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[45] **July 15, 1975**

[54] **ROPE SEALING MEANS**

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[73] Assignee: **Hitco**, Irvine, Calif.

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[52] **U.S. Cl.** **277/203**; 277/204; 277/229; 156/190; 156/194; 156/195; 161/47; 161/148; 29/191; 29/191.6

[51] **Int. Cl.** **F16j 15/00**

[58] **Field of Search** 161/47, 70, 89; 156/190, 156/194, 195; 29/191, 191.6; 277/203, 204, 229, 230, 233, 234

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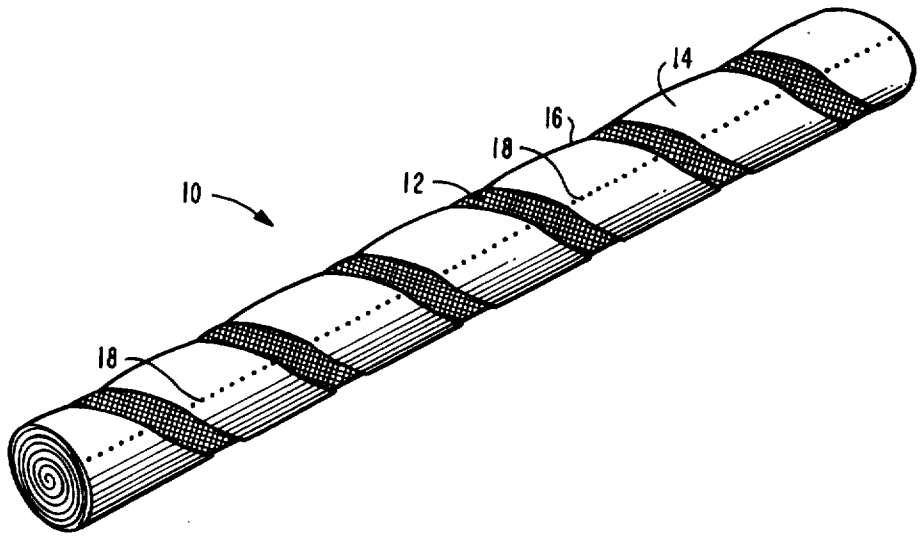
[57] **ABSTRACT**

A flexible, resilient, and deterioration-resistant seal is provided for use at high temperatures and pressures. A core of resilient mesh material is enveloped by covering means comprising inner and outer spirally wound strips of thin metallic foil. The inner strip comprises a spiral winding disposed upon the core, and the outer strip comprises a spiral winding disposed upon the inner strip core combination so that gaps left by the winding of the inner strip element are covered. The outer cover strip is affixed to the inner strip by a series of spot welds positioned so as to preserve flexibility of the seal in desired directions and to produce a desired shape of seal. The cover element may also comprise a single spiral winding disposed upon the core so as to leave related portions of the core exposed to fluid flow, thus maximizing resiliency of the seal.

A method is provided for fabricating flexible, resilient seals comprising feeding a thin roll of mesh through an orifice in a conical mandrel, upon which is disposed a continuous winding of flexible cover material. As the mandrel rotates about its axis the mesh material is fed through, and the flexible material is wound thereon to form a cover.

