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[54] **PIPE EXTRUSION APPARATUS INCLUDING WINDING A HOLLOW PROFILE**

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[52] **U.S. Cl.** **156/425; 156/500**

[58] **Field of Search** 156/195, 244.13, 156/425, 429, 500; 138/154, 150, 129, 144

[56] References Cited

U.S. PATENT DOCUMENTS

2,576,835	11/1951	Hewitt, Jr. .	
2,640,501	6/1953	Scott et al. .	
2,671,939	3/1954	Everhart et al. .	
2,874,722	2/1959	Hamblin .	
3,811,478	5/1974	Ahlqvist .	
3,839,126	10/1974	Haller .	
3,917,500	11/1975	Petzetakis et al.	156/244.13 X
3,926,223	12/1975	Petzetakis .	
4,642,158	2/1987	Steinel et al. .	
4,824,502	4/1989	Nagayoshi et al.	156/195
4,983,347	1/1991	Rahn .	
5,127,442	7/1992	Blomqvist	138/154
5,261,988	11/1993	Dikis et al.	156/195 X
5,271,794	12/1993	Jarrell et al. .	
5,591,292	1/1997	Blomqvist .	

FOREIGN PATENT DOCUMENTS

0060482 9/1982 European Pat. Off. .

0223768	5/1987	European Pat. Off. .	
265915	5/1988	European Pat. Off.	156/425
0418760	3/1991	European Pat. Off. .	
463611	5/1996	European Pat. Off.	156/425
82635	12/1990	Finland .	
1093546	11/1960	Germany .	
1943549	3/1971	Germany .	
3830627	9/1989	Germany .	
206175	7/1966	Sweden .	

OTHER PUBLICATIONS

Cincinnati Milicron sales brochure entitled TTL Series CNC Tape-Laying Machine Brings Automation To Thermoplastic Tape Laying, 1989, pp. 1 and 2.

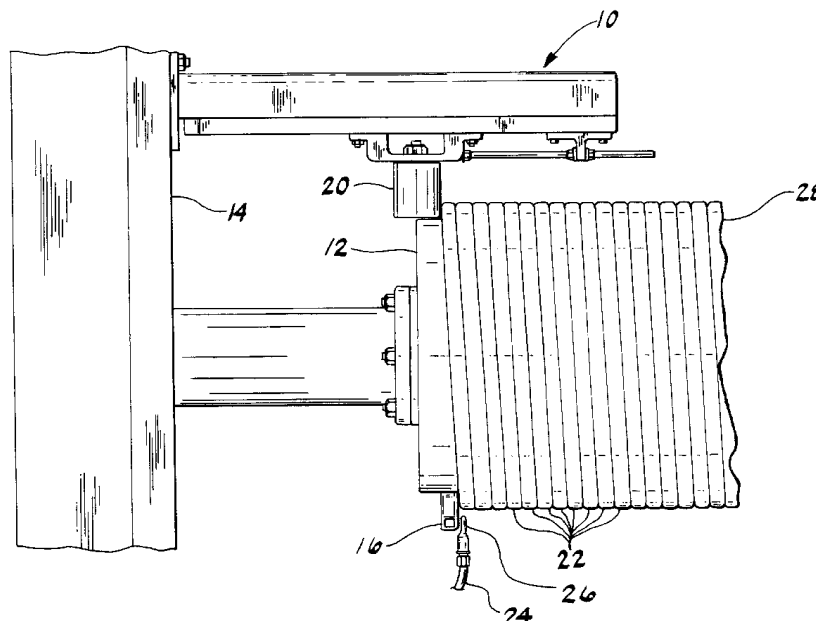
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[57] ABSTRACT

A process of making a continuous thermoplastic helical seam profile pipe. The thermoplastic material is extruded through a die to form a continuous square tube. The continuous tube is cooled and a filler material is applied. The continuous tube bearing the applied filler material is helically wound to form turns of wound continuous tube. Each turn of the continuous tube is pressed into the preceding turn on the mandrel for adhering the turns together to form the pipe. Apparatus for producing a helical seam profile pipe includes a frame, and a mandrel mounted on the frame for rotation on the frame about a longitudinal axis of the mandrel to helically wind the thermoplastic tube around the mandrel. A source of filler material, and a filler material applicator located adjacent to the mandrel continuously apply a bead of the filler material to the thermoplastic tube prior to being wound on the mandrel.

