section and the new section and along a second butt joint between the main section and the new section. The at least the one of the fuselage barrel assemblies additionally includes a first splice plate fastened to the main section of the fuselage barrel the new section over the first butt joint, and a second splice plate fastened to the main section of the fuselage barrel and the new section over the second butt joint. The at least the one of the fuselage barrel assemblies further includes a first replacement shear tie coupled to the first splice plate, a second replacement shear tie coupled to the second splice plate, and a frame element coupled to both the first replacement shear tie and the second replacement shear tie. The plurality of fuselage barrel assemblies are interconnected in an end-to-end configuration at abutting ends of respective fuselage barrels of the fuselage barrel assemblies.

The described features, structures, advantages, and/or characteristics of the subject matter of the present disclosure may be combined in any suitable manner in one or more embodiments and/or implementations. In the following description, numerous specific details are provided to impart a thorough understanding of embodiments of the subject matter of the present disclosure. One skilled in the relevant art will recognize that the subject matter of the present disclosure may be practiced without one or more of the specific features, details, components, materials, and/or methods of a particular embodiment or implementation. In other instances, additional features and advantages may be recognized in certain embodiments and/or implementations that may not be present in all embodiments or implementations. Further, in some instances, well-known structures, materials, or operations are not shown or described in detail to avoid obscuring aspects of the subject matter of the present disclosure.

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BRIEF DESCRIPTION OF THE DRAWINGS

In order that the potential advantages of the subject matter may be more readily understood, a more particular description of the subject matter briefly described above will be rendered by reference to specific embodiments that are illustrated in the appended drawings. Understanding that these drawings depict only typical embodiments of the subject matter and are not therefore to be considered to be limiting of its scope, the subject matter will be described and explained with additional specificity and detail through the use of the drawings, in which:

Figure **1** is a perspective view of an aircraft with multiple fuselage barrel assemblies, according to one or more embodiments of the present disclosure;

Figure **2** is a perspective view of a fuselage barrel assembly with splice lines, according to one or more embodiments of the present disclosure;

Figure **3** is a perspective view of a first section of a fuselage barrel removed from a main section of the fuselage barrel, according to one or more embodiments of the present disclosure;

Figure **4** is a perspective view of a new section of a fuselage barrel being coupled to a main section of the fuselage barrel, according to one or more embodiments of the present disclosure;

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Figure **5** is a perspective view of a new section of a fuselage barrel coupled to a main section of the fuselage barrel, according to one or more embodiments of the present disclosure;

Figure **6** is a perspective view of a new section of a fuselage barrel coupled to a main section of the fuselage barrel, shown without fasteners, according to one or more embodiments of the present disclosure;

Figure **7** is a perspective view of a new section of a fuselage barrel coupled to a main section of the fuselage barrel, shown with fasteners, according to one or more embodiments of the present disclosure;

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Figure **8** is a side elevation view of a new section of a fuselage barrel coupled to a main section of the fuselage barrel, shown without a replacement shear tie and frame element, according to one or more embodiments of the present disclosure;

Figure **9** is a side elevation view of a new section of a fuselage barrel coupled to a main section of the fuselage barrel, shown with a replacement shear tie and frame element, according to one or more embodiments of the present disclosure; and

Figure **10** is a method of repairing damage to a fuselage barrel of an aircraft, according to one or more embodiments of the present disclosure.

DETAILED DESCRIPTION

Reference throughout this specification to "one embodiment," "an embodiment," or similar language means that a particular feature, structure, or characteristic described in connection with the embodiment is included in at least one embodiment of the present disclosure. Appearances of the phrases "in one embodiment," "in an embodiment," and similar language throughout this specification may, but do not necessarily, all refer to the same embodiment. Similarly, the use of the term "implementation" means an implementation having a particular feature, structure, or characteristic described in connection with one or more embodiments of the present disclosure, however, absent an express correlation to indicate otherwise, an implementation may be associated with one or more embodiments.

Referring to Figure **1**, one embodiment of an aircraft **100** is shown. The aircraft **100** is a mobile complex structure. In some implementations, the aircraft **100** can be any of various other mobile complex structures, such as a vehicle (e.g., watercraft, rocket, automobile, etc.) or a stationary complex structure (e.g., a factory, building, machinery, etc.). The aircraft **100** includes a fuselage **105**, a pair of wings **160** coupled to and extending from the fuselage **105**, a vertical stabilizer **162** coupled to and extending from the fuselage **105**, and a pair of horizontal stabilizers **164** coupled to and extending from the fuselage **105** or the vertical stabilizer **162**. The aircraft **100**

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includes features representative of a commercial passenger or military transport aircraft. However, the aircraft **100** can be any of various other types of commercial or non-commercial aircraft, such as personal aircraft, fighter jets, helicopters, spacecraft, and the like.

The fuselage **105** of the aircraft **100** includes a plurality of fuselage barrel assemblies **101** interconnected to each other to form the fuselage **105**. As shown in Figure **2**, each fuselage barrel assembly **101** includes a fuselage barrel **102**. The fuselage barrel **102** has a hollow and elongate tubular construction. For example, the fuselage barrel **102** extends lengthwise along a longitudinal axis **106**, which defines a central axis of the fuselage barrel **102**, from a first end **112** of the fuselage barrel **102** to a second end **114** of the fuselage barrel **102**. The cross-sectional shape of the fuselage barrel **102** along a plane perpendicular to the longitudinal axis **106** is generally a circular or an annular ring.

The fuselage barrel **102** is formed as one-piece, monolithic, construction. In other words, the fuselage barrel **102** is seamless and does not include components that are separately formed and then assembled or joined together. Rather, the entire fuselage barrel **102** is formed as one-piece during the same manufacturing process. In some implementations, the fuselage barrel **102** is made from a fiber-reinforced polymer (e.g., carbon-fiber-reinforced polymer). For example, the fuselage barrel **102** can be formed from a continuous length of fiber that is spun, along with uncured resin or epoxy, into the shape of the fuselage barrel **102** and cured. After the fuselage barrel **102** is cured, features, such as window openings **166** and doorways **168**, can be formed into the fuselage barrel **102** by cutting and removing corresponding portions of the cured fuselage barrel **102**.

The fuselage **105** of the aircraft **100** is formed by interconnecting the plurality of fuselage barrel assemblies **101** in an end-to-end manner. Moreover, the fuselage barrel assemblies **101** are removably interconnected to each other by interconnecting respective first ends **112** and second ends **114** of adjacent fuselage barrels **102**. Generally, the first end **112** and second end **114** of adjacent fuselage barrels **102** together form a production splice (e.g., seam) of the fuselage **105**, such that the

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fuselage **105** includes multiple production splices. The first end **112** and second end **114** of adjacent fuselage barrels **102** can be removably interconnected using any of various coupling techniques, such as lap joints or butt joints that are reinforced with splicing elements. In some implementations, the first end **112** and second end **114** of adjacent fuselage barrels **102** can be removably interconnected using a bulkhead or similar interconnecting element. The first end **112** and second end **114** can be removably interconnected by using fasteners that are tightenable to interconnect together the first end **112** and second end **114** and loosenable to disconnect the first end **112** and second end **114** from each other.

Referring still to Figure **2**, each fuselage barrel assembly **101** includes a plurality of stringers **116** that are circumferentially spaced apart from each other about an interior surface **122** of the fuselage barrel **102**. Moreover, the plurality of stringers **116** extend along the interior surface **122** of the fuselage barrel **102** in a direction parallel to the longitudinal axis **106** of the fuselage barrel **102**. The stringers **116** can extend an entire length of the fuselage barrel **102** from the first end **112** to the second end **114**. The stringers **116** are coupled to the interior surface **122** of the fuselage barrel **102** and promote structural rigidity of the fuselage barrel **102**. As shown in Figure **9**, each stringer **116** includes a hat portion **180** (e.g., raised portion) and flanges **182** extending from opposite sides of the hat portion **180**. The flanges **182** are coupled directly to the interior surface **122** of the fuselage barrel **102**. In some implementations, the stringers **116** are made from a fiber-reinforced polymer and co-cured with the fuselage barrel **102** to couple the flanges **182** to the interior surface **122** of the fuselage barrel **102**.

Each fuselage barrel assembly **101** further includes a plurality of shear ties, such as first shear tie **134** and second shear tie **136**, removably coupled to the interior surface **122** of the fuselage barrel **102**. Referring to Figure **9**, each shear tie includes an upright portion **184** and flanges **186** extending perpendicularly relative to the upright portion **184**. The flanges **186** of each shear tie are substantially parallel to the interior surface **122** of the fuselage barrel **102** and the upright portion **184** of each shear tie is perpendicular to the interior surface **122** of the fuselage barrel **102**. In one implementation, each shear tie is removably coupled to the interior surface **122** of the fuselage barrel **102**, between a respective pair of stringers **116**, via one or more fasteners **176** that extend through the flanges **186** and at least partially into the fuselage barrel **102**. As shown in Figure **9**, the shear ties can be configured such that they extend from stringer to stringer of a respective pair of stringers **116**. In such an implementation, each shear tie may rest on the flanges **182** of the pair of stringers **116** and one or more fasteners **176** may extend through the flanges **186** of the shear tie and flanges **182** of the pair of stringers **116** and at least partially into the fuselage barrel **102** to removably couple the shear tie to the interior surface **122** of the fuselage barrel **102**. Although two rows of fasteners **176** are shown on each side of the splice line, defined by the edges **170**, more or less than two rows of fasteners **176** (e.g., three rows of fasteners **176**) may be used on each side of the splice line.

Additionally, each fuselage barrel **102** includes a plurality of frame elements **132** each removably coupled, such as via fasteners **176**, to the upright portions **184** of shear ties that are circumferentially aligned along a circumference of the fuselage barrel **102**. When removably coupled to the shear ties, the frame elements **132** promote structural rigidity of the fuselage barrel **102** by preventing ballooning of the fuselage barrel **102**. Each frame element **132** is an at least partially annular plate with a curvature complementing the curvature of the interior surface **122** of the fuselage barrel **102**. In some implementations, at least one of the frame elements **132** extends along at least a quarter of the circumference of the interior surface **122** of the fuselage barrel **102**. In certain implementations, multiple frame elements **132** can be circumferentially aligned to effectively or cooperatively extend along an entirety or a majority of the circumference of the interior surface **122** of the fuselage barrel **102**. According to one implementation, at least one of the frame elements **132** extends along an entirety of the circumference of the interior surface **122** of the fuselage barrel **102**. The frame element **132** includes a plurality of tabs **139** and notches **141** between the tabs **139**. The tabs **139** receive the fasteners **176** that couple the frame element **132** to the shear ties. In contrast, the notches **141** defines a space into which the hat portion **180** of a stringer **116** may extend. In this manner, the frame elements **132** are indirectly coupled to the fuselage barrel **102** via the shear ties.

