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Apparatus and method for production of duct members

Abstract

An apparatus for forming and sealing a duct member for use in an air handling system. At least one work station accommodates a work piece, which is generally a cylindrical tube.

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Background/Summary

CROSS REFERENCE TO RELATED APPLICATION (1) This application is a Divisional application of U.S. application Ser. No. 16/619,511 filed Dec. 5, 2019 (now U.S. Pat. No. 11,571,830 issuing on Feb. 7, 2023), which is a national phase application of PCT International Application No. PCT/US2018/014428, filed Jan. 19, 2018, which claims priority to, and the benefit of PCT International Patent Application No. PCT/US2017/037451, filed Jun. 14, 2017 with the U.S. Patent Office (acting as the U.S. Receiving Office). The disclosures of the above-referenced applications are incorporated herein by reference in their entirety.

TECHNICAL FIELD
(1) The invention relates generally to an apparatus and method for production of sealed or adjustable duct members.
BACKGROUND
(2) In general, duct work is commonly used in forced air heating and air-conditioning systems for buildings and the like, with the duct work providing a distribution system to various areas of the building from a furnace and/or air-conditioning system. The duct work is generally formed from cylindrical tubing which extends to various portions of the building or the like. Duct members include specialized sections such as elbows, which may be fixed in position or allow the orientation and position of duct to be adjusted, to make turns in runs of ductwork. Known machines for producing elbows or the like typically require a skilled operator that must handle a blank used for production of the elbow. The operator cuts and forms sections or gores for an elbow from the blank and assembles them together. The sections of the elbow are generally coupled to an adjacent section by means of a bead coupling which locks the pieces together. Known machines for producing elbows require the stages of production of the sections to be performed manually. A skilled operator is therefore necessary to properly form each section and couple the sections together. The difficulty of properly forming each section and connecting the sections together result in a high percentage of scrap.
(3) Other problems associated with these machines include the loss of air through the connections

or beads between the gores of the duct system. As air circulates through the duct system, air dissipates through the connecting beads or seams that are between the gores, which in turn, causes a loss of energy and thus creates a less efficient system. Sealing of the duct increases the efficiency of the HVAC system, and conserves energy, which is highly desirable. The sealing of such duct members has generally been performed after installation using tape or mastic for example, which though helping to prevent the egress of air, is not particularly efficient and increases the cost of installation. There have been attempts to produce sealed duct members, which are then installed, but the machines used to form such duct members require significant operator handling and pose safety hazards to the operators. The production process also takes significant time, thereby increasing the cost. There is thus a need to have an apparatus and method for automated manufacture of elbow ducts that may be sealed to be highly efficient with respect to the preventing leakage therefrom.

SUMMARY

(4) The invention is therefore directed in one respect to an apparatus for forming a sealed duct member for use in an air handling system. The apparatus comprises at least one work station adapted to accommodate a work piece. A cutting assembly is configured to cut the work piece in a predetermined manner to form first and second sections. A forming assembly including a forming member and at least one die member to form a connecting bead in the first and second sections which cooperate to reconnect the first and second sections together at a predetermined position. A work piece moving and rotating assembly moves the work piece relative to the cutting assembly and forming assembly, wherein the rotating assembly allows for rotation of the work piece and at least one of the first and second sections after being formed. A sealing assembly is further provided which cooperates with the at least one die member to seal the connecting bead in the first and second members after the connecting bead is formed. The sealing assembly comprises at least one crimping plate that forces the at least one die member against the formed connecting bead to crimp the connecting bead together. A control system is provided for controlling operation of the cutting, forming, work piece moving and rotating assembly and sealing assemblies.

(5) The invention also relates to a method of automated manufacturing of a duct member. The method includes providing a work piece having a cylindrical configuration and positioning the work piece in a work station at a first predetermined position. A clamping system includes a first clamp to secure the work piece in a first predetermined position, and the work piece is moved to the position where a first cut is to be made and may be rotated 180 degrees clockwise. A second clamp is activated to secure the work piece in a second predetermined position, and a cutting operation is performed to cut the work piece at a first predetermined position to form first and second sections. The first section is moved toward the second section a predetermined amount and a turning head is engaged to the interior of the second section. The second section is then rotated 180 degrees clockwise and the turning head is disengaged. A forming operation is initiated to form connecting beads in each of the first and second sections to reconnect the sections, and a crimping system seals the formed connecting beads together. The second clamp is then opened to release the work piece. The work piece is then moved to the position where a second cut is to be made and rotated 180 degrees counter clockwise. A second clamp is activated to secure the work piece in a predetermined position, and a cutting operation is performed to cut the work piece at a first predetermined position to form first and second sections. The first section is moved toward the second section a predetermined amount and a turning head is engaged to the interior of the second section. The second section is then rotated 180 degrees clockwise and the turning head is disengaged. A forming operation is initiated to form connecting beads in each of the first and second sections to reconnect the sections, and a crimping system seals the formed connecting beads together. The second clamp is then opened to release the work piece. The work piece is then moved to the position where at least a third cut is to be made and rotated 180 degrees clockwise. A second clamp is activated to secure the work piece in a predetermined position, and a cutting operation is