13 Claims, 9 Drawing Sheets



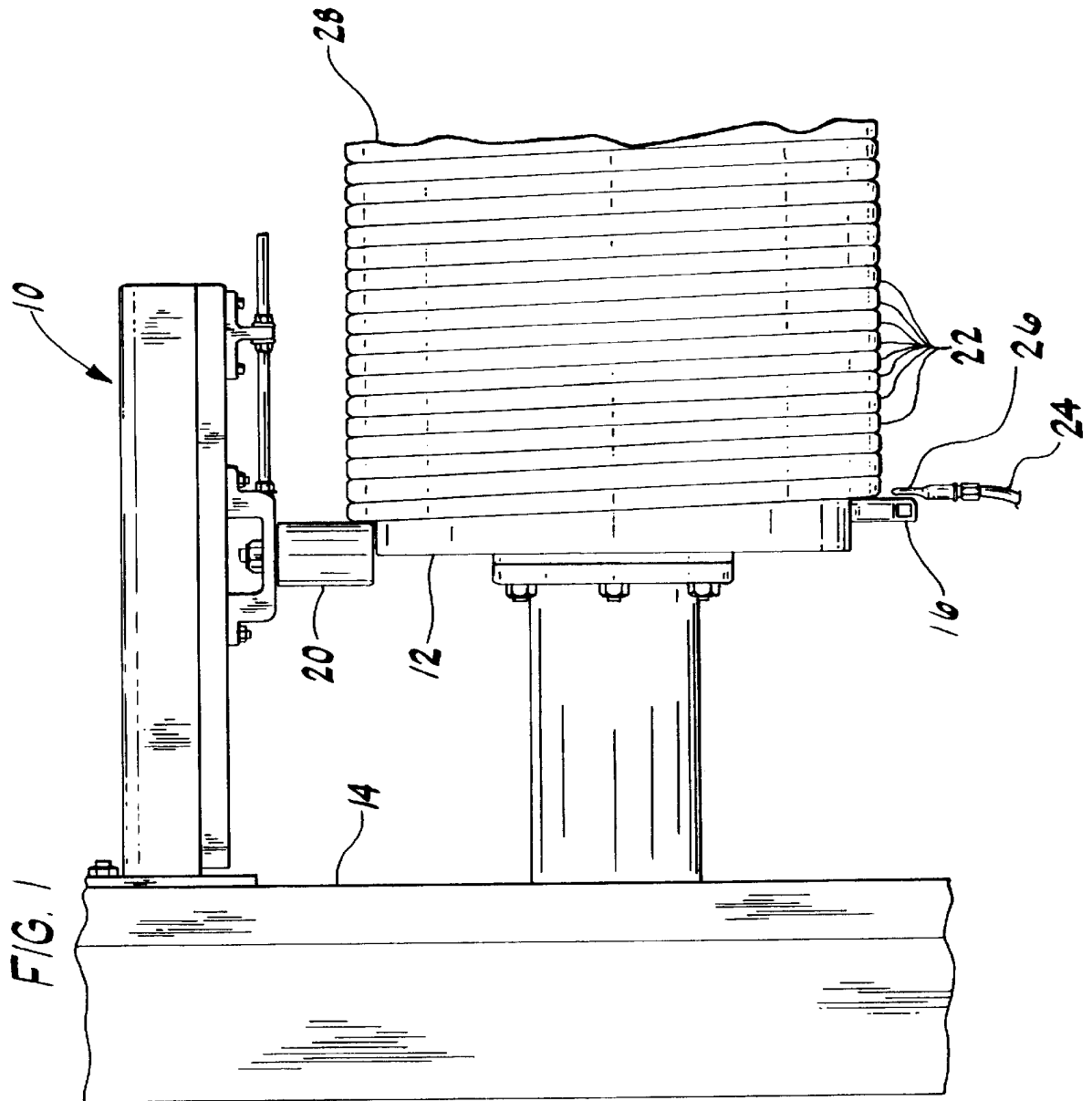


FIG. 2

