This invention relates to the perforation of well walls by means of explosive perforating charges, particularly those shaped explosive charges utilizing a jet effect for the perforation process, and it is especially concerned with the perforation of cased well walls to which access is possible only through pipe or tubing of small diameter.

The completion of wells for the production of oil, gas or other fluids by perforating the well walls at the source of expected productivity is a well established practice. Ordinarily perforation is performed in boreholes that extend into or through the zone of expected productivity, and usually these are lined with casing that is cemented in place while the borehole is filled with and under the relatively great hydrostatic pressure of the heavy drilling fluid or mud. In such cases, the perforating tool need only to have strength to resist the pressures encountered, which may be as great as 10,000 or more pounds per square inch, and be of a size that can be conveniently introduced within the least diameter of the casing, usually not less than about 5½ inches. Following perforation, tubing, usually of 2 or 2½ inches diameter, is run in the borehole and set above the perforated section. The heavy drilling fluid or mud is then washed or flushed from the well, the drilling rig is replaced by a well top piping and valve arrangement or "Christmas tree," and production from the perforated section is established.

In some cases it is desirable to perform all of these latter operations prior to perforation of the casing in order to avoid subjecting the perforated zone of expected productivity to the high hydrostatic pressure of the drilling mud or for other reasons, and in such practice, the casing and well wall to be perforated is accessible only through the small diameter tubing. The same situation prevails in those circumstances that require perforation or re-perforation of the casing and well wall in workover wells in which tubing has been set, since it would otherwise be necessary to pull the tubing, which is, of course, a time consuming and costly operation.

The problem presented in the perforation of well walls below tubing is that of providing a perforating tool of sufficiently small diameter to pass through the tubing and that will have penetrating power and perforating efficiency substantially the same as the larger tools that are customarily used in similar boreholes in which tubing has not been set.

I have found by test that this problem can be successfully solved by the use of explosive perforating charges, especially those shaped explosive charges that accomplish perforation by means of the jet effect, by a special arrangement of these charges in a perforating device small enough to be introduced through tubing having a diameter as small as 2 inches, and the provision of such a perforating device is a principal object of this invention.

Another object of this invention is to provide a perforating device of small diameter that is expendable, and which, after firing, will leave no objectionable debris in the well.

Still another object is to provide a perforating device of the class described, arranged to be severed at the time of firing from the supporting means by which it is positioned in the well, and which is provided with means to insure a high degree of disintegration of the device at the time of firing.

A further object is to provide an improved small diameter perforating device in which the body of the carrier is formed of a plurality of interengaging sections to allow the device to perform a large number of perforations, and to allow this number to be selected as desired.

A still further object of the invention is to provide a small diameter device of the class described within which the maximum amount of stand-off is provided for maximum jet penetrating efficiency and which is sealed against well fluids and capable of withstanding the high hydrostatic pressures encountered in wells without the necessity of using heavy materials of construction to permit perforation to be carried out successfully below tubing without introducing a substantial amount of objectionable debris in the hole.

The invention, both as to its organization and method of operation, together with additional objects and advantages will be apparent from the following description taken in connection with the accompanying drawings, in which:

Fig. 1 illustrates a perforating device of small diameter characterized by the features of this invention shown in position in a cased borehole to perforate the well wall below a string of small diameter tubing that has been run and set above the zone to be perforated;

Fig. 2 is a view, partially in section, illustrating a preferred embodiment of a perforating device incorporating the novel features of the present invention;

Fig. 3 is an exploded perspective enlarged view illustrating the arrangement of parts forming one embodiment of the carrier or body of a perforating device in accordance with this invention;

Figs. 4A, 4B and 4C, when considered end to end in the order named, present a side view, partially in section, illustrating in detail certain features characterizing the preferred embodiment of the perforating device shown in Fig. 2;

Fig. 5 is a cross-sectional view taken along the lines 5--5 of Fig. 4C; and

Figs. 6 and 7 are side and transverse partial views in cross-section showing an alternate construction of certain elements of the device.

Referring now to the drawings, and more particularly to Fig. 1, the improved perforating device of this invention generally indicated by the reference numeral 10 is there illustrated in perforating position within a borehole 11, which has been drilled into the earth passing in or through an oil-bearing structure represented by the zone bracketed at 12. As shown, the borehole 11 is lined by casing or pipe 13, which has been run in the borehole and cemented in place.

