July 22, 1958 W. L. ENGHAUSER 2,844,185

METHOD OF AND APPARATUS FOR BENDING WORKPIECES BY PUSHING THEM INTO A CURVED DIE-CAVITY

Filed March 9, 1954 3 Sheets-Sheet 1

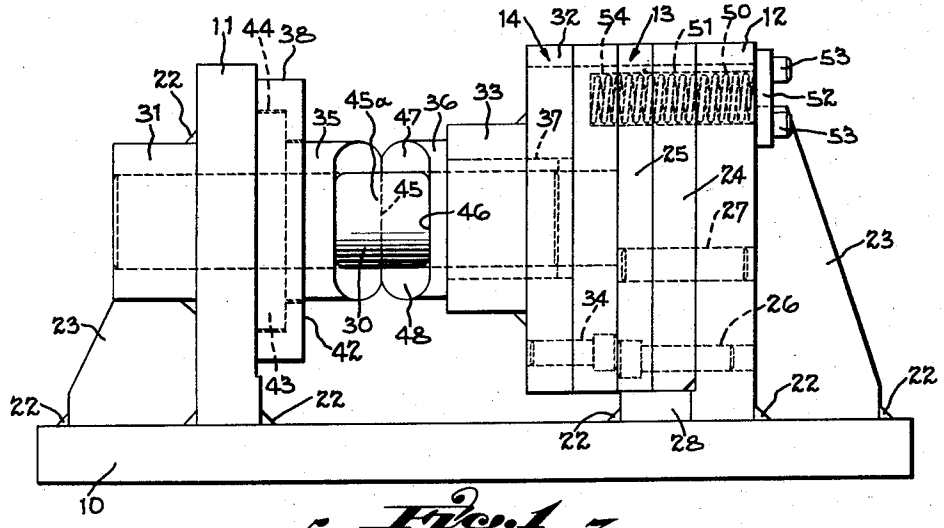


Fig. 1

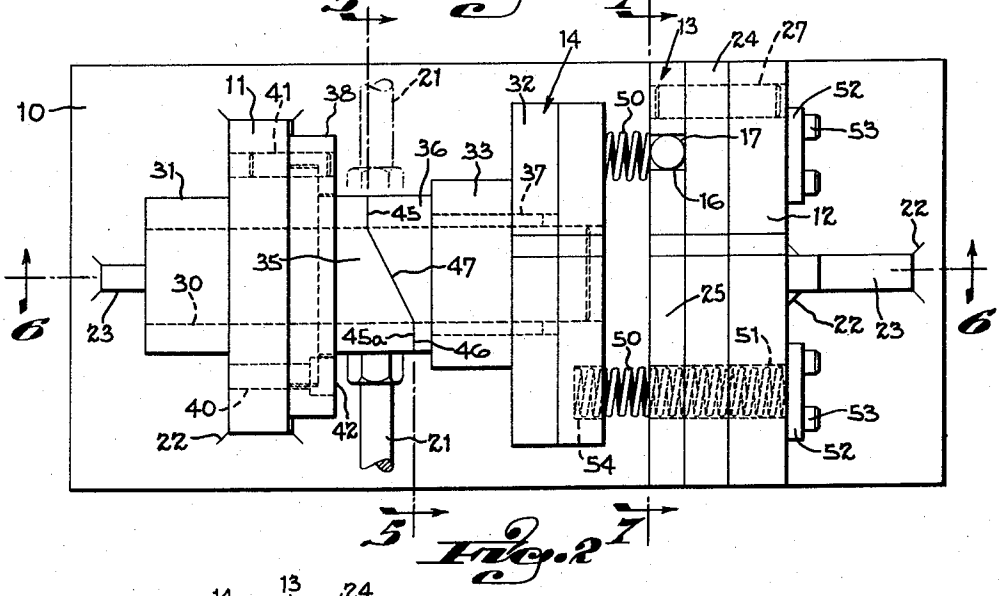


Fig. 2

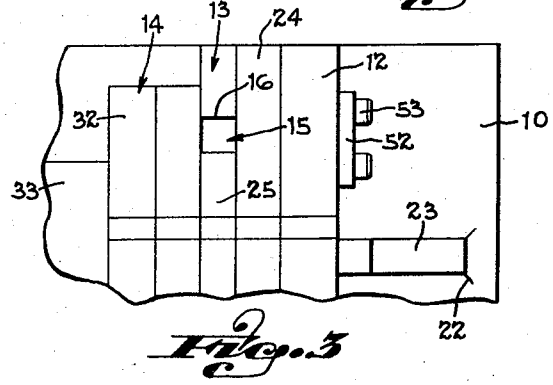


Fig. 3

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Filed March 9, 1954 3 Sheets-Sheet 2

