Aug. 12, 1969 R. J. EMINGER 3,460,770

STATOR WINDING APPARATUS

Filed Jan. 30, 1967 4 Sheets-Sheet 1

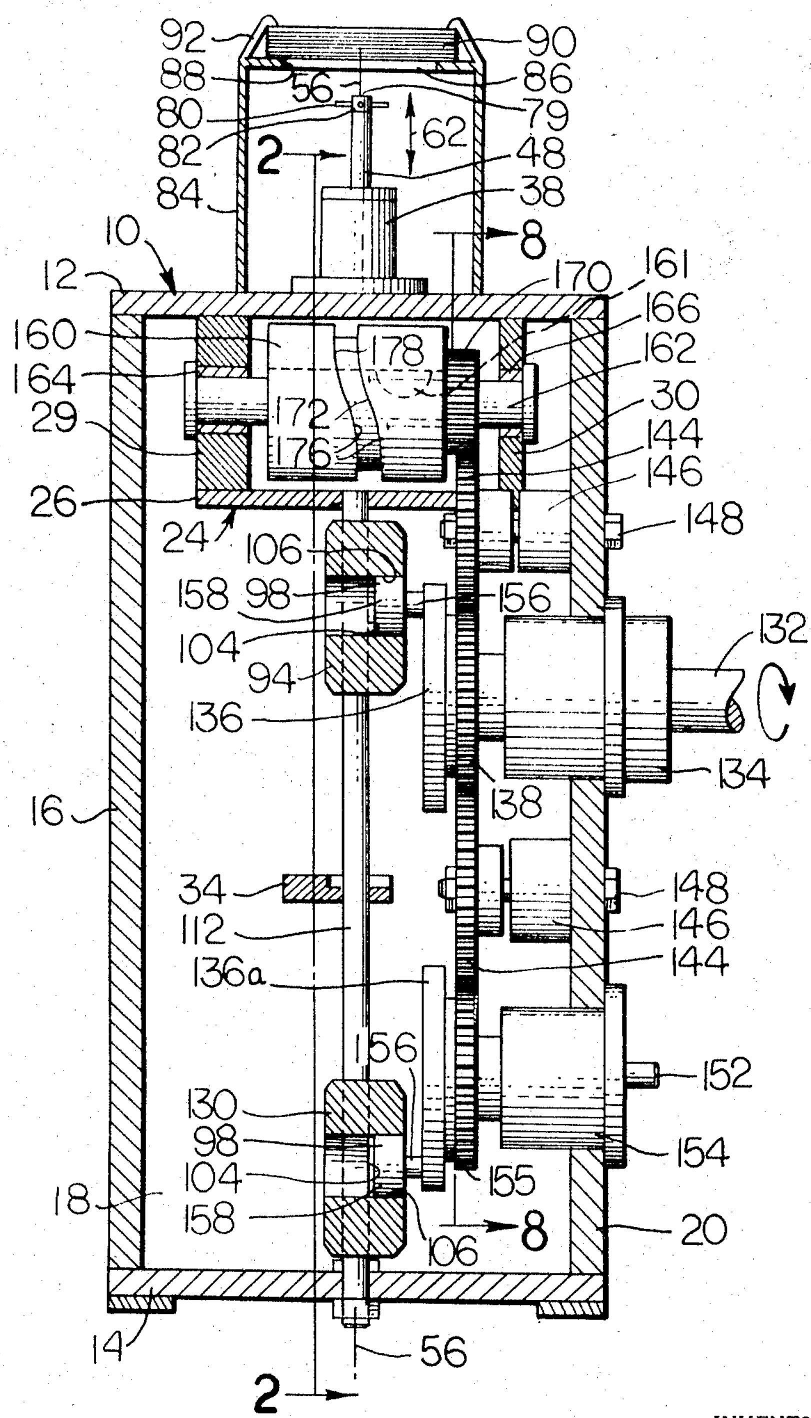

FIG. 1

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