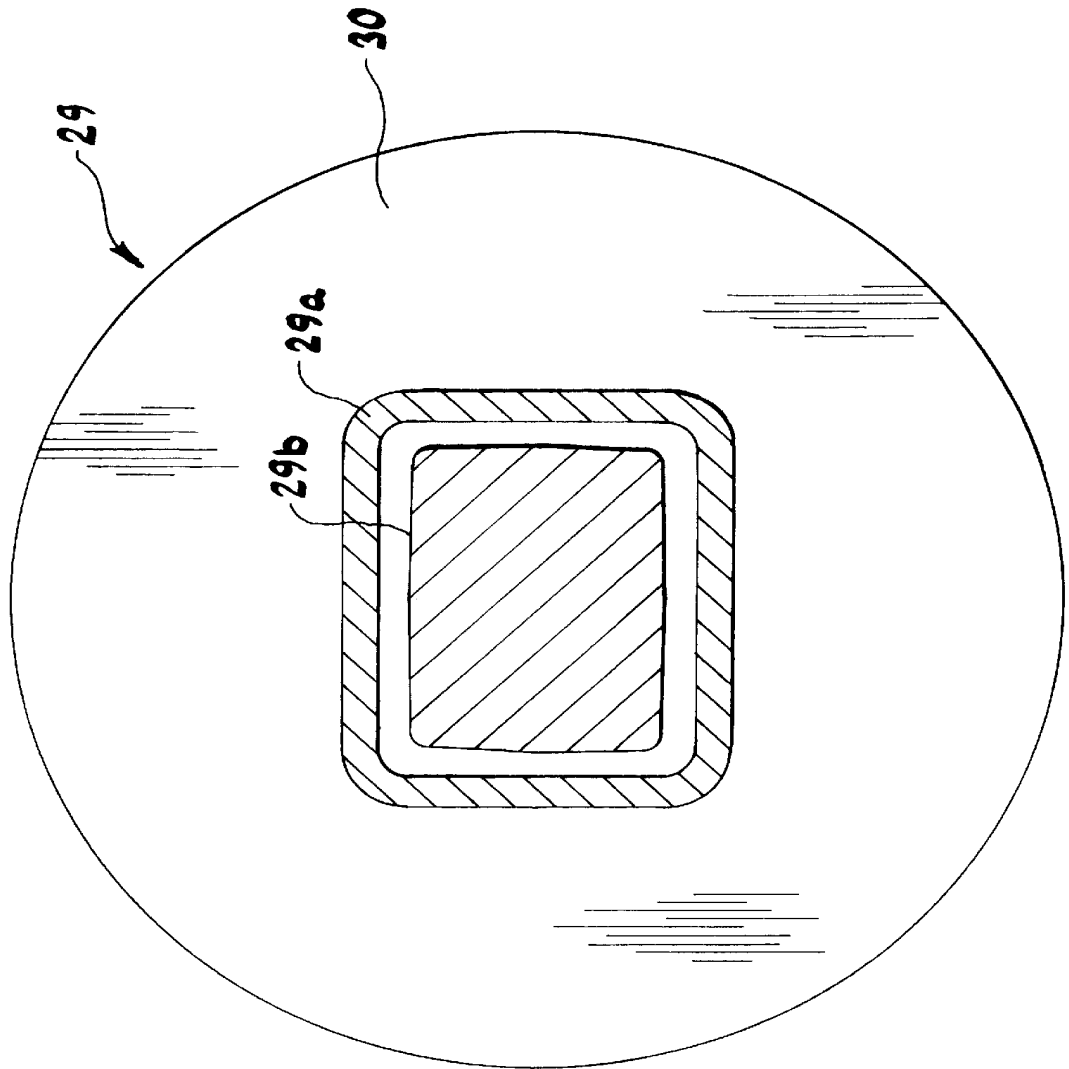


FIG. 3

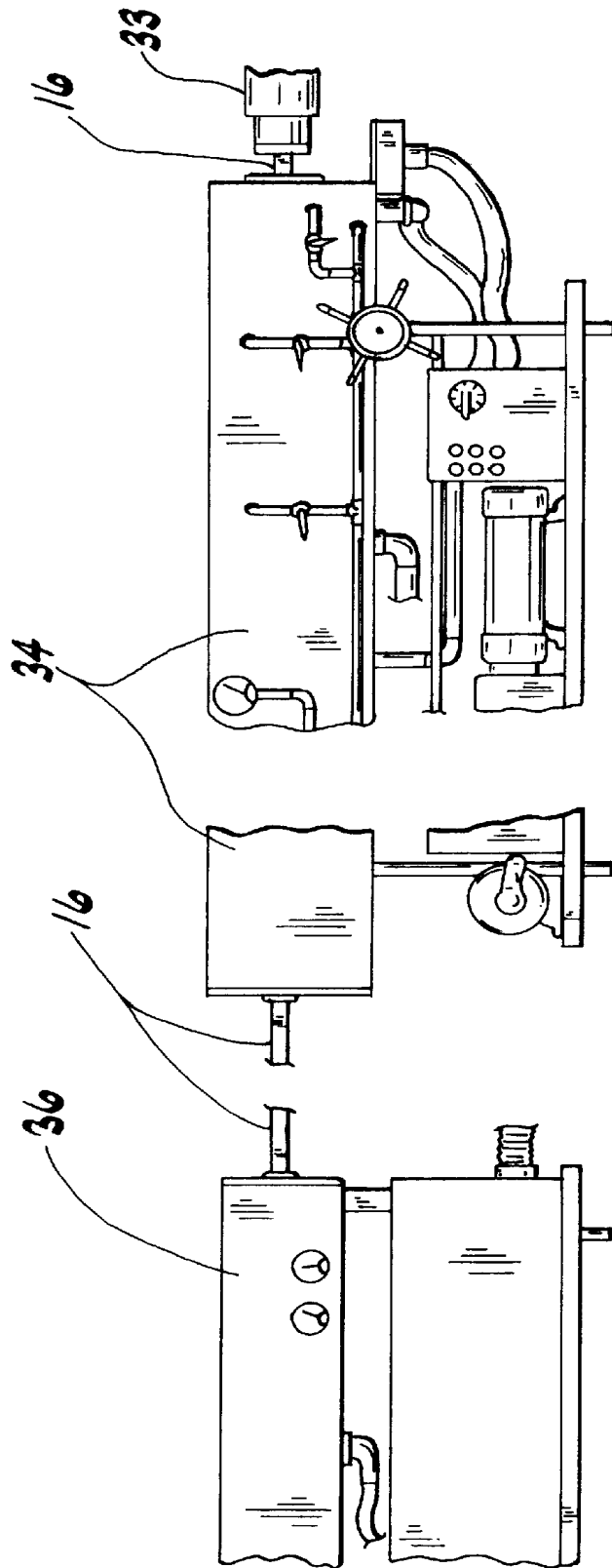
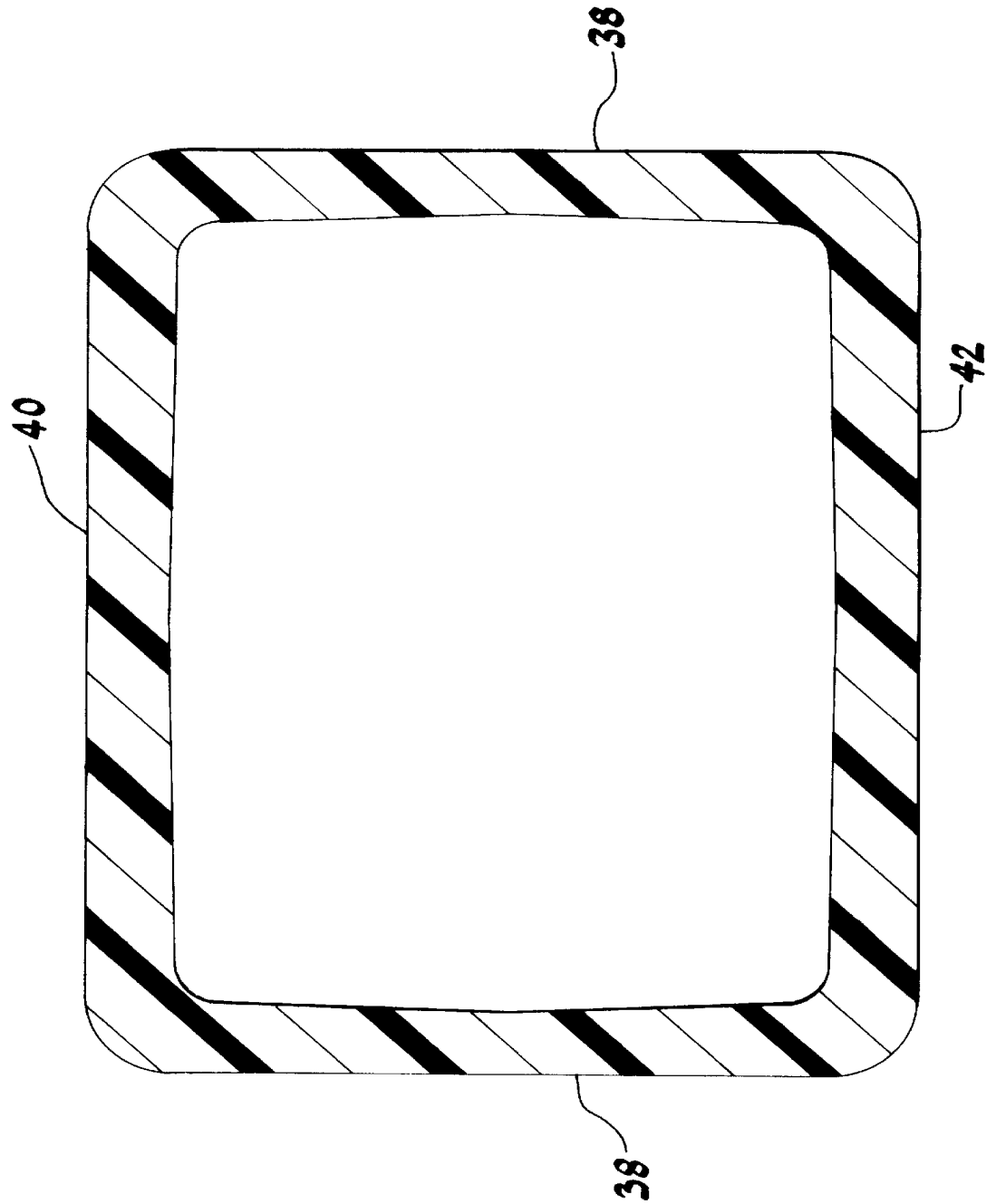
