(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 2 487 418 A2

# (12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
**15.08.2012 Bulletin 2012/33**

(51) Int Cl.:
***F23R 3/00*** *(2006.01)*

(21) Application number: **12155001.6**

(22) Date of filing: **10.02.2012**

(84) Designated Contracting States:
**AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR**
Designated Extension States:
**BA ME**

(30) Priority: **14.02.2011 US 201113026373**

(71) Applicant: **General Electric Company**
**Schenectady, New York 12345 (US)**

(72) Inventors:
- **Siddagangaiah, Prabhu Kumar Ippadi**
  **560066 Bangalore, Karnataka (IN)**
- **Sridhar, Kodukulla Venkat**
  **560066 Bangalore, Karnataka (IN)**
- **Kaleeswaran, Karthick**
  **560066 Bangalore, Karnataka (IN)**
- **Sarja, Nitin Subramanya**
  **560066 Bangalore, Karnataka (IN)**

(74) Representative: **Cleary, Fidelma**
**GE International Inc.**
**Global Patent Operation-Europe**
**15 John Adam Street**
**London WC2N 6LU (GB)**

## (54) A combustor

(57) A combustor (10) includes a combustion chamber (22) and a liner (20) surrounding the combustion chamber (22). A ridge (30) on top of the liner (20) extends continuously around the liner (20). In alternate embodiments, a ridge (30) extends continuously around the liner (20), and a groove (50) extends continuously around the liner (20) adjacent to the ridge (30), wherein both of the ridge (30) and the groove (50) are either substantially flat or curved.

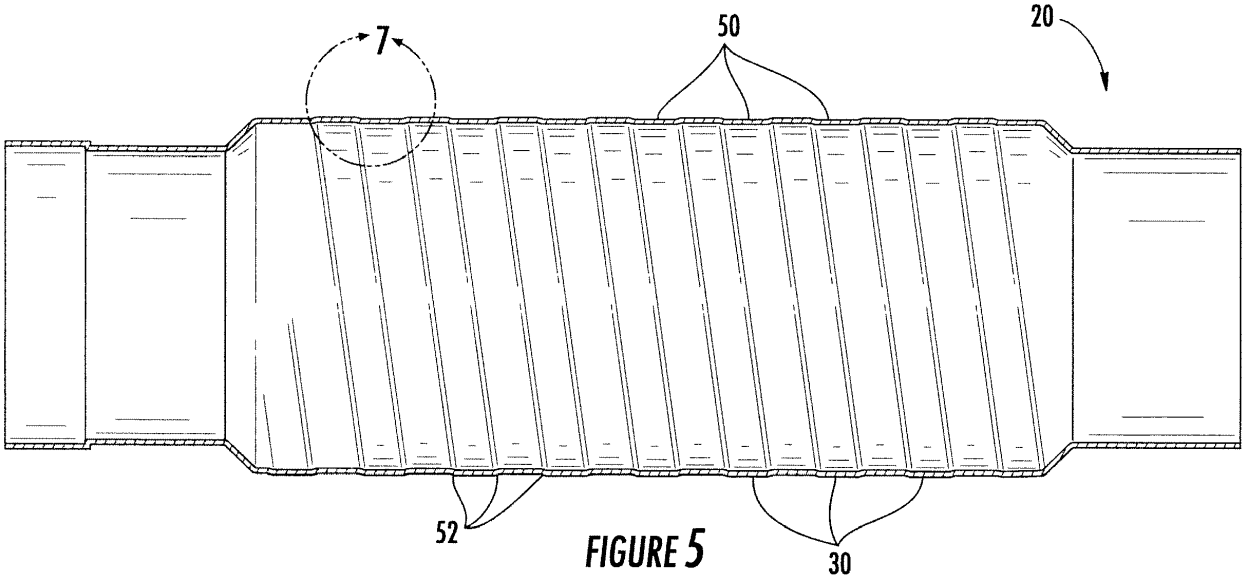


FIGURE 5

EP 2 487 418 A2

## Description

### FIELD OF THE INVENTION

**[0001]** The present invention generally involves a combustor. Specifically, various embodiments of the present invention include a combustor having a liner with enhanced durability.

### BACKGROUND OF THE INVENTION

**[0002]** Combustors are known in the art for igniting fuel with air to produce combustion gases having high temperature and pressure. For example, gas turbine systems typically include multiple combustors that mix a compressed working fluid from a compressor with fuel and ignite the mixture to produce high temperature and pressure combustion gases. The combustion gases then flow to a turbine where they expand to produce work.

**[0003]** Each combustor typically includes a liner that surrounds the combustion chamber to contain the working fluid and fuel during combustion. The temperatures associated with the combustion often exceed 3500°F, and the liner typically has a maximum operating temperature on the order of approximately 1500°F. Therefore, various systems and methods have been developed to cool the liner. For example, the working fluid may be directed over the external surface of the liner prior to flow into the combustion chamber to provide film or convective cooling to the liner. Alternately, or in addition, the thickness of the liner may be increased or thermal barrier coatings may be applied to the inside of the liner to protect the liner from excessive temperatures. Despite these and other measures, dynamic changes in pressure and power loads may cause plastic deformation, bulging, or creep to occur in the liner over time, resulting in additional maintenance, repairs, and unplanned outages. Therefore, an improved liner design with enhanced stiffness, rigidity, and/or cooling characteristics would be desirable.

### BRIEF DESCRIPTION OF THE INVENTION

**[0004]** Aspects and advantages of the invention are set forth below in the following description, or may be obvious from the description, or may be learned through practice of the invention.

**[0005]** In one aspect, the present invention resides in a combustor that includes a combustion chamber and a liner surrounding the combustion chamber. A ridge on top of the liner extends continuously around the liner.

**[0006]** The combustor may include a groove extending continuously around the liner adjacent to the ridge, wherein both of the ridge and the groove are either substantially flat or curved.

**[0007]** Those of ordinary skill in the art will better appreciate the features and aspects of such embodiments, and others, upon review of the specification.

### BRIEF DESCRIPTION OF THE DRAWINGS

**[0008]** Embodiments of the present invention will now be described, by way of example only, with reference to the accompanying drawings in which:

Figure 1 is a simplified cross-section of a combustor according to one embodiment of the present invention;

Figure 2 is a side plan view of a liner according to a first embodiment of the present invention;

Figure 3 is a side plan view of a liner according to a second embodiment of the present invention;

Figure 4 is an enlarged view of a portion of the liner shown in Figure 2 or 3;

Figure 5 is a side plan view of a liner according to a third embodiment of the present invention;

Figure 6 is a side plan view of a liner according to a fourth embodiment of the present invention;

Figure 7 is an enlarged view of a portion of the liner shown in Figure 5 or 6;

Figure 8 is a side plan view of a liner according to a fifth embodiment of the present invention;

Figure 9 is a side plan view of a liner according to a sixth embodiment of the present invention;

Figure 10 is an enlarged view of a portion of the liner shown in Figure 8 or 9;

Figure 11 is a side plan view of a liner according to a seventh embodiment of the present invention;

Figure 12 is a side plan view of a liner according to an eighth embodiment of the present invention; and

Figure 13 is an enlarged view of a portion of the liner shown in Figure 8 or 9.

### DETAILED DESCRIPTION OF THE INVENTION

**[0009]** Reference will now be made in detail to present embodiments of the invention, one or more examples of which are illustrated in the accompanying drawings. The detailed description uses numerical and letter designations to refer to features in the drawings. Like or similar designations in the drawings and description have been used to refer to like or similar parts of the invention.

**[0010]** Each example is provided by way of explanation of the invention, not limitation of the invention. In fact, it will be apparent to those skilled in the art that modifica-

tions and variations can be made in the present invention without departing from the scope or spirit thereof. For instance, features illustrated or described as part of one embodiment may be used on another embodiment to yield a still further embodiment. Thus, it is intended that the present invention covers such modifications and variations as come within the scope of the appended claims and their equivalents.

