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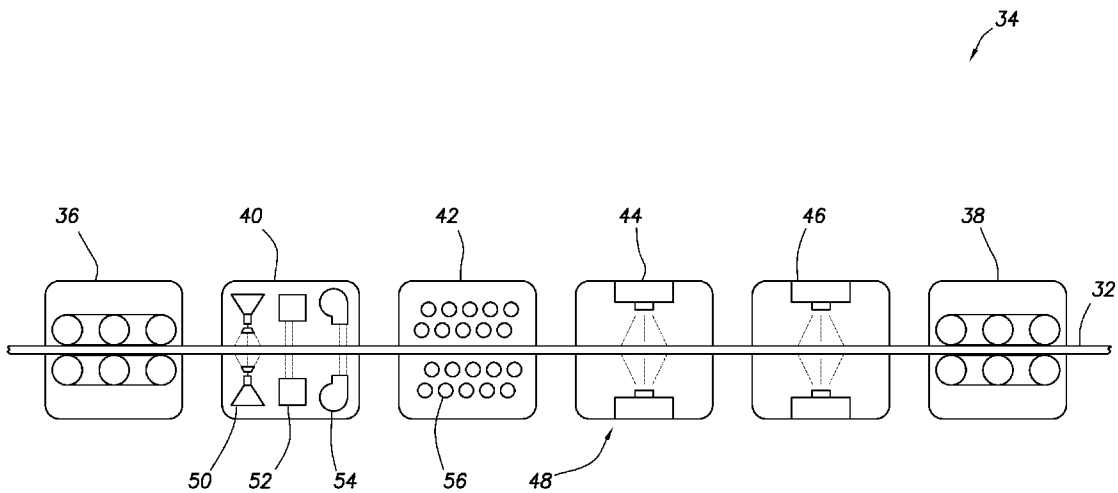

FIG.2

(57) Abrégé/Abstract:
A sucker rod can include a base metal, a corrosion resistant layer on the base metal, and an abrasion resistant layer external to the corrosion resistant layer, the abrasion resistant layer comprising a phenolic material. Another sucker rod can include a base metal, a corrosion resistant layer on the base metal, and an abrasion resistant layer external to the corrosion resistant layer, the abrasion resistant layer comprising an abrasion resistant particulate material and a matrix material. A method of producing a continuous sucker rod can include displacing the continuous sucker rod through a surface treatment system, applying a corrosion resistant layer on a base metal of the continuous sucker rod, then applying an abrasion resistant layer external to the corrosion resistant layer.

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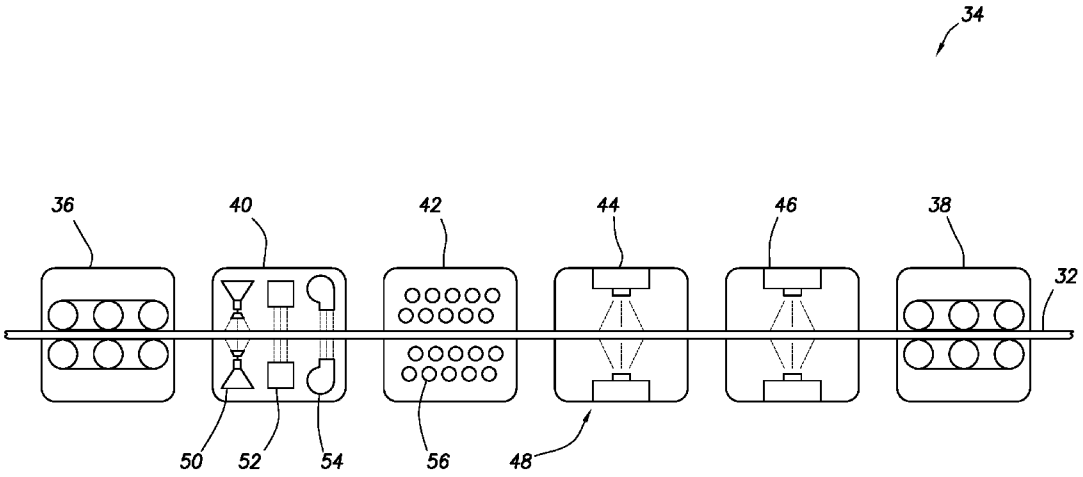

FIG.2

(57) Abstract: A sucker rod can include a base metal, a corrosion resistant layer on the base metal, and an abrasion resistant layer external to the corrosion resistant layer, the abrasion resistant layer comprising a phenolic material. Another sucker rod can include a base metal, a corrosion resistant layer on the base metal, and an abrasion resistant layer external to the corrosion resistant layer, the abrasion resistant layer comprising an abrasion resistant particulate material and a matrix material. A method of producing a continuous sucker rod can include displacing the continuous sucker rod through a surface treatment system, applying a corrosion resistant layer on a base metal of the continuous sucker rod, then applying an abrasion resistant layer external to the corrosion resistant layer.

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CORROSION AND ABRASION RESISTANT SUCKER ROD

TECHNICAL FIELD

This disclosure relates generally to equipment utilized and operations performed in conjunction with a subterranean well and, in an example described below, more particularly provides a corrosion and abrasion resistant sucker rod.

BACKGROUND

A sucker rod is typically used to transmit work from an actuator at surface to a downhole pump in a well. The actuator may reciprocate or rotate the sucker rod (or both) to operate the downhole pump.

A single sucker rod may extend substantially an entire distance from the surface actuator to the downhole pump (typically thousands of meters), in which case the sucker rod is of the type known to those skilled in the art as a "continuous" sucker rod. In other situations, many sucker rods (e.g., having lengths of ~20-30 ft. or 6-9 m) may be connected together, in order to extend the distance between the surface actuator and the downhole pump.

Therefore, it will be appreciated that improvements are continually needed in the arts of designing, producing and utilizing sucker rods. The disclosure below provides such improvements.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a representative partially cross-sectional view of an example of a well system and associated method which can embody principles of this disclosure.

FIG. 2 is a representative schematic view of an example of a sucker rod surface treatment method which can embody the principles of this disclosure.

FIG. 3 is a representative schematic view of another example of the sucker rod surface treatment method.

FIG. 4 is a representative perspective view of a sucker rod treated using the FIG. 3 method.

FIG. 5 is a representative schematic view of another example of the sucker rod surface treatment method.

FIG. 6 is a representative perspective view of a sucker rod treated using the FIG. 5 method.

FIG. 7 is a representative schematic view of another example of the sucker rod surface treatment method.

FIG. 8 is a representative perspective view of a sucker rod treated using the FIG. 7 method.

DETAILED DESCRIPTION

Representatively illustrated in FIG. 1 is a system 10 and associated method for use with a subterranean well, which system and method can embody principles of this disclosure. However, it should be clearly understood that the system 10 and method are merely one example of an application of the principles of this disclosure in practice, and a wide variety of other examples are possible. Therefore, the scope of this disclosure is not limited at all to the details of the system 10 and method described herein and/or depicted in the drawings.

