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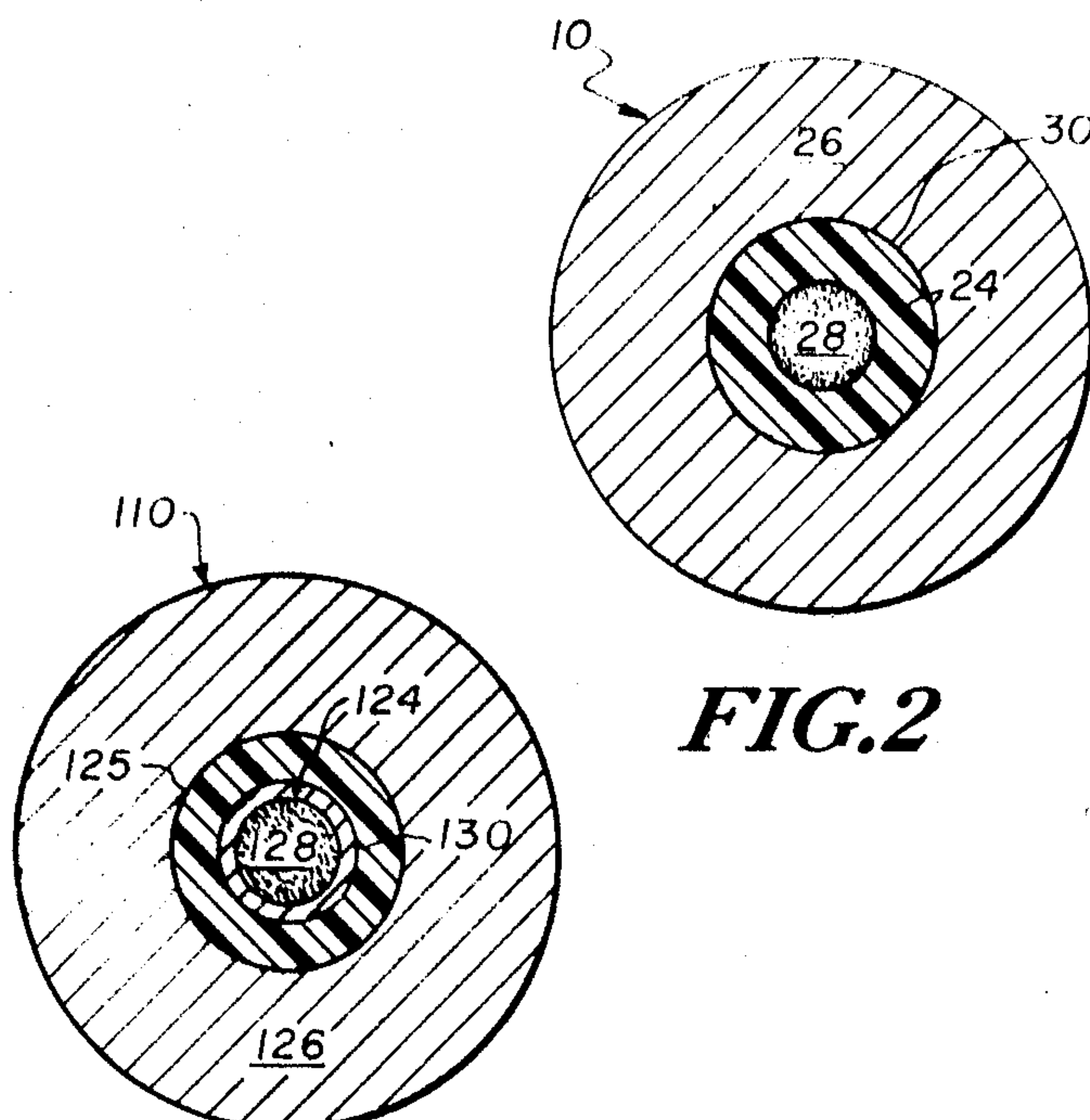
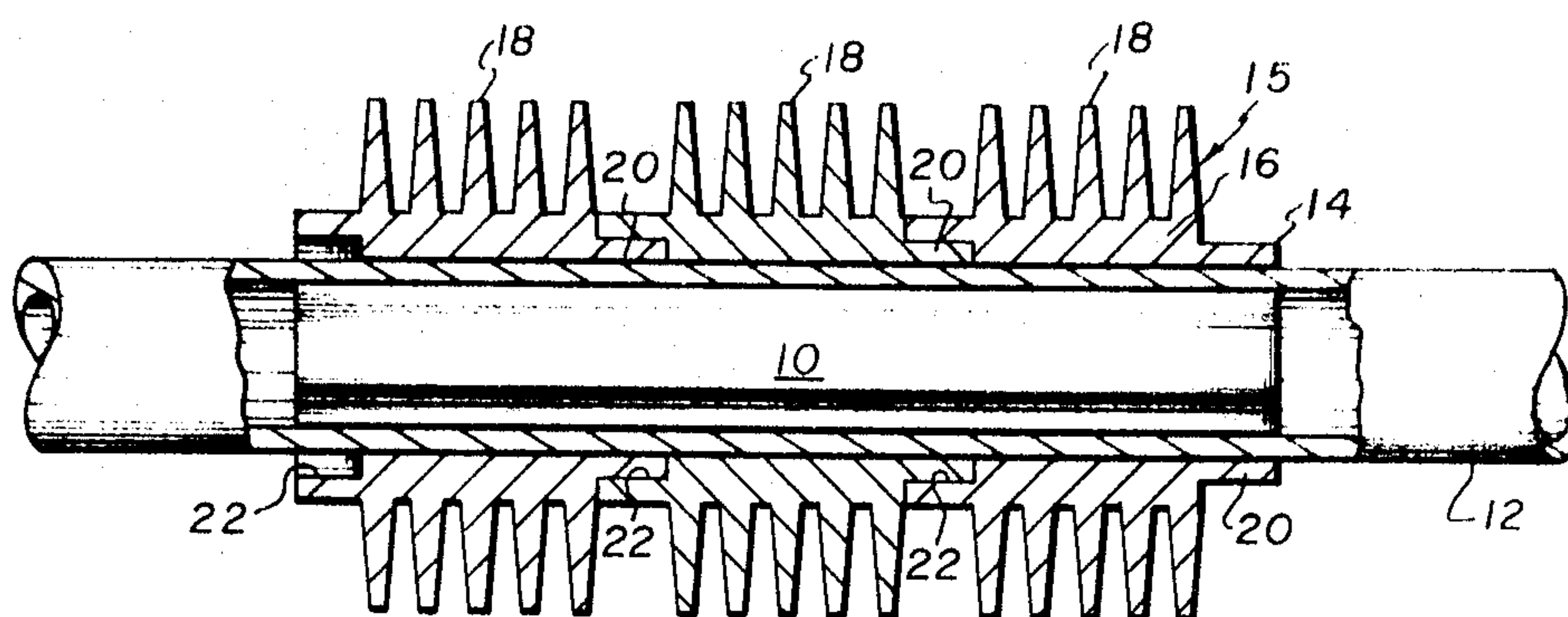
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**3,611,767**