**[0011]** Various embodiments of the present invention provide a combustor with any one of several improved liner designs that enhance the stiffness and/or rigidity characteristics of the liner. For example, in particular embodiments, the liner may include one or more ridges and/or one or more grooves that extend around the liner in a spiral or parallel pattern. In other particular embodiments, the liner may include one or more radii and substantially flat segments that extend around the liner in a spiral or parallel pattern. In each embodiment, the combination of ridges, grooves, radii, and/or substantially flat segments have been designed to improve the liner's resistance to premature buckling, creep, or deformation that may be caused over time by dynamic pressure and load changes. In addition, the various embodiments have been designed to enhance film or convective cooling of the outside of the liner without increasing manufacturing costs or difficulty.

**[0012]** Figure 1 shows a simplified cross-section of a combustor 10 according to one embodiment of the present invention. As shown, the combustor 10 may include one or more nozzles 12 radially arranged in a top cap 14. A casing 16 may surround the combustor 10 to contain the air or compressed working fluid exiting the compressor (not shown). An end cap 18 and a liner 20 generally surround a combustion chamber 22 downstream of the nozzles 12. A flow sleeve 24 with flow holes 26 may surround the liner 20 to define an annular passage 28 between the flow sleeve 24 and the liner 20. The compressed working fluid may pass through the flow holes 26 in the flow sleeve 24 to flow along the outside of the liner 20 to provide film or convective cooling to the liner 20. The compressed working fluid then reverses direction to flow through the one or more nozzles 12 and into the combustion chamber 22 where it mixes with fuel and ignites to produce combustion gases having a high temperature and pressure.

**[0013]** Figures 2 and 3 show side plan views of the liner 20 according to first and second embodiments of the present invention. In each particular embodiment shown in Figures 2 and 3, a ridge 30 on top of the liner 20 extends continuously around the circumference of the liner 20 to strengthen the liner 20. The ridge 30 may extend axially along a portion or the entire length of the liner 20, or a plurality of the ridges 30 may extend axially along some or all of the length of the liner 20. As shown in Figure 2, the ridge 30 may form a continuous substantially parallel spiral around the liner 20. Alternately, as shown in the embodiment illustrated in Figure 3, the liner 20 may include a plurality of the ridges 30, with the ridges 30 forming substantially parallel circles or hoops around the circumference of the liner 20.

**[0014]** Figure 4 provides an enlarged view of a portion of the liner 20 shown in Figure 2 or 3. The ridge(s) 30 may be forged or cast with the liner 20 to facilitate ease of manufacturing, or the ridge(s) 30 may be added to the liner 20 by welding and subsequent machining, if desired. The dimensions and spacing of the ridge(s) 30 may be selected according to various design considerations to optimize the strength, stiffness, and/or rigidity of the liner 20, as well as the cooling provided by the ridge(s) 30. For example, the height 32 and width 34 of the ridge(s) 30, as well as the distance 36 between adjacent ridge(s) 30 spiraling around or encircling the liner 20, may be selected based on the thickness 38 of the liner 20. In particular embodiments, the height 32 and/or width 34 of the ridge(s) 30 may be approximately 0.3-1.4 times the thickness 38 of the liner 20, and the distance 36 between adjacent ridges 30 may be approximately 8-45 times the thickness 38 of the liner 20.

**[0015]** As shown in Figure 4, each ridge 30 may comprise a base 40 proximate to the liner 20 and a distal end 42. The base 40 may include a radius 44 along at least a portion of the base 40. As used herein, the term "radius" includes any curved surface that reduces flow resistance across the outer surface of the liner 20. The length of the radius 44 may be selected based on the thickness 38 of the liner 20. For example, the radius 44 may have a curved length 49 of approximately .15-1 times the thickness 38 of the liner. The radius 44 may be forged or cast with the ridge(s) 30 during manufacture of the liner 20 or may be added separately, such as through lap welding and machining to produce a smooth, curved surface between the ridge(s) 30 and the liner 20. As shown in Figure 4, the distal end 42 may also include a radius 46 and/or terminate at a point 48 along at least a portion of the distal end 42.

**[0016]** Figures 5 and 6 provide side plan views of the liner 20 according to third and fourth embodiments of the present invention. In each particular embodiment shown in Figures 5 and 6, the ridge 30 again extends continuously around the circumference of the liner 20; however, the ridge 30 is substantially wider than in the embodiments shown in Figures 2-4. In addition, the particular embodiments shown in Figures 5 and 6 further include a groove 50 that extends continuously around the liner 20 adjacent to the ridge 30. A radius 52 between the ridge 30 and the groove 50 provides a smooth transition between the ridge 30 and the groove 50. The ridge 30 and groove 50 may extend axially along a portion or the entire length of the liner 20, or a plurality of the ridges 30 and/or the grooves 50 may extend axially along some or all of the length of the liner 20. As shown in Figure 5, the ridge 30 and groove 50 may form a continuous substantially parallel spiral around the liner 20. Alternately, as shown in the embodiment illustrated in Figure 6, the liner 20 may include a plurality of the ridges 30 and grooves 50, with at least one groove 50 between adjacent ridges 30. In

this manner, the ridges 30 and grooves 50 form substantially parallel circles or hoops around the circumference of the liner 20.

**[0017]** Figure 7 provides an enlarged view of a portion of the liner 20 shown in Figure 5 or 6. The ridge(s) 30, groove(s) 50, and radii 52 may be forged or cast with the liner 20 to facilitate ease of manufacturing, or the liner 20 may be pressed or stamped to form the ridge(s) 30, groove(s) 50, and radii 52, if desired. The dimensions and spacing of the ridge(s) 30, groove(s) 50, and radii 52 may be selected according to various design considerations to optimize the strength, stiffness, and/or rigidity of the liner 20, as well as the cooling provided by the ridge(s) 30 and groove(s) 50. For example, the height 54 and width 56 of the ridge(s) 30 and/or the groove(s) 50 continuously spiraling around or encircling the liner 20 may be selected based on the thickness 38 of the liner 20. In particular embodiments, the height 54 of the ridge (s) 30 and/or groove(s) 50 may be approximately 1.1-2.5 times the thickness 38 of the liner 20, and the width 56 of the ridge(s) 30 and/or the groove(s) 50 may be approximately 8-45 times the thickness 38 of the liner 20 for liner thicknesses greater than approximately 0.09 inches and approximately 16-90 times the thickness 38 of the liner 20 for liner thicknesses less than approximately 0.09 inches. Similarly, the radius 52 may have a curved length 58 of approximately 0.5-2.5 times the thickness 38 of the liner 20. The ridge(s) 30 and/or the groove (s) 50 may be substantially flat with the same height 54 and width 56, although such is not limitation of the present invention unless specifically recited in the claims.

**[0018]** Figures 8 and 9 provide side plan views of the liner 20 according to fifth and sixth embodiments of the present invention. In each particular embodiment shown in Figures 8 and 9, the ridge 30 again extends continuously around the circumference of the liner 20; however, the ridge 30 is curved with the convex surface facing outward. In addition, the particular embodiments shown in Figures 8 and 9 further include a groove 50 that extends continuously around the liner 20 adjacent to the ridge 30. A smooth transition between the ridge 30 and the groove 50 produces a wavy surface on the outside of the liner 20. The ridge 30 and groove 50 may extend axially along a portion or the entire length of the liner 20, or a plurality of the ridges 30 and/or the grooves 50 may extend axially along some or all of the length of the liner 20. As shown in Figure 8, the ridge 30 and groove 50 may form a continuous substantially parallel spiral around the liner 20. Alternately, as shown in the embodiment illustrated in Figure 9, the liner 20 may include a plurality of the ridges 30 and grooves 50, with at least one groove 50 between adjacent ridges 30. In this manner, the ridges 30 and grooves 50 form substantially parallel circles or hoops around the circumference of the liner 20.

