MACHINE TO PRODUCE EXPANDED METAL SPIRALLY LOCK-SEAMED TUBING FROM SOLID COIL STOCK

Abstract: An apparatus for expanding metal and forming tubing combines two metal-forming operations into a single process. Tubing, such as that used for filters, is desirably expanded so that air or liquid may pass thru “diamonds” formed in the tubing. Expanding metal and forming tubing is accomplished in a single, continuous process by first slitting and expanding the metal, and then locking its seams to form a spiral pipe. This avoids depending on vendors for delivery of expanded metal at fluctuating prices, eliminates intermediate steps of handling the coils, and eliminates rusting while the expanded steel coils await formation into tubing. Tubing made from expanded metal may be used for air filters, oil filters, water filters, separators and other types of filters. Double-wall HVAC ducting systems or silencers can also use expanded material for reducing heat transfer and noise.
MACHINE TO PRODUCE EXPANDED METAL SPIRALLY LOCK-SEAMED TUBING FROM SOLID COIL STOCK

This application claims the benefit of the filing date of Provisional U.S. Patent Application Serial No. 60/718,974, filed on September 20, 2005, which is hereby incorporated by reference in its entirety.

FIELD OF THE INVENTION
[0001] The field of the invention is that of manufacturing tubing and forming tubing from expanded coilstock, which is typically steel. The field of the invention also includes first forming the expanded coilstock and then directly forming the tubing spirally, which may be used for filters of all types, air, oil, and water, and separators. Such tubing may also be used for heating, ventilating, and air-conditioning (HVAC) systems as well as silencers.

BACKGROUND
[0002] A large potential for small diameter spiral pipes exists in the filtration market, such as automotive oil and air filters, as well the HVAC market, such as insulated duct systems and silencers. These products typically have a perforated inner metal cylinder that is at least one inch diameter, and an outer cylinder mainly to support the filter medium, which is usually paper. Because pipes such as these need to be accurately and cleanly cut in large quantities, a forming and cutting apparatus is necessary. There are several known ways to form and cut a pipe. A pipe may be formed by spirally or helically by winding a continuous strip of metal, and joining adjacent edges of the wound strip to form a spiral lockseam in the pipe, as shown in U.S. Pat. No. 4,567,742. 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, as shown in U.S. Pat. No. 4,706,481.

[0003] The performance of the filter depends on the performance of the spiral pipe, typically an outlet at the center of the filter, where a strong flow of air or
liquid is applied. A reliable and strong filter must be maintained to resist pressure and to insure functioning of the filter. An air filter consists of perforated inside and outside tubes with medium in-between. An end-cap closes one end of the filter, while the other end-cap closes the only medium surface, leaving a central area for inflow/outflow. The filter cleans by applying suction to the open-ended end-cap, drawing air through the filter medium, which retains debris.

[0004] Oil or liquid filters and separators typically have a solid outer tube and a perforated inner tube. The liquid to be filtered or separated is brought through one end between the outer tube and the medium. Under pressure, the liquid flows through the medium, which retains debris, and the liquid then flows through the perforated inner tube and leaves the filter. The filter element, or medium, is typically paper, but need not be, and may be made from any of a number of other materials.

[0005] In a double-wall HVAC system, the outer tube is solid and the inner tube is typically perforated. Insulation medium is inserted between the outer and inner tubes. The purpose of the medium is to reduce noise as well as heat transfer between the transported air and the outside environment. Silencers, made in a similar double-wall manner, are strategically placed into HVAC ductwork systems to reduce noise. The perforations in the center pipe necessary for the filter to function may be achieved in several ways.

[0006] The strip or coil used for the central pipe may be perforated off-line, that is, in a separate operation. Of course, this requires separate operations for perforating the metal. Perforating off-line has some advantages, in that a stock of perforated sheet metal may be accumulated and stored for later use. This technique, however, also has several disadvantages. One disadvantage is that expanded coil is usually purchased from a vendor with expensive expanding machinery, and the price of expanded metal is thus expensive compared to coilstock. Another disadvantage is that inventories of perforated coilstock may tend to accumulate, driving up inventory and thus adding additional manufacturing cost. Another disadvantage is that perforated steel tends to rust. The longer the inventory is kept, the more severe the problem may become. What is needed is a
way of perforating the coilstock in a "just-in-time" manner. Such a technique would avoid the accumulation of inventories of coilstock, would prevent inventories from deteriorating, would help to keep manufacturing costs low, and would eliminate dependence on expanded metal suppliers, with delivery and price variations.

BRIEF SUMMARY

[0007] One embodiment is an apparatus for continuously perforating coilstock and forming tubing. The apparatus comprises first and second cutter stations for receiving and perforating the coilstock, a spreader for receiving and expanding the perforated coilstock, and a tubing machine for receiving the expanded, perforated coilstock and forming the coilstock into tubing. The first and second cutter stations each include a tool for perforating coilstock.

[0008] Another embodiment is an apparatus for continuously perforating coilstock and forming tubing. The apparatus comprises a roll form unit, at least one cutter station for perforating the formed coilstock, a spreader that receives the perforated coilstock and spreads the coilstock, a strip guide plate assembly for re-forming the spread coilstock, a drive roller station for pulling the coilstock through the apparatus, and a pipe forming machine for forming the spread coilstock into tubing and cutting the tubing into a desired length.

[0009] Another embodiment is an apparatus for continuously perforating coilstock and forming tubing. The apparatus comprises a roll form unit for forming sides of the coilstock, a first cutter station for perforating the formed coilstock, a second cutter station for again perforating the perforated coilstock, a spreader that receives the perforated coilstock from the second cutter and spreads the coilstock, a strip guide plate assembly for flattening the spread coilstock, a drive roller station for pulling the coilstock through the apparatus, and a pipe forming machine for forming the spread coilstock into tubing and cutting the tubing into a desired length.

[0010] Another embodiment is a method for forming pipe from coilstock in a single continuous process. The method comprises providing coilstock, forming
edges on opposite sides of the coilstock, introducing a first set of perforations into the coilstock, introducing a second set of perforations into the coilstock between the first set of perforations and expanding the coilstock, and forming the coilstock into tubing.

