

- [54] **COLLAPSIBLE MANDREL**
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- [52] U.S. Cl. **242/1, 156/425, 242/72, 249/180**
- [51] Int. Cl. **B28b 7/30**
- [58] Field of Search..... **242/1, 72, 110.1, 242/110; 249/180, 178, 185; 156/173, 175, 184, 195, 425, 443, 446**

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[57] **ABSTRACT**

A collapsible mandrel is provided for use, for example, in the production of filament wound containers and has retractable side walls which are operative in such a manner as to permit the walls to be peeled-away from contact with the interior of a finished container so that the mandrel can be quickly and easily removed from the interior of the container and readily reusable for the production of another container. Retraction of the side walls is accomplished by the provision of a primary and secondary lever or linkage assembly. The secondary linkage assembly is operatively connected to the side walls of the mandrel while the primary linkage is connected to and controls the movement of the secondary linkage by means of a fluid power actuated cylinder.

[56] **References Cited**

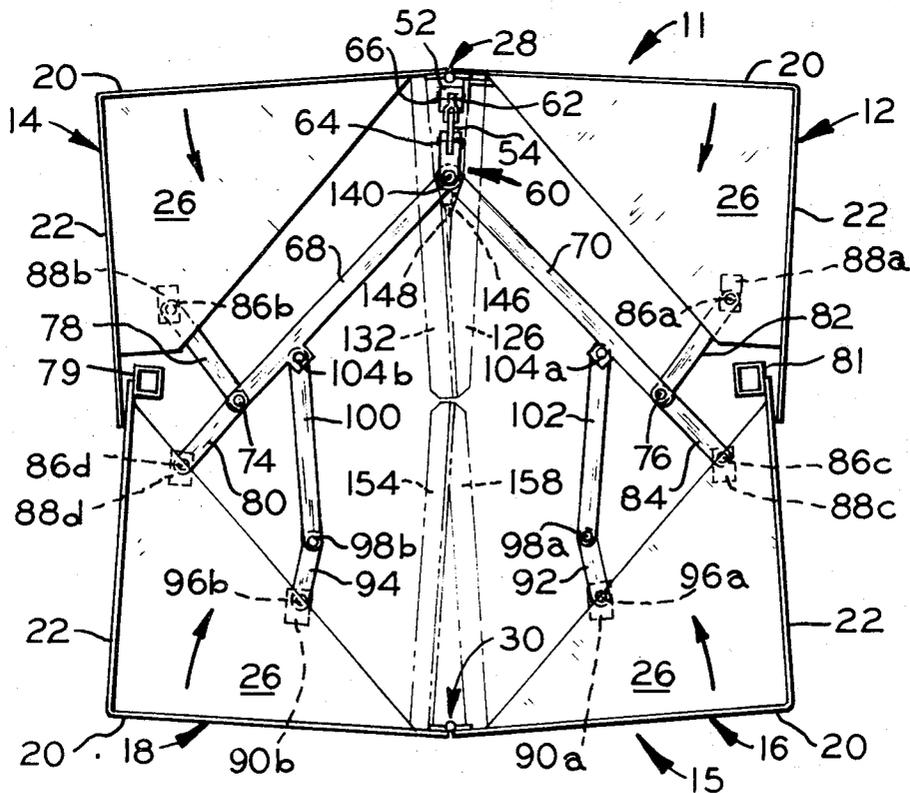
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4 Claims, 8 Drawing Figures



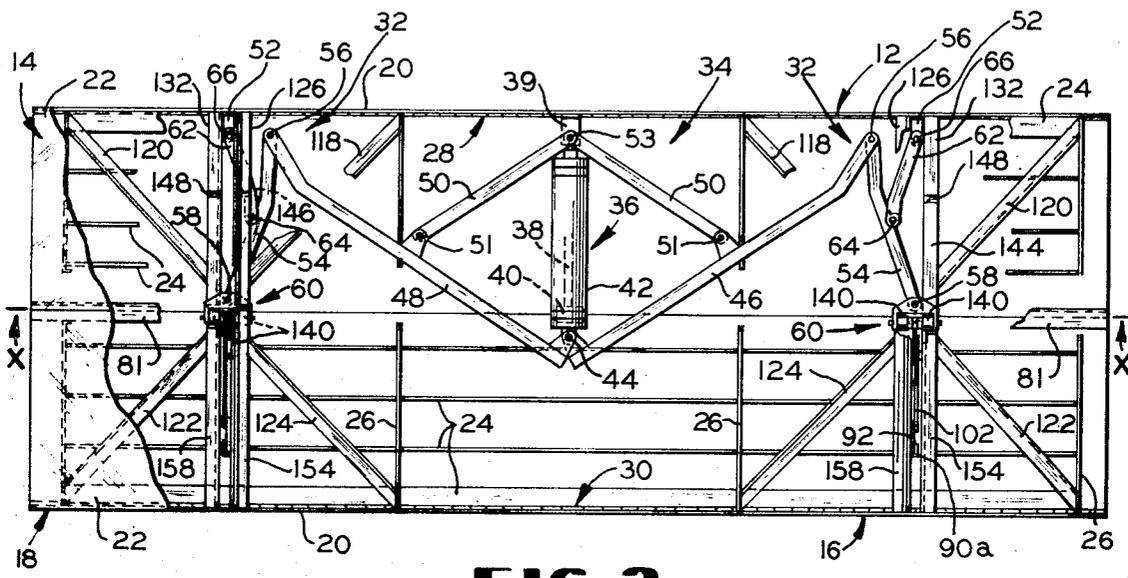
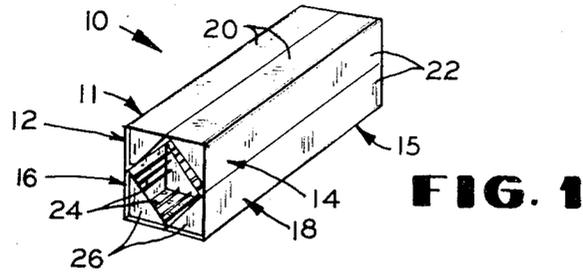


