Sept. 26 1967 D. SILVERMAN ETAL 3,343,248

APPARATUS FOR JOINING TWO TUBULAR METAL ELEMENTS BY SIMULTANEOUS DEFORMATION TO FORM INTERLOCKING RIDGES

Filed July 15, 1965 4 Sheets-Sheet 1

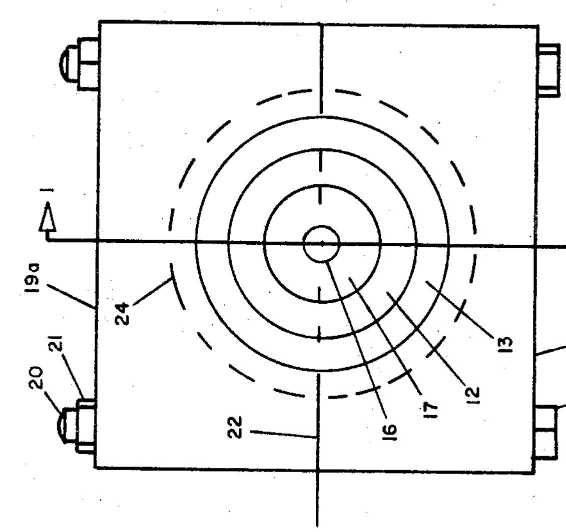

FIG. 2

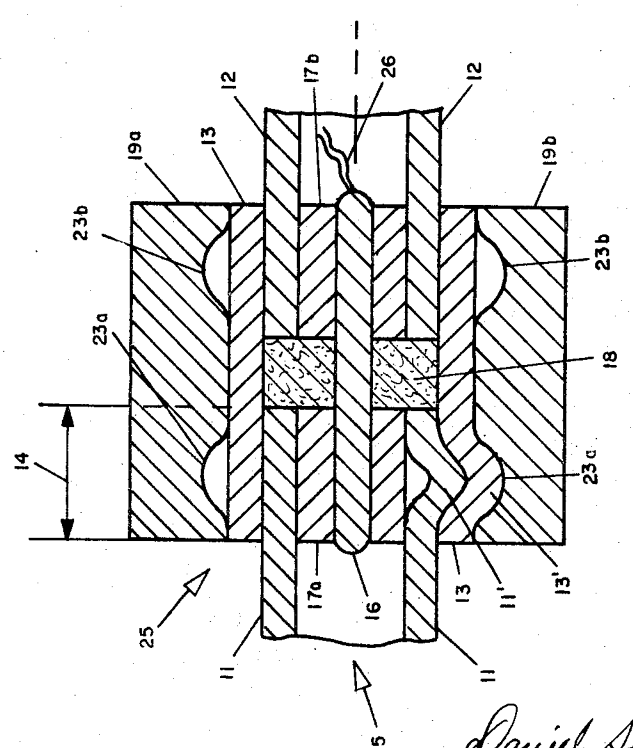

FIG. 1

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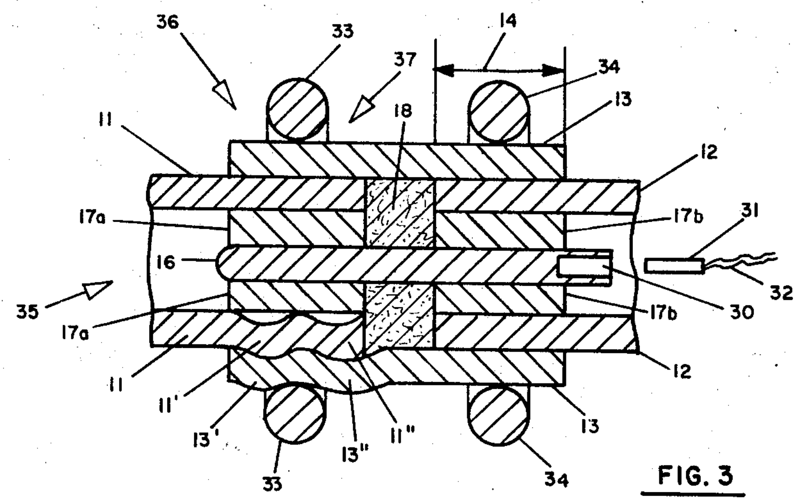