Small diameter tubing 14 has also been run in the hole to extend from the surface to a point above the oil-bearing structure 12. As shown, the lower end 14a of tubing 14 is bell-shaped and is sealed off from the upper part of the borehole by packer 15 interposed between the tubing 14 and casing 13. The perforating device 10 is positioned in the borehole 11 by means of a steel jacketed cable 16 which contains one or more electrically insulated conductors. For this purpose, the cable 16 is secured to the upper end of the perforating device 10 as will be more fully explained below, and passes over a sheave or measuring wheel 17 at the earth's surface, being supplied from a cable drum (not shown), and connected to a source of electrical power (not shown).
all in accordance with conventional practice. Conventionally, the tubing through which the perforating device must pass to reach the zone to be perforated has an internal diameter of approximately 2 inches, and therefore the maximum outside diameter of the device must not exceed 1½ inches. These dimensional relationships between the inside diameter of the well tubing and the diameter of the perforating device should be borne in mind throughout consideration of the description of the present invention.

Fig. 2 shows a completely assembled perforating device in which the portion bracketed at 18 contains the explosive perforating charge and is expendable, while the portion bracketed at 19 is a re-usable subassembly connecting the portion 18 with the cable 16.

The subassembly 19 comprises a rope socket and fishing bell 21, usually made of steel, within which the cable sheath is anchored, for example, by means of babbit or the like, as indicated at 22. An electrical conductor 23 carried within the cable sheath extends through the bell 21 to electrical contact 24 from which extends a spring-loaded contact pin 25. The bell 21 is attached to an adapter 26, also usually made of steel, being secured, for example, by means of threads as shown at 27 and a fluid-tight seal between bell 21 and adapter 26 is insured by appropriate means, such as gasket 28. Adapter 26 is provided with a central bore or opening through which pass electrical conductors 31 and 32 insulated from each other and from adapter 26. Conductor 31 is connected to a terminal 33 carrying insulated disc 34, and terminal 33 with contact pin 25 completes the circuit from conductor 31 to the conductor 23 of cable 16. Conductor 32 is connected to ground, for example, at terminal 35. The structure thus far described is retrieved from the well by means of cable 16 after the perforating charges in portion 18 have been detonated and the portion 18 has been severed from subassembly 19, all as more fully hereinafter explained.

The bracketed portion 18 of Fig. 2, as shown, includes an elongated cylindrical body or carrier indicated generally at 36, and which may be conveniently made up of a number of cylindrical sections 37 each formed of a solid frangible material, such as glass, plastic, ceramic, or the like. To facilitate assembly of the sections 37, they are preferably formed with engageable interengaging means to align them axially to constitute the elongated body or carrier 36. For example, the sections 37 may be provided with a protruding lug 38 at one end and with a complementary receptacle 39 at the other, as is best illustrated by Figs. 3 and 4. A plurality of recesses 41 extending transversely of the body 36 are formed at spaced intervals along its length. Each of the recesses 41 extends through the body 36, or substantially so, and terminates in a portion 42 of reduced dimension. As shown, the axis of each of recesses 41 is perpendicular to the longitudinal axis of the body or carrier 36, but it is only necessary that the recesses 41 be formed transversely or generally crosswise of the body 36, and they can equally well intersect the axis of the device at any desired angle from around 45° to 90°.

Explosive perforating charges indicated generally at 43 are confined within the recesses 41 with their perforating ends directed toward the open or larger ends of the recesses. As shown and as preferred for the purposes of this invention, the perforating charges 43 are shaped bodies 44 of high explosive provided with 45 that are lined with non-explosive material 46, which may be glass or plastic, and is preferably a metal, such as copper, aluminum, lead or steel. These shaped, lined, cavitated explosive charges and their employment in other associations to perforate well walls by means of the so-called jet effect or Munroe effect are known and need not be further described here.

In the preferred embodiment of the invention shown in Figs. 2, 3, 4 and 5, each of the sections 37 serves to contain one of the perforating charges 43, and the length of each such section 37 need be only that necessary to provide suitable casing for the charge 43. Any desired number of the sections 37 may be associated with the portion 18 to form the body or charge carrier 36, and a maximum of perforations can be obtained with a minimum overall length of the perforating tool.

A groove 47 is formed in the surface of the body or carrier 36 along its entire length intersecting or nearly intersecting each of the recesses 41, and is disposed thereof opposite the perforating ends of the charges 43. As shown, the groove 47 intersects and is in open communication with recesses 41, but a thin wall of the material of the body 36 may, if desired, be left between the recesses 41 and the groove 47. The purpose of groove 47 is to receive a detonating cord 48, such as Primacord, by means of which charges 43 may be detonated through the aid of a small booster charge 49 of explosive interposed between the shaped explosive bodies 44 and 45.