FIG. 2

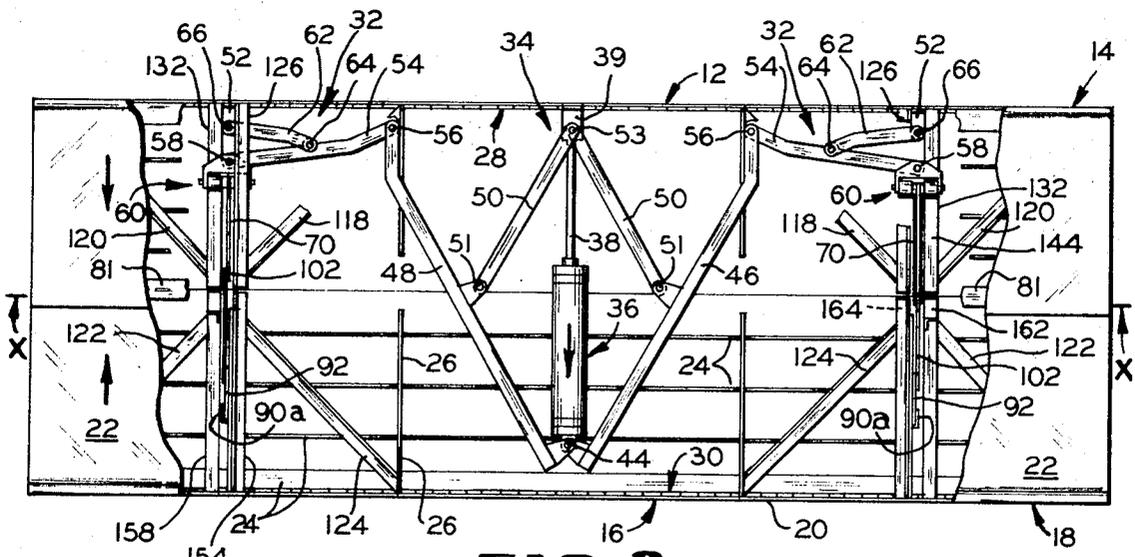


FIG. 3

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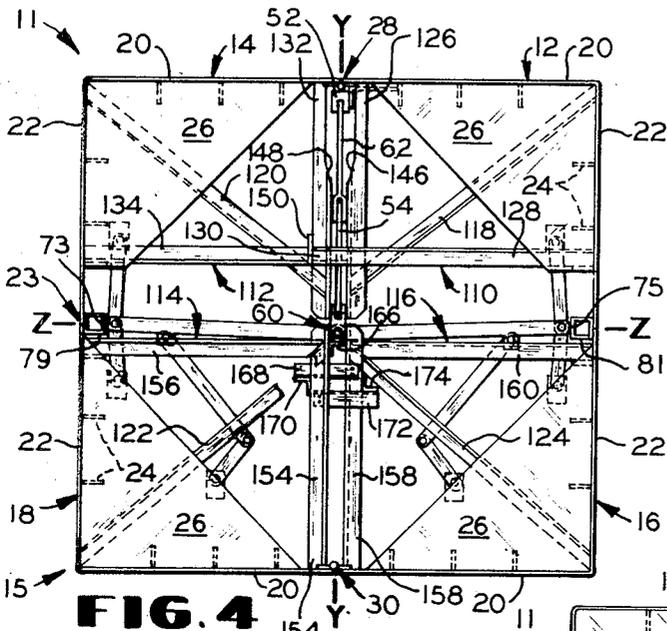