## EXPLOSIVE FORMING OF INNER CYLINDERS INTO OUTER CYLINDERS

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**FIG. 1**



**FIG.2**

**FIG. 3**

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## EXPLOSIVE FORMING OF INNER CYLINDERS INTO OUTER CYLINDERS

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2 Claims

### ABSTRACT OF THE DISCLOSURE

Apparatus for expanding a hollow inner tube into a hollow outer tube in which an explosive forming insert is mounted in the inner tube. The insert includes a two-piece coaxially polyethylene cylinder surrounding the explosive charge.

### BACKGROUND OF THE INVENTION

In the fabrication of heat exchangers of the type comprising an inner cylinder and a coaxially mounted outer cylinder it has been the usual practice to heat the outer cylinder for shrink-fitting onto the inner cylinder. This procedure does not result in a positive connection between the shrink-fitted cylinders.

In accordance with the present invention, explosive forming techniques have been utilized to provide an insert which can be coaxially positioned within the inner most cylinder. By using explosive forming techniques it is possible to achieve coining of the outer surface of the inner cylinder onto the inner surface of the outer cylinder. When coining occurs the abutting surfaces of the cylinders are brought into complete contact beyond the elastic limit of the material. Whereas, when only shrink-fitting procedures are utilized, it is not possible to obtain coining, since the surfaces cannot be brought into complete contact as the shrink-fitted materials remain within their elastic limit.

