(57) Abstract: An improved filter pipe (23) is disclosed, and also an improved apparatus (10) is disclosed for making the improved filter pipe. The apparatus is meant for perforating, forming and cutting the spirally formed pipe, particularly spiral pipes having a diameter of approximately one inch or more. The filter pipe has a unique corrugated or fluted configuration (15b) that adds section modulus to the pipe, potentially allowing for the use of thinner sheet metal in manufacturing such pipes. A machine for manufacturing the spiral pipe may include special machinery for forming the unique corrugated or fluted configuration.
before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments.

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PERFORATED SPIRAL PIPE

FIELD OF THE INVENTION

This invention relates to an improved apparatus for producing spirally formed pipe, particularly spiral pipes having a diameter of approximately one inch or more.

BACKGROUND

A large potential for small diameter spiral pipes exists in the filter market, such as automobile oil filters. These filters typically have a perforated inner metal cylinder that is approximately one inch in diameter. Because pipes such as those used in oil filters need to be accurately and cleanly cut in large quantities, a pipe forming and cutting apparatus capable of fast and accurate cuts is necessary. There are several known ways to form and cut a pipe. A pipe may be formed by spirally or helically winding a continuous strip of metal, and joining adjacent edges of the wound strip to form a spiral lockseam in the pipe. In some pipe forming and cutting machines, the spirally formed pipe is cut by moving a knife outside the pipe into an overlapping position with a knife inside the pipe. Other types of spiral pipe forming and cutting machines use multiple knives or rotate the knives around the pipe to cut the pipe into sections.

The performance of the oil filter depends on the performance of the spiral pipe, typically an oil outlet at the center of the filter, where a strong flow of oil must be maintained for engine performance, and a strong filter must be maintained to resist pressure and insure functioning of the filter. Oil inflow is typically achieved by perforating the spiral formed pipe, that is, by punching holes in the inlet pipe so that oil can flow from the pipe into a downstream filter element. The filter element is typically paper, but need not be, and may be made from any of a number of other materials. The perforations in the center pipe necessary for the filter to function may be achieved in one or more of several ways. The strip or coil used for the central pipe may be perforated off-line, that is, in a separate operation.
Prior art perforations and machinery for perforating sheet metal typically included punches and dies that performed a unit operation off-line before the strip was fed into the spiral tube forming machine. A typical prior art punch 105 is depicted in Fig. 11b. The punch 105 is V-shaped, having a low portion 104 and two high portions 114. The punch forces strip or sheet metal into a die, such as the die 115 depicted in Fig. 11a. As shown in Fig. 11c, these tools produce perforated sheet metal 107. The surface of the sheet metal 108 is pierced by V-shaped perforations 109. These perforations allow communication between one side of the metal and the opposite side, necessary for a filter. Typically, surface 108 becomes the outer surface of the filter pipe which is later formed, while the pierced portions 108 remain on the inside.

There are several drawbacks to the prior system and method. For example, the V-shaped punch is prone to chipping and breaking. This method results in very high tool wear, when chipping 106 or other damage occurs on the punch 105. Also, the configuration of the perforation, with two "high points" 114 and their separation from sheet metal surface 108, does not strengthen the pipe, but instead may form weak points, where the metal is stressed and may tear. In addition, to maintain flow of oil or other fluid medium, there must be sufficient distance between the pipe itself and the "tips" 114 of the V. The tips can be no further away from the sheet metal surface 108 than the tensile strength of the metal will allow, or there will be tears in the resulting pipe. This could lead to uncontrolled flow of oil or other medium.

What is needed is an improved way to perforate and form sheet metal for filter pipe with a pattern that yields longer tool life and does not require an off-line operation. What is needed is a better way to form perforated filter pipe.
BRIEF SUMMARY

One aspect of the invention is a filter pipe. The filter pipe comprises sheet metal having a first edge and a second edge, and having a first end and a second end. The pipe also comprises a lock seam formed by locking the first edge to the second edge in forming a spiral-shaped pipe. The filter pipe also has a plurality of perforations or flutes, the perforations or flutes allowing communication between an inside of the filter pipe and an outside of the filter pipe. At least one side of the perforations forms an angle of from about ten to about forty degrees to a plane of the sheet metal. In one embodiment, the perforations or flutes are generally in the shape of a rectangle or a square, joined to the sheet metal with two sloping sides and two open sides, the open sides allowing communication between an inside of the filter pipe and an outside of the filter pipe.

Another aspect of the invention is a method for forming a filter pipe. The method comprises drawing a strip of sheet metal into a forming machine, and forming seal forms on a first edge and a second edge of the sheet metal. The method also includes drawing the metal and forming perforations or flutes in the sheet metal, after the edges are formed. The method then forms the strip into a spiral. The first and second edges of the sheet metal are sealed to each other to form a lockseam. The pipe is then cut to a desired length.

Another aspect of the invention is an apparatus for forming a spiral pipe from a metal strip. The apparatus comprises rollers for forming lateral edge portions of the metal strip. The apparatus comprises a forming head having a lateral bore for guiding the metal strip into a spiral pipe. The apparatus further comprises a forming tool extending into the lateral bore of the forming head. The apparatus also comprises a closing assembly for coupling and compressing lateral edge portions of the metal strip into a lockseam of a pipe. The apparatus also has rollers for perforating and driving the metal strip around the forming tool, against an interior surface of the forming head, and in an axial direction, wherein the lateral edge portions of the strip mate and are coupled and compressed by the closing assembly to form a lockseam and provide a continuous spiral pipe.
Another aspect of the invention is a punch for perforating sheet metal. The punch comprises a roller having a plurality of protrusions radially extending from the roller, the protrusions arranged in at least two circumferential rows on the roller, the at least two rows staggered on a circumference of the roller, wherein the protrusions cause at least one of openings, perforations and corrugations in the sheet metal, but do not cause portions of the sheet metal to separate from the sheet metal. There are many ways to practice the invention. These and many other aspects of the invention will become apparent from the drawings below and the detailed descriptions of the preferred embodiments.

BRIEF DESCRIPTION OF SEVERAL VIEWS OF THE DRAWINGS

Fig. 1 is a perspective view of the back and right sides of a preferred embodiment of the present invention.

Fig. 2 is an elevation view of the back side of Fig. 1.

Fig. 3 is a plan view of Fig. 1.

Fig. 4 is an elevation view of the right side of Fig. 1.

Fig. 5 is a left side, elevational view of the forming head assembly of Fig. 1.

Fig. 6 is an front, elevational view of the forming head assembly of Fig. 1.

Fig. 7 is a plan view of the top side of the forming head assembly of Fig. 1.

Figs. 8 and 14 are side elevational views of a part of a spiral pipe forming machine forming a part of the present invention.

Figs. 9a-9d are sectional views of the edge forming and corrugation rollers that are used in the spiral pipe forming machine, with the strip edge configuration illustrated between the rollers.

Fig. 10 is a sectional view of the guide plates and clamping members that are used in the spiral pipe forming machine.

Figs. 11a-11c depict a prior art punch and die set useful for making perforations in sheet metal.
Figs. 12a-12g depict perforated coilstock and filter pipe according to a variety of embodiments of perforations or flutes.

Figs. 13a-13e depict upper and lower rollers useful in the present invention for driving and perforating coil stock.

Fig. 15 is a front, sectional view of an upper bracket and pipe support assembly for use in the apparatus of Fig. 1.

Fig. 16 is a cross-sectional view taken along line 12—12 of Fig. 15.

Fig. 17 is a fragmentary side view of the upper bracket and pipe support assembly of Fig. 15 with the outer knife in a cutting position.

Fig. 18 is a fragmentary side view of the upper bracket and pipe support assembly of Fig. 15 with the outer knife in a stand-by position.