FIG. 4

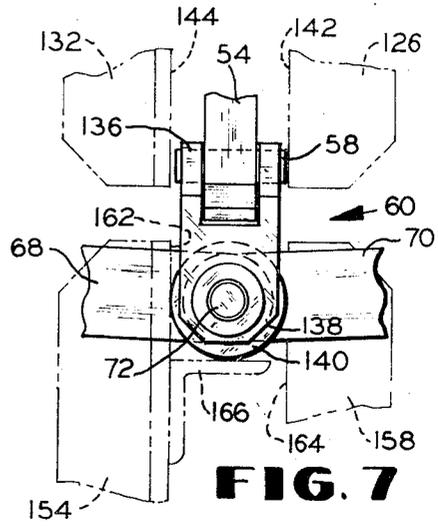


FIG. 7

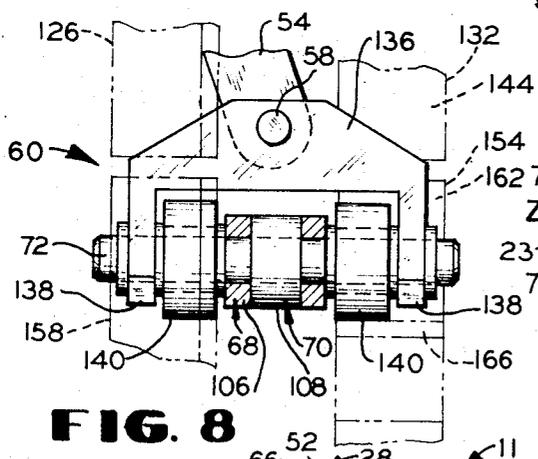


FIG. 8

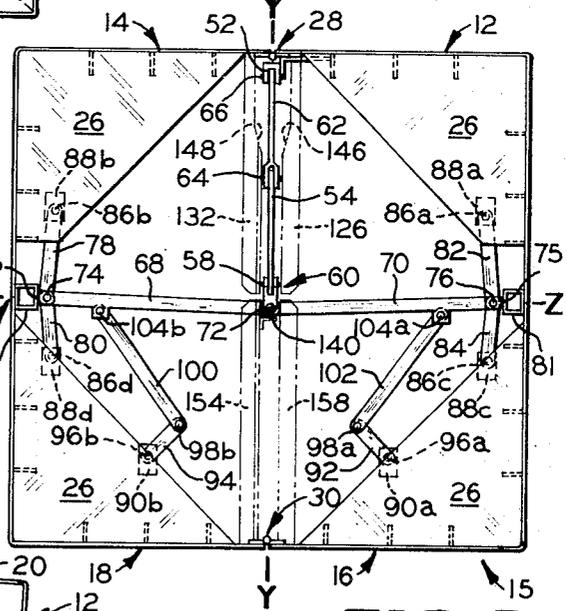


FIG. 5

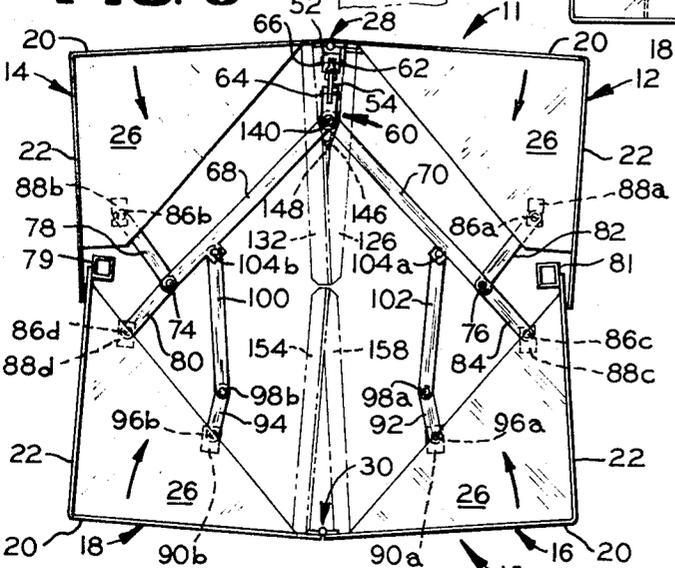


FIG. 6

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COLLAPSIBLE MANDREL

BACKGROUND OF THE INVENTION

1. Field of the Invention. This invention relates generally to mandrels and more particularly to an improved collapsible mandrel for use in the filament winding of large container-like structures.

2. Description of the Prior Art. Much activity has taken place in recent years in the area of filament winding and although there are numerous advantages in structures made by this process, a major problem that still exists and up until this time has not been satisfactorily overcome is the provision of a suitable reusable mandrel which (1) possesses sufficient flexibility to permit ready removal; (2) possesses sufficient stiffness (rigidity) to permit effective use as a forming mandrel and (3) has the ability to withstand the temperatures encountered during curing of the resin used in such processes.

The foregoing discussion of the problems indicates that an ideal situation is to have a mandrel which can be reusable, one that can be easily removed after the various winding operations have been completed and one that is made of a material which is light weight and also capable of withstanding the temperatures that are encountered during the curing stages of the filament wound structure.

Known mandrel devices have taken many forms, e.g., solid types such as shown in U.S. Pat. No. 2,614,058, inflatable types as seen in U.S. Pat. No. 3,366,522, collapsible type structures as shown in U.S. Pat. No. 3,524,780.

A mandrel related to the present invention is shown and described on pages 24 and 25 of a booklet published in 1968 by the University of Michigan Architectural Research Laboratory entitled "Research of Potential or Advanced Technology for Housing." The mandrel assembly disclosed in this publication is for use with filament wound units and comprises plate-like wall sections which are hinged at the corners and at the center of each of its four sides. A plurality of spaced jackscrews extend from a cylindrical central member and are attached to the center hinges of each side along the length of the mandrel; removal of the mandrel from the completed structure requires retracting of the side sections by the jackscrews.