performed to cut the work piece at a first predetermined position to form first and second sections. The first section is moved toward the second section a predetermined amount and a turning head is engaged to the interior of the second section. The second section is then rotated 180 degrees clockwise and the turning head is disengaged. A forming operation is initiated to form connecting beads in each of the first and second sections to reconnect the sections, and a crimping system seals the formed connecting beads together. The second clamp is then opened to release the work piece.
(6) These and other features of the claimed invention, as well as details of illustrated examples thereof, will be more fully understood from the following description and drawings.

Description

BRIEF DESCRIPTION OF DRAWINGS
(1) FIG. **1** is a plan view of a duct member as formed according to an example of the invention;
(2) FIG. **2** is a plan view of the tube or work piece used as a blank to form the cut member of FIG. **1**;
(3) FIG. **3** is a side view of an example of the apparatus for automated cutting and forming of an elbow or like duct member;
(4) FIG. **4** is a side view of the apparatus as shown in FIG. **3**;
(5) FIG. **5** is a top view of the apparatus as shown in FIG. **3**;
(6) FIG. **6** is a top view of a zero stop system associated with the apparatus;
(7) FIG. **7** is a sectional view taken along line A-A in FIG. **6**;
(8) FIG. **8** is a perspective view of die members and a cutting and forming assembly in the apparatus of FIG. **3**;
(9) FIGS. and **9** and **10** show sectional view along the line A-A of FIG. **8**, showing different operational states;
(10) FIG. **11** is a view of a cutting and forming head according to an example;
(11) FIG. **12** is a cross-sectional view of the cutting and forming head as shown in FIG. **11**;
(12) FIG. **13** is a partial perspective view of the cutting and forming head and associated die members of an example machine;
(13) FIG. **14** is a top view of a cutting and forming cassette according to an example, for use in the cutting and forming head;
(14) FIG. **15** is a cross-sectional view of the cutting and forming cassette as shown in FIG. **14**;
(15) FIG. **16** is a partial cross-section of a cutting wheel associated with the cutting and forming cassette as shown in FIG. **14**;
(16) FIG. **17** is a partial view of the cutting wheel associated with a cutting and forming cassette in association with die members of an example machine;
(17) FIG. **18** is a partial view of a forming wheel associated with a cutting and forming cassette in association with die members of an example machine;
(18) FIG. **19** is another example of a cutting and forming head of an example machine;
(19) FIG. **20** is a perspective view of a portion of a die assembly associated with an example machine;
(20) FIG. **21** is a top view of the portion of a die assembly as shown in FIG. **20**;
(21) FIG. **22** is a top view of a portion of an example machine showing a crimping system;
(22) FIG. **23** is a block diagram showing operation of the apparatus according to an example; and
(23) FIG. **24** shows an example operator interface to the control system for operation of the apparatus.
DESCRIPTION OF EXAMPLES OF THE INVENTION
(24) Turning now to FIGS., an example of the invention is directed at producing an elbow duct member **10** such as shown in FIG. **1**, wherein the duct member **10** is formed from a cylindrical tube

12 as shown in FIG. **2**. The elbow duct member **10** may be a ninety degree elbow as shown, or a forty-five degree elbow for example. To form the duct **10**, the tube **12** is cut into gores or sections **14-18** that are then re-attached to form the elbow configuration. In this example, the duct **10** is shown as a 90 degree elbow, which may be formed by cutting of the tube **12** with four cuts at increments of 22.5 degrees apart as shown at x, to form the 90 degree elbow configuration, but other configurations may be formed, such as from three sections cut in 30 degree increments for example. In this example, the sections or gores **14-18** are re-attached by a connecting bead, with a portion of one section positioned in overlapping relationship, and connected together at that location via the connecting bead. The duct member **10** further includes a first opening **20** and a second opening **22**, being adapted to be coupled between other duct members in a duct system. Though not shown, to facilitate connection of the duct member **10**, an opening may be crimped for engagement with an inner wall of anther duct member. The tube **12** may be produced from a flat blank of material which is rolled with opposed seams of the blank coupled to one another to form the tubular configuration. As an example, the tubular configuration of the formed blank of material may provide a starting work piece **12** as shown in FIG. **2**, which may then be operated on by the apparatus and methods of the invention. The work piece **12** as shown in FIG. **2** is designed to have a predetermined diameter for use in the apparatus and methods of the invention, but any suitable particular dimensional characteristics of the work piece can be accommodated.