After each of the fuselage barrel assemblies **101** are assembled and coupled together to form the fuselage **105** of the aircraft **100**, the further assembly, testing, and/or manufacturing process can be performed to ready the aircraft **100** for operation. Prior to operation of the aircraft **100**, virtual splice lines along the fuselage barrel **102**, in a direction parallel to the longitudinal axis **106** of the fuselage barrel **102**, are determined. Referring to Figure **2**, representations of four virtual splice lines (e.g., first virtual splice line **104**A, second virtual splice line **104**B, third virtual splice line **104**C, and fourth virtual splice line **104**D) are shown. Although four virtual splice lines are shown, more than four virtual splice lines can be determined prior to operation of the aircraft **100**. As defined herein, a virtual splice line can be considered a pre-defined splice or a splice that is modeled in virtual space as a provision for a possible future repair.

The circumferential location and quantity of the virtual splice lines on the fuselage barrel **102** can be determined as the aircraft **100** is designed and before assembly of the aircraft **100**, during assembly of the aircraft **100**, or after the aircraft **100** is assembled. Determination of the quantity and circumferential location of the virtual splice lines can be dependent on a variety of factors.

The location and quantity of the virtual splice lines can be based on the ease of cutting through the fuselage barrel **102** without obstruction from other features of or objects coupled to the fuselage barrel **102**. For example, in one implementation, at least one of the virtual splice lines is located along a path along the interior surface **122** of the fuselage barrel **102** that has a line of sight from one end of the path (e.g., the first end **112** of the fuselage barrel **102**) to an opposite end of the path (e.g., the second end **114** of the fuselage barrel **102**). In another example, at least one of the virtual splice lines is located along a path along the interior surface **122** of the fuselage barrel **102** that passes through the fewest features of the fuselage barrel **102** or objects coupled to the fuselage barrel **102**. According to one implementation, at least one of the virtual splice lines extends parallel to and between a pair of stringers (e.g.,

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pair of stringers **118** and pair of stringers **119**), of the plurality of stringers **116**, to limit the number of obstructions through which the virtual splice line passes through. Although at least a portion of each virtual splice line extends parallel to the longitudinal axis **106**, in some implementations, a portion of at least one virtual splice line may extend diagonally or perpendicularly relative to the longitudinal axis **106** (e.g., circumferentially) to avoid objects or where damage **107** to the aircraft **100** is minimal.

In some implementations, the location and quantity of the virtual splice lines can be based on a desired size and/or quantity of new sections **110** that are pre-manufactured or available prior to damage of the fuselage barrel **102** of the aircraft **100**. As defined herein, a new section **110** can be pre-manufactured by using a process that is qualified to be equivalent to the process for manufacturing the fuselage barrel **102** or excising the new section **110** from another (e.g., spare) fuselage barrel **102**. For example, where new sections **110** include only quarter sections of the fuselage barrel **102**, there may be four virtual splice lines an equidistance apart from each other to divide the fuselage barrel **102** into four equally sized sections. As shown in Figure **2**, the fuselage barrel **102** includes four virtual splice lines (e.g., first virtual splice line **104**A, second virtual splice line **104**B, third virtual splice line **104**C, and fourth virtual splice line **104**D) that divide up the fuselage barrel **102** into four sections (e.g., first section **108**A, second section **108**B, third section **108**C, and fourth section **108**D).

In certain implementations, the location and quantity of the virtual splice lines are determined automatically by a computing apparatus. The computing apparatus can receive inputs regarding the designed configuration of the fuselage barrel assembly **101**, as well as any of various user-specified inputs, such as a desired one of the above-mentioned or other approaches for determining the virtual splice lines. Then, based on the inputs, the computing apparatus determines the location and quantity of the virtual splice lines before damage **107** to the fuselage barrel **102** in operation or before/during assembly of the fuselage barrel **102** and fuselage barrel assembly **101**. The computing apparatus can be any of various computing devices known in the art.

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After the virtual splice lines are determined, the aircraft **100** can be operated as desired. Should damage **107** occur to the fuselage barrel **102** of a fuselage barrel assembly **101** during operation, the section of the fuselage barrel **102** in which the damage **107** occurs is determined after the damage **107** is detected. In some implementations, the section of the fuselage barrel **102** in which the entirety of the damage **107** occurs is determined. In some implementations, if damage **107** extends across a virtual splice line into two sections of the fuselage barrel **102**, other predetermined, alternative, splice lines can be used to determine an alternative section of the fuselage barrel **102** in which the entirety of the damage **107** occurs.

After the section of the fuselage barrel **102** with the damage **107** is determined, the fuselage barrel **102** is cut along the virtual splice lines, defining the section of the fuselage barrel **102**, to physically separate the section of the fuselage barrel **102** from a main or remaining section of the fuselage barrel **102**. For example, as shown in Figure **3**, the first section **108**A, which includes the entirety of the damage **107**, is separated from the main section **103** of the fuselage barrel **102** by cutting along the first virtual splice line **104**A and the second virtual splice line **104**B. Also, in some embodiments, the first section **108**A would be disconnected from adjacent fuselage assemblies **101** while the main section **103** remains connected to adjacent fuselage assemblies **101**. Generally, the entire first section **108**A is removed even if the damage **107** occupies only a small percentage of the first section **108**A. As defined herein, the main section **103** of the fuselage barrel **102** is the section of the fuselage barrel **102** that remains after the section of the fuselage barrel **102** with the damage **107** is removed.

Before the section of the fuselage barrel **102** with the damage **107** is removed from the main section of the fuselage barrel, and before or after the fuselage barrel **102** is cut along the splice lines, the fuselage barrel assembly **101** is at least partially disassembled in preparation for removing the section with the damage **107**. For example, referring again to Figure **3**, the frame elements **132** and the respective shear ties **134**, **136** spanning the first and second virtual splice lines **104**A, **104**B are removed from the fuselage barrel **102** before the first section **108**A is removed from the main section **103**. Removal of the frame elements **132** and shear ties **134**, **136** can be accomplished by loosening and removing the fasteners **176** coupling together the shear ties **134**, **136** and the fuselage barrel **102** and, in some implementations, the fasteners **176** coupling together the frame elements **132** and the shear ties **134**, **136**. However, in some implementations, the shear ties **134**, **136** are formed integrally (e.g., co-cured) with the frame elements **132**, such that removal of the shear ties **134**, **136** from the frame elements **132** includes trimming, shearing, or cutting the shear ties **134**, **136** from the frame elements **132**. Also, in certain implementations, such as where the shear ties **134**, **136** are non-removably coupled to the fuselage barrel **102** (e.g., being flush against and adhered or bonded to the interior surface **122** of the fuselage barrel **102**), removal of the shear ties **134**, **136** from the fuselage barrel **102** may include trimming, shearing, or cutting the shear ties **134**, **136** from the fuselage barrel **102**. It is noted that in Figure **3** only one of the multiple frame elements **132** and only some of the shear ties **134**, **136** are shown being removed from the fuselage barrel **102** for clarity in showing other features of the fuselage barrel assembly **101**.

As shown in Figure **4**, after the first section **108**A of the fuselage barrel **102** is removed from the main section **103** of the fuselage barrel **102**, a new section **110** is spliced to the main section **103** in place of the first section **108**A to create a repaired fuselage barrel assembly **101**A. The new section **110** is configured the same as the first section **108**A. For example, the new section **110** has the same size and shape as the first section **108**A. Additionally, the new section **110** is made from the same material as the first section **108**A, which, in some implementations, is a fiber-reinforced polymer. Moreover, in certain implementations, the new section **110** is made before the damage **107** occurs to the first section **108**A. In other words, the new section **110** is made to match the first section **108**A after the first and second virtual splice lines **104**A, **104**B are determined, but before any damage occurs to the first section **108**A. However, in other implementations, the new section **110** is made to match the first section **108**A after the first and second virtual splice lines **104**A, **104**B are determined and after the damage **107** occurs to the first section **108**A.

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The new section **110** is spliced to the main section **103** by constructing, between the new section **110** and the main section **103**, a first butt joint **124** along the first virtual splice line **104**A and a second butt joint **125** along the second virtual splice line **104**B. At least a portion of, or an entirety of, in some implementations, the first butt joint **124** and the second butt joint **125** extends parallel to the longitudinal axis **106**. As shown in Figures **8** and **9** any one of the first butt joint **124** and the second butt joint **125** is formed by locating the new section **110** relative to the main section **103** such that edges **170** of the new section **110** and the main section **103**, between the first and second ends **112**, **114** of the fuselage barrel **102**, substantially abut, or are directly adjacent, each other. In other words, no portion of the new section **110** and the main section **103** overlap with each other at the first butt joint **124** and the second butt joint **125**.

Referring to Figures **4-7**, the first butt joint **124** and the second butt joint **125** are reinforced by coupling together the new section **110** and the main section **103** with respective first and second splice plates **126**, **127** that overlay the first butt joint **124** and the second butt joint **125**, respectively. Referring again to Figures **8** and **9**, a portion of the first and second splice plates **126**, **127** is fixed to the new section **110** and another portion of the first and second splice plates **126**, **127** is fixed to the main section **103**. Accordingly, the first splice plate **126**, when fixed to the new section **110** and the main section **103**, spans across the first butt joint **124** and the second splice plate **127**, when fixed to the new section **110** and the main section **103**, spans across the second butt joint **125**. In some implementations, the first and second splice plates **126**, **127** sit flush against the interior surfaces **122**, **128** of the main section **103** and the new section **110**, interposed between the first and second stringers **150**, **152** and the third and fourth stringers **154**, **156**, respectively, such that the first and second splice plates **126**, **127** contact and are directly coupled to the interior surfaces **122**, **128**. However, in alternative implementations, such as shown in Figures **8** and **9**, the first and second splice plates **126**, **127** sit flush against the flanges **182** of the first and second stringers **150**, **152** and the third and fourth stringers **154**, **156**, respectively, such that a gap exists between the interior surfaces **122**, **128** of the main section **103**

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and the new section **110**. The gap can be filled with a filler, such as a respective one of first and second fillers **146**, **148**. Each of the first and second fillers **146**, **148** can be made from any of various materials, such as, for example, a fiber-reinforced polymer, polymer, metal, and/or the like. Alternatively, in certain implementations, each shear tie may rest directly on the interior surfaces **122**, **128** of the fuselage barrel **102**, without a filler.