Fig. 19 is a front sectional view of a support assembly for use in the apparatus of Fig. 1.

Fig. 20 is a magnified view of inset A of Fig. 19.

Fig. 21 is an alternate embodiment of a pipe-making machine.

Fig. 22 depicts a method for making a perforated spiral pipe.

DETAILED DESCRIPTION OF THE PRESENTLY PREFERRED EMBODIMENTS

Referring now to the drawings, Figs. 1 and 2 depict the spiral pipe forming apparatus 10 useful in making pipes according to the present invention. Many elements of the pipe forming machine 10 are conventional, and are described in greater detail in U.S. Pat. No. 5,636,541, issued June 10, 1997. The disclosure in that patent is incorporated by reference herein, and made a part hereof. Many of the parts disclosed therein can be used in the present pipe forming machine 10 with some adaptation to accommodate the one and one-half inch wide strip 15 and its particular edge and the flutes or corrugation/perforation configurations that are used in the present pipe forming machine 10.

Figs. 8 and 14 depict some of the elements of pipe forming machines 10, 100. The machine 10, 100 includes a frame 11 and a control cabinet 12. A control panel 13 contains a plurality of control elements 14, such as knobs,
gauges and dials, for controlling and monitoring the operation of the pipe forming machine 10, 100 and the slitter 75. The functions of the various control elements are described in U.S. Pat. No. 4,706,481, issued Nov. 17, 1987. The disclosures contained in that patent are hereby incorporated by reference in their entirety.

A continuous metal strip 15 is fed into the frame 11 of the pipe forming machine 10, 100. To make one inch diameter filter pipe, the strip 15 is preferably 1.5 inches wide. If the pipe diameter increases, a wider strip 15 can be used and is preferred. The metal strip 15 passes through a roller housing 16 that contains a plurality of rollers that bend the edges of the strip 15a into a predetermined shape for forming a lockseam. Figs. 9a-9d show the upper edge forming rollers 16-u and the lower edge forming rollers 16-l that are preferably used for forming the strip edges in forming filter pipe. The strip 15 first passes through the rollers shown in Fig. 9a, and successively through the rollers shown in Fig. 9b through Fig. 9d. Further information about the function and operation of the edge forming rollers is disclosed in U.S. Pat. No. 4,567,742, which is hereby incorporated by reference in its entirety and made a part hereof.

Returning to Figs. 8 and 14, a lower drive roller 17 and an upper drive roller 18 are rotatably mounted in the frame 11. The drive rollers cooperate to pull the metal strip 15 into the frame 11 and through the roller housing 16. The two drive rollers 17, 18 then push the metal strip 15 between the upper guide plates 19 and lower guide plates 20. The width of the drive rollers 17, 18 and the guide plates should be adapted to conform to the width of the strip 15. As shown in Fig. 10, the lower guide plates 20 are secured to the frame 11 by bolts 20a. The lower guide plate 20 also contains grooves to accommodate the edges formed in the strip 15. Clamps 20b are pivotally connected to a base 20c that is attached to the frame 11. The clamps 20b hold the upper guide plates 19 against the lower guide plates 20.

The strip 15 can be perforated before entering the pipe forming machine 10, or in the pipe forming machine 10 with perforating drive rollers 17, 18. In Fig. 8, lower drive roller 17 and upper drive roller 18 are perforating
rollers that also drive the strip through the pipe-forming machine. In Fig. 14, there are two sets of rollers, first set 17 and 18, and second set 17b and 18b. Either configuration may be used to drive the strip through the pipe forming machine and will also perforate the rollers as desired.

An improved perforation extends the metal no more than necessary and also strengthens the metal by adding "corrugations." Fig. 12a depicts strip 15 with "square" flutes or perforations 15b, each having two sloping sides 15c and two openings 15d. The sloping sides 15c provide continuity of metal and insure that the ribs will continue to form a continuum with the strip, that is, a continuous piece of sheet metal, with no welds or other means for attaching. The openings 15d will allow oil or other medium being filtered to communicate from one side to the other when the spiral pipe is used as the central pipe in a filter.

In a preferred embodiment, the flutes or perforations 15b are substantially in the form of a square or a rectangle. The angle formed by the plane of the sheet metal and the sloping sides 15c may be any angle consistent with good tooling and manufacturing practices. The perforations may be formed by drawing or punching the metal to a depth of from about two times to about four times the thickness of the metal, with a depth of about three times preferred. This technique is sufficient to enable perforations that are large enough for good medium flow through a filter made from the filter pipe. The resulting flutes or perforations are also sufficient to "corrugate" or "reinforce" the filter pipe with added dimensional stability. By limiting the draw or deformation of metal, this process also prevents or at least limits tearing the metal at corners of the perforations.

Using perforations or flutes 15b as shown in Fig. 12a may result in a strengthened filter pipe section 23a because of the reinforcing nature of the apertures 15b, as shown in the filter pipe section 23a in Fig. 12b. Rather than being arranged in rows perpendicular to a longitudinal axis of the metal strip, perforations may be formed at an angle C to a horizontal axis of the sheet metal. That is, each row of perforations may be staggered from the adjacent rows by a portion of a perforation, thus forming an "angle" or circumferential
distance from the adjacent rows. Thus, each row of perforations is offset from the other rows, preventing stress concentrations in the metal and in the resulting pipe. The pipe section 23a has been formed into a spiral shape with lock seams 23b. A cross sectional view of pipe section 23a is shown in Fig. 12c, in which the filter pipe section 23a has an outside surface 23c, an inside surface 23d, and the perforations 15b preferably reside on the inside of the pipe section 23a. In other embodiments, the perforations may be on the outside. Flutes or perforations formed as a rectangle or square are preferred.

In one embodiment, the indentations or perforations have a pitch from about ¼ inch to about ½ inch, as shown in Fig. 12a. A pitch of about 0.365 inch to 0.375 inch is particularly preferred. Indentations from about 0.25 inches square to about 0.375 inches square are preferred, as are rectangular indentations having sides of about this size. The axial spacing of the indentations may vary, as does the pitch. There should be sufficient space between the indentations or perforations to insure the strength of the resulting filter pipe. Areas between indentations are preferably from at least about 0.100 inches to about 0.200 inches. The sheet metal resulting from this processing desirably uses a considerable extent of its available surface area for these flutes, indentations, apertures, or perforations. The perforations preferably occupy from about thirty to about seventy percent of the surface area of the sheet metal, not including the edges of the sheet metal devoted to the lock seams or the forms on the edges that are later made into lock seams. Calculations to determine the area devoted to these features may include the transitions, such as sloping sides 15c as part of the area of the perforations or indentations 15b. Although the embodiment of Fig. 12a illustrates uniformly spaced perforations of a uniform shape, a mixture of perforation shapes fabricated in the same pipe with any of a number of spacings or patterns between perforations is also contemplated.

The preferred embodiments described above cause a separation or kerf between surfaces of the sheet metal strip that is perforated, but no metal is actually severed from the metal strip and no pieces of scrap are generated. In addition to the indentations described above, other perforations and
indentations may be used in embodiments of the present invention. Fluid communication between the outside and inside of the filter pipe may be achieved by processes that result in complete separation of pieces or metal from the metal strip, that is, processes that generate scrap from the sheet metal, and thus from the resulting pipe. Therefore, for purposes of this disclosure, perforation means a penetration or an opening in sheet metal whether scrap is generated or not. Besides the square and rectangular retained perforations, other openings in the sheet metal, and therefore the resulting pipe, are meant to be included in the present disclosure. For instance, Fig. 12d shows a triangular perforation in sheet metal 15, the perforation retained on the sheet metal. Fig. 12e shows a polygonal perforation in sheet metal, again retained on the sheet metal. Fig. 12f depicts a perforation in which the scrap 15e is severed from the sheet metal 15; such a configuration will work but is less preferred and may also be in the prior art. Fig. 12g includes another configuration in which the perforation is raised from sheet metal 15 and scrap 15e is severed from the sheet metal. The configuration shown in Fig. 12g may require a two-step operation, preferably a first punching step to sever the scrap and a second drawing step to form the raised portion or dimple in the sheet metal. Two sets of perforating rollers, as shown in Fig. 14, may be used for these operations. The punches should register within 0.001-0.002 inches of each other. This configuration allows a "dimpling" effect on the resulting pipe, less than a "corrugating effect," but still useful in lending dimensional stability. All the above configurations, and their equivalents, are meant to be included in the embodiments of the invention.

