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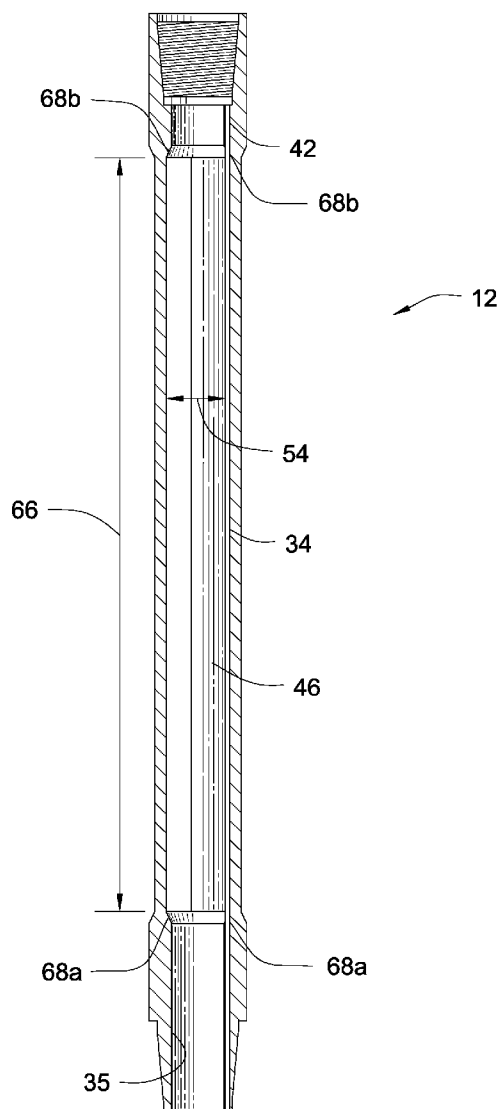
(52) U.S. Cl. **166/380**; 166/242.1; 175/320

(57) **ABSTRACT**

A liner insertable into the central bore of a downhole tool includes a resilient material rolled into a substantially cylindrical shape. The outside diameter of the liner is variable to allow the liner to be inserted into a narrowed bore of the downhole tool near the box end or pin end. Once past the narrowed bore, the outside diameter of the liner self-expands within the central bore of the downhole tool. The outside diameter of the liner may expand to contact the inside surface of the central bore. In selected embodiments, a transmission line may be routed between the central bore and the outside diameter of the resilient material. The liner may be effective to protect the transmission line from materials traveling through the central bore.

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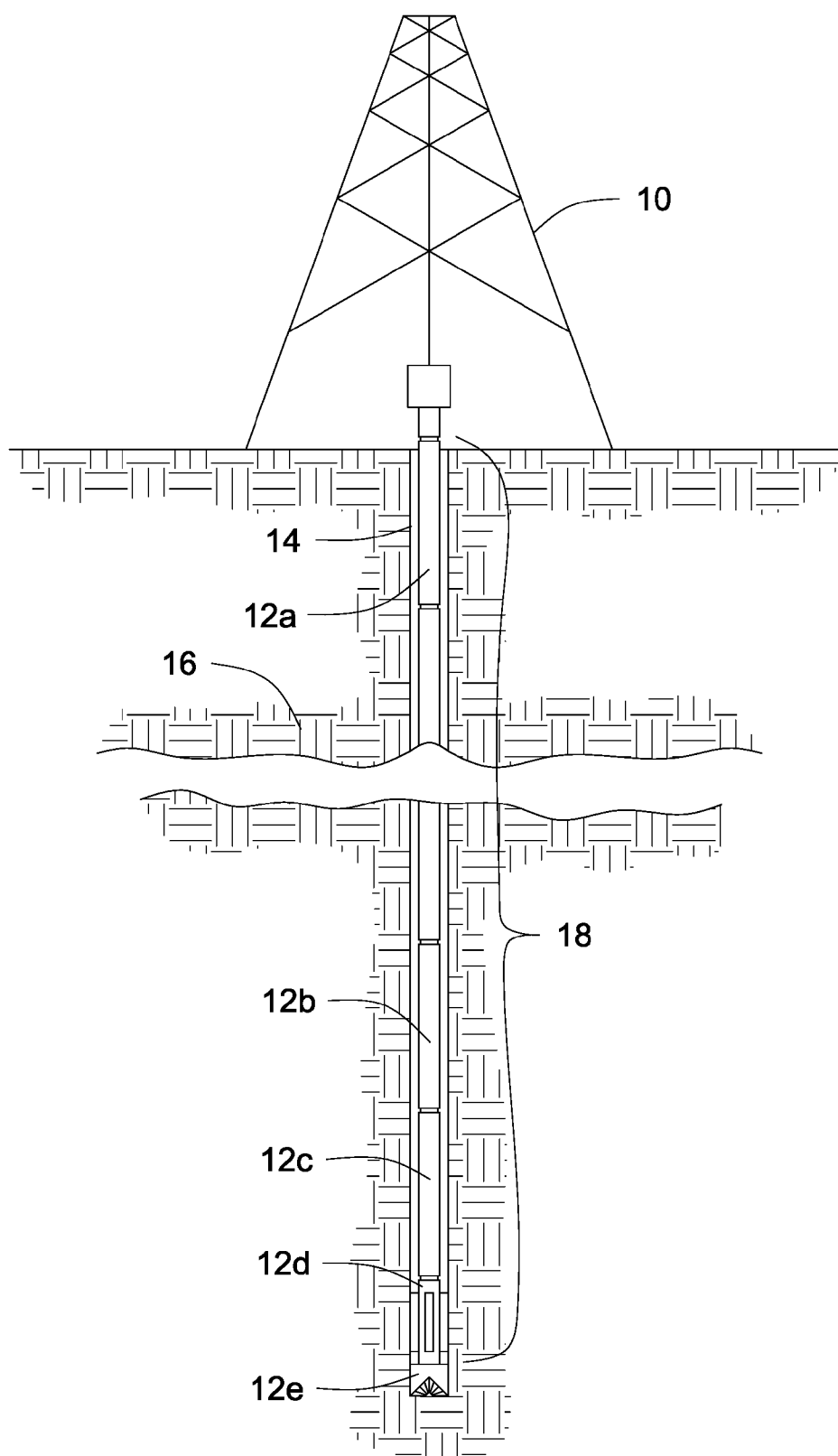