18 Claims, 10 Drawing Figures



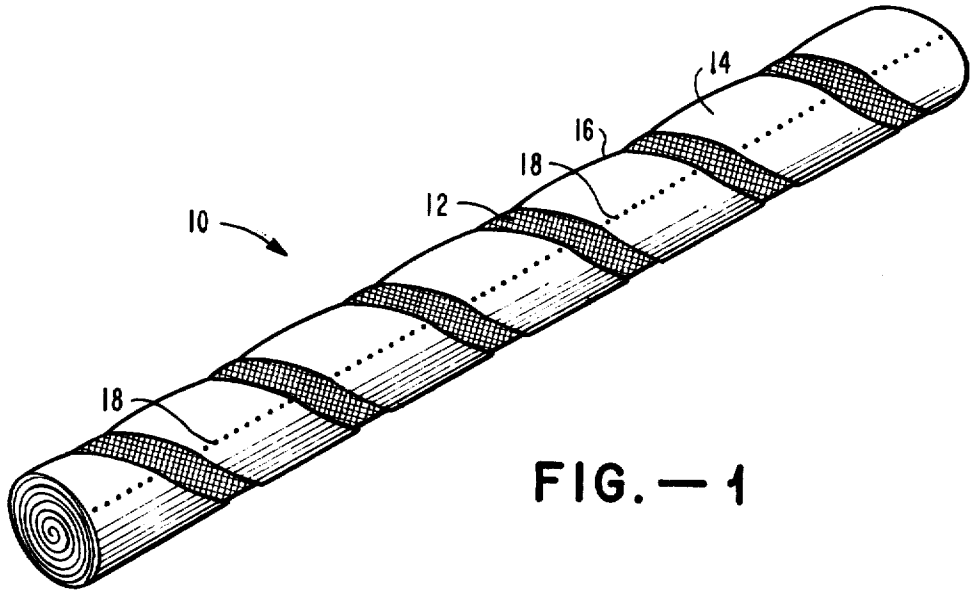


FIG.—1

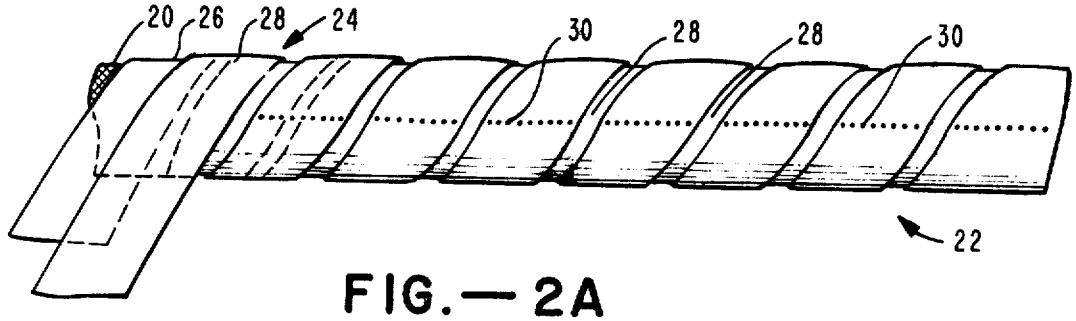


FIG.—2A

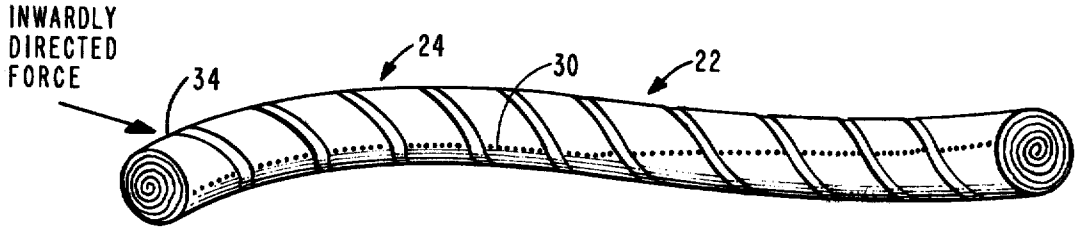


FIG.—2B

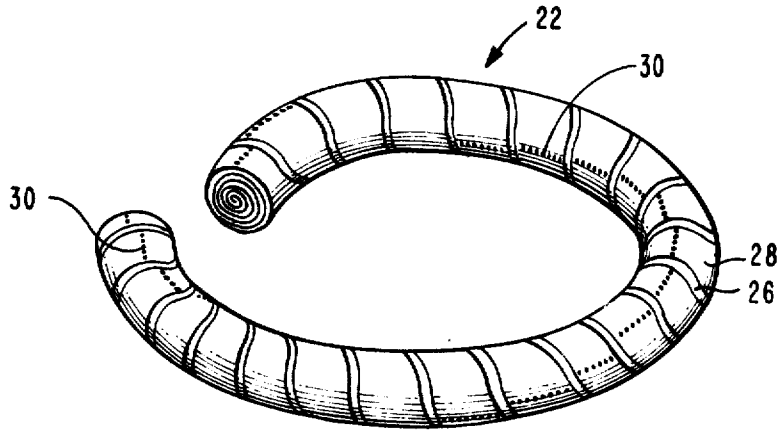


FIG. — 2C

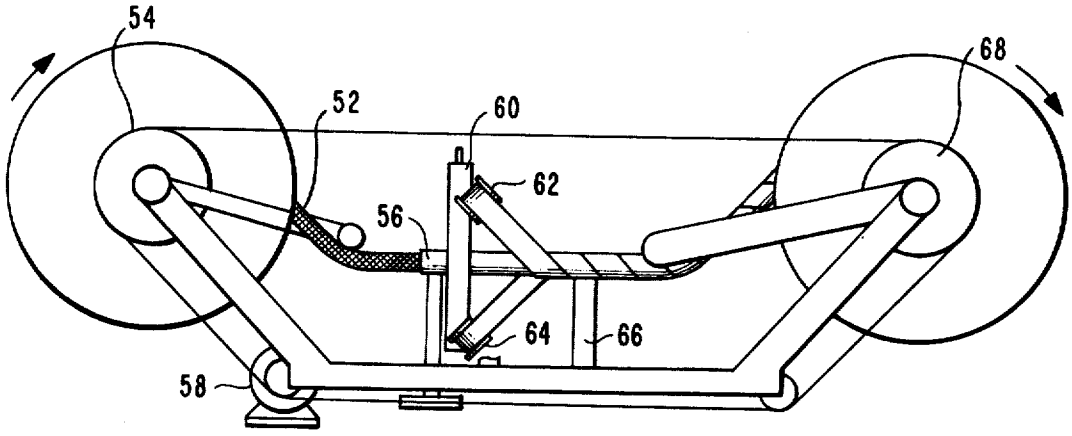