In the FIG. 1 example, a walking beam-type surface pumping unit 12 is mounted on a pad 14 adjacent a wellhead 16. A rod string 18 extends into the well and is connected to a downhole pump 20 in a tubing string 22. Reciprocation of the rod string 18 by the pumping unit 12 causes the downhole pump 20 to pump fluids (such as, liquid hydrocarbons, gas, water, etc., and combinations thereof) from the well through the tubing string 22 to surface.

The pumping unit 12 as depicted in FIG. 1 is of the type known to those skilled in the art as a "conventional" pumping unit. However, in other examples, other types of walking beam pumping units (such as, those known to persons skilled in the art as Mark II, reverse Mark, beam-balanced and end-of-beam pumping units), hydraulic, rotary or other types of pumping units may be used. The pumping unit 12 or other actuator may rotate the rod string 18 instead of, or in addition to, reciprocating the rod string. Thus, the scope of this disclosure is not limited to use of any particular type or configuration of pumping unit.

The rod string 18 may comprise a substantially continuous rod, or may be made up of multiple connected together rods (also known as "sucker rods"). At an upper end of the rod string 18, a polished rod 24 extends through a stuffing box 26 on the wellhead 16. An outer surface of the polished rod 24 is finely polished to avoid damage to seals in the stuffing box 26 as the polished rod reciprocates upward and downward through the seals.

In the FIG. 1 example, a carrier bar 28 connects the polished rod 24 to a bridle 30. The bridle 30 in this example comprises multiple cables that are secured to and wrap partially about a horsehead end of a beam of the pumping unit 12. In other examples, a hydraulic actuator, a motor or another type of actuator may be used to displace the polished rod 24 and the remainder of the rod string 18.

As depicted in FIG. 1, the rod string 18 includes the polished rod 24, the sucker rod(s) 32 and any adapters/connectors used to operatively connect the rod string to the downhole pump 20. It will be appreciated that the sucker rod 32 is exposed to fluids in the tubing, which may include corrosive agents (such as,

acid gases in the production stream, CO_2 and/or H_2S). This can lead to eventual failure, or the need to more frequently replace the sucker rod 32.

In addition, the sucker rod 32 is subject to damage due to shipping and handling, installation in the well and the pumping operation. If a corrosion resistant coating has been applied to the sucker rod 32, the coating could be breached by impacts, wear and abrasion at any point during shipping, handling, installation and operation. It would be beneficial to be able to protect a corrosion resistant layer on a sucker rod from such damage.

Referring additionally now to FIG. 2, an example of a sucker rod surface treatment method 34 is representatively illustrated in schematic form. The sucker rod 32 depicted in FIG. 2 may be used in the system 10 and method of FIG. 1, or it may be used in other systems and methods.

In the FIG. 2 method 34, the sucker rod 32 traverses multiple stations 36, 38, 40, 42, 44, 46 of a surface treatment system 48 as part of, or subsequent to, manufacture of the sucker rod. In other examples, the surface treatment system 48 may include other stations, other numbers of stations and different combinations of stations. Thus, the scope of this disclosure is not limited to the particular stations, number of stations or combinations of stations in the surface treatment system 48 as described herein or depicted in the drawings.

The method 34 may be performed prior to, or after, a base metal of the sucker rod 32 is in its final form. The method 34 may be performed for sucker rod 32 that is otherwise ready for installation in a well, or as part of initial manufacture of the sucker rod.

The input drive 36 is used to displace the sucker rod 32 through the other stations 40, 42, 44, 46. An output drive 38 may be used instead of, or in addition to, the input drive 36. If the surface treatment method 34 is part of an overall manufacturing operation, separate drives 36, 38 may not be included in the surface treatment system 48.

The sucker rod 32 displaces from left to right through the stations 40, 42, 44, 46 as viewed in FIG. 2. Thus, the sucker rod 32 displaces first through the

surface preparation station 40 (after the input drive 36, if included), then through the heating station 42 and application stations 44, 46.

The surface preparation station 40 in the FIG. 2 example includes an abrader 50, a cleaner 52 and a dryer 54. In other examples, other or different elements may be used in the surface preparation station 40, or the surface preparation station may not be used or may be integrated with one or more other stations.

The abrader 50 removes surface debris and any rust, and provides surface roughness for enhanced adherence of coatings, extrusions, layers, bonds, etc. later applied in the method 34.

The cleaner 52 removes undesired chemicals or other substances from the sucker rod surface. The cleaner 52 may use solvents, detergents or other cleaning agents for this purpose.

The dryer 54 removes any remaining cleaner and any undesired particulate matter or other debris from the surface of the sucker rod 32. The dryer 54 may produce a forced air flow, whether or not the air is also heated.

The heating station 42 in the FIG. 2 example includes an induction heater 56. In other examples, other types of heaters may be used, or the heater 56 may be integrated with one or more other stations (such as, one or both of the application stations 44, 46).

The application station 44 applies a corrosion resistant layer to the sucker rod 32. In this example, the corrosion resistant layer is applied directly to the base metal of the sucker rod 32, but in other examples a primer, an adhesive, a sealer or another type of layer may be applied to the base metal prior to the corrosion resistant layer being applied.

The corrosion resistant layer may be applied using a spray or powder coating technique. The corrosion resistant layer may comprise a thermosetting polymer material (such as a fusion bond epoxy), in which case the heat provided by the heating station 42 is selected to cause the material to form a coating that completely encloses the base metal of the sucker rod 32.

In other examples, the sucker rod 32 could be dipped or wrapped in a corrosion resistant material as the sucker rod passes through the application station 44. The corrosion resistant layer could be extruded onto the base metal of the sucker rod 32. Thus, the scope of this disclosure is not limited to any particular technique for incorporating the corrosion resistant layer into the sucker rod 32.

The application station 46 applies an abrasion resistant layer to the sucker rod 32. In this example, the abrasion resistant layer is applied directly to the corrosion resistant layer of the sucker rod 32, but in other examples a primer, an adhesive, a sealer or another type of layer may be applied to the corrosion resistant layer prior to the abrasion resistant layer being applied.

The abrasion resistant layer may be applied using a spray or powder coating technique. The abrasion resistant layer may comprise a thermosetting polymer material (such as, a phenolic or a phenolic and fusion bond epoxy composition), in which case the heat provided by the heating station 42 is selected to cause the material to form a coating that completely encloses the corrosion resistant layer of the sucker rod 32.

In other examples, the sucker rod 32 could be dipped or wrapped in an abrasion resistant material as the sucker rod passes through the application station 46. The abrasion resistant layer could be extruded onto the corrosion resistant layer. Thus, the scope of this disclosure is not limited to any particular technique for incorporating the abrasion resistant layer into the sucker rod 32.