Fig. 10

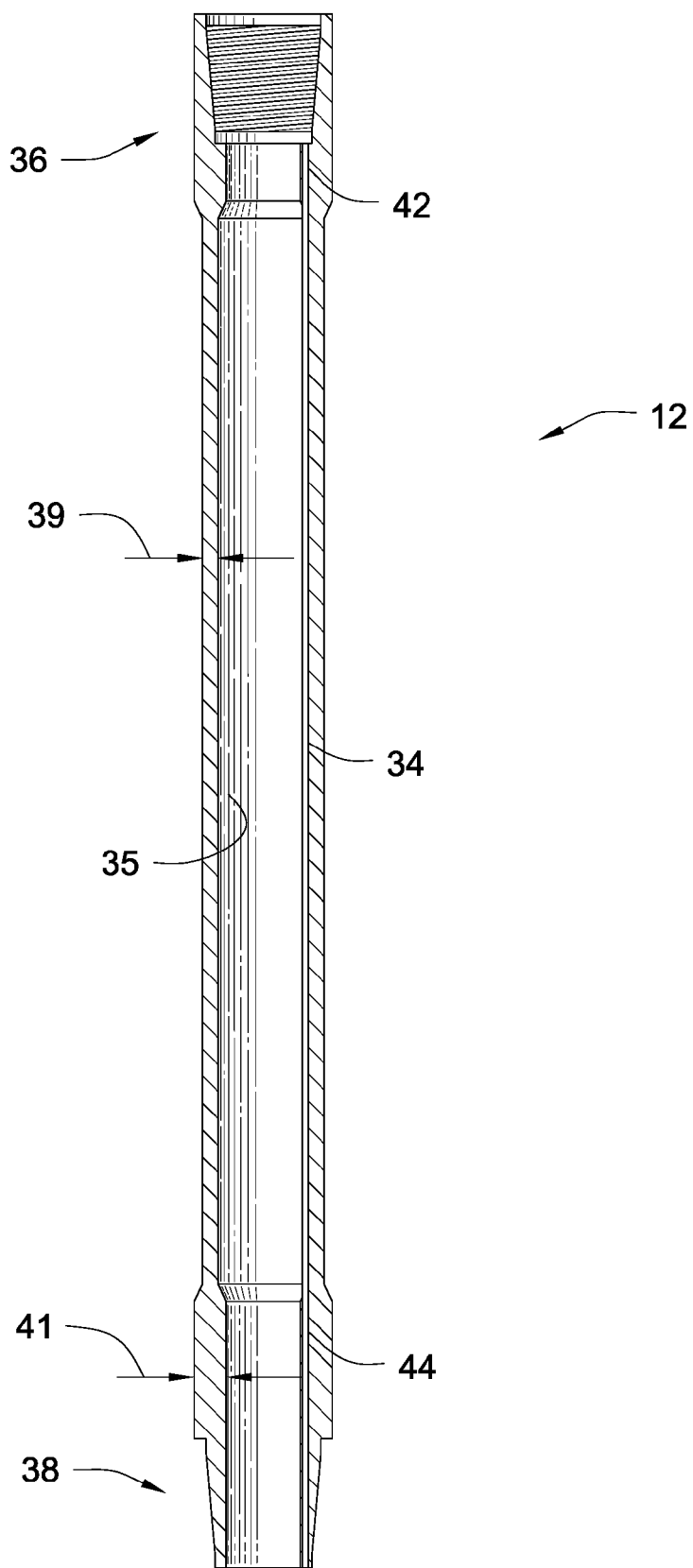


Fig. 2

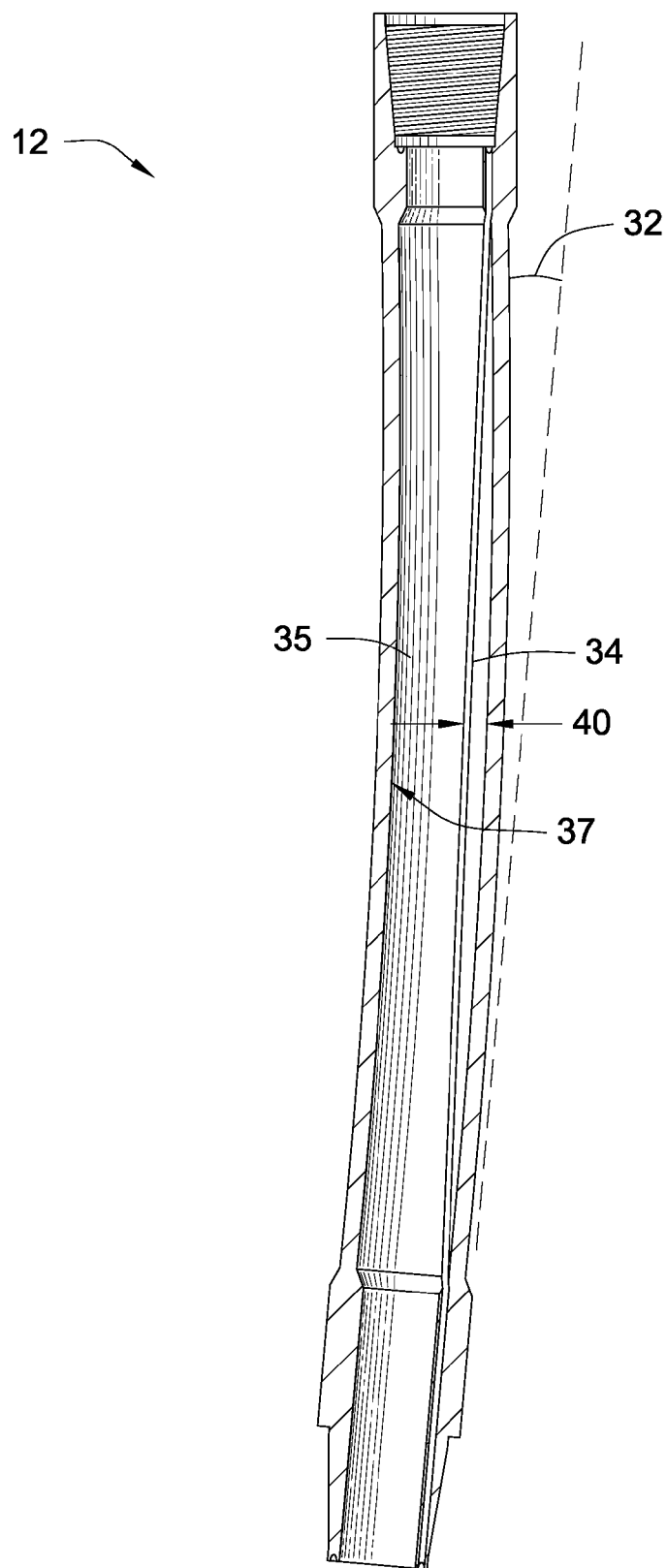


Fig. 3

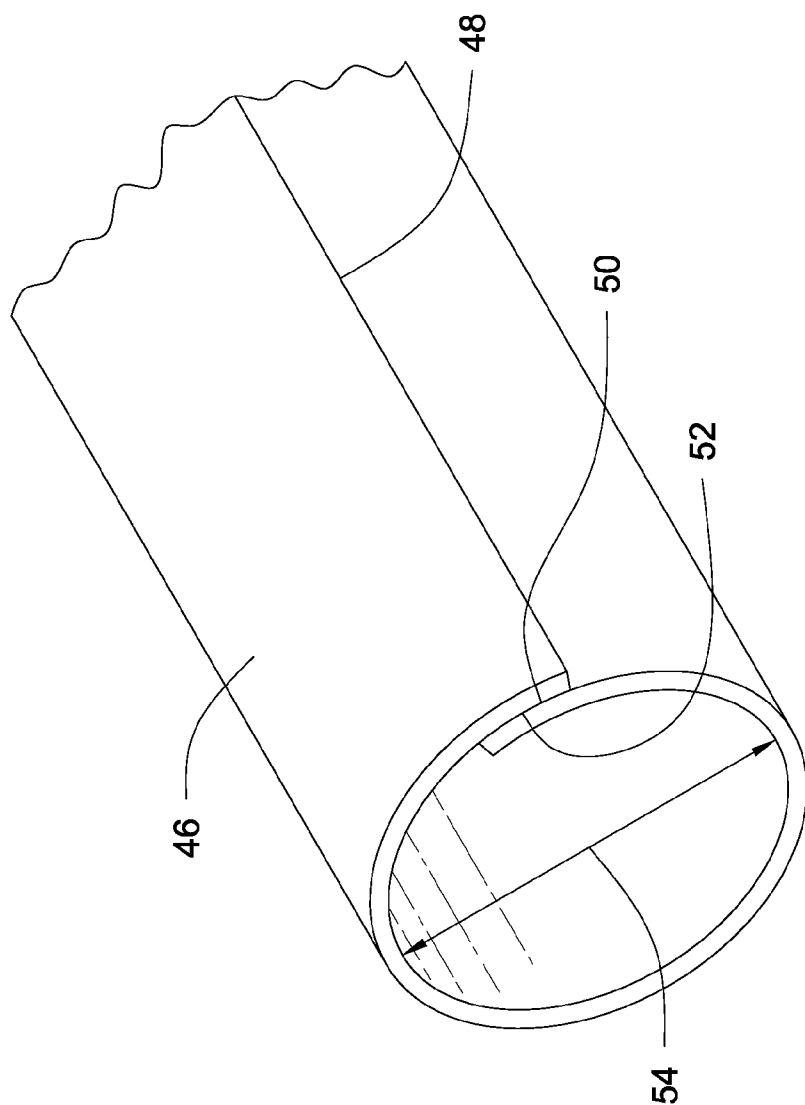


Fig. 4

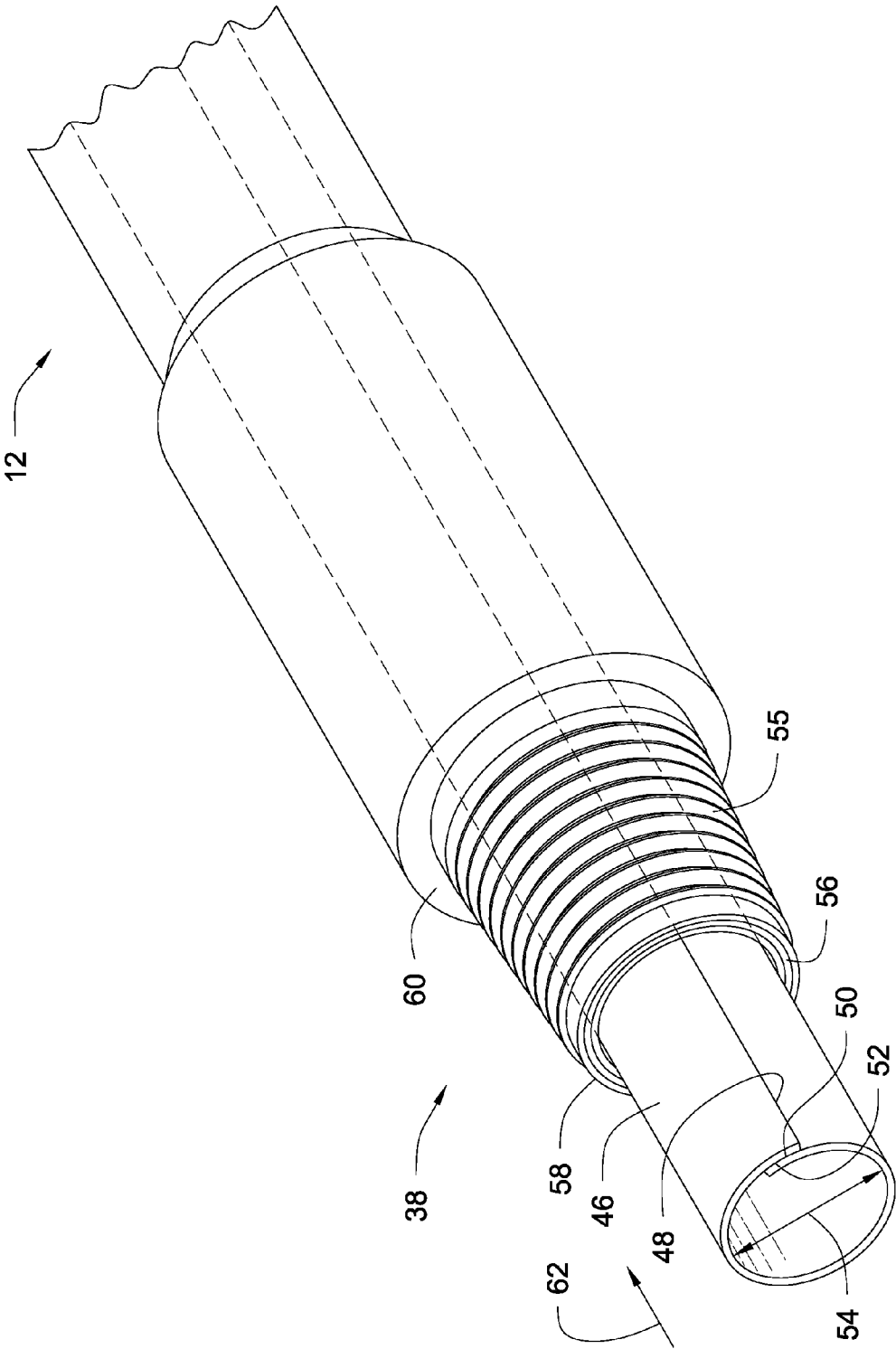


Fig. 5

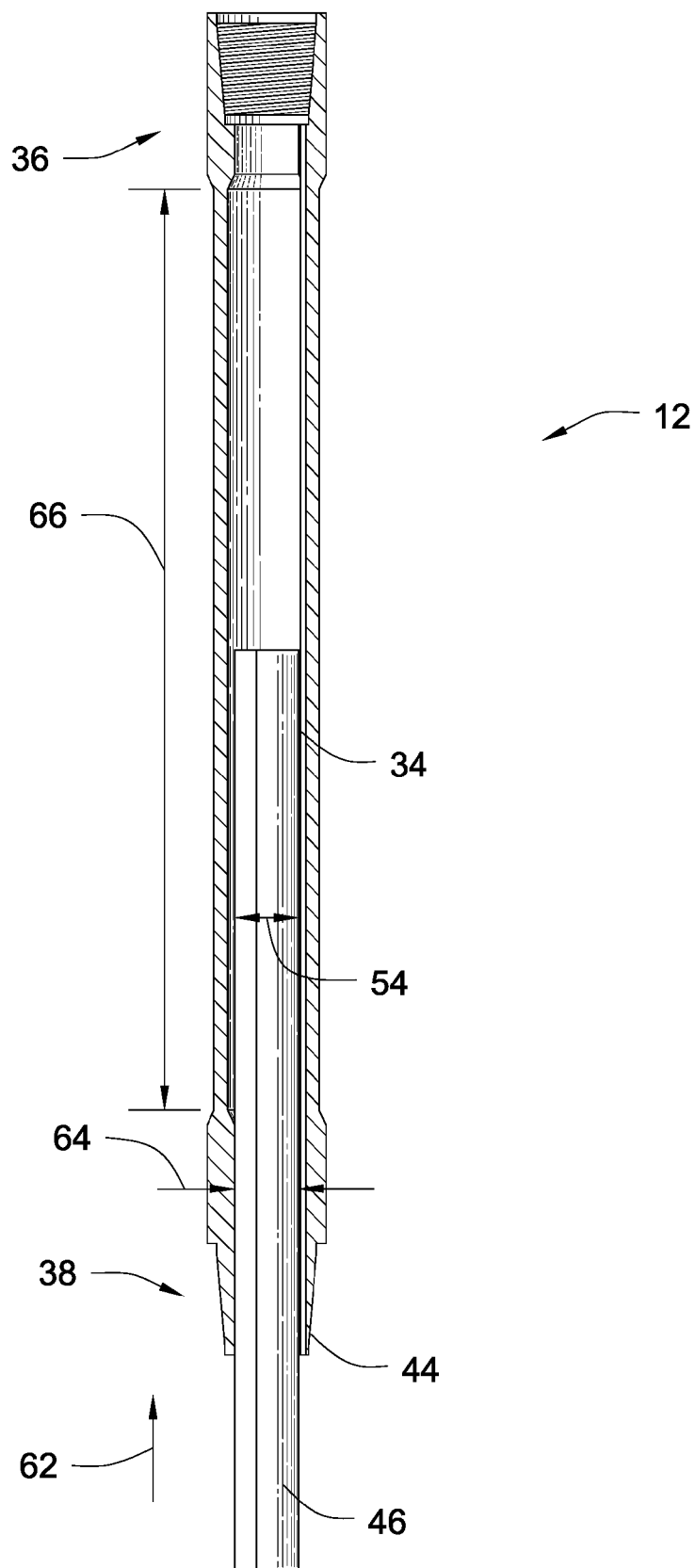


Fig. 6

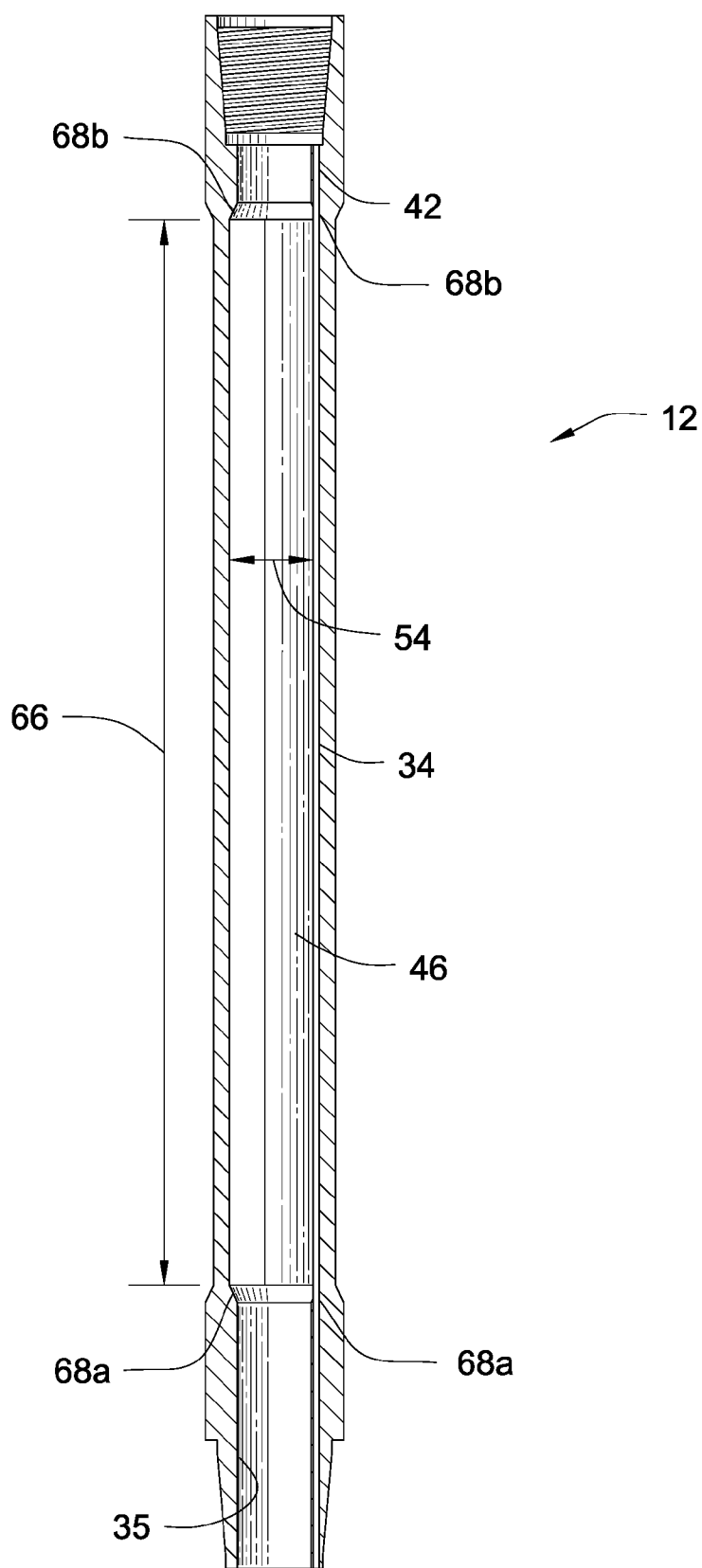


Fig. 7

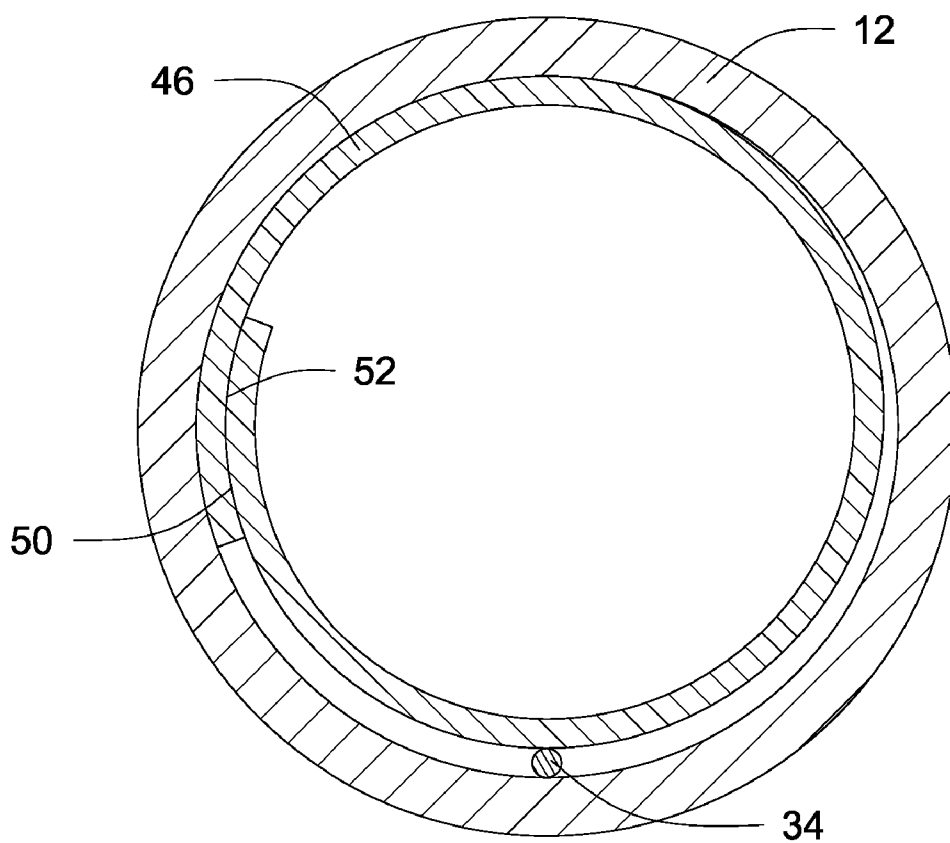


Fig. 8

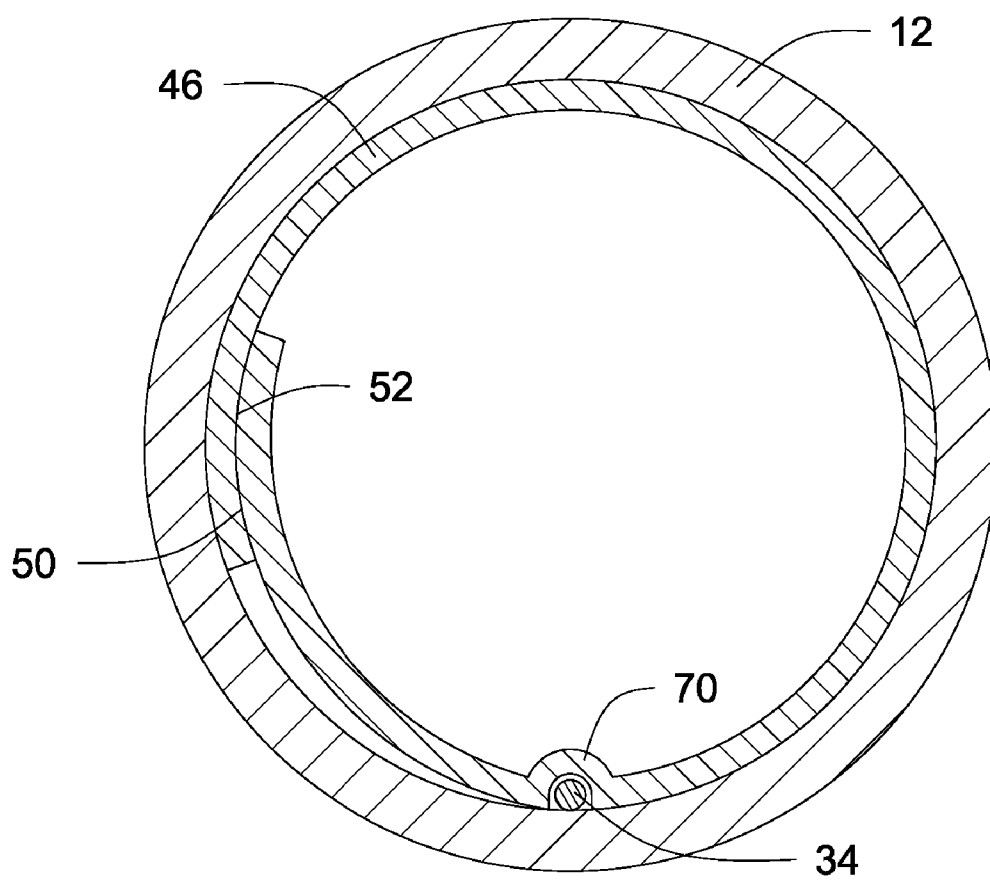


Fig. 9

IMPROVED DOWNHOLE TOOL LINER

FEDERAL RESEARCH STATEMENT

