

Nov. 9, 1965

C. A. SCHROEDER ETAL

3,216,459

FLEXIBLE INSULATED DUCT

Filed Feb. 8, 1963

4 Sheets-Sheet 1

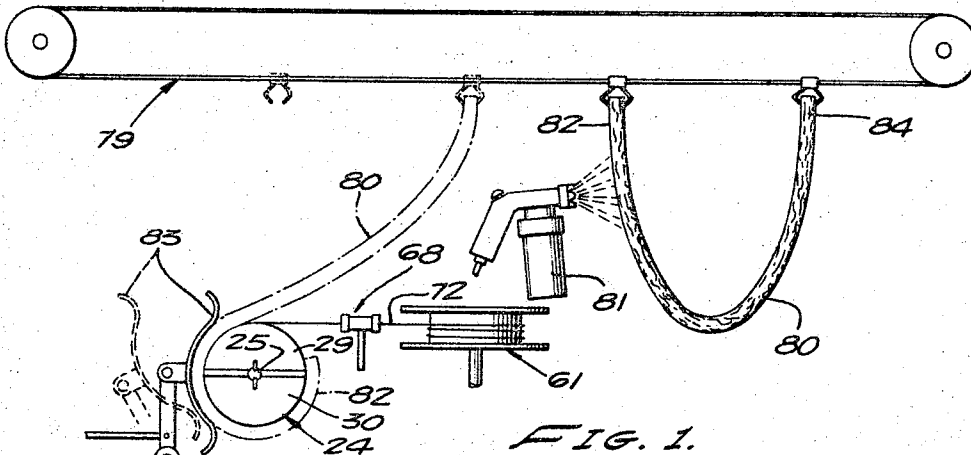


FIG. 1.

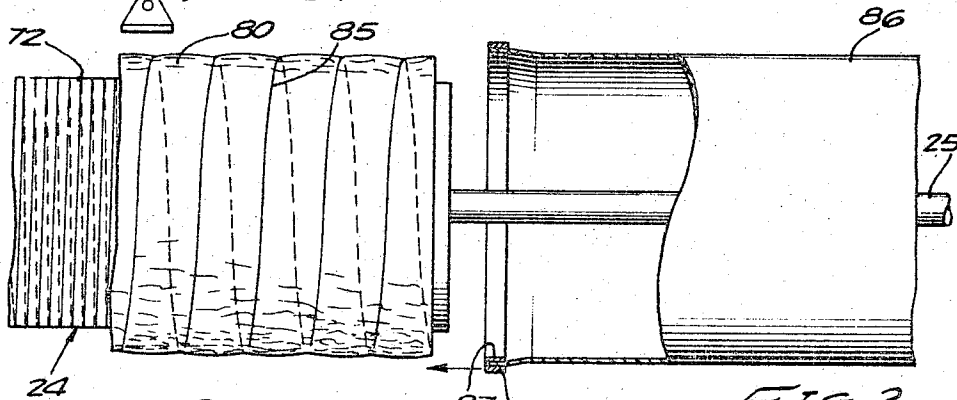


FIG. 2.

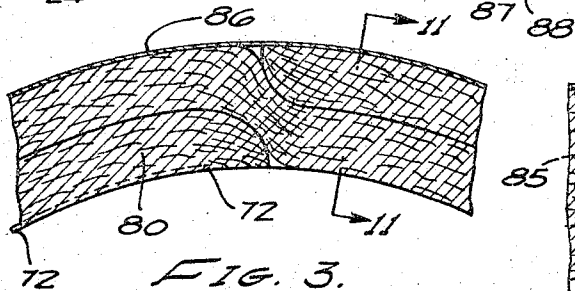


FIG. 3.

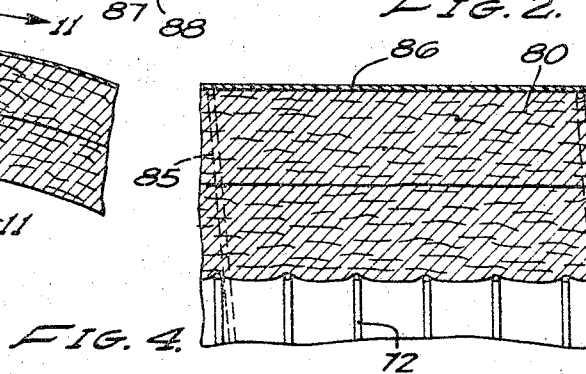


FIG. 4.

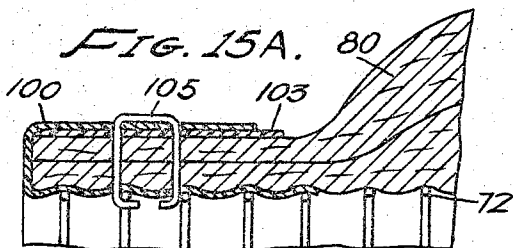


FIG. 15A.