The first and second splice plates **126**, **127** can be fixed to the main section **103** and new section **110** using fasteners, such as the same fasteners **176**, or similar fasteners, used to fix the first and second shear ties **134**, **136** to the fuselage barrel **102**. The fasteners **176** extend through the first and second splice plates **126**, **127**, through the flanges **182** of the stringers and/or fillers in some implementations, and into one of the main section **103** and new section **110**. When fixed to the main section **103** and new section **110** over the first and second butt joints **124**, **125**, the respective first and second splice plates **126**, **127** facilitate the transfer of pressure loads across the first and second butt joints **124**, **125** and help to promote load continuity in the fuselage barrel **102** in the circumferential or a hoopwise direction.

The first and second splice plates **126**, **127** each has a width greater than a thickness, and a length greater than the width. Moreover, the first and second splice plates **126**, **127** are made from the same material as the main section **103** and new section **110** of the fuselage barrel **102**. For example, the first and second splice plates **126**, **127** can be made from a fiber-reinforced polymer. The matrix of the fiber-reinforced polymer of the first and second splice plates **126**, **127** is cured prior to fixing the first and second splice plates to the main section **103** and new section **110**.

In some implementations, each of the first and second splice plates **126**, **127** is a continuous, one-piece and non-segmented, plate that extends from a first end of the respective first and second butt joints **124**, **125** (e.g., at the first end **112** of the fuselage barrel **102**) to a second end of the respective first and second butt joints **124**, **125** (e.g., at the second end **114** of the fuselage barrel **102**). However, as shown in Figure **5**, each of the first and second splice plates **126**, **127** can be segmented into multiple, interconnected, first and second splice plate segments **142**, **144**,

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respectively. Generally, the first splice plate segments **142** overlay the first butt joint **124** in an end-to-end manner longitudinally along the first butt joint **124**, and the second splice plate segments **144** overlay the second butt joint **126** in an end-to-end manner longitudinally along the second butt joint **126**. Segmenting the first and second splice plates **126**, **127** into multiple first and second splice plate segments **142**, **144** promotes tolerance to damage of the first and second splice plates **126**, **127** by ensuring that damage to one splice plate segment does not impact the performance of the other splice plate segments and thus the performance of the splice plate as a whole. To facilitate load continuity in the fuselage barrel **102** in a fore-aft or longitudinal direction, one or more couplers **130** fixed to and spanning at least portions of adjacent splice plate segments forming the splice plates. In other words, the coupler **130** effectively splices together the splice plate segments of a given splice plate. The coupler **130** can be any of various couplers, such as plates, brackets, shear ties, and the like. Moreover, the coupler **130** can be fixed to the splice plate segments via any of various techniques, such as fasteners, bonding, and the like.

Referring to Figure **9**, splicing the new section **110** to the main section **103** also includes fixing replacement shear ties, such as first and second replacement shear ties **138**, **140**, to the first and second splice plates **126**, **127**, respectively. The replacement shear ties **138**, **140** can be fixed to the first and second splice plates **126**, **127** by fasteners, such as fasteners **176**, that extend through flanges **186** of each replacement shear tie **138**, **140**. Like the first and second shear ties **134**, **136**, the replacement shear ties **138**, **140** includes flanges **186** and an upright **184** extending transversely from the flanges **186**. However, because the replacement shear ties **138**, **140** are fixed to the first and second splice plates **126**, **127**, and the shear ties **134**, **136** are fixed to the flanges of the stringers or the interior surface of the fuselage barrel **102**, the replacement shear ties **138**, **140** are located more radially inwardly than the shear ties **134**, **136**. Accordingly, to ensure the radial location of the frame elements **132** remains unchanged, the replacement shear ties **138**, **140** are configured differently than the shear ties **134**, **136**. More specifically, in some implementations, apertures, for receiving fasteners **176** to fix a frame element **132**, in the upright portion

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184 of each replacement shear tie **138**, **140** are located closer to the flanges **186** than the shear ties **134**, **136**. Additionally, according to certain implementations, the size of the upright portion **184** of the replacement shear ties **138**, **140**, may be different (e.g., shorter) than the upright portion **184** of the shear ties **134**, **136**. The shear ties **134**, **136** (e.g., production shear ties) and the replacement shear ties **138**, **140** can be made from a fiber-reinforced polymer that is the same as or similar to that of the fuselage barrel **102**.

With the replacement shear ties **138**, **140** fixed to the first and second splice plates **126**, **127**, respectively, a frame element **132** can be fixed to the upright portion **184** of each of the replacement shear ties **138**, **140**. Additionally, each frame element **132** is reattached to the original shear ties **134**, **136** secured to the main section **103** of the fuselage barrel **102** and circumferentially aligned with the replacement shear ties **138**. Furthermore, although not shown, shear ties **134**, **136** are fixed to the new section **110**, either before or after the new section **110** forms the first and second butt joints **124**, **125** with the main section **103**. Each frame element **132** is attached to the shear ties **134**, **136** fixed to the new section **110** of the fuselage barrel **102** and circumferentially aligned with the replacement shear ties **138**. In some implementations, the frame elements **132** are fixed to the upright portions **184** via one or more fasteners **176**. In some implementations, the frame elements **132** are fixed to the replacement shear ties **138**, **140** before the replacement shear ties **138**, **140** are fixed to the first and second splice plates **126**, **127**.

As shown in Figures **6** and **7**, the new section **110** of the repaired fuselage assembly **101**A is reconnected to one or more original or production fuselage assemblies **101** (e.g., the same one or more fuselage assemblies **101** from which the first section **108**A was disconnected to perform the repair to the fuselage barrel **102** of the damaged fuselage assembly). Generally, in some embodiments, a hoop strap **190** is used to splice together the ends (e.g., end **112**) of fuselage barrels **102** of adjacent fuselage barrel assemblies **101**. The hoop strap **190** extends about an interior of the adjacent fuselage barrel assemblies in a circumferential direction that is perpendicular to the longitudinal axis **106**. Moreover, the hoop strap **190** spans over the joint

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between abutting ends of adjacent fuselage barrels in an axial or longitudinal direction perpendicular to the circumferential direction. The hoop strap **190** can be fixed to the adjacent fuselage barrels using any of various fixation elements, such as fasteners **176**. In some implementations, the hoop strap **190** includes multiple hoop strap segments arranged in an end-to-end configuration along the joint between abutting ends of adjacent fuselage barrels.

The joint between abutting ends of adjacent fuselage barrels may further include at least one longitudinal member **194** that longitudinally spans over the abutting ends and the hoop strap **190**. In some implementations, the longitudinal member **194** can includes two longitudinal portions that extend an angle relative to each other such that the longitudinal member **194** has a substantially L-shaped or V-shaped cross-section. The longitudinal member **194** can be affixed to the flange of a respective one of the stringers **116** on each of the fuselage barrels abutting each other and to the hoop strap **190** using any of various fixation elements, such as fasteners **176**. If necessary, footings (not shown) can be positioned between each longitudinal member **194** and the flanges of the stringers **116** to promote proper spacing between the longitudinal member **194** and the flanges of the stringers **116**. In some implementations, as shown, two longitudinal members **194** are positioned, in a spaced apart manner from each other, and fixed between each pair of stringers **116**. Because the longitudinal members **194** between a pair of stringers **116** are circumferentially spaced apart, such longitudinal members **194** are used with a pair of stringers **116** between which no longitudinal post-production splice line or cut (e.g., edges **170**) in the fuselage barrel **102** is present.

For a pair of stringers **116** between which a longitudinal post-production splice line or cut in the fuselage barrel **102** is present, such as with the repaired fuselage assembly **101**A, the joint includes an additional fitting or splice plate over the hoop strap **190** between the spaced apart longitudinal members **194**. The additional fitting between the longitudinal members **194** spans and is affixed to the hoop strap **190**, such as with fasteners **176**, which helps to distribute circumferential loads placed on the joint. In some implementations, the two longitudinal members **194** and the additional fitting between the longitudinal members **194** can be consolidated into a single fitting, such as the H-fitting **192**. The H-fitting **192** includes two longitudinally straight portions **196** similar to two longitudinal members **194**. The two longitudinally straight portions **196** are circumferentially connected by a lateral portion **198** or cross-member, which spans the joint and the hoop strap **190** and helps to distribute circumferential loads between the two longitudinally straight portions **196**. Accordingly, in plan view, the H-fitting **192** has a substantially H-shape. The two longitudinally straight portions **196** are affixed to one of the splice plates **126**, **127** on one side of the H-fitting **192** and to the flanges (or footings) of the stringers **116** on the adjacent production fuselage assembly on the opposite side of the H-fitting **192**, such as with fasteners **176**. The lateral portion **198** of the H-fitting **192** can be affixed to the hoop strap **190**, such as with fasteners **176**. Because of the added thickness of the splice plate, in some implementations, a footing between longitudinal members **194** or a straight portion **196** of the H-fitting **192** and the flange of the stringer on the repaired fuselage assembly **101**A, to which the longitudinal members **194** of H-fitting **192** is affixed, is not needed.

Referring to Figure **10**, one embodiment of a method **200** of repairing damage to a fuselage barrel of an aircraft is shown. The fuselage barrel can have a one-piece construction and be made from a fiber-reinforced polymer in certain implementations. Moreover, the features and elements associated with the method **200** can be the same as or analogous to the like features and elements of the aircraft **100** and fuselage barrel assembly **101** presented above.

The method **200** includes, prior to damage of the fuselage barrel, determining at least a first virtual splice line and a second virtual splice line along the fuselage barrel in a direction parallel to a longitudinal axis of the fuselage barrel at step **202**. In some implementations, determining the first virtual splice line and/or the second virtual splice line includes detecting a path or paths along an interior surface of the fuselage barrel that has a line of sight from one end of the path or paths to an opposite end of the path. The first virtual splice line and/or the second virtual splice line is located along the one of the paths. The method **200** may also include determining at least a

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third virtual splice line along the fuselage barrel **102** in a direction parallel to a longitudinal axis **106** of the fuselage barrel **102**, prior to damage of the fuselage barrel **102**.

Additionally, the method **200** includes detecting damage in a first section of the fuselage barrel between the first virtual splice line and the second virtual splice line at step **204**. Generally, the damage to the fuselage barrel can be detected manually, such as via a visual inspection, or automatically, such as via sensors and electronic systems.