Machinery to create these flutes or perforations is also revealed herein. The drive rollers 17, 18 may be used as a punch and die to perforate the strip 15 as it enters the pipe forming machine 10. In a preferred embodiment, the lower drive roll is the punch and the upper drive roll acts as a die, although in other embodiments, the upper and lower drive rolls may be reversed. Figs. 13a and 13b depict drive rollers 17 and 18 formed as a punch and die, respectively. In Fig. 13a, the upper drive roller 18 has 6 lands or raised surfaces 18a with 5 grooves or lower surfaces between the lands, for
receiving and forming sheet metal pushed into the die by punch 17 with raised surfaces 17a.

Fig. 13c depicts one such raised surface 17a, with corner radii R on two sides and forming an angle B with the surface of the punch. Corner radii R and angle B will be reproduced in the sheet metal or strip that is perforated by drive rollers 17, 18. In one embodiment, angle B is from about 15 degrees to about 30 thirty degrees, but other angles may also be used. The radius used in the corner is preferably 0.040 inches, but may also take on other values as desired, and radii from about 0.010 inches to about 0.060 inches may also be used. The raised surface of Fig. 13c will produce the perforation or corrugation depicted in Fig. 12a. The other two sides S of raised surface 17a have sharp edges for piercing and separating portions of a strip of sheet metal passing between rollers 13a and 13b. The raised surface 17a will preferably have a depth (or height) of about two to three times the thickness of the metal strip to be processed through the rollers. The raised surfaces of the punch of Fig. 13a and the die of Fig. 13b cause the sheet metal to deform on radiused edges and cause separation or kerf on sharp edges, between the plane of the sheet metal and the corrugation formed. In preferred embodiments, there is no severing of the metal from the metal strip and thus no pieces of scrap produced.

In a preferred embodiment, as shown in Fig. 13c, the raised surface 17a is configured with rounded corners having radii R so that sheet metal will deform but not separate where the surface comes in contact with each corner radius R and will only separate where sharp edges S of the raised surface come in contact with the metal strip. An advantage of this configuration is that wear on the roller is reduced and there are no narrow, sharp regions on the teeth or raised surfaces that might chip or dull quickly. Further, the resulting square or rectangular perforations produced by the rollers of Figs. 13a and 13b have parallel openings or separations on two opposite sides while leaving the sheet metal connected on the other two opposite sides, shown in Fig. 12a. The invention is meant to include any technique consistent with sheet metal arts and good manufacturing practices.
Particulars about the flutes or perforations may be varied as desired. In one preferred embodiment, the raised surfaces 17a are staggered circumferentially as shown in Fig. 13b, and also shown earlier in Fig. 12b, at an angle C to an axis of the drive roller. In one embodiment, the angle may be about fifteen degrees. Other punches or perforating drive rollers may use other angles. This design staggering the impact and the load of the sheet metal formation on the drive rollers and may help “average” the effective instantaneous load over each turn or partial turn of the drive rollers.

The drive rollers will typically be part of a larger set of tools used within the pipe-forming machinery. As shown in Figs. 13d and 13e, the drive rollers are part of an assembly or combination. Fig. 13d depicts a die assembly 130, which is preferably used in an upper roller assembly. The die assembly 130 comprises a roller 131 and a die 132, the die having at least two grooves 138 for mating with punches from another roller assembly. The die 132 is mated to the roller 131 with a key 137 and a lock ring 133. There may also be a spacer ring 136 to space the assembly 130 in the pipe forming machine. There may preferably also be a gear 134 for driving the assembly and a second spacing ring 135. The assembly 130 is preferably mounted on a shaft through the center (not shown) for driving or being driven by conventional driving components within the pipe-forming machine 10.

A mating roller assembly 140 shown in Fig. 13e provides punches for the die of Fig. 13d. Assembly 140 is preferably used in a lower roller assembly. The assembly is similar, except for the protrusions that this assembly provides. There is a roller 141 and a punch 142, mated by key 149 and lock ring 143. The punch 142 has at least two rows of protrusions 142'. There is a spacer ring 146 for proper spacing of the assembly 140 within the pipe-forming machine. There is preferably a gear 144, mating with gear 134 for driving the assembly, and a second spacing ring 145. The gears and their drivetrain should be designed and assembled to be backlash-free. The assembly 140 is preferably mounted on a shaft through the center (not shown) for driving or being driven by conventional driving components.

The sheet metal used for filter pipe is preferably tin-plated or cold-rolled
steel, although the invention is not limited to this embodiment. Typical alloys that may be suitable include 1010 and 1020, in thicknesses from about 0.010 inches to about 0.030 inches. Galvanized steel, stainless steel, and other alloys may also be used. Coilstock thicker or thinner may also be used consistent with the strength and performance desired from the finished pipe. The flutes or perforations used are preferably drawn to a depth or height less than about five times the thickness of the sheet metal used, and preferably about two or three times the thickness of the sheet metal. For example, if SAE 1020 strip 0.020 inches thick is being perforated, the gap between the bottom surface of the sheet metal and the bottom surface of the perforation is desirably about 0.040 inches (twice the metal thickness) and the perforation itself is also displaced an additional 0.020 inches (the thickness of the metal). The gap and the thickness of the metal combine for a total displacement of three times the thickness of the metal. Other perforation dimensions are also possible, and may further depend on whether the user desires to remove or retain the perforation or aperture.

Referring now to Figs. 1 through 5, a forming head assembly 21 and a mandrel assembly 22 with cover plates 65, 67 cooperate to form the perforated metal strip 15 into a spiral pipe 23. The forming head assembly 21 includes a base 27 which is detachably secured to a forming head table 28. A clamp 26 is used to secure the forming head base 27 to the forming head table 28. As best shown in Figs. 5 and 6, the forming head assembly 21 also includes a forming head 29 which is bolted to the forming head base 27. The forming head 29 is enclosed around a lateral bore 30. In one embodiment, the metal strip 15 is formed inside of the lateral bore 30 into a spiral pipe having a diameter of approximately one inch to about five inches. Helical grooves 32 are provided for the formed edges 15a of the strip 15 and the resulting lockseam 24. Grooves 32 help guide the helically-wound strip 15 and spiral pipe 23 through the forming head 29. The inner diameter of the lateral bore 30 determines the outer diameter of the spiral pipe 23. If the diameter of the spiral pipe is to be varied, a forming head 29 with a different diameter lateral bore 30 should be used. Interchangeable forming heads with
different diameter lateral bores can be used in a preferred embodiment of the present invention. In one embodiment, the pipe forming apparatus of the present invention may be used to make spiral filter pipe one to two inches in diameter from a one and one-half inch wide perforated metal strip 15. It is expected that spiral pipe as small as one-half inch (1/2 inch) in diameter can be made with the pipe forming apparatus 10 of the present invention. The present invention is not limited to making perforated filter pipe and may also be modified to produce larger or smaller pipe diameters using wider strip.

