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<b>(21) International Application Number:</b> PCT/US96/17118  <b>(22) International Filing Date:</b> 1 November 1996 (01.11.96)  <b>(30) Priority Data:</b> 08/551,481      1 November 1995 (01.11.95)      US  <b>(71)(72) Applicants and Inventors:</b> BOYER, Robert, Charles [US/US]; 450 Cranes Roost Court, Annapolis, MD 21401 (US). ANTHONY, James, McDonald [US/US]; 311 Burnside Street, Annapolis, MD 21403 (US). PERKINS, Gregory, A. [US/US]; 5138 Honeysuckle Branch, Bulverde, TX 78163 (US). McGRATH, David, Francis [US/US]; 20007 Hickory Bend, San Antonio, TX 78266 (US).  <b>(74) Agents:</b> FELDHAUS, John, J. et al.; Foley & Lardner, Suite 500, 3000 K Street, N.W., Washington, DC 20007-5109 (US).		<b>(81) Designated States:</b> AU, CA, CN, JP, MX, European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).  <b>Published</b> <i>Without international search report and to be republished          upon receipt of that report.</i>
<b>(54) Title:</b> SANDWICH BELLOWS CONSTRUCTION		
<b>(57) Abstract</b>  <p>A sandwich bellows construction including three ply members has been provided. In a preferred embodiment of the invention, the outer plies are metal, while the inner ply is an elastomer. In one preferred embodiment of the invention, the ends of the inner and outer plies are joined together so that the intermediate ply member is sealed therebetween. In a further embodiment of the invention, the sandwich bellows construction is provided with a plurality of convolutions. This embodiment of sandwich bellows construction provides a continuous, leak tight convoluted bellows that forms an effective vibration damping bellows arrangement.</p>		

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## SANDWICH BELLOWS CONSTRUCTION

Background of the InventionField of the invention

5 This invention relates generally to the construction of a bellows that is typically used as a primary component of an expansion joint or flexible connector. More particularly, the present invention relates to a metal-elastomer-metal sandwich bellows construction.

Prior Art

10 Various types of bellows constructions have been previously advanced in the arts. For example, U.S. Patent 3,372,076 to Wilkinson issued March 5, 1968 shows a flexible bellows connection between two axially spaced members. The flexible bellows is provided with a sandwich construction with three layers. The inner layer  
15 of the sandwich comprises a first metal spring ring provided with a plurality of transverse slots. The transverse slots give the first metal spring ring flexibility so that it can be wrapped around a shaft. The outer layer of the sandwich bellows construction  
20 provides a second metal spring ring. Between the first metal spring ring and the second metal spring ring is a non-metallic sealing strip, which constitutes the intermediate layer of the sandwich. The sealing strip  
25 can consist of an extruded rubber or plastic section.

Although, the Wilkinson patent discloses a sandwich bellows construction consisting of two metal members disposed around an intermediate layer, the bellows is not convoluted. Moreover, the metal spring members are  
30 discontinuous members; that being, each of the members themselves is not leak tight. Thus, the intermediate layer is susceptible to deterioration from external contaminants. Furthermore, the ends of the intermediate layer are aligned beyond the ends of the first metal  
35 spring ring. This unenclosed alignment increase the intermediate layer's susceptibility to deterioration from external contaminants.

An alternative example of a bellows construction is provided in U.S. Patent 3,214,764 to Nelson et al. issued October 26, 1965. Nelson et al. also show a bellows construction with a three layer sandwich arrangement. However, only one of the layers in the bellows construction is metallic, and thus only one structural layer is provided. Therefore, the Nelson et al. bellows is extremely susceptible to damage from fatigue loading. Moreover, Nelson et al. disclose two separate non-metallic vibration damping layers that are individually bonded to the previous layer of the sandwich construction. This results in a manufacturing process that is labor-intensive, because each of the layers must be added in separate steps.

Furthermore, as with the bellows of Wilkinson, the bellows of Nelson et al. does not protect the non-metal vibration damping members from exposure to contaminants. Thus, the vibration damping members of Nelson et al. are subject to deterioration from contaminants passing through the device.

Additionally, U.S. Patent 3,800,398 to Harrington, Jr. issued April 2, 1974 teaches a method of forming a bellows having a concentrically spaced inner and outer ply. The bellows is formed from an initial bellows having concentrically inner, intermediate, and outer plies. However, Harrington, Jr. does not teach or suggest using the bellows that is used to form the final product in any manner. Moreover, the initial bellows used to form the end product of Harrington, Jr. does not employ a vibration damping material as the intermediate ply between the inner and outer plies.