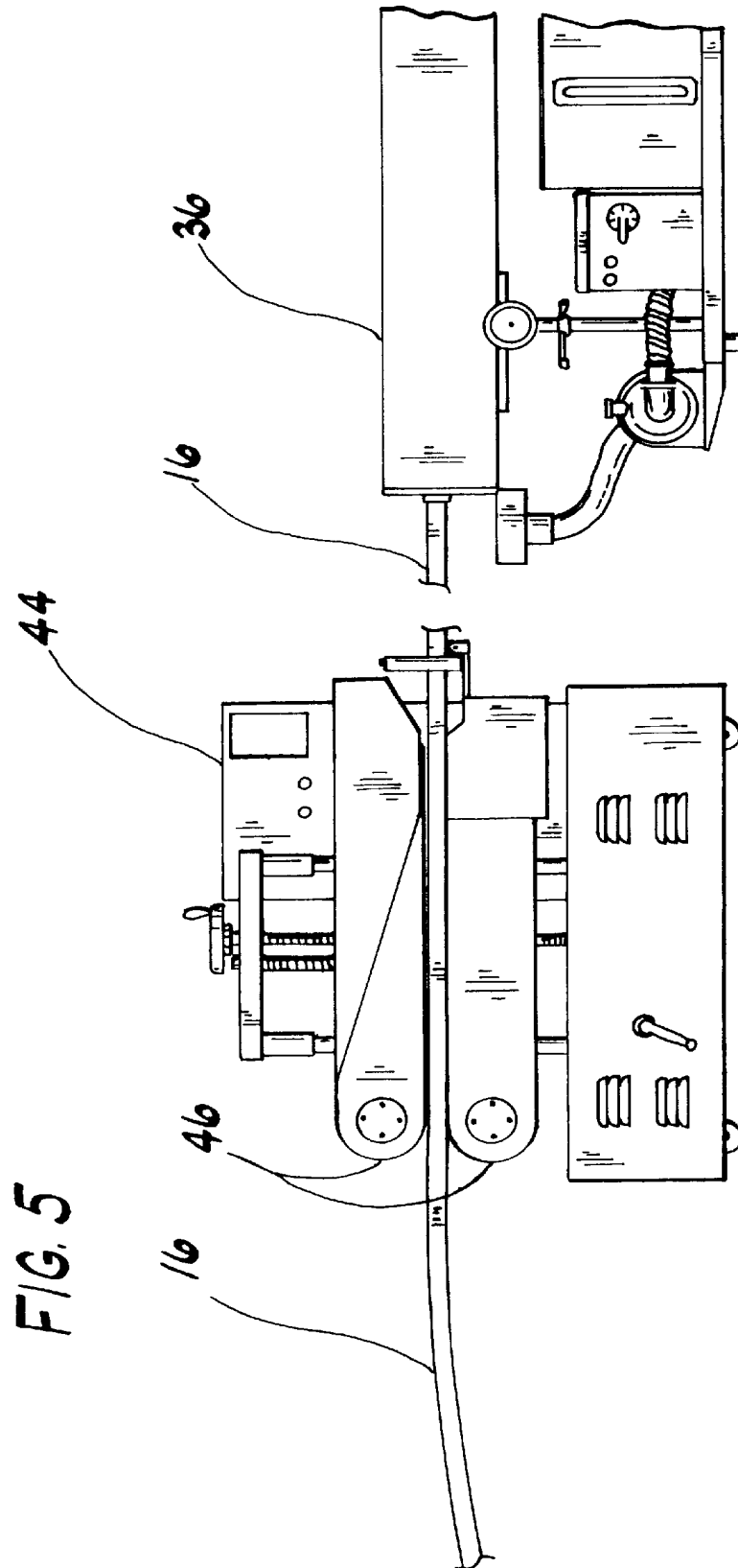
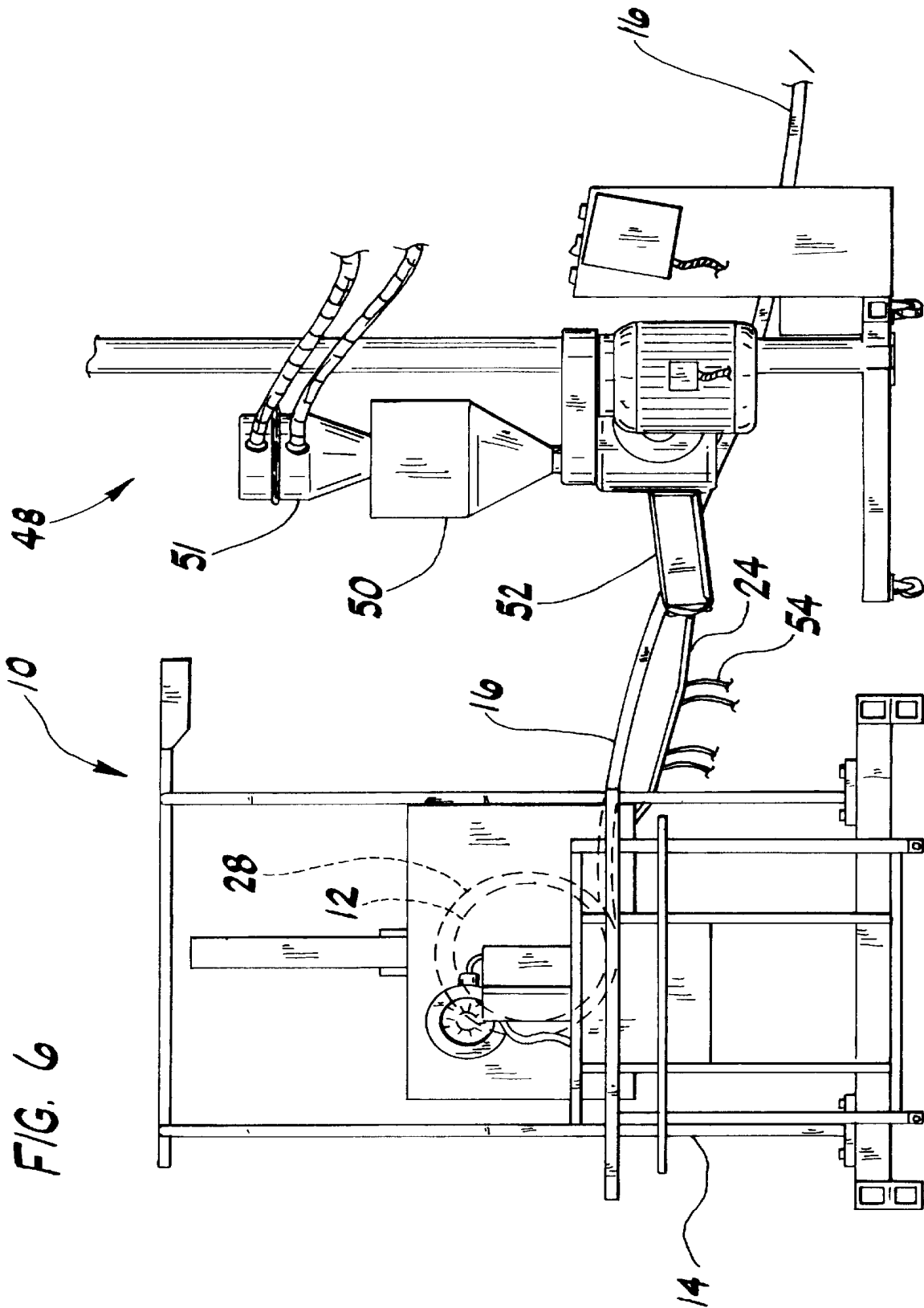


