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PANEL FORMING EQUIPMENT

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15 Claims. (Cl. 153—44)

This invention relates generally to methods and apparatus for forming panels into desired spatial configuration, and more particularly has to do with economically forming long panels and tapered panels, and with flattening extrusions, without the use of expensive forming equipment.

Generally speaking it is common practice in bending or forming large metal panels to utilize dies, or rolls, or press brakes and actuating equipment therefor. With greater length, rolls and press brakes become more and more cumbersome and expensive because of the great rigidity which they require. Also, rolls are not suited to bending long panels where the panel curvature must change from end to end, or where the thickness of the panel changes so that it will react differently to the rolls. The present method of forming panels marks a radical change from these previously known methods in that the panel is allowed to move bodily and freely during bending to desired configuration as controlled by forcible bending of rigidly gripped spaced portions of the panel, as will be described.

In accordance with the teachings of the invention, there are provided means, preferably but not necessarily comprising rotary clamps, rigidly attachable to spaced portions of the panel and operable to bend the spaced panel portions for bend forming the panel, guide means typically extending longitudinally and laterally in spaced relation to the clamps, and means supporting the clamps and movable on the guide means either in response to transmission of reaction therethrough to the guides during panel formation or in response to applied forces or both. In addition, the support means generally includes power means for transmitting torque to the rotary clamps for rotating them to bend form the panel, the different clamps gripping different portions of the panel being controllably rotatable to predetermined extents, resulting in controlled bend forming of the panel to desired configuration.

More particularly, oppositely laterally spaced clamps are attachable to opposite edge portions of the panel, and clamp support assemblies are laterally movable toward and away from one another on horizontally extending guides. Thus, equal and opposite reaction forces will be transmitted through the support assemblies, and the panel will bend in accordance with the opposite torques exerted upon laterally opposite edges of the panel.

Further with regard to the structure of the support assemblies, they preferably include pivots having vertical and horizontal axes about which the clamps and the power means are free to rotate. Thus, each support assembly may be said to have four degrees of freedom comprising rotation about a vertical and a horizontal axis, and linear translation of the support assemblies along two horizontal axes i.e. along longitudinal and lateral ways. As will be seen, when a plurality of support assemblies constructed in accordance with the principles of the invention are used to support clamps rigidly attached to edge portions of a metal panel, the latter may be subjected to bend forming productive of any desired final panel spatial configuration.

These and other objects of the invention, as well as the details of an illustrative embodiment, will be more

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fully understood from the following detailed description of the drawings, in which:

FIG. 1 is an elevation showing the bend forming apparatus gripping a panel prior to bend forming thereof;

FIG. 2 is a view similar to FIG. 1 but showing the panel and apparatus at the completion of bend forming;

FIG. 3 is a plan view of the panel and apparatus of FIG. 2;

FIG. 4 is an enlarged fragmentary plan view of a single clamp member gripping a panel edge, together with the support means for the clamp including the power equipment for rotating the clamp member;

FIG. 5 is an elevation taken on line 5—5 of FIG. 4 and also showing the horizontal guide means for the clamp support assembly;

FIG. 6 is a section taken on line 6—6 of FIG. 5;

FIG. 7 is a section taken on line 7—7 of FIG. 5;

FIG. 8 is a section taken through the guide means and the lower portion of the support assembly;

FIG. 9 is a perspective showing of the clamp member, and part of the power equipment for rotating the clamp member;

FIG. 10 is a cross sectional view of a panel member right and left sides of which have been subjected to rotary bending and outward pulling;

FIG. 11 is a cross sectional view of a panel member right and left sides of which have been subjected to outward pulling and rotary bending;

FIG. 12 is a cross sectional view of a panel member opposite sides of which have been subjected to rotary bending;

FIG. 13 is a cross sectional view of a panel member opposite sides of which have been subjected to inward pushing and rotary bending;

FIG. 14 is a cross sectional view of a panel member opposite sides of which have been subjected to rotary bending and outward pulling;

FIG. 15 is a cross section through a cylindrical extrusion to be flattened by the instant apparatus; and

FIG. 16 is a section through a V-shaped extrusion to be flattened by the apparatus.