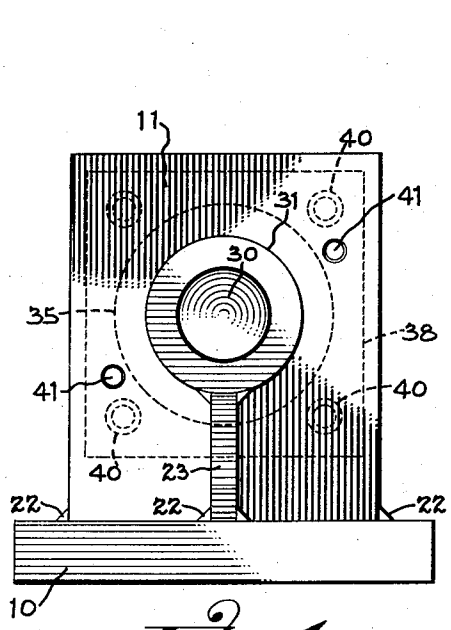


Fig. 4

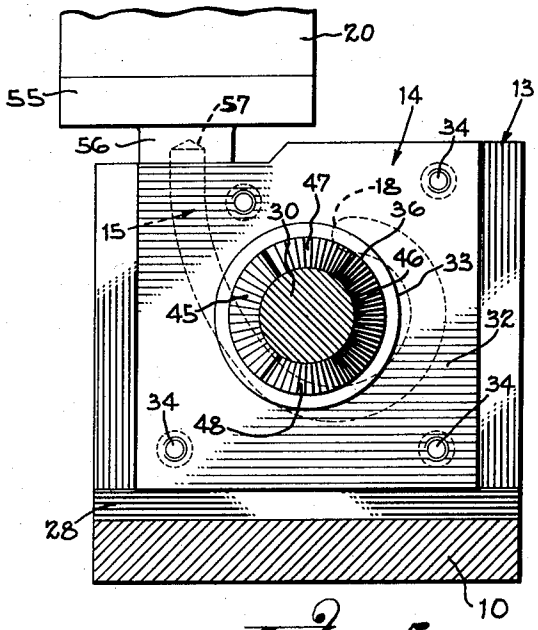


Fig. 5

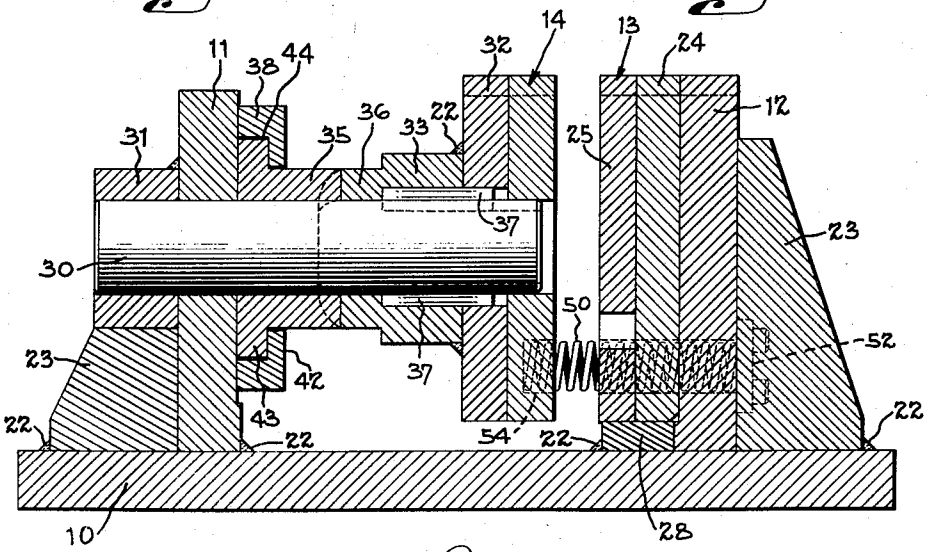


Fig. 6

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Filed March 9, 1954 3 Sheets-Sheet 3