#### Summary of the Invention

One objective of this invention is to provide a new and improved sandwich bellows construction that protects an intermediate layer from exposure to containments. This objective is achieved by sealing an intermediate ply of a sandwich bellows construction between first and second plies of the sandwich. This objective is further

achieved by providing an elastomeric core between the ends of the two metallic plies so that when the two metallic plies are joined together, in order to seal the elastomeric core therebetween, a gap is produced between the ends of the elastomeric core and the joined metallic plies. This arrangement further provides that the elastomeric core will be protected from deterioration from external contaminants.

Another objective of the present invention is to provide a sandwich bellows construction that maximizes fatigue resistance and that damps vibrations when the bellows is in use. This objective of the invention is achieved by providing a metal-elastomer-metal sandwich bellows construction. By providing the intermediate layer as an elastomeric member, the sandwich bellows produces particularly low-amplitude high-frequency vibration during operation, and thus reduces fatigue. Moreover, the metal-elastomer-metal bellows construction also provides a bellows with a low natural frequency, which reduces noise during shock loading and provides a stabilized support structure.

A further objective of the invention is to provide a sandwich bellows construction that uses thinner metal plies than conventionally used in typical metal bellows. Additionally, another objective of the invention is to provide a bellows construction which can be used at a higher pressure rating than conventional internally-reinforced elastomeric expansion joints. These objectives are achieved by providing a sandwich bellows construction with three layers. The layers comprise two outer metallic layers with a vibration damping material provided between the two outer metallic layers. By providing a bellows construction with a supportive damping material as the intermediate layer, the outer ply thickness can be reduced while the operational capacity of the device is improved over conventional bellows.

According to yet another aspect of the invention, a method for producing a sandwich bellows construction has

been provided. The method consists of aligning an elastomeric core in a sandwiched orientation between two metallic plies. The method further provides that the elastomeric core along with the two metallic plies are provided with at least one convolution by conventional bellows forming equipment. The method also provides that the convolutions in the elastomeric core and the two metallic plies are formed in a simultaneous manner. Thus, the method of the present invention produces a metal-elastomer-metal sandwich bellow construction in an efficient manner.

Additional objectives and advantages of the invention will be set forth in the description that follows, and in part will be obvious from the description or may be learned by practice of the invention. The objects and advantages of the invention may be realized and obtained by means of the instrumentalities and combinations particularly pointed out in the appended claims.

#### Brief Description of the Drawings

The accompanying drawings, which are incorporated and constitute a part of the invention, illustrate a presently preferred embodiment of the invention, and together with the general description given above and the detailed description of the preferred embodiment given below, serve to explain the principles of the invention. As discussed above, the present invention explains more fully with reference to the accompanying figures in which:

Fig. 1 is a cross-sectional view of the sandwich bellows construction of the present invention; and

Fig. 2 is an exploded view of the encircled portion A shown in Fig. 1.

#### Detailed Description of the Preferred Embodiments

Referring to Fig. 1, an expansion joint is shown. The expansion joint includes a flexible bellows disposed between a first flange 12 and a second flange 14. The first flange 12 and the second flange 14 are used to connect the expansion joint to two axially spaced

pipes (not shown in the figures). In order to form this connection, the flanges are provided with holes 13. The flexible bellows 10 is provided with a sandwich construction, as will be discussed below in detail. Moreover, the flexible sandwich bellows 10 is provided with a plurality of convolutions 16. Each of the convolutions has a crown 18 and a crest 20.

As shown in the preferred embodiment, the crest 20 of the convolutions 16 has a larger radius of curvature than the radius of curvature of each of the crowns 18 for the associated bellows. This is because the sandwich bellows 10 of the present invention can be formed in a conventional bellows-forming unit. Although, the crests 20 in the preferred embodiment are provided with a larger radius of curvature than the crowns 18, the convolutions can be formed so the crowns 18 have a larger radius of curvature than the crests 20, or with an equal radius of curvature to the crests 20.

As shown in Fig. 2, the sandwich bellows construction is provided with three separate layers. A first ply 22, a second ply 26, and a third ply 30. When installed in an operative environment between two axial spaced pipes, the first ply 22 and the second ply 26, respectively, act as the inner and outer plies of the bellows construction. Accordingly, during operation of a pipeline, the first ply 22 is in contact with the service fluid passing through the expansion joint, and the second ply 26 is in contact with the atmosphere. Because each of the first ply 22 and second ply 26 is a continuous member, the sandwich bellows construction 10 is leak tight. By providing plies that are continuous means that each of the plies itself is a member without any axial or longitudinal spaces providing therein.