FIG. — 5

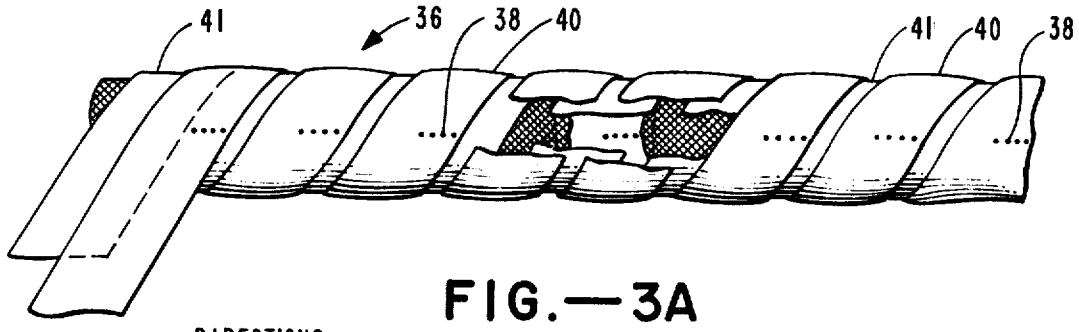


FIG.—3A

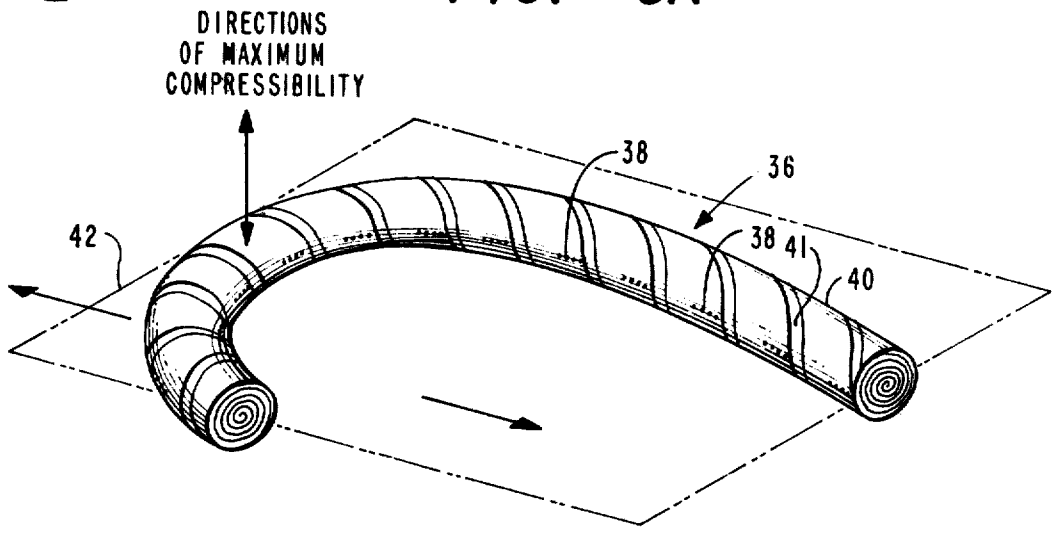


FIG.—3B

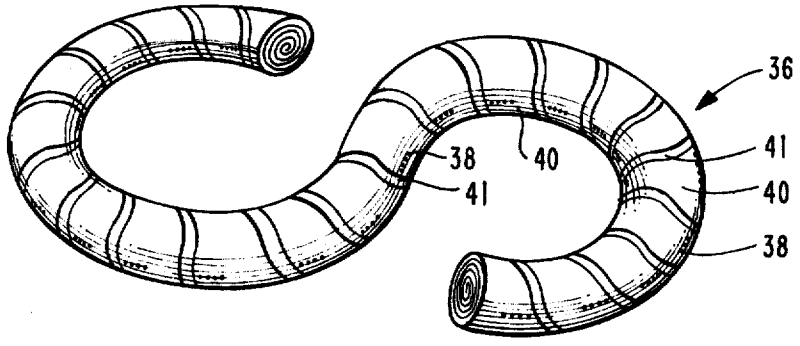


FIG.—3C

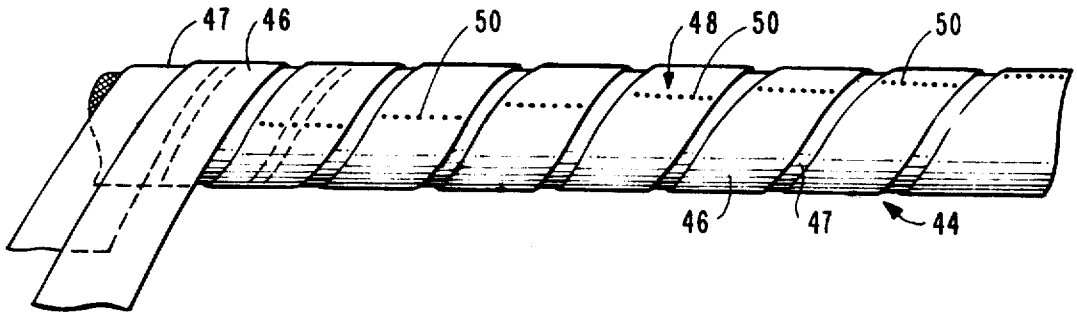


FIG. — 4A

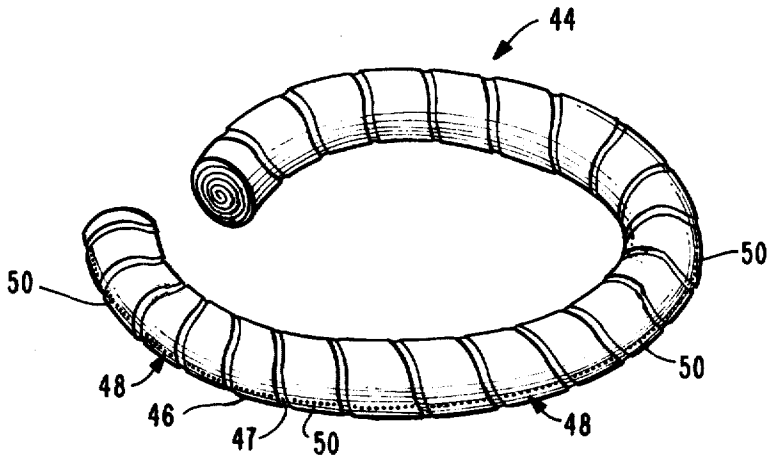


FIG. — 4B

ROPE SEALING MEANS

BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention concerns itself with flexible, resilient seals capable of operation at elevated temperatures and pressures and with methods of fabricating such seals.