(25) The apparatus and methods of the invention may be operated to take the work piece **12** as shown in FIG. **2** and produce the duct member **10** of FIG. **1** automatically into the final preferred form, which may be without operator intervention.

(26) Turning now to FIGS. **3-5**, an example of the apparatus for forming the elbow duct is shown in more detail. The apparatus generally designated **50** includes a housing or frame construction **52** which supports various components of the apparatus. Housing or frame **52** includes an upper surface **54**. The upper surface **54** is angled at a predetermined angle relative to horizontal or ultimately to the plane of the outlet opening on the tube **12** described previously. The top includes a nest **56** for receipt of the work piece **12** to perform the operations for cutting and forming the elbow duct member **10**. The nest **56** includes a die and crimping assembly **58** supported adjacent the nest **56**, which in this example comprises first and second semicircular die members **60** and **62** which are positioned on opposed sides of the nest **56**. The die members **60** and **62** may be stationary, or may be made moveable toward and away from the nest **56** if desired. The die members are positioned beneath a crimping plate **59**, that is moveable toward the die members **60** and **62**. Within the nest **56**, a cutting and forming system **70** is provided. The cutting and forming system **70** may include a turning head with levers in association with a forming head with a plurality of cassettes that carry cutting and forming wheels that are movable into engagement with the work piece, such as by cam biasing. Alternately, the cassette may be movable by an eccentric drive, such as shown and described in U.S. Pat. No. 6,105,227 or 6,363,764 as examples, which are hereby incorporated by reference. Between the die members **60** and **62** and the cutting and forming system **70**, a channel is formed to accept the work piece **12** as shown in FIG. **2**, with the work piece **12** extending into the channel to a predetermined depth. A moveable support surface or tub **68** is provided at the bottom of channel, on which the work piece is supported within the nest **56** and moved to predetermined positions relative to the die members **60** and **62** and cutting and forming system **70**. A moving assembly **55** (FIG. **3**) is provided to move the tube **12** to desired positions relative to the forming head and die members. The moving assembly **55** may move the work piece **12** by any suitable mechanism. The cutting and forming assembly **70** extends through the moveable support surface or tub **68**, and is connected to a drive system **73** and drive motor **75**. Also associated with the channel and tub **68** is a holding system and rotating system to clamp the cut section of work piece **12** into a desired position and rotate the work piece sections or gores thereof relative to one another, to form the desired duct member.

(27) In this example, there is also provided a zero hard stop system **80** as shown in FIGS. **6-7**,

which is provided to ensure proper rotation of tub **68** and the section of the work piece supported thereon. The hard stop system **80** may include a stop member **82** that will engage the main rotating gear **84** on the tub **68** to prevent movement during the cutting and forming operations, and ensure the 90 degree elbow configuration is accurately generated. In an example, the stop member **82** is a spring loaded pin **86** that is and suitably actuated to engage the gear **84** and prevent any movement of the tub **68** or the work piece section held therewith during the cutting and forming operations.

(28) The holding systems **64** may include an upper holding system **63** and a lower holding system **61** to clamp the work piece **12** the upper and lower sections or gores of the work piece **12** after being cut, to then be reconnected. Any suitable holding system may be provided, such as including a clamp assembly comprising one or more clamp members which are actuated to grip a surfaces of the work piece **12** above and below a cut. As seen in FIGS. **6** and **7** for example, a lower holding system **61** may include a plurality of clamps situated around the tube **68** to secure the work piece in position therewith. A rotating system may be employed with the bottom and/or top holding systems **61** and **63**, which may be a separate system to the holding systems **61** and **63**, to rotate and/or position each section of work piece **12** at a desired position relative to the other section after cutting. The work piece **12** and sections are securely held in place as cutting, forming and rotation operations are performed thereon, and the sections are re-attached and sealed as will hereafter be described.