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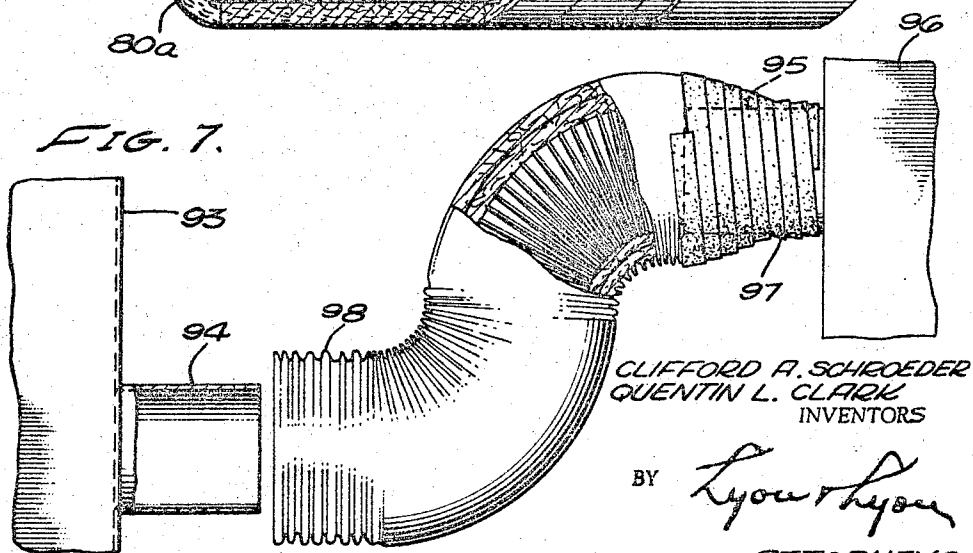
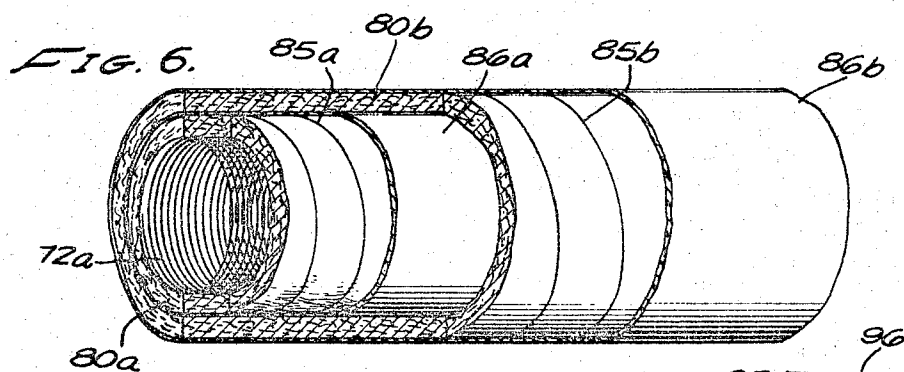
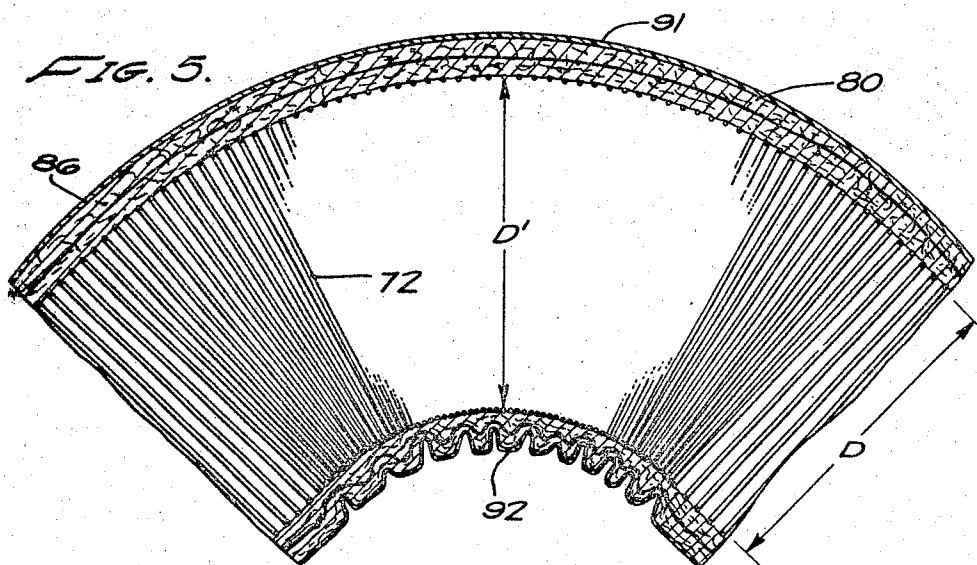
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FIG. 8.

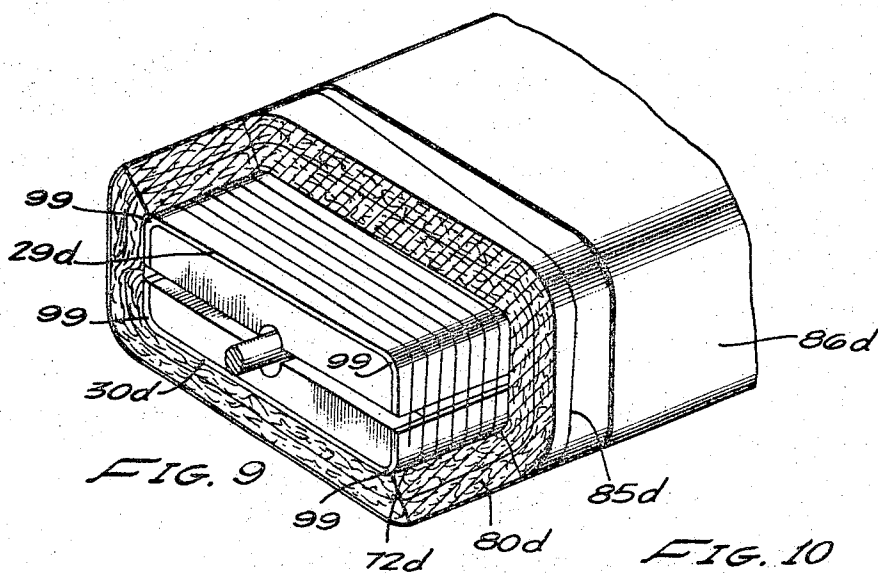
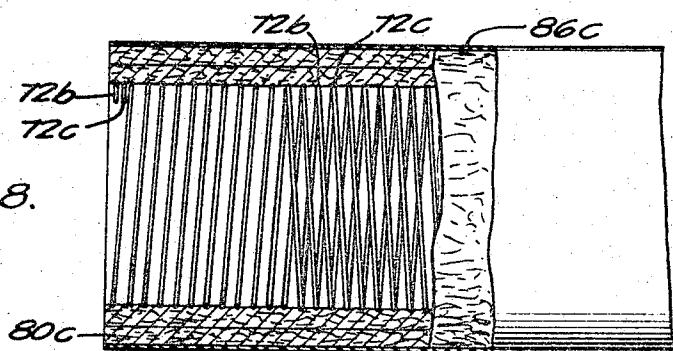
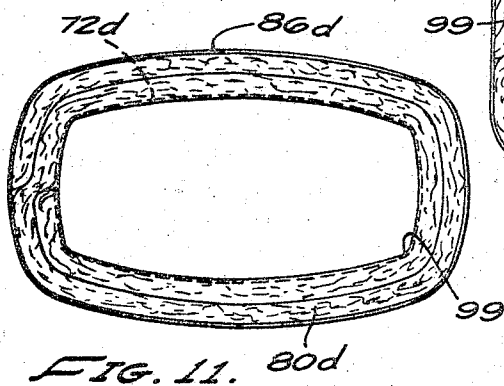
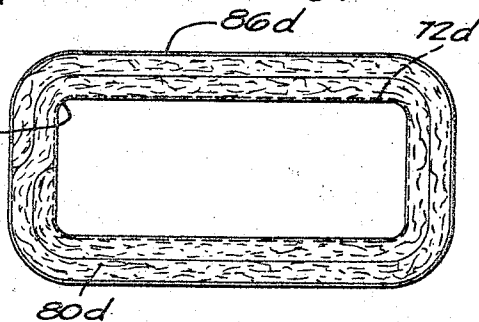