**[0019]** Figure 10 provides an enlarged view of a portion of the liner 20 shown in Figure 8 or 9. The ridge(s) 30 and groove(s) 50 may be forged or cast with the liner 20 to facilitate ease of manufacturing, or the liner 20 may be pressed or stamped to form the ridge(s) 30 and groove (s) 50, if desired. The dimensions and spacing of the ridge(s) 30 and groove(s) 50 may be selected according to various design considerations to optimize the strength, stiffness, and/or rigidity of the liner 20, as well as the cooling provided by the ridge(s) 30 and groove(s) 50. For example, the height 54 and width 56 of the ridge(s) 30 and/or the groove(s) 50 continuously spiraling around or encircling the liner 20 may be selected based on the thickness 38 of the liner 20. In particular embodiments, the height 54 of the ridge(s) 30 and/or groove(s) 50 may be approximately 1.1-5 times the thickness 38 of the liner 20, and the width 56 of the ridge(s) 30 and/or groove(s) 50 may be approximately 8-45 times the thickness 38 of the liner 20 for liner thicknesses greater than approximately 0.09 inches and approximately 16-90 times the thickness 38 of the liner 20 for liner thicknesses less than approximately 0.09 inches.

**[0020]** Figures 11 and 12 provide side plan views of the liner 20 according to seventh and eighth embodiments of the present invention. Each particular embodiment shown in Figures 11 and 12 may include a corrugated surface 60 with a radius 62 and a substantially flat segment 64 adjacent to the radius 62. The radius 62 and segment 64 extend continuously around the liner 20 to define an outer circumference of the liner 20. The segment 64 has a first end 66 and a second end 68, and the outer circumference of the liner 20 at the first end 66 is greater than the outer circumference of the liner 20 at the second end 68 to provide the corrugated surface 60. The direction of the corrugated surface 60 may vary according to particular embodiments. For example, in the embodiment shown in Figure 11, the first end 66 is upstream from the second end 68, and in the embodiment shown in Figure 12, the first and 66 is downstream from the second end 68.

**[0021]** The radius 62 and segment 64 may extend axially along a portion or the entire length of the liner 20, or a plurality of the radii 62 and/or the segments 64 may extend axially along some or all of the length of the liner 20. As shown in Figure 11, the radius 62 and the segment 64 may form a continuous substantially parallel spiral around the liner 20. Alternately, as shown in the embodiment illustrated in Figure 12, the liner 20 may include a plurality of the continuous radii 62 and segments 64, with at least one segment 64 between adjacent radii 62. In this manner, the radii 62 and segments 64 form substantially parallel circles or hoops around the circumference of the liner 20.

**[0022]** Figure 13 provides an enlarged view of a portion of the liner 20 shown in Figure 11 or 12. The radii 62 and segments 64 may be forged or cast with the liner 20 to facilitate ease of manufacturing, or the liner 20 may be pressed or stamped to form the radii 62 and segments 64, if desired. The dimensions and spacing of the radii 62 and segments 64 may be selected according to various design considerations to optimize the strength, stiffness, and/or rigidity of the liner 20, as well as the cooling

provided by the radii 62 and segments 64. For example, the slope 70 of the segments 64 may be approximately 2-8 degrees with respect to the axis of the liner 20. The height 72 of the corrugated surface 60 and the distance 74 between adjacent radii 62 or adjacent segments 64 continuously spiraling around or encircling the liner 20 may be selected based on the thickness 38 of the liner 20. In particular embodiments, the height 72 of the corrugated surface 60 may be approximately 1.1-3.0 times the thickness 38 of the liner 20. The distance 74 between adjacent radii 62 or adjacent segments 64 may be approximately 8-45 times the thickness 38 of the liner 20 for liner thicknesses greater than approximately 0.09 inches and approximately 16-90 times the thickness 38 of the liner 20 for liner thicknesses less than approximately 0.09 inches. Similarly, the radii 62 may have a curved length 76 of approximately 0.5-2.5 times the thickness 38 of the liner 20.

**[0023]** It is believed that the various embodiments described and illustrated in Figures 2-13 will provide increased stiffness and rigidity to the liner without increasing manufacturing difficulty or costs. In addition, the ridges, grooves, radii, and or flat segments will function as turbulators to enhance film or convection cooling of the liner. As a result, it is anticipated that the useful life of the liners may be extended, and maintenance, repairs, and/or unplanned outages may be produced.

**[0024]** This written description uses examples to disclose the invention, including the best mode, and also to enable any person skilled in the art to practice the invention, including making and using any devices or systems and performing any incorporated methods. The patentable scope of the invention is defined by the claims, and may include other examples that occur to those skilled in the art. Such other and examples are intended to be within the scope of the claims if they include structural elements that do not differ from the literal language of the claims, or if they include equivalent structural elements with insubstantial differences from the literal languages of the claims.

## Claims

**1.** A combustor (10) comprising:

a. a combustion chamber (22);
b. a liner (20) surrounding the combustion chamber (22); and
c. a ridge (30) on top of the liner (20) and extending continuously around the liner (20).

**2.** The combustor (10) as in claim 1, wherein the ridge (30) forms a continuous spiral around the liner (20).

**3.** The combustor (10) as in claim 1 or 2, wherein the ridge (30) comprises a base (40) proximate to the liner (20) and further comprising a radius (52) along at least a portion of the base (40).

**4.** The combustor (10) as in any preceding claim, wherein the ridge (30) comprises a distal end (42) having a radius (62) along at least a portion of the distal end (42).

**5.** The combustor (10) as in any preceding claim, wherein the ridge (30) comprises a distal end (42) terminating at a point (48) along at least a portion of the distal end (42).

**6.** The combustor (10) as in any preceding claim, further comprising a groove (50) extending continuously around the liner (20) adjacent to the ridge (30).

**7.** The combustor (10) as in a claim 6, wherein both of the ridge (30) and the groove (50) are either substantially flat or curved.

**8.** The combustor (10) as in claim 6 or 7, further comprising a radius (52) between the ridge (30) and the groove (50).

**9.** The combustor (10) as in any of claims 6 to 8, wherein the ridge (30) is approximately the same width (56) as the groove (50).

**10.** The combustor (10) as in any of claims 6 to 9, further comprising a plurality of the ridges (30) and a plurality of the grooves (50) extending continuously around the liner (20).

**11.** The combustor (10) as in claim 10, wherein the plurality of ridges (30) are substantially parallel to the plurality of grooves (50).

**12.** The combustor (10) as in claim 10 or 11, further comprising a radius (52) between each ridge (30) and each groove (50).

**13.** The combustor (10) as in any of claims 10 to 12, wherein each ridge (30) is approximately the same width (56) as each groove (50).