FIG. 4







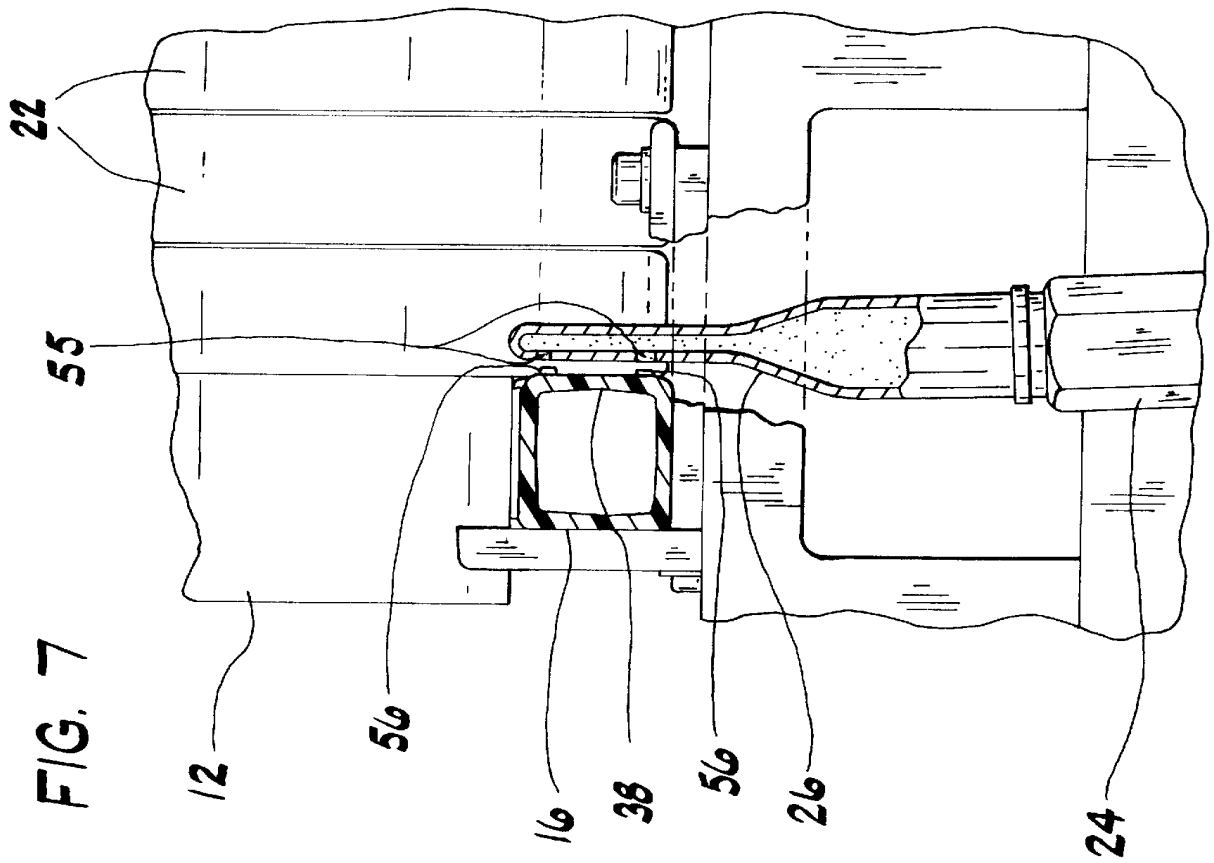


FIG. 8

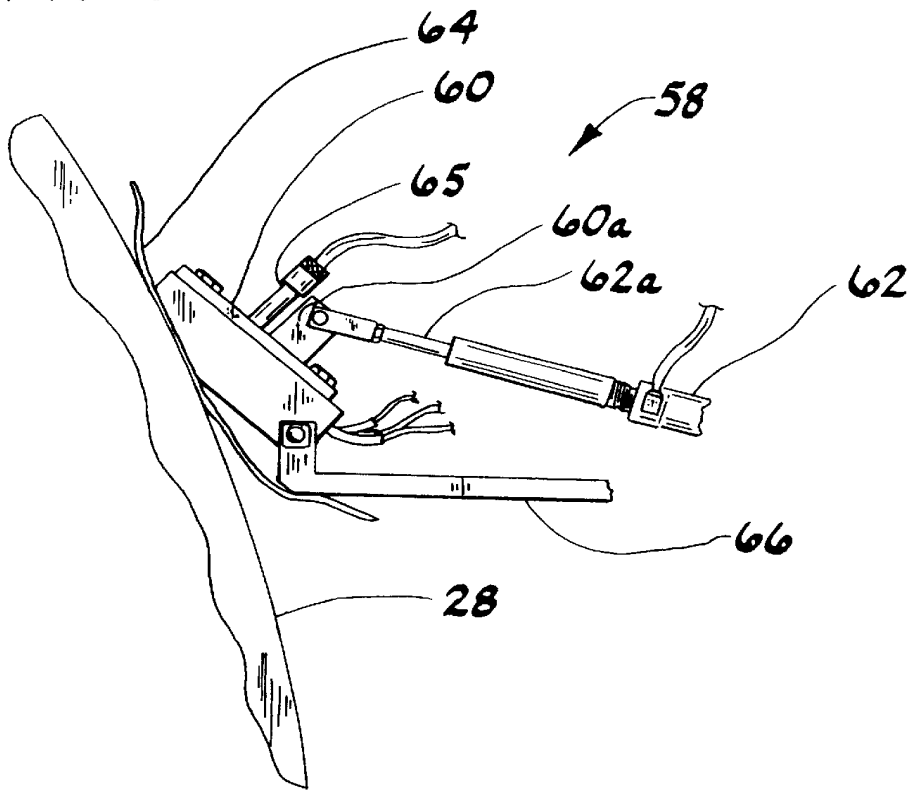
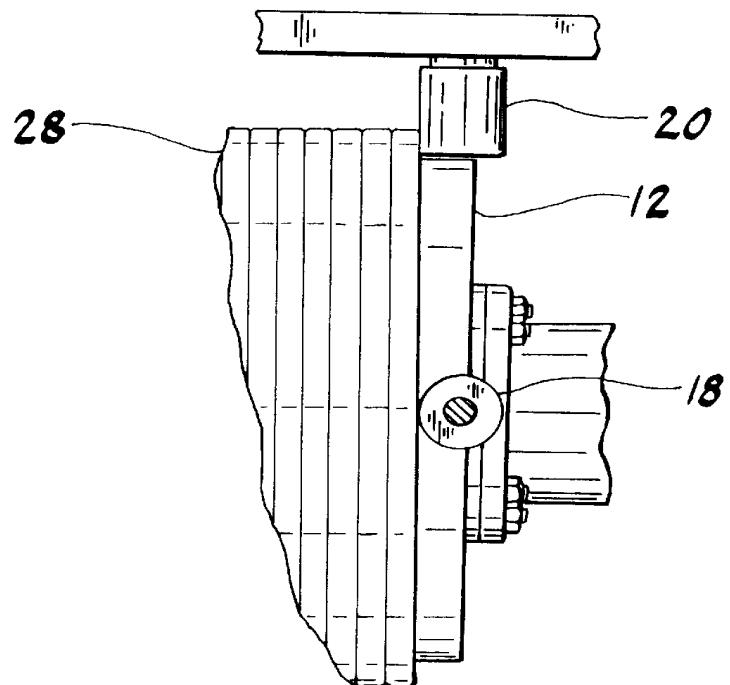
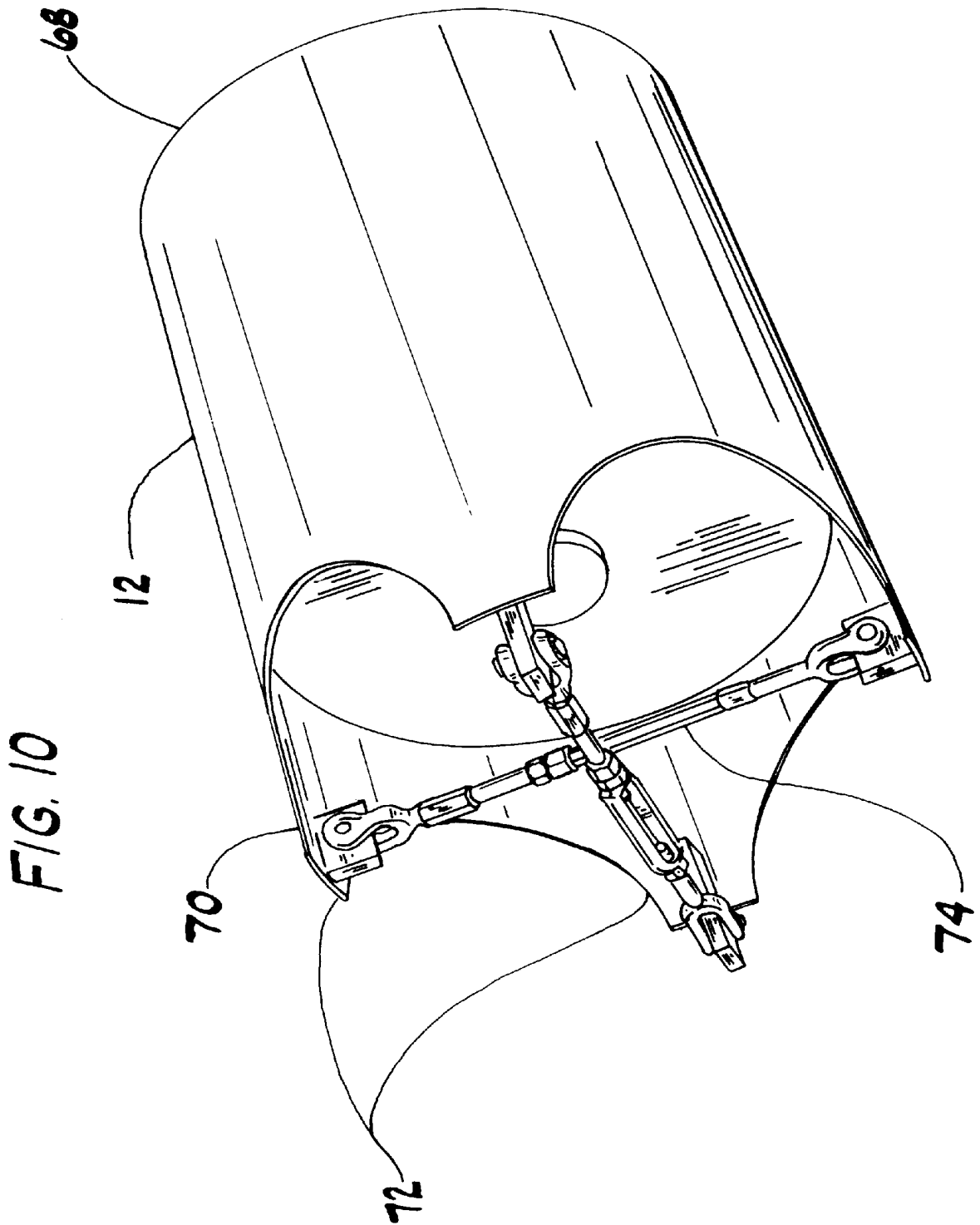


FIG. 9





PIPE EXTRUSION APPARATUS INCLUDING WINDING A HOLLOW PROFILE

BACKGROUND OF THE INVENTION

This invention relates generally to large-diameter ducts, tubes, or cylindrical containers, and in particular to a process and apparatus for the continuous production of thermoplastic helical seam profile pipe.