[0001] This invention was made with government support under Contract No. DE-FC26-97FT343656 awarded by the U.S. Department of Energy. The government has certain rights in the invention.

BACKGROUND OF INVENTION

[0002] 1. Field of the Invention

[0003] This invention relates to oil and gas drilling, and more particularly to apparatus and methods for reliably transmitting information along downhole drilling strings.

[0004] 2. Background of the Invention

[0005] In the downhole drilling industry, MWD and LWD tools are used to take measurements and gather information with respect to downhole geological formations, status of downhole tools, conditions located downhole, and the like. Such data is useful to drill operators, geologists, engineers, and other personnel located at the surface. This data may be used to adjust drilling parameters, such as drilling direction, penetration speed, and the like, to accurately tap into an oil, gas, or other mineral bearing reservoirs. Data may be gathered at various points along the drill string. For example, sensors, tools, and the like may be located at or near the bottom hole assembly and on intermediate tools located at desired points along the drill string.

[0006] Nevertheless, data gathering and analysis represent only certain aspects of the overall process. Once gathered, apparatus and methods are needed to rapidly and reliably transmit the data to the earth's surface. Traditionally, technologies such as mud pulse telemetry have been used to transmit data to the surface. However, most traditional methods are limited to very slow data rates and are inadequate for transmitting large quantities of data at high speeds.