[0011] In addition to the above-mentioned advantages, the invention also has the advantage of expanding coilstock in a manner that leaves the edges of the coil strip material solid, before it is made into a spirally wound tube. Solid edges make the tube-forming processes easier and the tube itself stronger, compared to a tube with edge-to-edge fully expanded strip material. There are many embodiments of the invention, only a few of which are depicted in the attached drawings and which are discussed in the description below. It will be understood that the drawings and descriptions are meant to be descriptive, not inclusive, and that the invention will be defined by the claims below, and their equivalents.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] Fig. 1 is a frontal view of the seamed, expanded-metal tubing product to be produced by embodiments of the invention;

[0013] Fig. 2 is an elevation view of one embodiment;

[0014] Fig. 3 is a top view of sheet metal as it travels through the forming equipment in one embodiment;

[0015] Figs. 4a, 4b and 4c are cross-sectional views of a profile of the sheet metal as it is processed by the forming machinery;

[0016] Fig. 5 is an elevation view of a first portion of the process, the form roll unit (FRU);

[0017] Figs. 6a, 6b, and 7 are views of rotary dies used to perforate the sheet metal;

[0018] Figs. 7a and 7b are, respectively, elevation and plan views of the sheet metal as it undergoes slitting in two successive steps;

[0019] Fig. 8 is an elevational view of the rotary dies as they slit sheet metal;

[0020] Fig. 9 is a partial cross-sectional view of a cutter station driven side;

[0021] Fig. 10 is a partial cross-sectional view of a first cutter station drive side;
Figs. 11a and 11b are side views of a cutter station and a gauge stop;

Figs. 12a, 12b, and 12c are cross-sectional views of a guide plate assembly;

Fig. 13 is a schematic view of an adjustable sprocket mounted on a hub of a cutter station;

Fig. 14 is a plan view of tooling for the spreader;

Fig. 14a is an elevational view of a retaining hook;

Fig. 14b is a top view of an alternate spreader;

Fig. 14c is a partial cross-sectional view of the alternate spreader of Fig. 14b about line Y-Y;

Fig. 15 is a frontal view of tooling for the spreader;

Fig. 16 is a machine for receiving the spread, formed coilstock and converting it to spiral tubing;

Figs. 17-18 depict processes for forming slit, expanded coilstock and for immediately taking the formed coilstock and manufacturing tubing and cutting the tubing into desired lengths;

Fig. 19 depicts a process for using the cut tubing for customer applications;

Fig. 20 depicts a filter made from a piece of tubing made by the apparatus described below; and

Fig. 21 depicts HVAC tubing made from the apparatus described below.

DETAILED DESCRIPTION OF THE DRAWINGS AND THE PRESENTLY PREFERRED EMBODIMENTS

The machinery and process used to produce expanded metal in a form immediately useful for producing seamed tubing is described below. The product desired is depicted in Fig. 1. Perforated tubing 11 is formed from sheet metal that has been perforated and expanded. The process that expands the metal preferably includes steps to form edges on the sheet metal so that the edges can later be joined to form a continuous cylinder of a desired length. The cylinder includes
expanded metal 12a formed into a cylindrical shape with edges from the sheet metal joined into seams 12b that hold the shape together. The edges that form the seam may require together about 0.75 inches of width (about 19 mm), in addition to the width required to form the tubing.

[0036] The machinery that accomplishes this process begins with steel or aluminum coilstock, or other metal or material as desired, and ends with tubing as depicted in Fig. 1, which is then preferably cut into desired lengths automatically. One embodiment of a processing line 10 that accomplishes this is depicted in Fig. 2. The equipment is preferably mounted rigidly on a base 10a. In one embodiment, the length of the process equipment in Fig. 1 is about 10 feet long. In other embodiments, the process may require longer process lengths for the coil. The process begins with coilstock 14 that is preferably fed from an unwinder (not shown), into a form roll unit (FRU) 13. The form roll unit takes flat coilstock and uses rotary forming dies to process the coilstock into a desired profile (cross-sectional form) so that the coilstock may be more easily processed into the desired end-product. The driving force for moving the coilstock through the process is provided by the drive rollers 15.

[0037] Coilstock 14 with the desired profile now enters a first cutter station 16a. The first cutter station includes rotary dies for a first perforation of the coilstock, part of the process to eventually "expand" the coilstock. If desired, the process may also include a first strip guide plate assembly 16b before entering a second cutter station 17a. The guide plate assembly includes dies or other forming machinery to adjust or "fine-tune" the position of the coilstock before the coilstock advances to the next process. Second cutter station 17a includes rotary dies for a second perforation of the coilstock.

[0038] The coilstock was slit one or more times in order to allow horizontal widening or expansion of the metal. This is accomplished with a spreader 18. The spreader includes dies that channel the slit coilstock through a gradually-widening horizontal path as it travels through the spreader, pulled through by the drive rollers in the spreader station. Two cutter stations are preferred. In general, to achieve close spacing of slits requires two cutter stations, with the most-closely
spaced slits on different cutter stations. This allows for wider and stronger tools. This also avoids placing too many features on a tool too close together, and thus makes it easier to make the tools for the cutter stations. While it is not impossible to produce closely-spaced slits with a single cutter station, it is much easier to avoid high stress on the tooling, to avoid tears and crinkles on the coilstock, and to make the tools more economically, by using two stations rather than one.

[0039] After passing through one or more cutter stations and a spreader, the coilstock has been slit and because of the action of the rotary dies, is at least partly expanded in vertical direction, with metal stretched both above and below the plane of the coilstock, in addition to horizontal spreading. Therefore, a flattening station 15, preferably with drive rollers, is used to flatten the coilstock before further processing. If desired, an additional strip guide plate assembly 19 may be used to adjust the profile of the coilstock before the now slit and expanded metal is fed to a pipe forming head 20 where the coilstock will be wound, formed into a cylindrical coil, and cut to length.