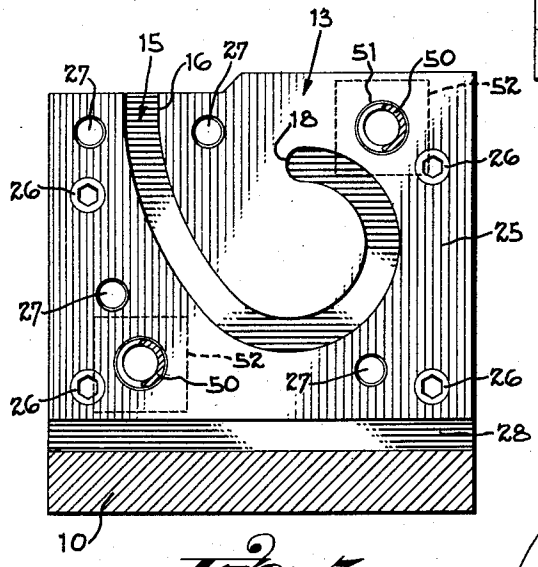
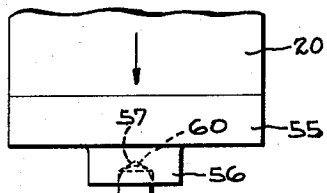


Fig. 7



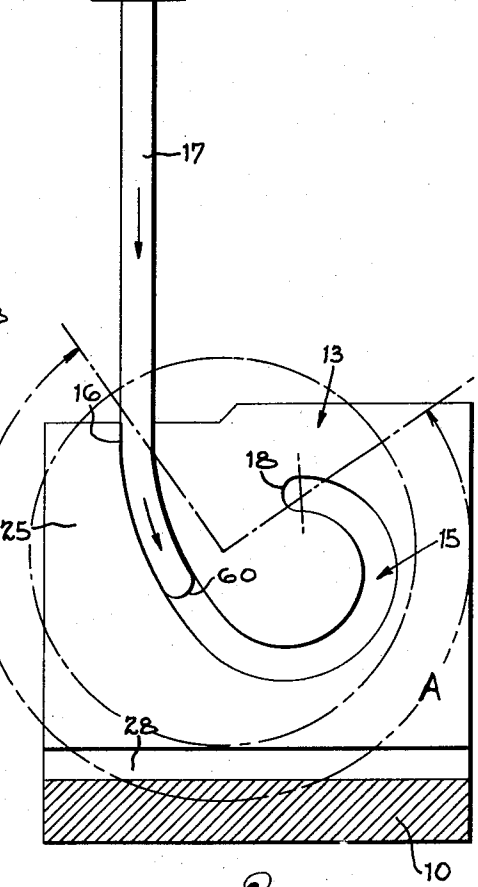


Fig. 8

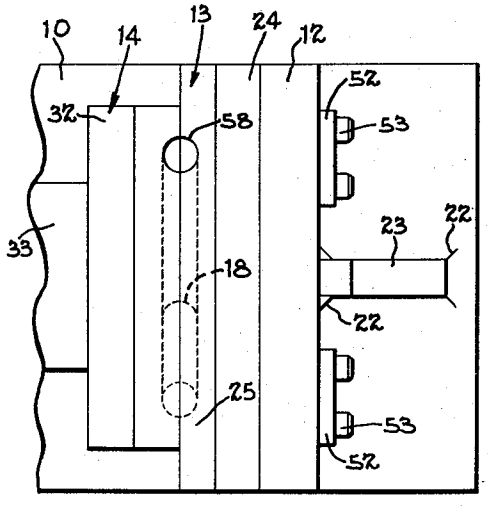


Fig. 9

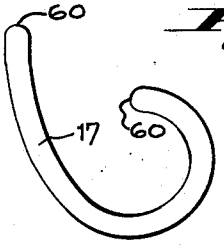


Fig. 10

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METHOD OF AND APPARATUS FOR BENDING WORKPIECES BY PUSHING THEM INTO A CURVED DIE-CAVITY

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Application March 9, 1954, Serial No. 414,953

5 Claims. (Cl. 153—48)

This invention relates to a die for imparting a convolute or sinuous form to a straight length of metal tubing or bar stock and is intended particularly for forming ornamental iron pieces or mechanical parts to a desired length configuration. The invention involves method and apparatus aspects, both relating to the bending of lengths of stock to a curved configuration.