Referring first to FIGS. 1 through 3, the initially rectangular panel member designated at **10** has its oppositely initially parallel edges rigidly gripped by clamps or jaws **11** on rotary arms **12**. The latter may be rotated clockwise and counter-clockwise respectively and toward one another in a generally upward direction about horizontal longitudinal pivot axes **13** by the power equipment including roller chains **14**, sprockets **15** and linear actuators **16** which comprise part of the support assembly **17** for the clamp members. The clamp members and support assemblies together comprise clamp assemblies.

Each support assembly also includes a parallel pair of horizontally longitudinally spaced frame members **18** mounting the power equipment and carried by a pair of rotary discs **19** rotatable about a horizontal lateral axis **22** in the plane of FIGS. 1 and 2. The discs **19** are in turn carried by vertical plates **20** which are connected by channels **21** and are free to pivot about a vertical axis **23**.

Finally, laterally opposite support assemblies **17** are movable toward and away from one another on laterally horizontally extending ways or guides **24**, and opposite pairs of support assemblies are movable together on longitudinally and horizontally extending ways or guides **124** so that during bend forming of the panel the clamp members **11** and the power equipment have two degrees of freedom in rotation i.e. about axes **22** and **23** and in addition have freedom of horizontal translation both longitudinally and laterally in the directions of the ways **24** and **124**. FIG. 3 shows two pairs of support assemblies and clamp members as described, with the clamps gripping opposite edge portions of the panel and with two clamps being spaced apart at each opposite edge of the panel, and it will be understood that as many such parallel pairs of clamps may be used as are necessary to grip opposite sides of a long panel, and that the clamp members are differentially rotatable for variably and controllably bending the panel, and at the same time lifting it bodily to varying degrees about the different axes of clamp rotation to achieve the desired final panel configuration, as illustrated in FIGS. 10 and 11.

Referring now to the detailed construction of the panel forming apparatus, reference to FIGS. 5 through 8 will show that each of the ways **24** includes a base **26**, laterally spaced upright plates **27** mounted on the base, and a pair of vertically spaced and horizontally elongated tracks **28** attached to the outside of each plate, each track having an L-shaped cross section. Confined between the vertically spaced tracks are two pairs of laterally and longitudinally spaced cam rollers **29** mounted on axles **30** carrying a frame **31** so that the latter may roll horizontally lengthwise along the tracks. Lateral displacement of the frame **31** is limited by engagement of two longitudinally spaced cam rollers **32** with the inside faces of the plates **27**, the rollers being carried by vertical axles **33**.

The frame **31** in turn supports an upright central pivot axle **34** comprising part of the turret type support assembly designated at **17**. As shown in FIGS. 5 through 7, and also in FIG. 9, the pivot axle **34** centers upper and lower bearings contained in upper and lower bearing housings **35** and **36**, which are in turn bolted to the upper and lower transverse channel members **37** which inter-connect the two plates **20**. Thus, the plates **20** are able to pivot about the axle **34** while being held against vertical displacement thereon by the radial and thrust bearings contained within the bearing housings.

The upper portion of each plate **20** is generally annular as better seen in FIGS. 6, 7 and 9, each annulus supporting a series of circularly spaced cam rollers **38** centering one of the discs **19**, and a cam roller **39** bearing against the inside face of the disc to prevent inward displacement thereof. It will be seen that each disc is diametrically larger than the circular opening **40** in its corresponding plate **20**, so that the disc overlaps the inner side thereof, and is confined between that inner side and the cam roller **39** while being centered by rollers **38**. Thus, the discs are free to rotate about their common axis **22**, and are furthermore interconnected by the parallel, longitudinally extending and laterally spaced plates **18**. These plates are welded to the inner side of the rear disc **19** and pass through an opening **41** in the front plate **19**, being welded to the latter at the sides of that opening.