2. Description of the Prior Art

There is an ever-increasing demand for seals which combine high temperature and high pressure operational capabilities with flexibility and resiliency. In jet engines, for example, where combustion occurs in, and exhaust emanates from, separate power chambers which align with one another, many such seals, commonly called "rope seals," are employed between and within the chambers. Existing seals, though performing satisfactorily for relatively short times, exhibit critical deterioration with use. It has been found in typical instances that such seals actually disintegrate over time. This presents a particularly serious problem because existing seals are generally fabricated of fibrous materials, primarily asbestos, and recent research has disclosed that asbestos dust is a strong carcinogenic agent. Thus, the dust expelled from jet exhausts due to deteriorating seals not only pollutes the atmosphere with particulates but with carcinogenic agents as well. Problems of fabrication have, however, precluded use of other, more durable materials, particularly of a metallic character.

Moreover, in jet engines, surfaces with which seals are made are often easily abraded, particularly at the high temperatures and pressures at which such engines operate. Consequently, a critical requirement for such seals has been that of soft sealing to provide a resilient, non-abrasive contact. Existing seals composed of materials such as high temperature elastomers, though somewhat resilient, tend to lose resiliency as temperature increases to solidify the material.

Consequently, there has been a recognized but unfulfilled need for flexible, resilient seals capable of operating at high temperatures and pressures without substantial deterioration and without polluting effects.

SUMMARY OF THE INVENTION

Rope sealing means in accordance with the invention comprise a resilient core or inner element sheathed by a covering element of high-temperature-resistant metal comprising one or more thin strips. Where the cover element comprises two cover strips a first or inner cover strip is spirally wound about the core and joined to a second or outer cover strip at a joinder locus comprising a series of weld points or regions positioned to provide flexibility in selected directions and to provide a desired shape of seal. In embodiments utilizing a single cover strip, the strip is disposed in a spiral upon the core leaving selected portions thereof exposed to fluid flow and may be joined to the core in a manner providing flexibility and desired shape.

An aspect of the invention is the possibility which it affords of providing controllably variable resiliency through controlling leakage. This control is provided by the arrangement of the cover element. When the cover element is arrayed so that selected fractions of the surface of the interior core are exposed to flow, controlled leakage is permitted and resiliency is promoted. Alternatively, the cover element may completely enclose the core and substantially eliminate leakage.

A further aspect of the invention is in the control of shape and flexibility provided by the relation of the cover element to the core. In a particular example, in which the joinder points are substantially coplanar, the seal is substantially compressible in a first plane perpendicular to the cover and including the joinder line and in a second plane perpendicular to the first and to the cover element. When bent within the joinder plane, the seal tends to form a spiral; the seal is also deformable into a planar curvilinear form. Another exemplary embodiment having a spiral array of joinder points, whose locus precesses by a substantially constant applied displacement with respect to a reference plane, tends to a linear form and can be readily deformed to circular or other curvilinear forms.

In accordance with the invention, a method is provided for fabricating resilient, flexible rope sealing means capable of use under conditions of elevated temperature and pressure. A spool of metallic foil covering material mounted on a conical rotating mandrel is wound about lengths of core material passing through an opening at the apex of the cone. A second spool may be utilized to provide a second cover element for forming a relatively tight seal. The core and cover elements are then joined at a substantially coplanar array of join points by spot welding or other means. Alternatively, the core element may be directed into an interior volume defined by a wound length of cover element material and joined thereto.

An aspect of the method is that the degree of curvature of the sealing means produced can be controlled through controlling the pitch of the winding of the cover elment.

DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view of sealing means having a single cover strip in accordance with the invention;

FIG. 2A is a perspective view of sealing means, partially disassembled, having a double cover element and a particular pattern of joinder points in accordance with the invention;

FIGS, 2B and 2C are perspective views, somewhat simplified, of the sealing means of FIG. 2A showing details of deformability thereof;

FIG. 3A is a perspective view of sealing means, partially disassembled, having a double cover element and a second particular pattern of joinder points in accordance with the invention;

FIGS. 3B and 3C are perspective views of the sealing means of FIG. 3A showing details of deformability thereof;

FIG. 4A is a perspective view of sealing means having a double cover element and a further particular pattern of joinder points in accordance with the invention;

FIG. 4B is a perspective view of the sealing means of FIG. 4A showing details of deformability thereof; and

FIG. 5 is a plan view of apparatus used in one method of fabricating rope seals in accordance with the invention.

DETAILED DESCRIPTION OF THE INVENTION

As depicted in FIG. 1, rope sealing means in accordance with the invention includes an elongated, cylindrical inner element or core 12 which is resilient and need not have any substantial sealing properties. Pref-

erably, the core **12** is permeable to fluid flow. As depicted, the core **12** comprises a substantially helically wound complex of layers of wire mesh. Other configurations are, of course, possible in accordance with the invention.

Sheath, cover or envelope means **14** envelop the core **12.** The cover means **14** comprises a single covering element **16** in the embodiment of FIG. **1** though, as noted below, in certain embodiments use of more than one cover element may be appropriate. The single covering element **16** of FIG. **1** comprises a substantially continuous thin metal strip helically wound about the core **12.** The pitch of the winding of the cover element **16** is determined by the degree of curvature of the finished seal desired as well as the amount of the surface of the interior element **12** which is to be left uncovered. The seal **10** depicted has relatively small curvature. In accordance with the invention, seals may have curvatures as dictated by manufacturing convenience, conditions of use, or other factors.

Cover means **14** is affixed and sealed to the core **12** by a succession of spot welds at joinder points **18.** Placement of points **18** is selected to promote flexibility. As depicted, for example, points **18** have a locus such that they are substantially coplanar with respect to a plane perpendicularly intersecting the seal **10.** This placement provides desirable rigidity of the cover core structure in the plane of the welds while preserving desirable flexibility in a plane perpendicular to the plane as is more fully discussed below in conjunction with FIG. **2.** Thus, the seal may be disposed in many orientations and conditions in which it will adapt to the contours of the surfaces against which it must seal. The core **12** and the element **16** may be composed of stainless steel or "inconel", a nickel-chromium-iron alloy sold under that name by International Nickel Co., or other metallic material having suitable strength and temperature resistance.

In many applications, for which leakage may be tolerable or desirable (to minimize rigidity due to internal pressurization of the seal) only a single cover element is needed. For use in contexts in which substantially tight or leakproof sealing is required, the embodiments depicted in FIGS. **2, 3** and **4** are appropriate.

In the embodiment of FIG. **2A**, a core **20** of a seal **22** is enveloped by a cover element **24** comprising first and second cover strips **26, 28,** respectively. The cover strips **26, 28** cover the core **20** substantially completely. The first or inner cover strip **26** is disposed substantially helically upon the core **20.** The second cover strip **28,** substantially helically wound about the core **20,** is joined to the first cover strip **26** through spot welds at a series of substantially coplanar join points **30** whose locus comprises a weld line disposed along one side of the core **20.** Thus, a structure is formed which provides variable slidability of cover strips **26, 28** upon each other at all points except the weld line **30** and thus provides substantial flexibility and a useful shape for the seal **22.** The ends of the cover elements **26, 28** may be left open or sealed together, as in the previously discussed embodiment.

As shown in FIG. **2B**, the seal **22** is readily bent into, and in practice tends to assume the form of a spiral. The weld line **30** is disposed upon the inner, concave portion of the spiral. Resilient compressibility is primarily in directions perpendicular to a plane intersecting the cover element **24** at right angles and including the weld line **30,** though, of course, there is limited compressibility at other points and in other directions with a minimum in the radial direction at the weld line **30.** Specifically, there is somewhat limited compressibility under force, indicated by an arrow, applied in the inward direction to the cover element **24** at a location **34,** 180° removed from the weld line **30.** Displacement of the weld line **30** by 180° results in compressibility in the opposite sense.