[0040] In order to start the process, it will be necessary to hand-feed coilstock through at least a portion of the line. In addition, it may be necessary during production runs to clear the line if jam-ups or breaks occur. Therefore, it will be helpful to be able to raise the upper portions of the strip guide assemblies. Accordingly, a way should be provided to raise the upper portions of the guide plate assemblies, such as with handwheels 16c, 19b, and 18b to enable operators to raise and remove the upper portions of guide plate assemblies 16b, 19a and the upper portion of spreader 18.

[0041] Fig. 14 depicts a spreader strip guide plate assembly (spreader assembly) 100 that may be used to expand the coilstock after it has been perforated. Spreader strip guide plate assembly 100 receives coilstock (not shown) after the coilstock has been slit. The coilstock is pulled though the process by drive rollers 112. In this embodiment, spreader assembly 100 includes two upper spreader guide plates 101a and 101b, and two lower spreader guide plates 102a and 102b. The plates are mounted on guide plate base 108 which may be secured to spreader base 109, or to the machine base 10a (Fig. 2).
Plate 103 pushes down on upper guide plates 101a, 101b with adapters/handles 104, 105. In order to push down on the plate and thus on the upper guide plates, a large fixed hook 106, see Fig. 14a, is provided, the hook mounted to guide plate base 108 and slidable in and out through slot 107. Hook 106 is in the shape of a large C-clamp that is open on one side and has an upper portion that has internal threads 106b. A threaded rod 111 is assembled through the threaded portion 106b of hook 106. A handwheel 113 is provided and is secured to threaded rod 111 by bolt 114. In order push down on plate 103 to secure in place the upper guide plate portions, a user simply turns the handwheel in the downward direction, reacting threaded rod 111 with internal threads 106b of hook 106, pushing plate 103 and adapters 104, 105 against upper guide plates 101a, 101b. In order to raise plate 103, the hand wheel is turned in the opposite direction to relieve the pressure on plate 103. Plate 103 may then be removed with handles 104, 105. The upper guide plates may then be raised to feed or clear the spreader station. The pressure on plate 103 may be adjusted so that the proper degree of pressure is applied to plates 101a, 101b. A plate, hook, and handwheel may also be used in guide plate assembly 16b.

As the sheet metal travels through the process it changes form, as depicted in Fig. 3. Coilstock 14 leaves the FRU 13 with a flange formed on one side 23 and a channel 24 formed on the other side. Coilstock 14 then enters the first cutter station 16a and is slit by rotary dies, forming a first series of slits or perforations 21 as desired. The coilstock then enters second cutter station 17a and is slit or perforated a second time, with a second series of perforations 22 preferably placed between the first series of perforations 21. After slitting, the slit coilstock 14b enters the spreader 18. Channels in a die (not shown) cause the metal to expand, forming ever-widening diamond-shaped perforations 25, 26, 27 in the coilstock. Drive rollers (not shown) are positioned in the distal portion of the spreader 18 to more directly pull the now-expanded coilstock 14c through the spreader.

The shape, opening size, and percentage of open area in the expanded metal are determined by the width of the coilstock, the number and spacing of the
slits or perforations, and the expanded width of the perforated coilstock. In one embodiment, steel coilstock from 20 to 27 gauge is perforated first with six slits, forming 7 areas between edges of the coilstock. These seven areas are then perforated again, in their centers, thus forming 13 slits between the flange and channel sides of the coilstock.

The shape of the coilstock is important in determining how easily the drive rollers can pull the coilstock through the several stations of the process. The channel and flange sides of the coilstock are also important, because they will eventually be needed to form seams for the desired tubing or piping to have sufficient length. One desired progression of the shape or profile of the coilstock is depicted in Figs. 4a, 4b and 4c. As shown in Fig. 4a, the cross-section 27 of the coilstock as it emerges from the form roll unit preferably has two right-angle bends on the flange side and on the channel side, forming lengths at right angles to the plane of coilstock 27. The channel side bend 27b preferably also has an extra length 27c as shown, at an angle to the metal bent at right angle. This angle may be any suitable angle from about 30° to about 60°. Lengths 27a and 27c preferably are equal so that length H₁ is equal to length H₂.

After perforating, and as discussed above, the coilstock is spread and then passes through drive rollers for flattening. During this process, the profile is re-formed as shown in Fig. 4b. Profile 28 is re-formed so that the coil stock 28 has the shape depicted in Fig. 4b. Flange side 28a continues to have the right angle bend which will eventually be inserted into the channel side form 28b. The stiffer right-angle bend is no longer needed for the guide rollers to pull the sheet metal through several energy-consuming processes. Finally, after the flattening station, the profile 29 of the coilstock is adjusted as shown in Fig. 4c, so that the flange side bend 29a is roughly parallel to the outer portion of channel side 29b, for ease in forming the seam of the desired tubing in pipe-forming head 20.

Greater detail will now be given for the individual elements of the process. As shown in Fig. 5, form roll unit (FRU) 13 receives coilstock 14, the coilstock preferably clean and rust-free. In order to ease the-processing of the preferably metallic coilstock, a lubrication station 44 is provided. The lubricant
may be in the form of pulsed, misting lubrication, and may be provided on the top or on the bottom of the coilstock, or on both. The amount of lubricant that remains on the coilstock should not cause the coilstock to slip in its driving rolls, but should be such as to minimize frictional forces during deformation by the FRU or by one of more strip guide plate assemblies downstream. FRU 13 preferably has one or more stations (sets of rotary dies) to form the coilstock profile depicted in Fig. 4a. The configuration; of the dies in the FRU may be designed on the basis of the amount of deformation required of each set of dies, or may be determined in any other suitable way. FRU 13 is preferably mounted rigidly on an FRU base plate 41, which is preferably mounted to a machine base plate 42 for the FRU and other process machinery as described in Fig. 2.