FIG. 3

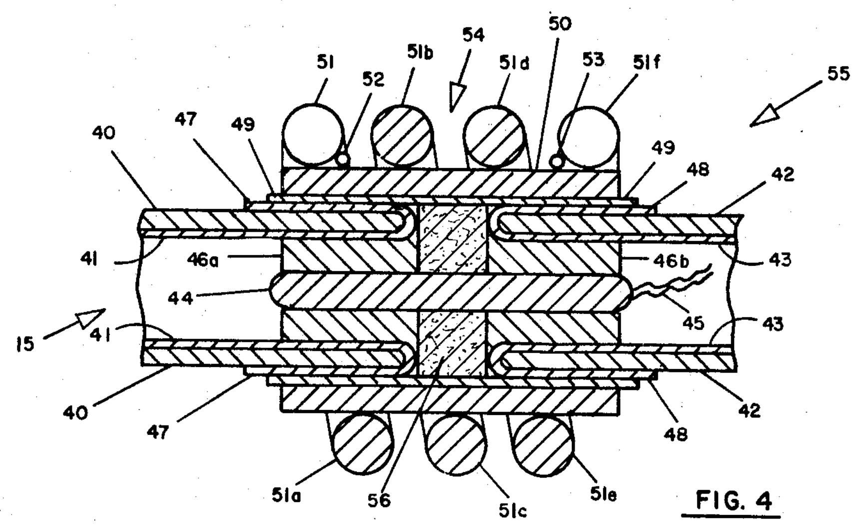

FIG. 4

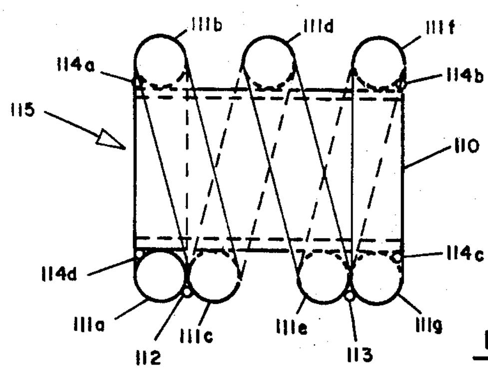

FIG. 13

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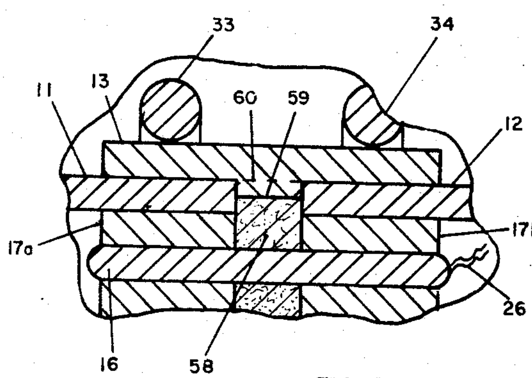


FIG. 5

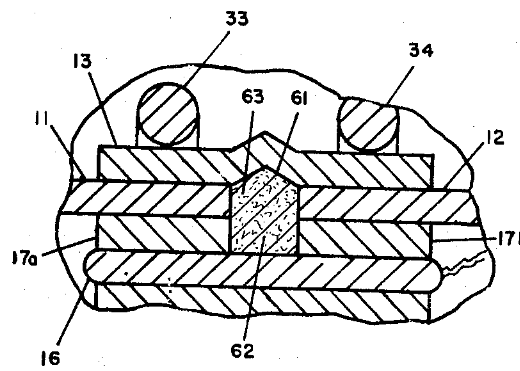


FIG. 6

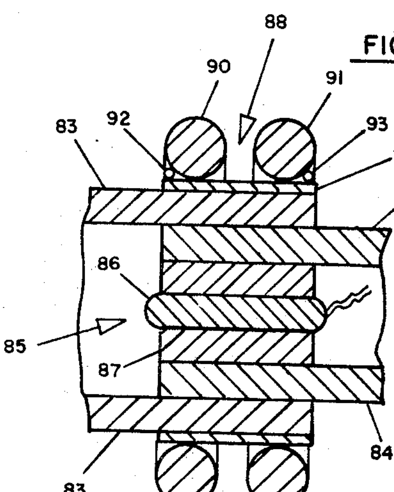


FIG. 10

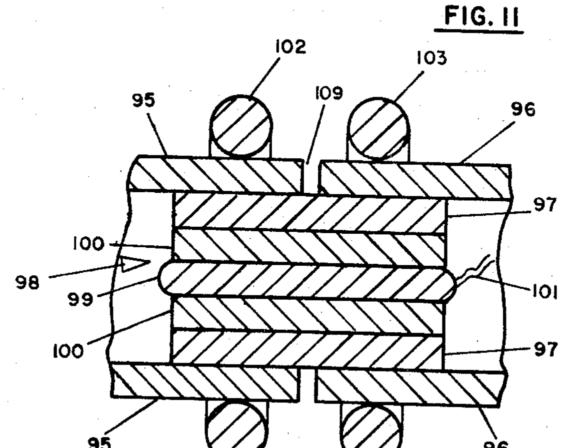


FIG. 11

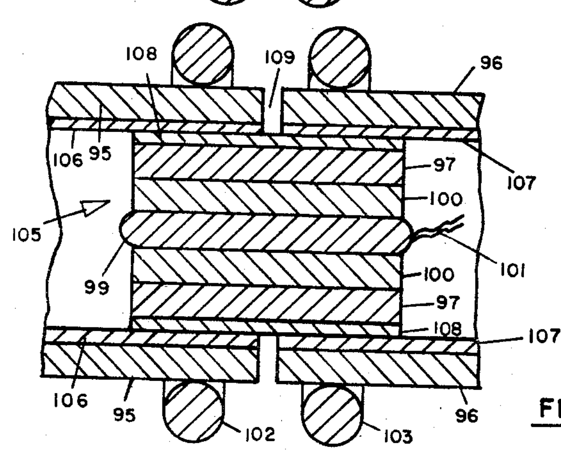
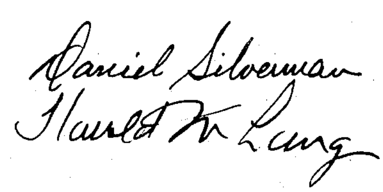


FIG. 12



INVENTORS

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APPARATUS FOR JOINING TWO TUBULAR METAL ELEMENTS BY SIMULTANEOUS DEFORMATION TO FORM INTERLOCKING RIDGES