The forming head 29 mates with a removable inset 33. The inset 33 is held in place by pins (not shown). The radius of curvature of the removable inset 33 is smaller than the radius of curvature of the lateral bore 30. The inner surface of the removable inset 33 can be coated with a friction reducing material. The removable inset 33 is intended to prevent the strip 15 from locking up as it is driven around the lateral bore 30 of the forming head 29.

Referring to Figs. 5-7, a lock seam closing roller assembly 50 is positioned on top of the forming head 29. The rotational axis of the lock seam roller head 52 is oriented in a laterally angled position, as shown in Figs. 5-7. The lock seam closing roller head 52 protrudes through an opening in the top of the forming head 29 and contacts the folded helically wound strip edges. The roller head 52 is rotationally attached to an end of a shaft 51. Bearings inside the roller head 52 allow the roller head to be passively rotatable. The shaft 51 passes through an upper roller holder 53 that is attached to the top of the forming head 29 by threaded bolts 54. The roller shaft 51 is also eccentric and has a hexagonal end 51a that can be accessed through an opening in the upper roller holder 53 (see Fig. 7). The lock seam roller head 52 can be adjusted vertically relative to the helically wound strip 15 by turning the hexagonal end 51a of the shaft 51. A set screw 56 adjusts the lock seam roller head 52 axially with respect to the folded, helically-wound strip edges. A nut 55 holds the set screw 56 in place. In this top view of the forming head, bore 45 is shown in phantom.

Referring to Figs. 1, 2 and 5, the spiral pipe 23 is not only formed inside the enclosed forming head 29, but at the same time is formed around a
completely cylindrical mandrel 60. The clearance between the mandrel 60 and the surface of the lateral bore 30 in the forming head 29 is approximately twice the thickness of the metal strip, plus 0.006-0.003 inches each side. The closely controlled clearance between the mandrel 60 and enclosed forming head 29 provides greater accuracy in producing pipe having a consistent diameter. If there is too much clearance, the strip 15 will buckle in the forming head. If there is too little clearance, the strip 15 will lock up inside the forming head. For a more detailed discussion of a suitable pipe forming apparatus, reference is made to U.S. Patent No. 4,924,684 issued May 15, 1990. The entire disclosure of U.S. Pat. No. 4,924,684 is incorporated by reference. The preferred embodiment of the present invention also includes an apparatus for slitting the spiral pipe made with the pipe forming apparatus 10. The present slitting apparatus 75 includes many elements of the slitting apparatus disclosed in U.S. Pat. No. 4,706,481 and U.S. Pat. No. 4,924,684. The descriptions of the slitting apparatus contained in these patents, as well as the disclosure in their entirety, are hereby incorporated by reference.

Referring now to Figs. 1-4 and 15-18, an inner knife 80 is attached to a boom 81 with a bolt 82. A washer 83 is positioned between the bolt 82 and the inner knife 80. The inner knife 80 has an oversized central opening 84 (not shown), which permits the position of the inner knife to be adjusted in any radial direction relative to the inner surface of the spiral pipe 23. In general, the knife 80 will be centered within the spiral pipe 23. It is preferred that the inner knife can be centered within the pipe without an oversized opening 84.

The boom 81 passes through the mandrel 60, and is free floating within the mandrel 60. Thus, the boom 81 does not necessarily rotate with the mandrel, but is designed to rotate only during this slitting process. The boom is preferably passively rotatable, i.e., it is rotationally driven by the overlapping inner knife 80 and outer knife 110 during the slitting process. Other embodiments are possible, however, wherein the boom is drivably rotatable. To provide the passive rotation, the end of the boom 81 opposite the inner knife 80 is surrounded by combination needle/thrust bearings (not shown). These needle/thrust bearings can be obtained from IKO Bearings, of Arlington
Heights, Ill. The bearings are held in a boom holder assembly 86 by an annular support member 87, a lock washer 88, and a lock nut 89.

The boom holder assembly 86 has an upper section 90 and a lower section 91. Each section has a central semi-cylindrical cavity which abuts the annular support member 87. The upper section 90 and the lower section 91 are clamped to each other by a plurality of allen bolts 92. The lower section 91 is mounted on an attachment block 93, and fixed thereto by allen bolts 94. The attachment block 93 passes between guide shafts 95, and is secured to a shaft connector 96 by allen bolts (not shown). A plurality of allen bolts 97 squeezed together the ends of the shaft connector 96 around the guide shafts 95, so that the shaft connector 96 slides axially with the guide shafts 95. The guide shafts 95 pass through openings in the forming head table 28, and slide through the bearing housings 98, which preferably include THK Slide Bearing SC 30 assemblies. There are four such bearing housings 98, each of which is attached to the top of a mounting leg 99 by allen bolts 101. The four mounting legs 99 are provided to support the mandrel assembly 22 and the slitting apparatus 75 at the correct height with respect to the forming head table 28 and the pipe 23. The mounting legs 99 are attached to the base plate 102 by allen bolts 103. The base plate 102 is attached to the pipe forming machine 10. Oval pivot slots (not shown) are provided in the base plate 102, so that the pipe cutting apparatus can be pivoted about the center of the inner knife 80. Most of the bolts that connect the various components of the boom assembly 86 pass through oval slots so that the position of the components can be adjusted relative to each other.

As can be seen in Fig. 1-4 and in Figs. 15-18, an outer knife 110 is generally positioned below the inner knife 80 and outside of the pipe 23. The outer knife is held in a vertical holder 111 by a lock washer and lock nut 114 that are connected to the shaft of the knife. Bearings (not shown) permit the outer knife 110 to be passively rotatable, that is, rotationally driven by contact with the rotating pipe 23. The vertical holder 111 is attached to a slide bearing assembly 111a (not shown) (e.g., THK Roller Table Type VRM 3105A). The slide bearing assembly 111a is also attached to the central
portion of a knife slide block 112. The vertical holder 111 and outer knife 110 can thus slide up and down relative to the knife slide block 112. The knife slide block 112 has two cylindrical openings through which the guide shafts 95 pass. A plurality of allen bolts 113 squeeze together the sides of these openings around the shafts 95, so that the knife slide block 112 is also affixed to and slides axially with the guide shafts 95.

During the pipe forming process, the outer knife 110 should be maintained in a standby position, where it will not interfere with the spirally moving pipe 23. When it is time to cut the pipe, the outer knife blade is moved to a cutting position, where it punctures the spiral pipe 23 and overlaps the inner knife 80 (see, e.g., Fig. 17).

The outer knife blade 110 is moved into and out of its cutting position by the pneumatic cylinder assembly 116. This assembly includes a pneumatic cylinder 117 that controls a piston 118. A lower clevis 119 is attached to the piston 118 and a set of links 120, 121. The lower links 120 are pivotally connected to the clevis 119 and an arm 122 which is integral with and extends from the central portion of the knife slide block 112. The upper toggle links 121 are pivotally connected to the clevis 119 and the bottom of vertical holder 111. Thus, when the piston 118 is fully extended, the vertical holder 111 and outer knife 110 will be raised vertically into the cutting position where the cutting edges of the inner and outer knives overlap and puncture the pipe 23. See Figs. 2, 4, and 17. When the piston 118 is retracted into cylinder 117, toggle links 120 and 121 will collapse and pull down the vertical holder 111 and the outer knife 110 to the standby position. See Fig. 1.

An upper clevis 123 is attached to the top of the cylinder 117. The upper clevis 123 is pivotally connected to a threaded shaft 124. Nuts 125 secure the threaded shaft 124 to one end of a cylinder support bracket 126. The other end of the cylinder support bracket 126 is attached to the central position of the knife slide block 112. The vertical holder 111 and slide bearing assembly 111a (not shown) are connected to the opposite side of the knife slide block 112. As a result of its connection to the knife slide block 112, the cylinder support bracket 126 and other components of the pneumatic cylinder
assembly 116 move axially with the guide shafts 95. The threaded shaft 124 of the pneumatic cylinder assembly 116 permits adjustment of the standby and cutting positions of the lower knife 110.