[0048] The rotary cutting or slitting dies are depicted in Figs. 6a, 6b and 7. One set of dies is used in each cutting station. These dies are used to place slits or cuts in the sheet metal in a desired pattern. Only one set of slitting dies or other cutters (such as perforating knives) are required, but more than one may be used. Any desired configuration of perforations may be used. In one embodiment, a first set of slits in sheet metal is made by using two rotary dies 50. Each rotary die 50 includes six lands 51 and five grooves 52, and a center bore 49. The lands include reliefs or cutouts 51a as depicted in Fig. 8. When dies 50 are aligned vertically in a cutter station, the lands of one die are aligned with the grooves of the other die. This allows the aligned lands to pierce the sheet metal with minimal side distortion.

[0049] To make a second set of slits, another rotary die 45 may be used with rotary die 50. In this instance, rotary die 45 includes seven lands 46 and six grooves 47. Dies 45 and 50 are preferably the same diameter. The lands 46 of rotary die 45 may include the same semi-circular reliefs described above for rotary die 50. In this embodiment, die 45 is designed so that the slits or cuts produced by dies 45 and 50 lie centered in the slits made previously by dies 50. Fig. 7 is an isometric view of rotary die 50, with center bore 49 and alignment bores 51.

[0050] The desired pattern 53 is depicted in Figs. 7a and 7b. Fig. 7a depicts a cross-section of sheet metal 14 after first and second cuts have been made, while
Fig. 7b depicts a top view of where the slits are made across the width of the sheet metal web. The second set of dies makes the slits in outer row 54b and in every second row thereafter. The first set of dies makes the slits in second row 55b and in every second row thereafter. The slits in each row are preferably offset by one-half the pitch of the slits, the pitch being the distance from the start of one slit to the start of the next slit in the same row. In this instance, the pitch is designated as distance J. Each row of slits is preferably separated from each other row by the same distance, designated as K in Fig. 7b.

[0051] The profile of the expanded metal is shown in Fig. 7a. As shown in Fig. 7b, the first set of dies makes row 55b, and the profile of the metal that has been moved in making the slits is depicted as row 55a in Fig. 7a. Note that the top points of row 55a coincide with the center of each slit in row 55b. In the same manner, the high points of row 54a coincide with the centers of the slits in row 54b. It is preferable if the movement of metal resulting from the slitting process is equal in both up and down directions from the center of coilstock 14, as shown in Fig. 7a, with distance L/2 in both up and down directions. The actual amount of movement is determined by the thickness of the coilstock and the desired amount of expansion. In one embodiment, 27 ga sheet metal (0.016 inches thick) is used with dies that move the metal about 0.096" above and below the plane of the web. The dies also make 13 rows of slits separated by about 0.060 inches.

[0052] The construction of the dies to make these cuts is shown in Fig. 8. A set of rotary slitting dies 60 includes identical upper and lower dies 61, 62. The outer diameter 63 of the dies between semi-circular reliefs 64 is the shape of the cut or slit that will be made in the sheet metal, as seen in the coincidence between the front (solid) lines of upper die 62 and the rear (dashed) lines of lower die 61. Reliefs 64 of the upper and lower dies coincide once per pitch or segment where the reliefs momentarily form a circular relief 65. This corresponds to the space between slits in Figs. 7a and 7b.

[0053] Adjustment or alignment may be needed for proper positioning of the upper die with respect to the lower die in each cutting station. An adjustment mechanism is depicted in Fig. 9. Adjustment for gear 75 and thus driven (upper)
roller or shaft 77 is provided by tapered split bushing 76 which is fastened to driven gear 75 with bolt 78. Adjustment is accomplished by unlocking the tapered split bushing of the upper shaft 77 and turning the drive (lower) shaft 71 until the lower shaft has its cavity at TDC (top dead center), as shown in Fig. 8. Then the upper roller is rotated to match the lower cavity until a pin will slide into relief 65 as shown in Fig. 8. The split taper bushing is then locked in place.

When the upper and lower cutting dies are in registration, the semi-circular cutouts on the outer surfaces of the lands will align during rotation to form a complete circle, as shown in Fig. 8. To check this, an operator can jog the machine to check if a go/no-go gauge can be inserted into matching cut-outs 64 as shown with relief 65.

Power is provided to the stations used in the slitting and expansion process via chain drives on one side of the line. Power may be thus provided to lower roll or drive shaft 71 with drive gear 72. Drive gear 72 is affixed to the drive shaft with bolt 73 and lock washer 73a. Drive gear 72 meshes with driven gear 75 via split bushing 72 for driving driven shaft 77.

Power for the cutting station is provided by a double sprocket system using identical sprockets or gears 80 mounted in tandem with drive shaft 71 and causing drive shaft 71 to rotate. One sprocket 80 receives power from a chain extending directly from a drive station or through one or more process stations. The other sprocket 80 may transmit power to another process station further down the line. Sprockets and chain drives are preferred because the timing is important in keeping the cutting stations coordinated if more than one cutting station is used. This is important to keep the first set of slits aligned with the second set of slits. If timing is not important, another method, such as sheaves and belts may be used.

It is also important to make sure that the lands of the upper die do not extend too low, or that the lands of the lower dies do not extend too high. In order to insure this, a cutter stop depth gauge may be used between the dies. As shown in Figs. 11a and 11b, a cutter station 16a mounted on base 10a may include an upper die assembly 82 and a lower die assembly 83. A cutter stop depth gauge or spacer 81 is placed between the housings of the upper and lower dies to prevent
adjustment of the upper die bearing housing from extending too low and thus causing undesirable interference between the dies. Lower roller 83 is fixed vertically, and vertical adjustment of the dies is provided only for upper roller 82. Spacer 81 is placed between the bearing housings of upper and lower rollers 82, 83. Adjustment of upper roller 82 is provided by manual adjustment of threaded rod 84 and nut 85. Nut 85 is mounted atop cutter station 16a. Fig. 11b is a top view of spacer 81, showing that spacer 81 is provided with bolt holes for mounting between the bearing housings 82, 83.