The method **200** also includes cutting through the fuselage barrel along the first virtual splice line and the second virtual splice line to physically separate the first section from a main section of the fuselage barrel at step **206**. Cutting the fuselage barrel can be performed using any of various cutting techniques known in the art, such as mechanical (e.g., blade) cutting, optical or laser cutting, plasma cutting, and the like. Generally, cutting the fuselage barrel does not include cutting the underlying sub-structure attached to the fuselage barrel, such as shear ties and frame elements. In some implementations, the shear ties and frame elements are removed prior to cutting through the fuselage barrel.

Also, the method **200** includes removing the first section from the main section of the fuselage barrel at step **208**. Removing the first section from the main section can include decoupling a frame element from a first shear tie coupled to the fuselage barrel over the first virtual splice line and from a second shear tie coupled to the fuselage barrel over the second virtual splice line. Additionally, removing the first section from the main section may include decoupling the first shear tie from the fuselage barrel and decoupling the second shear tie from the fuselage barrel. As defined herein, decoupling can include trimming, cutting, shearing, loosening, unfastening, or otherwise removed. Where the aircraft includes multiple fuselage barrels, removing the first section from the main section of the fuselage barrel can include decoupling, along production splices, the first section of the fuselage barrel from adjacent fuselage barrels.

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The method **200** additionally includes splicing a new section to the main section of the fuselage barrel in place of the first section at step **210**. Splicing the new section to the main section of the fuselage barrel can include forming a first butt joint, along the first virtual splice line, and a second butt joint, along the second virtual splice line. Splicing can include overlaying the first butt joint with a first splice plate, overlaying the second butt joint with a second splice plate, and fastening the first splice plate and the second splice plate to the main section of the fuselage barrel the new section. Splicing may also include coupling a first replacement shear tie to the first splice plate, coupling a second replacement shear tie to the second splice plate, and coupling the frame element to the first replacement shear tie and the second replacement shear tie. Furthermore, splicing can include intercoupling adjacent first splice plate segments of the first splice plate with at least one coupler, and intercoupling adjacent second splice plate segments of the second splice plate with at least one coupler. Splicing can also include positioning a first filler between the first splice plate and the first butt joint and between the first stringer and a third stringer of the new section and positioning a second filler between the second splice plate and the second butt joint and between the second stringer and a fourth stringer of the new section.

In the above description, certain terms may be used such as "up," "down," "upper," "lower," "horizontal," "vertical," "left," "right," "over," "under" and the like. These terms are used, where applicable, to provide some clarity of description when dealing with relative relationships. But, these terms are not intended to imply absolute relationships, positions, and/or orientations. For example, with respect to an object, an "upper" surface can become a "lower" surface simply by turning the object over. Nevertheless, it is still the same object. Further, the terms "including," "comprising," "having," and variations thereof mean "including but not limited to" unless expressly specified otherwise. An enumerated listing of items does not imply that any or all of the items are mutually exclusive and/or mutually inclusive, unless expressly specified otherwise. The terms "a," "an," and "the" also refer to "one or more" unless expressly specified otherwise. Further, the term "plurality" can be defined as "at least two."

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Additionally, instances in this specification where one element is “coupled” to another element can include direct and indirect coupling. Direct coupling can be defined as one element coupled to and in some contact with another element. Indirect coupling can be defined as coupling between two elements not in direct contact with each other, but having one or more additional elements between the coupled elements. Further, as used herein, securing one element to another element can include direct securing and indirect securing. Additionally, as used herein, “adjacent” does not necessarily denote contact. For example, one element can be adjacent another element without being in contact with that element.

As used herein, the phrase “at least one of”, when used with a list of items, means different combinations of one or more of the listed items may be used and only one of the items in the list may be needed. The item may be a particular object, thing, or category. In other words, “at least one of” means any combination of items or number of items may be used from the list, but not all of the items in the list may be required. For example, “at least one of item A, item B, and item C” may mean item A; item A and item B; item B; item A, item B, and item C; or item B and item C. In some cases, “at least one of item A, item B, and item C” may mean, for example, without limitation, two of item A, one of item B, and ten of item C; four of item B and seven of item C; or some other suitable combination.

Unless otherwise indicated, the terms "first," "second," etc. are used herein merely as labels, and are not intended to impose ordinal, positional, or hierarchical requirements on the items to which these terms refer. Moreover, reference to, e.g., a “second” item does not require or preclude the existence of, e.g., a “first” or lower-numbered item, and/or, e.g., a “third” or higher-numbered item.

The schematic flow chart diagrams included herein are generally set forth as logical flow chart diagrams. As such, the depicted order and labeled steps are indicative of one embodiment of the presented method. Other steps and methods may be conceived that are equivalent in function, logic, or effect to one or more steps, or portions thereof, of the illustrated method. Additionally, the format and symbols employed are provided to explain the logical steps of the method and are understood

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not to limit the scope of the method. Although various arrow types and line types may be employed in the flow chart diagrams, they are understood not to limit the scope of the corresponding method. Indeed, some arrows or other connectors may be used to indicate only the logical flow of the method. For instance, an arrow may indicate a waiting or monitoring period of unspecified duration between enumerated steps of the depicted method. Additionally, the order in which a particular method occurs may or may not strictly adhere to the order of the corresponding steps shown.

The present subject matter may be embodied in other specific forms without departing from its spirit or essential characteristics. The described embodiments are to be considered in all respects only as illustrative and not restrictive.

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EMBODIMENTS IN WHICH AN EXCLUSIVE PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:

1. A method of replacing a portion of a fuselage barrel of an aircraft having a seamless construction, comprising:

determining at least a first splice line and a second splice line along the fuselage barrel in a direction parallel to a longitudinal axis of the fuselage barrel;

subsequent to determining at least the first splice line and the second splice line, detecting damage in a first section of the fuselage barrel between the first splice line and the second splice line;

cutting through the fuselage barrel after detecting damage, along the first splice line and the second splice line to physically separate the first section from a main section of the fuselage barrel;

removing the first section from the main section of the fuselage barrel; and

splicing a new section that is not co-formed with the main section of the fuselage barrel in place of the removed first section, wherein the splicing comprises forming a first butt joint along the first splice line and a second butt joint along the second splice line, parallel to the longitudinal axis, between the new section and the main section of the fuselage barrel.

2. The method of claim **1**, wherein:

the fuselage barrel extends longitudinally along the longitudinal axis from a first end to a second end; and

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the first splice line and the second splice line both extend from the first end of the fuselage barrel to the second end of the fuselage barrel.

3. The method of claim **2**, wherein splicing the new section to the main section of the fuselage barrel further comprises:

overlaying the first butt joint with a first splice plate;

overlaying the second butt joint with a second splice plate; and

fastening the first splice plate and the second splice plate to an interior surface of the main section of the fuselage barrel and an interior surface of the new section.

4. The method of claim **3**, wherein:

removing the first section from the main section of the fuselage barrel comprises:

decoupling a frame element, extending circumferentially about the fuselage barrel, from a first shear tie coupled to the fuselage barrel over the first splice line and from a second shear tie coupled to the fuselage barrel over the second splice line;

decoupling the first shear tie from the fuselage barrel;

decoupling the second shear tie from the fuselage barrel; and

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splicing the new section to the main section of the fuselage barrel comprises:

coupling a first replacement shear tie to the first splice plate, wherein the first replacement shear tie is configured differently than the first shear tie;

coupling a second replacement shear tie to the second splice plate, wherein the second replacement shear tie is configured differently than the second shear tie; and

coupling the frame element to the first replacement shear tie and the second replacement shear tie.

5. The method of claim **3 or 4**, wherein:

the first splice plate comprises multiple first splice plate segments arranged substantially end-to-end along the first butt joint;

the second splice plate comprises multiple second splice plate segments arranged substantially end-to-end along the second butt joint;

splicing the new section to the main section of the fuselage barrel further comprises intercoupling adjacent first splice plate segments with at least one coupler fixed to and spanning at least portions of the adjacent first splice plate segments; and

splicing the new section to the main section of the fuselage barrel further comprises intercoupling adjacent second splice plate segments with at least

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one coupler fixed to and spanning at least portions of the adjacent second splice plate segments.

6. The method of any one of claims **3**-**5**, wherein:

a plurality of stringers, circumferentially spaced apart from each other and extending along the fuselage barrel parallel to the longitudinal axis of the fuselage barrel, are coupled to the fuselage barrel;

the plurality of stringers are grouped into at least a first pair of stringers, comprising a first stringer, and a second pair of stringers, comprising a third stringer;

the first splice line extends between the first pair of stringers; and

the second splice line extends between the second pair of stringers.

7. The method of any one of claims **3**-**6**, wherein splicing the new section to the main section of the fuselage barrel comprises:

positioning a first filler between the first splice plate and the first butt joint and between the first stringer and a second stringer of the new section; and

positioning a second filler between the second splice plate and the second butt joint and between the third stringer and a fourth stringer of the new section.

8. The method of any one of claims **3**-**7**, wherein the fuselage barrel, first splice plate, second splice plate, and plurality of stringers are made from a fiber-reinforced polymer.

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9. The method of any one of claims **1**-**8**, wherein:

the aircraft comprises multiple fuselage barrels coupled to each other in an end-to-end manner to form a fuselage of the aircraft;

removing the first section from the main section of the fuselage barrel comprises decoupling the first section of the fuselage barrel from adjacent fuselage barrels; and

splicing the new section to the main section of the fuselage barrel comprises coupling the new section to adjacent fuselage barrels.

10. The method of any one of claims **1**-**9**, wherein the new section is pre-manufactured, prior to damage of the fuselage barrel, responsive to a location on the fuselage barrel of the first splice line and the second splice line.

11. The method of any one of claims **1**-**10**, wherein determining at least the first splice line and the second splice line comprises:

detecting a path along an interior surface of the fuselage barrel having a line of sight from one end of the path to an opposite end of the path; and

locating one of the first splice line and the second splice line along the path.

12. The method of any one of claims **1**-**11**, wherein each of the first section and the new section forms at least a quarter of the fuselage barrel.

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13. The method of any one of claims **1**-**12**, further comprising, prior to damage of the fuselage barrel, determining at least a third splice line along the fuselage barrel in a direction parallel to a longitudinal axis of the fuselage barrel.

14. A fuselage barrel assembly of an aircraft, comprising:

a main section of a fuselage barrel having a one-piece construction;

a new section of the fuselage barrel having a one-piece construction and spliced to the main section along a first butt joint between the main section and the new section and along a second butt joint between the main section and the new section;

a first splice plate fastened to the main section of the fuselage barrel and the new section over the first butt joint;

a second splice plate fastened to the main section of the fuselage barrel and the new section over the second butt joint;

a first replacement shear tie coupled to the first splice plate;

a second replacement shear tie coupled to the second splice plate; and

a frame element coupled to both the first replacement shear tie and the second replacement shear tie.