Extending between the two plates **18** are front and rear lateral axles **45** and **46** upon which are mounted two laterally spaced pairs of front sprockets **15** and two laterally spaced pairs of rear sprockets **15** appropriate bearings **49** being provided for this purpose. The sprockets in turn carry the roller chains **14**, opposite ends of which are retained on pins **51** carried by attachment blocks **52**. Since each pin retains the ends of two chains, there are two pairs of attachment blocks, and tension screws **53** interconnect the pairs of blocks **51** and **52**. A yoke member **54** extends between the two laterally spaced blocks **52** and is connected thereto for transmitting translational motion to all the chains from a piston rod **55**, a threaded connector **56** interconnecting the rod and the yoke. The piston rod projects forwardly from within a hydraulic cylinder **57**. A piston **58** connected on the rod is movable forwardly and rearwardly in the cylinder by the pressure of hydraulic fluid admitted through ports **59** and **60** respectively.

Carried by a hub **61** integral with the forward sprockets **15** is a rotary arm **12** supporting the clamp member or jaw **11** which has been previously referred to. The jaw is C-shaped in cross section as viewed in FIG. 5 and set screws **62** threaded therein are adapted to forcibly engage the edge portion of panel **10** inserted in the jaw opening, so that the panel may be rigidly clamped or gripped by the jaw.

FIGS. 1–3 show that laterally opposite ways **24** are rigidly interconnected by the beam member **70** to form a gantry type assembly spanning a bed **71**. The latter has longitudinally horizontally extending ways or tracks **124** upper and lower sides of which are engaged by rollers **72** carried by vertical supports **73** supporting the laterally opposite ways **24**. Thus each opposite pair of support assemblies **17** is freely movable longitudinally on ways **124**, as well as being movable laterally toward and away from one another on ways **24**. Also, ways **24** always extend at right angles to ways **124**.

FIGS. 1 and 2 show laterally opposite support assemblies **17** to be connected with the beam **70** through laterally extending hydraulic or pneumatic power cylinders **75**, piston rods **76** and structure **77** interconnecting rods **76** with the frames **31**. It will be understood that different power cylinders **75** may be left unactivated so as to permit free lateral movement on ways **24** of the support assemblies **17** connected thereto, and that selected power cylinders **75** may be activated to desired extent for exerting forces on the support assemblies connected thereto tending to displace them inwardly or outwardly, as desired, the amount of force exerted being controlled.

Referring now to the operation of the panel forming apparatus, a long panel member, for example a lengthwise elongated rectangular or tapered piece of sheet metal, is inserted into the space between the banks of opposed clamps and is then rigidly connected into the clamp or jaw openings **63**, the set screws **62** then being tightened on the panel inserted edge portions. At this time, the rotary arms **12** extend downwardly and slightly outwardly toward the support assemblies **17**. Assuming that the panel is to be bent to semi-cylindrical shape as seen in FIGS. 1, 2 and 12, pressurized hydraulic fluid is passed to the inlets **69** of all cylinders **57** to displace the pistons and piston rods horizontally outwardly to a controlled extent, thereby controllably rotating the rotary arms **12** and the clamps **11** about their respective axes **13**, for transmitting bending torque to the panel. During this process the opposite edge portions of the panel are bodily rotated clockwise and counter-clockwise respectively, and the entire panel is bodily lifted as viewed in FIG. 2. Since the panel intermediate the gripped opposite edges thereof is unconstrained, it bends in accordance with its stiffness characteristics and so as to remain in equilibrium as respects moments of force exerted thereon through the clamps, the spatial positions of the clamps affecting the transmitted moments and therefore the resultant configuration of the permanently deformed panel. In order that the extent to which the rotary arms **12** have rotated may be known at all times, measuring discs **65** are attached to the stationary axles **45** of the front sprockets, and rim portions of the discs are inscribed with degree markings **66** as viewed in FIG. 9, whereby the widely laterally flanged jaw or clamp **11** may pass closely adjacent the degree markings. Thus, when the jaw rotates the forward edge **67** thereof in passing adjacent the degree markings registers the extent to which the clamp has rotated, and pressurized fluid may be transmitted to the power cylinder until the clamp has rotated to the desired degree for appropriately bend forming the panel.