[0058] As discussed above, guide plate assemblies may be used after one or more of the processing stations in the line depicted in Fig. 2. Guide plates and assemblies of an upper and lower guide plate, do not have moving parts, but are similar to extrusion dies. A metal web or coilstock with sufficient lubrication may be pulled through the die to make slight adjustments in the profile of the web. A typical guide plate assembly 86 is depicted in Fig. 12a. The assembly includes an upper guide plate 87 and a lower guide plate 88. Upper guide 87 plate may rest on lower guide plate 88, which rests on guide plate support 89. Guide plates 87, 88 preserve the coil stock profiles 87a, 88a.

[0059] In order to minimize tearing or ripping of the coilstock while re-forming the coilstock in the guide plate assembly, there is desirably a gap between the upper and lower guides. The gap at the edges of the guide plates (where only non-slit coilstock is run) should be wide enough to allow an adjustment to the profile, but not so wide that raised and lowered portions resulting from slitting are not somewhat pressed back toward the plane of the coilstock, and also not so loose as to lose control of the web. The gap between the upper and lower guides must be at least the thickness of the metal with some extra tolerance. The gap is desirably about equal to the thickness of the raised and lowered metal with an additional thickness of from about 0.005 inches to about 0.020 inches.

[0060] While the guide plates as discussed will re-form the bulk of the coilstock, additional steps may be needed to retain the angular configuration of the flange and channel portions of the coilstock profile. Fig. 12b depicts a guide plate assembly 90 with guide plate support 93, and upper and lower guide plates 91, 92.
(The view of FIG. 12b is similar to a cross-sectional view within the spreader 100 discussed below). Lower guide plate 92 includes additional guide elements 94, 95 to help retain the form of the channel and flange portions of the coilstock as it passes through the guide plate assembly. The profile of the expanded metal is not substantially changed, continuing to retain profile steps 91a, 91b, 92a, 92b. Lower guide plate 92 has additional guide portions 94, 95. Guide portion 94 helps to retain the right-angle bend needed in the flange 96, while guide portion 95 helps to retain the outer configuration 97 needed for the channel. Guide portion 95 could also be made in a form to retain the right angle bend and the outer portion by using a guide that more closely matches the channel profile. Fig. 12c depicts "liftoff," one possible way in which the outer edges of the coilstock may deform if sufficient guidance is not provided in the design of the guide plate assembly. If the bending or "liftoff" is sufficiently severe, the coilstock may eventually lose track position during processing or could tear or jam in the guide plate or downstream, causing production to cease and requiring clearing of the guide plate assembly or other machines in the process.

[0061] The process for expanding metal in an intricate manner as described above may require adjustment or fine-tuning of the angular position of one of the first or second cutter station dies so that the each slitting operation is precisely in registration with the other. One way of accomplishing this is to provide an adjustable sprocket on one or both (preferably only one) of the cutter rollers in a cutter station. Fig. 13 depicts a hub 134 of a roller shaft, the hub having three keyways 137 for engaging a sprocket 130. If the keyways 137 are separated by angles D, E, and F, then the angular position of the sprocket may be adjusted by selecting the desired keyway for the angular position of the sprocket. Sprocket 130 is mounted to hub 134 with four bolts 133 through sprocket slots 132. The angular position of sprocket 130 with respect to hub 134 is adjusted by turning hub set screws 136 against sprocket drive lip 135.

[0062] With keyways at positions other than 120° to each other, a user may adjust the angular position and also the timing of when the dies begin and end their cut into the coilstock. It is important that both cutter stations are not cutting
into the coilstock at the same time, because this may result in undesirable stress on
the drive train. In one embodiment, angles D, E and F may be 132°, 114° and
114°. In other embodiments, other angles may be used, such as 110°, 120° and
130°. Fine tuning may be accomplished with the set screws 136 as provided.

[0063] The spreader assembly is depicted in Figs. 14 and 15. The spreader is
similar in some ways to the guide plate assemblies described above. Spreader 100
is placed in line after one or more slit roller assemblies. In Fig. 14, coilstock
enters from the left after the second slit roller assembly 110 and is pulled to the right
by drive assembly 112. The spreader may be manufactured as a single upper and a
single lower tool, or it may be made as shown in Fig. 14, with dual upper tools
101a, 101b, and two lower tools, 102a, 102b. Guide support assembly base 115 is
bolted to base 108, which may be bolted to a spreader base 109, or to machine
base 10a (Fig. 2) so that the spreader tooling is firmly fixed in place.

[0064] The spreader upper tools 101a, 101b bear on plate 103 via adapters or
handles 104, 105. In order to adjust the pressure on spreader tools 101a, 101b, the
assembly includes a hook 106, as shown in Fig. 14a, which is joined to base 108
by a transverse portion 106a for mechanical stability and support. The hook may
move in and out of slot 108a. The upper portion of hook 106 includes an
internally-threaded portion 106b whose threads match the external threads of
threaded rod 111 which is connected to an adjustment handwheel 113. When a
user wishes to adjust upper spreader tools 101a, 101b, the user rotates the
handwheel in the desired direction. As the handwheel and stationary threaded rod
106 turn, the pressure on plate 103 and tools 101a, 101b is increased or decreased
according the direction the handwheel is rotated. When rod 111 is raised and the
pressure is released from plate 103 and tools 101a, 101b, they may be removed,
moved, or adjusted as desired. Note also that the upper spreader tools are
prevented from moving upward during operation by use of the hook and the plate.
Thus, if pressure from the moving coil exerts upward force on the upper spreader
tools, hook 106 and plate 103 tend to prevent upward movement. This helps to
maintain pressure on the coilstock and on the tools, ensuring that the coil has the
desired shape when it emerges from the spreader assembly and enters driving rolls 112.

[0065] A cross-sectional end-view of the left portion of the spreader tooling is depicted in Fig. 15. Spread assembly base 115 may be bolted to base 108 via bolts inserted into counter sunk holes 118a, 118b. Horizontal adjustments may be made with 117a, 117b. Lower die 102a is secured in place with fasteners 117, 119, which are preferably bolts or rods threaded into holes tapped into spreader assembly base 115. The profile of lower die 102a preferably includes additional portions 102c and 102d for guiding the flange and channel portions, respectively, of the coilstock. The gap 116 between the upper die and the highest portions of the lower die is preferably the thickness of the metal profile, as shown in Fig. 7a.