This latter design, while being much more satisfactory than the previously mentioned mandrels, still possesses certain drawbacks such as having many hinges and requiring the individual operation of a plurality of jackscrews in order to collapse or retract the sides so that the mandrel can be removed from the completed structure.

SUMMARY OF THE INVENTION

The above mentioned problems and disadvantages have been solved by the present invention by providing a collapsible mandrel having side walls comprising quarter sections which are hinged at the center of the upper and lower walls and engageable at the center of the side walls. Cooperating first and second linkage assemblies are carried by one of the quarter sections and operatively connected to the remaining sections so that in the fully expanded or opened position the side walls form flush plate-like winding surfaces or sides. In the collapsed position the hinged upper and lower wall sections are pivoted with respect to each other while the

mating portions of the side walls are movable inwardly with respect to each other. The expanding and collapsing operation of the quarter sections is accomplished by means of a centrally located hydraulically operated power cylinder which is secured at one end to one of the quarter sections and at the opposite end to the first linkage assembly which in turn is connected to the second linkage assembly located at the opposite ends of the mandrel. The power cylinder is operative in its closed position through the linkage assemblies to maintain the quarter sections in a position where their winding surfaces are held flush in a position to have the filament winding applied. Actuating the power cylinder to its extended position causes the various linkage assembled to operate and draw the quarter sections toward the center of the mandrel in a fashion which causes the sections to be peeled-away from contact with the interior of the completed unit.

It is accordingly an object of this invention to provide a mandrel having upper and lower walls which are pivotally connected and side walls which are movable relative to each other.

A further object of this invention is to provide a single means for controlling the collapsing of the walls of a mandrel.

A further object is to provide a collapsible mandrel having a system of links which operate to peel the walls completely free of the finished product when being retracted to its collapsed condition.

Another object of this invention is the provision of a collapsible mandrel which is made up of a plurality of substantially identical sections. These and other objects, features and advantages of the present invention will become more fully apparent from the following description of the preferred embodiments of the invention taken together with the accompanying drawings wherein:

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings:

FIG. 1 is a perspective view of the mandrel of the present invention in its expanded condition;

FIG. 2 is a longitudinal sectional view taken substantially along the longitudinal center of the mandrel shown in FIG. 1 with certain parts shown in full and others broken away for a clearer understanding of the present invention;

FIG. 3 is a view similar to FIG. 2 but with the mandrel in its collapsed position;

FIG. 4 is an enlarged end elevational view looking from the right of the mandrel shown in FIG. 2;

FIG. 5 is an end view similar to FIG. 4 but with the support structure removed to more clearly see the linkage system;

FIG. 6 is a view similar to FIG. 5 showing the mandrel in its collapsed position;

FIG. 7 is an enlarged partial view of the center pivot assembly illustrated in FIGS. 4 through 6;

FIG. 8 is a side elevational view of the center pivot assembly shown in FIG. 7.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to the drawings, FIG. 1 shows a mandrel 10 comprising a longitudinally extending body having an upper portion, shown generally at 11 including quarter sections 12 and 14 and, a lower portion 15 including

lower quarter sections 16 and 18. A central longitudinal extending hinge 28 pivotally connects the upper quarter sections 12 and 14 while a similar central longitudinally extending hinge 30 pivotally interconnects the lower sections 16 and 18 (as seen in FIGS. 4 and 6). Each quarter section is formed with longitudinally extending flat side wall portions 20-22 which are disposed at right angles and, when the quarter sections are assembled in abutting engagement, they make up the smooth plate-like winding surfaces of the mandrel. The adjacent side wall portions 20 and 22 may be formed in one piece or of two separate pieces which have been suitably joined as by welding. A plurality of spaced longitudinally extending reinforcing ribs 24 extend along the length of the interior or each wall portion 20 and 22 of the quarter sections 12, 14, 16 and 18 and terminate short of the outer ends thereof into abutting engagement with angled plates 26; additional plates 26 are arranged along the length of the mandrel at spaced intervals to provide added rigidity to the structure. Both ribs 24 and plates 26 are secured to the side walls 20-22 in a suitable manner, such as by welding.

The parts thus far described are preferably made from aluminum in order to provide a light-weight portable structure (heat resistant) and also a sufficiently rigid structure capable of withstanding both radial and circumferential forces.

Referring in greater detail to the structure disclosed in FIG. 4., it can be seen that the quarter sections 12 and 14, making up the upper portion 11, are interconnected at the center of the top adjacent side walls 20-20 by means of the longitudinally running hinge 28 and that the quarter sections 16 and 18 making up the lower portion 15 are interconnected at the center of the adjacent side walls 20-20 by the longitudinally running hinge 30 while the side wall portions 22 of each quarter section are adapted to be in abutting relation, at such time as the mandrel 10 is expanded, as shown by the reference numeral 23 to form a continuous flat surface.

As best seen in FIG. 2, a compound linkage assembly, shown generally at 32, is provided adjacent the opposite ends of the mandrel 10 to interconnect the upper and lower portions 11 and 15 in such a manner as to permit the upper and lower quarter sections to be pivoted about the hinges 28 and 30 so that the top walls 20 will be pulled or collapsed slightly inwardly at the hinge connection, as seen in FIG. 6, while the ends of the adjacent side walls 22-22 will break-away from contact with each other by moving relative to each other in both a horizontal and a vertical direction. This break-away feature is an important part of the present invention and will be discussed in greater detail later in the specification.

