Dec. 27, 1966 L. G. SHARP 3,294,122

TUBING PROTECTOR

Filed Dec. 30, 1963

FIG. 1

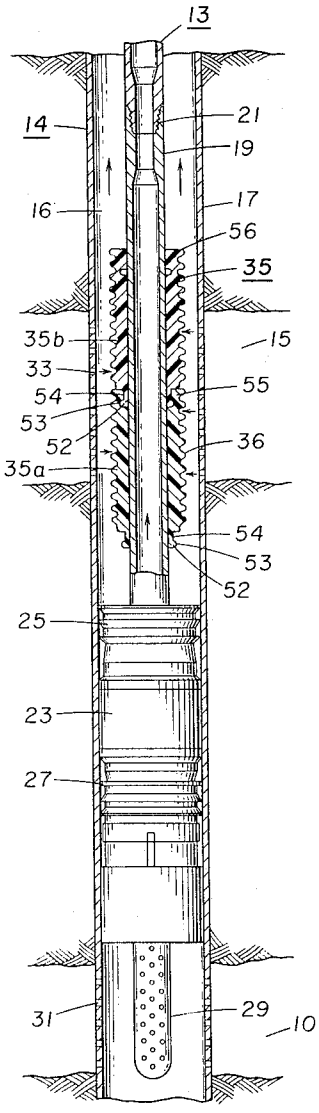


FIG. 4

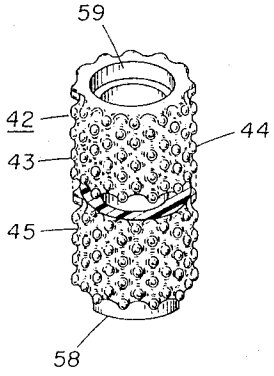


FIG. 2

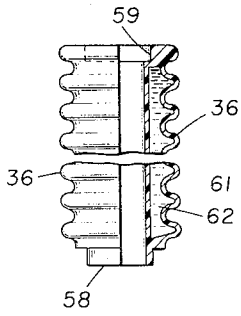
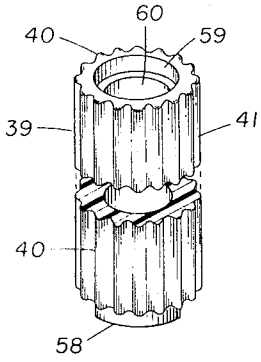


FIG. 3



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TUBING PROTECTOR

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This invention is concerned with protection means for a structure subjected to erosion by a fluid stream containing particulate matter. More particularly, it is concerned with protection means for the tubing or other pipe extending into an oil or gas well and being subjected to a jet of hydrocarbons containing sand or other particulate matter.

This invention is useful where a structure is subjected to abrasion, corrosion, and erosion by a stream of fluids containing particulate matter. It will be described in detail with regard to use in protecting the tubing in an oil or gas well completed in more than one producing formation.

Many oil or gas wells produce from two or more formations at different levels. The conventional manner of producing dual formations is to set a casing packer between the formations and extend metal tubing through the packer with a perforated tailpipe, or open end, at the lower end adjacent the lower producing formation. The casing packer thus effectively seals off the tubing and isolates the lower formation in communication with the interior of this tubing. The fluid from the lower formation flows through the tubing to the surface of the earth. The fluid from the upper formation can then be produced through perforations in the casing and thence through the annulus between the tubing and the casing to the surface of the earth. The well thus constructed is said to be completed in both the lower producing formation and the upper producing formation. The term "completed" is used herein as a term of art. A well is completed in a subterranean formation when the necessary equipment has been installed to afford a conduit which enables fluids from the formation to flow to the surface but which excludes fluids from other subterranean formations. A well which is separately completed in more than one producing formation is referred to as a multiply completed well.

In another form of a multiply completed well, a separate string of tubing is used to produce the fluid from each producing formation. Suitable packers seal off the producing formations and strings of tubing, and isolate each formation in communication with its respective string of tubing.

In either form wherein multiple completions are effected, a section of well tubing will extend past a productive formation and thus be exposed to the produced fluid as it enters through perforations in the wall of the casing. The fluid is usually under pressure and passes from the formation through the restricted perforations in the casing at high velocity and in jetted streams. This is particularly true where the primary fluid being produced is gas. Such fluid often has a content of sand or other particulate, abrasive material which impinges against the tubing. Such a solid-containing, fluid jet abrades and erodes the surface and intensifies the corrosion of the surface.