As pointed out previously, the freedom of the support assemblies **17** to pivot about the vertical and horizontal axes **23** and **22** and to translate longitudinally and laterally and along the guides **24** and **124** enables panel formation to be carried out without undesirable constraints which would adversely effect the forming of the panel to desired configuration. Also, since the power equipment is free to rotate and translate with the clamps about axes **22** and **23** and along the guides respectively, the transmission of torque or moments of force to the clamps is neither affected nor limited by their freedom to rotate and translate during panel formation as described.

When the opposite pairs of clamps **11** and support assemblies **17** are free to translate laterally along ways **24**, the clamps transmit a couple which produces a bending moment exerted on the panel and also transmit the downwardly exerted weight of the panel to the ways **24**. The support assemblies **17** may also be constrained against free lateral translation along ways **24** by activation of selected power cylinders **75** tending to push or pull the piston rods **76** and support assemblies **17** outwardly or inwardly, in combination with clamp rotation or independently thereof. Thus, the motions can vary along the panel as between various pairs of clamps and they can vary as between the opposite clamps constituting any pair of same. The variation may consist in the predetermined amount of rotation of the clamps or in the distance between the clamps of one pair.

FIG. 10 shows a panel cross-sectional configuration resulting from clockwise rotation of the right hand clamp; FIG. 11 shows a panel cross-sectional configuration resulting from counter-clockwise rotation of the left hand clamp; FIG. 12 shows a panel cross-sectional configuration resulting from clockwise and counter-clockwise rotation of the right and left hand clamps respectively; FIG. 13 shows a panel cross-sectional configuration resulting from equal clockwise and counter-clockwise rotation of the right and left hand clamps plus equal inward displacement thereof effected by cylinders **75**; and FIG. 14 shows a panel configuration resulting from equal clockwise and counter-clockwise rotation of the right and left hand clamps plus equal outward displacement thereof by the power cylinders **75**, all as indicated by the arrows in FIGS. 10–14.

In FIG. 3 at the right there is seen a master programming controller **80** for the various power cylinders **16** and **75**, having hydraulic conduits **59**, **60**, **81** and **82** which will be understood to be connected with the cylinder inlets and outlets having the same numbers. Supply of hydraulic fluid through these conduits to the cylinders is programmed in relation to the amount of rotary and lateral displacement to be imparted to the clamps **11** gripping the panel sides along its length, so as to produce the final panel configuration desired.

FIGS. 15 and 16 are cross sections taken through cylindrical and V-shaped elongated extrusions **90** and **91** respectively, to be subjected to deformation as indicated by the arrows, resulting in flattening of the extrusions as indicated by the broken lines **92** and **93**. Such extrusions are generally produced with ribs on the outside as indicated at **94**, for keeping the extrusion die design practical. Flattening of such extrusions for use as panels is very conveniently carried out by the presently described panel forming apparatus, since the clamps **11** may be fastened to the edge portions **96** of these extrusions and then displaced as described, without interference by the ribs **94**.

FIG. 12 also shows a method of relieving high tension stresses produced in the outer concave surface portions of the panel during bending thereof. The panel is shown in solid lines in its deliberately over-formed, i.e. excessively curved, configuration, shot peening as carried out by shot delivery through nozzles **100** acting to relieve the tension stresses resulting in relaxing of the panel to the desired curvature as indicated by the broken lines **101**. This method also has the advantage that the damaging tension stress is changed to a beneficial compression stress on opposite surfaces of the panel. FIG. 2 shows that such shot peening being carried out while the panel **10** is still under bending restraint in the forming equipment.