One of the primary objects of the invention has been to provide a die which may be used with a conventional die press to bend successive workpieces to a simple or complex lineal configuration at a rapid, economical production rate.

Machines for bending bar stock, tubes and pipes are well known and have been used for many years. One class of such machines utilizes the principle of bending the stock progressively around a forming block having the desired curve formation. The stock may be forced around the forming block by a shoe member attached to a swinging arm, or the forming block may be forced against an intermediate portion of the stock while the end portions of the stock are engaged against stops. In another type of equipment, the stock is formed between fixed and movable dies mounted in a press, the two dies having complementary curved faces arranged to bend the stock as the two dies are forced toward one another. These structures necessarily are limited to the formation of regular curves, or a combination of curves and straight sections of fairly simple design.

The present invention is intended for bending lengths of cylindrical stock to relatively irregular curves, which may extend through an arc greater than 180 degrees, for example, generally spiral or sinuous forms which are difficult to reproduce with conventional methods or apparatus. Briefly, the invention involves the use of a die having an elongated cavity or passageway which is generally convolute along its length, the length of stock being forced under pressure lineally into an open end of the cavity so as to progressively reproduce the configuration of the cavity in the length of stock. The longitudinal curvature of the die cavity preferably extends through an arc substantially greater than 180 degrees of a circle inscribed about the die cavity. The cavity is open along one side throughout its length and the die includes a closure plate which resides along the open side of the cavity, the closure plate being shiftable laterally for removing the workpiece after it has been formed in the cavity. In other words, since the cavity imparts its lineal configuration to the length of stock, the stock must be dislodged laterally from the cavity after it is formed.

As applied to the bending of tubular stock such as pipe, which is circular in cross section, the cavity preferably is square in cross section and loosely confines the pipe about four sides. This provides flat lineal bearing surfaces tangent to the cylindrical surface of the stock at four sides for guiding the stock with the least possible frictional resistance as it is forced longitudinally through the die cavity. The surface of the closure plate delineates one of the four walls of the cavity to simplify the construction of the die assembly. In another form, the cavity is circular in cross section and is delineated by a pair of semi-circular grooves formed in the die and closure plate and mating with one another. The die is mounted in fixed position upon a base plate and the closure plate is slidably mounted upon the base plate for movement laterally to and from the open side of the cavity. Actuating means, which may be hand or power operated, shifts the closure plate relative to the die cavity and clamps it under pressure against the die in closed position to confine the stock as it is forced into the cavity. For the purpose of illustrating the principle of operation, a hand operated cam is disclosed as the means for actuating and clamping the closure plate; however, it will be apparent that a power actuated clamp structure may be used.

In operation, the die assembly is mounted directly upon the platen or table of a press with the open end of the cavity exposed at the top surface of the die assembly. The straight length of stock is inserted into the open end of the cavity and is forced lineally into the cavity upon downward motion of the ram of the press or by upward motion of the table, depending upon the type of press. After the stock is formed, the ram is elevated, the closure plate is retracted for removal of the formed piece and the closure plate is shifted back to closed position for the next operation, thus allowing the successive pieces to be formed at a rapid production rate. The die is useable with practically any type of press which has a stroke of sufficient length to accommodate the length of the workpieces and sufficient power to form them.

Various other features and advantages of the invention will be more fully apparent to those skilled in the art from the following detailed description taken in conjunction with the drawings.

In the drawings:

Figure 1 is a side elevation of the die assembly in closed position.

Figure 2 is a top plan view projected from Figure 1, showing the die in open position for removal of the formed length of stock.

Figure 3 is a fragmentary top plan view similar to Figure 2, showing the die in closed position.

Figure 4 is an end view of the die assembly.

Figure 5 is a cross sectional view taken on line 5—5, Figure 2, illustrating the face of the cam which actuates the closure plate of the die assembly.

Figure 6 is a longitudinal sectional view taken along line 6—6, Figure 2.

Figure 7 is a sectional view taken along line 7—7, Figure 2, detailing the forming plate of the die.

Figure 8 is a diagrammatic view of the die, showing a length of stock being forced therein by the ram of a press.

Figure 9 is a top plan view illustrating a die assembly of slightly modified construction.

Figure 10 is a side view illustrating the workpiece after being ejected from the die.