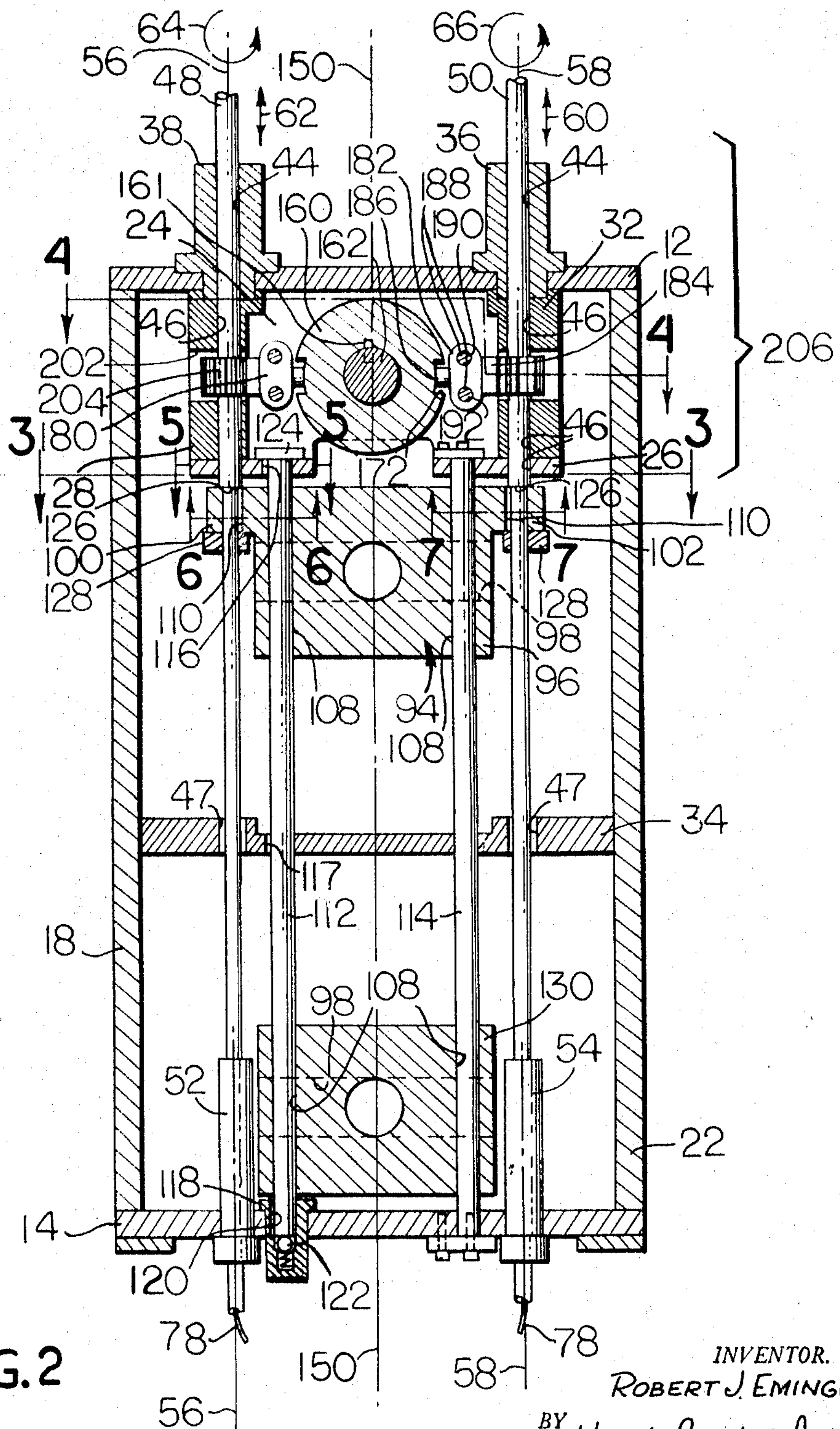

FIG. 2

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STATOR WINDING APPARATUS

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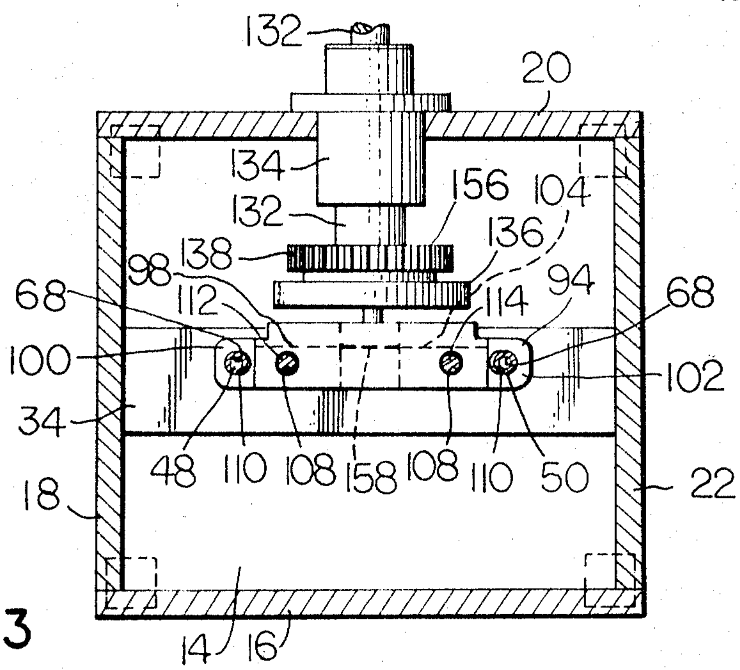