15. The fuselage barrel assembly of claim **14**, wherein:

the main section comprises a first stringer extending parallel to the first butt joint, and a second stringer extending parallel to the second butt joint;

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the new section comprises a third stringer, extending parallel to the first butt joint, and a fourth stringer, extending parallel to the second butt joint;

the fuselage barrel further comprises:

a first filler between the first splice plate and the first butt joint and between the first stringer and the third stringer; and

a second filler between the second splice plate and the second butt joint and between the second stringer and the fourth stringer.

16. The fuselage barrel assembly of claim **14** or **15**, wherein:

the main section comprises a first stringer, extending parallel to the first butt joint, and a second stringer, extending parallel to the second butt joint;

the new section comprises a third stringer, extending parallel to the first butt joint, and a fourth stringer, extending parallel to the second butt joint;

the first splice plate is supported on and fastened to the first stringer, the third stringer, and the first filler; and

the second splice plate is supported on and fastened to the second stringer, the fourth stringer, and the second filler.

17. The fuselage barrel assembly of any one of claims **14-16**, wherein:

the first butt joint and the second butt joint are circumferentially spaced apart from each other;

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the first butt joint and the second butt joint extend parallel to a longitudinal axis of the fuselage barrel; and

the first butt joint and the second butt joint extend from a first end of the fuselage barrel to a second end of the fuselage barrel.

18. The fuselage barrel assembly of any one of claims **14**-**17**, wherein the main section, new section, first splice plate, and second splice plate is made from a fiber-reinforced polymer.

19. The fuselage barrel assembly of claim **14**, wherein the main section of the fuselage barrel has a seamless construction.

20. The fuselage barrel assembly of claim **19**, wherein the new section of the fuselage barrel has a seamless construction.

21. The fuselage barrel assembly of claim **14**, wherein: an entirety of the main section of the fuselage barrel is circumferentially open; and an entirety of the new section of the fuselage barrel is circumferentially open.

22. The fuselage barrel assembly of claim **14**, wherein an entire length of the new section of the fuselage barrel is equal to an entire length of the main section of the fuselage barrel.

23. The fuselage barrel assembly of claim **14**, wherein:

the first butt joint and the second butt joint extend an entire length of the main section of the fuselage barrel and an entire length of the new section of the fuselage barrel;

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the first splice plate extends the entire length of the main section and the new section of the fuselage barrel; and

the second splice plate extends the entire length of the main section and the new section of the fuselage barrel.

24. The fuselage barrel assembly of claim **23**, further comprising a plurality of first replacement shear ties and a plurality of second replacement shear ties, and wherein:

the plurality of first replacement shear ties are coupled to and spaced apart along the first splice plate; and

the plurality of second replacement shear ties are coupled to and spaced apart along the second splice plate.

25. The fuselage barrel assembly of claim **23**, wherein: the first splice plate has a seamless construction; and the second splice plate has a seamless construction.

26. The fuselage barrel assembly of claim **23**, wherein: the first splice plate comprises multiple first splice plate segments; and the second splice plate comprises multiple second splice plate segments.

27. The fuselage barrel assembly of claim **26**, wherein: the first splice plate segments are interconnected in an end-to-end manner longitudinally along the first butt joint; and the second splice plate segments are interconnected in an end-to-end manner longitudinally along the second butt joint.

28. The fuselage barrel assembly of claim **26**, further comprising: first couplers each fixed to and spanning at least portions of adjacent ones of the multiple first splice

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plate segments; and second couplers each fixed to and spanning at least portions of adjacent ones of the multiple second splice plate segments.

29. The fuselage barrel assembly of claim **14**, wherein the first splice plate and the second splice plate are made from the same material as the main section of the fuselage barrel and the new section of the fuselage barrel.

30. The fuselage barrel assembly of claim **15**, wherein the first filler and the second filler are made from a fiber-reinforced polymer.

31. The fuselage barrel assembly of claim **15**, wherein:

the first stringer comprises a first flange;

the second stringer comprises a second flange;

the third stringer comprises a third flange; the fourth stringer comprises a fourth flange;

the first splice plate sits flush against the first flange and the third flange;

the second splice plate sits flush against the second flange and the fourth flange;

the first filler is interposed between the first flange and the third flange; and the second filler is interposed between the second flange and the fourth flange.

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32. The fuselage barrel assembly of claim **14**, wherein the first splice plate and the second splice plate sit flush against an interior surface of the main section of the fuselage barrel and an interior surface of the new section of the fuselage barrel.

33. An aircraft, comprising: a plurality of fuselage barrel assemblies interconnected to each other, wherein at least one of the fuselage barrel assemblies comprises:

a main section of a fuselage barrel having a one-piece construction;

a new section of the fuselage barrel having a one-piece construction and spliced to the main section along a first butt joint between the main section and the new section and along a second butt joint between the main section and the new section;

a first splice plate fastened to the main section of the fuselage barrel the new section over the first butt joint;

a second splice plate fastened to the main section of the fuselage barrel and the new section over the second butt joint;

a first replacement shear tie coupled to the first splice plate;

a second replacement shear tie coupled to the second splice plate; and

a frame element coupled to both the first replacement shear tie and the second replacement shear tie,

wherein the plurality of fuselage barrel assemblies are interconnected in an end-to-end configuration at abutting ends of respective fuselage barrels of the fuselage barrel assemblies.

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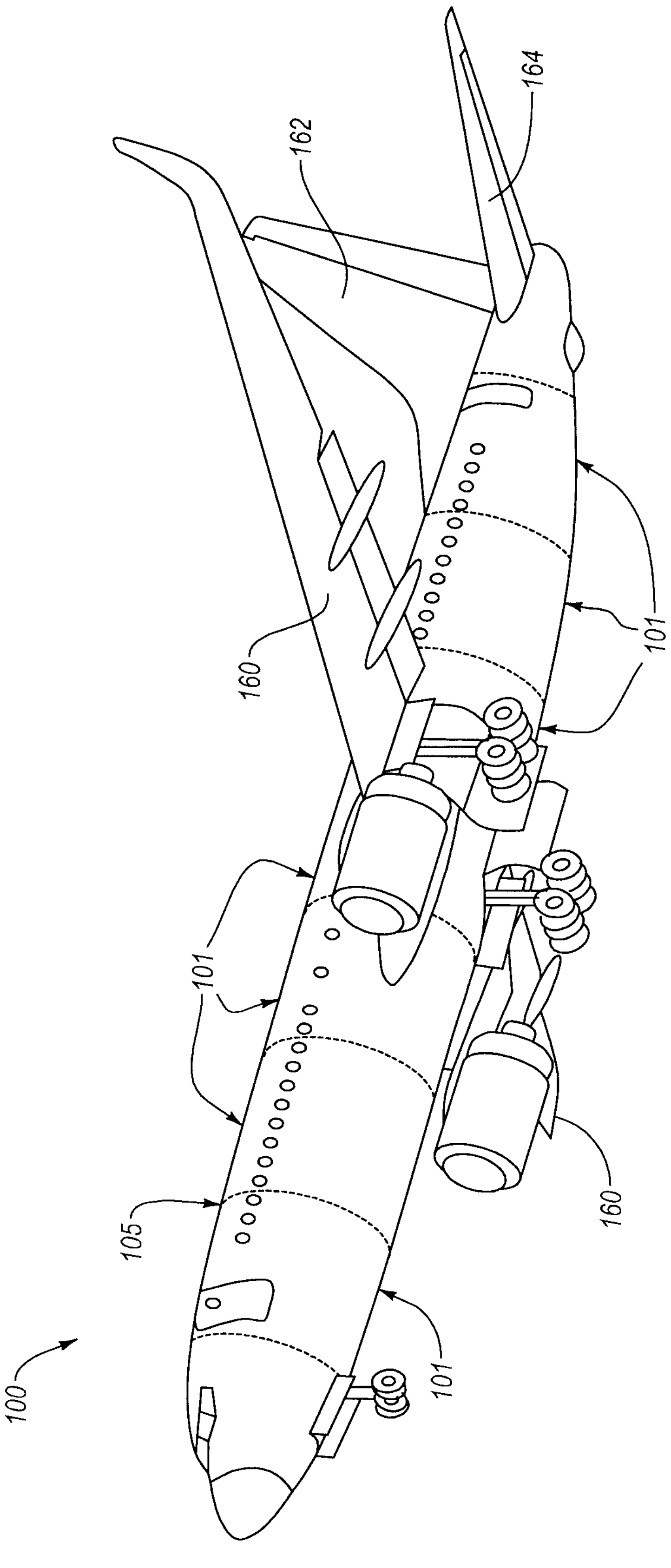