Described generally with reference to Figures 1 and 2, the die assembly is of welded construction consisting of a base plate 10 having a pair of mounting blocks 11 and 12 rising upwardly from its opposite end portions. The block 12 supports the forming plate assembly which is indicated generally at 13 and the second block 11 movably carries a closure plate assembly 14 which is shifted to an open or closed position relative to the forming plate as shown in Figures 1 and 2. The forming plate assembly includes at its open face an elongated die cavity or passageway indicated generally at 15 (Figure 7)

which determines the shape to be imparted to the workpiece.

In the present disclosure, the cavity is generally convolute as viewed in Figures 7 and 8, the cross section of the cavity being generally square (Figure 3). In this example, the longitudinal curve of the cavity is irregular and the arc of the curve decreases progressively in the form of a spiral from the open end towards the closed end of the cavity. The degree of curvature from the open end to the closed end of the cavity is indicated diagrammatically as the arc A of a circle inscribed about the cavity. It will be noted in the example, that the arc A extends approximately three quarters around the inscribed circle, being substantially greater than 180 degrees. The open end of the cavity at the top of the forming plate includes a straight portion indicated at **16** to facilitate the entry of the stock, such as the cylindrical tube or rod **17** illustrated in the drawings. With the die in closed position, the length of stock is forced axially into the cavity by the ram of the press (Figure 8), causing the leading end of the stock to follow the curving passageway delineated by the cavity. The length of stock thus is progressively bent to a spiral or convolute shape corresponding to the cavity. When the leading end of the stock engages the end **18** of the passageway the forming operation is complete. At this point the ram **20** is retracted and the closure plate is shifted to its open position shown in Figure 2, allowing the formed part to be slipped laterally from the open side of the cavity.

In a production operation, the base **10** of the die is mounted upon the bed or platen of a conventional press, the ram **20** being movable vertically in alignment with the open end of the cavity. The stock is cut to the required length and the pieces are placed endwisely into the open end **16** of the cavity, with the ram in its elevated position above the upper end of the stock. A suitable lubricant may be applied to the stock or to the die passageway to reduce frictional resistance as the stock is forced through the passageway by the ram. As described later in detail, the die assembly may include a manually operated lever **21** for opening and closing the die. This lever is swung to closed position during the forming operation and is shifted to open position at completion of the operation to allow the formed workpiece to be removed.

Described in detail, the base plate consists of a relatively heavy plate which may be clamped in the usual manner upon the bed of the press. The mounting blocks **11** and **12** preferably are welded directly to the top surface of the base plate as indicated at **22**. The blocks **11** and **12** each include a reinforcing web **23** which is welded to the surface of the respective blocks and mounting plate to resist the forces tending to separate blocks **11** and **12** during the forming operation.

Mounting block **12** carries upon its inner face a spacer plate **24** and a forming plate **25** which, as best shown in Figure 7, includes the cavity or forming passageway **15**. The cavity as disclosed, is machined as an open curved slot completely through the forming plate, one side of the cavity being enclosed by the spacer plate **24** and the other side by the closure plate **14** when in closed position. The forming plate preferably is fabricated from tool steel suitably hardened to resist wear. The spacer plate **24** and closure plate **14**, which are subjected to less wear, may be fabricated from hardened steel but need not be of the same hardness as the forming plate. The active surfaces of the plates are ground to a smooth finish to facilitate the passage of the stock into the cavity.

As best shown in Figure 7, the forming plate and spacer plate are attached to the mounting block by means of the screws **26** having heads countersunk in the forming plate. The shanks of the screws pass through both plates and are threaded into the mounting block **12** as indicated in broken lines in Figure 1. In addition to the screws, a series of dowel pins **27** pass through the assembled plates and mounting block to maintain them in accurate alignment with one another. In order to sustain the forming and spacer plates under the force imposed by the ram during the forming operation, a block **28** is interposed between the base plate and lower edge of the forming and spacer plates. The block transmits the ram pressure directly from the forming plate to the base plate which is seated upon the table of the press.

The closure plate assembly **14** is mounted for axial motion along the shaft **30** which projects from mounting block **11** toward the forming plate assembly. Mounting block **11** includes a boss **31** welded as at **22** to the external surface of the block and to the upper end of the reinforcing web **23**. The outer end portion of shaft **30** is press fitted into a bore which is common to the block **11** and boss **31**. The closure plate assembly is mounted for axial movement along the shaft upon a backing plate **32** which includes a boss **33** welded as at **22** to the surface of the backing plate on the side opposite the closure plate. The closure plate is attached to the backing plate by the screws **34** having their heads countersunk in the closure plate similar to the screws **23** (Figures 1 and 5).