[0066] Turning now to Figs. 14b and 14c with continued reference to Fig. 14, an alternate embodiment of the spreader assembly that includes spreader 100a. Spreader 100a is placed in line after one or more slit roller assemblies similar to spreader 100 discussed above. Specifically, as shown in Fig. 14, the coilstock enters spreader 100a after passing through the second slit assembly 110 and is pulled toward the right by drive assembly 112. Spreader 100a includes a lower guide plate, which may be formed as a single guide plate (not shown), or a series of two lower guide plates 102a, 102b shown in Fig. 14. The lower guide plates are supported on the guide support assembly base 115, which is bolted or similar fastened to base 108, which may be bolted to a spreader base 109 or machine base 10a to fix the spreader assembly with respect to the remainder of the machine. Spreader 100a does not require the upper guide plates (tools) 101a, 101b, the plate 103, or the hook 106 shown in Figs. 14 and 14a. Accordingly, the processing line 10 that includes spreader 100a includes less parts, which reduces the overall cost, weight, and complexity of the processing line 10.

[0067] Spreader 100a includes first and second steering plates 140a, 140b that support a portion of the top surface of coilstock 14 as it moves through the spreader 100a. Each steering plate 140a, 140b is removeably attached to a supporting block 142a, 142b, respectively with fasteners 146. The supporting blocks 142a, 142b are connected with the lower guide plates 102a, 102b (or a
single lower guide plate (not shown) with a plurality of alignment bolts 144 that may be tightened and relaxed with handles 145. In other embodiments, supporting blocks 142a, 142b may be removeably connected with the guide supporting assembly base 115 instead of the lower guide plates 102a, 102b.

[0068] Steering plates 140a, 140b may be made from bronze, or another material that minimizes friction between the steering plates 140a, 140b and translating coilstock 14. More specifically, steering plates may be made from phosphorous bronze or another suitable bronze alloy. In other embodiments, steering plates 140a, 140b may be constructed from steel that is coated with nickel or another suitable coating to minimize friction and wear on the steering plates 140a, 140b and the coilstock 14. In further embodiments, steering plates 140a, 140b may be constructed from other materials with or without coatings that minimize friction and wear on the steering plates 140a, 140b and the coilstock 14.

[0069] Steering plates 140a, and 140b may be oriented substantially perpendicular to each other, as shown in Fig. 14c, or in other embodiments may be arranged differently to constrain coilstock 14 as it moves through the spreader 100a. Specifically, first steering plate 140a is may be connected to a top surface of supporting block 142a such that first steering plate 140a is mounted generally parallel to the direction of movement Z (Fig. 14b) of coilstock 14 through spreader 100a. As shown in Fig. 14c, first steering plate 140a is provided such that the lower surface of first steering plate 140a contacts the coilstock 14 above or in the vicinity of the flange portion 14a. A pocket 150a is provided between the lower guide plate 102a and the first supporting block to accept the downwardly extending portion of the flange portion 14a. First steering plate 140a is spaced from lower guide plate 102a (102b) with a clearance that is only slightly thicker than the original thickness of coilstock 14 to allow the flange portion 14a of coilstock 14 to be tightly gripped by spreader 100a.

[0070] Second steering plate 140b may be mounted to second supporting block 142b to be generally perpendicular to the direction of movement Z of coilstock 14 through spreader 100a. As shown in Fig. 14c, second steering plate 140b is mounted to the internally facing side of second supporting block 142b, with a
portion of second steering plate 140b extending below a central portion 14d of coilstock 14. A bottom edge 141b of second steering plate is oriented to be received within the vertex 14c in channel portion 14b of coilstock 14. Accordingly, as coilstock 14 translates through spreader 100a, bottom edge 141b of second steering plate 140b supports the vertex of the channel portion 14c to retain the channel portion within a pocket 150b between lower guide plate 102a (102b) and second supporting block 142b.

[0071] As shown in Fig. 14b, the profile of the lower guide plate 102a (102b) and first and second steering plates 140a, 140b expands along the length of spreader 100a. Accordingly, as this profile expands, the coilstock 14 is placed in horizontal tension (due to the force applied to flange and channel portions 14a, 14b by the first and second steering plates 140a, 140b and the lower guide plate 102a (102b)), which expands the width of coilstock 14 as coilstock moves in direction Z through spreader 100a by stretching the perforations 25, 26, 27 (with additional reference to Fig. 3). The profile of first and second steering plates 140a, 140b and lower guide plate 102a (102b) are designed to gradually widen coilstock 14 to the width used in forming the tubing or piping, to minimize the amount of stress placed on the coilstock 14, while also limiting the length of spreader 100a.

[0072] Once the metal has been slit, expanded, and flattened, with a suitable flange on one side and channel on the other side, the coilstock may be fed, preferably immediately, to a machine for forming a lockseam by twisting the coilstock, placing the flange within the channel, thus forming a seam, and forming a seal by applying great mechanical pressure to the seam thus formed. This pressure is preferably applied by both an inside roller and an outside roller acting on both sides of the seam. An example of a machine to take the perforated, expanded metal and form tubing or piping from the metal is also described herein. This described in U.S. Pat. Appl. Publ. 2003/0230127, which is assigned to the assignee of the present application, and which is hereby incorporated by reference in its entirety.
The slit, expanded and formed metal strip 11a passes into a machine for forming piping or tubing from coilstock. Such machines are disclosed in U.S. Pat. Nos. 4,706,481 and 4,924,684. The descriptions of the pipe forming apparatus contained in these patents, as well as the disclosures in their entirety, are hereby incorporated by reference. Other machines may also be used to convert the expanded metal into tubing, including but not limited to those described in U.S. Pats. No. 4, 706,481; 4,711,110; 5,105,639; 5,193,374; 5,257,521; 5,421,185; and 5,636,541; all of which are hereby incorporated by reference in their entirety.