(29) The cutting and forming system **70** is designed to cut, pre-form and finish form the connecting beads between sections or gores of the work piece **12** and can also be utilized to seal the connections after being made. As shown in FIGS. **8-10**, the cutting and forming assembly **70**, in association with the dies **60** and **62** operate to cut and reconnect the gore sections of the work piece **12**. The dies **60** and **62** in this example are formed from a cutting plate **65** and a forming plate **67**. The cutting and forming assembly includes at least one cutting roller **72** and forming roller **74**, that are moveable toward and away from the cutting plate **65** and forming plate **67** to perform the cutting and pre-forming, forming and crimping operations on the work piece **12** positioned in the channel. In FIG. **9**, the cutting roller **72** is shown in the advanced position to engage the work piece **12** and cut the work piece **12** in association with the cutting plate **65**. In FIG. **10**, the forming roller **74** is shown in the advanced position to engage the work piece **12** and reconnect the cut pieces of the work piece **12** in association with the forming plate **67**.

(30) In FIGS. **11** and **12**, there is shown an example cutting and forming assembly **70** is shown in more detail, with a cutting/forming cassette removed. As seen in FIG. **11**, the assembly **70** includes a rotating head **400** with a mounting section **402** to mount the cutting/forming cassette. The rotating head **400** is positioned at an angle as shown to accommodate the angled arrangement of the cutting and forming plates to provide the desired angled cutting of work piece **12** from a straight tube. The head **400** is precisely driven by a drive system **403** generally including a drive shaft **404** connected through a direct gear drive **406** to rotate shaft **408** and head **400** at a high speed, which allows cutting and forming operations to be achieved very quickly. The rotation of shaft **408** is transferred to shaft **410**. The shaft **410** interfaces with the cassette when mounted at **402**, and causes deployment of a cutting wheel and forming wheel as will be described in more detail hereafter. The shaft **410** rotates a drive member **412** that interfaces with a cassette mounted at **402**. The drive shaft **410** is rotated at a speed to allow cutting and forming operations to be achieved very quickly in conjunction with rotation of head **400**. In an example, the entire formation of the elbow from a straight tube using the machine may be performed in approximately 17 seconds. This includes positioning the straight tube work piece **12** in the machine, and cutting, forming, rotating, re-connecting the gore sections and sealing of the connections of the work piece to form the four connections resulting in the 90 degree elbow as in FIG. **2**. The ability to automatically form the elbow configuration without operator intervention this quickly allows production of duct members in a very efficient and optimized manner. As the drive shaft **408** is oriented at an angle relative to drive shaft **404**, the direct gear drive **406** may be a set of bevel gears coupled to a collar and

directly to the drive shaft **408**, to enable driving shaft **408** in a direct manner, rather than using a mechanism such as a universal joint for example. This reduces maintenance of the drive system **406**. The rotation of shafts **408** and **410** are provided at selected ratios to the rotation of drive shaft **404**. The positioning, cutting, rotation, forming and sealing of the connections between gore sections of the work piece **12** may be performed by computer driven servo drivers for accurate position and speed control. A servo drive receives a command signal from a computer control system to operate a servo motor in order to produce motion proportional to the command signal. The command signals produce movements of the head **400** and operation of the cassette at desired speeds, and also provide very accurate control of the position of the gore sections during elbow formation, both with respect to one another and to form each section of the elbow during construction by movement of the support surface or tub **68** and relative rotation of the gore sections for re-attachment. In an example as shown in FIG. **13**, the cutting and forming assembly **70** with drive member **412** that interfaces with a cassette may be an eccentric drive **412** that causes engagement of a cutting wheel and forming wheel in succession as the head **400** rotates relative to the work piece **12**. The eccentric drive allows very quick movement of the cutting and forming wheels into and out of engagement with the work piece for very efficient cutting and forming operations that allow the extremely fast operation of machine **10** to be achieved.

(31) In an example, a cutting and forming cassette **500** is used in association with head **400**, such as shown in FIGS. **14** and **15**. The cassette **500** carries a cutting wheel **502** and a forming wheel **504**, which are independently deployed into engagement with the work piece **12** to cause cutting of the work piece **12** into gore sections, pre-forming a coupling portion in each section, and re-attaching the gore sections via a coupling portion formed in each section. The cassette **500** is engaged by the drive member **412** in channel **506**, and drive member **412** causes the cassette **500** to slide relative to mounting channel **402** in head **400**, such that cutting wheel **502** and forming wheel **504** are moved outwardly and inwardly relative to work piece **12**, and into and out of engagement of the work piece **12**. The cutting and forming wheels operate in conjunction with cutting and forming plates as previously noted.