In order to space the perforations angularly from each other, adjacent recesses 41 are angularly spaced apart, and the groove 47 intersecting the ends 42 of recesses 43 describes a spiral in the surface of the body or carrier 36. As shown in Figs. 2, 3 and 4, the angular spacing of the recesses 41 is 90° and each of the sections 37 has a segment of spiral groove 47 formed in its surface along its entire length. Thus, when a plurality of sections 37 are assembled end to end by engaging lugs 38 with receptacles 39, the segments of groove 47 may be aligned to form a continuous spiral, and the openings of recesses 41 will be angularly spaced apart at 90° intervals. The assembled sections 37 are secured together by any suitable fastening means, such as counter sunk set screws 51, as shown, or by means, such as drift pins, bayonet locks, threads, and the like.

When a large number of perforations are desired to be made at one time, it may be desirable to connect two or more groups of the assembled sections 37 into a single perforating device 10. Also, in some circumstances, it may be desirable to perforate above and below a blank unperforated segment of the well wall. For these purposes, there is provided a connecting unit 52 (Figs. 2 and 4B). Unit 52 is a hollow member formed of aluminum, brass or other suitable material of sufficient wall thickness to resist the pressures encountered. One end of unit 52 is formed as shown at 53 to receive the lug 38 of sections 37 and the opposite end is reduced as shown at 54 to engage receptacle 39. The maximum exterior dimension of unit 52 is not greater than that of the completed perforating device 10.

The perforating device 10 terminates in a bull plug 55 formed of any suitable material, usually a metal, such as aluminum, brass or copper. The bull plug 55 may be solid, but is preferably hollow and closed at one end, as shown by Figs. 2 and 4C, and of no greater wall thickness than is required by the pressures encountered. The open end 56 of bull plug 55 is reduced in diameter to engage the receptacles 39 of the sections 37 and 50.

The assembled components included within the expendable portion 18 of the device are attached to the adapter 26 by a metal ring 57 seated on a reduced portion 58 of adapter 26 and on a connector 59. The connector 59 is made of the same frangible material as the body section 37, and is provided with a lug 61 and receptacle 62 corresponding to lugs 38 and receptacles 39. The ring 57 is secured to the adapter 26 and to the connector 59, which in turn is secured to one of the body sections 37, in the same manner as the sections 37 are secured to each other, for example, by set screws 81.

In the surface of connector 59 there is formed a special circumferential groove 63 as well as a longitudinal groove 64 (see Fig. 4A), both adapted to receive the detonating
The receptacle 62 receives the lug 38 of the uppermost body section 37 and the lug 61 engages the interior of ring 57. Within the ring 57, one end of the detonating cord 48 is securely attached to a conventional blasting cap 65 that is adapted to be fired electrically. The leads of the blasting cap 65 are connected to the conductors 31 and 32 previously described.

From the blasting cap 65, the detonating cord 48 lies within the groove 64 of connector 59, and one turn or coil 66 of cord 48 follows the circumferential groove 63. From connector 59 the cord 48 continues along the groove 47 throughout the entire length of the body 36 and terminates in the plug bulg 55, within which the cord 48 is looped back at least once upon itself, as indicated at 67. Within each of the units 52, in case these are employed, an additional length 68 of detonating cord or some other suitable small quantity of explosive, is attached to and arranged to be detonated by the cord 48 that passes through the hollow interior of the unit 52.

The entire assembly from the lower portion of adapter 26 to the plug bulg 55 is enclosed within a thin-walled tube 69, preferably made of aluminum, brass, or steel. The tube 69 may be continuous over the entire length of the assembly or may be two or more sections separated by the units 52. The ends of the tube 69 (or of the separate lengths thereof) are secured to the adapter 26, to the plug bulg 55 and to the units 52, which in each case are provided with portions 26a 55a and 52a, respectively, of reduced diameter on which the tube 69 is snugly seated. The tube 69 may be secured to the parts named by any suitable means, for example, by means of a groove and gasket arrangement as shown at 73.