FIG. 3

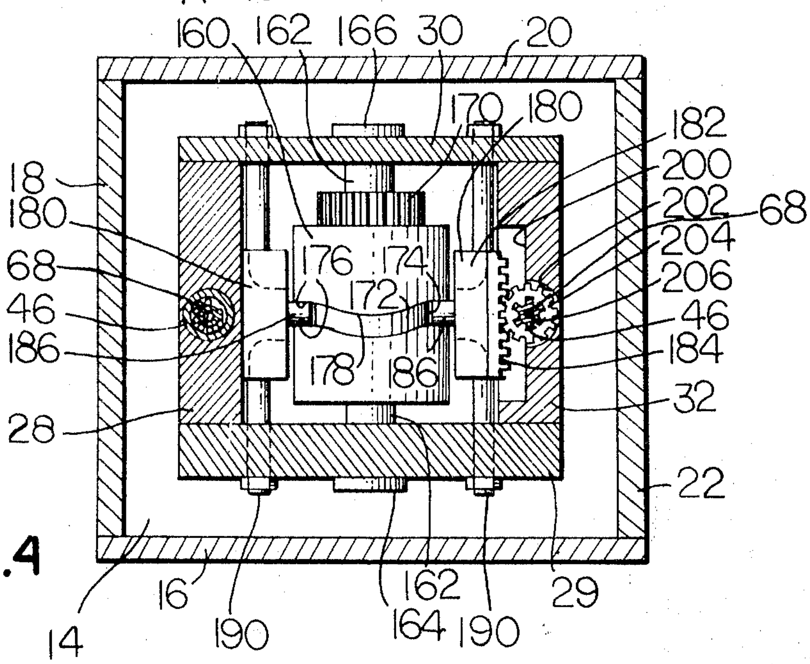

FIG. 4

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STATOR WINDING APPARATUS

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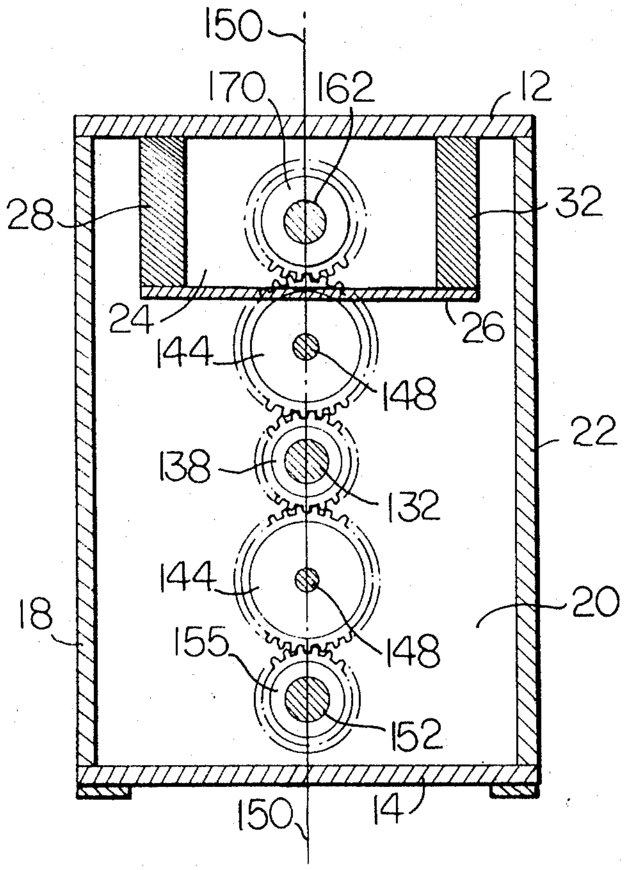


FIG.8

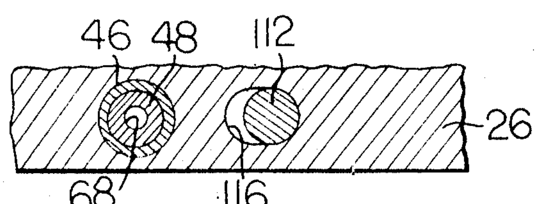
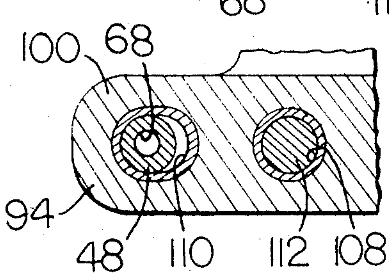


FIG.5



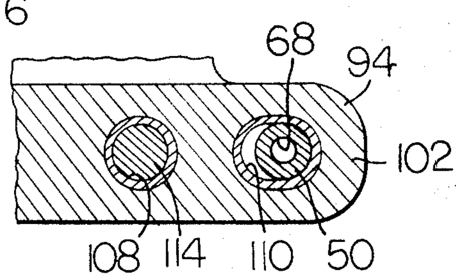


FIG.6

FIG.7

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United States Patent Office

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STATOR WINDING APPARATUS

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Int. Cl. B65h 81/06
U.S. Cl. 242—1.1 11 Claims