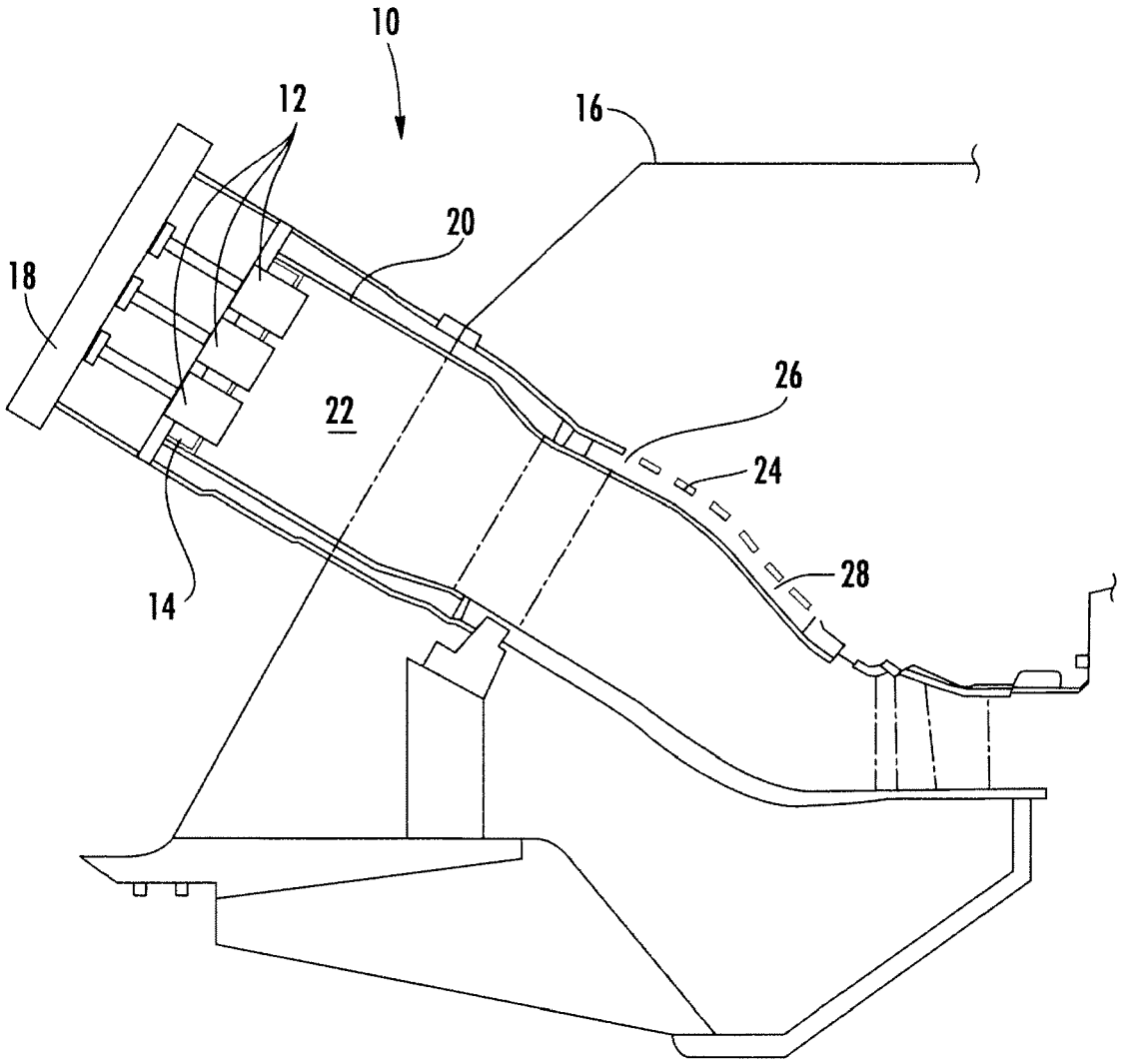


FIGURE 1

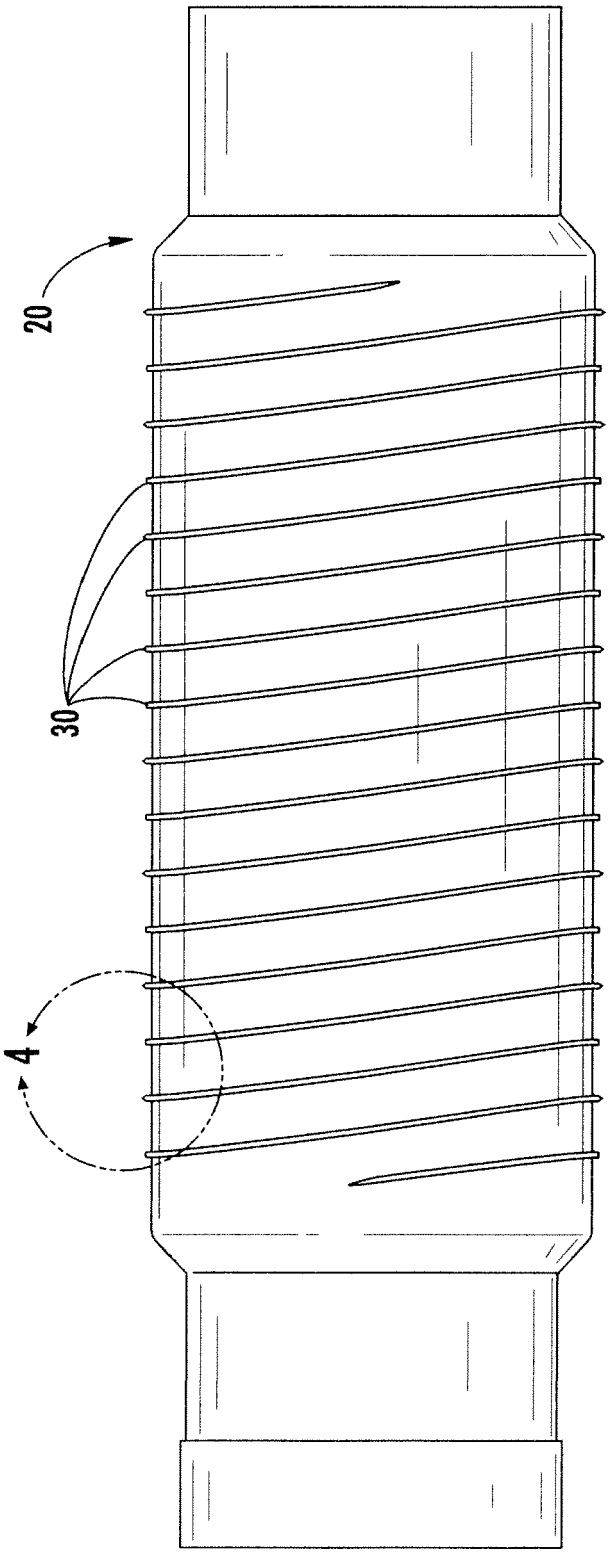


FIGURE 2

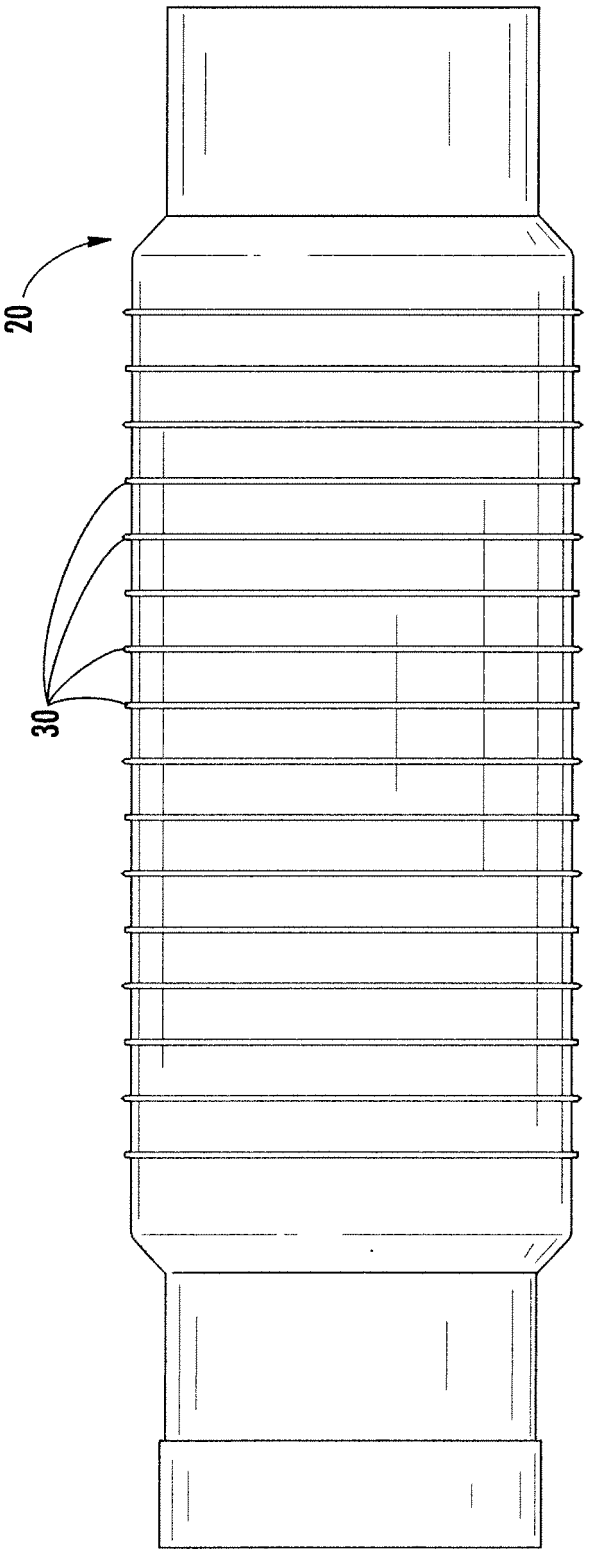