The function of the tube 69 is to add strength and rigidity to the entire assembly and to provide a seal against well fluids. At the same time, the tube 69 is made as thin as possible in order that it will be largely disintegrated when the device is fired so that a minimum of debris will remain in the hole. Aluminum is preferred as a material for the tube 69, because this metal is more or less frangible and readily shattered upon detonation of the explosives employed. Additionally, the aluminum fragments remaining in the well can be readily destroyed by the acids commonly used in well treatments, or, if acid is not employed, the aluminum will be attacked and eliminated by the salt water that ordinarily accumulates at the bottom of wells.

Because the thin-walled tube 69 does not of itself possess sufficient strength to resist even the least hydrostatic pressures likely to be encountered in the use of a perforating device of the type described, it is essential that the tube 69 be supported over as much of its surface as possible. This can be accomplished by maintaining the outside dimensions of all parts of the device enclosed by the tube 69 within close tolerances to fit snugly within the tube 69.

It will be seen, however, that each of the recesses 41 presents a relatively large area over which the tube 69 would be unsupported. To overcome this, and to enable the pressure developed to withstand severe pressures, there are provided special reinforcing covers 74 to cover the recesses 41. The covers 74 take the form of a segment of a cylinder, the outside diameter of which is that of the outside diameter of the body 36 (or sections 37). To accommodate the covers 74, the body 36 (sections 37) is cut away to a depth equal to the thickness of the covers 74 for part of its circumference surrounding each recess 41, as shown at 75 of Fig. 3.

In order to obviate reduction in the efficiency of the penetration accomplished by the perforating charges 43 by the necessity of penetrating the re-enforcing covers 74, openings 76 are formed in the covers 74 in alignment with the perforating ends of the charges 43, that is, the axes of the cavities 45. The interposition of the covers 74 between the charges 43 and the tube 69 necessarily also reduces the effective stand-off space available to the shaped charges, and this tends to reduce correspondingly the effectiveness of the jet perforating effect. Accordingly, to regain as much as possible of this stand-off distance that would otherwise be lost, the openings 76 in covers 74 are flared or tapered and are made larger at the interiors of the covers 74 decreasing in size toward the exterior, as illustrated at 77. By this means, the maximum stand-off space is provided for the shaped cavitated perforating charges 43, and at the same time a minimum area of the wall of tube 69 remains unsupported.

In operation, the perforating device is described as being run in the well through the tubing, and positioned opposite the zone to be perforated in accordance with conventional practice. Thereafter, a source of electrical power, which may be either A.C. or D.C., is connected to the conductor 23 of cable 16 at the earth's surface to complete a circuit through the conductor 23, contact 24, pin 25, terminal 33, conductor 31, blasting cap 65 and detonator 32 and terminal 35 to ground. This fires the blasting cap 65 and detonates cord 48 which, in turn, detonates charges 43, all substantially simultaneously. The jet effects produced by the shaped cavitated charges 43 are applied through the stand-off distance between charges 43 and tube 69 perforates the casing wall 13 which penetrates through the casing outside the casing and into the surrounding formation. The degree of penetration obtained is equal or nearly equal to that obtained in the use of conventional jet perforators of a size at least twice that of the device of this invention. This is possible by reason of the unique design of the present device which permits the use of a relatively large charge despite the small diameter of the tool.

Also simultaneously with the detonation of the perforating charges 43, the small quantities of explosive constituted by the cords of detonating cord 66, the loop 67, and the additional cord 68, are detonated. These sever the expendable portion 18 of the perforating device, and assist in disintegration of the heavier portions of the device, specifically, the plug bulg 55 and units 52. The detonation of the cord 48 which is borne in the groove 47 tangentially to the inner wall of the casing as the detonating cord 48 or the charges 43. Other forms of explosives can obviously replace the portions of the detonating cord described above for this purpose.

By way of a specific example for purposes of illustrating one embodiment of the invention, a perforating device was constructed substantially as shown in Fig. 4. The outside diameter of the device 134 inches. In this connection it may be noted that as to this specific device, Fig. 4 of the drawings is drawn to full scale except that the wall thickness of the aluminum tubing (69) actually used in the device was only 3/8 inch. This device was subjected to test and it successfully withstood external hydrostatic pressures as great as 10,000 pounds per square inch. If still greater pressures were to be encountered, additional strength could be gained by substituting a tube of brass for that of aluminum. By way of comparison, a hollow jet perforating gun formed of aluminum tubing 134 inches outside diameter but having a wall thickness
four times as great, i.e. \( \frac{1}{4} \) inch, is reported to be capable of withstanding no more than 4,000 pounds per square inch of hydrostatic pressure. It will therefore be apparent that this ability of the device of the present invention to operate successfully under extreme pressures is due to the principles of its construction as herein disclosed, particularly the support of the thin-walled tubing provided by the cylindrical body sections, since it is obvious that aluminum tubing of only \( \frac{1}{4} \) inch wall thickness, if unsupported, would collapse under pressures of only a few hundred pounds per square inch.