The abrasion resistant layer protects the corrosion resistant layer against damage due to impacts, wear and abrasion. In addition, the abrasion resistant layer can in some examples reduce friction between the sucker rod 32 and the tubing string 22 during operation.

Referring additionally now to FIGS. 3 & 4, another example of the surface treatment system 48 and method 34 is representatively illustrated, along with an example sucker rod 32 produced by the system and method. In FIG. 3, the

stations 40, 42, 44, 46 are depicted in simplified form. The input and output drive stations 36, 38 are not depicted in FIG. 3, but could be included if desired.

In FIG. 4, the sucker rod 32 is depicted with both of the corrosion resistant layer 58 and the abrasion resistant layer 60 on a base metal 62. The corrosion resistant layer 58 is applied over the base metal 62 in the application station 44, and the abrasion resistant layer 60 is applied over the corrosion resistant layer 58 in the application station 46.

The base metal 62 may be any material suitable for transmitting work from the surface actuator 12 to the downhole pump 20 (see FIG. 1) and otherwise operating in a well environment. If the sucker rod 32 is a continuous sucker rod, the base metal 62 may have a length of 1000 meters or greater.

The base metal 62 should have suitable strength and toughness for transmitting torque and tensile loads, particularly fatigue strength to withstand varying loads for long periods of time, and yet be economical to obtain and process. Some examples of suitable materials for the base metal 62 include carbon and low alloy steels. However, the scope of this disclosure is not limited to use of any particular material in the base metal 62.

In this example, the corrosion resistant layer 58 is suitable for preventing corrosion of the base metal 62 due to exposure to fluids in a well. The corrosion resistant layer 58 comprises a corrosion resistant material 64. Examples of suitable corrosion resistant materials include fusion bonded epoxy and other thermosetting polymers such as silicone, polyurethane, phenolic and polyester.

The corrosion resistant material 64 may mitigate corrosion by isolating the base metal 62 from well fluids, by chemically hindering a corrosive reaction, or by another means. The corrosion resistant material 64 may be applied by spraying, dipping, wrapping, extruding or any other technique. The scope of this disclosure is not limited to use of any particular type of corrosion resistant material or manner of applying the corrosion resistant material.

In the FIGS. 3 & 4 example, the corrosion resistant layer 58 is applied directly to the base metal 62. In some examples, an adhesive, primer, sealer or

other layer may be included between the corrosion resistant layer 58 and the base metal 62.

The abrasion resistant layer 60 is suitable for preventing damage to the corrosion resistant layer 58 due to various impacts, wear and abrasion experienced by the sucker rod 32. The abrasion resistant layer 60 comprises an abrasion resistant material 66. Examples of suitable abrasion resistant materials include phenolics, fusion bonded epoxy and other thermosetting polymers, polyolefins and other thermoplastic polymers, hard particles or friction reducing particles, and combinations thereof.

The abrasion resistant material 66 may mitigate abrasion by reducing friction, by presenting a hard or tough surface, or by another means. The abrasion resistant material 66 may be applied by spraying, dipping, wrapping, extruding or any other technique. The scope of this disclosure is not limited to use of any particular type of abrasion resistant material or manner of applying the abrasion resistant material.

In the FIGS. 3 & 4 example, the abrasion resistant layer 60 is applied directly to the corrosion resistant layer 58. In some examples, an adhesive, primer, sealer or other layer may be included between the abrasion resistant layer 60 and the corrosion resistant layer 58.

Referring additionally now to FIGS. 5 & 6, another example of the surface treatment method 34 and system 48, and the sucker rod 32 produced thereby, are representatively illustrated. The FIGS. 5 & 6 example is similar in many respects to the FIGS. 3 & 4 example, except that a particulate material 68 is applied over the corrosion resistant layer 58.

The particulate material 68 is applied by an application station 70. The application station 70 is positioned between the application stations 44, 46 as depicted in FIG. 5.

The particulate material 68 may be any material suitable to resist impact, wear or abrasion. The resistance to impact, wear or abrasion may be due to a relatively high strength, hardness or toughness of the particulate material 68. The

particulate material 68 may comprise silicon carbide, silicon dioxide (e.g., sand), carbides, nitrides, oxides, borides, minerals, or other suitable materials. The particulate material 68 may be selected from a variety of friction reducing agents, including fluorocarbons, graphite, graphene, molybdenum disulfide and other friction reducing agents. The scope of this disclosure is not limited to use of any certain particulate material.

The application station 70 may apply the particulate material 68 directly to the corrosion resistant layer 58, or another layer may be applied between the particulate material and the corrosion resistant layer. For example, an adhesive could be applied to the corrosion resistant layer 58 prior to applying the particulate material 68 onto the adhesive. The particulate material 68 may embed partially or fully into the corrosion resistant layer 58.

The remainder of the abrasion resistant layer 60 is applied by the application station 46, for example, as described above for the FIGS. 3 & 4 example. However, in the FIGS. 5 & 6 example, the abrasion resistant layer 60 includes the particulate material 68 in a matrix material 66a. The matrix material 66a may be the same as the abrasion resistant material 66 in the FIGS. 3 & 4 example. Thus, the abrasion resistant material 66 in the FIGS. 5 & 6 example includes both the particulate material 68 and the matrix material 66a.

When the matrix material 66a is applied to the corrosion resistant layer 58, the particulate material 68 is “absorbed” into the matrix material, so that the matrix and particulate materials become a single composite element. In some examples, the particulate material 68 may become dispersed or embedded in the matrix material 66a.

Referring additionally now to FIGS. 7 & 8, another example of the surface treatment method 34 and system 48, and the sucker rod 32 produced thereby, are representatively illustrated. The FIGS. 7 & 8 example is similar in many respects to the FIGS. 5 & 6 example, except that the abrasion resistant layer 60 (including the particulate material 68 and the matrix material 66a) is applied by the application station 46.

The abrasion resistant material 66 in this example includes both the matrix material 66a and the particulate material 68. The matrix and particulate materials 66a, 68 may be combined to form the abrasion resistant material 66, prior to the application station 46 applying the abrasion resistant material onto the corrosion resistant material 64 (or any layer applied on the corrosion resistant layer).

In some examples, the matrix material 66a could comprise a thermoplastic material. The application station 46 can be configured to extrude the thermoplastic matrix material 66a, along with the particulate material 68 embedded therein, onto the corrosion resistant layer 58. However, if the corrosion resistant material 64 comprises a thermosetting material, an adhesive or other tie layer may be used between the corrosion resistant layer 58 and the abrasion resistant layer 60.

It may now be fully appreciated that the above disclosure provides significant advancements to the art of designing, producing and utilizing sucker rods for use in wells. In examples described above, a corrosion resistant layer 58 is applied on a base metal 62 of a sucker rod 32, and the corrosion resistant layer 58 is protected by an abrasion resistant layer 60. An abrasion resistant material 66 of the abrasion resistant layer 60 may comprise a phenolic based matrix material 66a and/or a particulate material 68.