Filed July 15, 1965 4 Sheets-Sheet 4

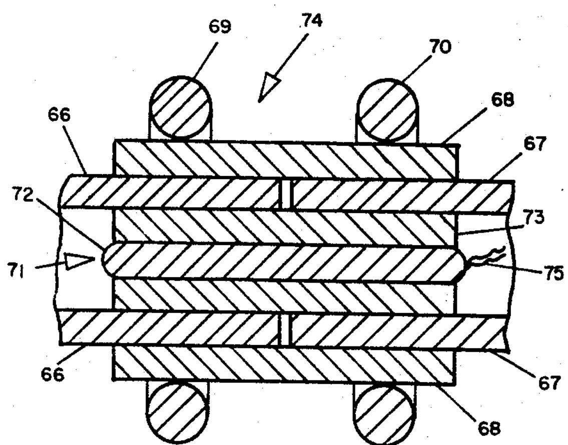


FIG. 7a

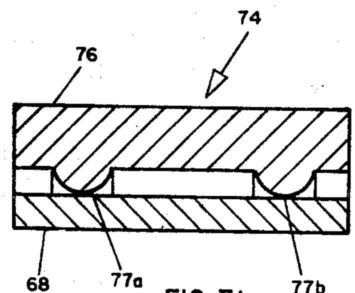


FIG. 7b

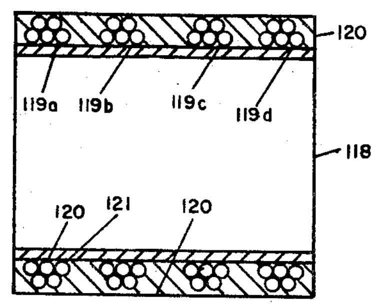


FIG. 14

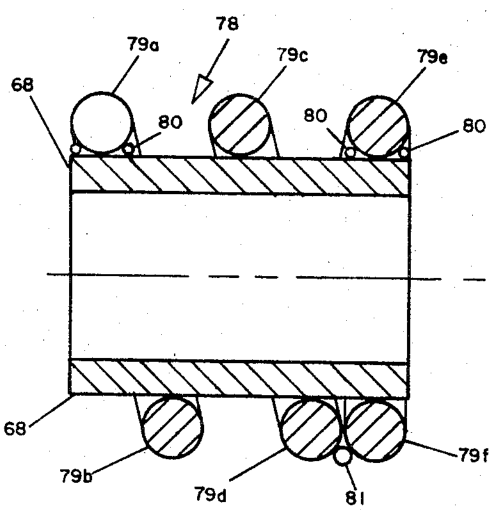


FIG. 8

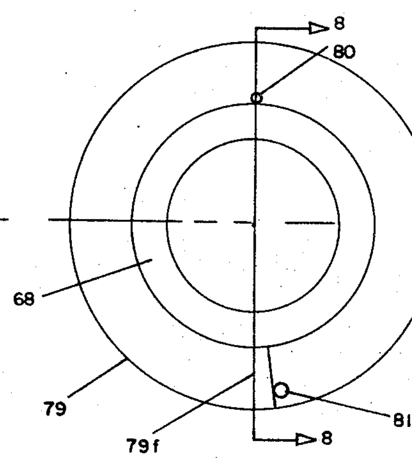
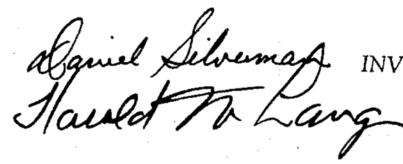


FIG. 9



INVENTORS

United States Patent Office

3,343,248
Patented Sept. 26, 1967

3,343,248
APPARATUS FOR JOINING TWO TUBULAR METAL ELEMENTS BY SIMULTANEOUS DEFORMATION TO FORM INTERLOCKING RIDGES

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Filed July 15, 1965, Ser. No. 472,258
32 Claims. (Cl. 29—200)

This application is a continuation-in-part of our copending application Ser. No. 250,417, filed Jan. 9, 1963, entitled, "Coupling Means for Tubular Elements," now abandoned.

Our copending application Ser. No. 455,556, filed May 13, 1965, entitled, "Method of Simultaneously Deforming Two Overlapping Tubular Metal Elements To Form Interlocking Ridges," is also a continuation-in-part of the above application S.N. 250,417, now abandoned, and illustrates a number of methods for joining together tubular metal elements to form structures of various geometrical construction.

This invention is concerned with means for joining such tubular metal elements, and more particularly is concerned with the coupling assemblies, explosive assemblies and like apparatus for joining said tubular elements, tubes and pipes.

More particularly, this invention is concerned with apparatus for joining tubular metal elements in pairs by inserting one into the other to form an overlapping section and applying radial shock pressure of sufficient magnitude to force said overlapping elements together. This invention includes also the provision of explosive assemblies for creating and transmitting to said elements shock force pressures of sufficient magnitude to force them together. Also contemplated is the use of high radial pressure to force the overlapping elements into intimate contact with each other and with an encircling means which provides a pattern of restraint against which the elements are simultaneously deformed to form a corresponding pattern of interlocking ridges and depressions or other deformations, in the mating surfaces of the two elements which lock them together.

Means are available in the market for joining pipes, such as by the use of threaded collars, welding, clamped couplings, etc. These methods are not entirely satisfactory, each type having one or more serious limitations and disadvantages. One of the most important disadvantages is that, in order to provide longitudinal tensile, or torsional strength in the joint, threads, grooves or other mechanical procedures which remove metal and make the wall thinner must be used. This weakens the pipe at the areas where the metal is removed. To avoid this loss of strength at the couplings, the entire length of the pipe is usually made heavier than would otherwise be necessary, at considerably greater expense.

In this invention the methods of providing the pressure sealing contact is obtained by overlapping the two elements and explosively driving one element into intimate contact with the other element. In addition, we can provide tensile and torsional strength to the joint by forming interlocking ridges or convolutions in the mating surfaces of the two elements. These interlocking deformations are formed by simultaneously deforming the two elements while they are restrained over part of their surface by a third specially shaped, substantially rigid encircling restraining means. The encircling means can have depressions in its inner surface so that the elements are deformed or bulged outward into the depressions to form ridges on the outside of the outer element. Or the encircling means can have ridges on its inside surface, and the internal explosive pressure will deform the elements over and around these ridges to form depressions in the outer surface of the outer element. Corresponding matching depressions or bulges or deformations are formed on the mating surfaces of the two elements, which intimately interlock together to provide tensile and torsional strength to the joint. The encircling means can have a circumferential pattern of depressions or projections, continuous or discontinuous, or perforations and since there is simultaneous deformation of the two elements, their interlocking projections or ridges will be in exact conformity with each other and with the pattern on the encircling means.