FIGURE 3

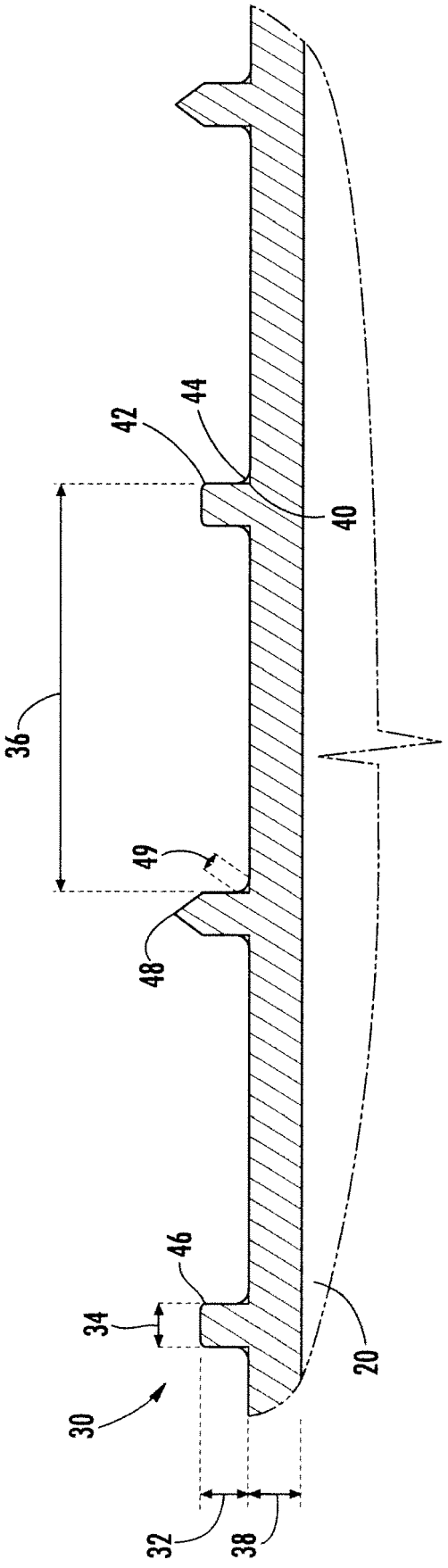


FIGURE 4

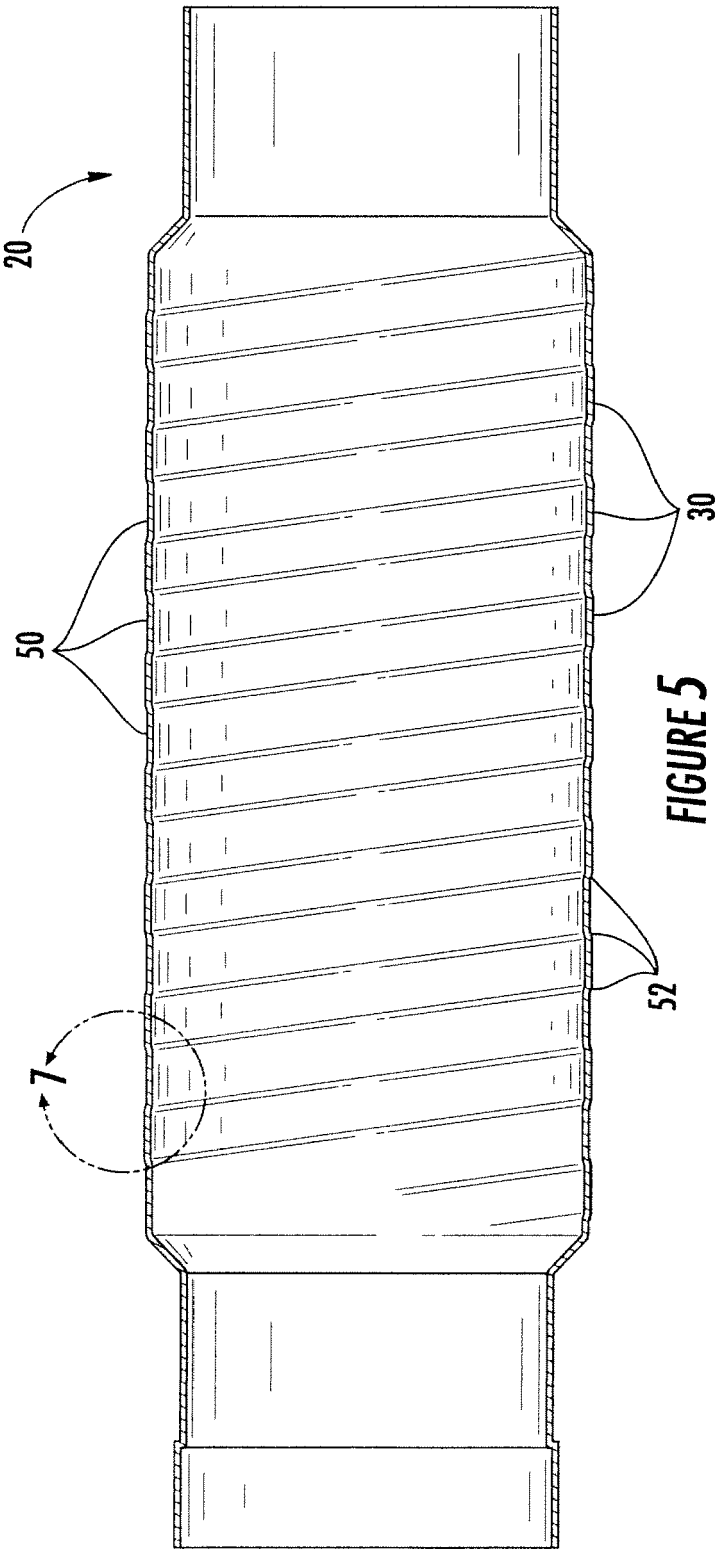


FIGURE 5