ABSTRACT OF THE DISCLOSURE

An apparatus for converting rotary motion into reciprocal motion which is especially useful in high-speed gun-type stator winding machines. Two elongated gun-type winding head assemblies are mounted on a frame. Each of the assemblies has a longitudinal axis and is movable in relation to the frame in the direction of its axis. Two "Scotch yokes" are mounted on the frame in a manner rendering them also movable in relation to said frame in the direction of the assembly axes. One of the yokes is secured to both assemblies; the other of the yokes is movable independently of the assemblies. A shaft and two cranks are mounted on the frame. Each of the cranks and the shaft are rotatable with respect to the frame. The cranks have separate and spaced-apart axes of rotation. The cranks are operatively connected to the yokes, respectively. The cranks are fixed in relation to the shaft, and are 180° out of identical rotational relation in respect to the shaft. Selective clearances between the assemblies, yokes and frame are provided to allow for any expansion of the yokes in a direction transverse to the assemblies during operation. A barrel cam is positioned between the assemblies and mounted on the frame in a manner allowing the cam to rotate with respect to said frame. The barrel cam is connected to the shaft and to each of the assemblies whereby the rotation of the shaft simultaneously rotates each of the assemblies alternately in opposite directions as the assemblies and yokes reciprocate in the direction of the assembly axes in a manner minimizing vibration and wear due to the expansion of the yokes during operation.

BACKGROUND OF THE INVENTION

Field of the invention

This invention generally relates to an apparatus for converting rotary motion into reciprocal motion, and more particularly, to a gun-type stator winding apparatus which can be operated at speeds higher than heretofore practicable.

DESCRIPTION OF PRIOR ART

Prior gun-type stator winding machines have been limited in speed of operation due in part to the vibration caused by the reciprocating motion of the winding head assemblies. Further limiting the speed of such winding machines is the expansion of certain parts of the machine which become heated by frictional heat and for which no allowance has been made in the design of the machine. It is therefore highly desirable to provide an improved apparatus for converting rotary motion into reciprocal motion which is especially adapted for gun-type stator winding machines and which has the advantages of minimizing vibration and making allowance for the expansion of certain parts of the machine which are frictionally heated during the operation of the machine.

SUMMARY OF THE INVENTION

In the broader aspects of this invention there is provided an apparatus for converting rotary motion into

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reciprocal motion having a frame and an elongated element mounted on the frame. A counterweight is also mounted on the frame; both said counterweight and the element are movable in relation to the frame in the direction of the longitudinal axis of said element. A shaft and two cranks are mounted to the frame. Each of the cranks and the shaft are rotatable in respect to the frame. The cranks have separate and spaced-apart axes of rotation. The shaft is operatively connected to the cranks, and the cranks are operatively connected to the element and the counterweight, respectively. The cranks have a fixed rotational relation with the shaft and are 180° out of identical rotational relation with the shaft whereby the rotation of the shaft causes the rotation of both of the cranks and the movement of the element said counterweight in opposite directions.

It is therefore the primary object of this invention to provide an improved apparatus for converting rotary motion into reciprocal motion which is especially desirable when used in an improved gun-type stator winding machine.

Another object of this invention is to provide an improved apparatus for converting rotary motion into reciprocal motion which minimizes the vibration caused by the reciprocal motion.

Yet another object of this invention is to provide an improved apparatus for converting rotary motion into reciprocal motion in which a plurality of reciprocating elements are driven by a single rotating shaft in a manner resulting in a minimum of vibration.

Still another object of this invention is to provide an improved apparatus for converting rotary motion into reciprocal motion which makes allowance for the expansion for certain parts of the apparatus which are frictionally heated during the operation of the apparatus.

A further object of this invention is to provide an improved gun-type stator winding machine in which a plurality of winding heads are driven by a single shaft in a manner resulting in a minimum of vibration.

Still further an object of this invention is to provide an improved high speed gun-type stator winding machine having a plurality of winding heads driven by a single shaft in which the vibration caused by the reciprocating motion of the winding heads is minimized and which makes allowance for the expansion of certain parts of the apparatus which are frictionally heated during operation, and which also includes a simplified mechanism for rotating each of the winding heads as desired and for connecting the driven shaft to the various winding heads.

The above-mentioned and other features and objects of this invention and the manner of attaining them will become more apparent and the invention itself will be best understood by reference to the following description of an embodiment of the invention taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a side elevational view, partially in cross-section, illustrating the entire apparatus of an improved stator winding machine incorporating this invention;

FIG. 2 is a fragmentary and cross-sectional front view of the apparatus illustrated in FIG. 1 taken substantially along the section line 2—2;

FIG. 3 is a cross-sectional view of the apparatus illustrated in FIG. 2 taken substantially along the section line 3—3;

FIG. 4 is a cross-sectional view of the structure shown in FIG. 2 taken substantially along the section line 4—4;

FIG. 5 is a fragmentary, cross-sectional and greatly exaggerated view of one portion of the apparatus illustrated in FIG. 2 which makes allowance for the expansion of certain parts which are frictionally heated during the operation of the apparatus, taken substantially along the section line 5—5;

FIGS. 6 and 7 are fragmentary, cross-sectional and greatly exaggerated views of other portions of the structure illustrated in FIG. 2 which combine with the structure of FIG. 5 to make allowance for the expansion of certain parts during the operation, respectively taken substantially along the section lines 6—6 and 7—7; and

FIG. 8 is a front, cross-sectional view of the apparatus illustrated in FIG. 1 taken substantially along the section line 8—8.