Because of the location of the join points **30,** the seal **22** resists bending into a circular configuration. However with some force applied, the seal **22** will assume a curved configuration as shown in FIG. **2C.** When in such a configuration, the seal **22** is distorted to a certain extent as evidenced by the fact that the join points **30** on the cover strip **28** are no longer coplanar but rather define lines which successively advance around the axis of the seal **22** from one end of the seal to the other. Because of the distortion undergone by the seal **22** when in a circular configuration, it may be desirable for certain applications of the seal to utilize the embodiments of FIGS. **3** and **4** which minimize or eliminate such distortion.

FIG. **3A** depicts a seal **36** having a discontinuous locus of joinder points **38** comprising coplanar weld lines rotated by 180° on successive half-turns of an outer cover strip **40.** In another view, the weld pattern comprises two separate weld lines displaced by 180° from each other and broken symmetrically about the midpoint of each turn of the cover element **40.** An inner cover strip **41** is helically wound so that the edges thereof fall at about the midpoint of each turn of the core element **40.** Thus, the two half weld lines for each turn of the outer cover strip **40** couple the outer strip to successive turns of the inner strip **41.**

As shown in FIG. **3B**, the seal **36** can be deformed curvilinearly so that the perimeter boundaries of longitudinal sections of the seal are in a plane; that is, so that the deformed seal can rest upon a planar surface with a line along the perimeter extending throughout the length of the seal in contact with the plane. The seal **36** is compressible in both the inward and outward senses because of the symmetrical nature of the joinder locus **38,** as well as maximally compressible in the direction of a line perpendicular to a plane **42** including the joinder locus **38.**

FIG. **3C** depicts seal **36** in still another configuration into which it can be deformed, an S form. In this form, seal **36** retains the property of having perimetral lines in a simple plane exhibited by the seal **22** in the curved configuration of FIG. **2.** This provides a further illustration of the versatility of seals in accordance with the invention, which can be utilized under extremely diverse types of constraints.

FIG. **4A** depicts a seal **44** having outer and inner cover elements **46** and **47** respectively, the outer element **46** having a spiral locus **48** of joinder points **50** disposed thereon. For each turn of the cover element **46** the locus **48** traverses or precesses an angle or $360°/n$, where n is the number of turns per 360° displacement of the cover element **46.** The character of the joinder locus **48** in the seal **44** produces a seal which has a substantially rectilinear form in the undeformed state. However when deformed curvilinearly as shown in FIG. **4B** the spiral locus **48** becomes linear such that all of the joinder points **50** lie in a common plane. This embodiment of the invention is particularly

versatile and can be used in conjunction with extremely many variations of geometric and physical constraints.

FIG. 5 illustrates apparatus used in a method for fabricating seals in accordance with the invention. The process may be conveniently implemented as shown by unwinding a length of core material 52 disposed upon a spool 54 and directing the unwound core material to a hollow shaft 56. The assembly is powered by a spooler drive 58.

Conventional counterweighting of the spool may be employed to prevent undue vibration as the quantity of core material carried by the spool diminishes. The shaft 56 exits at an orifice defined at the apex of a rotatable conical winding means 60 powered by the spooler drive 58. Spools 62, 64 upon which are wound spools of foil strips are mounted radially opposite each other upon the winding means 60. As the winding means 60 rotates, the foil stripping from spools 62, 64 is wound about the core material 52 as it exits the shaft 56. As shown, the strips from the respective spools are laid down substantially 180° out of phase with each other. Other phase relationships are possible in accordance with the invention and, as noted above, in accordance with the invention there may be only one foil covering element and thus there may be only one spool rather than two.