One embodiment of a machine for receiving the slit, expanded coilstock 14 and converting it into spiral pipe is depicted in Fig. 16. A pipe forming head or machine 200 for forming spiral pipe includes 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 fixed on machine base 242. Rails 255 are used for moving a slitter two cutting knives (not shown) for cutting the formed spiral pipe to the desired length. One knife is ideally mounted on a front end of boom (not shown), the knife and the boom inside the formed pipe. The other knife is mounted outside the boom and the formed pipe. The boom and the knives move with the pipe to cut the pipe while it is moving. With this technique, the forming process does not have to be stopped for cutting the pipe, which now is automatically cut and ejected from the forming machinery.

The forming head 241 curls the metal strip 14 into a cylindrical spiral, whereby the opposing preformed edges of the strip 14 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 is continuously pushed by the drive rollers described above so that a hollow, perforated and expanded 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.
hydraulic cylinder assembly 247 provides the pressure on clinching roller 245 to close the lockseam on the filter pipe. Knives (not shown) then cut the pipe into desired lengths.

[0076] Flow diagrams describing these processes are depicted in Figs. 17-18. Fig. 17 illustrates a process 120 for forming expanded coilstock and using the coilstock immediately for forming piping. Coilstock is fed 121 from an unwinder into a machine for slitting and expanding preferably metallic (steel or aluminum) coilstock. A form roll unit or similar forming machine forms flange and channel edges 122 on opposite sides of the coilstock so that the machinery downstream can grip the coilstock. The coilstock is then fed into one or more cutter stations, where rotary "knives" or "punch and die" rotary tools place slits 123 into the metal. After the slitting operation, the coilstock may be re-formed 124 or "guided" into a desired shape for subsequent processes. If there is a second slitting operation, the second set of cuts is preferably centered on the first set of cuts, so that coilstock will be symmetrical when it is expanded 125 in a later step.

[0077] After expansion, the metal may require another reforming or guiding step 126. The coilstock or web is then passed through drive rollers 127 which pull the coilstock through the process and flatten 128 the coilstock as it passes through. The formed, slit, and expanded coilstock then travels immediately to the next step of the process, a machine 129 which forms the coilstock into tubing and cuts the tubing into desired lengths. Thus, coilstock passes through several steps in which it is formed into expanded metal, and the formed metal then passes immediately into a pipe-forming machine where the formed coilstock is immediately made into seamed tubing of a desired length.

[0078] Fig. 18 is a flowchart for the second portion of the process, wherein the expanded coilstock is formed into spiral shaped pipe and then cut into desired lengths. The coilstock is pushed or drawn into the coil-forming machine 13 15 where the edges are joined into a seam 132. The coil-stock is formed into a spiral shape 133 and the edges are locked and formed into an edge seal 134. An oscillating knife or two knives then cut the pipe into desired lengths 135. Further details may be in U.S. Pat. Appl. Publ. 2003-0230127A1.
Once the pipe has been cut to length, it may be used for a variety of filters, or even as a noise filter or silencer. As shown in flowchart Fig. 19, the pipe, having been cut to length, may now be adapted 141 for a particular purpose, such as for an oil, water, air, or noise filter. It may be adapted by placing circumferential grooves or other features for mounting a housing 142 around the tube and adding a filter medium inside the housing and around the center filter pipe. The medium may be fiber glass, cotton, or other suitable medium for filtering out the desired undesirable particles or contaminant. There is usually also provided an outlet 143 with a series of orifices or holes, so that the oil, water or air that is being filtered can leave the filter. Thus, particles may be removed from oil, air or water. In addition, noise may be reduced from air through the use of the appropriate medium or media to dissipate sound. An example of a filter, such as an oil filter, made from pipe according to the above apparatus and process is depicted in Fig. 20. Filter 190 is made from a piece of tubing 191 from the apparatus and process described above. Tubing 191 is adapted according to the process of Fig. 20 by having threads 195 machined into the inner portion of the pipe. Filter 190 also includes a cylindrical housing 192, the housing including end portion 193 with orifices 194 so that the oil or other fluid being filtered can exit filter 190. The filter may also include medium 196, such as cotton, fiber glass, or other filter medium or media on the inside of the filter.

As mentioned above, tubing made by the above-described process may be used in HVAC piping to absorb sound. Just as an air or oil filter can have two sides, double-wall ventilation duct work 200 can also have two sides. As shown in Fig. 21, double-wall ventilation may have an inner side 201 formed from expanded metal and joined by lock seams 202, and an outer side 205 with spiral locked seams 206 which is also formed from a spiral seam lock process, but which in this instance is solid, not expanded. Just as air or oil filters use a medium, duct work 200 may also have a medium 203 between inner and outer sides 201, 205. Medium 203 may be mineral wool or other desirable sound-absorbing material, and may also reduce heat loss from air traveling the length of the duct work. By mineral wool is meant synthetic vitreous fibers (SVFs),
commonly known as rock or slag wool, typically based on amorphous silicates. Other sound-absorbing materials or insulators may be used, such as prefabricated or loose ceramic insulation or blankets of fiberglass or other suitable material. The insulated/sound-absorbing portion of the duct work may include all the duct work or only selected portions to reduce noise as desired.

[D0081] Duct work 200 may be made by first forming the inner side 201 using the expanded metal and spiral lock seam process described above. Medium 203 may then be wrapped around the outside of inner side 201. A cover made from outer side 205 may then be assembled around the medium. Outer cover 205 may be made from spiral wrapped tubing or piping, with seams 206. However, outer cover 205 may also be solid plastic or sheet metal tubing or piping, with no seams, assembled over insulation 203 and inner side 201. Outer edges 208 may be butted against one another, may be left unsealed, or may be sealed as desired for better performance.

[D0082] It will be recognized by those having skill in the art that not all the steps of the process must be accomplished in the order described here. For instance, the coilstock may be slit, expanded, and reformed in a flat manner, without forming the edges into shapes of a channel and a flange. The flange and channel, for instance, may be formed in the pipe-forming machine, as also described in U.S. Pat. Appl. Publ. 20030230127, which is assigned to the assignee of the present invention, and which is hereby incorporated by reference in its entirety. However, the Applicant has found that it is preferred to form the channel and flange portion in order to facilitate the process described above for slitting and perforating coilstock.