The encircling means is substantially undeformable and the elements are deformed to take on the contour of the inner surface of this encircling restraining means. While no material is truly undeformable, some have greater yield strength than others, and what we desired is that the strength of the encircling restraining means be greater than that of the tubular elements, and it thus has the ability to withstand greater tensile stress without being substantially deformed itself. The elements will thus bulge outwardly into the convolution of the encircling restraining means.

The encircling restraining means, which can be a ring or anvil, can be removable, or fixed. If removable, it can be an assembly of two or more closely fitting parts that are hinged or bolted or otherwise clamped around the outer element. We prefer that it be a single metal or other means, closely fitted around the outer element. The cross-sectional shape of the encircling means is such as to provide circumferential depressions or ridges in the elements similar to the contour of the inner surface of the encircling means, against which the elements are forced by internal explosive pressure.

The encircling means might be considered to provide a pattern of restraint against the outer surface of the outer element, coupling or collar. Thus the ridges on the inner surface of the encircling means pressing on the outer surface provide the restraint, while the troughs or depressions, being separated from the surface of the outer element do not provide restraint until the outer element is deformed to fill the depression. Thus the convolutions of the internal surface of the encircling means will have a predetermined pattern which will provide a corresponding pattern of restraint and freedom over the surface of the outer element. The encircling means does not have to be co-extensive with the outer surface of the outer element, but need only be as extensive as the pattern of restraining areas since the pattern of free areas can be provided by free space. Thus the encircling restraining means can be a heavy extensive metal ring with convolutions on its internal surface, or it can be an open work of rings, wires, helices, perforations etc., provided only that restraint is provided at the proper areas, and non-restraint or freedom at other areas to provide the desired "pattern of restraint." Of course, as the outer element is deformed, the inner element is correspondingly deformed simultaneously to form a pattern of interlocking ridges and troughs in the mating surfaces of the elements to lock them together.

The encircling restraining means must be made of material which is less deformable than the material of which the elements are constructed. One possible material is, of course, high yield strength metals such as steel or special alloys. However, other materials such as fiberglass fibers, or fiberglass reinforced plastic may be used, or molded plastic wrapped with strands of fiberglass may be used, or any combination of these materials.

In operation, the low yield strength material of which the tubular elements are made is stressed beyond its elastic limit in those areas of low restraint where there are depressions or perforations in the encircling ring thus permanent bulges or deformations are formed. In those areas where the encircling ring provides great restraint, the stress in the high yield strength material is below the elastic limit. And, while the ring may expand slightly under the shock force, it returns to its original shape and size when the shock force has passed. In the meantime, those areas of the tubular element in contact with the high yield strength material are restrained from strain beyond their elastic limit. Thus they are not deformed and remain at substantially their original size. Furthermore, after the shock force has passed, they are held in compression by the tensile stress in the encircling ring.

The shock force required to deform the elements is derived from the detonation of a volume of explosive composition. The explosive shock force of the detonation can be transmitted from the explosive composition to the elements by filling the annular space between them with an explosive-shock-force transmitting material that is in intimate shock force transmitting contact with the exposive composition and with the inside of the inner element. This is fully explained in our copending application S.N. 455,556.

This shock force transmitting medium is a means for carrying the shock force substantially undiminished (except for radial divergence) from the explosive source to any desired portion of the overlapped section of the elements. Thus the axial extent of this material need only be as great as those portions of the elements that are to be deformed. This is generally comparable to the axial dimension of the groove or ridge pattern of the encircling restraining means.

The two elements that are to be joined need not both be long pipes. One of them can be a short length of tube which is used as a coupling element or collar. In this case, one pipe element is deformed in and with one end of the collar and another pipe element is deformed in and with the other end. The joining of the collar to the two pipe ends can be done sequentially or simultaneously. Or the end of one pipe can be belled out to form an overlap area with the unbelled end of another pipe. Or a rod element can be joined with a tube element by drilling or boring a central hole in one end of the rod to form a short tubular wall, which is overlapped with the tubing element, and so on.

The principal object of this invention is to provide apparatus for joining two overlapping tubular elements by simultaneously deforming them by explosive shock force. The elements may be unlined or lined with material of various compositions.

Another object of this invention is to provide coupling assemblies, and explosive assemblies for accomplishing the deformations.

Another object of this invention is to provide circumferential means for restraining the outward movement of the elements so as to cause controlled deformations.

Another object is to provide an encircling means which provides a predetermined pattern of restraint against the outward movement of the elements.

These and other new and novel uses, benefits and objectives of our invention will be more clearly described and understood in connection with the attached drawings, in which like elements are identified by the same numeral, and in which:

FIGURES 1 and 2 show, in cross-section and end view, respectively, one embodiment of this invention in which a coupling assembly is used for joining two tubular elements.

FIGURE 3 shows in cross-section another embodiment with a pair of closed metal rings as restraining means.

FIGURE 4 shows in cross section another embodiment joining lined tubular elements and using a metal helix as a restraining means.

FIGURES 5 and 6 show details in which a porous ring is supported by the tubular coupling.

FIGURES 7*a* and 7*b* show in cross-section details of the encircling restraining means to provide a pattern of restraint about the outside of the tubular coupling.

FIGURES 8 and 9 show in cross-section and end view, respectively, one embodiment of a coupling assembly.

FIGURE 10 shows another embodiment of an encircling restraining means, and

FIGURES 11 and 12 show two embodiments of a coupling assembly in which the coupling is placed inside the tubular elements. FIGURE 11 is for unlined and FIGURE 12 for lined tubular elements.