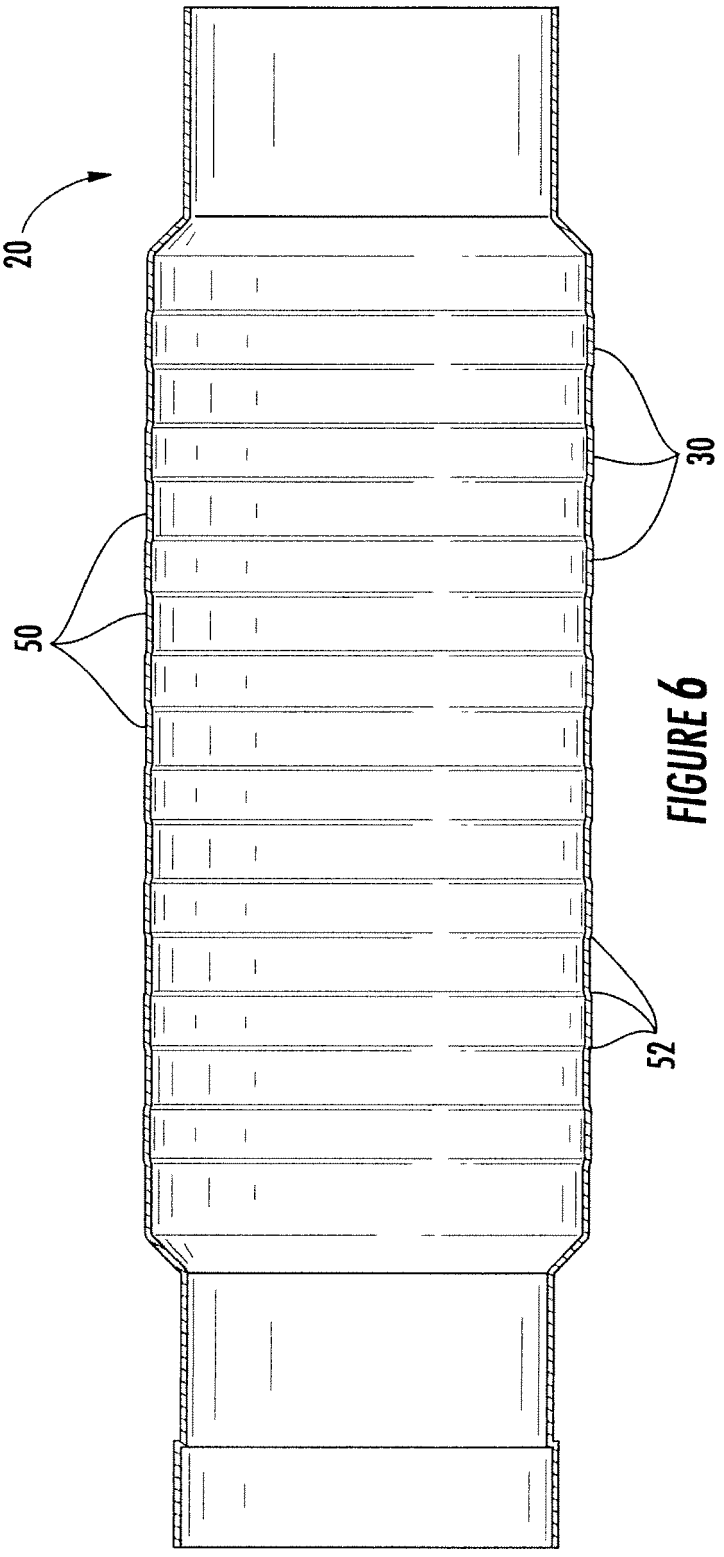


FIGURE 6

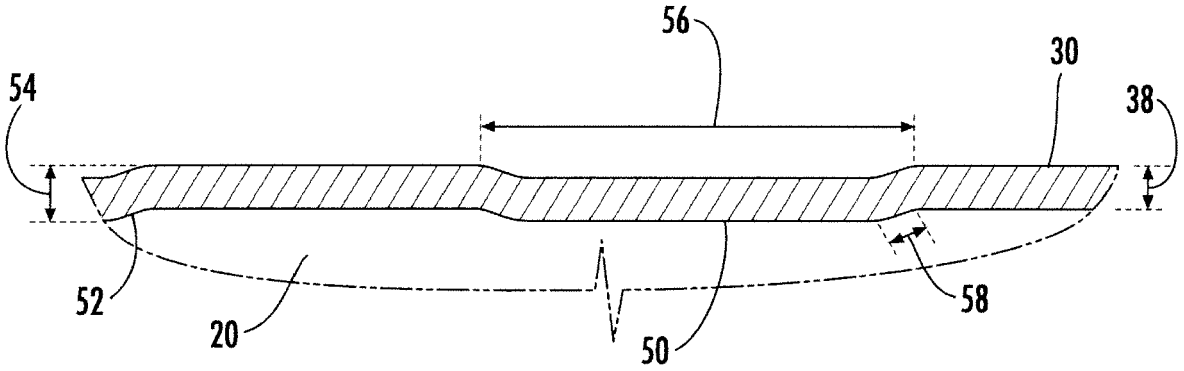


FIGURE 7

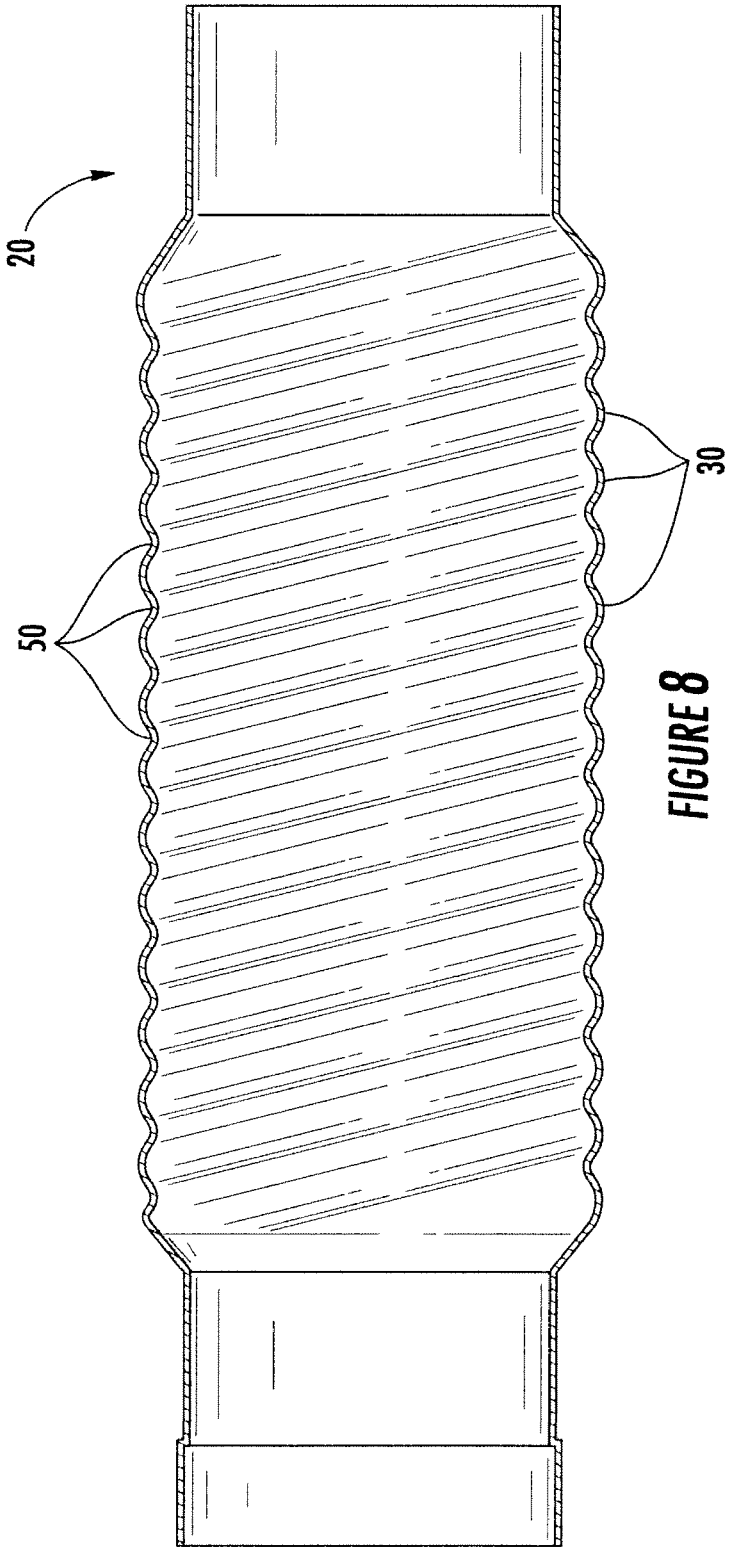