The foil-core combination then passes to joining means 66 for joining by spot welding or other means. The combination passes to a takeup spool 68 for storage or other disposition. The core-cover combination may be cut into separate lengths as desired. The cover element may be caused to overlap the ends of the core to permit sealing of the device by fastening together the cover element ends, by cutting out portions of the core or by other conventional means.

Alternatively, in accordance with the invention, the core material 52 may be directed into the interior volume defined by prewound welded foil stripping as an alternative to winding the foil about the core material as described.

While the invention has been particularly shown and described with reference to preferred embodiments thereof, it will be understood by those skilled in the art that the foregoing and other changes in form and details may be made therein without departing from the spirit and scope of the invention.

What is claimed is:

1. A flexible sealing device usable in conjunction with fluid flows at elevated temperatures and pressures without deterioration comprising:
resilient core means; and,
a covering element comprising a cover strip impermeable to fluid flow and disposed over at least portions of the core element and fastened thereto at a plurality of spaced-apart, substantially coplanar joinder points.

2. The invention as set forth in claim 1 wherein the cover strip comprises metallic foil disposed in a continuous spiral about the core element at a selected pitch to leave a selected proportion of the core element means exposed to fluid flow.

3. The invention as set forth in claim 2 wherein said core means is comprised of metallic mesh and the metallic foil is welded to the mesh at each of the joinder points.

4. The invention as set forth in claim 1 wherein the cover element includes a second cover strip, disposed over the first-mentioned cover strip and the core means so that substantially all of the core means is covered and fastened to the first-mentioned cover strip at a plurality of spaced-apart joinder points substantially coplanar with the joinder points between the first-mentioned cover means and the core element.

5. The invention as set forth in claim 1 wherein the cover strip has an arcuate contour and wherein the join points are substantially all included in a plane parallel to a plane perpendicularly intersecting the core element means.

6. A high temperature, high pressure, flexible rope seal comprising:
a resilient, high-temperature resistant core; and
a cover element comprising a first cover strip covering at least portions of said core and a second cover strip disposed upon the first cover strip and the core and joined to the first cover strip at a plurality of spaced-apart, substantially coplanar joinder points.

7. The invention as set forth in claim 6 wherein the core has an arcuate shape and wherein the locus of the joinder points is substantially a line along the concave side of the core.

8. The invention as set forth in claim 6 wherein the core has an arcuate contour and wherein the locus of the joinder points is substantially a line along the convex side of the core.

9. The invention as set forth in claim 8 wherein the core comprises a plurality of layers of wire mesh spirally wound into a generally cylindrical elongated shape.

10. A flexible seal comprising:
a flexible core;
a cover element including an inner cover means and an outer cover means disposed upon the core, the inner and outer cover means being slideable with respect to each other to permit deformation of the seal and being joined to each other at joinder points selectively positioned to provide flexibility in selected directions.

11. The invention as set forth in claim 10 wherein the inner and outer cover means are spirally wound in a plurality of turns upon the core, and the joinder points have a locus of substantially two lines displaced at 180° from each other and are interrupted at alternate turns of the second cover means substantially symmetrically about the midpoint of each turn of the outer cover means.

12. The invention as set forth in claim 11 wherein the cover means are disposed so that the boundary edges of each turn of the outer cover means fall at approximately the midpoints of each turn of the outer cover means.

13. The invention as set forth in claim 10 wherein the first and second cover means are spirally wound upon the core, and the joinder points have a locus of substantially spiral shape.

14. The invention as set forth in claim 13 wherein the spiral locus of the joinder points traverses substantially equal angular displacements for every turn of the second cover means.

15. A seal comprising the combination of a resilient core comprised of mesh having a high resistance to deterioration due to high temperatures and pressures and wound into a generally cylindrical, elongated shape, and at least one cover element of material having a high

resistance to deterioration due to high temperatures and pressures, the cover element being disposed upon the core.

16. The invention as set forth in claim **15**, wherein the mesh is made of metal.

17. The invention as set forth in claim **15**, wherein the cover element is made of metal foil.

18. The invention as set forth in claim **15**, wherein the mesh is made of metal, the cover element is made of metal foil, and the cover element is spot welded to the mesh at a plurality of spaced-apart points.

* * * * *