FIG. 10



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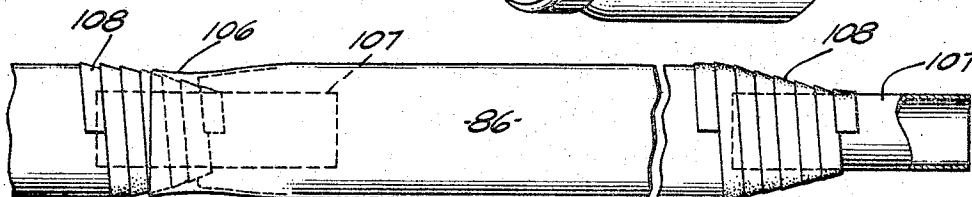
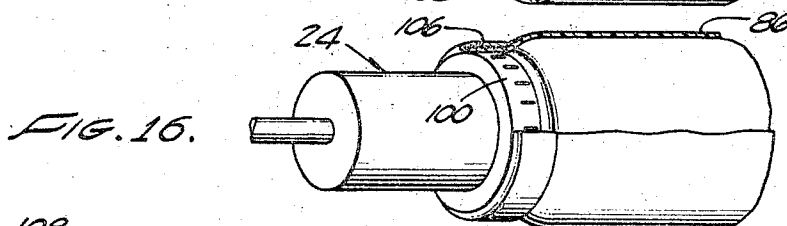
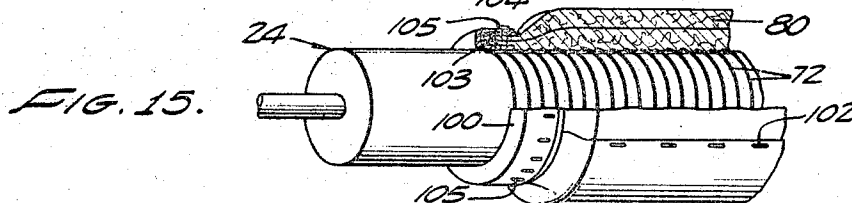
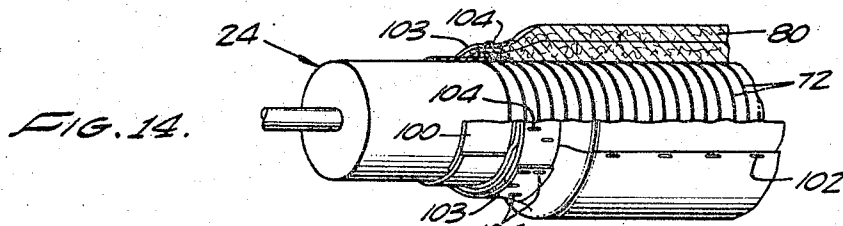
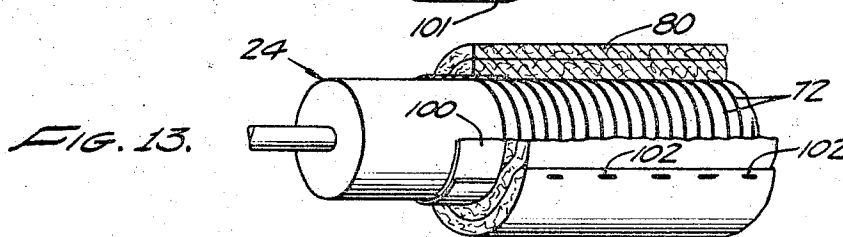
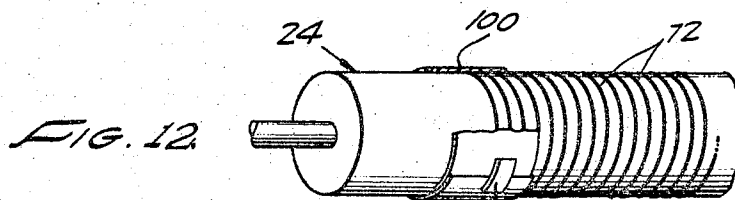
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4 Sheets-Sheet 4



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3,216,459

FLEXIBLE INSULATED DUCT

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Filed Feb. 8, 1963, Ser. No. 257,196

14 Claims. (Cl. 138—139)

This is a continuation-in-part application of our pending application entitled "Insulated Duct and Method and Apparatus for Making Same," Serial No. 187,120; filed April 12, 1962.

This invention relates to insulated ducts for conducting air or other gaseous fluids and, in particular, this invention is directed to a duct of this type which is comparatively flexible and inexpensive for versatile and practical use. While this application is directed to the duct itself, an apparatus and method for making the duct is described for a more thorough understanding of the structure and configuration of the duct.

There are numerous different types of ducts and conduits for transmitting air and other gases from one place to another. The particular purpose for transmitting the air or gas and the type of gas being transmitted greatly influences the physical requirements which are desired for a particular conduit or duct. In the heating and air-conditioning of various types of buildings, it has become relatively common to provide a central heating and air-conditioning system. In such a system, air is heated or cooled as desired and circulated through various ducts to the individual rooms for discharging the heated or cooled air into the room. The ducts are generally positioned within the ceilings, walls, attics, or between floors of multiple floor buildings.

It is generally necessary, or at least desirable, to insulate the air-conditioning and heating ducts for proper and efficient operation of the system. For example, in a typical residence or other single-level building having a central air-conditioning and heating system the ducts are commonly positioned in the attic with individual branch ducts leading to each room of the building. In the summer months, when the system is being used to cool the building, the air within the attic reaches relatively high temperatures and yet the air passing through the ducts is relatively cool for cooling the rooms. Thus, it has become common practice to use insulated ducts so that the heat transfer between the interior of the duct and the exterior of the duct, i.e., warming of the cool air being circulated, is minimized to increase the overall efficiency and effectiveness of the system. Likewise, in the winter months when warm air is circulated through the ducts to heat the rooms, the temperature in the attic may be relatively low, so that the heat loss from the duct to the attic would be excessive if the ducts were not insulated.