FIGURE 8

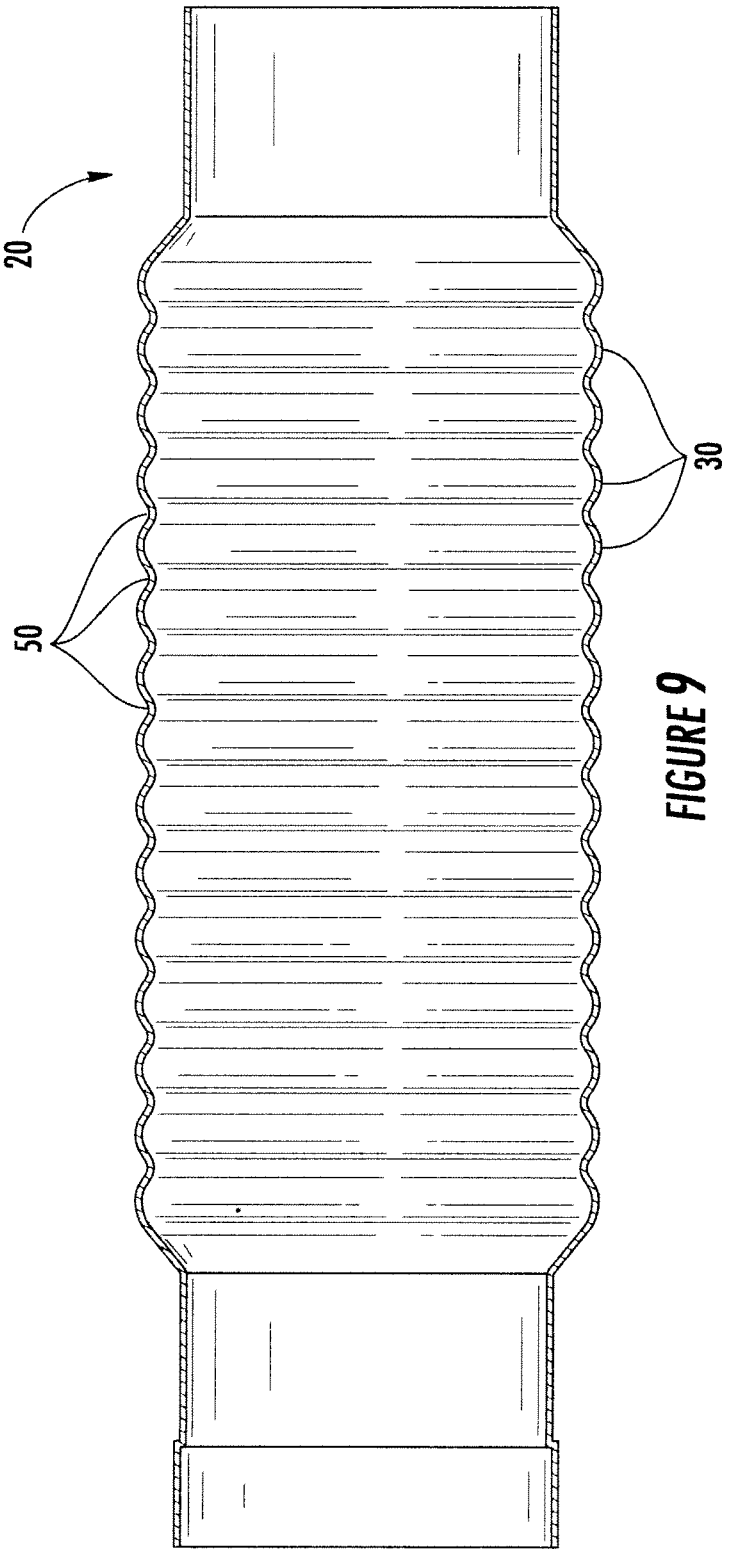


FIGURE 9

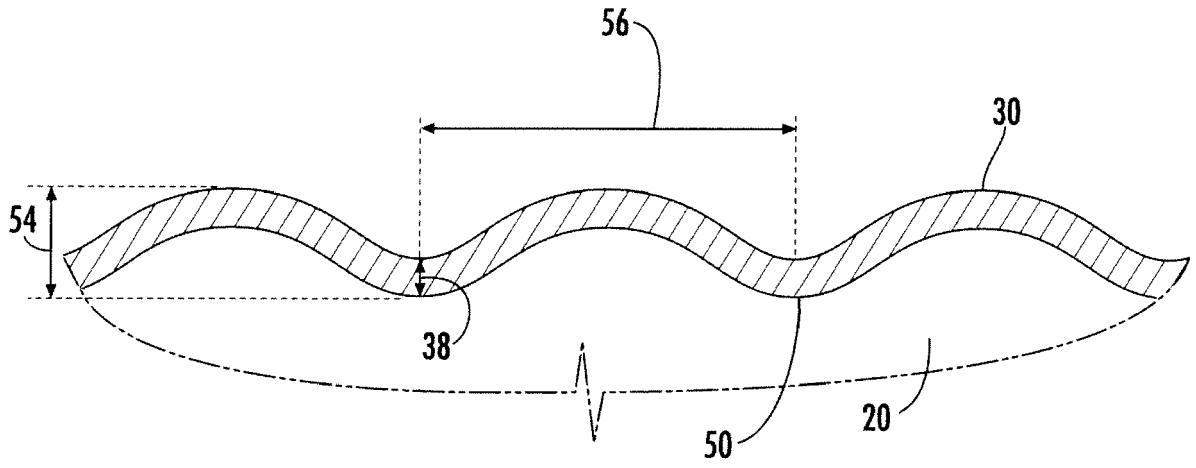


FIGURE 10

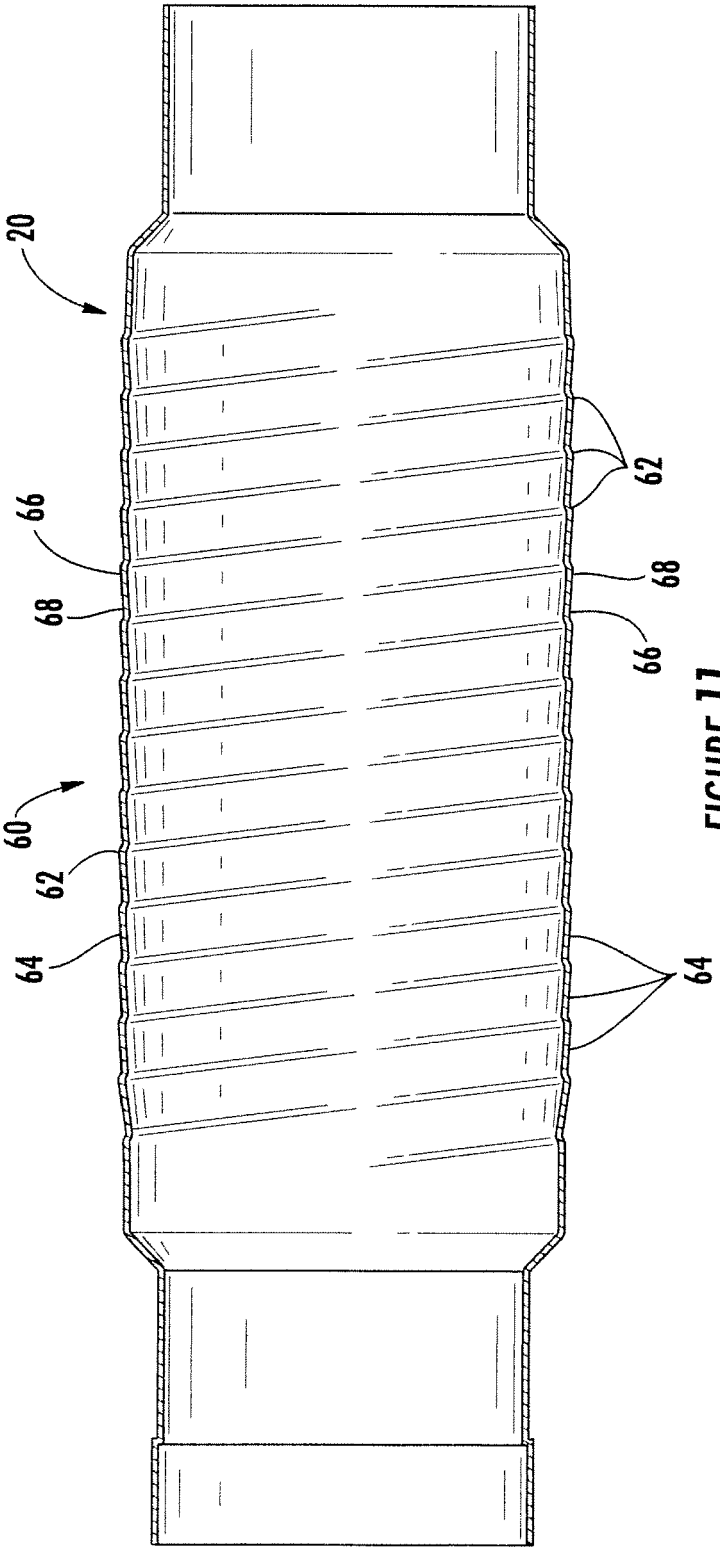