Thermoplastic pipes of large diameter have found widespread use in storm and sanitary sewers, roadway drainage projects, and anyplace where gravity-flow conduit is useful. Pipes composed of high density polyethylene (HDPE) thermoplastic provide strength, durability, corrosion resistance, light weight, long service life, and cost effectiveness.

The continuous production of thermoplastic pipe and cylindrical containers has been accomplished in prior art using, among other methods, the helical seam technique. In that system, a strip of thermoplastic in a heated, plastic state is wound around a cylindrical surface or mandrel to produce a succession of turns of the strip which laterally abut or overlap each other. The abutting or overlapping turns are joined together, thereby forming a helically-wound pipe of any desired length.

In practice, helical pipes formed of strips of a tubular profile have demonstrated superior strength and rigidity to those formed of strips that are substantially flat. Pipes made from flat strips are often susceptible to being crushed when buried in the ground and exposed to radially-inward directed compression forces. By contrast, pipes made of wound hollow tubular profile strips exhibit good load distribution characteristics and can withstand larger forces.

Although superior in strength, the manufacture of tubular profile pipes has proven difficult. The steps of forming, winding, joining, and cooling are more complex when the continuous strip of hot thermoplastic is a hollow tube. Previous tubular profile designs have used thermal butt welds to join abutting turns of tube, whereby hot, un-cooled tubular strips are wound together. Abutting turns are naturally welded together on contact by the heat energy residual within the thermoplastic. A disadvantage is that a substantial portion of cooling must be accomplished after the tubular strips are wound. This necessitates compromises in the shape and design of the mandrel to accommodate air circulation or other cooling scheme.

Further, external seams or joints, at regions where abutting turns of pipe are joined can be uneven, resulting in an unsightly appearance. If the inconsistencies are severe, a pipe may have reduced strength when exposed to bending or compression loads.

SUMMARY OF THE INVENTION

Among the several objects and features of the present invention may be noted the provision of a process and apparatus for forming profile wall pipe which forms pipe continuously; the provision of such a process and apparatus which produces pipe which has high strength and low weight; the provision of such a process and apparatus which produces pipe having a commercially acceptable appearance; and the provision of such a process and apparatus which are economical to use.

Briefly, a process of the present invention for making a continuous thermoplastic helical seam tubular-profile pipe comprises melting thermoplastic material, extruding the thermoplastic material through a die to form a continuous tube. The continuous tube is cooled and a molten filler

material is applied to the cooled tube. The continuous tube bearing the applied filler material is helically wound on a mandrel, thereby forming turns of wound continuous tube. Each turn of the continuous tube is pressed into the preceding turn on the mandrel for joining the turns to form the pipe.

In another aspect, apparatus of the present invention produces helical seam profile pipe from thermoplastic tube having a generally rectangular cross section. The apparatus comprises a frame, and a mandrel mounted on the frame for rotation on the frame about a longitudinal axis of the mandrel to helically wind the thermoplastic tube around the mandrel forming adjacent turns of the tube on the mandrel. A source of molten filler material and an applicator, located adjacent to the mandrel, continuously apply a bead of the filler material to the thermoplastic tube prior to being wound on the mandrel. Each new turn of the thermoplastic pipe is brought into engagement with the preceding turn such that the applied filler material is brought into contact with a wall of the thermoplastic tube in the preceding turn for joining the new turn to the preceding turn.

Other objects and features will be in part apparent and in part pointed out hereinafter.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a fragmentary elevational view of apparatus of the present invention showing a frame and mandrel for winding a thermoplastic continuous tube to produce helical seam profile pipe;

FIG. 2 is an elevational view of a die for extruding a continuous tube of thermoplastic;

FIG. 3 is a fragmentary elevational view of the apparatus showing two cooling devices that reduce the temperature of the continuous tube of thermoplastic and a canister containing a die that forms the continuous tube;

FIG. 4 is an enlarged cross-sectional view of the continuous tube of thermoplastic;

FIG. 5 is an elevational view of a belt puller of the apparatus that pulls the continuous tube of thermoplastic and shows a portion of one of the cooling devices;

FIG. 6 is an elevational view of the frame that supports the mandrel and a source of molten filler material;

FIG. 7 is an enlarged fragmentary elevational view of a filler material applicator located adjacent to the mandrel;

FIG. 8 is a fragmentary transverse section through the mandrel and pipe showing a wiper disposed adjacent to the mandrel for wiping the pipe in a joint between adjacent turns of thermoplastic tube;

FIG. 9 is a fragmentary end elevational view of the mandrel and frame showing a pair of rollers located in axially and circumferentially offset positions on the mandrel; and

FIG. 10 is a perspective view of a mandrel.

Corresponding reference characters indicate corresponding parts throughout the drawings.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to the drawings and in particular to FIGS. 1, 3, 5, & 6, an apparatus for producing a helical seam profile pipe from thermoplastic tube having a generally rectangular cross section is indicated generally at 10

The apparatus 10 includes a rotatable mandrel 12 mounted on a frame 14 for rotation about a longitudinal axis of the mandrel. A continuous tube 16 of a thermoplastic

material such as HDPE is supplied to the mandrel 12 as it rotates, and is helically wound on the mandrel. A first roller 18 (FIG. 9) and a second roller 20 (Figs. 1 & 9) guide the thermoplastic tube onto the mandrel into a generally helical configuration, forming adjacent turns 22.

The apparatus also includes a conduit 24 that conveys molten filler material to an applicator 26 located adjacent to the mandrel 12. The applicator 26 continuously applies filler material to the tube 16 prior to being wound on the mandrel 12. Each new turn 22 of thermoplastic tube 16 is brought into engagement with the preceding turn so that the applied filler material is brought into contact with a wall of the thermoplastic tube in the preceding turn for joining the new turn to the preceding turn. The first roller 18 and second roller 20 press each turn into the preceding turn on the mandrel 12. The turns 22 collectively form a thermoplastic helical seam profile pipe 28 of substantially any desired length.

A process of making thermoplastic helical seam profile pipe begins by forming the continuous tube 16. As established in the art, an extruder device (not shown) melts thermoplastic material and extrudes it through a die 29 (FIG. 2). In practice, a type of extruder found useful has been a 3½ inch model equipped with temperature control manufactured by Akron Extruders, Inc. of Canal Fulton, Ohio. Extruders of other sizes may be employed without departing from the scope of the present invention. The die 29 is configured to form molten thermoplastic into the cross-sectional shape of square tube 16, described hereinafter. The die 29 includes a flange 30 and is adapted to fasten the die 29 within a canister 33 of the extruder. The die further includes a tubular outer member 29a and a solid inner member 29b. The outer member 29a defines the shape of the exterior of the continuous tube 16 and the inner member 29b defines the shape of the interior of the continuous tube.

The continuous tube 16 of thermoplastic proceeds out from the cannister 33 in a very hot, collapsed plastic state. The continuous tube 16 is substantially cooled and solidified during passage through a first cooling device 34 and a second cooling device 36. Each cooling device is an elongate water tank designed for uniform flood cooling of continuous tubes. As established in the art, flood cooling tanks such as first and second cooling devices 34, 36 provide water turbulence to break up any temperature strata that form around the tube 16 for improved cooling efficiency. Types of cooling devices found useful are those manufactured by Metaplast Ltd. of Canada or Conair Gatto of Bay City, Mich.