The above disclosure provides to the art a sucker rod 32 for use in a subterranean well. In one example, the sucker rod 32 may comprise a base metal 62 configured to connect a surface actuator 12 to a downhole pump 20, a corrosion resistant layer 58 on the base metal 62, and an abrasion resistant layer 60 external to the corrosion resistant layer 58. The abrasion resistant layer 60 comprises a phenolic material 66a.

In any of the examples described herein, the abrasion resistant layer 60 may further comprise an epoxy material.

In any of the examples described herein, the abrasion resistant layer 60 may comprise an abrasion resistant particulate material 68.

In any of the examples described herein, the abrasion resistant layer 60 may comprise a friction reducing particulate material 68.

In any of the examples described herein, the particulate material 68 may be embedded in the phenolic material 66a.

In any of the examples described herein, the particulate material 68 may be positioned between the corrosion resistant layer 58 and at least a portion of the phenolic material 66a.

In any of the examples described herein, the particulate material 68 may be selected from the group consisting of silicon carbide, silicon dioxide, oxides, borides, nitrides and carbides.

In any of the examples described herein, the particulate material 68 may be selected from a variety of friction reducing agents, including fluorocarbons, graphite, graphene, molybdenum disulfide and other friction reducing agents.

In any of the examples described herein, the corrosion resistant layer 58 may comprise an epoxy material.

In any of the examples described herein, the sucker rod 32 may be a continuous sucker rod.

In any of the examples described herein, the base metal 62 may have a length of at least 1000 meters.

Another sucker rod 32 for use in a subterranean well is provided to the art by the above disclosure. In this example, the sucker rod 32 comprises a base metal 62 configured to connect a surface actuator 12 to a downhole pump 20, a corrosion resistant layer 58 on the base metal 62, and an abrasion resistant layer 60 external to the corrosion resistant layer 58. The abrasion resistant layer 60 comprises an abrasion resistant particulate material 68 and a matrix material 66a.

In any of the examples described herein, the matrix material 66a may comprise a phenolic material.

In any of the examples described herein, the particulate material 68 may be embedded in the matrix material 66a.

In any of the examples described herein, the particulate material 68 may be positioned between the corrosion resistant layer 58 and at least a portion of the matrix material 66a.

A method 34 of producing a continuous sucker rod 32 is also provided to the art by the above method. In one example, the method 34 comprises displacing the continuous sucker rod 32 through a surface treatment system 48; applying a corrosion resistant layer 58 on a base metal 62 of the continuous sucker rod 32; then applying an abrasion resistant layer 60 external to the corrosion resistant layer 58.

In any of the examples described herein, the abrasion resistant layer 60 applying step may comprise applying a phenolic material 66a.

In any of the examples described herein, the abrasion resistant layer 60 applying step may comprise applying an abrasion resistant and/or friction reducing particulate material 68.

In any of the examples described herein, the abrasion resistant layer 60 applying step may comprise applying an abrasion resistant and/or friction reducing particulate material 68 dispersed in a matrix material 66a.

Although various examples have been described above, with each example having certain features, it should be understood that it is not necessary for a particular feature of one example to be used exclusively with that example. Instead, any of the features described above and/or depicted in the drawings can be combined with any of the examples, in addition to or in substitution for any of the other features of those examples. One example's features are not mutually exclusive to another example's features. Instead, the scope of this disclosure encompasses any combination of any of the features.

Although each example described above includes a certain combination of features, it should be understood that it is not necessary for all features of an example to be used. Instead, any of the features described above can be used, without any other particular feature or features also being used.

It should be understood that the various embodiments described herein may be utilized in various orientations, such as inclined, inverted, horizontal, vertical, etc., and in various configurations, without departing from the principles of this disclosure. The embodiments are described merely as examples of useful applications of the principles of the disclosure, which is not limited to any specific details of these embodiments.

The terms “including,” “includes,” “comprising,” “comprises,” and similar terms are used in a non-limiting sense in this specification. For example, if a system, method, apparatus, device, etc., is described as “including” a certain feature or element, the system, method, apparatus, device, etc., can include that feature or element, and can also include other features or elements. Similarly, the term “comprises” is considered to mean “comprises, but is not limited to.”

Of course, a person skilled in the art would, upon a careful consideration of the above description of representative embodiments of the disclosure, readily appreciate that many modifications, additions, substitutions, deletions, and other changes may be made to the specific embodiments, and such changes are contemplated by the principles of this disclosure. For example, structures disclosed as being separately formed can, in other examples, be integrally formed and *vice versa*. Accordingly, the foregoing detailed description is to be clearly understood as being given by way of illustration and example only, the spirit and scope of the invention being limited solely by the appended claims and their equivalents.

WHAT IS CLAIMED IS:

1. A sucker rod for use in a subterranean well, the sucker rod comprising:

a base metal configured to connect a surface actuator to a downhole pump;

a corrosion resistant layer on the base metal; and

an abrasion resistant layer external to the corrosion resistant layer, the abrasion resistant layer comprising a phenolic material.

2. The sucker rod of claim 1, in which the abrasion resistant layer further comprises an epoxy material.

3. The sucker rod of claim 1, in which the abrasion resistant layer further comprises an abrasion resistant particulate material.

4. The sucker rod of claim 1, in which the abrasion resistant layer further comprises a friction reducing particulate material.

5. The sucker rod of claim 1, in which the abrasion resistant layer further comprises a particulate material embedded in the phenolic material.

6. The sucker rod of claim 1, in which the abrasion resistant layer further comprises a particulate material positioned between the corrosion resistant layer and at least a portion of the phenolic material.

7. The sucker rod of claim 1, in which the abrasion resistant layer further comprises a particulate material selected from the group consisting of silicon dioxide, oxides, borides, nitrides, carbides, fluorocarbons, graphite, graphene and molybdenum disulfide.

8. The sucker rod of claim 1, in which the corrosion resistant layer comprises an epoxy material.

9. The sucker rod of claim 1, in which the sucker rod is a continuous sucker rod.

10. The sucker rod of claim 1, in which the base metal has a length of at least 1000 meters.

11. A sucker rod for use in a subterranean well, the sucker rod comprising:

a base metal configured to connect a surface actuator to a downhole pump;

a corrosion resistant layer on the base metal; and

an abrasion resistant layer external to the corrosion resistant layer, the abrasion resistant layer comprising an abrasion resistant particulate material and a matrix material.

12. The sucker rod of claim 11, in which the matrix material comprises a phenolic material.

13. The sucker rod of claim 11, in which the particulate material is embedded in the matrix material.

14. The sucker rod of claim 11, in which the particulate material is positioned between the corrosion resistant layer and at least a portion of the matrix material.

15. The sucker rod of claim 11, in which the particulate material is selected from the group consisting of silicon dioxide, oxides, borides, nitrides, carbides, fluorocarbons, graphite, graphene and molybdenum disulfide.