It is relatively common practice in present commercial and residential installations to use sheet-metal ducts for conducting the heated or cooled air to the various rooms. These sheet-metal ducts are usually insulated with fiber glass insulation blankets, low density rock wool, etc., that are either wrapped around the exterior of the sheet-metal duct or are secured to the interior of the duct. In many commercial buildings, it is necessary to secure the insulation to the interior of the duct in order to provide acoustical insulation, so that sounds from one room are not transmitted through the duct to another room. Positioning the insulation on the interior of the duct also serves to reduce the noise level caused by the movement of air through the duct from the central system. Mounting the insulation on the interior of the ducts acoustically insulates the ducts due to the porous and fibrous nature of the insulation material.

Since air-conditioning and heating system ducting must extend throughout a building and is positioned in attics, walls, and between floors of multi-story buildings, the ducting often passes through extremely restricted spaces and around numerous corners and bends. Thus, for installation purposes, it is often desirable to have a flexible duct which can be readily passed through restricted spaces and around corners without requiring modification of the structure of the building or special construction. Although short lengths of flexible ducts are often used to pass through these restricted spaces and around corners, it is common practice to limit the use of this flexible ducting to these particular locations. This limited use of flexible ducting is a result of the higher cost per linear foot of flexible ducting as compared to rigid ducting and due to the poor air-flow characteristics of conventional flexible ducting. The air-flow characteristics of a duct are extremely important in that if a particular type of duct resists the flow of air therethrough to an objectionable degree, the size of the duct must be increased or the capacity of the air-circulating blower must be increased in order to pass a sufficient amount of air through that duct to accomplish the heating or air-conditioning. The resistance to air-flow through a duct is commonly referred to as the "static friction" of the duct which is measured by standard tests wherein air is passed through a predetermined length of duct and the pressure drop through the duct is observed. Most conventional flexible ducts are fabric, or other impervious material, reinforced with wire and therefore have an irregular or "corrugated" inner wall that is impervious. Further, such irregularity of the inner wall of the duct is increased by bending the duct around a corner and thus these ducts have a relatively high "static friction" characteristics. Also, the impervious inner surface of such ducts provides very little acoustical insulation. Thus, conventional flexible ducting is used sparingly in air conditioning and heating systems to avoid these undesirable characteristics of conventional flexible ducting.

Accordingly, it is a principal object of this invention to provide a novel form of insulated duct which is highly flexible and yet highly resistant to collapsing from externally applied radial forces or flexing.

Another object of this invention is to provide a flexible insulated duct which is relatively inexpensive to manufacture and lends itself to easy installation.

A further object of this invention is to provide a novel form of insulated duct wherein the insulation is exposed to the interior of the duct for producing acoustical insulation as well as thermal insulation.

A still further object of this invention is to provide a flexible insulated duct wherein the internal surface of the duct is relatively smooth to produce good air-flow characteristics through the duct. A more specific object is to produce such a duct wherein bending of the duct around a corner does not appreciably affect the smooth interior surface and, thus, the good air-flow characteristics of the duct are maintained in the bent condition.

Another object of this invention is to provide a novel form of insulated duct wherein the insulation is exposed to the interior of the duct for sound insulation and yet mechanically supported from the interior of the duct to maintain a smooth and regular interior surface.

A further object of this invention is to provide a novel form of flexible insulated duct wherein wire forms the structural support for the insulating material and prevents radial collapsing of the duct but such wire does not inhibit bending, flexing or longitudinal collapsing of the duct.

Other and more detailed objects and advantages of this invention will appear from the following description and the accompanying drawings.

In the drawings:

FIGURE 1 is a schematic elevation illustrating some of the steps employed in the method of making the duct of this invention.

FIGURE 2 is a fragmentary sectional view of a partially completed duct of this invention and showing one of the steps for completing the duct.

FIGURE 3 is a fragmentary sectional view of a completed duct with the plane of the section taken perpendicular to the axis of the duct.

FIGURE 4 is an enlarged longitudinal fragmentary sectional view of the duct taken substantially on the line 11—11 as shown in FIGURE 10.

FIGURE 5 is a sectional view of the duct of this invention taken substantially on the axis of the duct and illustrating the duct as being flexed to bend around a 90° corner.

FIGURE 6 is a fragmentary sectional view of a modified form of the duct of this invention.

FIGURE 7 is an elevation view of our duct being installed between two sheet metal conduits with portions in cross-section for illustrating the flexibility of the duct.

FIGURE 8 is a fragmentary sectional view of a second modified form of the duct of this invention.

FIGURE 9 is a fragmentary sectional view of a third modified form of the duct of this invention, and of the collapsing mandrel used in manufacturing such form.

FIGURE 10 is a cross-sectional view of the modified form of the duct shown in FIGURE 16.

FIGURE 11 is a cross-sectional view similar to FIGURE 17, showing the modified form of duct shown in FIGURES 16 and 17 in its non-strained condition as it would appear after removal from the collapsing mandrel.

FIGURES 12, 13, 14, 15 and 16 illustrate the successive steps, in that order, for providing an end closure on the duct of this invention.

FIGURE 15A is an enlarged fragmentary sectional view of the end closure for the duct in its intermediate stage of construction as illustrated in FIGURE 15.

FIGURE 17 illustrates the manner of connecting two ducts of this type to one another.

The flexible insulated duct of this invention may be constructed on an apparatus of type described in our aforementioned application of which this is a continuation-in-part and in the manner therein described. The structure of the duct is such as to require some understanding of at least one method of manufacture, such as is shown in FIGURE 1, in order to fully comprehend the structural cooperation of the elements of the duct in its completed form. Briefly, the manufacturing apparatus includes means for supporting and rotating the shaft 25 of a cylindrical mandrel assembly, generally designated 24, which is as long or longer than the desired length of the duct and of a diameter equal to the desired inside diameter of the duct. Cylindrical mandrel assembly 24 is comprised of a pair of semi-cylindrical mandrels 29 and 30 that are adapted to collapse radially toward each other to facilitate the removal of a completed duct from the assembly. The manufacturing apparatus includes means for supporting a wire feeding assembly, generally designated 61, and an adhesive applicator assembly, generally designated 68, and moving them longitudinally along the mandrel assembly 24 in synchronization with the rotation of the mandrel assembly for feeding adhesive-coated wire 72 onto the mandrel assembly in a continuous helix as shown in the left-hand portion of FIGURE 2. A mold release compound may be applied to mandrel assembly 24 first to inhibit adhering of the wire 72 thereto. The spacing between each convolution of wire 72 is established by the predetermined adjustment of the rate of longitudinal movement of the wire feeding assembly 61 relative to the rate of rotation of the mandrel assembly 24. Although this spacing between convolutions of wire may be greatly varied for various requirements and sizes of ducts, it