Several means have been employed in the past in attempts to protect the tubing. Layers of lead have been wrapped around the tubing, on the theory that a malleable metal could absorb some of the energy more readily than the tubing itself. Alternatively, hard, brittle materials, such as ceramics and glass, have been employed as sleeves for the tubing. Resilient coatings around the tubing have been used with more success than the foregoing. These resilient coatings have been bonded directly on the tubing. They also have been applied as sleeves which could be prepositioned on the tubing before it was placed in the wellbore. None of these means, however, have been entirely satisfactory.

It is therefore a primary object of this invention to provide a tubing protector. It is another object of this invention to provide an abrasion protector for a structure subjected to an impinging, abrading stream. It is another object of this invention to provide a protected tubing assembly. It is another object of this invention to provide a tubing protector assembled on the tubing to encase and cover the tubing in the area desired and to maintain complete coverage and protection of the tubing while it is being run into the well and while it is being subjected to the jetting force of the production fluid. A further object of the invention is to provide protector sections of an elastomeric material which can be constructed to resist the erosive and/or corrosive action of well fluids. A further object of the invention is to provide protector sections which can be conveniently and inexpensively applied to tubing in the field in such numbers as may be desired to cover and protect the tubing when emplaced subject to the abrading fluid jets.

Further objects and advantages of the invention may be had from reference to the following detailed description and drawings.

FIGURE 1 is an elevation partly in cross section of a tubing protector in place in a dually completed well.

FIGURE 2 is an elevation partly in cross section of another tubing protector wherein the annular space within the protector is filled with a fluid.

FIGURE 3 is a perspective view of another tubing protector wherein the outer surface has corrugations parallel with the longitudinal axis of the protector.

FIGURE 4 is a perspective view of another tubing protector wherein the outer surface is continuously curving.

In accordance with the invention, there is provided an erosion protector comprising a sleeve which has a continuously curving external surface which minimizes the area normal to the direction of impinging abrasive jets. It has been found by experimental work using fluid streams having sand injected thereinto that abrasion protectors, regardless of the material from which they are constructed, are eroded away quickly when the stream impinges normal or perpendicular to the tubing protector surface. On the other hand, when the abrasive stream impinges upon the protector at an angle other than normal, the solid particles are deflected and their intense erosion effect become greatly attenuated.

Referring to FIGURE 1, a conventional dual completion installation is illustrated wherein a lower producing formation **10** is produced through tubing string **13** in well **14** and an upper productive formation **15** is produced through annular space **16** between the tubing string **13** and casing **17**. Tubing string **13** is comprised of a plurality of joints of pipe, similar to joint **19**, extending from the earth's surface. The joints are preferably of the "flush-joint, upset-thread" type, having uniform external diameter at connections, illustrated by connection **21**. Joint **19** extends through a conventional casing packer **23** which is set to seal against the wall of casing **17**, packer **23** being anchored to casing **17** by conventional slips **25** and **27**. A perforated tailpipe **29** is attached to the lower end of joint **19**. Production fluid from the lower producing formation **10** enters casing **17** through perforations **31** in the wall of casing **17**, passes through the perforated tailpipe **29**, and upward through the tubing string **13** to the surface. Fluid from the upper productive formation **15** enters the casing **17** through perforations **33** and rises to the surface through the annular space **16** between the casing **17** and the tubing string **13**.

In each instance in which fluid is produced from the producing formations **10** and **15**, high velocity jets are formed upon production of the fluid through the perforations **31** and **33**, respectively. Such fluid being produced generally has entrained therein solid particulate matter such as sand particles. Impingement of the high speed jet having suspended therein the solid particulate matter erodes well equipment upon which it impinges.

The degree of erosion and wear of the tubing is attenuated by the insertion of a protector comprised of a sleeve of at least one section having an outer surface on which the minimal area is presented normal or perpendicular to the incident abrasive jet. With this sleeve a portion of the kinetic energy of the high speed particles of the jet is absorbed before it strikes normal to a surface. The turbulence thus induced creates a greater area for dissipation of the energy of the particles. Accordingly, the wear is spread out over a larger area than where the jet impinges normal to the surface, and erosive action is reduced.

The significant structural feature of the sleeve of the invention is that of the external surface. Sleeve **35** is positioned about the portion of tubing string **13** adjacent formation **15**. As illustrated, sleeve **35** is formed of two sections **35***a* and **35***b*. Outer surface **36** of the sleeve **35** is illustrated in FIGURE 1 in cross section. The outer surface of the sleeve has corrugations which are transverse to the longitudinal axis of the sleeve. For protection tubing in an oil well having perforations made by a conventional perforator, the radius of curvature for the continuously curving outer surface should preferably lie between 0.025 inch and 0.25 inch, i.e., the diameter should lie between 0.05 inch and 0.50 inch. An external surface **36** having corrugations transverse to the longitudinal axis of the sleeve is also shown in FIGURE 2.