[0007] In order to overcome these limitations, various efforts have been made to transmit data along electrical or other types of cable integrated directly into drill string components, such as sections of drill pipe. In such systems, electrical contacts or other transmission elements are used to transmit data across tool joints or connection points in the drill string. Nevertheless, many of these efforts have been largely abandoned or frustrated due to unreliability and complexity.

[0008] For example, one challenge is effectively integrating a transmission line into a downhole tool, such as a section of drill pipe. Due to the inherent nature of drilling, most downhole tools have a similar cylindrical shape defining a central bore. The wall thickness surrounding the central bore is typically designed in accordance with weight, strength, and other constraints imposed by the downhole environment. In some cases, milling or forming a channel in the wall of the downhole tool to accommodate the transmission line may excessively weaken the wall. Thus, in certain embodiments, the only practical route for the transmission line is through the central bore of a downhole tool.

[0009] Nevertheless, routing the transmission line through the central bore may expose the transmission line to drilling fluids, cements, wireline tools, or other substances or objects

passing through the central bore. This can damage the transmission line or cause the transmission line to interfere with objects or substances passing through the central bore. Moreover, in directional drilling applications, downhole tools may bend slightly as a drill string deviates from a straight path. This may cause the transmission line to deviate away from the inside surface of the central bore, thereby worsening the obstruction within the central bore.

[0010] Thus, what are needed are apparatus and methods to protect a transmission line, routed through the central bore of a downhole tool, from drilling fluids, cement, wireline tools, or other components traveling through the central bore.

[0011] What are further needed are apparatus and methods to maintain a transmission line against the inside surface of the central bore even when the downhole tool bends or deviates from a linear path.

[0012] What are further needed are apparatus and methods for lining the inside surface of the central bore to isolate a transmission line from objects or substances traveling through the central bore.

SUMMARY OF INVENTION

[0013] In view of the foregoing, it is a primary object of the present invention to provide apparatus and methods for protecting a transmission line, routed through the central bore of a downhole tool, from drilling fluids, cement, wireline tools, or other components traveling through the central bore. It is a further object to maintain a transmission line against the inside surface of the central bore even when the downhole tool bends or deviates from a straight path. It is yet a further object to provide apparatus and methods for lining the inside surface of the central bore to isolate a transmission line from objects or substances traveling through the central bore.

[0014] Consistent with the foregoing objects, and in accordance with the invention as embodied and broadly described herein, a liner insertable into the central bore of a downhole tool, wherein the central bore has a standard diameter along a central portion of the tool, and a narrower diameter near the ends of the downhole tool, is disclosed in one embodiment of the invention as including a resilient material rolled into a substantially cylindrical shape. The outside diameter of the resilient material is variable to allow the resilient material to move through the narrower diameter of the central bore. Once past the narrower diameter of the central bore, the outside diameter of the resilient material self-expands within the standard diameter of the downhole tool.

[0015] In selected embodiments, the outside diameter of the resilient material expands to contact the inside surface of the central bore. In other embodiments, a transmission line is routed between the central bore and the outside diameter of the resilient material. The resilient material may keep the transmission line in contact with the inside surface of the central bore. The resilient material may also be effective to protect the transmission line from materials traveling through the central bore.

[0016] In certain embodiments, a channel is formed in the resilient material to accommodate the transmission line. In other embodiments, the resilient material includes two mating surfaces that come together to form the cylindrical

shape. Movement between these mating surfaces is effective to cause a change in diameter of the resilient material. In selected embodiments, the mating surfaces are sealed together to prevent substances from leaking into or out of the liner. In certain embodiments, once the resilient material has expanded within the central portion of the downhole tool, the resilient material is maintained in place by shoulders in the central bore.

[0017] In another aspect of the invention, a method for lining the central bore of a downhole tool, wherein the central bore has a central portion of a standard diameter, and tool ends of a narrower diameter, includes rolling a resilient material into a substantially cylindrical shape. The resilient material is then inserted into the central bore through the one of the tool ends into the central portion of the central bore. Once in place, the diameter of the resilient material self-expands within the central portion of the central bore.

[0018] In selected embodiments, the method includes expanding, by the resilient material, the outside diameter of the resilient material to contact the inside surface of the central bore. In other embodiments, the method includes routing a transmission line between the central bore and the outside diameter of the resilient material. The resilient material may maintain contact between the transmission line and the inside surface of the central bore. The resilient material may also protect the transmission line from materials traveling through the central bore.

[0019] In selected embodiments, the method may include forming a channel in the resilient material to accommodate the transmission line. In other embodiments, the resilient material includes two mating surfaces that mate together to form the cylindrical shape. The diameter of the resilient material may be varied by moving the mating surfaces with respect to one another. In selected embodiments, the method may further include sealing the mating surfaces to one another to prevent substances from leaking into or out of the liner.

[0020] In another aspect of the invention, a method for lining the central bore of a downhole tool includes providing a resilient liner having a substantially cylindrical shape and an outside diameter sized to fit within the central bore. The method further includes inserting the resilient liner into the central bore and expanding, by the resilient material, the outside diameter of the resilient material within the central bore.

BRIEF DESCRIPTION OF DRAWINGS

[0021] The foregoing and other features of the present invention will become more fully apparent from the following description, taken in conjunction with the accompanying drawings. Understanding that these drawings depict only typical embodiments in accordance with the invention and are, therefore, not to be considered limiting of its scope, the invention will be described with additional specificity and detail through use of the accompanying drawings.

[0022] FIG. 1 is a cross-sectional view illustrating one embodiment of a drill rig in accordance with the invention.

[0023] FIG. 2 is a cross-sectional view illustrating one embodiment of a transmission line integrated into a downhole tool.

[0024] FIG. 3 is a cross-sectional view illustrating one embodiment of a transmission line routed through the central bore of a downhole tool when the downhole tool is curved or bent as is customary in directional drilling applications.

[0025] FIG. 4 is a perspective view illustrating one embodiment of a downhole tool liner in accordance with the invention.

[0026] FIG. 5 is a perspective view illustrating one embodiment of a downhole tool liner in accordance with the invention as it is initially inserted into the central bore of a downhole tool.

[0027] FIG. 6 is a cross-sectional view illustrating one embodiment of a downhole tool liner as it is initially inserted into the central bore of a downhole tool.

[0028] FIG. 7 is a cross-sectional view illustrating one embodiment of a downhole tool liner after it expands into the larger diameter of the central bore.

[0029] FIG. 8 is a cross-sectional view illustrating one embodiment of a downhole tool liner within the central bore of a downhole tool, wherein the liner is used to isolate a transmission line from objects or substances passing through the central bore.

[0030] FIG. 9 is a cross-sectional view illustrating one embodiment of a downhole tool liner inserted into the central bore of a downhole tool, wherein the liner includes a channel to accommodate a transmission line.