Moreover, when the sandwich bellows construction is installed in an operative arrangement, the bellows act as a flexible sealing member between the two axially spaced members. Although, shown between two flanges that are typically connected to the flanges of two axial spaced

pipes, it is to be understood that the sandwich bellows construction of the present invention can be employed between any axial spaced members that require a flexible seal therebetween.

5           In the preferred embodiment shown in Fig. 2, the first and second plies 22 and 26 are metallic, while the intermediate ply consists of an elastomeric member. Any material suitable for the intended operation environment can be used to create the metallic plies. For example,  
10           the metallic plies may be selected from the group of metals consisting of stainless steel, monel, or high-nickel alloy. Furthermore, it is to be understood that the metallic plies can constitute the same metal or different metals. Moreover, while in the preferred  
15           embodiment the intermediate ply 30 is shown as an elastomeric member, the intermediate ply could also be metallic in a similar manner as the first and second plies 22 and 26.

          As stated above, in the preferred embodiment, the  
20           intermediate ply member 30 is an elastomeric member. By providing the intermediate ply as an elastomeric member, the sandwich bellows 10 contains a self-vibration reducing feature. That being, the use of the elastomeric member helps create a sandwich bellows construction that  
25           provides a low natural frequency when compared to a sandwich bellows construction of all metal. Moreover, use of the elastomeric member in combination with the two metallic plies provides a sandwich bellows construction that permits higher pressure ratings than typically  
30           available with conventional expansion joints.

          In the preferred embodiment, the elastomeric member is a core made of synthetic rubber. The rubber can be selected from a group of materials comprising ethylene-propylene-diene, butyl, neoprene, fluoroelastomer,  
35           silicone, and expanded polytetrafluoroethylene. The elastomeric core may be provided in a cured or uncured manner. Moreover, the elastomeric core may also be bonded or not bonded to the first and second metal plies.

By providing the elastomeric core in an unbonded configuration, the elastomeric core is freely moveable relative to the first and second plies. This feature assists in the damping of the sandwich bellows.

5           As shown in Fig. 2, the first ply 22 is provided with an end 24. Moreover, as with the first ply, the second ply 26 includes an end 28. The ends 24 and 28 are joined together so that the intermediate ply 30 is sealed between the first ply 22 and the second ply 26. It is to  
10 be understood that the first ply 22 and the second ply 26 have other ends similar to the ends shown in the enlarged circle A.

          The end portion of first ply 22 is expanded so that its end 24 aligns with the end 28 of the second ply 26.  
15 These two ends 24 and 28 can be connected together by any suitable connection method. In the preferred embodiment, these two ends are welded together. By joining the two ends in the manner shown in Fig. 2, a gap 34 is developed between the end 32 of the intermediate ply 30 and the two  
20 joined ends 24 and 28. This gap provides the necessary space for the intermediate ply 30 to move during loading conditions. By providing this internal space, the intermediate ply provides effective vibration damping for the bellows construction. Furthermore, by sealing the  
25 two respective ends of the first ply 22 and the second ply 26, the intermediate ply 30 is protected from any external contaminants. Thus, when, as shown in the preferred embodiment, the intermediate ply is an  
30 elastomeric member, this member is fully protected and not subject to deterioration from external contaminants. Accordingly, the sandwich bellows construction 10 of the present invention provides a bellows with a long operative life when compared to the previously discussed bellows arrangements.

35           Although, shown in Fig. 2, the two ends of the first ply 22 and the second ply 26 have been joined so that the ends are aligned along an oblique plane, the ends can be joined in any manner. Any type of connection between the

two plies can be employed as long as the intermediate ply member is sealed therebetween. For example, a secondary connection member could be provided between the two ply members. Furthermore, each of the ends of the first and second plies could be folded, and then, the plies joined to one another.

The sandwich bellows construction of the preferred embodiment is formed by conventional bellows forming equipment. As an initial step in creating the sandwich bellows construction, the first, the second, and the intermediate plies are formed into a geometric arrangement. In the preferred embodiment, the geometric arrangement is a circular tube, i.e. a cylinder with open ends. However, it is to be understood, that any configuration could be employed, such as square or triangular when forming the tube. However, because typically, pipes are provided in a circular configuration, in creating the preferred embodiment, the plies are formed into a circular tubular configuration. The tubes are formed from rectangle sheets of material that is used to form the plies. Once the tubular configurations for each of the ply members is formed, the plies are aligned such that the intermediate ply, which in the preferred embodiment is elastomeric core, is installed between the first ply and the second ply. Thus, the sandwich arrangement is created. After the sandwich arrangement is created, a conventional bellows forming machinery is used to simultaneously form convolutions in the three aligned members.