This collapsing movement of the quarter sections 12, 14, 16 and 18 by the opposed compound linkage assembly 32 is made possible by a manipulation of a main lever or linkage assembly shown generally at 34 which is controlled by means of a vertically extending power cylinder 36 pivotally supported at its upper end by a bracket 39 fixed to the interior of the wall 20 of the quarter section 12. The power cylinder 36 is moved downwardly to its extended position, shown in FIG. 3 in a well-known manner such as by a suitable pressure fluid. The lower end of the cylinder 36 is operatively connected to the actuating linkage 34 in a manner to be discussed later.

As best seen in FIG. 2 the compound lever assembly 32 and cooperating actuating lever assembly 34 comprise a system of levers or links which are constructed and arranged in such a manner as to permit the precise geometry of the levers or links and the relation between them to operate to transmit movement from the power cylinder 36 to the actuating lever assembly 34 and therefrom to the compound lever assembly 32 which in turn controls the movement of the upper and lower portions 11 and 15. Two positions are made possible by this construction, in one position the portions 11 and 15 comprising the quarter sections 12, 14, 16 and 18, are rigidly held in their expanded position illustrated in FIGS. 2 and 5 wherein the mandrel 10 is in a position to have a forming process take place thereon, for example, a filament winding process, or in the second position wherein it can be retracted or collapsed to the position seen in FIGS. 3 and 6 with the mandrel 10 assuming a condition making it readily removable from the structure formed thereon.

More particularly, the actuating lever assembly 34 is located longitudinally intermediate the spaced actuating lever assemblies 32. The power cylinder 36 has a piston rod 38 which has its remote end pivotally connected to the bracket 39 and a piston 40 at its opposite end operatively disposed within a cylindrical housing 42. The lower-most portion of the cylindrical housing 42 has a clevis 44 for pivotally receiving the inner ends of a pair of outwardly extending links or levers 46 and 48 which are a part of the actuating lever assembly 34 and are adapted to be connected to and thereby control and translate movement to the compound lever assemblies 32 located at opposite ends of the mandrel 10. The various operating parts of the compound lever assemblies 32 are identical and accordingly the following description and discussion will be made with reference to only one of the assemblies.

In order to translate the movement of the links 46 and 48 to the compound lever assembly 32, a secondary guiding lever or link 50 is pivotally connected at its outer end at 51 to the levers 46 and 48 at a point substantially intermediate the ends thereof. The opposite or inner end of the secondary link 50 is pivotally connected at 53 to the bracket 39 which serves as one of a pair of relatively stationary fixed reaction points in the linkage or lever system.

A second relatively stationary or fixed point in the linkage or lever system is provided by a bracket 52 (for each of the lever assemblies 32) which is axially aligned with but spaced longitudinally outwardly from the bracket 39. The brackets 39 and 52 are secured to the upper or interior portion of the wall 20 of the quarter section 12 and as a result this one quarter section can be considered a reaction member for the entire lever system. Although both the actuating linkage assembly 34 and the compound lever assembly 32 are supported at fixed points on the same quarter section the operation of the various levers in the system is such that, when the quarter sections are moved to their collapsed position, this movement will draw the hinges 28 and 30 inwardly a slight distance which will be sufficient to separate the mandrel from the structure formed thereon.

The compound lever or linkage assembly 32 comprises a system of primary and secondary levers which are pivotally connected at various points on the quarter sections to permit the expanding and collapsing opera-

tions to take place in response to movement of the actuating lever assembly 34 by the power cylinder 36. More particularly, the lever assembly 32 includes a first or main upwardly extending link 54 which is pivotally connected at its upper end at 56 to the outer end of lever 46 and pivotally connected at its opposite or lower end at 58 to a center pivot assembly 60 positioned at a point midway between the top and bottom of the expanded mandrel. A second link 62 is provided to connect the first link 54 to the stationary bracket 52. This is accomplished by having the inner end of link 62 pivoted at 64 to the first lever 54 at a point substantially intermediate the ends thereof, while the outer end of link 62 is pivotally connected at 66 to the bracket 52 thereby supporting the main lever 54 on the quarter section 12 and setting up the reaction point for the linkage assembly 32 (primary lever system). These links 54 and 62 and center pivot assembly 60 can be considered a primary lever portion of the assembly 32. Cooperating with these links 54 and 62 and center pivot assembly 60 is what is referred to as a secondary lever portion of the assembly 32.

As best seen in FIG. 5, this portion of the linkage assembly 32 is connected to the center pivot assembly 60 which, when the mandrel 10 is expanded, is located substantially at the center of the quarter sections 12, 14, 16 and 18 and is operatively connected to the quarter sections 12, 14, 16 and 18 through a plurality of links and levers making up the secondary lever system of the actuating lever assembly 32.