has been found satisfactory to use a spacing of about 1/2 inch between wire convolutions in a duct having an internal diameter of six inches. If a structurally stronger or weaker duct is desired, the spacing may be decreased or increased, respectively, by adjusting the rate of movement of wire feeding assembly 61 relative to the rotation of the mandrel assembly 24. When the mandrels 29 and 30 are covered with the desired length of duct (usually the length of the mandrels), the wire is severed between the mandrels and adhesive applicator 68 and the end is releasably secured to the mandrels by any convenient means such as a clamp (not shown).

Referring now to FIGURE 1, the mandrel assembly 24 is schematically shown as pulling the wire 72 off the wire feeding assembly 61 and through the adhesive applicator 68. An overhead support apparatus, generally designated 79, may be provided above the machine 10 for supporting the sheet-like member or blanket 80 of insulation material which is used in the duct. The sheet-like member or blanket 80 has a width equal to the length of the duct which is being produced (generally the length of the mandrels 29 and 30, although the duct produced may be shorter). Although it is not essential, with some types of insulation blanket we prefer to apply a thin coat of glue, adhesive or other type of coating to the portion of the surface of the blanket 80 which is to be applied to the mandrels 29 and 30. This coating may be applied by any convenient means, such as spray gun 81. The thin coating on the blanket 80 may serve to enhance the adhesion of the blanket to the adhesive-coated wire 72 and, also, may serve as a coating to prevent erosion of the insulation blanket when the duct is used, as will hereinafter be described. With the adhesive-coated wire 72 wrapped onto the mandrels 29 and 30, one end 82 of the insulation blanket 80 is released from the support apparatus 79 and applied to the wire-covered mandrels 29 and 30 with end 82 positioned parallel to the axis of the mandrel assembly 24. The mandrel assembly 24 is then rotated to wrap the blanket 80 around the mandrels 29 and 30. A pressure pan 83 or series of rollers (not shown) may be provided and extend the length of the mandrels for engaging the outer surface of the blanket to hold the blanket uniformly on the mandrels and apply sufficient pressure to cause the blanket to adhere to the adhesive-coated wire. The pressure pan 83 may be moved out of engagement with the blanket for subsequent operations. After the blanket 80 has been partially wrapped onto the mandrels 29 and 30, the other end 84 of the blanket is released from the support apparatus 79 and the entire blanket is wrapped around the mandrels to form an encircling tubular member or blanket of the insulation material.

Although as many wraps of insulation blanket 80 may be made as is desired or required for the particular duct, FIGURE 1 (and FIGURES 2 and 3) shows a sufficient length of blanket to make two wraps around the mandrels. The number of wraps of insulation blanket which are used will obviously depend on the insulation quality of the blanket and the desired insulation properties of the completed duct. We prefer to use an insulation blanket which is compressible and yet has some resistance to lengthwise and width-wise stretching of the blanket, such as, but not limited to: fiber glass insulation blankets of a typical density of 0.3 to 1.0 pound per cubic foot, low-density rock wool, flexible plastic foam insulation, or rotary fiber glass insulation blanket. Further, when a fibrous type of insulation blanket is used that has a particular predetermined orientation of the individual fibers where the fibers tend to extend more in one lengthwise direction of the blanket than the other, we prefer to orient the blanket when applied to the glued wire on the mandrels 29 and 30 such that the fibers extend circumferentially around the mandrels rather than longitudinally along the length of the mandrels. For example, it is inherent in the process for making glass fiber

blankets that although individual fibers are randomly positioned, the fibers tend to be oriented along the length of the blanket or at least at only small angles to the length. Thus, in using a glass fiber blanket the length of the blanket would be from end 82 to end 84, as seen in FIGURE 1, and the width of the blanket would extend the length of the mandrels 29 and 30. Although the reasons for this particular orientation of a fibrous insulation blanket will hereinafter become more apparent, at this point it should be noted that this fiber orientation tends to prevent circumferential expansion, i.e., enlarging of the duct, and permits longitudinal collapsing of the duct, such as by flexing, without tending to compress the fibers length-wise which could cause undesirable bulging of the fibers.

Means are then applied to the insulation blanket 80 for keeping it wrapped to the mandrel for subsequent operations, and these means may be of various types such as means for securing the outer end 84 to the previous convolution of blanket or encircling the blanket. For example, it has been found satisfactory to use staples along end 84 which pass into the previous convolution of blanket. Also, it has been found satisfactory to use a tie cord 85, such as conventional fiber glass tie cord, which is wrapped around the outside of the insulation blanket 80 in a continuous helix and slightly compresses the blanket 80. The convolutions of the tie cord 85 are substantially spaced one from another as shown in FIGURE 2, the actual spacing depending on such factors as the size of the duct and the wall thickness of the insulation. A flexible and substantially nonexpansible sleeve 86 of a length equal to the length of the duct which is being produced is then positioned on the shaft 25 at the end of mandrel assembly 24. The sleeve 86 may be of any conventional material, but it is more desirable if the material is relatively flexible, relatively unaffected by the temperature changes to which the duct is to be subjected, and sufficiently inexpensive to be used without greatly increasing the overall cost of the duct. Various types of thin vinyl plastic sleeves have been found to be satisfactory.

A pair of hoops 87 and 88 may be used to facilitate the installation of the sleeve 86 over the exterior of the insulation blanket 80. The smaller hoop 87 is inserted inside of the sleeve 86 and the larger hoop 88 is fitted over the exterior of the sleeve, thereby clamping the sleeve between the hoops as shown in FIGURE 2. The sleeve 86 is then pulled over the exterior of the insulation blanket 80 and is preferably of a size to slightly compress the insulation blanket 80. The hoops 87 and 88 may then be removed and the ends of the wire 72 unclamped from mandrels 29 and 30. The mandrels 29 and 30 are then collapsed toward each other, as previously described, and the completed duct may be slid off the mandrels.