As a further feature of the invention, a multipart plastic insert of polyethylene is provided by forming the outer polyethylene section with a substantially greater cross-sectional wall thickness than that of the inner section, it is possible to reuse the outer section. This is possible since the outer section can withstand the detonation of the explosive charge without being permanently deformed.

### SUMMARY OF THE INVENTION

In accordance with illustrative embodiments demonstrating features and advantages of the present invention there is provided an apparatus for expanding an inner cylinder into an outer cylinder comprising an insert coextensive with the inner cylinder. The insert includes an inner section formed with a central axial bore having a predetermined number of grains of explosive uniformly disposed along the axis of the insert, and an annular tubular force transmitting outer section between the inner section and the inside surface of the inner cylinder. The outer section has a substantially greater cross-sectional area than the inner section and the outer section and the inner section are formed from a thermoplastic hardenable resin of the class consisting of polyethylene, and resins having essentially the same flexibility, formability, resiliency, density and at least about as high a melting point as polyethylene.

### BRIEF DESCRIPTION OF THE DRAWINGS

The above brief description, as well as further objects, features and advantages of the present invention will be more fully appreciated by reference to the following

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detailed description of a presently preferred but nonetheless illustrative embodiments in accordance with the present invention, when taken in connection with the accompanying drawings wherein:

FIG. 1 is a sectional view of a portion of an inner cylinder coaxially mounted within an outer cylinder in which the explosive forming apparatus of the present invention is employed;

FIG. 2 is an enlarged sectional view of the explosive forming insert shown in FIG. 1 but removed from the inner cylinder; and

FIG. 3 is an enlarged sectional view similar to FIG. 2 but showing an insert having two separate outer sections.

### DESCRIPTION OF THE PREFERRED EMBODIMENTS

With reference to FIG. 1, in accordance with the present invention there is provided an explosive expanding insert generally designated by the reference numeral 10 which is coextensively and coaxially positioned with respect to an inner cylinder 12. The insert 10 is for explosively expanding the inner cylinder 12 into an outer cylinder generally designated 14 to form a tubular heat exchanger 15. The outer cylinder 14 includes a plurality of gill rings 16. It is preferable to form the gill rings 16 from cast iron such that each of the gill rings 16 is provided with a series of heat transmitting fins 18. Each of the gill rings 16 are provided with a cylindrical boss 20 at one end and an annular socket 22 at the opposite end, in order that the gill rings 16 can be assembled in abutting relationship to form outer cylinder 14 which is coaxially mounted onto inner cylinder 12.

For generating an explosive force, the insert 10 is formed with an external diameter for positioning within the inner cylinder 12 and with a length which is substantially coextensive with that of outer cylinder 14.

In accordance with the embodiment shown in FIG. 2, the explosive forming insert 10 comprises an inner section 24 and an outer section 26. The inner section 24 includes a central axial portion 28 which contains a predetermined number of grains of explosives, generally from 25 grains per foot to 100 grains per foot, which are uniformly disposed along the axis of the insert 10, and a shell 30 of fiber or plastic material in which the explosive of axial portion 28 is embedded. The inner section 24 is marketed under the registered trademark "Primacord." It is preferable to fabricate the outer insert 26 from a force transmitting medium such as polyethylene or a thermoplastic hardenable resin having essentially the same properties of polyethylene, such as the flexibility, formability, resiliency, density, and at least as high a melting point. Suitable mediums other than polyethylene are polyvinyl acetals, polyvinyl butyrals, polystyrene, nylon, Teflon, polyester resins, Delrin, Lexon, polypropylene and Tygon. These materials have essentially the same flexibility, formability, resiliency, density, and at least about as high a melting point as polyethylene.

In FIG. 3 there is illustrated a further embodiment of the invention in which corresponding parts have been designated by the same reference numerals as part of a 100 series. In this form of the invention, a multiple layer insert 110 is provided. The insert 110 includes an inner section 124 which is coaxially positioned within an intermediate section 125, which in turn is coaxially positioned in an outer section 126. The inner section 124 includes an axial portion 128 which is encompassed by a thin outer shell 130. The axial portion 128 contains a predetermined number of grains of explosive which are embedded in the shell 130 that is fabricated from a fiber or plastic mate-



rial, and the inner section 124 is generally marketed under the registered trademark "Primacord."