As shown in Fig. 1, and also in Figs. 15-18, the slitting apparatus 75 of the present invention also includes a pipe support assembly 230. The support assembly 230 includes a support sleeve 231 mounted on a sleeve holder 232. The sleeve is removably affixed to the sleeve holder 232 by bolts 235. The sleeve holder 232 is secured to an upper bracket 233 by bolts 234 extending vertically through the sleeve holder 232 and upper bracket 233 such that it is fixed in a radial direction with respect to the pipe 23.

During the pipe forming process, the support assembly 230 is maintained in a fixed position where it does not interfere with the spirally moving pipe 23 (see, e.g., Figs. 16 and 18). When it is time to cut the pipe and the outer knife 110 is moved to its cutting position, the support sleeve 231 will keep the pipe from being deflected where it contacts the spiral pipe (see, e.g., Fig. 17). The support sleeve 231 is positioned at the end of the pipe and preferably surrounds the pipe. The support sleeve 231 thus operates to prevent the boom 81 from deflecting upward or laterally in response to the force exerted by the outer knife 110. Additionally, the sleeve prevents the pipe material at the cut end from flaring out as it is being cut.

With small diameter pipes (i.e., approximately 1 inch), it is difficult to keep the boom 81 rigid when the outer knife 110 engages the pipe 23. If the boom 81 deflects away from the outer knife 110 during the cutting process, the inner and outer knives will move apart and will not overlap to cut the pipe. The support sleeve 231, by limiting deflection of the pipe, maintains the inner and outer knives in an overlapping relationship during the slitting process. The support sleeve 231 is preferably constructed from a heat-treated steel such as AISI A2 steel. It may be noted that many of the components of the pipe forming apparatus 10 and slitter apparatus 75 are made of tool steel (58°-62° HRC), CRS or Mehanite.

Referring to Fig. 15, the sleeve 231 substantially surrounds the pipe material to be cut. The sleeve is configured such that a predetermined
distance, preferably 0.005 inch, is maintained between the outer diameter of the pipe and the inner diameter of the sleeve. The sleeve therefore preferably has an inner diameter 241 that is about 0.010 inches greater than the predetermined outer diameter of the pipe being cut. Different size support sleeves 231 may be constructed to accommodate specific pipe diameter requirements. In one embodiment, the sleeve 231 surrounds the entire circumference of the pipe where the pipe enters the sleeve and surrounds approximately 270 degrees of the pipe's circumference leaving a gap where the outer knife engages the pipe. In another embodiment, the sleeve may surround the entire circumference of the pipe and not have a gap. When the embodiment of a sleeve with no gap is used, the outer knife engages the pipe outside of the sleeve.

Figs. 16-18 illustrate the extended upper portion 236 of the sleeve. The upper portion of the sleeve 232, opposite the outer knife 110, preferably has a width of 1.5 inches extending axially from approximately 1.3 inches behind the cutting edge of the inner knife 80 toward the pipe forming portion of the apparatus to approximately 0.2 inches past the cutting edge of the inner knife. The sleeve also includes a beveled or tapered receiving edge 237. The tapered receiving edge preferably extends around the entire inner diameter of the sleeve and aids in guiding the pipe through the sleeve. The recessed lower portion 238 of the sleeve 231 permits necessary clearance for the outer knife 110 to engage the pipe 23.

As best shown in Figs. 19 and 20, the support sleeve 231 also preferably includes an angled edge 244. The angled edge 244 is positioned on one side of the recessed lower portion 238 of the sleeve 231. When a section of pipe rotates between the inner and outer knives during a cut, sharp or jagged edges may develop at the newly formed pipe edges. The pipe forming and cutting apparatus 10 may jam due to the sharp edges catching on the sleeve 231 as the newly cut edges are rotated in the sleeve. A more gradual transition to the preferred 0.005 inch clearance between the sleeve 231 and pipe is accomplished with the angled edge 244. In one embodiment, the angled edge 244 forms approximately a 15 degree angle with the vertical
axis. In other preferred embodiments, this angle may be optimized for the type of material to be cut or for different cutting applications. By providing a gradual transition for a freshly cut edge of a pipe rotating in the sleeve, the angled edge minimizes potential jamming difficulties.

The description so far has focused on pipe forming machines using a mandrel inside the forming head, the metal strip being wrapped around the mandrel by the forming head to form the filter pipe. Other embodiments of pipe forming machines may also be used to form pipes, especially those for pipes having larger diameter, such as 2" to about 5" in diameter (from about 50 mm to about 125 mm). Certain embodiments are further described in U.S. Pat. No. 4,706,481, the contents of which are hereby incorporated by reference. It is easier for large diameter pipes to utilize a boom and an inside roller and an outside roller, rather than a mandrel and forming head.

One embodiment of a machine with these features is depicted in Fig. 21. A pipe forming machine 200 for forming larger diameter pipe includes a boom 240 and a forming head 241. The forming head 241 is mounted to the forming head base 242 by clamping bars 249, 251 and bolts 253. In a preferred embodiment, the forming head base is movable on guide rails 255. The forming head 241 curls the metal strip 15 into a cylindrical spiral, whereby the opposing preformed edges of the strip 15 mesh. The meshed edges are then compressed between a support roller 243 and a clinching roller 245 to form a lockseam. The metal strip, as described above for other pipe forming machine embodiments, is continuously pushed by the drive rollers so that a hollow cylindrical metal pipe is continuously produced with a spiral lockseam. The clinching roller 245 is moved into and out of its clinching position by a conventional hydraulic cylinder assembly 247. The hydraulic cylinder assembly 247 includes a yoke 257 which holds the clinching roller 245. The yoke is appended to a piston rod 263 which slides in and out of cylinder head 261. The cylinder head 261 is attached to the cylinder barrel 259 by bolts 265. The hydraulic cylinder assembly 247 provides the pressure on clinching roller 245 to close the lockseam on the filter pipe.

Referring again to Fig. 4, the support assembly 230 preferably attaches
to the upper bracket 233 which is connected to opposite ends of the knife slide block 112. The upper bracket 233 includes an overhead member 233-U bolted to the tops of two vertical members 233-F and 233-B. The bolts pass through oval slots in the overhead member 233-U, which permit angular adjustment of the support sleeves position. The support sleeve is connected to the overhead member 233-U via the sleeve holder 232 and support bolts 234. Each vertical member of the upper bracket 233 includes oval slots 233-S. These oval slots 233-S permit the height of the overhead member 233-U, and hence the position of the support assembly 230, to be adjusted.

Although fixed in a radial direction with respect to the pipe 23, the support sleeve 231 moves in the axial direction of the pipe during the cutting operation because the upper bracket 233 is connected to the guide shafts 95 via the knife slide block 112. A slide 147 is provided to catch pipe sections 23a that have been severed by the slitter apparatus 75. The slide 147 has a vertical flange 148 that is connected to the cylinder support bracket 126. Thus, the slide 147 also moves in unison with the cutting knives 80, 110 and support sleeve 231 during the cutting operation.