DESCRIPTION OF PREFERRED EMBODIMENT

Referring to the drawings, there is shown a gun-type stator winding machine incorporating the apparatus of this invention. The specific embodiment illustrated in the drawings comprises two winding head assemblies which are operatively connected to a single driving shaft; however, it will become obvious from the description hereinafter that portions of the improved apparatus of this invention including the mechanism which connects and simultaneously rotates the two winding head assemblies and the mechanism which provides allowance for the expansion of certain parts of the apparatus which are frictionally heated during operation is equally applicable to gun-type winding machines having more than two winding assemblies. Further, it will also become obvious from the description following that the improved mechanism which converts rotary motion into reciprocal motion is applicable to machines other than winding machines and to winding machines having only one or more than two winding head assemblies.

Referring specifically to FIGS. 1 through 4, the apparatus of this invention is shown to have a rigid box frame **10** having a top **12**, a bottom **14**, and upstanding sides **16** through **22**. Secured to and depending from the top **12** within the confines of the frame **10** is a drive compartment **24**. Compartment **24** comprises four compartment sides **28** through **32** which are secured to frame top **12** and are spaced from and generally parallel to frame sides **18** through **22**, respectively, and a compartment bottom **26** which extends between the sides **18** through **22** in general parallelism with the frame top **12** and frame bottom **14**. Frame **10** also comprises an elongated support and guide element **34** which is positioned midway between and generally parallel to the frame top **12** and frame bottom **14** and is secured to the opposite frame sides **18, 22**. Element **34** does not extend to and is spaced apart from frame sides **16, 20** (see FIG. 3).

Mounted on the frame top **12** are two spaced apart winding head assembly guide members **36, 38**. Members **36, 38** each have a centrally located bore **44** extending therethrough. Members **36, 38** are respectively positioned in registry with compartment sides **28** and **32** and equally spaced from frame sides **16** and **20**. Frame top **12** and compartment sides **28, 32** each have bores **46** therein which are substantially of the same size as bores **44** and are located on the same axis. Element **34** has bores **47** therein on the same axes as bores **46**. Bores **47** are substantially larger than bores **46**. Secured to the frame bottom **14** and extending on both sides of bottom **14** are two tubular guide members **52, 54**. Guide members **52, 54** have interior bores (not shown) substantially the same size as bores **44** and **46** and are positioned on the common axes **56, 58** of bores **44, 46** and **47**, and the members **36, 38** and **52, 54**. (see FIG. 2).

Positioned in bores **44, 46** and within the members **36, 38** and **52, 54** are two elongated winding head assemblies **48, 50**. Winding head assemblies **48, 50** are coaxial of the bores **44, 46** and **47** and members **36, 38** and **52, 54** and are slidably movable therein with respect to frame **10** in both of the opposite axial directions indicated by the arrows **60, 62** of FIG. 2.

Each of the winding head assemblies **48, 50** has secured thereto a winding head **82** having a plurality of needles **80**. In relation to the frame **10**, the winding heads **82** are respectively secured to an end **79** of assemblies **48, 50** in spaced-apart relation with frame top **12**. In the embodiment illustrated in FIG. 1, winding head **82** is provided with four needles **80** and is of the type used to simultaneously wind four-pole stator cores of the type which have poles each comprising a single coil per pole. Both of the assemblies **48, 50** have a bore **68** therein which extends longitudinally of the assemblies the entire length thereof to accommodate wires **78** which respectively feed the various needles **80** of the winding heads **82**.

A pair of stator core support assemblies **84** are secured to frame top **12** and respectively surround the members **36, 38** and the winding heads **82** of the assemblies **48, 50**. Supports **84** each have a platform **86** which has an opening **88** therein and are spaced apart and parallel to frame top **12**. The openings **88** are positioned on axes **56, 58**, respectively, and are substantially larger than the bores **44, 46** and **47**. Stator cores **90**, which are desirably wound, are positioned on the platform **86** coaxial of the axes **56, 58**. Openings **88** are large enough to expose the winding slots of the cores **90** such that coils may be wound therein by the winding assemblies **48, 50**. Supports **84** have members **92** for holding the cores **90** to platform **86** during the winding operation.