The closure plate assembly is slidably mounted upon shaft **30** for movement to its open and closed positions by means of a cam **35** which is mounted for rotation upon shaft **30**. The cam is rotated by lever **21** which projects outwardly from the cam. The boss **33** of the closure plate assembly includes a non-rotatable cam **36** at its outer end which is complementary to the surface of cam **35**. The closure plate assembly **14** and its cam **36** are non-rotatably keyed to the shaft by the keys **37—37** fixed to the boss **33** and slidably interfitting the keyways **38** formed in the shaft. Rotation of the cam **35** is effective to shift the closure plate assembly axially along shaft **30** while the keys **37** prevent the assembly and its cam **36** from rotating.

The rotatable cam is confined against axial motion by a retainer block **38** which is attached to the mounting block **11** by the screws **40** and dowel pins **41** (Figure 2). The retainer block includes an opening having an annular lip **42** which overhangs the annular flange **43** of the rotatable cam. The flange **43** thus is confined against axial motion between the overhanging flange and the surface of the mounting block **11** as shown in Figure 6. Suitable clearance, as indicated at **44**, is provided around the periphery of the cam.

Referring to Figure 5, the face of cam **36** is provided with two flats **45** and **46** which are located at diametrically opposite sides as indicated. As viewed in Figure 2, the flats are located in planes which are spaced from one another along the axis of shaft **30**, the flats being joined by the inclined camming surfaces indicated at **47** and **48** on respectively opposite sides. The faces of the fixed cam and rotatable cam are complementary to one another and nest together when the rotatable cam is positioned to retract the closure plate (Figure 2). When the actuating lever **21** is swung in closing direction, the inclined camming surface of the rotatable cam **35** advances or planes relative to the inclined camming surface of the non-rotatable cam **36**, causing cam **36** and its associated closure plate assembly to be shifted toward the forming plate. Upon rotation of approximately one half turn, the flat **45***a* of the rotatable cam, advances toward and over the flat **45** of the non-rotatable cam, the closure plate having thus been shifted into pressure engagement against the surface of the forming plate as shown in Figure 1. In closed position, the actuating lever **21** is in the position shown in broken lines in Figure 2. It will be evident that upon facial engagement with one another, the two flats **45** and **45***a* clamp the closure plate assembly rigidly against the forming

plate to withstand the pressure tending to separate the two plates as the stock is forced lineally into the cavity.

After the bending operation, the lever **21** is swung back to the position shown in Figure 2 and the closure plate assembly is shifted to its retracted position by the compression springs **50**. As shown in Figure 7, these springs are located at diagonally opposite corner portions of the forming plate assembly and are confined in bores **51** extending through the plates. Each spring is seated against a plate **52** attached by screws **53** to the mounting block **12**. The opposite end of each spring is seated against the end of a bore **54** formed in the face of the closure plate.

The lower end of the ram **20** is provided with a pressure plate **55** which includes a central boss **56** projecting downwardly (Figure 8). Centrally of the boss there is provided a bore **57** having a diameter corresponding to the stock **17** to confine the upper end of the stock as it is forced into the die cavity. The bore **57** is coaxial with the open end **16** of the cavity such that the stock is confined against lateral displacement. The forming pressure is in direct thrust or compression upon the stock so as to drive it into the cavity without imposing buckling forces upon the portion of the stock projecting from the die. It will be noted that the straight portion **16** of the cavity allows the stock to be placed partially in the die cavity without pressure so as to facilitate the start of each operation.

The die assembly lends itself to rapid production of workpieces since the operator may place the lengths of stock rapidly in the open end of the cavity with the ram elevated, initiate press operation and remove the finished workpieces in rapid sequence. Following conventional practice, the press may be equipped with an automatic control system including power means for opening and closing the closure plate in response to the position of the ram. For this purpose it is contemplated to utilize a power motor, such as an air cylinder, to shift the closure plate to its open and closed positions instead of the cam structure. Since mechanism of this type is well known, it has been omitted from the drawings.