FIGURES 13 and 14 show other embodiments of "encircling restraining means."

Referring now to the drawings and in particular to FIGURES 1 and 2, we show two tubular elements **11** and **12** placed in colinear relation, almost end to end. One end of each element is slipped into one end of the tubular collar or connector **13** to form two overlap zones, such as **14.**

In the inside center of the collar **13** is a ring of material **18** characterized as a compressible, lossy, porous material incapable of transmitting efficiently explosive shock forces. This material may be papier mache, compressed sawdust, or similar porous material, although we prefer foamed plastic or similar semi-rigid cellular, porous material. This porous ring **18** is pressed into the center of the collar **13.** It has a central opening by means of which it supports an elongated volume of explosive composition **16** which may also contain its own detonator, or which may be adapted, as will be described in connection with FIGURE 3, to receive a separate detonator.

This axial explosive composition **16,** supported as it is by ring **18,** carries on either side of the porous ring **18,** two rings of material **17*a*** and **17*b*.** These are characterized as being of substantially incompressible, deformable material capable of transmitting efficiently an explosive shock force, and as explained in our copending application, S.N. 455,556, might be composed of rubber, plastic, or other elastomer, wax, grease, etc. These rings **17*a*** and **17*b*** are tightly fitted around the explosive **16,** and are of such outer diameter that when the elements **11** and **12** are inserted into collar **13,** there will be intimate, contiguous, shock-force-transmitting contact between the explosive composition **16,** the rings **17*a*** and **17*b*,** and the tubular elements **11** and **12.**

To seal the elements **11** and **12** to the collar **13** in the regions of overlap **14,** it is convenient to place tightly around the collar a restraining ring or anvil **19.** This can be made in two parts **19*a*, 19*b*,** which can be clamped together by means such as the bolts **20** and nuts **21** shown in FIGURE 2 (but omitted from FIGURE 1). A central opening is bored to take the explosive assembly **15,** the elements **11** and **12,** and the collar **13.** The restraining ring or anvil **19** tightly fits the collar **13** over predetermined areas to support it against the outward shock force from the explosive composition **16.**

However, the inner surface of the anvil is relieved in one or more areas such as **23*a*, 23*b*,** to form circumferential troughs or other patterns of depressions. Over these areas where the collar is unsupported, the shock force will deform the elements and collar, as shown at **11′** and **13′** to the contour of the depressions. This simultaneous deformation will serve to lock the elements separately to the collar to form a strong joint.

It will be clear, of course, as explained in our copending application S.N. 455,556, that the depressions **23*a*, 23*b*,** can be complete circumferential depressions, or patterns of smaller depressions, or patterns of ridges or ridges and depressions. The important thing is that under the influence of the explosive shock force pressing the elements to the collar and the collar to the anvil, the elements and collar in their overlap areas will form matching deformations which will lock them together. Also as explained in our copending application S.N. 455,556, there are preferred relations between the dimensions of ridges and troughs and the thicknesses of the walls of the elements and the collar, and the dimensions of the rings **17***a*, **17***b*.

Also in S.N. 455,556, we discuss the type and amount of explosive composition that can be used to perform this deformation. One important part of our invention is the use of the deformable, incompressible, shock-force-transmitting rings **17***a* and **17***b* to transmit the shock force from the explosive composition **16**, to a selected part of the inner area of the elements, to which the shock force must be applied, and to no other areas.

The porous ring **18**, being of the opposite nature, than shock-force-transmitting rings **17***a*, **17***b* does not transmit the shock wave from **16**, but rather absorbs it, and prevents its efficient transmission to the central area of the collar, where no deformation is desired. This is one of the important uses of the porous ring **18**. Another is that it serves as a centering element to ensure that the elements **11** and **12** when inserted into the collar extend only to the edge of the ring **18**. The third important use of the porous ring **18** is that it serves to support the explosive assembly **15** in the proper position within the coupling **13**.

If we remove from consideration, for the moment (from FIGURE 1) the anvil **19** and the elements **11** and **12**, we have a *coupling assembly* **25** which comprises the coupling tube or collar **13** carrying on its inside, an *explosive assembly* **15**. The explosive assembly comprises the explosive composition **16**, with or without detonator carrying the two force conducting rings **17***a*, **17***b*, and the porous ring **18**. Each of these assemblies, the explosive assembly and the coupling assembly, are unitary combinations of essential elements for the joining of tubular elements, the explosive assembly being a sub-assembly of the coupling assembly.

In FIGURE 3, we show another embodiment illustrating the principles of FIGURE 1, but differing in two ways. In FIGURE 1, the explosive composition **16** includes its own detonator **26**. In FIGURE 3, we show a tubular extension at one end of the explosive, forming a circular opening **30**. A detonator **31** with electric lead wires **32** is adapted to be inserted into the opening **30**, and when the appropriate voltage is applied to lead wires **32**, the explosive composition will be detonated. In all of the descriptions that follow, it will be clear that the explosive composition may include the detonator, or the detonator may, at the time of use, be placed with the explosive composition.

In FIGURE 1, we show a removable anvil **19** surrounding the coupling assembly. The purpose of the anvil is to provide restraint for some portions of the surface of the collar, while allowing the collar and tubular elements to deform to the internal contour of the anvil at other portions of the surface of the collar. In FIGURE 3, we show another way in which this "pattern of restraint and freedom" over the surface of the collar can be provided. Over each of the overlapped areas such as **14** is placed at least one closed metal ring **33, 34**. These are of material of greater yield strength than the metal of the elements and collar, and serve to provide a circumferential ridge around which the elements and collar can deform. As pointed out in S.N. 455,556, the cross-sectional shape of the rings **33, 34**, can vary to provide the desired pattern of ridges and troughs to provide the desired pattern of restraint to best deform the elements and the collar.