16. The sucker rod of claim 11, in which the sucker rod is a continuous sucker rod.

17. The sucker rod of claim 11, in which the base metal has a length of at least 1000 meters.

18. A method of producing a continuous sucker rod, the method comprising:

displacing the continuous sucker rod through a surface treatment system;

applying a corrosion resistant layer on a base metal of the continuous sucker rod; then

applying an abrasion resistant layer external to the corrosion resistant layer.

19. The method of claim 18, in which the abrasion resistant layer applying comprises applying a phenolic material.

20. The method of claim 18, in which the abrasion resistant layer applying comprises applying an abrasion resistant particulate material.

21. The method of claim 18, in which the abrasion resistant layer applying comprises applying a friction reducing particulate material.

22. The method of claim 18, in which the abrasion resistant layer applying comprises applying an abrasion resistant particulate material dispersed in a matrix material.

23. The method of claim 18, in which the abrasion resistant layer applying comprises applying a friction reducing particulate material dispersed in a matrix material.

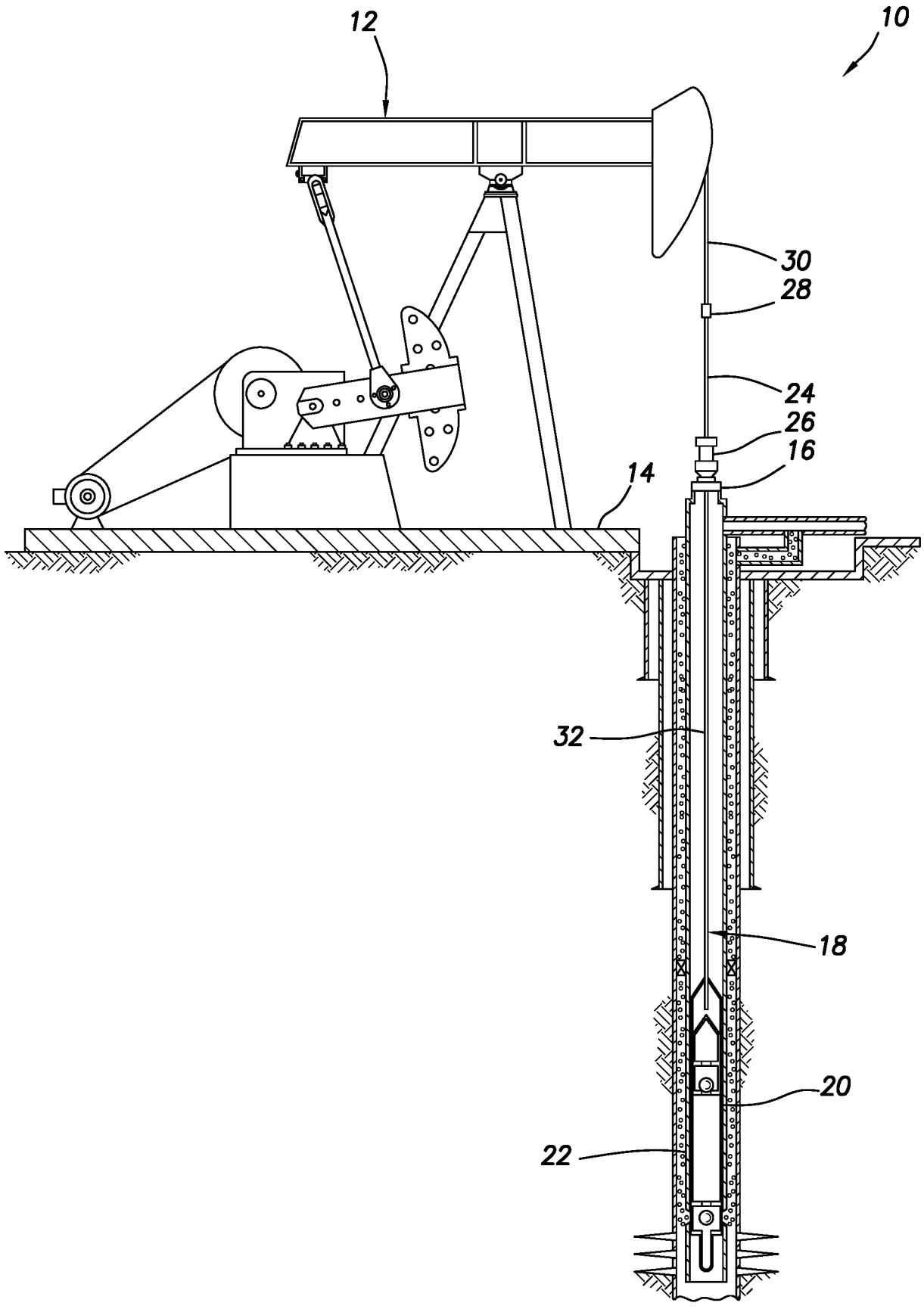