In the fabrication of the tubular heat exchanger 15, the inner tube 12 is generally cold drawn with close tolerances, and the gill rings 16 are preferably cast in approximately six inch lengths with the inner portion of the gill rings 16 being broached. The gill rings 16 are then carefully heated and shrunk onto the inner tubes 12 in sequence. This results in an elastic compression of the inner tube 12 by the gill rings 16 as they cool and shrink. In this heat shrinking operation, it is difficult to obtain complete metal to metal contact between the outer surface of cylinder 12 and the inner diameter of gill ring 16. When complete surface to surface contact is obtained, this is known as "coining." In order for coining to occur the two metallic surfaces are brought into contact such that the inner cylinder 12 is extended beyond its elastic limit, whereas in the shrink fitting operation, the inner cylinder 12 is not passed beyond its plasticity phase and there are sharp corners along the contacted surfaces between the gill rings 16 and the inner cylinder 12, which result in discontinuities where there is lack of contact, and this serves as a barrier to good heat transfer between the inner cylinder 12 and the gill rings 16.

In view of the difficulties attendant with the shrink-fitting step, after the inner cylinder 12 has been inserted in the gill ring 16 in the manner outlined above, the explosive expansion insert 10 or 110 is coaxially placed within the inner cylinder 12 in a position which is co-extensive with the length of the gill ring 16. The expansion inserts 10 and 110 can be detonated by an electrical type detonator which is well known in the art. By utilizing the explosive forming technique in accordance with the present invention, the explosive force generated through the wall thickness of inner cylinder 12 will follow the surface contour for small and sharp variations along the inner bore of the gill ring 16, such that the portion of the inner cylinder 12 which contacts the gill ring 16 passes beyond the elastic limit.

A latitude of modification, change and substitution is intended in the foregoing disclosure and in some instances some features of the invention will be employed without a corresponding use of other features. Accordingly, it is appropriate that the appended claims be construed broadly and in a manner consistent with the spirit and scope of the invention herein.

What is claimed is:

1. An insert for explosively expanding an inner cylinder into an outer cylinder that includes a plurality of individual gill rings of a frangible material and said gill rings formed with annular sockets at one end and cylindrical bosses at the other end, such that said gill rings can be positioned in abutting relation along said inner cylinder with said cylindrical boss received in the annular socket of adjacent gill rings and said outer cylinder being coextensively and coaxially positioned with respect to said inner cylinder, and said insert comprising

an outer tubular section coaxially positioned in said inner cylinder,

an inner tubular section coaxially positioned in said outer tubular section,

said inner tubular section including an explosive section formed with a central bore having a predetermined number of grains of explosive uniformly disposed along said bore and an inner shell which coaxially surrounds said explosive section,

said outer tubular section and said inner shell being formed from a thermoplastic hardenable resin of the class consisting of polyethylene, and resins having essentially the same flexibility, formability, resiliency, density and at least about as high a melting point as polyethylene, and

said outer tubular section having a substantially greater cross sectional area than said inner shell.

2. An insert for explosively expanding an inner cylinder into an outer cylinder that includes a plurality of individual gill rings of a frangible material and said gill rings formed with annular sockets at one end and cylindrical bosses at the other end, such that said gill rings can be positioned in abutting relation along said inner cylinder with said cylindrical boss received in the annular socket of adjacent gill rings and said outer cylinder being co-extensively and coaxially positioned with respect to said inner cylinder, and said insert comprising

an outer tubular section coaxially positioned in said inner cylinder,

an inner tubular section coaxially positioned in said outer tubular section,

said inner tubular section including an explosive section formed with a central bore having a predetermined number of grains of explosive uniformly disposed along said bore and an inner shell which coaxially surrounds said explosive section,

an intermediate tubular section coaxially positioned between said inner tubular section and said outer tubular section,

said outer tubular section, said intermediate tubular section, and said inner shell being formed from a thermoplastic hardenable resin of the class consisting of polyethylene, and resins having essentially the same flexibility, formability, resiliency, density and at least about as high a melting point as polyethylene, and

said outer tubular section having a substantially greater cross sectional area than said intermediate tubular section.

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