The rings **33, 34** are preferably tightly fitted to the collar, and positioned approximately at the center of the overlap area. After the elements and collar are deformed the rings remain in place as part of the joint. Thus the *coupling assembly* **36** of FIGURE 3 is similar to the coupling assembly **25** of FIGURE 1, except for the permanent rings **33, 34** that form part of the coupling assembly itself. Thus this *coupling assembly* **36** is really made up of two sub-assemblies, the *coupling unit* **37** comprising the

coupling element **13** plus restraining rings **33, 34**, and the *explosive assembly* **35** comprising the supporting ring **18**, explosive composition **16** and shock-force-transmitting rings **17***a*, **17***b*.

In FIGURE 4, we show a variation of the embodiment shown in FIGURE 3. In this illustration, the explosive assembly **15** comprising explosive composition **44**, shock force transmitting rings **46***a*, **46***b*, and porous ring **47** are similar to those of FIGURE 1. Also the coupling unit **54** of FIGURE 4 is similar to that, **37**, of FIGURE 3, except that we show a helix **51** wrapped around the collar **50** in place of the restraining rings **33, 34**. This helix is preferably of material of high yield strength. This can be metal spring wire formed to a helix of smaller diameter than that of **50**, so that when it is placed around the coupling **50** it will cling tightly. It may also be desirable to fasten, such as by spot welding, the ends **51** and **51***f* of the helix to the collar **50** by welds **52** and **53**. This will permit the ends as well as the intermediate turns to provide restraint to the collar against the internal explosive pressure. The multi-turn helix thus presents a more complex pattern of restraint and freedom against the outer surface of the collar **50** than do the rings of FIGURE 3 or the anvil of FIGURE 1. However, the action of the helix in operation is similar to that of the rings, and, of course, after detonation the helix remains on the collar to form part of the final joint.

In FIGURE 4, we have a *coupling assembly* **55** comprising a *coupling unit* sub-assembly **54** and an *explosive sub-assembly* **15**.

In FIGURE 4, we have shown also, that it is possible to join and couple lined tubular elements. The tubular elements **40, 42**, have thin-walled flexible liners **41, 43**, respectively, which extend beyond the ends of the elements and are turned over and back, to form cuffs **47, 48**. Also, inside of the collar **50** is a plastic liner **49** which completely bridges the gap between the overlap regions. Then, when the explosive is detonated, the overlapped elements and collar, with intermediate layers of plastic liner, are deformed together to form an interlocked pattern of ridges and troughs.

In FIGURE 5, we show a variation of the collar and porous ring of FIGURES 1 and 3. In FIGURES 1 and 3, the porous ring is pressed into place in the collar **13** and serves to center the collar over the ends of the tubular elements. In FIGURE 5, we show on the inside of the collar **13** a circumferential shoulder **59** that serves as a stop for the elements. The porous ring **58** is a little smaller in diameter and is pressed into the inner surface of the shoulder **59**. The shoulder **59** can be joined as part of hte collar **13**, or it can be a separate metal or plastic ring **60** pressed into place.

In FIGURE 6, we show another variation in which the collar **13** has an internal circumferential trough **61** and the porous ring **62** has a corresponding circumferential ridge **63**. The ridge **63** fits the trough **61** and permits exact placement of the porous ring.

In FIGURE 7*a*, we show another embodiment of apparatus for joining in colinear array two tubular elements by overlapping them with a tubular collar and simultaneously deforming them, by internal shock force against an encircling restraining means. The encircling restraining means comprises an encircling element which is in close contact with part of the surface of the outer of the two elements or collar (although this may be a hand slip fit, or a clamped fit). The internal surface of the restraining means, considering that it is of the full axial extent of the outer surface, say of the collar, provides a pattern of areas, some of which are restrained against outward movement under the shock force, and others of which are unrestrained against outward movement, and so can deform under the shock force. Thus, by restraining only a portion of the outer surface of the collar, there is a deformation of the two tubular parts in such a way that a pattern of interlocking ridges and matching troughs are formed which securely lock the tubular parts together.

In FIGURE 7*a* we show two tubular elements **66**, **67**, inserted end to end in an encircling tubular collar **68**. The explosive assembly **71** inside of the elements comprises simply an elongated explosive composition **72** and encircling shock force conducting ring **73** which snugly fits inside the elements **66**, **67**. A detonator **75** may be attached to or detached from the composition **72**.

The coupling tube **68** forms part of a coupling unit **74**, the other part of which are the two encircling ring elements **69**, **70**. We prefer to look on this coupling unit **74** as a coupling collar **68** surrounded by a restraining means which covers its entire surface, but presses against and restrains the coupling only at selected points, or areas, namely, where the elements **69** and **70** press against the collar.

In FIGURE 7*b* we show a ring **76**, of substantially the same axial extent as the collar **68**. Its internal surface contour has two circumferential ridges **77***a*, **77***b*, identical with those parts of the ring elements **69**, **70**. The remainder of the internal surface of the ring **76** is relieved sufficiently to provide no restraint to the outward bulging of the collar. So far as the restraining action goes it is immaterial whether we use the two ring elements **69**, **70**, or the larger ring **76**. In other words, the space between and around the ring elements **69**, **70**, are as much a part of the encircling restraining means as the metal elements themselves. So we will speak of an "encircling ring assembly" or an "encircling restraining means" having a pattern of restraining areas and free areas, against which the overlapped tubular elements are deformed. This "encircling restraining means" may comprise a heavy broad ring **76** with a pattern of ridges and troughs on its inner surface. Or it may comprise a plurality of separate ring elements such as **69**, **70**, of FIGURE 7*a*, or it may comprise a helix, such as **51** of FIGURE 4, or any combination or variation of these or similar elements.