When the outer knife 110 punctures the pipe 23 and overlaps the inner knife 80, the guide shaft system allows the axially moving pipe to push the overlapping knives and the support sleeve, and their connected components, in unison with the pipe. An axial motion cylinder assembly 150 is provided to assist the axial movement of the pipe cutting apparatus 75. As best shown in Fig. 2, this assembly 150 includes a pneumatic cylinder 151 which is supported by a piece of flat stock 152, and held in place by a nut 153. The flat stock 152 is attached to a mounting leg 99. The piston 154 is secured to a second piece of flat stock 155 by a pair of nuts 156. The second piece of flat stock 155 is bolted to the central inner portion of the shaft connector 96. When air is supplied to the cylinder 151 in one direction, the piston 154 extends out of the cylinder, and pushes the shaft connector 96, and its connected components, in the axial direction of the pipe 23. When the air to the cylinder 151 is reversed, the piston 154 retracts and pulls the inner and outer knives 80, 110, back to their starting or “begin-cut” position.
A stop/shock-absorber mechanism 160 is provided to fix the begin-cut position of the inner and outer knives. (See Fig. 2.) This mechanism comprises a mounting plate 161 which is attached to the forming head table 28. A commercially available hydraulically-dampened plunger 162 extends through the mounting plate 161 in the axial direction of the pipe. The plunger 162 is held in place by nuts 163, which mate with the threaded portions of the plunger 162. A plastic tip 164 is mounted on the piston (not shown) of the plunger 162. The stop/shock-absorber assembly 160 serves two functions. First, it serves as a stop, which sets the begin-cut position of the pipe slitting apparatus 75. When the axial motion of the piston 154 fully retracts, a strip of flat stock 165 attached to the upper bracket 233 comes to rest against the plastic tip 164 of the fully retracted plunger 162 as shown in Fig. 2. Thus, the nuts and threaded portions of the plunger 162 can be adjusted to set the begin-cut position. In the second function, when the piston 154 extends and pushes the upper bracket 233 and flat strip 165 away from the stop/shock-absorber mechanism 160, a spring (not shown) in the plunger 162 pushes its piston (not shown) and plastic tip 164 out of the plunger 162. When the upper bracket 233 and flat strip 165 return to the begin-cut operation, they will push the plastic tip 164 and its piston into the plunger 162, until the upper bracket 233 returns to the begin-cut position. While the piston is pushed back into the plunger 162, it provides a hydraulic cushion or shock-absorber effect on the upper bracket 233 and its connected components.

A proximity sensor 170 is also mounted in the mounting plate 161 adjacent to the stop/shock absorber mechanism 160. The sensor 170 is connected to the slitter control circuit, and prevents the slitting process from beginning if the slitter is not completely in its begin-cut operation. If the slitter is not in its begin-cut position and the slitting process begins, the axial motion piston 154 will reach its end of travel before the pipe 23 is fully severed.

In the pipe forming machine 10 a perforated strip of metal 15 is pulled into the roller housing 16 by the drive rollers 17 and 18. In the roller housing 16, the strip is corrugated and the edges of the strip are formed in the shapes desired to produce a spiral lockseam. Drive rollers 17 and 18, or drive rollers
17, 17b, 18, 18b then perforate the strip and push the perforated, corrugated and edge-formed strip through the guide plates 19 and 20 and into the forming head assembly 21. The strip is driven around the rotatable mandrel 60 and inside the lateral bore 30 of the forming head 29. The metal strip is driven between the mandrel 60 and inside the lateral bore 30 of the forming head 29. The metal strip is driven between the mandrel 60 and forming head 29 in a helical manner, so that the outer edges of the strip are positioned adjacent to each other in helical fashion. The folding rollers 36 and 37 cooperate to fold the adjacent, mated edges of the helically wound strip. The lockseam closing roller 52 compresses the folded strip edges against the mandrel 60 to form a tight lockseam 24. During the pipe forming operation, the mandrel 60 is passively rotatable and pivotable, thereby eliminating friction that might otherwise cause the helically wound strip and pipe to lock up between the mandrel 60 and forming head 29.

As the spiral pipe production continues, the pipe 23 moves out of the forming head block 29 in a helical fashion. That is, the pipe 23 moves in its axial direction while it rotates. During the pipe production process, the outer knife 110 is in its standby position, as well as in the begin-cut position. Thus, the pneumatic cylinder assemblies 116, 150 have their respective pistons fully retracted. When the pipe 23 reaches its desired length, air is sent to both of these pneumatic cylinder assemblies to fully extend their respective positions. Thus, the pneumatic cylinder assembly 116 pushes the outer knife 110 upward so that it punctures the pipe 23 and overlaps the inner knife 80. The pneumatic cylinder assembly 150 extends its piston, which pushes all of the components and outer knives and the support sleeve, in the axial direction of the pipe. As the pipe forming machine 10 continues to produce the pipe 23 in a spiral manner, the pipe moves axially with, and rotates between the overlapping inner knife 80 and the outer knife 110. After the pipe completes one revolution, the section of the pipe 23a in front of the overlapping knives will be completely severed and will fall into slide 147.

Once the cutting process is complete, the air supplied to the pneumated cylinder assemblies 116, 150 will be reversed. As a result, the outer knife 110
will be returned to its standby position, and the piston 154 will pull all the
components connected to the guide shafts 95, including both knives and the
support sleeve, back to the begin-cut position.

Referring now to Figs. 2, 8 and 14, to operate the cutting apparatus 75
in an automatic mode, an electrical encoder 27' is coupled to the lower drive
roller 17, or lower drive rollers 17 and 17b, of the pipe producing machine 10
by a pulley belt 28'. The encoder 27' is adapted to generate pulses
 corresponding to the number of rotations of the lower drive roller 17 or 17b.
These pulses are transmitted over a cable 29' to a control box 44'. The
control box 44' is programmed to check for a first pulse count corresponding
to the desired length of the pipe, a second pulse count corresponding to a
slow-down point for pipe production, and a third pulse count corresponding to
the amount of axial travel of the pipe required for the pipe to be completely cut
by the cutting apparatus 75. Three counters 45', 46' and 47' are included in
the control box 44'. These counters can be incremented or decremented, one
pulse at a time. The first pulse count (i.e., pipe length) is set with the first
counter 45', the second pulse count (i.e., slow-down point) is set with the
second counter 46', and the third pulse count (i.e., cut length) is set with the
third counter 47'. The control box 44' sends pneumatic signals to the
pneumatic cylinders 117, 151 over line 48' in response to the first, second
and third pulse counts.

The control box 44' also has four control switches 147', 148', 149',
and 150'. A first control switch 147' selects manual or automatic control of
the pipe cutting apparatus 75. In the manual mode, the second, third and
fourth control switches 148', 149' and 150' are operable to manually actuate
the pneumatic cylinders 117, 151. That is, the second control switch 148'
may be used to move the piston rod 118 in and out of its cylinder 117, and
thereby move the outer knife 110 into and out of its cutting position. The third
control switch 149' may be used to move the piston 154 in and out of its
cylinder 151, and hence slide the inner knife 80, outer knife 110 and support
sleeve 231 in the axial direction of the pipe 23. When the first control switch
147' is put into automatic mode, the second, third and fourth control switches
148", 149" and 150" are deactivated, and all three counters 45", 46" and 47" are reset to zero. The pipe cutting apparatus 75 will automatically cut the pipe 23 into sections 23a as pipe is produced on pipe forming apparatus 10.

The control panel 13 is provided with an on/off switch for the pipe cutting machine 75 and three speed adjustment knobs 135", 136" and 137". The first speed adjustment knob 136" controls the production speed of the pipe as it is formed with the pipe forming machine 10. The second speed adjustment knob 136" controls the speed at which the pipe is formed prior to the outer knife 110 moving from its standby position to its cutting position. In order to consistently obtain pipe sections that are cut to the same length, it is important that the pipe 23 travels at a constant, relatively slow speed while the outer knife 110 moves from its standby position to the cutting position. A relatively low speed minimizes the effect of any pulse count errors on the length of the pipe sections 23a. Thus, prior to moving the outer knife 110 to the cutting position, it is preferred that the pipe production is slowed from its fastest, most efficient production speed to a transitional, "slow-down speed."