A further step in the method of forming the sandwich bellows construction is to join the ends of the first and second ply as discussed above. While joining the ends of the first and second plies, the intermediate ply is aligned therebetween such that a gap is formed between the ends of the intermediate ply and the ends of the first and second plies.

The sandwich bellows construction of the present invention can be formed with diameters ranging from 1

inch to 200 inches. When forming the sandwich bellows construction, the first and second plies are preferably metallic in structure. These metallic plies have a thickness in the range of 10 to 100 millionths of an inch. As discussed above, in the preferred embodiment, the intermediate ply is an elastomeric member. This elastomeric member is usually provided with a thickness in the range of 10 to 250 millionths of an inch. By providing the plies of the sandwich bellows construction with these structural dimensions, a sandwich construction is created that is stronger than previously known. Moreover, the sandwich bellows construction of the present invention can be attached to any type of pipe because of the joined ends of the first and second plies. That being, a pipe with welded end flanges and/or vanstoned ends.

Additional advantages and modifications will readily occur to those skilled in the art. Therefore, the invention in its broadest aspects is not limited to the specific details and the representative device, shown and described herein. Accordingly, various modifications may be made without departing from the spirit or scope of the general inventive concept as defined by the appended claims and their equivalents.

What Is Claimed Is:

1. A sandwich bellows construction, comprising:  
an first ply including two ends;  
an second ply including two ends, said second ply being concentric with and radially spaced from said first ply; and

an intermediate ply disposed between said first ply and said second ply;

wherein said two ends of said first ply are respectively joined with said two ends of said second ply so that said intermediate ply is sealed between said first ply and said second ply.

2. A sandwich bellows construction as recited in claim 1, wherein said first ply and said second ply comprise a metallic ply, and said intermediate ply comprises a non-metallic ply.

3. A sandwich bellows construction as recited in claim 2, wherein said metallic ply comprises a material selected from the group consisting of stainless steel, monel, and high-nickel alloy.

4. A sandwich bellows construction as recited in claim 2, wherein said non-metallic ply comprises an elastomeric member.

5. A sandwich bellows construction as recited in claim 4, wherein said elastomeric member is movable relative to said first ply and said second ply.

6. A sandwich bellows construction as recited in claim 4, wherein said elastomeric member comprises a synthetic rubber.

7. A sandwich bellows construction as recited in claim 6, wherein said synthetic rubber comprises a material selected from the group consisting of ethylene-propylene-dilene, butyl, neoprene, fluoroelastomer, silicone, and expanded polytetrafluoroethylene.

8. A sandwich bellows construction as recited in claim 2, wherein said first ply, said second ply, and said intermediate ply are convoluted.

9. A sandwich bellows construction as recited in claim 1, wherein one of said two ends of said first ply and said two ends of said second ply are expanded so that said two ends of the first ply and said second ply have a substantially uniform longitudinal length.

10. A sandwich bellows construction as recited in claim 1, wherein said joined two ends of said first ply and said two ends of said second ply are respectively spaced from two ends of said intermediate ply.

11. A sandwich bellows construction as recited in claim 1, wherein said two ends of said first ply are respectively joined to said two ends of said second ply by a weld.

12. A sandwich bellows construction as recited in claim 1, wherein said respectively joined two ends of said first ply and said two ends of said second ply are each separately joined to a flange to form an expansion joint.

13. A sandwich bellows construction, comprising:  
a first convoluted metallic ply;  
a second convoluted metallic ply concentric with and radially spaced from said first convoluted metallic ply; and  
an intermediate convoluted elastomeric member disposed between said first metallic ply and said second metallic ply.

14. A sandwich bellows construction as recited in claim 13, wherein said first convoluted metallic ply and said second convoluted metallic ply comprise a material selected from the group consisting of stainless steel, monel, and high-nickel alloy.

15. A sandwich bellows construction as recited in claim 13, wherein said convoluted elastomeric member is detached from said first metallic ply and said second metallic ply.

16. A sandwich bellows construction as recited in claim 13, wherein said convoluted elastomeric member comprises a synthetic rubber material selected from the

group consisting ethylene-propylene-dilene, butyl, neoprene, fluoroelastomer, silicone, and expanded polytetrafluoroethylene.