Secured to the winding head assemblies **48, 50** at a position within the frame **10** and between compartment bottom **26** and element **34** is a yoke **94**. Yoke **94** comprises a body **96** which is elongated and has a longitudinally extending slot **98** and opposite ears **100** and **102**. Slot **98** is defined by a bottom **104** and upstanding sides **106** and extends the entire length of the body **96**. Slot **98** has opposite open ends and an open top. Yoke **94** has two pair of bores **108, 110** therein. Bores **110** are centrally positioned of the ear portions **100, 102**, respectively, and extend transversely of the longitudinal direction of the yoke **94**. Bores **108** are positioned between the bores **110** and extend through the body portion **96** of the yoke **94** and substantially parallel to the bores **110**. Yoke **94** is mounted on the frame **10** by means of two guide rods **112, 114**. Both guide rods generally extend from the compartment bottom **26** through the element **34** and to the frame bottom **14**. Guide rod **114** is secured to both the bottom **26** and the frame bottom **14**, and thus, is rigid and stationary. Guide rod **112** is not rigidly secured to the compartment bottom **26**, the element **34** or the frame bottom **14**. In contrast, slightly elongated openings **116** and **117** are formed in the compartment bottom **26** and in the element **34** as shown, for example, in the greatly exaggerated view of FIG. 5 and in FIG. 2. Secured to the frame bottom **14** is a guide member **118** having a bore **120** which has a cross-sectional shape substantially the same as openings **116, 117**. Guide rod **112** is positioned within the openings **116, 117** and bore **120** and is held therein in a manner allowing the rod **112** to move within the bores **116, 120** laterally, but not axially of the assemblies **48, 50** by means of a swing-ball device **122** and an abutment plate **124**. Plate **124** is secured to the compartment bottom **26** to cover the opening **116** therein and the ball device **122** is positioned in the bottom of the bore **120** of the guide member **118**. The opposite ends of the rod **112** abut the plate **124** and the ball device **122**, respectively, so as to be held fast therebetween but still capable of movement laterally of the guide rod **114**.

The guides **112, 114** are positioned within the bores **108** of the yoke **94** thus mounting the yoke **94** on the frame **10** in a manner which allows the yoke **94** to move with respect to the frame **10** axially of the guide rods **112, 114** and the assemblies **48, 50**.

As afore-mentioned, the yoke **94** is secured to the assemblies **48, 50**. This is achieved by providing each assembly **48, 50** with a step-diametered exterior surface and an annular abutment surface **126**. The surfaces **126** face away from the winding heads **82** and are positioned in engagement with the respective ears **100, 102** of the yoke **94**. Holding the ears **100**, **102** in engagement with the surfaces **126** of the assemblies **48**, **50** are two annular clamps **128** which are respectively positioned on the assemblies **48**, **50** and secured thereto in engagement with the ears **100**, **102**. Thus, each of the ears **100**, **102** of the yoke **94** is engaged, on opposite sides thereof, respectively, by a surface **126** and by a clamp **128**.

For a purpose to be mentioned hereinafter, each of the bores **110** are elongated similarly to the openings **116** as is shown in the highly exaggerated illustrations of FIGS. 6 and 7. At this juncture, it should be stated that only openings **116**, **117** and bores **110** and **120** are elongated in the manner above-described and illustrated in FIGS. 5, 6 and 7. All of the other openings and bores in which the assemblies **48**, **50** and the guide rods **112** and **114** are positioned are circular in cross-section and only slightly larger than the respective assembly or rod positioned therein so as to hold stationary the respective assemblies or rods and prevent movement therein in a direction lateral to the assemblies **48**, **50** and rods **112**, **114**.

A yoke **130** is provided and positioned on guide rods **112**, **114** beneath the yoke **94** and between the element **34** and the frame bottom **14**. Since yoke **130** is similar in many respects to the yoke **94**, like reference numerals will be used to identify like parts. Yoke **130**, for example, has two bores **108** therein in which guide rods **112**, **114** are positioned. Further, yoke **130** has a slot **98** therein which extends longitudinally of the yoke **130**. Yoke **130** differs from yoke **94** in that no ears **100**, **102** are provided, and the yoke **130** is not attached in any manner to the assemblies **48**, **50**. However, the yoke **130** has a mass which is substantially identical to the combined mass of the yoke **94** and the assemblies **48**, **50**. Otherwise, the yoke **130** is substantially identical to the yoke **94**. Thus, as above-described, the yoke **130** is movable on the rods **112**, **114** independently of the yoke **94** in the direction of the axes **56**, **58**.

Both the yokes **94**, **130** are driven by a common shaft **132** which is driven by a brake motor (not shown) in the conventional manner. Shaft **132** is mounted on and extends through the side **20** of the frame **10** by means of a suitable bearing **134** secured to the side **20**. Positioned within the frame **10** and coaxially mounted on the shaft **132** are a crank **136** and a spur gear **138**. Gear **138** is positioned on the shaft **132** between the crank **136** and the bearing **134**. A pair of substantially identical idler gears **144** are mounted on suitable shafts **148** and mounted by journals **146** on the frame wall **20**. The centers of these gears are located on a line **150** drawn through the center of the shaft **132** and substantially parallel to and equally spaced from the winding head assemblies **48**, **50**. Gears **144** are further positioned on opposite sides of the shaft **132** and in mesh with gear **138** which is secured to the shaft **132**. Thus mounted, the line **150** extends through the centers of each of the shafts **132** and **148**.