We claim:

1. A machine having lateral and longitudinal extent for forming a panel having laterally spaced opposite edge portions, said machine comprising laterally extending rigid way means, and clamp assemblies mounted on said way means for relative movement therealong, said clamp assemblies including rotary clamps rigidly attachable to said panel opposite edge portions, said clamps having substantially longitudinally extending axes of rotation nad said assemblies including actuators for rotating said clamps about said longitudinally extending axes, said clamp assemblies including pivot means having axes of rotation extending directionally in substantially perpendicular relation to both the lateral directional extent of said way means and longitudinal directional extent of said clamp axes of rotation, said clamps and actuators being freely bodily pivotable about said pivot axes during clamp rotation by said actuators.

2. A machine having lateral and longitudinal extent for forming a panel having laterally spaced opposite edge portions, said machine comprising laterally extending rigid way means, and clamp assemblies mounted on said way means for relative movement therealong, said clamp assemblies including rotary clamps rigidly attachable to said panel opposite edge portions, said clamps having substantially longitudinally extending axes of rotation and said assemblies including actuators for rotating said clamps about said longitudinally extending axes, said clamp assemblies including first pivot means having axes of rotation extending directionally in substantially perpendicular relation to both the lateral directional extent of said way means and the longitudinal directional extent of said clamp axes of rotation, said clamp assemblies including second pivot means having axes of rotation extending directionally in substantially perpendicular relation to both said first pivot axes and said clamp longitudinal axes of rotation, and said clamps and actuators being freely bodily pivotable about said pivot axes during clamp rotation by said actuators.

3. The invention as defined in claim 2 in which said machine includes rigid longitudinally extending ways on which said clamp assemblies are mounted for longitudinal displacement therealong.

4. The invention as defined in claim 3 comprising plural clamp assemblies and laterally extending ways supporting laterally opposite pairs of said clamp assemblies on said longitudinally extending ways for independent bodily displacement therealong of said pairs of clamp assemblies in response to differential panel beading by longitudinally spaced rotary clamps.

5. The invention as defined in claim 4 in which said machine includes linear actuators operatively connected with clamp assemblies for forcibly relatively displacing said clamps laterally during panel bending.

6. The invention as defined in claim 5 in which said machine includes structure through which reaction forces are transmissible from said linear actuators to said lateral ways whereby said linear actuators are differentially operable to control lateral displacement of said clamps to desired extent.

7. The invention as defined in claim 4 in which said lateral and longitudinal ways and said second pivot axes extend substantially horizontally, and said first pivot axes extend substantially vertically.

8. The invention as defined in claim 7 in which said actuators include chain and sprocket drives for said rotary clamps.

9. The invention as defined in claim 7 in which said clamp assemblies are held by said lateral ways against vertical bodily displacement of the clamp longitudinal axes of rotation relative to said ways.

10. The method of bend forming a panel having directionally lateral and longitudinal extent and laterally spaced opposite edge portions, including rigidly gripping said opposite edge portions, forcibly rotating said gripped panel edge portions about longitudinally directed axes thereby bending the panel and shortening the lateral spacing between oppositely gripped panel edge portions, accurately controlling the extent of rotation of the gripped panel edge portions in predetermined relation to one another, and allowing said gripped panel edge portions to

pivot freely about pivot axes extending directionally in substantially perpendicular relation to both said lateral and longitudinal directions during said rotation.

11. The method of bend forming a panel having directionally lateral and longitudinal extent and laterally spaced opposite edge portions including rigidly gripping said opposite edge portions, forcibly rotating said gripped panel edge portions about longitudinally directed axes thereby bending the panel and shortening the lateral spacing between oppositely gripped panel edge portions, accurately controlling the extent of rotation of the gripped panel edge portions in predetermined relation to one another, allowing said gripped panel edge portions to pivot freely about first pivot axes extending directionally in substantially perpendicular relation to both said lateral and longitudinal directions during said rotation, and allowing said gripped panel edge portions to pivot freely about second pivot axes extending directionally in substantially perpendicular relation to both said first pivot axes and said longitudinal axes of rotation.