(32) An example of the cutting wheel **502** is shown in FIG. **16**. The cutting wheel **502** includes a profile that engages the work piece **12** to perform several functions. A first radiused portion **510** is formed at a top portion of wheel **502**, and causes pre-forming of a top section of work piece as a second knife portion **512** cuts the work piece **12** into top and bottom gore sections. A second radiused portion **514** is provided at the bottom of the wheel **502** to cause pre-forming in a bottom section of the work piece **12**. The top radiused portion **510** includes a varying radius from the top to the bottom thereof, and in this example comprises a first radius R**1** forming portion **516** extending from the top to approximately the middle of portion **510**, and a second radius R**2** forming bottom section **518** of portion **510**. The first radius R**1** provides pre-forming of a top section of work piece **12** as it is cut with knife portion **512**. The pre-forming provided by section **516** enables precise formation of a coupling bead that can then be sealed to form a flat, small dimension sealed coupling between gore sections of the work piece **12**. As seen in FIG. **16**, the portion **510** pre-forms a coupling bead in a top section of a work piece after being cut that has a dimension that is greater than pre-forming provided by section **514** in a bottom section of work piece after being cut. This allows the cut top and bottom section of the cut work piece **12** to then be quickly moved into overlapping relationship with the pre-formed coupling beads adjacent one another, for completion of the forming operation on the coupling beads provided by the forming wheel **504**. In the operation of the cutting and forming assembly **70**, a pre-forming operation may be performed as described, to simultaneously pre-form the bottom edge of the top cut section and the top edge of the bottom section with a slight inward taper to assist in moving the cut sections into overlapping relationship. The forming operation provides a second stage of crimping of the produced reconnection between gore sections, to form a predetermined reconnection that is suitably sealed after subsequent high pressure crimping by a crimping system as will hereafter be described. In

general, the material from which the work piece **10** is formed is of significant structural integrity whereby the connecting beads formed are deep and consistently formed to facilitate maintaining the connection between the gores and providing the desired seal.

(33) The operation of the cutting and forming cassette **500** provides deployment of the cutting wheel **502** and forming wheel **504** independently as shown in FIGS. **17** and **18**. As the cassette **500** is driven by member **412** in cutting and forming head **400**, the cutting wheel **502** is extended into engagement with the work piece **12** in conjunction with cutting and forming plates **65** and **67** as previously described. The bottom plate **65** includes a cutting knife and a radiused channels that interface with the knife portion **512** and radiused portions **510** and **514**. The top plate **67** is the forming ring, and includes a radiused channel that interfaces with the forming wheel **504**. As will be described in more detail hereafter, a crimping plate **59** operates to push forming plate **67** downwardly after formation of the coupling bead between gore sections, to engage the formed coupling bead and crimp or seal it tightly closed. Between the plates **65** and **67** are provided springs **79** to bias the plates to an open position after crimping of the formed coupling bead, as seen in FIG. **19**. The forming ring provided by forming plate **67** creates the form of the gore before it is crimped and then is pushed down to crimp the formed coupling bead between gores of the elbow duct.

(34) Another example of cutting and forming head is shown in FIG. **13**, comprising a rotating head **300** driven by a central gear **302**. The head **300** includes three cassettes **304** which are movable on a support **306**. Associated cams **308** cause movement of the cassettes to move outwardly and engage the work piece as described in association with the cutting and forming wheels in each cassette **304**. Other suitable configurations may be used.

(35) Turning to FIGS. **20** and **21**, there is shown a portion of the tooling to form the coupling beads between gore sections and to seal these connections after being formed, in conjunction with the cutting and forming head **400**. In this example, the die assembly **58** supported adjacent the nest **56** as shown in FIG. **3**, is formed by the first and second semicircular die members **60** (and **62**) which are positioned on opposed sides of the nest **56**. The tooling includes three plates that are stacked and attached to one another for cooperative operation. In this example, the die member **60** includes a cutting plate **65** positioned at the bottom, along with a forming plate **67** positioned above the cutting plate **65**. There is a spacer **71** between plates **65** and **67** as previously described, for maintaining the spacing between the cutting and forming plates **65** and **67** during sealing the joint between gore sections of the work piece **12** after being formed. The pair of thin semicircular plates or spacer rings **71** are mounted in association with the cutting plate **65** and forming plate **67** to facilitate forming the desired sealed connections between gore sections in association with the operation of crimping plate **59**. The spacers **71** may be about 0.040″, for example, and maintain the spacing between portions of the formed connection between gore sections of the work piece **12** to properly seal the connection after being formed.