A second crank **136*a*** is mounted on the wall **20** by means of a suitable shaft **152** and a suitable bearing **154**. Secured to the shaft **152** is a spur gear **155** between the crank **136*a*** and the bearing **154**. The shaft **152** is positioned beneath the shaft **132** and in spaced-apart and parallel relation therewith; and thus, the cranks **136**, **136*a*** have separate axes of rotation which are spaced apart and parallel to each other. Further, the center of the shaft **152** is positioned on the line **150** and the gear **155** is both coaxial of the shaft **152** and is connected to the gear **138** by means of the idler gear **144** located therebetween. Thus, the centers of each of the gears **138**, **144** and **155** are positioned on the line **150**. Further, as shown in FIG. 1, each of these gears are also aligned one over the other such that the end surfaces of the gears are in common planes which are substantially parallel to the axes **56**, **58** and are adjacent to the frame side **20**.

Both the cranks **136**, **136*a*** have a crank pin **156** secured to the crank adjacent to the periphery thereof. Each crank pin **156** is spaced-apart from and substantially parallel to the axis about which the respective crank rotates. A roller **158** is journalled on each of the crank pins **156** so as to be rotatable about the crank pins **156** independently of the cranks **136**, **136*a***. The rollers **158** are positioned within the slots **98** of the respective yokes **94**, **130** afore-described. By this means, the cranks operatively connect the yokes **94**, **130** to the shaft **132**.

Each of the cranks **136**, **136*a*** has a fixed rotational relationship with the drive shaft **132**. Crank **136** is secured directly to the drive shaft **132** such that as the drive shaft **132** rotates so does the crank **136**. Crank **136*a***, on the other hand, is connected to the drive shaft **132** by means of the gears **138**, **155** and the idler gear **144**. Each of these gears is chosen to have an appropriate number of teeth and size such that the crank **136*a*** also rotates at the same speed as the shaft **132**. However, as shown in FIG. 1, each of the cranks are positioned 180 degrees out of identical rotational relation with the shaft **132**. In other words, when the crank pin **156** of crank **136** is positioned at the top-most position, the crank pin **156** of the crank **136*a*** is positioned at the bottom-most position.

Mounted within the drive compartment **24** is a barrel cam **160**. Barrel cam **160** is secured by a key **161** to a shaft **162** which is appropriately journaled at **164** and **166**, respectively, and secured to the compartment sides **29**, **30**. Barrel cam **160** is also equally spaced from compartment sides **28**, **32**; and thus, is equally spaced from the winding head assemblies **48**, **50**. Secured to the barrel cam **160** is a drive gear **170**. Gear **170** is connected to the gear **138** by means of the idler gear **144** located therebetween. Thus, rotation of shaft **132** also rotates the cam **160**. Further, the gears **170**, **144** and **138** are chosen with the appropriate number of teeth and size that one revolution of the shaft **132** equals one revolution of the barrel cam **160**.

Cam **160** has an annular cam track or groove **172** therein. Groove **172** is defined by a bottom **174** and upstanding side walls **176**. Groove **172** is continuous and extends completely around the circumference of the cam **160**. Bottom **174** of the groove **172** is at all points substantially parallel to the exterior surface of the cam **160** and the oppositely facing side walls **176** are substantially parallel to each other. However, the side walls **176** have certain undulations **178** therein as indicated in FIGS. 1 and 4.

Also mounted within the drive compartment **24** are two cam followers **180**. Since each of these cam followers **180** and the means by which they are mounted within the compartment **24** are identical the description of one will suffice for both of them. Cam followers **180** each have a body portion **182**, a rack **184** and a cam-engaging portion **186**, both of which are secured to the body **182**. Body **182** has two bores **188** extending therethrough in a direction generally parallel to the longitudinal direction of the rack **184**. Bores **188** are generally parallel to each other. The cam followers **180** are each mounted on the frame **10** within the compartment **24** by means of two guide rods **190** and **192**. Rods **190**, **192** are respectively positioned within the bores **188** and are secured adjacent their opposite ends to the sides **29**, **30** of the drive compartment **24**. Guide rods **190** and **192** are substantially parallel to each other and parallel to shaft **162** of the barrel cam **160**. Further, the guide rods **190**, **192** are spaced apart from the shaft **162** a distance such that when the follower **180** is positioned on the rods, the cam engaging portion **186** of the follower **180** is positioned within the groove **172**. Thus positioned, as the barrel cam **160** rotates the cam followers **180** slide axially on the rods **190**, **192** in response to the undulations **178** of the groove **172** of the barrel cam **160**.