The insulated duct of our invention is completed by the installation of the sleeve 86 and it will be noted that no heat curing is necessary in producing our flexible insulated duct. Connectors of any convenient type may be added to either or both ends of the duct as desired for facilitating on-the-job installation, and means such as a vinyl sleeve, may be added on either end for preventing fraying of the insulation blanket. The outer surfaces of the mandrels 29 and 30 then may be cleaned with an appropriate solvent to remove the excess glue and mold release compound, and new coating of mold release compound may be applied for producing another duct in the same manner as heretofore described.

In our finished duct, the insulation member or blanket 80 is exposed to the interior of the duct thereby producing the desired acoustical insulation as well as providing a thermally insulated duct. The wire 72 may be of any convenient size, cross-section and material within certain limits and yet exhibit all of the desired characteristics. The wire 72 must have sufficient strength and rigidity to

prevent collapse of the duct in a radial direction upon the application of moderate forces that may be encountered. But also, since flexibility of the duct is of paramount importance and yet the wire is formed in a continuous helix, the wire cannot be of such a strength as to resist bending of the duct. Further, the wire must be sufficiently resilient as to not be permanently deformed upon flexing of the duct. The term "wire" therefore as used through this application, including the claims, is intended to mean and include any element in the form of a slender rod whether comprised of metal, plastic, resin-coated fiber or other material and whether circular or non-circular in cross-section, if that element exhibits these characteristics of relative flexibility, resiliency and strength.

For example, we have found spring steel wire to be excellent and by using certain different diameters of wire for the range of different diameters of the ducts the proper balance between maintenance of radial strength against collapse and maximum longitudinal flexibility has been obtained. Spring steel wire of 0.037" diameter is excellent for ducts of less than 7" inside diameter and spring steel wire of 0.051" diameter has been found satisfactory for ducts of inside diameters of substantially 7" up through 16" inside diameter, with the blanket being of the same material and thickness in all duct sizes. These wires when formed into the continuous helix of these sizes give excellent radial strength against collapse to the duct, but it should be noted that if these wires are removed from the mandrels without remaining secured to the insulation blanket or being secured to anything else, the coils of wire would merely collect into a randomly arranged and intertwined series of coils rather than forming a coil spring with substantially regular axial spacing between each convolution of wire. In this sense the helix of our invention may be said to be, except radially of each individual coil, dimensionally unstable. While no particular formula has been devised for selecting the size of wire to use for a particular size duct, since many variations can be used, it is to be noted that the wire of any particular composition and hardness cannot exceed certain sizes of wire diameter for certain sizes of ducts. A wire of sufficient rigidity to form a self-supporting coil spring of these sizes and capable of maintaining their spaced convolutions, commonly referred to as a "compression coil spring," would be too rigid when incorporated in the duct to permit the desired flexibility of the duct. It is well known to those skilled in the art of springs that for a particular diameter, composition and hardness of wire there is a limit to the maximum diameter of an operable compression coil spring that can be fabricated. This upper limit in spring diameter when using round spring steel wire is roughly 40 times the diameter of the wire, whereas it can be seen from the above that the diameter of the wire helix of our duct is over 100 for a duct of larger than 3.7 inches inside diameter and even as high as over 300 times the diameter of the spring steel wire for a duct of 16" inside diameter. Stated differently, the wire helix of our duct is of such a large helix diameter in relation to the wire cross-sectional size, composition and hardness that the helix is inherently dimensionally unstable except in a direction radially of each coil individually. Thus, in effect, the insulation blanket supplies the longitudinal strength and axial stability while the wire supplies the radial strength against collapse.

Since the wire 72 is exposed to the interior of the duct, we prefer to use a wire which resists corrosion. We have found galvanized steel spring wire and copper wire to be highly satisfactory although other types of wire, as heretofore defined, may be used. Although the wire 72 is deformed by being wrapped on the mandrels 29 and 30 to form circular convolutions which tend to conform to the size of the mandrels, when the wire is unclamped from the mandrels and the mandrels are collapsed the wire tends to expand slightly outwardly to a larger size

and become imbedded in the inner surface of the insulation blanket 80. As shown in FIGURE 4, the inner surface of the duct is relatively straight and smooth since the wire only embeds itself in the insulation blanket to a depth about equal to the diameter of the wire. The wire continually tends to expand slightly outwardly due to its own resiliency. The wire is prevented from excessive circumferential expansion due to the insulation blanket having a certain amount of strength to resist circumferential stretching, particularly in part due to the fiber orientation previously described, and the wire being secured by adhesive to the insulation blanket. Further, radial expansion of the entire duct is limited by the sleeve 86 and tie cord 85 or other means employed to secure the end 84 of the blanket.

It has also been found that it is unnecessary to use a tie cord 85 or other permanent securing means on the blanket if a sufficiently strong sleeve 86 is used which will resist the radial expansion of the entire duct. When the tie cord 85 is omitted, it has been found satisfactory to use a length of non-adhesive cellophane tape which is wrapped helically around the insulation blanket to compress the blanket for ease in pulling the sleeve 86 over the blanket 80. The convolutions of cellophane tape are widely separated so that when the sleeve is in the proper position the tape may be released and pulled out from between the sleeve 86 and the blanket 80.

Since the insulation blanket 80 is easily compressed the overlapping of wraps of insulation blanket do not form excessive bulges in the finished duct as may be seen in FIGURE 3. The spacing between convolutions of wire 72 is maintained due to being secured to the insulation blanket in spaced relationship and the insulation blanket having sufficient longitudinal strength to resist axial elongation of the entire duct. When the duct is flexed around a corner, as shown in FIGURE 5, the outer radius portion 91 of the duct merely bends whereby any wrinkles in the material of sleeve 86 are straightened out but this portion of the material of the sleeve is not appreciably stretched lengthwise; whereas the inner radius portion 92 of the duct is compressed so that the adjacent convolutions of wire 72 are brought closer together while the insulation blanket merely compresses and the sleeve 86 assumes a folded condition around the curve. Thus the length of the axis of the duct is actually foreshortened upon bending of the duct. The wires 72 remain secured to the insulation blanket so that if the duct is returned to its original straight condition the convolutions of wires will return to their original spaced condition. The cylindrical configuration of the duct is structurally maintained only by the convolutions of wire 72 since the insulation blanket 80 is flexible and compressible and the sleeve 86 is also flexible. As the duct is flexed around a corner as in FIGURE 5, the circular cross-section of the duct is substantially maintained by the convolutions of wire 72 and, therefore, the inside diameter D' of the duct at the bend is substantially the same as the normal diameter D of the duct. The relatively smooth interior surface of the duct is not adversely affected by flexing the duct around a corner since the insulation blanket is merely compressed rather than bulging inwardly. This compression rather than bulging is further enhanced by the previously described fiber orientation of fibrous insulation blankets. Since the fibers tend to be aligned with or at small angles to the circumference of the duct, when the duct is flexed or compressed lengthwise the fibers merely bend slightly and compress laterally toward each other rather than being forced to bend lengthwise as would occur if the fibers were aligned with the axis of the duct.