(36) There is also provided an upper holding system **81** that may be used in addition to the holding system **63** as previously described. The holding system **81** ensures that the upper gore section of the work piece **12** after cutting remains in the proper position for re-attachment to the lower gore section. In operation, after cutting of the work piece **12** at a location x in FIG. **1**, to form the elbow configuration, the cut gore sections are rotated relative to one another before re-attaching. The relative rotation between the parts should be precise to ensure the ultimate 90 degree elbow configuration is formed properly, and maintaining the desired position of the upper gore section relative to the lower gore section during cutting is facilitated by the upper holding system **81**. The upper holding system **81** in this example is a slidable plate movable between engaged and disengaged positions by an actuator **85** (as shown in FIG. **22**), that moves into and out of engagement with angled surfaces **83** formed on opposing plates **81** to move plates **81** into engagement with the top gore section. Return springs **87** are provided to move plates **81** out of engagement upon movement of actuator **87** out of engagement with surfaces **83**. The holding system **81** operates independently to allow secure holding of the top gore section during the cutting

operation.
(37) After formation of the connecting beads, the beads may be crimped and sealed to substantially prevent the egress of air therethrough. As shown in FIG. **22**, a crimping assembly **59** or plate is provided above the die assemblies **60** and **62** and moved downwardly against the forming plates **67** to cause downward movement of the forming plate **67** against the formed connecting beads in each gore section. This applies force to the formed connecting beads to seal the connecting beads. In this example, the crimping plate **59** is moved by twin servo driven ball screws **77** on opposing sides, controlled by a computer driven servo drive. The use of twin servo driven ball screws **77** ensures that each portion of the formed connecting beads are properly and evenly sealed. Other suitable systems for crimping may be used. A block diagram of an exemplary, non-limiting embodiment to describe operation of the system is shown in FIG. **23**. Operation of the apparatus and components may be controlled by a control system, including a computing device that may comprise one or more processor(s) configured to execute computer-executable instructions, such as instructions composing operation of one or more components of the machine **50**. Such computer-executable instructions can be stored on one or more computer-readable media including a non-transitory, computer-readable storage medium such as memory associated with the computing device.
(38) In general, once the work piece **12** is positioned in nest **56**, the operation is started at 100. The bottom clamp **61** is closed at **102** to secure the work piece **12** into positon. The work piece is moved to the position of a first cut at **104** by the moving system **55** and may be rotated 180 degrees clockwise at **106** by the clamping and rotating assembly. The first top holding system or clamp assembly **63** is closed at **108** and the secondary top clamping device **81** is closed at **109** to ensure the top duct section does not move during a first cutting operation performed at **110**. The cutting operation is performed by the cutting and forming system **70**, which will initially cut the work piece along a predetermined angular position defined by the angle of the die members **60** and **62** and cutting and forming assembly **70** relative to the work piece **12** positioned within the channel. The cutting operation is performed by engaging the cutting wheel **72** with the work piece in association with the cutting plate **65**. Once the work piece is cut by the cutting and forming system **70**, the top secondary holding system **81** is disengaged at **111** and a support surface or tub **68** is moved up a predetermined amount, such as between 0.03 to 0.10 inches, or in this example, 0.060 inches, at **112**, to position a portion of the cut section relative to the cutting and forming system **70**. The cutting and forming assembly **70** is then operated to pre-form a portion of the work piece by engaging the turning head of system **70** at **114** to engage the forming wheel **74** with the work piece. The top section of the cut work piece is then rotated 180 degrees clockwise at **116**, and the turning head is disengaged at **118**. At this point, the machine operation performs a breed lift operation at **120**. After being cut and pre-formed, the breed lift causes the bottom section of tube to be inserted into an overlapping position with the top section. A pre-crimping operation is performed at **122**, to form a portion of the work piece for subsequent sealing. The semi-circular rings associated with the cutting and forming assembly **70** facilitate controlling the flow or forming of material of the work piece during the breeding and pre-crimping processes. Thereafter, a forming operation is performed at **124**, wherein the forming wheel in association with the forming plate produce a connecting bead in the work piece sections to reconnect the sections. The forming operation provides a second stage of crimping of the produced reconnection between gore sections, to form a reconnection that is suitably sealed after subsequent high pressure crimping by a crimping plate **59**. A step of moving of the crimping plate **59** is performed at **126** to provide a final or third stage of crimping at **128** and tightly seal the reconnection between gore sections. The pressure applied by the crimping plate **59** may be controllable and adjustable if desired. At this point, the first sealed connecting bead is formed between gores or sections in the work piece **12**.
(39) As noted from the first operation, after cutting and preforming the connecting bead, the machine will automatically turn the first section 180 degrees, and then machine will complete the forming operation of the connecting bead. After the connecting bead is complete, the crimping

plate **59** will apply pressure and make a tight non-adjustable seal. The machine can produce an adjustable duct member by not using full pressure on the crimping process if desired.