In practice, it has been found useful for the is first cooling device 34 to also comprise a vacuum sizing tank. As established in the art, vacuum sizing tanks provide a decreased atmospheric pressure in the tank above the water. Pressure within the hollow tube 16, which is greater than that within first cooling device 34, expands the collapsed tube to provide a smooth, accurate profile shape corresponding to the shape formed by the die 29. In practice, a vacuum sizing tank manufactured by Metaplast Ltd., having three sections of selectable pressure, has been effective. Pressure levels in a first section of the first cooling device 34 between 8 and 12 inches of mercury below atmospheric pressure have been useful to cause the tube 16 to expand to a desired shape. Pressure levels in the second and third sections of about 6 and 2 inches of mercury vacuum, respectively, maintain the desired tube shape as the thermoplastic solidifies as it passes through the first cooling device 34.

After passage through the first and second cooling devices 34, 36, the thermoplastic tube 16 is cooled to a temperature

level that provides a self-sustaining cross-sectional shape. However, the tube 16 remains sufficiently pliant and bendable to permit winding on the mandrel 12.

Referring now to FIG. 4, a cross-section of the continuous tube 16 is shown. The cross-section is generally rectangular, and includes opposed lateral walls 38, an upper wall 40, and a lower wall 42. Each wall 38, 40, and 42 has a straight external edge to facilitate formation of the pipe 28. When wound on the mandrel 12, the lateral walls 38 abut adjacent turns 22, the upper wall 40 engages the mandrel surface and forms an internal surface of the pipe 28, and the lower wall 42 forms an external surface of the pipe. The cross-section has rounded corners, and it has a variable wall thickness, being generally greater in thickness at a corner than a mid-wall location. More specifically, the thickness of the lateral walls 38 tapers, on the inside of the tube 16 from the corners to the center of the wall such that the inner surface of such lateral wall is about two degrees from vertical. The thickness of the upper and lower walls 40, 42 tapers such that the inner surface of such wall is about one degree from horizontal.

It has been found that a cross-section of the tube 16 having ratio of width to height equal to a length ratio of upper wall 40 to lateral wall 38, of about 1.25 works well. In addition, a ratio of minimum wall thickness to wall length of about 0.07 to 0.10 works well for a sturdy construction. Other dimension ratios, however, are envisioned to be within the scope of this invention. The following dimensions have worked well in practice: 2.91 inch length of walls 40 and 42, 0.228 inch minimum thickness of walls 40 and 42, 2.32 inch length of wall 38, and 0.196 inch minimum thickness of wall 38.

Referring now to FIG. 5, the continuous tube 16 travels into a belt puller 44. The belt puller provides the motive force that pulls the extruded continuous tube 16 from the canister 30 and through the first and second cooling devices 32, 34. As established in the art, belt puller 44 contains motor-driven belts 46 that grip the continuous tube and pull. In practice, a series 1000 belt puller manufactured by Conair Gatto has worked well. After passage through the belt puller 44, the continuous tube 16 travels to the mandrel 12 for winding thereon.

Referring now to FIG. 6, a source of molten filler material is indicated generally at 48. The function of filler material is to fuse abutting turns 22 of tube 16 together. In practice, it has been found efficient to use filler material made from thermoplastic of the same composition as that forming the continuous tube 16. In that way, the same polymer material may be procured for both the tube and the filler material, thereby providing simplicity.

The source of molten filler material 48 includes a hopper 50 into which a supply of solid thermoplastic is deposited by a vacuum feeder 51. An extruder 52 melts the thermoplastic and pumps it in liquid form into the filler material conduit 24. The conduit has heaters placed therealong to keep the thermoplastic molten as it flows toward the mandrel 12. Electrical lines 54 provide power to the heaters on the conduit 24.

In the illustrated embodiment, the extruder 52 is manufactured by Akron Extruders, Inc. The conduit 24 is ¾-inch stainless steel tubing. Heaters keep the filler material at a temperature level preferably between 465 and 510° F. (and most preferably at about 500° F.) so that the filler material will remain on the lateral wall 38 when applied and to adequately fuse abutting turns 22 together.

Also depicted in FIG. 6 is the frame 14. The frame is constructed of steel or other sturdy material to support the

mandrel **12** for rotation relative to the frame. Rotation of the mandrel **12** is driven by an electric motor (not shown) mounted on the frame **14**. The frame is adjustable in vertical and horizontal directions to selectively position the mandrel **12** at a desired location.

Referring now to FIG. 7, the conduit **24** supplies molten filler material to the applicator **26**. The applicator is positioned adjacent the continuous tube **16** at a point immediately before it is wound on the mandrel **12**. The applicator **26** has two outlets **55** for dispensing the filler material in two spaced apart beads **56** upon one of the lateral walls **38** of the continuous tube **16**. Each bead **56** forms a stripe of filler material extending lengthwise along continuous tube **16** as it passes the applicator **26**. The beads **56** are preferably located near the top and bottom of lateral wall **38**. However, a different placement of the beads or use of a single bead of filler material are included within the scope of this invention.

Referring now to FIG. 9, the first roller **18** and the second roller **20** guide the thermoplastic tube onto the mandrel into a generally helical configuration. The rollers **18**, **20** are located in axially and circumferentially offset positions on the mandrel **12**, and apply force to the tube **16** lengthwise of the mandrel to press the pipe **28** to slide along the surface of the mandrel. The offset positions of the rollers **18**, **20** establish the helical path of the tube **16**, since the tube must travel from the first roller **18** to the second roller **20**, thereby moving axially lengthwise of the mandrel while rotating circumferentially.

Referring now to FIG. 8, a wiper assembly for pressing the regions where abutting turns **22** are joined is indicated generally at **58**. The wiper assembly compresses the pipe **28** at joints between abutting turns to smooth the pipe and shape the filler material, thereby enhancing strength and external appearance. The wiper assembly **58** is located adjacent the pipe **28**, positioned within about two turns **22** of the first roller **18**.

The wiper assembly **58** includes a heater block **60** for applying heat, a cylinder **62** for applying a controlled force, a sheet **64** of low friction material for engaging the pipe and filler material, and a support bracket **66** for upholding the assembly. A rod **62a** of the cylinder **62** is pivotally mounted on an upstanding tab **60a** of the block **60** and the bracket **66** is pivotally connected to a lower end of the block to permit some movement of the block. In the preferred embodiment, the sheet **64** is made of polytetrafluoroethylene (TEFLON). A temperature sensor **65** mounted on heater block **60** provides information to control the heater block, thereby maintaining the sheet **64** at a constant temperature.

The cylinder **62** applies a constant force against the pipe **28**. That force, together with the applied heat, align the turns **22** and re-distribute and wipe filler material at joints to obtain a smooth, uniform external contour. In practice, about **200** pounds force have been applied by the cylinder **62**, although other forces are within the scope of this invention.

Referring now to FIG. 10, the mandrel **12** is displayed without any tube **16** wound thereon and apart from the apparatus **10**. The mandrel **12** produces pipe **28** of circular internal cross-section, because the cylindrical external surface of the mandrel shapes and molds the pipe. The diameter of the mandrel **12** is therefore selected for a desired inner diameter of pipe **28**. To produce a smaller diameter pipe, the mandrel **12** is removed from frame **14** and replaced with a mandrel of smaller size.