12. The method of bend forming a panel having directionally lateral and longitudinal extent and laterally spaced opposite edge portions, including rigidly gripping said opposite edge portions at multiple longitudinally spaced locations, forcibly rotating said gripped panel edge portions about longitudinally directed axes thereby bending the panel and shortening the lateral spacing between oppositely gripped panel edge portions, accurately controlling the extent of rotation of the gripped panel edge portions in predetermined relation to one another, allowing said gripped panel edge portions to pivot freely about first pivot axes extending directionally in substantially perpendicular relation to both said lateral and longitudinal directions during said rotation, and allowing said gripped panel edge portions to pivot freely about second pivot axes extending directionally in substantially perpendicular relation to both said first pivot axes and said longitudinal axes of rotation.

13. The method of claim 10 including the step that comprises relatively laterally forcibly displacing the longitudinal axes of rotation of certain gripped opposite edge portions of the panel during bend forming rotation thereof, whereby the panel is given desirably variable curvature transversely thereof.

14. The method of claim 13 including the step that comprises allowing gripped panel edge portions to move freely in longitudinal directions during bend forming of the panel.

15. The method as defined in claim 10 including the step that comprises impacting the bend formed panel with shot particles while panel edge portions remain gripped, whereby spring-back of the panel upon subsequent release thereof is reduced.

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PANEL FORMING EQUIPMENT

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FIG. 1.

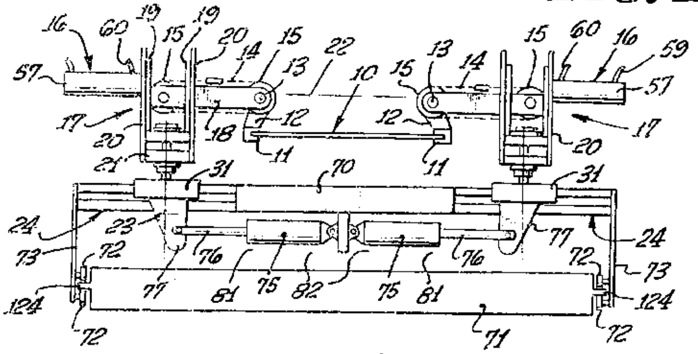


FIG. 2.

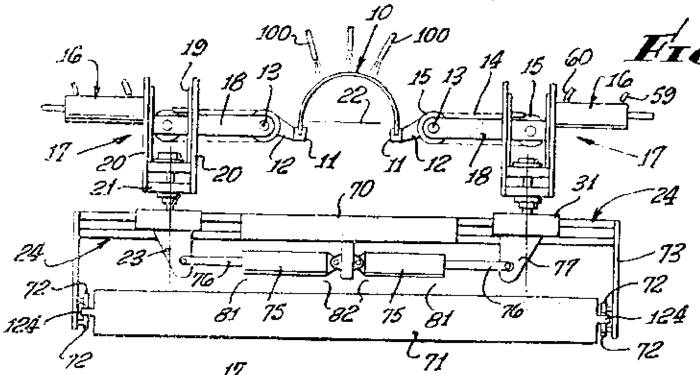
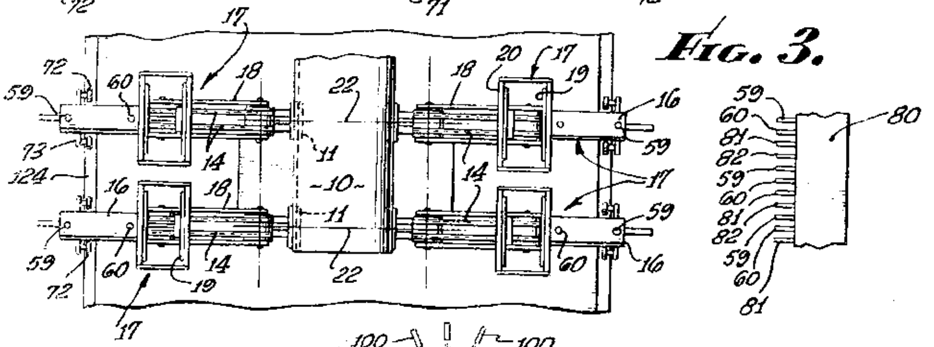


FIG. 3.