(40) The tub **68** is then moved to the position to form the second connecting bead at **132**, and is rotated 180 degrees counter clockwise at **134**. The top clamp **63** is closed at **136** and a secondary top clamp is closed at **137**. A cutting operation performed at **138**, and secondary top clamp **81** is opened at **139**. As in the first connecting bead forming operation, the tub is moved up an amount, such as 0.060 inches at **140** and the turning head is engaged at **142**. The top cut section is then rotated 180 degrees clockwise at **144**, and the turning head disengaged at **146**. The breed lift is performed at **148** and pre-crimping at **150**. A second forming operation is then performed at **152**, to form the second connecting bead. The forming operation provides a second stage of crimping of the produced reconnection between gore sections, to form a reconnection that is suitably sealed after subsequent high pressure crimping by a crimping plate **59**. The crimping plate **59** is operated at **154** to crimp the formed connecting bead at **156**. The top clamp **63** is then opened at **158**, and the sealed second connecting bead is formed between gores or sections.

(41) The tub **68** is then moved to the position to form the third connecting bead at **160**, and is rotated 180 degrees clockwise at **162**. The top clamp **63** is closed at **164** and a secondary top clamp **81** is closed at **165**. A cutting operation is performed at **166**, and secondary top clamp **81** opened at **167**. As in the first and second connecting bead forming operations, the tub is moved up an amount, such as 0.060 inches at **168** and the turning head is engaged at **170**. The top cut section is then rotated 180 degrees clockwise at **172**, and the turning head disengaged at **174**. The breed lift is performed at **176** and pre-crimping at **178**. A third forming operation is then performed at **180**, to form the third connecting bead. The forming operation provides a second stage of crimping of the produced reconnection between gore sections, to form a reconnection that is suitably sealed after subsequent high pressure crimping by a crimping plate **59**. The crimping plate is operated at **182** to crimp the formed connecting bead at **184**. The top clamp **63** is then opened at **186**, and the sealed third connecting bead is formed between gores or sections.

(42) The tub **68** is then moved to the position to form the fourth connecting bead at **188**, and is rotated 180 degrees counter clockwise at **190**. The top clamp **63** is closed at **192** and secondary top clamp **81** closed at **193**. A fourth cutting operation is performed at **194**, and secondary top clamp **81** opened at **195**. As in the prior connecting bead forming operations, the tub is moved up an amount, such as 0.060 inches at **196** and the turning head is engaged at **198**. The top cut section is then rotated 180 degrees clockwise at **200**, and the turning head disengaged at **202**. The breed lift is performed at **204** and pre-crimping at **206**. A fourth forming operation is then performed at **208**, to form the fourth connecting bead between gores. The forming operation provides a second stage of crimping of the produced reconnection between gore sections, to form a reconnection that is suitably sealed after subsequent high pressure crimping by a crimping plate **59**. The crimping plate is lifted at **210** to crimp the formed connecting bead at **212**. The top clamp **63** is then opened at **214**, and the sealed fourth connecting bead is formed, and the part is now formed into a sealed 90 degree elbow in final form, without operator intervention except to position work piece **12** and remove the final form, sealed elbow duct member.

(43) In the above operations, each step may be performed automatically. As seen in FIG. **24**, a control system **250** for the machine **50** may be provided by suitable systems, such as computer, including processor(s), PLC controllers or any other suitable system. A computer typically includes a variety of computer readable media and can be any available media that can be accessed by computer. The system memory may include computer storage media in the form of volatile and/or nonvolatile memory such as read only memory (ROM) and/or random access memory (RAM). By way of example, and not limitation, there may be provided an operating system, application programs, other program modules, and program data. A user or operator is enabled to enter commands and information into the computer. In this example, the control system **250** includes a touch screen to allow setting and selection of operation of machine **50**, which may be by an

unskilled operator. The machine **50** may be started at 251 and set up in automatic mode at **252**. Recipes or predetermined operational steps such as outlined in the above example, may be set in relation to the production of desired duct members, and such recipes may be called up and implemented automatically at button **254**. In this way, an unskilled operator can simply recall a particular recipe for the type of duct member to be produced, alleviating the necessity for a skilled operator and simplifying the manufacturing process. A manual mode may be provided at **256**. A machine drive reset button **258** may be provided to reset the starting position of the machine if needed. A parts counter **260** may be provided, with a reset button at **262**. Indicators may be provided to indicate operation of systems as noted, and an emergency stop button **264** may be provided for emergencies. But, as noted above, the formation of the duct member is automatically performed on a work piece **10** inserted into the channel, and there are no further actions by an operator required.