The various links and levers in the secondary system are pivotally connected to the quarter sections 12, 14, 16 and 18 in such a manner as to be capable of drawing the sections inwardly to the position shown in FIG. 6, so that the side wall portions 20 and 22 of each section will move gradually angularly inwardly with respect to the longitudinal axis $x-x$ of the mandrel. This movement forms an important part of the present invention since it is most desirably in the filament winding of structures of this type to have the mandrel removed from the completed filament wound structure in a manner which will not cause damage to the interior surface thereof. Thus in the present invention, the side walls 20 and 22, which form the winding surfaces, are capable of being peeled-away gradually from contact with the interior of the structure making it a very desirable arrangement.

The secondary lever portion of the actuating lever assembly 32 comprises a pair of opposed radially outwardly extending control arms or levers 68 and 70 having their inner ends pivotally secured at 72 to the center pivot assembly 60 (clearly seen in FIGS. 7 and 8). The outermost ends of the control arms 68 and 70 are pivotally connected at 74 and 76, respectively, to the inner ends of a pair of opposed upwardly and downwardly extending connecting links 78 and 80 for control arm 68 and 82 and 84 for control arm 70. The outermost ends of arms 68 and 70 are provided with arcuate cam surfaces 73 and 75 respectively, which are adapted, when the mandrel is in its fully expanded position, to bear against the adjacent faces of a pair of longitudinally extending guide members 79 and 81 secured to the quarter sections 16 and 18 at their free ends. The guide members further serve as a means to accomplish the flush engagement between the mating side walls 22-22 when the mandrel 10 is in its expanded condition. The outer portions of each link 82,

78, 84 and 80, respectively, are pivotally connected at 86a, 86b, 86c and 86d to a plurality of suitable supports 88a, 88b, 88c and 88d fixed at spaced locations on one of the plates 26 associated with each of the quarter sections 12, 14, 16 and 18 at points above and below a transverse axis $z-z$ adjacent the inner faces of side walls 22. Also spaced further below the transverse axis $z-z$ and inwardly toward the vertical axis $y-y$ are similar rigid supports 90a and 90b secured to the same plates 26 as the supports 88c and 88d respectively. Supports 90a and 90b are connected to arms 70 and 68 through a short link 92 and 94 and an angularly extending link 102 and 100, respectively. The links 92 and 94 are pivotally connected at 96a and 96b to the supports 90a and 90b at one end and the other end pivotally connected at 98a and 98b to the angularly extending arms 102 and 100 which in turn have a pivotal connection at 104a and 104b with the lower portion of arms 70 and 68 adjacent the outer ends thereof.

For a clearer understanding of the parts associated with the center pivot assembly 60, reference can be made to FIG. 8 where it can be seen that the inner end of the arm 68 is rotatably journaled on pivot pin 72 by means of a female portion 106 and the inner end of arm 70 is rotatably journaled on pivot pin 72 by a male portion 108.

Rigid supports are provided at opposite ends of the mandrel 10 for cooperating with the opposed center pivot assemblies 60 to function as a guide means therefor. As best seen in FIGS. 7 and 8 the center pivot assembly 60 has a supporting bracket 136 including a pair of spaced downwardly extending ears 138, 138 which are adapted to pivotally support the pivot pin 72 while the supporting bracket 136 carries pivot 58 for pivotally connecting thereto the inner end of link 54. As mentioned earlier the female and male portions 106 and 108 of horizontal arms 68 and 70 are also pivotally connected to the pivot pin 72 intermediate the ears 138. A space is provided between the portions 106 and 108 of the arms 68 and 70 and the ears 138, 138 for rotatably mounting therein, on the pin 72, a pair of spaced rollers 140. The function of the rollers 140 in the operation of the mandrel will be discussed in greater detail later in the specification. For a clearer understanding of the support structure and associated linkage reference will be made throughout the following description to the longitudinally extending central axis $x-x$ as shown in the side elevational view of the mandrel in FIG. 2 and a vertical axis $y-y$ and a transverse axis $z-z$ shown in the end view of the mandrel illustrated in FIGS. 4 and 5.

Referring first to the end view of the mandrel 10 of FIG. 4, it will be seen that each quarter section 12, 14, 16 and 18 includes a substantially right angle connecting or support structure shown generally at 110, 112, 114 and 116 and a diagonal brace 118, 120, 124 and 122, respectively.

The right angle support structure 110 associated with the quarter section 12 includes a vertically extending angle member 126 and a transversely extending angle member 128 located a distance to the right of the vertical axis $y-y$ equal to one-half the diameter of the rollers 140 and terminating a substantial distance above the transverse axis $z-z$. The member 126, at its upper end, is secured, as by welding, to the interior of the top wall portion 20 and adjacent its inner end is secured, as by welding, to the transverse angle member 128; the

inner end extending beyond this connection to a position just above the axis $z-z$. The transverse member 128 has its right or outer end secured to the interior of the side wall portion 22 adjacent one side of one of the longitudinally extending ribs 24 while an extension 130 is secured on the inner end thereof and projects beyond its connection with the vertical member 126; the extension 130 terminating at a point to the left of the vertical axis $y-y$. The purpose of this extension 130 will be discussed hereinafter.