In the sleeve of the invention illustrated by a single section **39** in FIGURE 3, external surface **40** is continuously curving with respect to the transverse axis only. Therein, corrugations **41** are parallel to the longitudinal axis of section **39**. The radius of curvature of corrugations **41** should conform to the preferred radius of curvature mentioned above.

In the sleeve of the invention illustrated by a single section **42** in FIGURE 4, external surface **43** is continuously curving, with respect to both longitudinal and transverse axes, within the preferred radius of curvature mentioned above. The outer surface **43** has convex protrusions **44** and concave valleys **45** between these protrusions **44**. These protrusions and valleys should both continuously curve within the preferred radii.

The sleeve of the invention can be made of any suitable material. For example, the sleeve may be constructed of any material heretofore employed. Preferably, however, the sleeve will be constructed of an elastomeric material which is resistant to both erosion and corrosion. Suitable elastomeric materials are synthetic resins including polyethylene, polypropylene, polybutylene, polybutadiene, and neoprene.

Unitary sleeves are preferred from a protection standpoint since they are more resistant to being parted during placement or by the turbulence of the jets. However, practical considerations may place a limit on the length of a unitary sleeve. Some producing intervals extend for several hundred feet along the length of a well. Handling and fabricating such great length of sleeve present problems. Thus, it is often advisable to have the sleeve comprised of multiple sections having a more convenient length. For example, in areas having long producing intervals, section lengths on the order of 10 feet, 20 feet, or even 30 feet may be used. In other areas having producing intervals on the order of 2 feet to 10 feet in length, sections having shorter lengths, such as on the order of 1 foot to 2 feet or less, may be used.

Where multiple sections are jointed to form the sleeve of the invention, they are assembled around the exterior

of the tubing or pipe to create a continuous protector which maintains its integrity and provides protection even under adverse placement or production operations. It is important that the joints between each section seal and mutually grip and support each other to prevent their being separated or parted by the turbulence induced by the impinging jets of high velocity fluid or by friction during the placement operation. A satisfactory seal or joint useful with the elastomeric materials is shown in FIGURE 1. Referring thereto, cylindrical sections **35***a* and **35***b* are joined to form sleeve **35** surrounding the tubing joint **19** within the zone producing the erosive jets of fluid. There may be any number of sections joined as illustrated therein to protect the tubing throughout the producing interval. The details of the particular joint by which sections **35***a* and **35***b* are joined is shown therein. Extensions **52** of sections **35***a* and **35***b* are protrusions **53** of reduced diameter but having slightly greater diameter than necks **54** and are adapted to be inserted into a conforming recess **55** of the adjacent section. The internal dimensions of recess **55** are slightly smaller than the external dimensions of extension **52**, but are elastic enough to be stretched thereover. In this manner, a gripped and sealed joint is provided which is resistant to separation by the turbulence induced by the impinging jets of high velocity fluid. Each section has one end which contains recess **55** and thus has reduced thickness. Being elastic, however, it will curl inward to conform to the wall of the tubing as shown at position **56** when there is no extension **52** inserted therebeneath.

An alternate type of joint construction is illustrated in FIGURES 2, 3, and 4. Therein, extension **58** of each section is adapted to be inserted into a recess, such as **59**, on the adjacent section. The outside diameter of extension **58** is slightly greater than the internal diameter of recess **59** so when the sections are assembled the joint is comprised of concentric cylinders engaged in gripping and sealing relationship. Because of recess **59**, the end of each section containing the recess will have reduced thickness. Being elastic, however, it will curl inward to conform to the wall of the tubing as discussed above. While this joint can be constructed and assembled more easily, it is less resistant to being parted by the turbulence of the impinging fluid.

The tubing protector sleeve **35** is placed on the tubing joint **19** while the tubing string is being made up at the earth's surface. A tubing joint provided with the protector sleeve is incorporated in the tubing string at the appropriate depth as the tubing string is run into the well. Referring to FIGURE 3 as illustrative of all sections of sleeve **35**, the bore **60** when relaxed is slightly smaller than the tubing about which it is to be stretched. The degree of elasticity of the material from which the section has been constructed will control how much less the diameter of bore **60** can be and still be assembled or stretched over the external diameter of the tubing. Thus, when the protector sleeve is stretched over the tubing, it forms a tight elastic sleeve which is resistant to movement, either longitudinal or rotational.