The construction described above is generally preferred, and is possible and may, in some instances, be desirable for reasons of economy or for other reasons. For example, the unitary body sections 35 may be replaced by two-piece sections as shown in Figs. 6 and 7. In this case, the elongated carrier or body 36 is made up of body sections 137, each constituted by the complementary portions 137a and 137b. The portions 137a and 137b are generally semi-cylindrical in form and may be solid or of any desired wall thickness commensurate with the strength requirements of the device. For the specific instance shown in Figs. 6 and 7, the portions 137a and 137b are illustrated as being of substantial wall thickness and, when joined, they enclose a central opening 137c. The body sections 137 may be made of any desired material, including various metals, such as aluminum, brass or steel, or they can be made of plastics or other non-frangible substances, such as aluminum, plastics, glass or ceramics, and they are usually preferred for reasons explained above.

The body sections 137 are formed with appropriate interfacing means to align them axially when assembled into the carrier 36. These means may take the form of the lugs 138 and recesses 139, and the sections 137 have formed in their surface a groove 147 to receive the detonating cord 48. The perforating charges 43 for use with the embodiment of the invention shown in Figs. 6 and 7 are constituted as described above, but the components of each charge 43 are enclosed in a relatively thin case 141 made of any desired material, such as plastic or glass, or a metal, such as aluminum or the like. The semi-cylindrical portions 137a and 137b include between them approximately recesses to receive the charge cases 141, as, for example, in the recess portion 142 provided in portion 137a to receive the end of charge case 141 opposite the perforating end of charge 43, and corresponds generally to the reduced end portion 42 of the recesses described above. This recess portion 142 communicates normally with the groove 147. An opening 176 is provided in the portion 137a in alignment with the axis of recess 142, and a flared enlargement 177 leads from opening 176 toward the interior face of portion 137b complementing the recess 142 to receive the perforating end of charge 43 enclosed in case 141. By this means, the necessity of a separate re-enforcing cover, such as covers 74 of Figs. 4 and 5, is eliminated, and by the selection of the degree of taper of the flared enlargement 177 of opening 176, there can be provided a thickness of material over charge 43 that will lend the desired strength to the assembly. At the same time, the tapered enlargement 177 and opening 176 provide the maximum standoff distance for the charge 43 and a minimum area of tube 69 remains unsupported.

As in the case of the embodiments previously described, the assembly with portions 137 with the charges 43 and detonating cord 48 are encased in the tube 69 which is sealed against well fluids. The remainder of the device may be as set forth previously.

In the event that the body sections 137 enclose a central opening 137c as illustrated, there may be provided a filling of cushioning material between adjacent charge cases 141 within this opening. For example, shredded paper, cotton, cermiculite, expanded cereals, or equivalent substances may be used as this filling, although none is essential to the function of the device. The purpose of such a filling material is, as is known in this art, to reduce the possibility of so-called "interference" between the charges. Although the charges are detonated substantially simultaneously, there is nevertheless a discrete time interval between the several detonations, the first of which can cause misalignment of the others in the exceedingly small though finite interval before the subsequent detonations occur. The filling material slows, cushions or absorbs the shock waves in the central opening 137c and thereby helps to prevent this interference.

While there have been described what is currently believed to be the preferred embodiments of this invention, it will be understood that various modifications may be made therein which are within the spirit and scope of the invention as defined by the appended claims.

What is claimed as new and desired to be secured by Letters Patent of the United States is:

1. An expendable and substantially disintegratable perforating device for well walls comprising an elongated cylindrical carrier of frangible material of sufficiently small diameter to pass through approximately two inch inside diameter well tubing; a plurality of recesses formed transversely in said carrier and extending at least substantially therethrough; a plurality of shaped, cavitated explosive charges confined in said recesses and unsealed at the periphery against well fluids; and a groove formed in said carrier at least substantially intersecting the ends of said recesses opposite the cavities of said charges; a detonating cord in said groove for detonating said charges; a thin-walled frangible tube supported by and enclosing said carrier, said covers and said cord, the interior of said tube being sealed against the entry of well fluids; and the device, said support and said groove being so arranged with the groove to leak off when said device is expanded.