FIG. 1

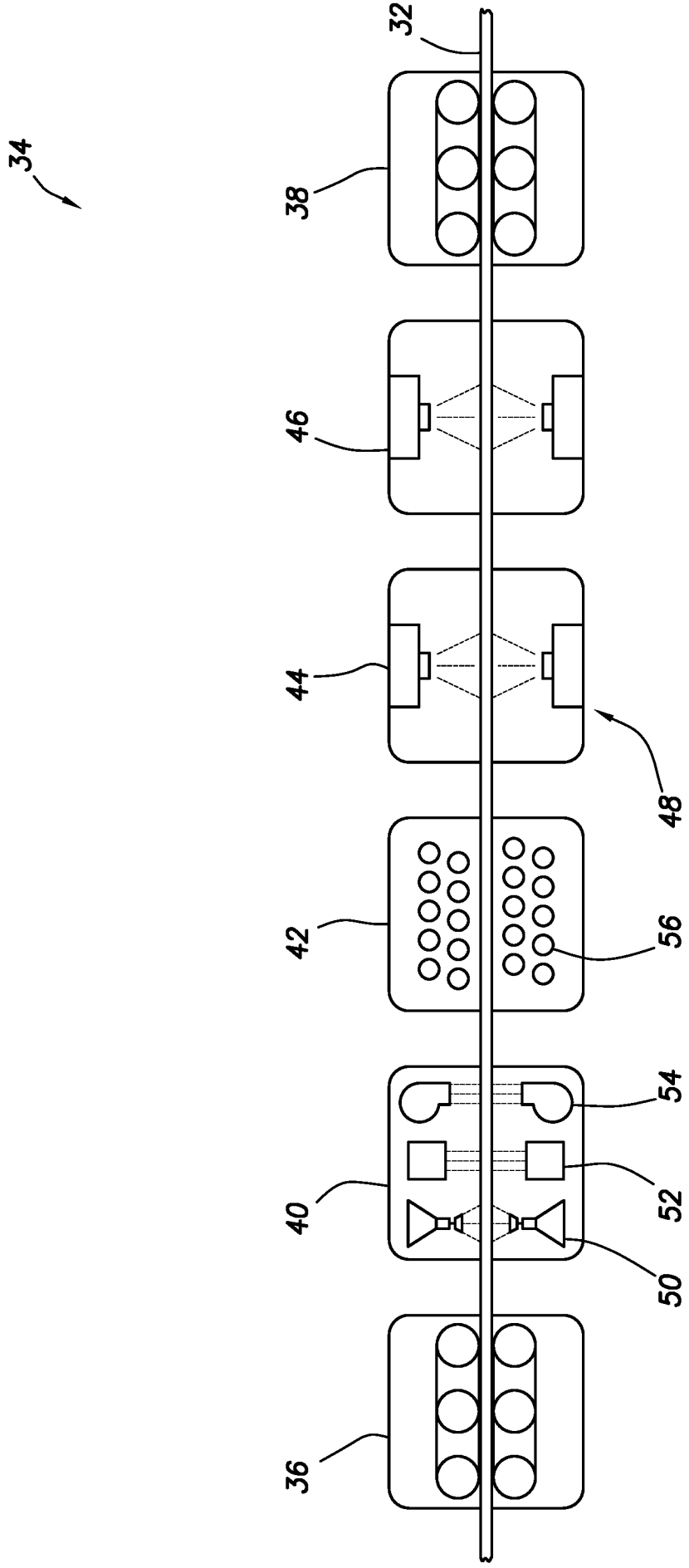

FIG.2

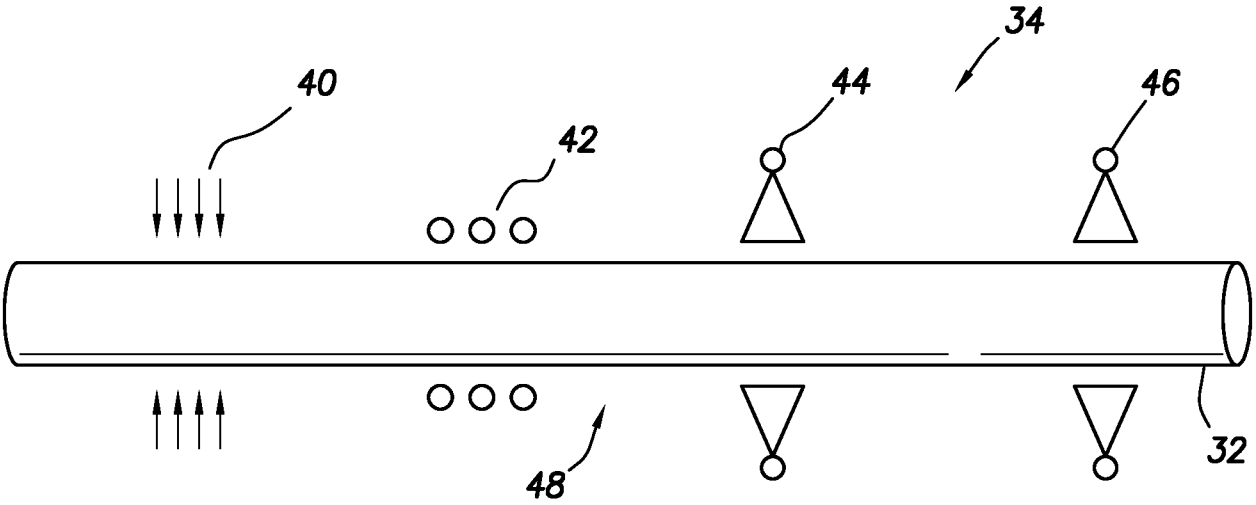

FIG.3

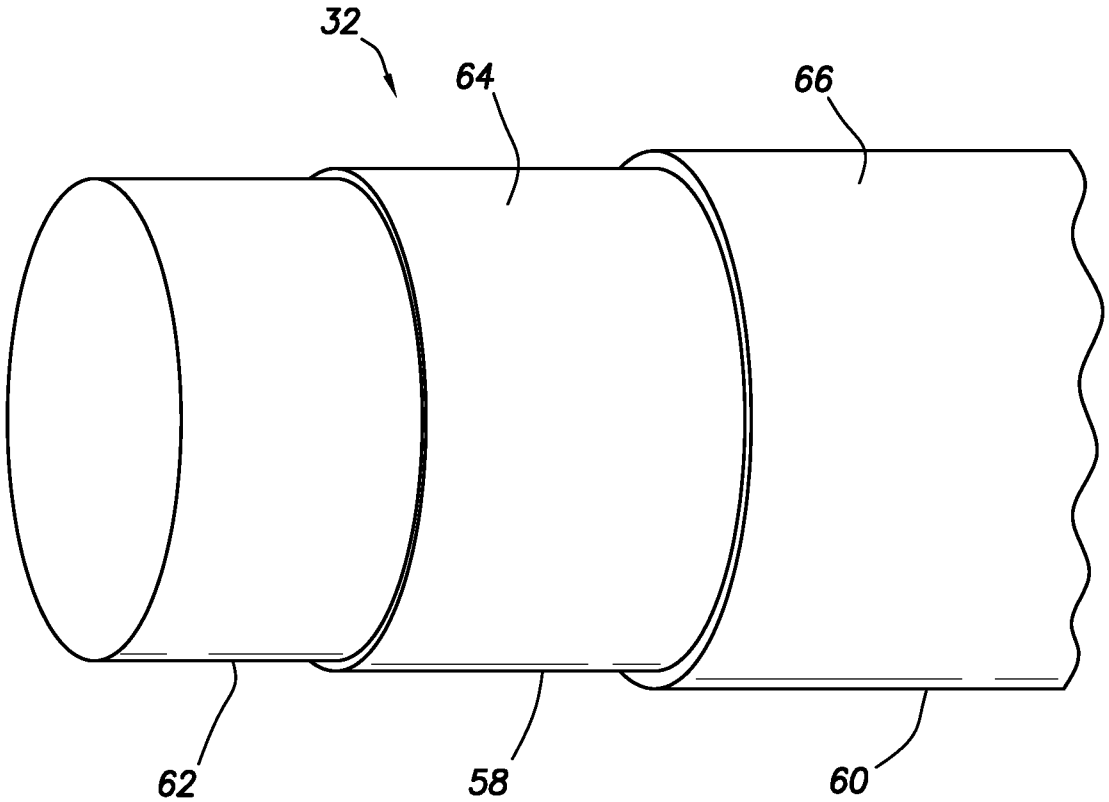

FIG.4

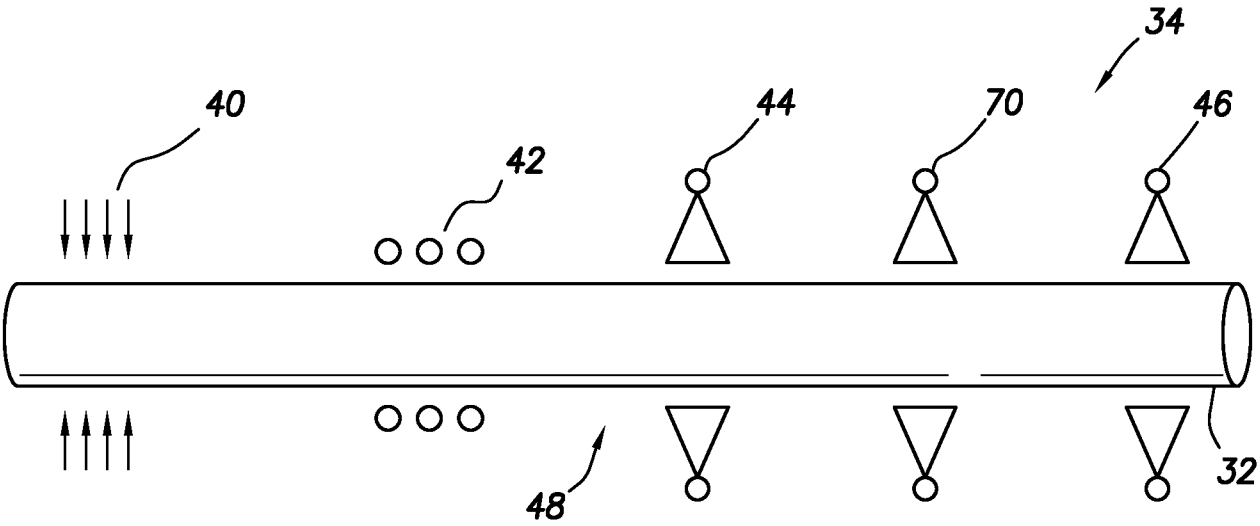

FIG.5

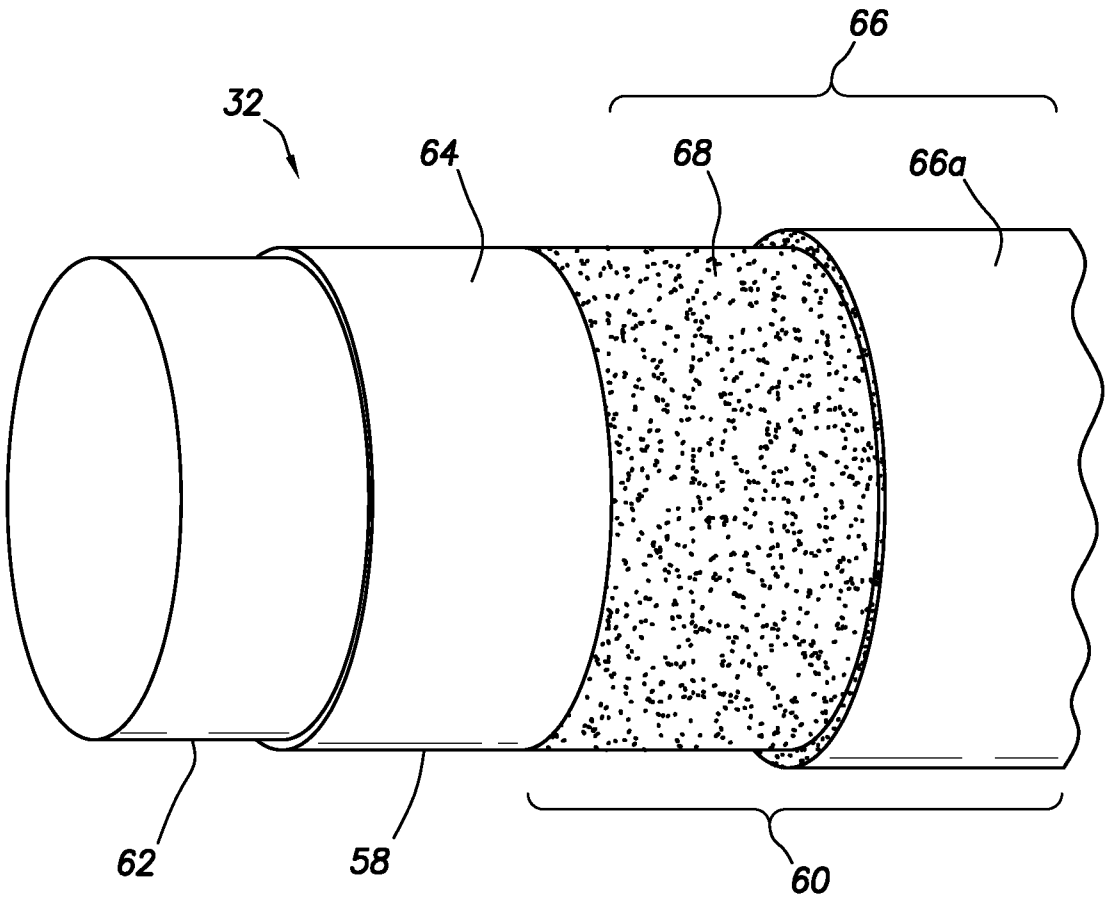

FIG.6

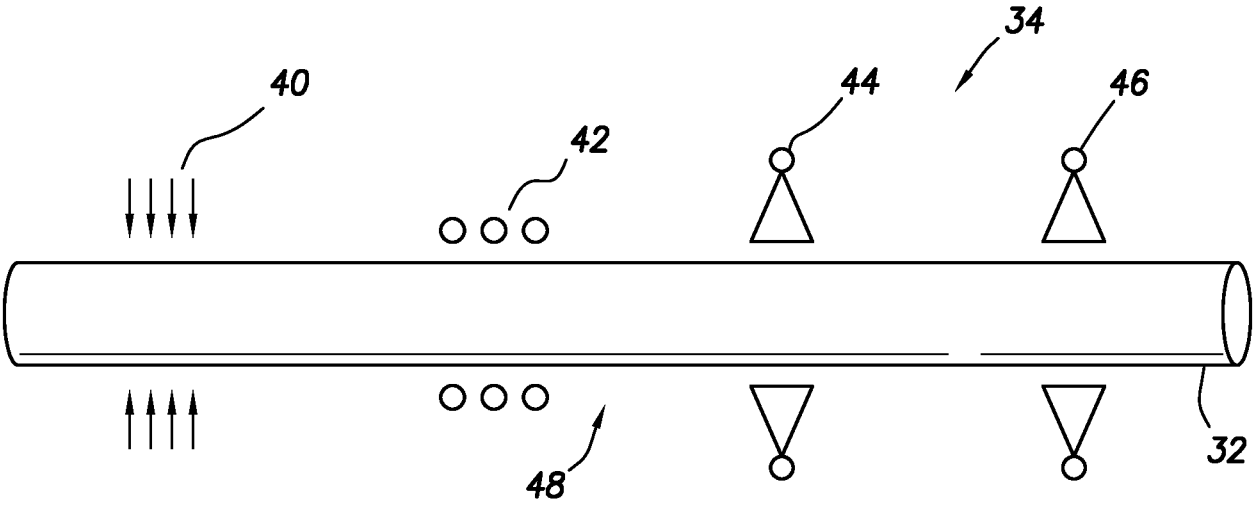

FIG.7

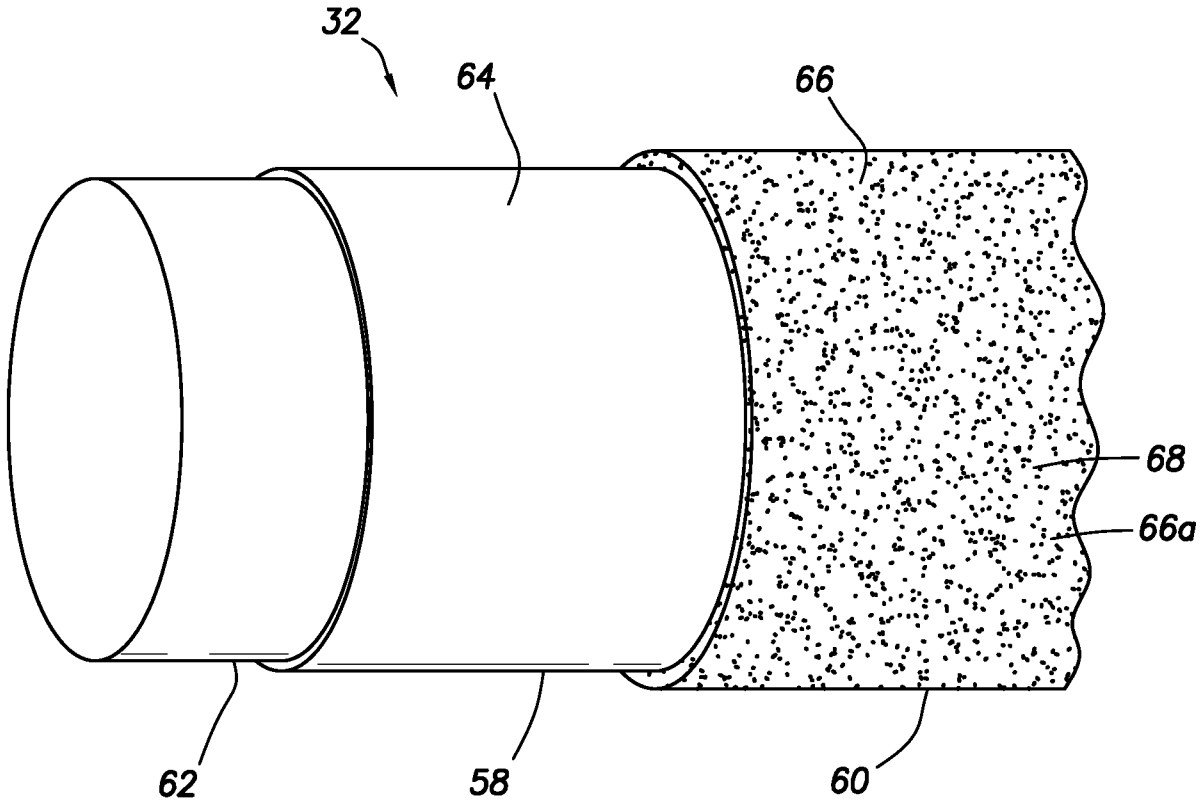

FIG.8

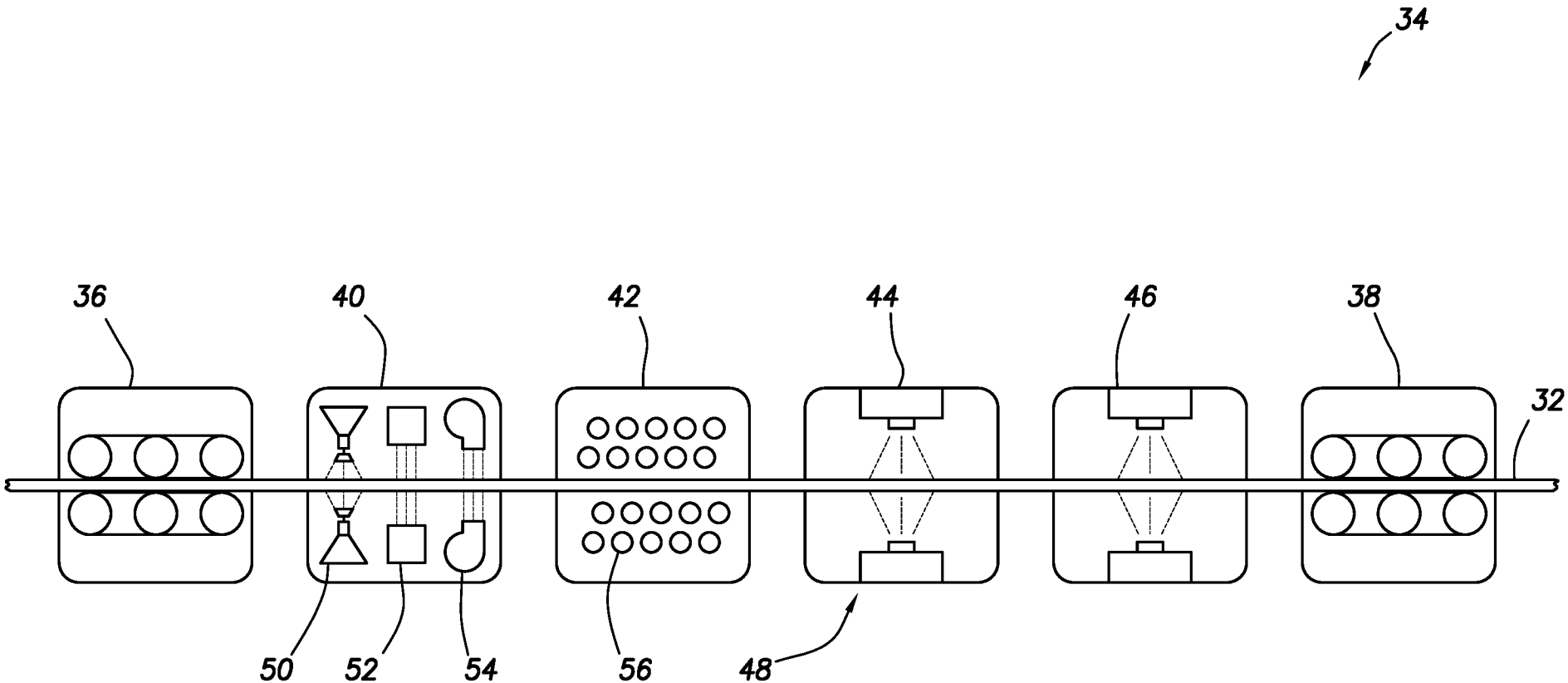

FIG.2