The right angle support 112 associated with the quarter section 14 includes a vertically extending angle member 132 and a transversely extending member 134. The vertical member 132 is similar in structure to the adjacent member 126 but reversed and spaced a distance to the right or in front of the vertical member 126 when viewed in FIG. 2. The vertical member 132 is located to the left of the vertical axis $y-y$ a distance equal to one-half the diameter of the rollers 140 so as to have the opposed flat facing surfaces 142 and 144 of the vertical members 126 and 132 aligned with and adapted to be in rolling engagement with the spaced rollers 140 of the center pivot assembly 60 as seen in FIG. 7, when the rollers move upwardly. The vertical member 132, at its upper end, is secured, as by welding, to the interior of the top wall portion 20 and adjacent its lower end is secured, as by welding, to the transverse member 134. The lower end of the member 132 extends beyond the member 134 and terminates just above the axis $z-z$. The transverse member 134 is located above the axis $z-z$ and is secured at its inner or right end to the vertical member 132 while the outer end thereof is secured to the interior of the side wall 22 of quarter section 14. Thus, as seen in the end view in FIG. 5, the spacing of the vertical members 126 and 132 is such that the rollers 140 will ride upwardly along the faces 142 and 144 as the linkage is being moved to a collapsed position causing the center pivot assembly 60 to be raised upwardly. The spacing allows one of the rollers 140 to ride up the surface or face 142 of the vertical member 126 while the opposite spaced roller 140 rides up the surface or face 144 of the vertical member 132. It will be evident that during such movement the quarter sections 12 and 14 are restrained by the rollers from pivoting inwardly about their hinged connection 28 since the surfaces 142 and 144 are parallel. In order to permit the required relative pivotal movement to take place between the quarter sections 12 and 14 further means is provided on the surfaces or faces 142 and 144 of the vertical members 126 and 132 which will enable the rollers 140 to allow inward angular movement to occur between the pivotally connected quarter sections 12 and 14. This means takes the form of an outwardly sloping, inclined cam surface 146 on the vertical member 126 and an opposed outwardly sloping inclined surface 148 on the vertical member 132. As the rollers continue to move upwardly along the surfaces 142 and 144, they will come in contact with and ride along the cam surfaces 146 and 148 permitting the quarter sections 12 and 14 to pivot about the hinge 28 moving the lower ends of the sections 12 and 14 downwardly toward the axis $z-z$ and toward each other. Downward movement begins at the hinge 28 which is only drawn in a short distance along the axis $y-y$ while the upper sides 20-20 thereof move away from their original position a distance which increases as the distance from the hinge increases. This movement, when

occurring with the completed container surrounding the mandrel, results in what can be considered as a gradual peeling away of the outer surfaces 20 of the quarter sections 12 and 14 as the sections pivot about hinge 28 and the side wall portions 22 are drawn inwardly at their free ends 23 by the links 78 and 82.

Referring now to the extension 130 provided on the transverse member 128, it is seen in FIG. 4, that the extension 130 terminates at the left of or transversely outwardly of the vertical member 132. An angle or guide member 150 is secured to the outermost part of the transverse member 128 and engages the outer side of the vertically extending member 132 to limit outward movement of the vertical members 126 and 132 beyond that shown in FIG. 4 when the container 10 is fully expanded.

The rigid supports for the quarter sections 16 and 18 comprise the right angle structures 116 and 114 and associate braces 124 and 122 respectively. The right angle structure 114 includes a vertically extending angle member 154 and a mating transversely extending member 156, while the right angle structure 116 includes a vertically extending member 158 and a mating transversely extending member 160 with the mating members secured together, as by welding, adjacent the inner end or apex to form a right angle. The outer ends of the transverse members 156 and 160 are secured, as by welding, to the interior of the side walls 22 and the outer ends of the vertical members 154 and 158 are secured, as by welding, to the interior of the bottom walls 20 of the quarter sections 18 and 16 respectively. The vertical members 154 and 158 are in alignment with the vertical member 132 in the quarter section 14 and the vertical member 126 in the quarter section 12 respectively. Thus, as seen in FIG. 7, the spacing provides opposed faces 162 and 164 on the vertical members 154 and 158 which are engageable by the spaced rollers 140 of the center pivot assembly 60.

As shown in FIG. 4, the inner ends of the members 154 and 158 stop short of engagement with the opposed members 132 and 126 and the rollers 140 are positioned in contact with the faces 162 and 164 of the lower members 154 and 158 when the mandrel 10 is expanded. A stop means, in the form of an angle 166 is secured to the face 162 of the vertical member 154 and serves as a lower locating means for the rollers 140 of the pivot assembly 60 when the mandrel 10 is in its fully expanded position.

Referring to FIGS. 2 and 4, the diagonal members 118, 120, 122 and 124 act as additional braces for the right angle structures 110, 112, 114 and 116 respectively. The members 118 and 122 are secured adjacent the inner end of the vertical members 126 and 154, respectively, and extend to the inside of and toward the corner of the quarter sections 12 and 18 and being secured at the interior thereof at this location. The members 120 and 124 have their inner ends secured to the right angle portions 112 and 116 adjacent the apex thereof and extends angularly to the front and to the corners of the quarter sections 14 and 16 and secured thereto at this location.