[D0083] There are many embodiments of the method used to form coilstock and to make tubing in a continuous process as described above, of which those described above are only a few. For instance, the adjustment mechanisms for many of the operating stations are described as threaded rods or bolts. Each of these may be considered to be a screw mechanism for making fine adjustments. Accordingly, it is intended that the foregoing detailed description be regarded as illustrative rather than limiting, and that it be understood that it is the following
claims, including all equivalents, that are intended to define the spirit and scope of this invention.
WHAT IS CLAIMED IS:

1. An apparatus for continuously perforating coilstock and forming tubing, the apparatus comprising:
   5 first and second cutter stations for receiving and perforating the coilstock, the first and second cutter stations each comprising a tool for perforating coilstock;
   10 a spreader for receiving and expanding the perforated coilstock; and
   15 a tubing machine for receiving the expanded, perforated coilstock and forming the coilstock into tubing.

2. The apparatus of Claim 1, further comprising a strip guide plate assembly for aligning the coilstock, the strip guide plate assembly placed in the apparatus after the first cutter station or the second cutter station.

3. The apparatus of Claim 1, further comprising a roll form unit for forming sides of the coilstock into a profile before the first cutter station.

4. The apparatus of Claim 3, further comprising a roll form unit for forming a channel and a flange on opposite sides of the coilstock.

5. The apparatus of Claim 1, further comprising a roll form unit positioned to receive coilstock, and configured to form sides on edges of the coilstock and to feed the edged coilstock to a first cutter station.

6. The apparatus of Claim 1, wherein one of the first and second cutter stations comprises: a male cutter roll and a female cutter roll for perforating the coilstock; a stand frame supporting the male and female cutter rolls; and a stop gauge attached to the stand frame and maintaining a separation between the male and female cutter rolls.

7. A filter comprising a piece of tubing made by the apparatus of Claim 1.
8. The apparatus of Claim 1, wherein the second cutter station is mounted such that perforations produced by the second cutter station in the coilstock are placed between perforations produced by the first cutter station.

9. The apparatus of Claim 1, wherein the first cutter station or the second cutter station further comprises a sprocket and a shaft on which the sprocket and a portion of the tool are mounted, the sprocket suitable for adjusting a position of the tool.

10. The apparatus of Claim 1, wherein edges of the expanded, perforated coilstock are solid, with no perforation or expansion of metal on the edges, before the coilstock is formed into tubing.

11. The apparatus of claim 1, wherein the spreader comprises a first steering plate, a second steering plate, and a lower guide plate, wherein a first side of the coilstock is maintained between the first steering plate and the lower guide plate, and the second opposite side of the coilstock is maintained between the second steering plate and the lower guide plate.

12. The apparatus of claim 11, wherein the first and second guide plates are positioned substantially perpendicular to each other.

13. The apparatus of claim 4, wherein the spreader comprises a first steering plate, a second steering plate, and a lower guide plate, wherein the first steering plate and the lower guide plate engage the coilstock in the vicinity of the flange and the second steering plate and the lower guide plate engage the coilstock in the vicinity of the channel.

14. An apparatus for continuously perforating coilstock and forming tubing, the apparatus comprising:
a roll form unit for forming sides of the coilstock;
a first cutter station for perforating the formed coilstock;
a second cutter station for again perforating the perforated coilstock;
a spreader that receives the perforated coilstock from the second cutter station and spreads the coilstock;
a strip guide plate assembly for flattening the spread coilstock;
a drive roller station for pulling the coilstock through the apparatus; and
a pipe forming machine for forming the spread coilstock into tubing and cutting the tubing into a desired length.

15. The apparatus of Claim 14, wherein the apparatus further comprises at least one additional strip guide plate assembly positioned between the first cutter station and the second cutter station.

16. The apparatus of Claim 14, wherein the apparatus further comprises at least one lubrication station.

17. The apparatus of Claim 14, wherein the first or second cutter station comprises rotary knives or a set of a rotary punch and a rotary die.

18. The apparatus of Claim 14, wherein the apparatus further comprises a chain drive operatively connected to the drive roller station for transmitting power.

19. The apparatus of Claim 14, wherein the first cutter station or the second cutter station further comprises a tool for cutting coilstock, a sprocket and a lower shaft on which the sprocket and a portion of tool are mounted, the sprocket suitable for adjusting a position of the portion of the tool relative to another portion of the tool.

20. The apparatus of Claim 14, wherein at least one of the cutter stations, the spreader station, the strip guide plate assembly, and the strip guide plate
assembly further comprises at least one manual adjustment screw for making an adjustment.

21. A method for forming pipe from coilstock in a single continuous process, the method comprising:
   providing coilstock;
   forming edges on opposite sides of the coilstock;
   introducing a first set of perforations into the coilstock;
   introducing a second set of perforations between the first set of perforations and expanding the coilstock; and
   forming the coilstock into tubing.

22. The method of Claim 21, further comprising cutting the coilstock into a desired length as part of the continuous process.

23. The method of Claim 21, further comprising forming the coilstock into cut tubing and adding a medium to form the cut tubing into a filter.

24. The method of Claim 21, further comprising flattening the coilstock after introducing the second set of perforations.

25. The method of Claim 21, wherein the edges of the coilstock are solid, with no perforation or expansion of metal on the edges, before the coilstock is formed into tubing.

Fig. 17

120

Feed coilstock into forming machine

122
Form flange and channel edges for gripping

123
Slit coilstock at least once

124
Re-form coilstock into desired form

125
Expand coilstock as desired

126
Re-form coilstock into desired form

127
Use drive rollers to pull coilstock through process and to flatten coilstock

128
Flatten coilstock

129
Send to pipe-forming machine
Fig. 18

1. Draw strip into coil-forming machine
2. Form edges of coilstock into seams
3. Form strip into a spiral shape
4. Lock edges and form edge seal
5. Cut formed pipe into desired length
6. Add medium and customize

Fig. 19

1. Adapt pipe
2. Add housing and medium
3. Provide outlet ports