The second speed adjustment knob 136" controls this speed. The third speed adjustment knob 137" controls the speed of the pipe production while the outer knife 110 moves to, and is in, the cutting position where it cooperates with the inner knife 80 and support sleeve 231 to cut the pipe 23. The cutting speed is usually set at one-half the production speed, or whatever speed is convenient. The speed control knobs 135", 136", 137" can be used to adjust the production speed, slow-down speed and cutting speed of the pipe cutting apparatus 75 during both manual and automatic modes of operation.

The cutting apparatus 75 operates in conjunction with the pipe producing machine 10 in automatic mode in the following manner. The spiral pipe forming process is initiated with the pipe forming machine 10 in a known way. When the leading edge of the pipe 23 begins to leave the forming head 29, the pipe producing machine is temporarily halted, and the pipe cutting apparatus 75 is energized by turning on the on/off switch on the control panel 13. The pneumatic cylinder assemblies 116, 150 are initialized to be in their standby positions, so that the outer knife 110 does not overlap the inner knife
80. The first counter 45°, the second counter 46°, and the third counter 47° are set to zero. Air is sent to the axial motion cylinder 151 to fully retract piston 154, so that the inner and outer knives are in the begin-cut position.

Typically, the pipe cutting apparatus 75 will be initially operated in its manual mode to cut a few sections of pipe to determine the optimum positional adjustments for the inner knife 80, outer knife 110 and support sleeve 231. The pipe cutting apparatus 75 then run in and out of automatic mode a few times to find the optimum settings for the production speed, slow-down speed, cutting speed, and the pulse counts for the pipe length, slow-down point, and cut length. Once these variables are determined, the pipe cutting apparatus 75 is ready for continuous automatic operation.

In a typical example of automatic operation, the first counter 45° may be set to 1250 pulses for pipe length, the second counter 46° may be set to 1100 pulses for the slow-down point, and the third counter 47° may be set to 375 pulses for the cut length. A cutting cycle begins by resetting all three counters 45°, 46°, 47° to zero, and by cutting the part of the pipe 23 that extends past the inner and outer knives will in the begin-cut position. This part of the pipe will be referred to as the "leading section".

When the pulse count is at zero in all three counters, the control box 44° sends a first pneumatic pulse signal, via line 48°, to the pneumatic cylinder assembly 116. The piston 118 is thereby energized and pushed downward to its extended position. The outer knife 110 is thereby moved to the cutting position where the cutting edges of the inner and outer knives puncture the pipe 23. The first pneumatic pulse signal also reverses the direction of air supplied to the axial motion cylinder 151, so that the piston 154 pushes the shaft connector 96, and all components connected to the guide shafts 95, axially with the pipe. The pipe forming machine 10 continues to produce the pipe 23 in a spiral manner. The pipe 23 thus moves axially with, and rotates between, the overlapping inner knife 80 and the outer knife 110. The encoder 27° generates a train of pulses that correspond to the length of the next section of pipe being formed, which has its leading edge at the overlapping knives. This section of pipe will be referred to as the "new
section.” All three counters 45°, 46°, 47° count in unison as the new section of pipe is formed and the leading section of pipe is severed.

The guide shafts 95 allow the inner and outer knives to move in the axial direction of the pipe under the forces provided by the new section of pipe pushing on the overlapping knives and the extension of the axial motion piston 154. Thus, the inner knife 80, outer knife 110 and support sleeve 231 cooperate to cut the complete circumference of the leading section of pipe as the pipe moves axially and rotates between the inner and outer knives. The third pulse count will be set at the number of pulses corresponding to the axial travel corresponding to slightly more than one pipe rotation. It is generally preferred to have a little overlap in the cut to assure that the leading pipe section is completely severed.

When the third pulse count is reached, the third counter 47° stops counting, but the first and second counters 45° and 46° continue to count as the new section of pipe continues to be produced. Also, the control box 44° sends a second pneumatic pulse signal to the pneumatic cylinder assemblies 116, 150 along line 48°. This second pneumatic signal indicates that the cutting process is completed, and thus operates the pneumatic cylinders 117, 151 to fully retract their respective pistons. The outer knife 110 is then moved to its standby position. The air supplied to the cylinder 151 is also reversed, so that the piston 154 pulls the cutting assembly 75 mounted on the guide shafts 95 back to its begin-cut position. When the third pulse count is reached, the new section of pipe also stops being produced at the cutting speed, and begins to be formed at the production speed.

The new section of pipe will continue to be produced at the production speed, and the first and second counters 45°, 46° will continue to count pulses, until the second pulse count is achieved. At that time, the slowdown point will be reached. The second counter 45° will stop counting, and the new section of pipe will be formed at the slow-down speed. The new section of pipe will continue to be formed at the slow-down speed, and the first counter 45° will continue to count pulses, until the first pulse count is reached. The first pulse count indicates that the new section of pipe has reached its desired
length. When the first pulse count is reached, all three counters are reset to zero, and cutting process just described is repeated for the new section of pipe. The same cutting process will continue to be repeated as additional sections of pipe are produced.

The control scheme just described for the pipe cutting machine 75 is preferred because the pulse counts for the pipe length, slowdown point and cut length can be set independently, and the cut length is automatically accounted for in the pipe length. Moreover, the foregoing control scheme is preferred for cutting the spiral pipe into sections up to approximately five feet in length. For longer sections of pipe, the first pulse counter can be eliminated, and a limit switch connected to the pipe runoff table can be used to indicate that the desired pipe length has been reached. Other control schemes and considerations are disclosed in U.S. Pat. No. 4,823,579 issued Apr. 25, 1989. The control schemes disclosed in that patent, as well as all other disclosures in that patent, are hereby incorporated by reference.

The invention may be practiced in many ways. One embodiment of the invention is a method of forming a perforated spiral pipe. One step of the method is to draw coilstock or a strip of sheet metal into a machine for forming spiral pipe. A second step is to form indentations or perforations in the strip, which may be formed by the same drive rollers that propel the strip into the machine. The method includes one or more steps of forming seal forms on the edges of the strip, and then forming the strip into a spiral. The edges of the strip are then sealed to form a lockseam, and a desired length of pipe is cut and released from the machine. The method may include other steps as desired for further finishing the pipe so produced.

It should be understood that changes and modifications to the preferred embodiment described above will be apparent to those skilled in the art. It is intended that the foregoing description be regarded as illustrative rather than limiting, and that it is the following claims, including all equivalents, which are intended to define the scope of the invention.
WHAT IS CLAIMED IS:

1. An apparatus for forming spiral pipe from a metal strip, the apparatus comprising:
   forming rollers for forming lateral edge portions of the metal strip;
   a forming head having a lateral bore;
   a forming tool extending into the lateral bore of the forming head;
   a closing assembly for coupling and compressing lateral edge portions
   of the metal strip into a lockseam of a pipe; and
   rollers for perforating the metal strip and driving the metal strip around
   the forming tool, against an interior surface of the forming head, and in an
   axial direction, wherein the lateral edge portions of the strip mate and are
   coupled and compressed to form a lockseam and provide a continuous spiral
   pipe.

2. The apparatus of Claim 1, wherein the rollers for perforating yield
   perforations selected from the group consisting of square and rectangular
   perforations.

3. The apparatus of claim 1 wherein the rollers for perforating the metal
   strip and driving the metal strip comprise a first set and a second set of rollers.

4. The apparatus of claim 1 wherein the forming tool extending into the
   lateral bore of the forming head is a mandrel and the closing assembly
   includes at least one roller protruding through an opening in the top of the
   forming head.