FIG. 1

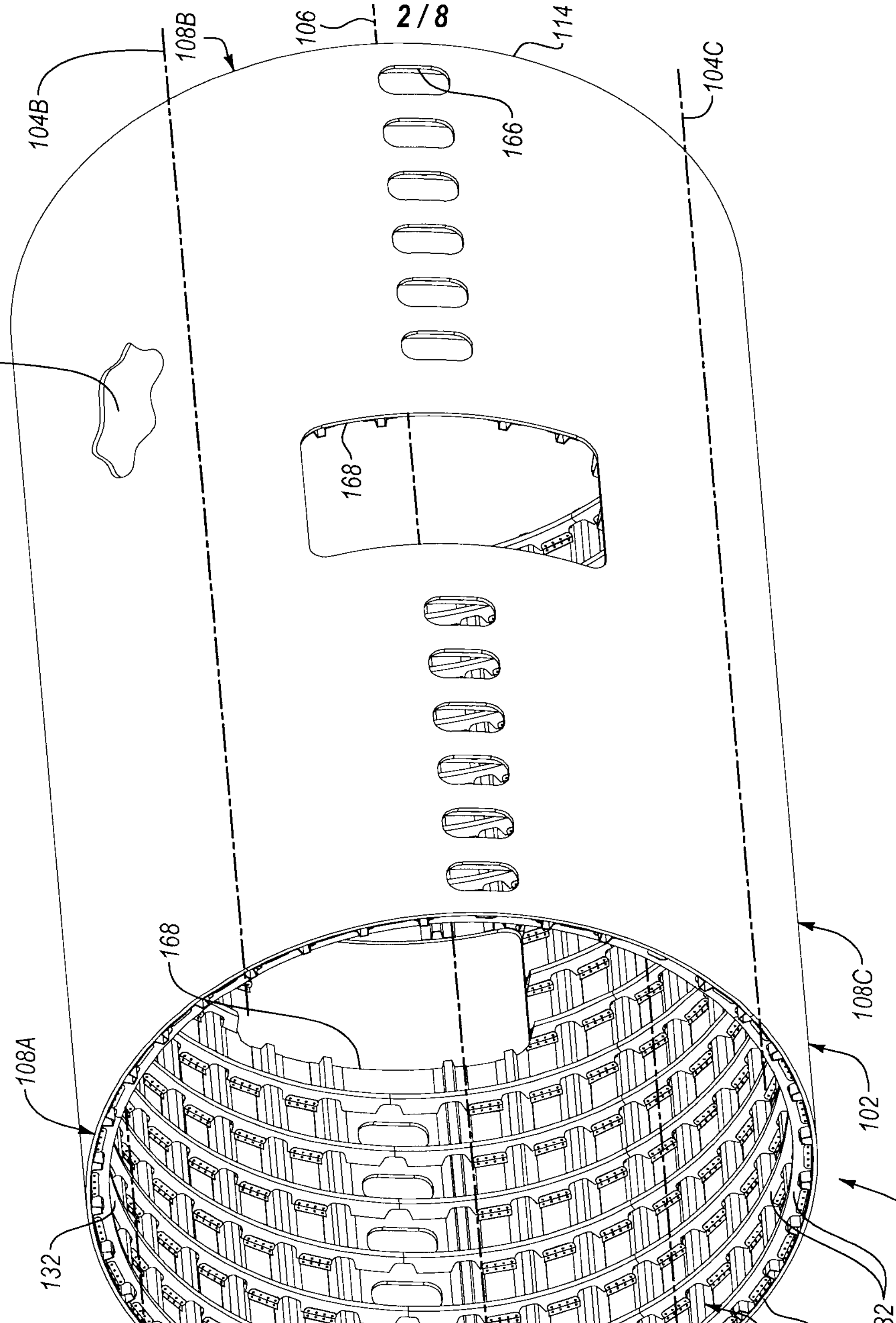
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FIG. 2

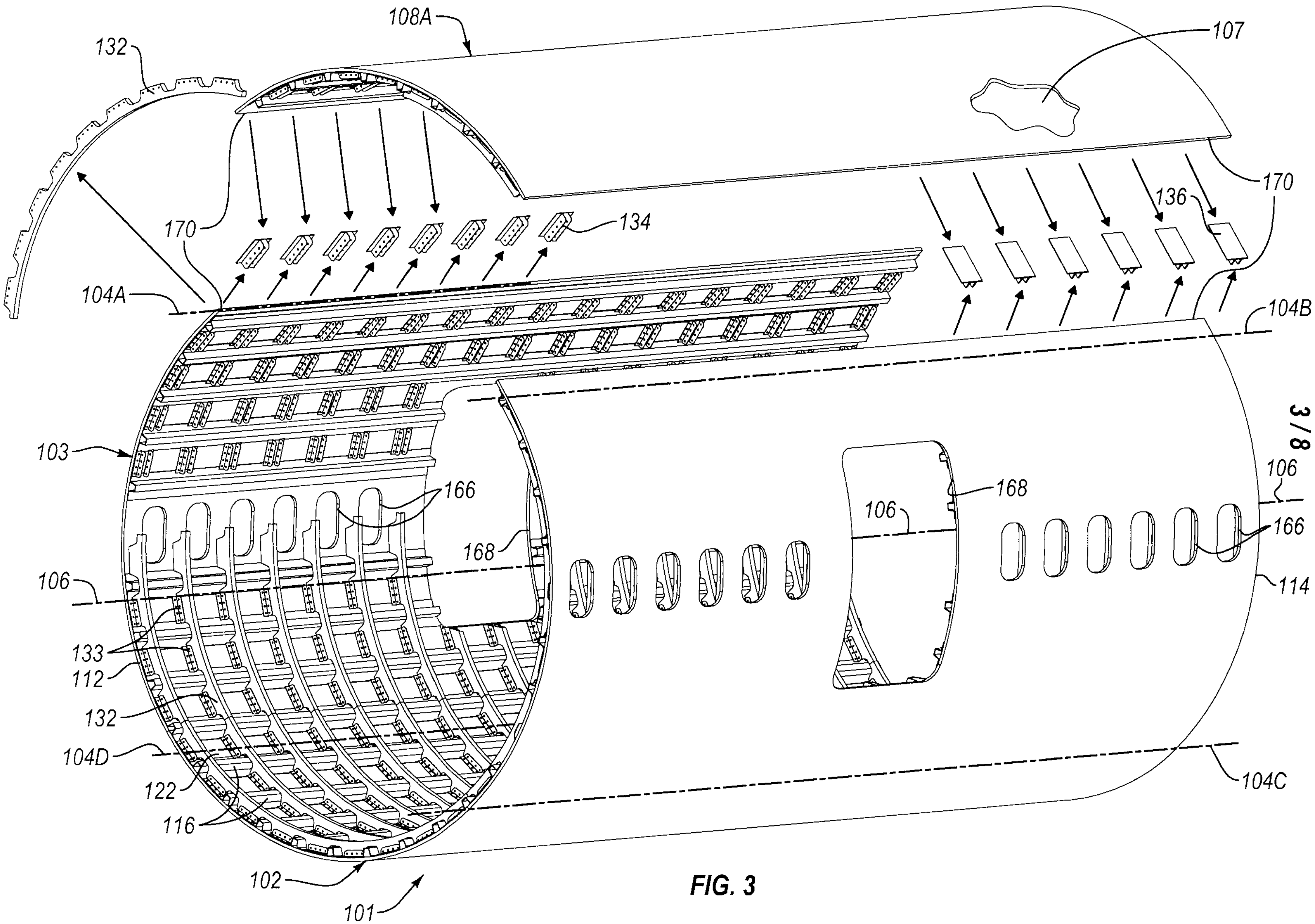
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FIG. 3

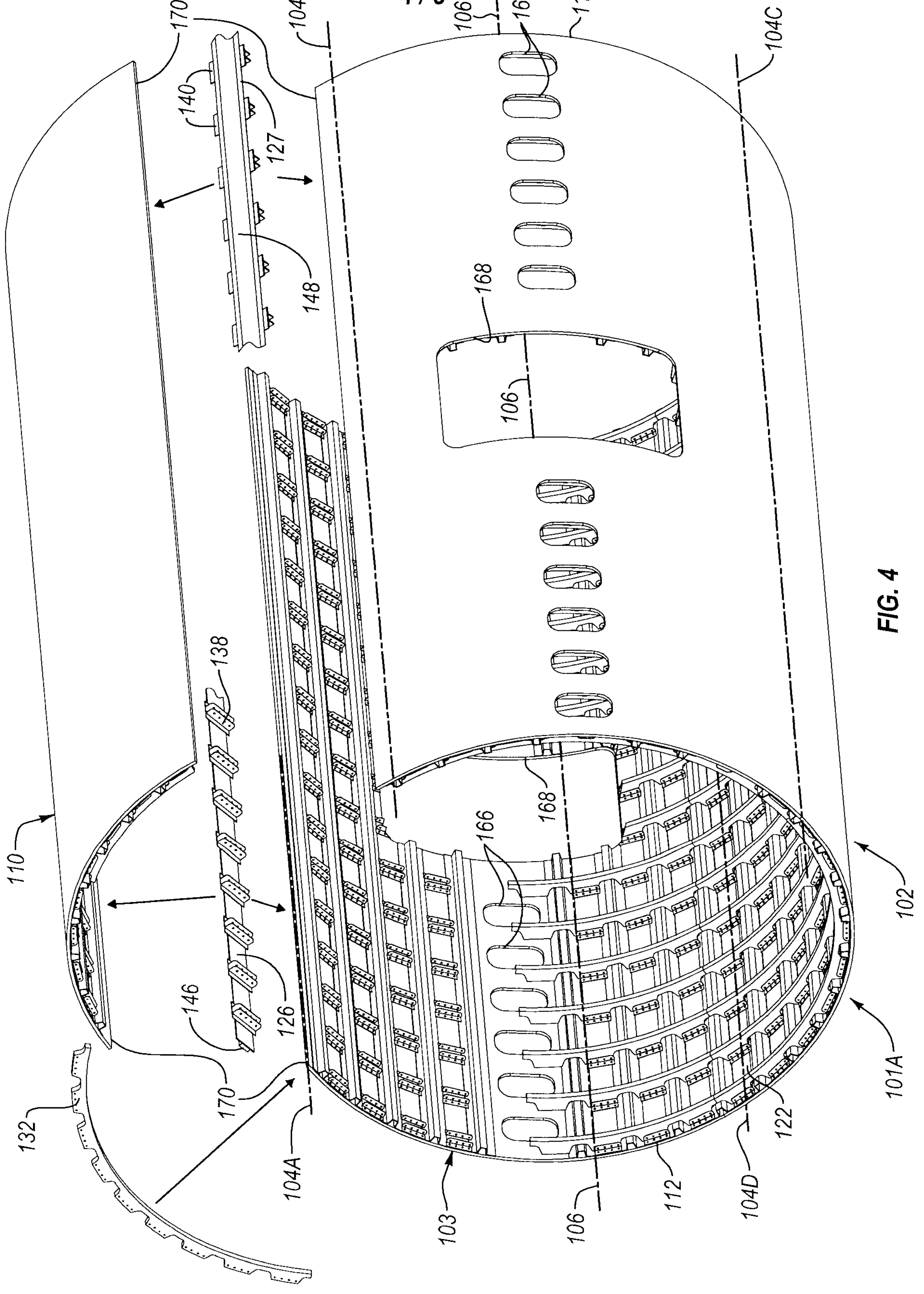
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FIG. 4