DETAILED DESCRIPTION

[0031] It will be readily understood that the components of the present invention, as generally described and illustrated in the Figures herein, could be arranged and designed in a wide variety of different configurations. Thus, the following more detailed description of embodiments of apparatus and methods of the present invention, as represented in the Figures, is not intended to limit the scope of the invention, as claimed, but is merely representative of various selected embodiments of the invention.

[0032] The illustrated embodiments of the invention will be best understood by reference to the drawings, wherein like parts are designated by like numerals throughout. Those of ordinary skill in the art will, of course, appreciate that various modifications to the apparatus and methods described herein may easily be made without departing from the essential characteristics of the invention, as described in connection with the Figures. Thus, the following description of the Figures is intended only by way of example, and simply illustrates certain selected embodiments consistent with the invention as claimed herein.

[0033] Referring to FIG. 1, a cross-sectional view of a drill rig 10 is illustrated drilling a borehole 14 into the earth 16 using downhole tools (collectively indicated by numeral 12) in accordance with the present invention. The collection of downhole tools 12 form at least a portion of a drill string 18. In operation, a drilling fluid is typically supplied under pressure at the drill rig 10 through the drill string 18. The drill string 18 is typically rotated by the drill rig 10 to turn a drill bit 12e which is loaded against the earth 16 to form the borehole 14.

[0034] Pressurized drilling fluid is circulated through the drill bit **12e** to provide a flushing action to carry the drilled earth cuttings to the surface. Rotation of the drill bit may alternately be provided by other downhole tools such as drill motors, or drill turbines (not shown) located adjacent to the drill bit **12e**. Other downhole tools include drill pipe **12a** and downhole instrumentation such as logging while drilling tools **12c**, and sensor packages, (not shown). Other useful downhole tools include stabilizers **12d**, hole openers, drill collars, heavyweight drill pipe, subassemblies, under-reamers, rotary steerable systems, drilling jars, and drilling shock absorbers, which are all well known in the drilling industry.

[0035] Referring to FIG. 2, a downhole tool **12** may include a box end **36** and a pin end **36**. A pin end **38** may thread into a box end **36**, thereby connecting multiple tools **12** together to form a drill string **18**. Due to the inherent nature of drilling, most downhole tools **12** are characterized by a similar cylindrical shape defining a central bore **35**. The central bore is used to transport drilling fluids, wireline tools, cement, and the like down the drill string **18**.

[0036] The wall thickness **39** around the central bore **35** is typically designed in accordance with weight, strength, and other constraints, needed to withstand substantial torque placed on the tool **12**, pressure within the central bore **35**, flex in the tool **12**, and the like. Because of immense forces placed on the tool **12**, milling or forming a channel in the wall of the downhole tool **12** to accommodate a transmission line **34** may excessively weaken the wall. Thus, in selected embodiments, the only practical route for a transmission line **34** is through the central bore **35** of the downhole tool **12**.

[0037] Nevertheless, routing the transmission line **34** through the central bore may expose the transmission line **34** to drilling fluids, cements, wireline tools, or other substances or objects passing through the central bore **35**. This can damage the transmission line **34** or cause the transmission line **34** to negatively interfere with objects or substances passing through the central bore **35**. Thus, in selected embodiments, a transmission line **34** is preferably maintained as close to the wall **39** of the central bore **39** as possible to minimize interference. In selected embodiments, the transmission line **34** is protected by a conduit **34** or other protective covering **34** to protect it from damage.

[0038] As illustrated, at or near the box end **36** and pin end **38** of the tool **12**, the central bore **35** may be narrower and the walls **41** may be thicker. This may increase the strength of the downhole tool **12** at or near the tool joints. In addition, this added thickness **41** may enable channels to be milled or formed in the walls **42**, **44**, to accommodate a transmission line **34** without overly weakening the downhole tool **12**. The channels **42**, **44** may exit the downhole tool at or near the ends of the downhole tool **12**, where the transmission line **34** may be coupled to transmission elements (not shown) for communicating across tool joints.

[0039] Referring to FIG. 3, In an effort to tap into gas, oil, or other mineral deposits, a drill string **18** may be guided or deviate from a linear path. Thus, in selected directional drilling applications, tools **12** may bend to veer off in a desired direction at an angle **32**. Since a drill string **18** may consist of many hundreds of sections of drill pipe **12** and other downhole tools **12**, the cumulative bend or curve in each tool **12** may enable a drill string **18** to drill horizontally in some cases.

[0040] As was previously mentioned, in order to transmit data up and down the drill string **18**, a transmission line **34** may be integrated into a downhole tool **12**. If the transmission line **34** is routed through the central bore **35** of the downhole tool **12**, the transmission line **34** may separate or detach from the inside surface of the central bore **35** when the downhole tool **12** bends. This may create problems since the transmission line **34** may then obstruct or interfere with fluids, wireline tools, concrete, or other objects or substances traveling through the central bore. In fact, in some cases, when a downhole tool **12**, such as a section of drill pipe **12**, bends significantly, the transmission line **34** may actually come into contact with the opposite side **37** of the central bore **35**. Thus, apparatus and methods are needed to route a transmission line **34** through the central bore **35** such that the transmission line **34** stays in relatively constant contact with the inside surface of the central bore **35** even when the downhole tool **12** bends.

[0041] Referring to FIG. 4, in selected embodiments, a liner **46** may be provided to line the inside surface of the central bore **35**. The liner **46** may be used to protect or isolate the transmission line **34** from substances or objects passing through the central bore **35**. As illustrated, a liner **46** may be formed from a rolled material and have a substantially cylindrical shape.

[0042] In selected embodiments, the liner **46** may include mating surfaces **50**, **52** that contact one another to form the cylinder. The mating surfaces **50**, **52** may move with respect to one another to roll the liner **46** more tightly to provide a smaller diameter **54**. Thus, the diameter **54** of the liner may be adjusted as needed. This may be helpful to initially insert the liner **46** into the central bore **35** of a downhole tool **12**. The liner may be constructed of any suitable resilient material capable of withstanding the wear of a downhole environment. For example, a liner **46** may be constructed of a material such as metal, plastic, or the like, having sufficient durability and resiliency.

[0043] Referring to FIG. 5, a liner **46** like that described in Figure 4 may be inserted into either the box end **36** or pin end **38** of a downhole tool **12**. As illustrated, a pin end **38** may include a primary **60** and secondary shoulder **58**, and a threaded portion **55**, which may contact another downhole tool **12**. The primary shoulder **60** may absorb the majority of the stress at the tool joint. Nevertheless the secondary shoulder **58** may also absorb some of the stress at the tool joint. The two shoulders **58**, **60** together may create a stronger tool joint than either shoulder by itself.

[0044] As illustrated, a transmission element **56** may be installed into the secondary shoulder **58**. The transmission element **56** may be used to transmit a signal across the tool joint by communicating with a corresponding transmission element **56** located on another downhole tool **12** (not shown). The transmission element **56** may transmit energy in several different ways. For example, in selected embodiments, the transmission element **58** may transmit electrical energy by direct electrical contact another transmission element **58**.