FIGURE 11

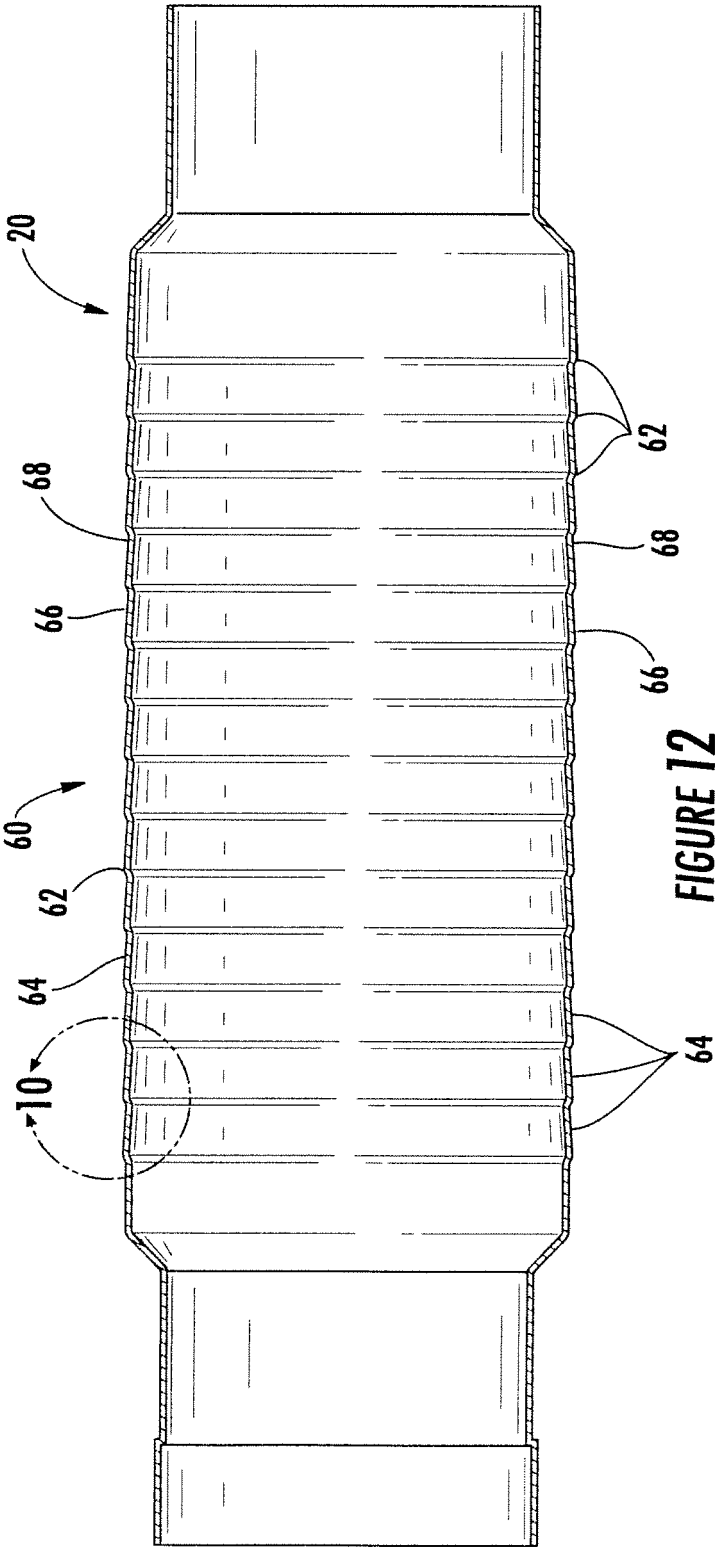


FIGURE 12

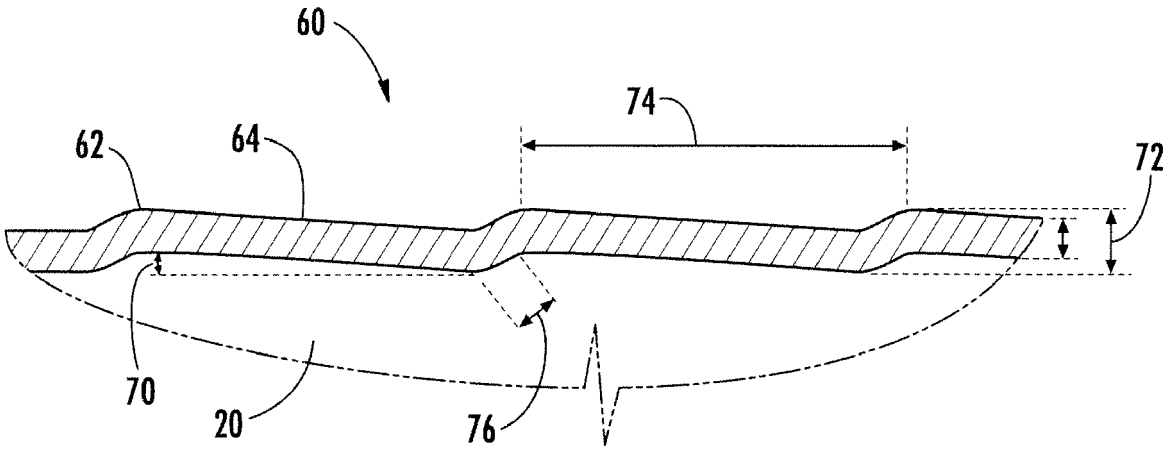


FIGURE 13