17. A sandwich bellows construction as recited in claim 13, wherein said first convoluted metallic ply, said second convoluted metallic ply, and said intermediate convoluted elastomeric member are circular in cross-section with diameters in the range of 1 inch to 200 inches.

18. A sandwich bellows construction as recited in claim 13, wherein said first convoluted metallic ply, and said second convoluted metallic ply has a thickness in the range of 10 to 100 millionths of an inch, and said intermediate convoluted elastomeric member has a thickness in the range of 10 to 250 millionths of an inch.

19. A method of forming a bellows, comprising the steps of:

aligning an elastomeric core in a sandwiched orientation between two metallic plies; and

forming at least one convolution, simultaneously, in said elastomeric core and said two metal plies.

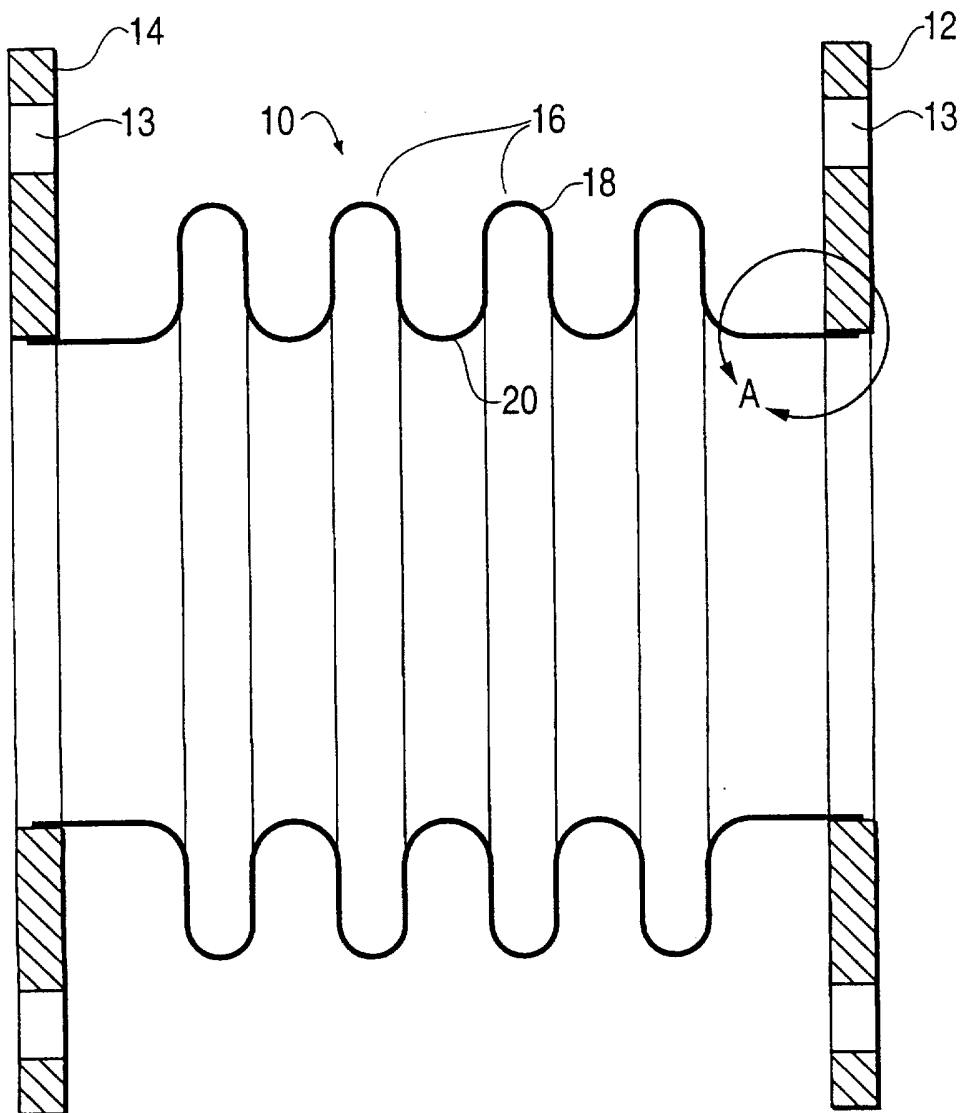
20. The method of claim 18, further comprising the step of:

sealing said elastomer core between said metallic plies by joining respective ends of said metallic plies.

21. The method of claim 19, further comprising the step of:

aligning said elastomeric core between said respectively joined ends so a gap is provided between each of said joined ends and ends of said elastomeric core.

**FIG. 1**



**FIG. 2**