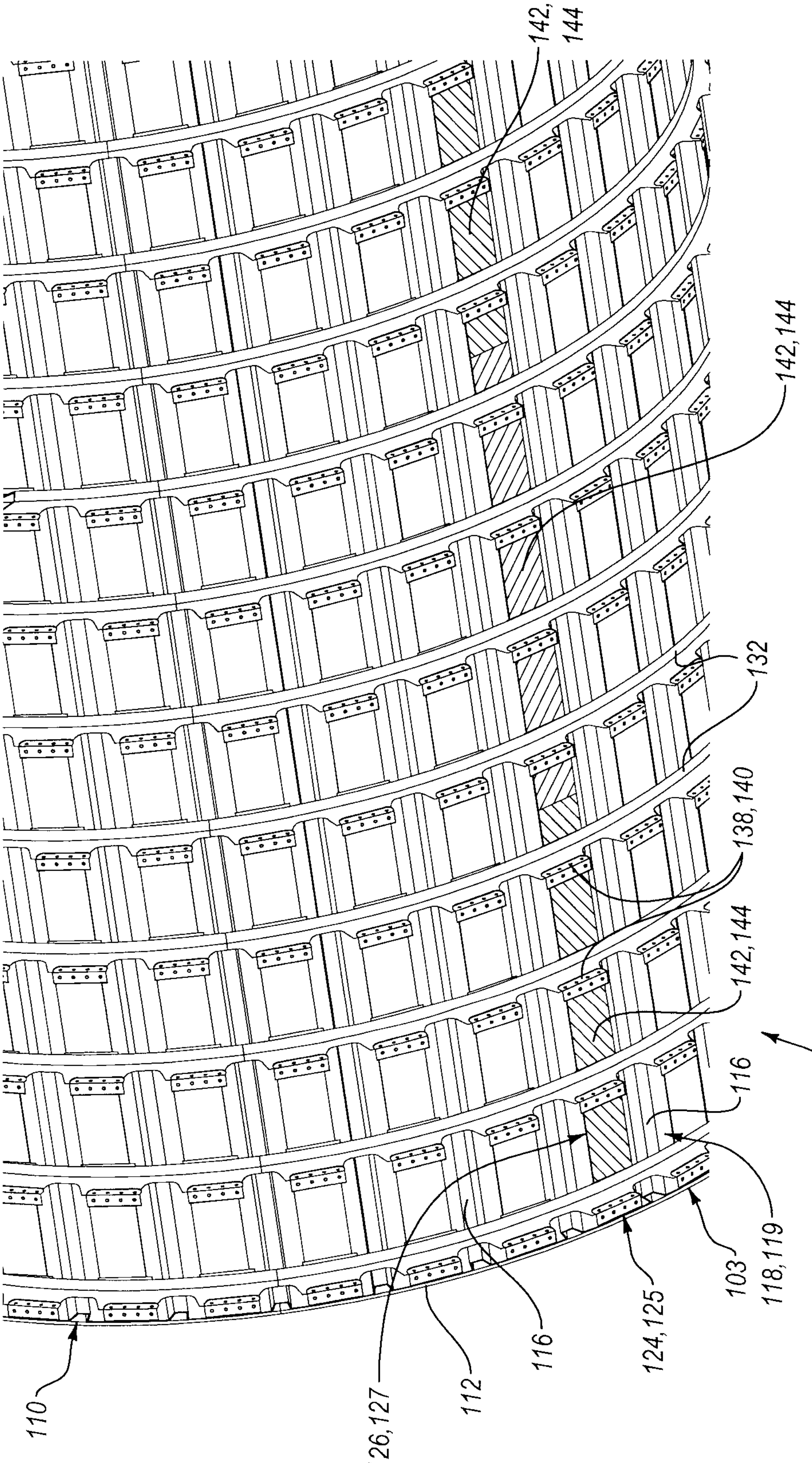
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FIG. 5

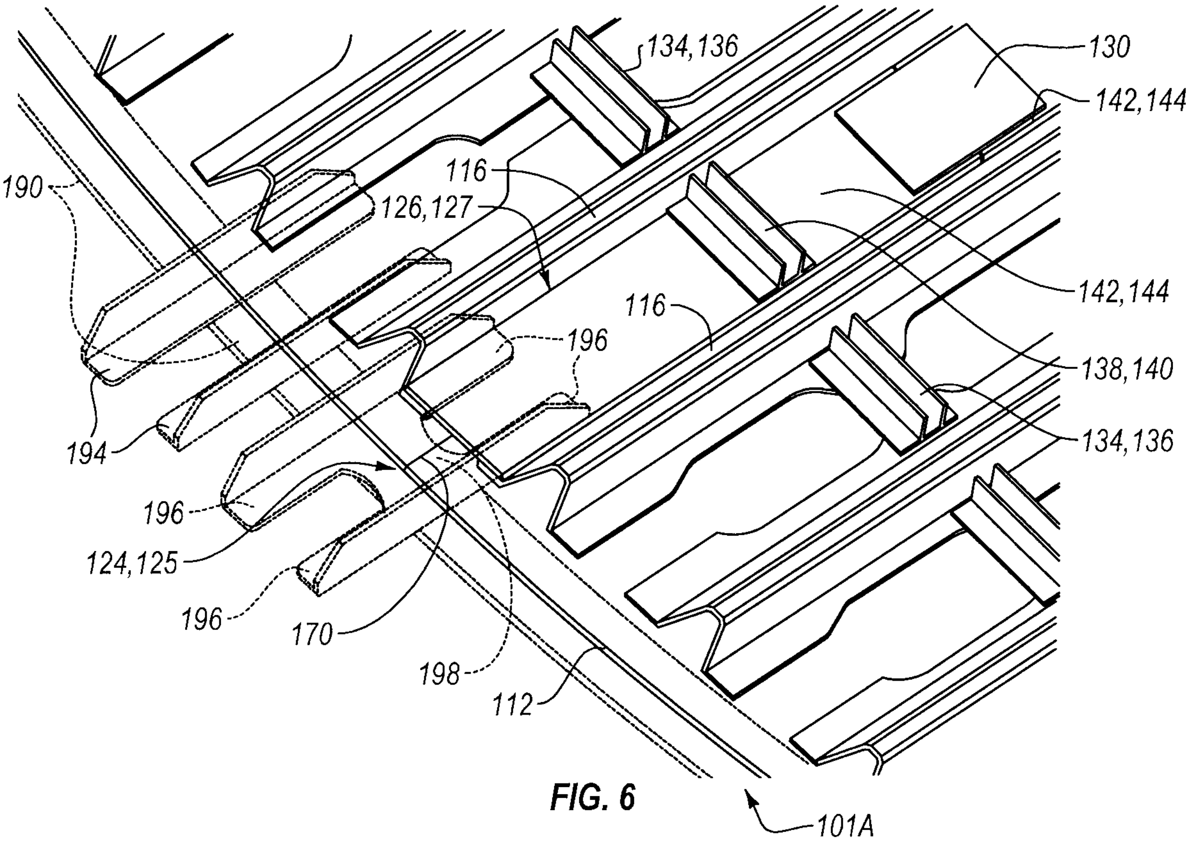
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FIG. 6

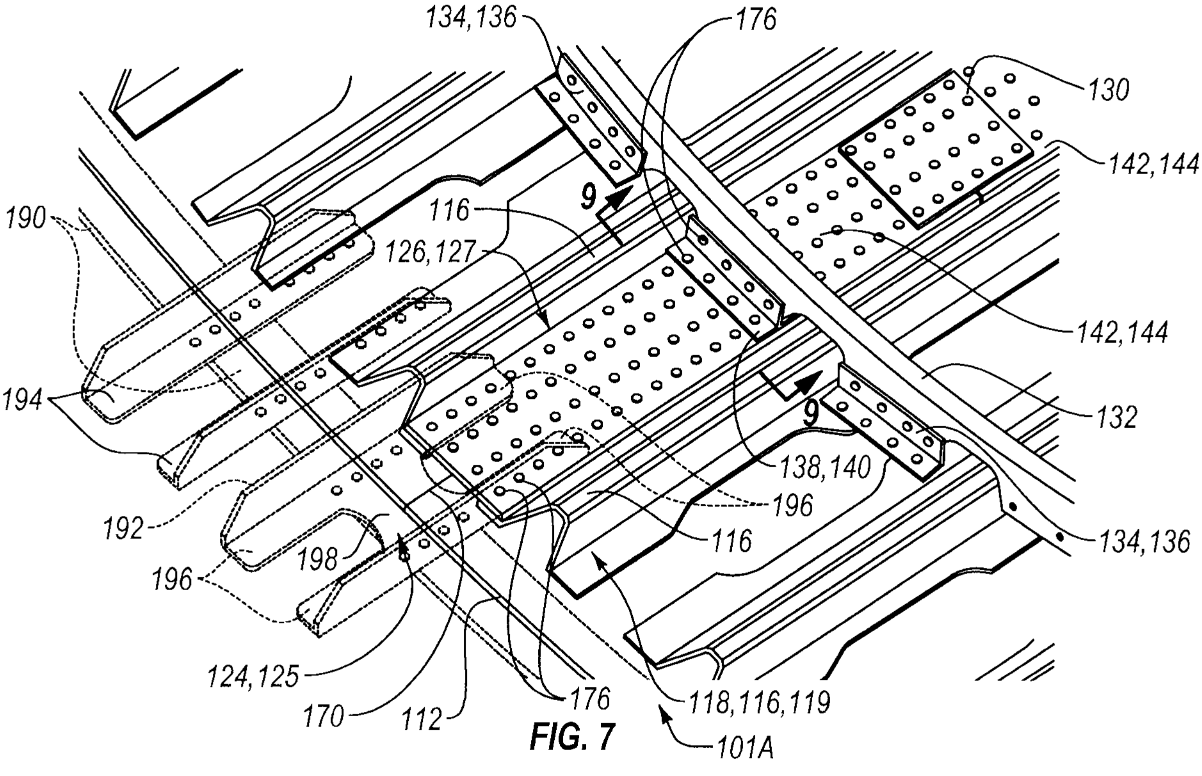
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FIG. 7

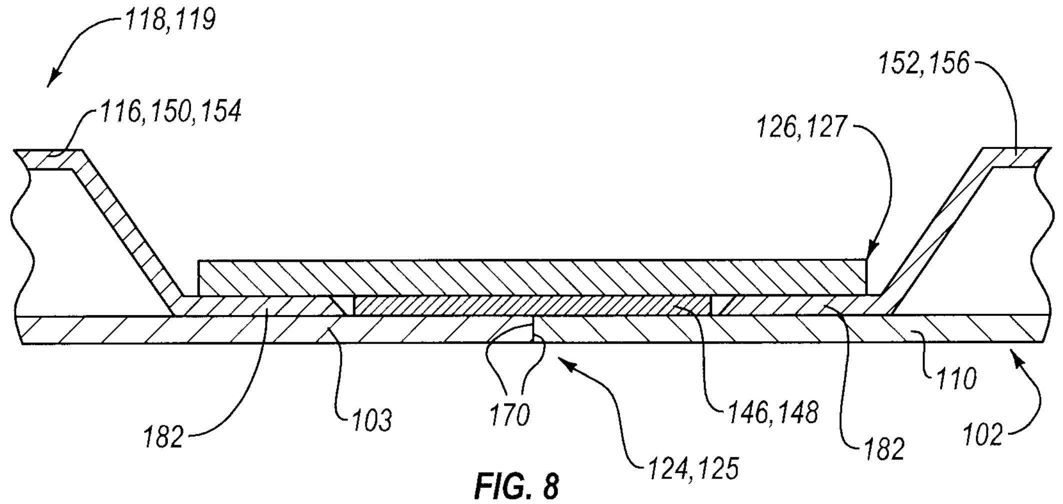
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FIG. 8