In FIGURES 8 and 9, we show another variation of the "coupling unit" comprising the coupling collar **68** with a circumferential restraining means, the helix **79** encircling the collar. The ends of the helix may be fastened to the collar, such as by tack welds **80**, or the end turns of the helix may be fastened to adjacent turns of the helix such as by the tack weld **81**, FIGURE 8, fastening the end **79***f* to the adjacent turn **79***d*.

In FIGURE 10, we show still another form of the "encircling restraining means" **88**. This comprises a thin metal tube **89** adapted to fit over the outer of the two overlapped elements. This tube **89** itself is not sufficiently strong to provide restraint, but it serves to carry, in proper space relation, a plurality of smaller ring elements **90**, **91**, to provide the desired "pattern of restraint" against the surface of the outer elements.

In FIGURE 11, we show another embodiment of our invention in which the coupling assembly **98**, including coupling collar **97**, shock force transmitting ring **100** and explosive composition **99**, forms a unitary assembly which is inserted *into* the ends of the tubular elements **95**, **96**. Circumferential restraining means, such as rings **102**, **103**, may be placed on the outside of the elements **95**, **96**, to form a pattern of restraint against which the collar **97** and elements **95**, **96**, are simultaneously deformed by the shock force from the detonating explosive **99**.

In FIGURE 12 we show another variation of the embodiment of FIGURE 11 in which the tubular elements **95**, **96**, have internal liners **106**, **107**, respectively, which are substantially coextensive with the elements. The coupling assembly **105** differs from the coupling assembly **98** of FIGURE 11 in having a deformable sealing means **108** surrounding the collar **97**, so that the gap **109** between the liners **106**, **107**, is covered and sealed by the sealing means **108**.

In FIGURE 13, we show another embodiment of an "encircling restraining means" **115**. Like the encircling restraining means **88** of FIGURE 10, the restraining means **115** of FIGURE 13 has a thin-walled tube **110** about which is placed a restraining means in the form of a multi-turn helix **111**. This helix can be formed of high yield strength metal, or other suitable material. It can be fastened to the tube **110** by means such as the tack welds **114***a*, **114***b*, **114***c*, **114***d*, or other means. Also, the end turns may be fastened to the adjacent turns of the helix such as by the welds **112**, **113**, that fasten **111***a* to **111***c* and **111***e* to **111***g*, respectively.

The material of the tube **110** is not critical, it should have a low yield strength so that it will deform with the collar. This tube serves to carry the high yield strength elements that provide the restraint, such as the rings **90**, **91**, of FIGURE 10 or the helix of FIGURE 13. The material of which the restraining means is made likewise is not critical so long as it is of high yield strength.

For example, in FIGURE 14, we show another embodiment of an encircling restraining means. This comprises a thin-walled tube **118**, corresponding to **89** of FIGURE 10, which can be made of metal or plastic or the like. Surrounding and restraining this tube in the desired pattern, is a pattern of turns **120**, **121**, etc., of thin fibers of metal, plastic, fiberglass, or the like. These can be arranged in separate ring groups **119***a*, **119***b*, **119***c*, **119***d*, for example, or in any desired pattern. The group of thin fibers in each ring group **119** will have sufficient strength to restrain the outward movement of the tube **118** and of the collar which it surrounds.

Thus the encircling restraining means can be made of metal, plastic, fiberglass, fiberglass impregnated plastic, or any variation or combnation of these materials. The encircling restraining means is a unitary assembly, capable of being used with any of a number of different types of coupling assemblies, and as such can be a separate article of commerce. It may or may not include the thin tube **110** of FIGURE 13, or **118** of FIGURE 14. Thus the helix **111** of FIGURE 13 with end turns fastened to the adjacent turns is a complete and workable encircling restraining means. Of course, it would not be possible to provide the assembly of FIGURE 14 without the tube **118** since the turns **119** would all collapse. However, by molding the fiber windings **119** in plastic, say within the outline **120**, the assembly would be held together and be perfectly workable without the tube **118**.

We have, by the use of various illustrations, described specific embodiments of our invention. However, various changes and modifications to these embodiments will be apparent to those skilled in the art, and may be made without departing from the scope of this invention, which is to be determined by the scope of the appended claims.

We claim:

1. In an explosive assembling apparatus, coupling means for use in joining the ends of two tubular elements which are inserted into said coupling means to form two overlapping zones, said assembling apparatus including explosive means inside said elements for generating an explosive shock force inside said elements to drive them and said coupling means outward against a circumferential means providing a pattern of restraint to simultaneously deform said elements and said coupling means, the improvement comprising, a coupling collar, a multi-turn helix of high yield strength material tightly surrounding said collar and a thin-walled deformable tube lining said collar.

2. In an explosive assembling apparatus for joining a coupling collar to the end of at least one tubular element which is inserted into one end of said coupling collar to form an overlapping zone, said assembling apparatus including explosive means inside said end of said at least one element for generating an explosive shock force inside said element in the overlapping zone sufficient to drive it and said coupling collar outward against a circumferential restraining means of high yield strength material providing a predetermined pattern of restraint, to simultaneously deform said element and coupling collar to form interlocking ridges and depressions in the mating surfaces thereof, the improvement comprising a coupling collar of low yield strength material and at least one circumferential turn of high yield strength material tightly surrounding said collar.

3. Apparatus as in claim **2** in which said high yield strength material comprises at least one closed ring of high yield strength material.

4. Apparatus as in claim **2** including two tubular elements, the ends of which are inserted one into each end of said coupling collar to form two overlapping zones in which said high yield strength material comprises at least two closed rings of high yield strength material spaced apart in alignment with said two overlapping zones and tightly surrounding said collar.