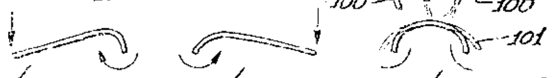


FIG. 10. FIG. 11. FIG. 12.

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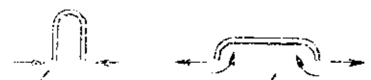


FIG. 13. FIG. 14.

FIG. 4.

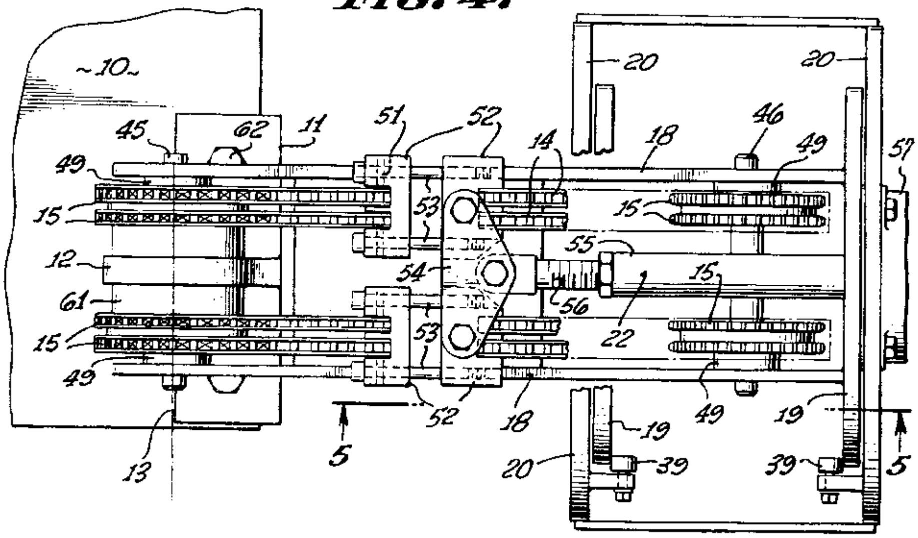


FIG. 8.

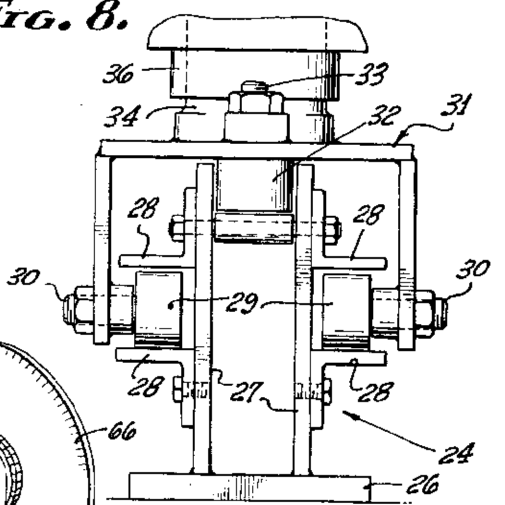
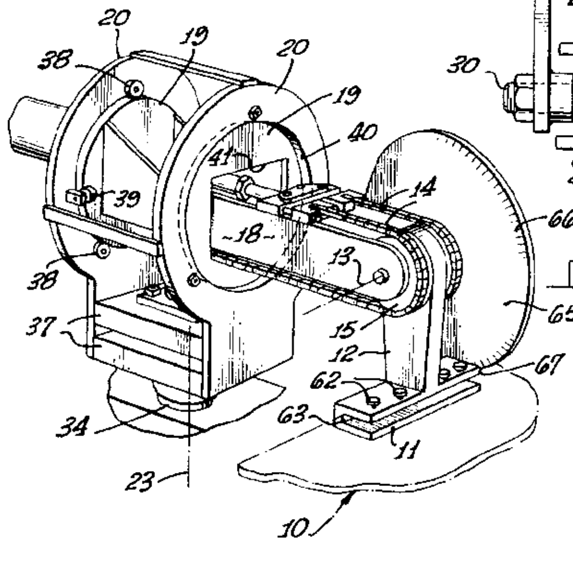


FIG. 9.