It will be understood that the press may be of the type having a movable table and a fixed stop member as distinguished from the movable ram disclosed in the present example. In this case the forming operation is identical except that the die assembly is moved toward the fixed stop during the forming operation.

The spiral form of the elongated cavity illustrated in the drawings is selected to illustrate the operating principles of the invention. It will be understood that the cavity takes various other forms as dictated by the shape to be imparted to the stock. The desired configuration is machined as an open slot in the forming plate, such as by a milling operation; thereafter, the forming plate is hardened, ground and attached to the spacer plate as described earlier. When utilizing a die cavity having a curvature extending substantially beyond an arc of 180 degrees, as shown in Figure 8, the frictional resistance to the advancement of the stock increases sharply as the length of stock curves beyond 180 degrees. Moreover, the resistance is further increased as the spiral curvature increases toward the closed end of the die. However, the flat lineal bearing surfaces of the die cavity reduces the friction sufficiently to make it possible to bend the stock without requiring undue pressure or causing collapse of the walls of the tube. It will be understood that the stock is forced longitudinally into the cavity until its leading end contacts the closed end **18** of the cavity. The closed end thus controls the bending operation and makes it possible to bend successive lengths of stock to identical configuration.

The die assembly shown in Figure 9 is similar to the structure already described except that the cavity is cylindrical in cross section instead of square. The cavity is constituted by a pair of complemental semi-circular grooves **58** let into the surface of the forming plate **25** and closure plate **14**. The cylindrical cavity is intended particularly for thin walled tubing since it creates a slightly different bending action by embracing the cylindrical stock around its entire periphery. In bending thin walled tubular material around a relatively sharp curve, there is a tendency for the tube to collapse more or less at the bend, depending upon the ductility of the material and other factors. As the tube begins to collapse, it necessarily becomes wider along the sides at right angles to the collapsing area. By confining the tube wall for its full circumference in the cavity, the wall is restrained against expanding and hence is supported against collapse. The cylindrical cavity also has the advantage of providing rapid dislodgment of the formed workpiece when the cavity is opened.

As outlined earlier, the die structure is intended particularly for working tubular stock such as iron pipe which is cylindrical in cross section. These parts are used in ornamental iron work, for example, railings, support columns for porches and other structures having the characteristics of wrought iron. The workpiece illustrated in Figure 10 represents such a workpiece formed in the illustrated die cavity. In the present disclosure, the workpiece consists of iron pipe, which is provided with closed rounded ends as indicated at **60** for appearance and weather protection. The end **18** of the die cavity is similarly rounded and the bore **57** of the pressure plate has a tapered end wall conforming generally to the rounded pipe end. It will be understood that the invention can also be applied to the formation of stock having a square or other form of cross section and may be either solid or hollow.

Having described my invention I claim:

1. A die arranged to be mounted upon a press having a relatively movable table and ram, the die adapted to bend a straight length of cylindrical metal stock to a generally curved form along its length, said die comprising a base adapted to be mounted upon the table of the press, a die mounting member rising at right angles from said base, a forming plate attached to the mounting member, said forming plate having an elongated open slot formed therein, said slot comprising a pair of flat bearing surfaces spaced apart from one another residing in right angles to the plane of the forming plate, and extending to the upper edge thereof, said slot being generally curved along its length and providing a die cavity, said mounting member having a flat face enclosing one side of the slot, the other side being open, a closure plate having a flat face, support means on the base connected to the closure plate shiftably supporting the same for movement relative to the forming plate, key means on said support means slidably engaging the closure plate and locking the closure plate against rotary motion relative to the forming plate, said closure plate engaging the forming plate at the open side of said slot to enclose the die cavity, said cavity being generally square in cross section providing flat bearing surfaces tangent to the cylindrical stock about four sides thereof, the cavity having an open end portion at the upper edge of the forming plate, the longitudinal curvature of the die cavity residing in a flat plane and extending through an arc substantially greater than 180 degrees of a circle inscribed about the longitudinal cavity, compression spring means interposed between the closure plate and forming plate, and actuating means connected to the closure plate for forcing the same against the forming plate counter to said compression spring means, the open end portion of said slot being effective to receive and confine an end portion of the straight length of stock with the stock projecting outwardly toward the ram of the press, thereby to be forced lineally into the cavity upon relative movement of the ram and table, the actuating means releasing the closure plate for movement by the compres-

sion spring means from the forming plate for removing the formed stock from the open side of the slot.