Means are also provided for preventing excessive relative movement between the quarter sections 16 and 18. To this end, as seen in FIG. 4, a transversely extending bracket 168 is secured to the vertical member 158 at a point a short distance below the stop means 166 and projects to the left of the vertical member 154 and

terminates in a right angle arm 170 adapted to engage the outer side of the member 154 to act as a stop against outward relative movement of members 154 and 158 beyond that shown in FIG. 4 when the mandrel 10 is expanded. Similarly, the vertical member 154 is also provided with a transversely extending bracket 172 spaced below the bracket 168 and bracket 172 extends to the right and terminates in a right angle arm 174 adapted to engage the outer side of the vertical member 158.

OPERATION

Assuming the mandrel 10 is in its fully expanded position as seen in FIGS. 1, 2, 4 and 5 and it is desired to collapse the same to the position shown in FIGS. 3 and 6, the power cylinder 36 is actuated in a well-known manner to cause the cylindrical housing 42 to be moved downwardly to its fully expanded position, as seen in FIG. 3. As a result of this movement the pivot 44, which is fixed to the lower end of the cylindrical housing 42, drives the inner ends of the levers 46 and 48 down toward the bottom of the mandrel resulting in a somewhat scissoring effect to take place between the arms 46 and 48 and associate secondary links 50 connected at 51 thereto and at 53 to stationary bracket 39. The scissoring or inward movement of levers 46 and 48 results in the center pivot assemblies 60 moving upward toward the fixed brackets 52. As the center pivot assembly 60 moves up, the inner ends of the arms 68 and 70 move upwardly as seen in FIG. 6. In moving to this latter position, the pivots 74 and 76 at the outer ends of the arms 68 and 70 and the adjacent pivots 104b and 104a there-on move inwardly and thereby tend to straighten angular arms 100 and 102 in an upward direction and at the same time inwardly collapse the upper and lower connecting arms 78-82 and 80-84 by the pivotal connection 74 and 76. As the arms 100 and 102 are moved upwardly, the movement is such that pivots 98b and 98c at the lower ends thereof, is sufficient to draw links 94 and 92 slightly inward and by so doing results in pivots 96b and 96a at the opposite end of links 94 and 92, moving the center of the hinge 30 a slight distance inwardly toward the center of the mandrel 10. Since the rollers 140 prevent relative angular movement of the sections 12 and 14 until the rollers reach the cam surfaces 146 and 148, the sections 16 and 18 will move angularly inwardly, as seen in FIG. 6, before the sections 12 and 14. Additionally, links 80 and 84 are shorter than links 78 and 82 and move the lower sections 16 and 18 farther inwardly than sections 12 and 14.

Each hinge 28 and 30 moves radially inwardly a distance sufficient to break the seal from the completed filament wound structure and allow removal of the mandrel in longitudinal direction. Also, it can be clearly seen in FIG. 6 that the previously mated ends 23 of the sides 22 have moved inwardly relative to each other and the walls 20 and 22 have moved angularly inwardly a sufficient distance to enable the mandrel to be easily present invention greatly the completed structure. the

Due to the fact that filament winding processes impose rather large forces on the mandrel it is necessary that the mandrel be constructed in such a manner as to be capable of withstanding both radial and circumferential loads. The present invention greatly lends itself

to such a structure not only by the reinforcing means provided but also through the location and arrangement of the various links used in the system. Thus the present invention provides a structure having the necessary resistance for withstanding the excessive winding forces present in such devices.

The present mandrel design has many applications, for example: it can be used for constructing reusable shipping containers, van bodies and the like; and also has potential applications for use in construction of room-size modules for housing use such as a module for high rise structures, school buildings and hospitals. Another possibility is the combining of two or more such mandrels to produce larger structures.

From the foregoing, it can be seen that the present invention provides an improved durable and reliable collapsible mandrel which has sufficient flexibility to permit easy removal, possesses sufficient stiffness and has the ability to withstand very high temperatures.

The present invention is not limited to use in constructing a structure of rectangular configuration but with alterations to the quarter sections is capable of handling a variety of forms such as circular cylinders. Thus, it should be understood that the particular mandrel is shown by way of illustration only and not as a limitation of the invention. The principals and features of this invention may be employed in varied and numerous embodiments without departing from the scope of the invention.

Having thus described my invention, what is claimed is:

1. A hollow collapsible mandrel comprising a pair of opposed concave longitudinally extending major sections, each of said major sections having transversely spaced and longitudinally extending free edges, with the free edges of one major section being movable independently of the free edges of the other major section and with the free edges of one major section being disposed cooperatively with the free edges of the other major section at such times as the mandrel is expanded, each of said major sections comprising a pair of longitudinally extending minor sections, longitudinally extending hinge means pivotally connecting said minor sections, and linkage means connected to said minor sections for pivoting the minor sections of each major section inwardly toward each other and for moving said hinge means toward each other and collapsing said mandrel and for pivoting said minor sections away from each other and for moving said hinge means away from each other for expanding said mandrel to its expanded condition, said linkage means pivoting the minor sections of one of said major sections toward each other a greater amount when collapsing said mandrel than said linkage means pivots the minor sections of the other of said major

2. A mandrel according to claim 1 wherein said major sections are half sections.

3. A mandrel according to claim 2 wherein said minor sections are quarter sections.

4. A mandrel according to claim 3 wherein said mandrel is rectangular when viewed in transverse cross-section, and said quarter sections each have a right angled configuration.

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