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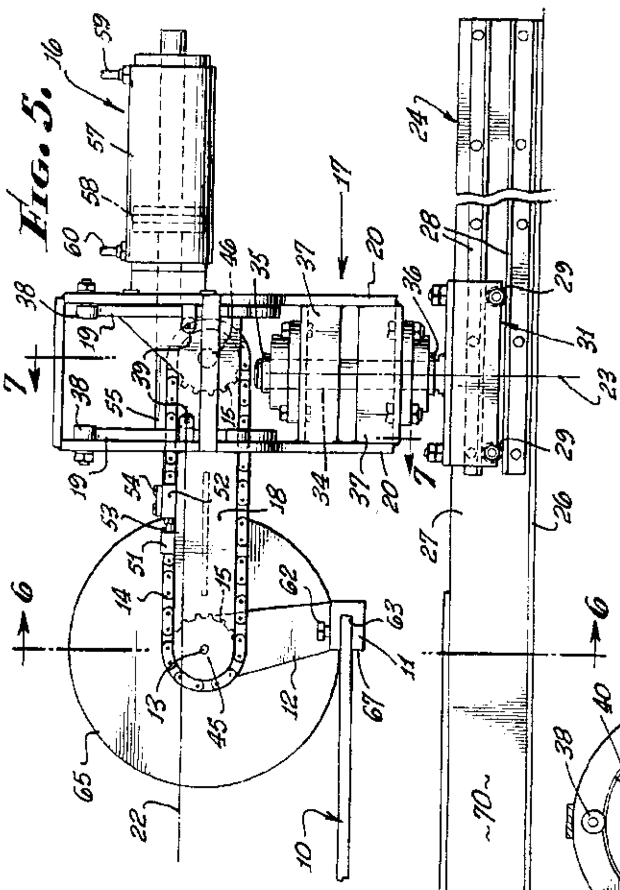

FIG. 5.

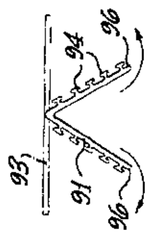

FIG. 16.

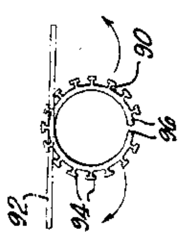

FIG. 15.

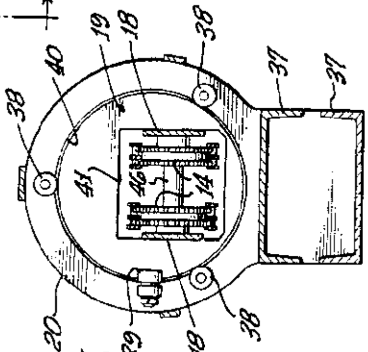

FIG. 7.

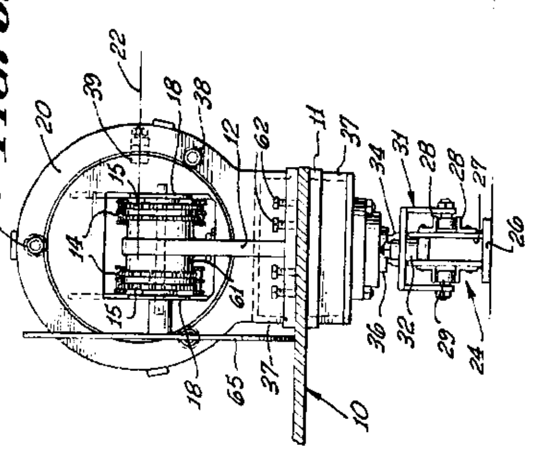

FIG. 6.

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