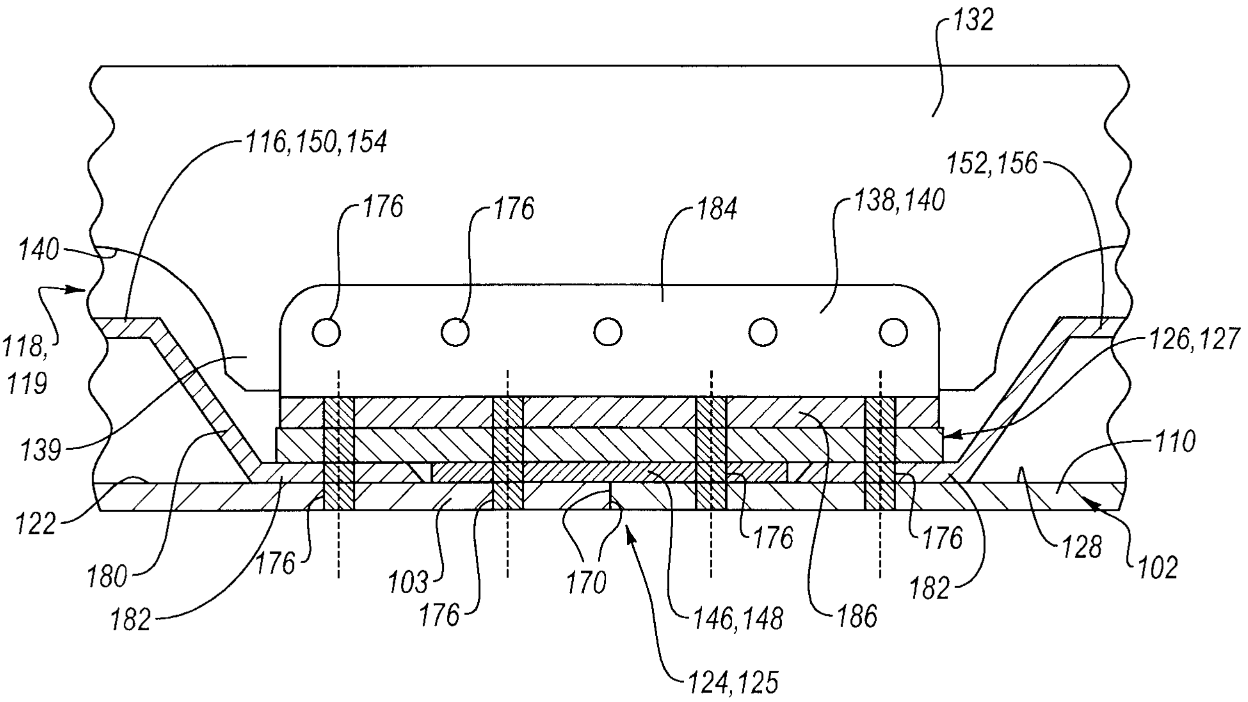
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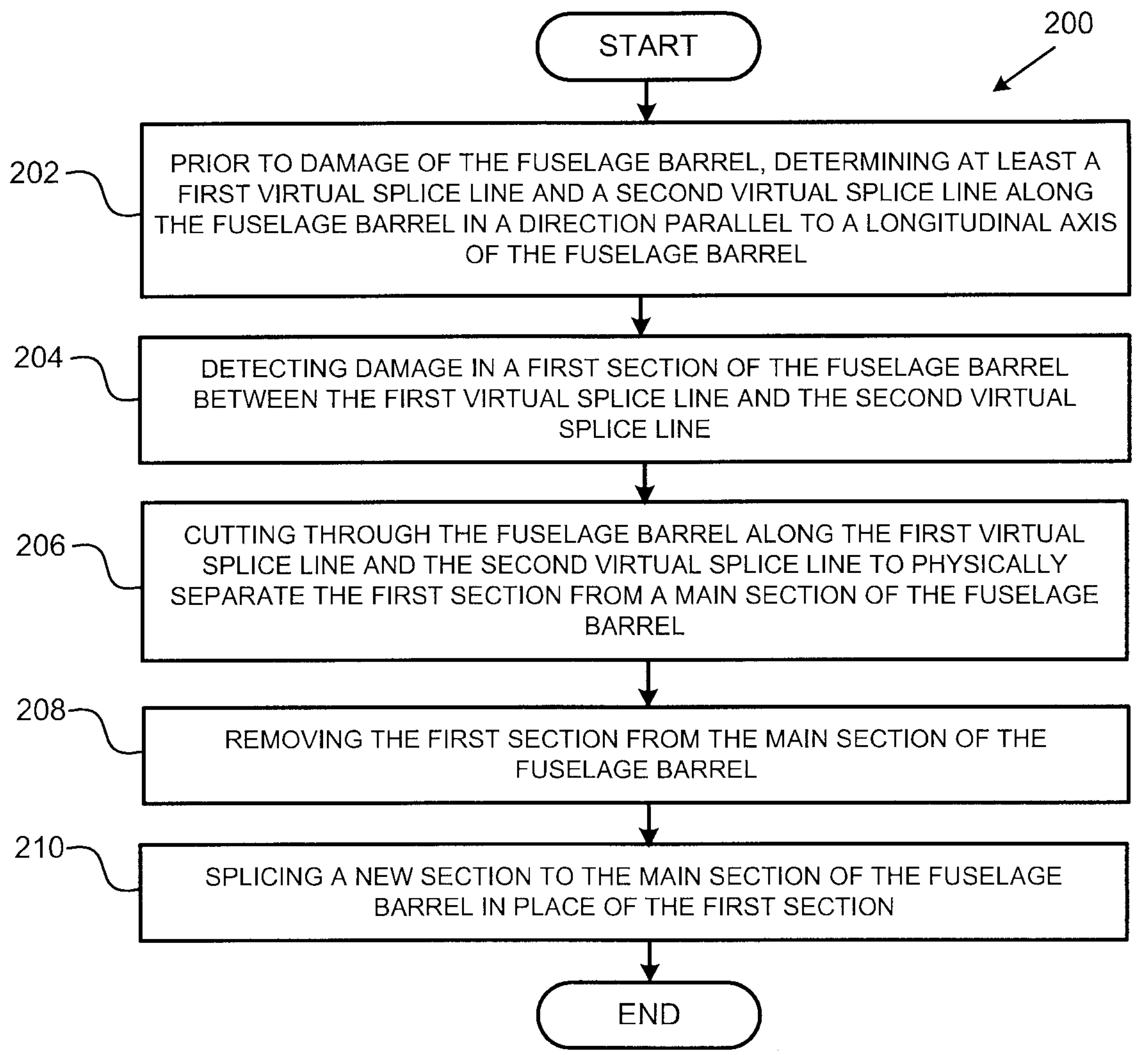
FIG. 9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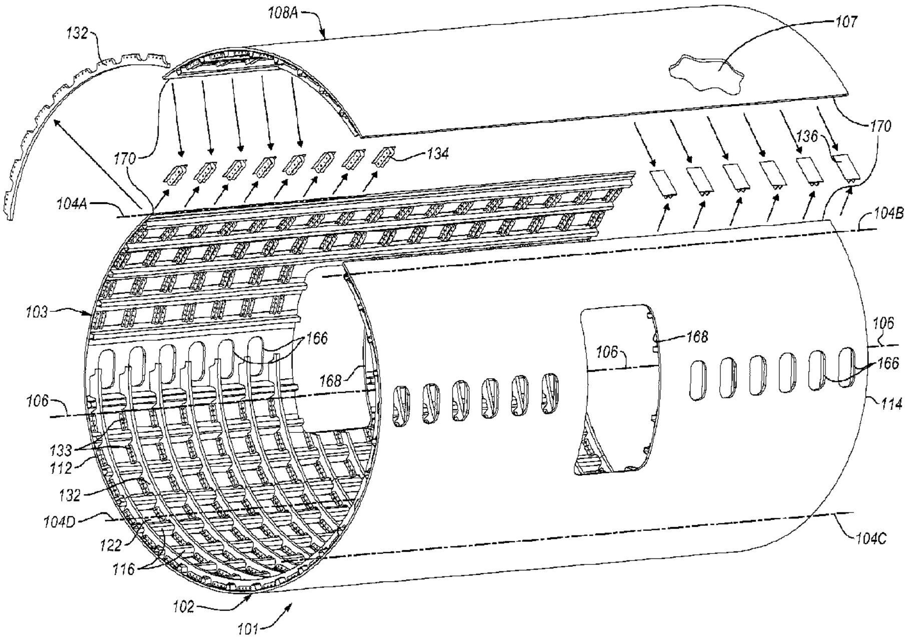
PRIOR TO DAMAGE OF THE FUSELAGE BARREL, DETERMINING AT LEAST A FIRST VIRTUAL SPLICE LINE AND A SECOND VIRTUAL SPLICE LINE ALONG THE FUSELAGE BARREL IN A DIRECTION PARALLEL TO A LONGITUDINAL AXIS OF THE FUSELAGE BARREL
204
DETECTING DAMAGE IN A FIRST SECTION OF THE FUSELAGE BARREL BETWEEN THE FIRST VIRTUAL SPLICE LINE AND THE SECOND VIRTUAL SPLICE LINE
206
CUTTING THROUGH THE FUSELAGE BARREL ALONG THE FIRST VIRTUAL SPLICE LINE AND THE SECOND VIRTUAL SPLICE LINE TO PHYSICALLY SEPARATE THE FIRST SECTION FROM A MAIN SECTION OF THE FUSELAGE BARREL
208
REMOVING THE FIRST SECTION FROM THE MAIN SECTION OF THE FUSELAGE BARREL
210
SPLICING A NEW SECTION TO THE MAIN SECTION OF THE FUSELAGE BARREL IN PLACE OF THE FIRST SECTION
END

FIG. 10



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