The adhesive which is applied to the wire by the applicator 68 may be any conventional glue or adhesive, although we prefer to use a non-flammable type for safety and to comply with some building ordinances and codes. The glue or adhesive is also preferably of a type which remains flexible after setting so that the duct may be

flexed without damaging the bond between the wire and insulation blanket. We have found various rubber-base adhesives to be satisfactory, such as the adhesive manufactured and sold under the trademark Hypolon by the Lurado Manufacturing Co. of Anaheim, California, and those which may be thinned with methylene chloride or other non-flammable type thinners. The adhesive glue, or coating, which is sprayed on the insulation blanket may be of the same or a similar type which will inhibit fiber erosion of the insulation blanket when air flows through the duct.

In the modified form of our duct shown in FIGURE 6, the wire 72a is glued and wound onto a collapsible mandrel and one or more wraps of insulation blanket 80a are wrapped onto the wire as previously described. A tie cord 85a may then be applied and a sleeve 86a installed as previously described. One or more additional wraps of insulation blanket 80b are then wrapped around the sleeve 86a, a tie cord 85b is applied, and an outer flexible sleeve 86b is installed over the entire assembly. This modified form of duct is adapted to withstand higher internal air pressures than the duct previously described due to the double sleeves 86a and 86b.

In the modified form of our invention shown in FIGURE 8 the wire framework is comprised of two separate continuous wires 72b and 72c wound onto a collapsible mandrel side-by-side at the same time in a manner similar to our preferred form. For making this modified form on the afore-described apparatus, it is preferred that the apparatus be provided with two separate wire feeding assemblies 61 and adhesive applicators 68 to accommodate the two separate wires. The wires are coated with adhesive and an insulation blanket 80c is wrapped around the wires in the manner previously described. A flexible sleeve 86c is also installed in the previously described manner. Likewise, more than two separate wires could be used if so desired.

In the modified form of our invention shown in FIGURES 9, 10 and 11, the semi-cylindrical mandrels 29 and 30 of the collapsible mandrel assembly 24 are replaced with rectangular mandrels 29d and 30d. The mandrels 29d and 30d have rounded corners 99 to prevent excessive stressing of the wire 72d as the wire is wound onto the mandrels in a manner substantially the same as previously described. The mandrels 29d and 30d are collapsible toward each other the same as mandrels 29 and 30. The wire 72d is glued and wrapped onto the mandrels 29d and 30d, the insulated blanket 80d is wrapped around the glued wire and mandrels, and the tie cord 85d is applied, all in a manner similar to the manner previously described. A flexible sleeve 86d is installed in a manner similar to the installation of sleeve 86, except that hoops of a rectangular shape are used instead of the circular hoops 87 and 88. This duct will have a rectangular cross-section as shown in FIGURE 10 while the duct is still on the mandrels 29d and 30d, but when removed from the mandrels will tend to assume an irregular rectangular cross-section similar to that shown in FIGURE 11. This form of duct is particularly useful in relatively flat restricted spaces since although the duct normally has the configuration shown in FIGURE 11 the sides may be pressed in to force the duct into the configuration shown in FIGURE 10, thereby maximizing the cross-sectional air-flow area while minimizing the lateral dimensions of the duct.

In some air conditioning and heating system installations it is necessary to fit a duct between two previously installed ducts, plenums, or registers to transmit air from one to the other. In FIGURE 7 is shown a main air plenum 93 with a cylindrical conduit 94 tap-off opening which is to be connected to the cylindrical conduit 95 of the register 96. As shown the conduits 94 and 95 may be substantially offset from one another. The duct of our invention is inserted over one of the conduits, shown on conduit 95, and an adhesive tape 97 is spiral-wrapped

onto the conduit and onto the outside of the duct, thereby securing the duct to the conduit and forming an air-tight seal. Note that the tape 97 compresses the end of the duct. The other end of the duct may then be compressed longitudinally, as at 98 and inserted over the conduit 94. The high flexibility and compressibility of our duct makes such an installation relatively easy whereas conventional ducts would be difficult to install.

It has been found that since the wire 72 and insulation blanket 80 of a completed duct, as heretofore described, is exposed on each end of the duct, that it is possible for the wire and/or insulation blanket to become somewhat unravelled at the ends of the duct under extremely rough conditions of handling, shipping or installation. We, therefore, prefer to provide means for enclosing the ends of the duct to prevent this unravelling and these means may be comprised of those shown in FIGURES 12 through 16. After the glued wire 72 has been wrapped onto the collapsible mandrel 24 (shown in FIGURES 12-16 as solid for simplicity), as heretofore described, a length of flexible material 100, such as vinyl, is wrapped around the wire and mandrel with a portion of the material 100 extending beyond the last convolution of wire, as shown in FIGURE 12. The material 100 is secured in this position such as by tape 101. The insulation blanket 80 is then wrapped on the mandrel and wire, and secured by any convenient means such as a tie cord, as heretofore described, or by staples 102 driven into and through the layers of blanket. The material 100 extends beyond the end of the insulation blanket 80, as shown in FIGURE 13. Another length of the flexible material 103, although narrower than material 100, is wrapped tightly around the end portion of the blanket 80 and secured thereto by any convenient means such as staples 104, as shown in FIGURE 14. The portion of material 100 that extends beyond the wire 72, blanket 80 and material 103 is then pulled back over the top of material 103 and secured thereto such as by staples 105, as shown in FIGURES 15 and 15A, thus enclosing the end of the insulation blanket 80. The sleeve 86 is then pulled over the insulation blanket as heretofore described thus completing the duct in the normal manner. It is preferred that a sleeve of excess length be used so that a portion 106 of the end may be doubled back, as shown in FIGURE 16, until used for connecting to another duct.