In the preferred embodiment, the mandrel is of a circular cross-section in order to produce cylindrical pipe having a circular internal cross-section. However, other cross-

sectional shapes are envisioned, such as elliptical or rectangular, to produce unconventional pipe geometries if desired.

The mandrel **12** has an originating end **68** and a distal end **70**, oriented so the continuous tube **16** is first wound on the originating end. The distal end **70** has two sets of diametrically opposed ears **72** formed thereon and two variable length turnbuckles **74** extending between the opposed ears. A diameter of the distal end **70** of mandrel **12** may be selectively varied by changing the length of the turnbuckles **74**. In practice, the diameter of the distal end **70** may be varied by as much as about 8% of its nominal length.

An increase in the diameter of the distal end **70** relative to originating end **68** increases resistance to axial travel of pipe **28** on the mandrel **12**, because axial movement simultaneously requires slight stretching of diameter. Therefore, the axial force applied by rollers **18**, **20** must increase to continue helically winding and moving the pipe **28** along the surface of mandrel **12**. The result is a more tightly wound pipe **28**.

When the pipe **28** is wound to a desired length, rotation of the mandrel **12** is stopped and the pipe is removed for delivery. The pipe **28** is removed simply by cutting off the pipe at the desired length. The process is continuous and theoretically may form pipes of arbitrary length.

As various changes could be made in the above constructions without departing from the scope of the invention, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. Apparatus for producing a helical seam profile pipe from thermoplastic tube having a generally rectangular cross section, the apparatus comprising:

- a frame;
- a mandrel mounted on the frame for rotation on the frame about a longitudinal axis of the mandrel to helically wind the thermoplastic tube around the mandrel forming adjacent turns of the tube on the mandrel, the mandrel having a smooth, continuous external surface, an originating end, and a distal end, with a diameter of the mandrel at the originating end being generally fixed and a diameter of the mandrel at the distal end being selectively adjustable thereby to increase or decrease resistance to axial travel of the pipe formed on the mandrel for use in controlling the force by which adjacent turns are compressed together, the distal end of the mandrel having four ears formed thereon disposed at equally spaced relation to form two pairs of diametrically opposed ears;
- a variable length connector extending directly and continuously between each pair of opposed ears, with a turnbuckle on each connector to selectively change the length of the connector and thereby change the diameter of the mandrel at the distal end;
- a source of filler material;
- a filler material applicator located adjacent to the mandrel for continuously applying a bead of the filler material to the thermoplastic tube prior to being wound on the mandrel, each new turn of the thermoplastic pipe being brought into engagement with the preceding turn such that the applied filler material is brought into contact with a wall of the thermoplastic tube in the preceding turn for joining the new turn to the preceding turn.

2. Apparatus as set forth in claim 1 wherein the filler material applicator has a pair of outlets for dispensing the

filler material in two beads along one wall of the thermoplastic tube, the applicator being arranged so that the beads extend longitudinally of the continuous tube.

3. Apparatus as set forth in claim 2 wherein the source of filler material is an extruder constructed for delivering molten thermoplastic material to the filler material applicator.

4. Apparatus as set forth in claim 1 further comprising a wiper disposed adjacent to the mandrel for wiping the pipe in a joint between adjacent turns of thermoplastic tube to form the applied filler material into the seam.

5. Apparatus as set forth in claim 4 wherein the wiper includes a heater for applying heat to the pipe and the filler material in the joint.

6. Apparatus as set forth in claim 5 wherein the wiper has a surface which engages the pipe and filler material, said surface being made of polytetrafluoroethylene.

7. Apparatus as set forth in claim 1 further comprising a pair of rollers located in axially and circumferentially offset positions on the mandrel for guiding the thermoplastic tube onto the mandrel into a generally helical configuration.

8. Apparatus as set forth in claim 1 further comprising a die for forming the thermoplastic tube, the die configured to form molten thermoplastic into a generally rectangular cross-section having non-uniform wall thickness wherein the thickness tapers on an inside surface of the tube, with greater thickness at a corner region of the cross-section than at a mid-wall location.

9. Apparatus as set forth in claim 8 wherein the die is configured to form the thermoplastic tube to have four wall including an upper wall, a lower wall and opposing lateral walls between the upper and lower walls thereof, the upper and lower walls each extending between the lateral walls, and wherein the die is shaped to form the walls such that the ratio of minimum wall thickness of each wall to the dimension of the wall between adjacent walls is about 0.07 to 0.10.

10. Apparatus for producing a helical seam profile pipe from thermoplastic tube having a generally rectangular cross section, the apparatus comprising:

- a frame;
- a mandrel mounted on the frame for rotation on the frame about a longitudinal axis of the mandrel to helically wind the thermoplastic tube around the mandrel forming adjacent turns of the tube on the mandrel;
- a source of filler material; and
- a filler material applicator located adjacent to the mandrel and just upstream from a location where the thermoplastic tube first contacts the mandrel as it is wound onto the mandrel, the applicator being adapted to continuously apply a bead of the filler material to the thermoplastic tube prior to being wound on the mandrel, each new turn of the thermoplastic pipe being brought into engagement with the preceding turn such that the applied filler material is brought into contact with a wall of the thermoplastic tube in the preceding turn for joining the new turn to the preceding turn, the filler material applicator having an outlet side positioned for facing toward the thermoplastic tube and other sides, and an outlet on said outlet side for

dispensing the filler material along only one lateral wall of the thermoplastic tube prior to being wound on the mandrel, said other sides of the applicator being free of any outlets whereby said one lateral wall is the only lateral wall to which filler material is applied, the applicator being arranged so that an applied bead of filler material extends longitudinally on said lateral wall of the tube being wound on the mandrel, with no filler material directly applied from the applicator to the tube of the preceding turn, the apparatus being free of any other filler material applicators located downstream of said filler material applicator.

11. Apparatus as set forth in claim 10 wherein the filler material applicator has exactly two outlets, both located on the first side of the applicator, for applying spaced apart beads of filler material on said one lateral wall.

12. Apparatus for forming thermoplastic tube having a generally rectangular cross section and winding the tube to make a helical seam profile wall pipe, the apparatus comprising:

- a first extruder for extruding molten thermoplastic material;
- a die for receiving the extruded material from the first extruder for forming the thermoplastic tube, the die being configured to form the molten thermoplastic material into a generally rectangular cross-section having non-uniform wall thickness wherein the thickness tapers on an inside surface of the tube, with greater thickness at a corner region of the cross-section than at a mid-wall location;
- at least one cooling device for cooling the tube exiting the die;
- a frame;
- a mandrel mounted on the frame for rotation on the frame about a longitudinal axis of the mandrel to helically wind the thermoplastic tube around the mandrel forming adjacent turns of the tube on the mandrel;
- a second extruder for extruding filler material;
- a filler material applicator located adjacent to the mandrel and adapted to receive filler material from the second extruder for continuously applying a bead of the filler material to the thermoplastic tube prior to being wound on the mandrel, each new turn of the thermoplastic pipe being brought into engagement with the preceding turn such that the applied filler material is brought into contact with a wall of the thermoplastic tube in the preceding turn for joining the new turn to the preceding turn.

13. Apparatus as set forth in claim 12 wherein the die is configured to form the thermoplastic tube to have four wall including an upper wall, a lower wall and opposing lateral walls between the upper and lower walls thereof, the upper and lower walls each extending between the lateral walls, and wherein the die is shaped to form the walls such that the ratio of minimum wall thickness of each wall to the dimension of the wall between adjacent walls is about 0.07 to 0.10.