5. Apparatus as in claim **2** in which said high yield strength material comprises a multiturn helix of high yield strength material.

6. Apparatus as in claim **2** in which said high yield strength material comprises a plurality of turns of high yield strength fibers wrapped tightly around said collar to form the desired pattern of restraint.

7. Apparatus as in claim **2** including an explosive assembly placed inside of said coupling collar, said explosive assembly adapted to generate the explosive shock force to deform said element and said coupling collar.

8. Apparatus as in claim **7** in which said explosive assembly comprises an elongated volume of explosive composition of lesser diameter than the inner diameter of said element and including at least one ring of substantially incompressible deformable shock-force-transmitting material in intimate surrounding contact with said explosive composition and of outer diameter adapted for slip fit into said element when said at least one element is inserted into said collar.

9. The apparatus of claim **7** including means to detonate said explosive composition.

10. Apparatus as in claim **2** including a thinwalled tube of low yield strength material adapted for snug fit over said coupling collar, and said at least one circumferential turn of high yield strength material tightly surrounding said tube.

11. Apparatus as in claim **10** in which said high yield strength material comprises at least one closed ring of high yield strength material.

12. Apparatus as in claim **10** in which said high yield strength material comprises a multiturn helix of high yield strength material.

13. Apparatus as in claim **10** in which said high yield strength material comprises a plurality of turns of high yield strength fibers wrapped tightly around said tube to form the desired pattern of restraint.

14. Apparatus as in claim **13** in which said fibers are glass fibers.

15. Apparatus as in claim **2** in which said at least one circumferential turn of high yield strength material comprises a cylindrical structure adapted for snug fit over said coupling collar, at least part of said structure made of high yield strength material disposed in a pattern to form areas of great restraint to outward movement of said elements, with intervening areas of low restraint.

16. Apparatus as in claim **15** in which said high yield strength material is disposed in the form of a cylindrical shell with a pattern of depressions on its inner surface.

17. Apparatus as in claim **15** in which said high yield strength material is disposed in the form of a cylindrical shell with a pattern of projections on its inner surface.

18. Apparatus as in claim **15** in which said high yield strength material is disposed in the form of a cylindrical shell with a pattern of perforations over its surface.

19. Apparatus as in claim **15** in which said cylindrical structure is made in at least two parts and is removeable from said collar.

20. Apparatus as in claim **8** in which there are two overlapping zones and said explosive assembly includes at least two rings of shock force transmitting material symmetrically placed with respect to said two overlapping zones.

21. Apparatus as in claim **20** in which said two overlapping zones are formed by the ends of two tubular elements inserted one into each end of a coupling collar, said explosive assembly supported centrally in said collar by a third ring of material positioned between said two rings of shock force transmitting material, said third ring characterized as porous, compressible, lossy, and incapable of efficiently transmitting shock forces, said third ring supported on its outer surface by said collar and supporting said explosive composition on its inner surface.

22. In an explosive assembling apparatus for joining two tubular elements of substantially the same diameter by setting them end to end and overlapping their joint with a short tubular coupling to form two overlapping zones, said assembling apparatus including explosive means inside said overlapping zones for generating an explosive shock force inside said overlapping zone sufficient to drive said elements and said coupling outward against a circumferential restraining means of high yield strength material providing a predetermined pattern of restraint to simultaneously deform said elements and coupling to form interlocking ridges and depressions in the mating surfaces thereof, the improvement comprising, a coupling collar of low yield strength material overlapping the ends of said elements and at least one closely fitting circumferential turn of high yield strength material surrounding said overlapping zone.

23. Apparatus as in claim **22** in which a thin-walled tube of deformable material is inserted within the annular space between said elements and said coupling.

24. Apparatus as in claim **22** in which said coupling collar surrounds the ends of said elements and said high yield strength material surrounds said coupling collar.

25. Apparatus as in claim **22** in which the ends of said elements surround said coupling collar and said high yield strength material surrounds said elements.

26. Apparatus as in claim **2** including a thin-walled tube of deformable material lining said collar.

27. Apparatus as in claim **26** in which said deformable material is a plastic material.

28. In an explosive assembling apparatus for joining two tubular elements of different diameter such that one end of the smaller element is inserted in slip fit engagement into one end of the larger element to form an overlapping zone and an explosive means is positioned inside of said overlapping zone for generating an explosive shock force inside said elements in said overlapping zone sufficient to drive them outward against a circumferential restraining means of high yield strength material providing a pattern of restraint, to simultaneously deform said elements to form interlocking ridges and depressions in the mating surfaces thereof, the improvement comprising, a thin-walled tube of low yield strength material adapted to fit snugly over the outer of said elements, said tube placed over said overlapping zone, and at least one circumferential turn of high yield strength material closely fitting the outside of said tube.

29. Apparatus as in claim **28** in which said high yield strength material comprises a multi-turn helix of high yield strength material.

30. Apparatus as in claim **28** in which said high yield strength material comprises a plurality of turns of high yield strength fibers wrapped around said tube to form the desired pattern of restraint.

31. The apparatus of claim **30** with plastic composition surrounding said turns to hold them in relative position.

32. In an explosive assembling apparatus for joining two tubular elements of different diameter such that one end of the smaller elements is inserted in slip fit engagement into one end of the larger element to form an overlapping zone and an explosive means is positioned inside of said overlapping zone for generating an explosive shock force inside said elements in said overlapping zone sufficient to drive them outward against a circumferential restraining means of high yield strength material providing a pattern of restraint, to simultaneously deform said elements to form interlocking ridges and depressions in the mating surfaces thereof, the improvement comprising, a multi-turn helix of high yield strength material closely fitting the outer surface of the outer of said two elements.

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