The greater the thickness of the sleeve about the tubing, the longer will be the time, other conditions being equal, the sleeve will protect the tubing and afford a deflecting, erosion-resistant zone. It is apparent, however, that in multiply completed wells, one or more sleeves must be inserted through packer elements. The internal diameter of the opening in such a packer element will control the outside diameter which is allowable for the continuously curving outer surface of the sleeve **35**. Thus, for each area in which wells are completed, there will be a normally used packer and tubing combination which will dictate the internal and external diameter dimensions of sections of sleeves which will be used.

While the continuously curving outer surface has been described as a preferred embodiment, it will be readily apparent that small departures therefrom will operate to

minimize the erosion without setting up undue stresses in the sleeve. For example, instead of hemispherical surfaces such as illustrated by protrusion **44** in FIGURE 4 or corrugations **41** in FIGURE 3, semipyramidal portions or elongated portions having triangular cross section would operate as well. Such other embodiments which offer a minimum of surface area normal to the impinging jet are deemed to be within the scope of my invention.

It will also be apparent that, instead of constructing the sleeve as a solid angular ring, a space can be provided within the angular ring for the insertion of a suitable fluid to help absorb the energy of the impinging high velocity particles and transfer that energy elsewhere for dissipation. Such construction is illustrated in FIGURE 2. Therein, external corrugations **36** are made such that an inner annular opening **61** is provided. Into this annular opening **61** a fluid **62** such as a viscous oil, water, or air may be injected.

The invention has been particularly described with regard to the preferred embodiment wherein the sleeve, whether unitary or in sections, is made of an elastomeric material. Assembly is made taking advantage of the relatively low modulus of elasticity. Where relatively inelastic materials such as metals are used in the construction of the sleeve, or sections thereof, the cofficient of expansion under heating is taken advantage of in assembly. The sleeve is heated and assembled on the cold tubing. When cooled it grips the tubing as described above. Where mutiple sections of inelastic material are assembled to form the sleeve, each section is made with an extension **58** and a recess **59**, as illustrated in FIGURE 3. Each successive section is heated and placed in position such that thermally expanded recess **59** and bore **60** encircle, respectively, extension **58** of the cooled adjacent section and the cold tubing.

Other embodiments suggest themselves. It is intended to cover such embodiments as are within the scope of the appended claims.

What is claimed is:

1. A protective tubing assembly for use in a well separately completed in more than one subterranean formation wherein a fluid stream containing particulate matter impinges thereon which comprises tubing and a sleeve radially enclosing and gripping said tubing, said sleeve when relaxed having a bore of lesser diameter than the outer diameter of said tubing and said sleeve having an outer surface continuously curving at a radius between 0.025 inch and 0.25 inch to minimize the surface area normal to the impinging stream.

2. A protected tubing assembly for use in a well separately completed in more than one subterranean formation wherein a fluid stream containing particulate matter impinges thereon which comprises tubing and a sleeve comprising a plurality of elastomeric sections radially stretched about said tubing and held in stretched condition thereby, each section when relaxed having a bore of lesser diameter than the outer diameter of said tubing, a portion of reduced outer diameter on one end thereof, and internal annular recess provided inside the other end thereof, said recess and said reduced end portion being complementary in shape and length and joined so that the reduced end portion fills the recess and the overlapped ends are in elastically gripped and sealed relationship, and an outer surface continuously curving at a radius between 0.025 inch and 0.25 inch to minimize the surface area normal to the impinging stream

3 The protected tubing assembly of claim **2**, wherein said elastomeric section is constructed of a synthetic resin selected from the class consisting of polyethylene, polypropylene, polybutylene, polybutadiene, and neoprene.

4. The protected tubing assembly of claim **2** wherein said outer surface is continuosuly curved in the form of corrugations of diameter between 0.050 inch and 0.50 inch.

5. The protected tubing assembly of claim **4** wherein said corrugations are parallel to the longitudinal axis of the tubing.

6. The protected tubing assembly of claim **4** wherein said corrugations are transverse to the longitudinal axis of the tubing.

7. In a protected tubing assembly being comprised of tubing and multiple sections joined in gripped and sealed relationship to form a unitary protective sleeve covering the exterior of the tubing, the improvement which comprises an outer surface continuously curving with a radius between 0.025 inch and 0.25 inch so as to expose minimal surface area normal to an abrading jet.

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