[0045] In other embodiments, the transmission element **58** may communicate inductively. That is, the transmission element **58** may convert an electrical signal to magnetic energy for transmission across the tool joint. The magnetic energy may then be converted back to an electrical signal by

another transmission element **58**. To accommodate the transmission element **58**, a recess may be formed in the secondary shoulder **58**. The transmission line **34** may connect to the transmission element **58** through the channel **44** in the pin end **38**.

[0046] As was previously mentioned, the central bore **35** traveling through the pin end **38** may be narrower than the central bore **35** traveling through the central portion of the tool **12**. Thus, in order to insert the liner **46** into the downhole tool **12**, the diameter **54** of the liner **46** may be reduced. This may be accomplished by rolling the liner **46** into a smaller cylinder. The liner **46** may then be inserted in a direction **62** into the downhole tool **12**. In selected embodiments, the liner **46** may be lubricated to facilitate sliding the liner **46** into the tool **12**.

[0047] Referring to FIG. 6, a cross-sectional view of a liner **46** is illustrated as it is inserted into a downhole tool **12**. As shown, the liner **46** may be inserted with an initial diameter **54** so it can slide through the narrow bore **64** in either the box end **36** or pin end **38**. The liner **46** may be cut to a specified length **66** to fit within a central portion **66** of the downhole tool **12**.

[0048] Referring to FIG. 7, once the liner **46** reaches the central portion **66** of the central bore **35**, the diameter **54** of the liner **46** may increase to contact the inside surface of the central bore **35**. As was previously described, the liner **46** may self-expand within the central bore **35** due to its resiliency. For example, if the liner **46** is a sheet of a resilient material rolled into a cylindrical shape, the diameter **54** of the liner **46** may automatically expand due to its resiliency.

[0049] Once the diameter **54** of the liner **46** has expanded to contact the inside surface of the central bore **35**, the liner **46** may be kept in place **12** by shoulders **68a**, **68b** near the box and pin ends **36**, **38**. The shoulders **68a**, **68b** may be present where the central bore **15** narrows near the box end **36** and pin end **38**. Likewise, the resiliency of the liner **46** may keep the liner **46** from slipping past the shoulders **68a**, **68b**. In selected embodiments, the more resilient the material **46**, the better the retention between the shoulders **68a**, **68b**.

[0050] It is important to securely retain the liner **46** between the shoulders **68a**, **68b**. For example, if the liner **46** slips past the shoulders **68a**, **68b**, the liner **46** may create an obstruction within the central bore **15**. This may cause the drill string to malfunction, possibly causing time-consuming and costly delays. In other embodiments, the liner **46** may be welded or otherwise bonded to the inside of the downhole tool **12** to keep it from moving.

[0051] Referring to FIG. 8, a cross-sectional view of the central portion **66** of a downhole tool **12** is illustrated. As shown, the transmission line **34** may be sandwiched between the liner **46** and the surface of the central bore **35**. This may protect the transmission line **34** from objects or substances passing through the central bore **35**. In selected embodiments, the mating surfaces **50**, **52** may be sealed together to prevent fluids or other substances from leaking from the liner **46**. In other embodiments, the mating surfaces **50**, **52** may be left unsealed.

[0052] Referring to FIG. 9, in other embodiments, a channel **70** may be formed in the liner **46** to accommodate the transmission line **34**. The channel **70** may maintain the

transmission line **34** in place and provide better contact between the liner **46** and inside surface of the central bore **35**.

[0053] The present invention may be embodied in other specific forms without departing from its essence or essential characteristics. The described embodiments are to be considered in all respects only as illustrative, and not restrictive. The scope of the invention is, therefore, indicated by the appended claims, rather than by the foregoing description. All changes within the meaning and range of equivalency of the claims are to be embraced within their scope.

1. A liner insertable into the central bore of a downhole tool, the central bore being characterized by a standard diameter along the central portion of the tool, and a narrowed diameter proximate the ends of the tool, the liner comprising:

a resilient material rolled into a substantially cylindrical shape and having an outside diameter, wherein:

the outside diameter of the resilient material is variable to allow the resilient material to move through the narrowed diameter of the downhole tool; and

the outside diameter of the resilient material, once past the narrowed diameter, is expandable within the standard diameter of the downhole tool.

2. The liner of claim 1, wherein the outside diameter of the resilient material expands to contact the inside surface of the central bore.

3. The liner of claim 1, further comprising a transmission line routed between the central bore and the outside diameter of the resilient material.

4. The liner of claim 3, wherein the resilient material keeps the transmission line in contact with the inside surface of the central bore.

5. The liner of claim 3, wherein the resilient material is effective to protect the transmission line from materials traveling through the central bore.

6. The liner of claim 3, wherein a channel is formed in the resilient material to accommodate the transmission line.

7. The liner of claim 6, wherein the resilient material comprises two mating surfaces that mate to form the cylindrical shape.

8. The liner of claim 7, wherein movement between the mating surfaces is effective to cause a change in diameter of the resilient material.

9. The liner of claim 7, wherein the mating surfaces are sealed together to prevent substances from leaking out of the liner.

10. The liner of claim 1, wherein the resilient material, once expanded, is maintained in place by shoulders within the downhole tool.

11. A method for lining the central bore of a downhole tool, the central bore having a central portion of a standard diameter, and tool ends of a narrower diameter, the method comprising:

rolling a resilient material into a substantially cylindrical shape;

inserting the resilient material into the central bore through at least one tool end into the central portion of the downhole tool; and

expanding, by the resilient material, the outside diameter of the resilient material within the central portion of the central bore.

12. The method of claim 11, further comprising expanding, by the resilient material, the outside diameter of the resilient material to contact the inside surface of the central bore.

13. The method of claim 11, further comprising routing a transmission line between the central bore and the outside diameter of the resilient material.

14. The method of claim 13, further comprising maintaining, by the resilient material, contact between the transmission line and the inside surface of the central bore.

15. The method of claim 13, further comprising protecting, by the resilient material, the transmission line from materials traveling through the central bore.

16. The method of claim 13, further comprising forming a channel in the resilient material to accommodate the transmission line.

17. The method of claim 11, wherein the resilient material comprises two mating surfaces that mate to form the cylindrical shape.

18. The method of claim 17, further comprising moving the mating surfaces with respect to one another to change the diameter of the resilient material.

19. The method of claim 17, further comprising sealing the mating surfaces to one another to prevent substances from leaking out of the liner.

20. A method for lining the central bore of a downhole tool, the method comprising:

providing a resilient liner formed into a substantially cylindrical shape, the resilient liner having an outside diameter sized to fit within the central bore;

inserting the resilient liner into the central bore; and

expanding, by the resilient material, the outside diameter of the resilient material within the central bore.

* * * * *