In FIGURE 17 there is shown a manner for connecting the ends of two ducts in air-tight relation. A rigid or semi-rigid tube 107 is inserted inside one duct a distance of about half the tube's length. The tube is then secured to the duct by any convenient means such as tape 108. The extending end of the tube is then inserted into another duct and if the end of the other duct is provided with a doubled back portion 106 of sleeve 86, then portion 106 is pulled over the exterior of the first duct. The ducts are joined by securing their sleeves 86 together such as by merely wrapping tape (not shown in FIGURE 17) around the sleeves 86 at the juncture. Thus, an air-tight connection is formed and although the presence of tube 107 interferes with the flexibility and acoustical insulation characteristics of the duct at this point, this has not been found objectionable since the tube 107 is extremely short relative to the overall length of the duct.

Thus, it may be seen that we have provided a flexible duct which is relatively inexpensive, easy to install, has good air-flow characteristics, and is both thermal and acoustical insulating. The structure of our duct is such that the range of thermal insulating properties which may be obtained is not limited since it is merely necessary to provide more or fewer wraps of insulation blanket or to provide a different type of insulation blanket as requirements dictate. The interior surface of our duct is relatively smooth and consistent in cross-sectional flow area even though the duct is flexed around the corner.

Having fully described our invention, it is to be understood that we do not wish to be limited to the details

herein set forth or to the details illustrated in the drawings, whether such details be as to structure or materials, but our invention is of the full scope of the appended claims.

We claim:

1. In a duct the combination of: a continuous wire forming a helix having spaced convolutions, a tubular member of porous compressible insulating material encircling said wire helix with substantially the entire inner surface exposed as the inner surface of the duct, means for maintaining the wire convolution in spaced relation to each other, and a sleeve encircling said member, said sleeve having a normal inside diameter relative to the outside diameter of the helix and to the normal inside and outside diameters of the tubular member and said sleeve being of a firmness only sufficient to provide no more than slight radial compression of the insulation material against the convolutions of the wire helix thereby permitting the thickness of the tubular member to remain substantially constant along the length of the duct.

2. In a duct the combination of: a continuous wire forming a helix having spaced convolutions, a tubular blanket of porous compressible insulating material encircling said wire helix with substantially the entire inner surface exposed as and forming the inner surface of the duct, said blanket being secured directly to said wire helix for maintaining the spacing of the convolutions of wire, and a flexible substantially nonexpansible sleeve encircling said blanket, said sleeve being of a normal inside diameter relative to the outside diameter of the helix and to the normal inside and outside diameters of the tubular blanket and said sleeve being of a firmness only sufficient to provide no more than slight radial compression of the insulation material against the convolutions of the wire helix thereby permitting the thickness of the blanket to remain substantially constant along the length of the duct.

3. The duct of claim 2 wherein said means for maintaining the wire convolutions in spaced relation is comprised of an adhesive securing the wire helix directly to the insulating material.

4. A flexible insulated duct comprising, a continuous wire helix having spaced convolutions, a tubular member of porous compressible insulation material encircling the wire helix and forming substantially the entire interior surface of the duct, and means for maintaining the wire convolutions in spaced relation to each other while the duct is in an unflexed condition, said tubular member having a normal inside diameter substantially equal to the diameter of the wire convolutions and said tubular member being retained in encircling relation on said wire helix with interacting radial forces between said tubular member and wire helix of a magnitude only sufficient to provide no more than slight radial compression of the insulation material against the convolutions of the wire helix thereby permitting the thickness of the member to remain substantially constant along the length of the duct.

5. The duct of claim 4 wherein the wire helix per se is self sustaining only radially of each individual coil.

6. The duct of claim 4 wherein the diameter of such wire helix in the duct is less than the diameter of said helix in an unrestrained condition for the convolutions of the wire helix to tend to expand slightly in a radial direction.

7. The duct of claim 4 wherein the ratio of the diameter of the wire helix to the diameter of the wire is from about 100:1 to 300:1.

8. The duct of claim 4 wherein the said means for maintaining the wire convolutions in spaced relation is an adhesive adhering said convolutions directly to the insulation material.

9. The duct of claim 4 wherein the insulation material has a density of about 0.3 to 1.0 pound per cubic foot and is composed of glass fibers disposed angularly to each

other but oriented generally around the circumference of the duct.

10. The duct of claim 4 wherein the said wire helix per se is dimensionally unstable in the axial direction of the helix, said wire helix has a diameter in the duct less than the diameter of said wire helix in an unrestrained condition thereof for causing said convolutions of the wire helix to tend to expand slightly in a radial direction and said means for maintaining the wire helix convolutions in spaced relation includes an adhesive adhering said wire helix directly to said insulation material.

11. The duct of claim 4 wherein said means for maintaining the wire convolutions in spaced relation comprises means securing said member to said wire helix.

12. The duct of claim 4 wherein said wire helix is of a rigidity which is sufficient only for maintaining the tubular shape of said tubular member against collapse and of a sufficient longitudinal flexibility for permitting complete flexibility of the duct.

13. The duct of claim 4 wherein a flexible impervious sleeve encircles said tubular member.

14. The duct of claim 13 wherein a second sleeve of flexible material encloses the insulation material of at least one end of the duct, said second sleeve having a portion positioned between said wire helix and said insulation material and having another portion doubled back over the end of said insulation material, said last-mentioned por-

tion positioned between said insulation material and said first sleeve, said first sleeve being of a length and unattached to said second sleeve, for extending beyond its end of the duct for cooperating with and connecting to other duct means.

References Cited by the Examiner

UNITED STATES PATENTS

10	1,009,465	11/11	Bowers	138—131
	1,872,540	8/32	White	138—109 X
	2,011,781	8/35	Tabozzi	138—131
	2,050,023	8/36	Slayter	285—293
	2,226,523	12/40	Peck	138—149 X
	2,312,282	2/43	Peet	138—137
15	2,330,966	10/43	Gottwald et al.	138—149
	2,580,872	1/52	Wise	138—131 X
	2,597,806	5/52	Martin	138—122
	2,790,464	4/57	Stephens et al.	138—149 X
20	2,858,854	11/58	Daggett.	
	2,861,598	11/58	Carder et al.	138—133
	2,943,644	7/60	Moseley	138—139 X
	2,949,133	8/60	Rothermel et al.	138—133 X
	2,980,144	4/61	Edwards et al.	138—131 X

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