5. The apparatus of Claim 1 wherein the forming tool is a boom
   extending into the lateral bore of the forming head and the closing assembly
   includes a support roller inside the forming head and a clinching roller.

6. The apparatus of Claim 1, further comprising a cutting assembly for
   cutting a pipe section from the spiral pipe.
7. An apparatus for forming spiral pipe from a strip of metal, the apparatus comprising:
   rollers for forming edge portions of the strip;
   a forming head for providing an external guide for the metal strip, the forming head having an entrance for the metal strip and an interior surface which has a predetermined radius of curvature;
   a mandrel rotatable about its centerline, positioned inside the forming head, the mandrel providing a guide for an interior surface of the metal strip and a compression surface for forming a lock seam;
   rollers for perforating and driving the metal strip into the forming head entrance, around the mandrel, against the interior surface of the forming head, and in an axial direction, wherein the edges of the strip mate to form a spiral cylinder, the rollers for perforating and driving only contacting the metal strip prior to entry into the forming head entrance; and
   a closing assembly external to the mandrel for deforming and coupling the mated edges of the strip to form a lockseam in a spiral pipe.

8. The apparatus of Claim 7, wherein the rollers for perforating yield perforations selected from the group consisting of square and rectangular perforations.

9. The apparatus of claim 7 wherein the rollers for perforating and driving the metal strip comprise a first and a second set of rollers, each of the sets of rollers for performing one of perforating and driving the metal strip.

10. The apparatus of Claim 7, further comprising a cutting assembly for cutting a pipe section from the spiral pipe.
11. A method of forming a filter pipe, the method comprising:
drawing a strip of sheet metal into a forming machine;
forming seal forms on a first edge and a second edge of the sheet
metal;
drawing the metal and forming perforations in the sheet metal after the
seal forms are formed;
forming the strip into a spiral;
sealing the first and second edge of the sheet metal into a lockseam;
and
cutting a filter pipe from the formed strip.

12. The method of Claim 11, wherein the perforations are substantially
in the form selected from the group consisting of a rectangle and a square.

13. The method of Claim 11, wherein the perforations are severed
from the sheet metal.

14. The method of Claim 11, wherein the perforations are retained on
the sheet metal and are raised from a surface of the sheet metal to a height of
from about one to about three times a thickness of the sheet metal.

15. The method of Claim 11, wherein the perforations are from about
thirty percent to about seventy percent of a surface area of the filter pipe.

16. The method of Claim 11, wherein a thickness of the sheet metal is
from about 0.010 inch to about 0.030 inch (from about 0.25 mm to about 0.76
mm).
17. The method of Claim 11, wherein the step of perforating the metal is completed before the step of drawing the metal.

18. A punch for perforating sheet metal, the punch comprising:
   a roller having a plurality of protrusions radially extending from the roller, the protrusions arranged in at least two circumferential rows on the roller, the at least two circumferential rows staggered on a circumference of the roller, wherein the protrusions cause at least one of openings, perforations and corrugations in the sheet metal.

19. A combination of the punch according to Claim 18 and a die, the die comprising a roller and at least two grooves for mating with the protrusions.

20. The combination of Claim 19, further comprising a drive gear on at least one of the punch and the die.

21. The punch according to Claim 18, wherein the at least two circumferential rows are staggered at an angle of from about ten degrees to about thirty degrees.

22. The punch according to Claim 18, wherein the protrusions form at least one of openings, perforations and corrugations in the sheet metal, but does not sever scrap from the sheet metal.

23. The punch according to Claim 18, wherein the protrusions form at least one of openings, perforations and corrugations in the sheet metal, and do sever scrap from the sheet metal.

24. The punch according to Claim 18, wherein the plurality of protrusions have sharp edges on two sides and radiused edges on two sides.
25. The punch according to Claim 18, wherein a depth of the punch is from about two to about four times the thickness of the sheet metal.

26. A filter pipe, comprising:
   sheet metal having a first edge and a second edge, and also having a first end and a second end;
   a lock-seam formed by locking the first edge to the second edge, in forming a spiral-shaped pipe; and
   a plurality of perforations in the filter pipe allowing communication between an inside of the filter pipe and an outside of the filter pipe, at least one side of the perforations forming an angle from about ten to about forty degrees to a plane of the sheet metal.

27. The filter pipe of Claim 26, wherein an outside diameter of the pipe is from about 0.5 inches to about 1.5 inches.

28. The filter pipe of Claim 26, where the perforations are about thirty percent to about sixty percent of a surface area of the filter pipe.

29. The filter pipe of Claim 26, wherein the perforations are substantially in a form selected from a group consisting of a rectangle and a square.

30. An oil filter further comprising the filter pipe of Claim 26.
FIG. 12d

FIG. 12e

FIG. 12f
PRIOR ART

FIG. 12g
TWO STEP OPERATION

---

15
15
15
15
15e
15
FIG. 22

210
Draw strip into forming machine

211
Form seal forms on edges of strip

212
Form indentations in strip

213
Form strip into a spiral

214
Seal edges to form a lock seam

215
Cut filter pipe
INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER
IPC(7) : B21C 37/12
US CL. : 72/50; 210/437
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
U.S. : 72/49, 50, 186, 187, 368; 210/437, 457, 494.2, 497.1, 498

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
<thead>
<tr>
<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
</tr>
</thead>
<tbody>
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<td>US 475,700 A (OHL) 24 May 1892 (24.05.1892), whole doc.</td>
<td>18, 22</td>
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<td>US 4,507,200 A (MEISSNER) 26 March 1985 (26.03.1985), whole doc.</td>
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☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
  *A* document defining the general state of the art which is not considered to be of particular relevance
  *E* earlier application or patent published on or after the international filing date
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“A” document member of the same patent family

Date of the actual completion of the international search
01 October 2003 (01.10.2003)

Date of mailing of the international search report
17 OCT 2003

Authorized officer
Lowell A Larson
Paralegal Specialist
Tech. Center 3700

Form PCT/ISA/210 (second sheet) (July 1998)
# INTERNATIONAL SEARCH REPORT

## Box I Observations where certain claims were found unsearchable (Continuation of Item 1 of first sheet)

This international report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. □ Claim Nos.:
   because they relate to subject matter not required to be searched by this Authority, namely:

2. □ Claim Nos.:
   because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. □ Claim Nos.:
   because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

## Box II Observations where unity of invention is lacking (Continuation of Item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

Please See Continuation Sheet

1. ✗ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. □ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3. □ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. □ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

**Remark on Protest**

- □ The additional search fees were accompanied by the applicant’s protest.
- ✗ No protest accompanied the payment of additional search fees.

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BOX II. OBSERVATIONS WHERE UNITY OF INVENTION IS LACKING
This application contains the following inventions or groups of inventions which are not so linked as to form a single general inventive concept under PCT Rule 13.1. In order for all inventions to be examined, the appropriate additional examination fees must be paid.

Group I, claim(s) 1-17, drawn to an apparatus and method for forming perforated spiral pipe.

Group II, claim(s) 18-25, drawn to a perforating roller.

Group III, claim(s) 26-30, drawn to a perforated filter pipe.

The inventions listed as Groups I, II and III do not relate to a single general inventive concept under PCT Rule 13.1 because, under PCT Rule 13.2, they lack the same or corresponding special technical features for the following reasons: The apparatus and method of the Group I claims includes the inventive concept of employing the perforating roller(s) to draw the strip through the edge-forming station and drive the strip into the forming head. The perforating roller of Group II includes the inventive concept of staggered rows of perforating punches. The filter pipe of Group III includes the inventive concept of perforations having a specified profile. None of the inventions, as grouped above, requires the inventive concept of any of the other groups, but instead have separate utility one from another. Thus, the separate inventions are not considered to involve the same special technical features required for unity of invention to be present.