2. A perforating device according to claim 1, in which a small amount of explosive charge is confined in a stock arranged to be detonated by said cord is provided within said tube adjacent to at least a portion of its periphery adjoining said subassembly to sever said tube and said body from said subassembly when said cord and said charges are detonated.

3. A perforating device according to claim 1, in which relative small amounts of explosive adapted and arranged to be detonated by said cord are provided within said tube adjacent to those portions of said tube and said body that are not in close proximity to said cord and said charges to sever said tube and said body from said subassembly and at least partially to disintegrate the severed portions of said device.

4. An expendable and substantially disintegratable perforating device for well walls comprising an elongated cylindrical body of frangible material of sufficiently small diameter to pass through approximately two inch inside diameter well tubing, means defining a plurality of recesses extending transversely of said body and having restricted openings of substantially reduced cross section at one end thereof, a plurality of shaped cavitated explosive charges confined in said recesses and unsealed at the periphery against well fluids with the cavitated ends thereof facing said restricted openings, the portions of said body adjacent said restricted openings substantially defining stand-off areas in front of the cavitated ends of said charges, a thin walled tube enclosing and sealing said body and said charges against well fluids and supported by said body except in the areas of said restricted openings, said restricted openings being...
of sufficiently small area to prevent said tube from collapsing when subjected to well fluid pressure within the well, a passageway in said body at least substantially intersecting the other ends of said recesses, a detonating cord in said passageway for detonating said charges, and means for detonating said cord.

5. A perforating device according to claim 4, in which said thin walled tube is formed of frangible material and said detonating cord is positioned in contact with the inner surface of said tube to facilitate disintegration of said tube upon detonation of said cord.

6. A perforating device according to claim 4, in which said body is formed of a plurality of generally cylindrical sections of frangible material each having one of said recesses and a segment of said passageway formed therein.

7. A perforating device according to claim 4, in which said restricted openings are formed by means of removably cover plates having openings aligned with said cavitated ends of said charges.

8. A perforating device according to claim 4, in which said restricted openings are formed by means of removably cover plates having openings decreasing in size toward the exterior thereof and aligned with said cavitated ends of said charges.

9. A perforating device according to claim 4, in which said body is formed of a plurality of generally cylindrical sections of solid frangible material, each having one of said recesses and a segment of said passageway formed therein, and interengaging means to align said sections to constitute said elongated cylindrical body.

10. A perforating device according to claim 4, in which said body is formed of generally semi-cylindrical sections having said recesses included therebetween.

11. A perforating device according to claim 4 in which said body is formed of a plurality of pairs of generally semi-cylindrical sections, each pair of said sections including one of said recesses therebetween, a segment of said passageway in the surface thereof, said restricted opening communicating with the recess in alignment with and flared inwardly toward said cavitated end of said charge, and interengaging means to align said pairs of sections axially to constitute said elongated body.

12. A perforating device comprising a substantially solid cylindrical body, said body being formed of a frangible material, a plurality of diametral holes spatially arranged along said body member, a plurality of cavited jet forming cartridges respectively disposed in said holes with the cavited ends thereof exposed, a plurality of frangible cover means respectively disposed over the ends of said holes adjacent to said cavited ends of said cartridges, said cover means lying substantially flush with the outer surface of said cylinder, each of said cover means including a central aperture aligned with the principal axis of the associated one of said cartridges, the cross sectional area of said apertures being substantially less than that of said holes, and a thin walled, frangible tube enclosing said cylinder to seal said cartridges, the internal diameter of said tube being only slightly larger than the external diameter of said solid body thereby to provide a tight fit between said tube and said cylinder.

References Cited in the file of this patent

UNITED STATES PATENTS

866,838 Broadway ------------ Sept. 24, 1907
2,402,153 Elliott --------------- June 18, 1946
2,418,486 Smylie --------------- Apr. 8, 1947
2,433,231 Martin --------------- Dec. 23, 1947
2,494,256 Muskat et al. ------- Jan. 10, 1950
2,629,325 Sweetman ---------- Feb. 24, 1953
2,669,928 Sweetman ---------- Feb. 23, 1954
2,708,408 Sweetman ---------- May 17, 1955
2,742,857 Turechek ----------- Apr. 24, 1956
2,749,840 Babcock ---------- June 12, 1956

FOREIGN PATENTS

146,615 Austria --------------- July 25, 1936
1,023,832 France --------------- Jan. 7, 1953