2. The method of cold bending a straight length of cylindrical metal stock longitudinally to an irregularly curved form which extends through an arc greater than 180 degrees, said method consisting of introducing the end portion of the length of cylindrical stock into an open end of a longitudinal die cavity which is curved longitudinally from said open end to a closed opposite end and having a coextensive opening along one side, said curvature extending through an arc greater than 180 degrees of a circle inscribed about the longitudinal cavity and about the opposite ends thereof, forcing a cover element against the co-extensive opening along one side of said longitudinal die cavity, thereby closing the longitudinal die cavity, said closed die cavity having in cross section a plurality of flat surfaces which are tangential to the cylindrical metal stock, said flat surfaces providing line bearing surfaces for guiding the stock longitudinally through the die cavity, applying sufficient pressure upon the outer end of the stock to force the same longitudinally through the open end of the die cavity and concurrently bending the stock toward said degree of curvature greater than 180 degrees, continuing to force the stock through the cavity until its leading end advances into abutment with said closed opposite end, thereby to bend the length of stock to the curvature of the longitudinal cavity, and removing the formed stock laterally from the coextensive opening of the die cavity.

3. The method of cold bending a straight length of cylindrical metal stock longitudinally to an irregularly curved form which extends through an arc greater than 180 degrees, said method consisting of introducing the end portion of the length of cylindrical stock into an open end of a longitudinal die cavity which is curved longitudinally from said open end to a closed opposite end and having a coextensive opening along one side, said curvature extending through an arc greater than 180 degrees of a circle inscribed about the longitudinal cavity and about the opposite ends thereof, the die cavity being generally square in cross section providing flat surfaces tangent to the cylindrical stock surface at four sides thereof, said flat surfaces providing line bearing surfaces for guiding the stock longitudinally through the cavity, applying sufficient pressure upon the outer end of the stock to force the same longitudinally through the open end of the die cavity and concurrently bending the stock toward said degree of curvature greater than 180 degrees, continuing to force the stock through the cavity until its leading end advances into abutment with said closed opposite end, thereby to bend the length of stock progressively to the curvature of the longitudinal cavity, and removing the formed stock laterally from the said coextensive opening of the die cavity.

4. The method of cold bending a straight length of cylindrical metal stock longitudinally to an irregularly curved form which extends through an arc greater than 180 degrees, said method consisting of introducing the end portion of the length of cylindrical stock into an open end of a longitudinal die cavity which is curved longitudinally from said open end to an opposite end and having a coextensive opening along one side, said curvature extending through an arc greater than 180 degrees of a circle inscribed about the longitudinal cavity and about the opposite ends thereof, forcing a cover element having a flat face against the opening along one side of the die cavity, the enclosed die cavity being generally square in cross section providing flat surfaces tangent to the cylindrical stock surface and providing line bearing surfaces for guiding the stock longitudinally through the cavity, applying sufficient pressure upon the outer end of the stock to force the same longitudinally through the open end of the die cavity and concurrently bending the stock toward said degree of curvature greater than 180 degrees, continuing to force the stock through the cavity until its leading end advances to said opposite end, thereby to bend the length of stock progressively to the curvature of the longitudinal cavity, removing the cover element from the said coextensive opening, and removing the formed stock laterally from the opening of the cavity.

5. A die arranged to be mounted upon a press having a relatively movable table and ram, the die adapted to bend a straight length of cylindrical metal stock longitudinally to an irregular curvature extending through an arc greater than 180 degrees, said die comprising a base adapted to be mounted upon the table of the press, a forming plate rising at right angles from said base, said forming plate having a flat meeting face and having a longitudinal slot therein, said slot having flat spaced side walls joined by a right angular bottom, said slot having an open end at the upper edge of the forming plate and a closed opposite end, the spaced side walls of the slot being irregularly curved longitudinally from said open end to said opposite closed end, said curvature extending through an arc greater than 180 degrees of a circle inscribed about the longitudinal slot, a closure plate having a flat meeting face, means securing the closure plate to the forming plate with said meeting faces engaged against one another, thereby covering the open side of said slot and providing a die cavity which is generally square in cross section, the open end of the die cavity thereby being effective to receive and confine an end portion of the stock with the stock projecting outwardly toward the ram of the press to be forced longitudinally into the cavity to the closed end thereof upon relative movement of the ram and table.

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