(44) The control system **250** also provides access to control all machine functions, such as the top clamp **63** at **266**, bottom clamp **61** at **268**, and the crimping system at **270**, including a low pressure crimp option at **271**. The cutting and forming head may be controlled at **272**, while tub movement is controllable at **274**. Rotational movement of the tub or top clamp is controllable at **276**. Other functionality may be provided, such as setting the desired positions of connecting beads to form the gores of the duct member at **278** for example, or any other requirements as may be desired.

(45) While the above description has been presented with specific relation to particular examples of the systems and methods, it is to be understood that the claimed invention is not to be limited thereby. Illustrative embodiments have been described, hereinabove. It will be apparent to those skilled in the art that the above devices and methods may incorporate changes and modifications without departing from the general scope of the claimed subject matter. It is intended to include all such modifications and alterations within the scope of the claimed subject matter. Furthermore, to the extent that the term “includes” is used in either the detailed description or the claims, such term is intended to be inclusive in a manner similar to the term “comprising” as “comprising” is interpreted when employed as a transitional word in a claim.

Claims

1. A method of forming a sealed duct member comprising, providing a blank work piece and positioning the work piece in a work station at a starting position, automatically forming the sealed duct member from the blank work piece by: clamping the work piece and moving the work piece to a position where a cut is to be made, clamping the work piece above the position where a cut is to be made, cutting and pre-forming the work piece to form first and second sections, wherein the pre-forming produces different predetermined radiused portions in the first and second sections adjacent the cut, the radiused portions pre-crimping the first and second sections in a first crimping stage, moving the first section toward the second section a predetermined amount, rotating the second section relative to the first section, forming connecting beads in each of the first and second sections using at least one die member and at least one forming wheel, the connecting beads reconnecting to reconnect the first and second sections and the least one forming wheel configured to provide a second stage of crimping, and crimping the formed connecting beads together by forcing at least one crimping plate positioned above the connecting beads downwardly under pressure in a third stage of crimping to form a flat sealed connection between the first and second sections.

2. The method of claim 1, where a plurality of recipes for manufacture of predetermined duct members are provided, and an operator selects a recipe and positions the blank work piece in the work station to automatically produce a selected predetermined duct member without further intervention by the operator.

3. The method of claim 2, wherein a recipe for an elbow duct configuration may be selected by the

operator to automatically form the elbow duct configuration from a blank cylindrical work piece.
4. The method of claim 1, wherein the at least one die member has a top surface and the at least one crimping plate engages the top surface of the at least one die member under pressure to crimp and evenly seal the first and second sections into the flat sealed connection.
5. The method of claim 1, wherein the clamping the work piece above the position where a cut is to be made is performed by a first top clamp engaging the interior of the first section above the position where a cut is to be made and secondary top clamp engaging the exterior of the first section above the position where a cut is to be made.
6. The method of claim 1, wherein at least one cutting plate is provided to cut the work piece and at least one forming plate is provided adjacent the at least one cutting plate to form the connecting beads and at least one spacer is positioned between the at least one cutting plate and the at least one forming plate.
7. The method of claim 1, wherein the pre-crimping of the first and second sections in the first crimping stage is performed by forming the different radiused portions in the first and second sections to form the flat sealed connection after the second and third stage crimping operations are performed.
8. The method of claim 7, wherein the radiused portion in the first section is formed with multiple radii.
9. The method of claim 8, wherein the multiple radii include a first radius and a second radius, wherein the first radius pre-forms a portion of the first section to allow the third stage crimping operation to form the flat sealed coupling.
10. The method of claim 1, wherein at least one cutting wheel is used for cutting and pre-forming the workpiece that includes a first radiused portion, a knife portion and second radiused portion, wherein the first and a second radiused portions pre-form the first and second sections upon being cut by the knife portion, and wherein the first radiused portion has a dimension that is greater than the second radiused portion.
11. The method of claim 1, wherein top and bottom clamps are sequentially operated to secure and rotate the first and second sections relative to one another.
12. The method of claim 1, wherein a forming wheel is used to form the connecting beads in each of the first and second sections, with the forming wheel having a section interfacing with the at least one die member to provide the shape of the connecting beads for the second stage of crimping.
13. The method of claim 1, wherein the at least one crimping plate is moved downwardly by twin servo driven ball screws on opposing sides of the at least one crimping plate.
14. The method of claim 1, wherein the second stage of crimping is performed after reconnection of the first and second sections of the work piece by forming the connecting beads to produce the flat sealed connection with the crimping plate in the third stage of crimping.
15. The method of claim 1, wherein the first and second sections are automatically rotated 180 degrees relative to one another before being reconnected and the work piece is automatically rotated in either clockwise or counterclockwise directions after reconnection of the first and second sections.