The sides **28**, **32** of the drive compartment **24** are provided with slots **200** therein. The rack portion **184** of the cam follower **180** fits in the slot **200** and the slot **200** accommodates the above-described movement of the cam follower **180**. Slot **200** faces inwardly of the compartment

24 and communicates with a bore **202** which is coaxial of and substantially larger than the bore **46**. Both the slots **200** and the bores **202** have a dimension in the direction of the axes **56, 58** only slightly larger than the transverse dimension of the rack **184**. Positioned within the bore **202** is a gear **204** which is in mesh with the rack **184**. The gears **204** are positioned on the assemblies **48, 50**, respectively. The assemblies **48, 50** in the portion between the annular surface **126** and the winding heads **82** are splined adjacent to the surfaces **126**. The gears **204** are positioned on this splined portion of the assemblies **48, 50** and are in mesh therewith such that the gears **204** cannot rotate independently of the assemblies **48, 50**. On the other hand, because of the splined portion of the assemblies **48, 50**, the assemblies **48, 50** can move reciprocally in the opposite directions indicated by the arrows **60, 62** in relation to the gears **204**. The splined portion of the assemblies **48, 50** is referred to generally by the reference numeral **206** in FIG. 2. This portion only need be long enough in the direction of the axes **56, 58** in order to insure that the gear **204** will stay in mesh with such a portion during the reciprocal motion of the winding head assemblies **48, 50**.

In operation, the structure above-described of this invention functions to simultaneously move the winding heads **82** of the assemblies **48, 50** reciprocally through the bore of the stator core **90** to be wound and also to rotate the heads **82** adjacent to the opposite ends of the reciprocal stroke. This motion is conventional with gun-type stator winding machines. Movement of the head **82** with its wire dispensing needles **80** through the stator core **90** in one direction carries the wires **78** (one wire for each needle **80**) therethrough to form one side of a coil. The head **82** is then rotated a part revolution at the end of the stroke to form one end turn of the coil; then, the head **82** is moved in the opposite axial direction back through the core **90** to form the other side of the coil; and then, the head **82** is rotated in the opposite direction back to its original rotational position thus completing the cycle, and one complete turn for each of the needles **80**. Both winding head assemblies **48, 50** undergo this movement simultaneously and at a relatively high speed. For example, in one embodiment, the assemblies **48, 50** each complete 1800 of the cycles above-described per minute. Thus, 1800 turns of the stator are wound by each of the needles **80** of the assemblies **48, 50** during each minute of operation.

Each of the winding head assemblies **48, 50** are driven by a common drive shaft **132**. Shaft **132** being driven by a brake-motor (not shown) rotates both the gear **138** and the crank **136** which are secured to the shaft **132**. As will become obvious from the description hereinafter, the shaft **132** is rotated at a speed, measured in r.p.m. which is identical to the desired speed of the winding head assemblies **48, 50**, measured in cycles or turns per minute. The rotation of the shaft **132** by means of the idler gears **144** also rotates the shaft **152** and the barrel cam **160** at the same speed. Thus, both of the cranks **136, 136*a*** and the barrel cam **160** rotate at the same speed; and a single rotation of the shaft **132** will rotate the barrel cam one complete revolution and will move both assemblies **48, 50** through one cycle of movement.

The assemblies **48, 50** are moved through each cycle in the following manner. As the shaft **132** rotates the crank **136** attached thereto rotates to move the yoke **94** upwardly. Since both assemblies **48, 50** are secured to the yoke **94** the assemblies also move upwardly. When the crank pin **156** is at the top-most position, the assemblies **48, 50** are at their top-most position. At this position, the cam engaging porton **186** of the cam followers **180** engage an undulation **178** of the slot **172** of the barrel cam **160** so as to move the cam followers **180** axially of the rods **190, 192** so as to rotate the assemblies **48, 50** in one direction a part revolution. The crank **136** continues rotating moving the yoke **94** and the assemblies **48, 50** downwardly into the lower-most position. At this moment, the cam engaging portions **186** of the cam followers **180** engage another undulation **178** of the slot **172** of the barrel cam **160** to move the cam followers **180** in the opposite axial direction of the rods **190, 192** so as to rotate the assemblies **48, 50** back to their initial rotational position and the cycle is started all over again.

While the specific embodiment illustrated in the drawings and above described have the cranks **136, 136*a*** and the barrel cam **160** rotating at the same speed, obviously this is not essential to the operation of the structure and could be modified. For example, the barrel cam **160** could be rotated at a speed one-half that of the crank **136** if the groove **172** had twice as many undulations **178** to move the cam followers **180**. Other such modifications to the speed of the crank **136** and the barrel cam **160** could also be made.

In prior gun-type winding machines having winding head assemblies such as **48, 50** reciprocally moving, considerable vibration is experienced. Such vibration is minimized by the structure of this invention; and more specifically, by the provision of the yoke **130**. As above-described the rotation of the shaft **132** rotates both cranks **136, 136*a*** at the same speed. The rotation of the crank **136*a*** reciprocally moves the yoke **130** axially of the guide rods **112, 114** at the same time as the yoke **94** is similarly moving; and both yokes **94, 130** move at the same speed. However, the cranks **136, 136*a*** are 180 degrees out of identical rotational relationship with the shaft **132**. This fixed rotational relationship of the cranks **136, 136*a*** to the shaft **132** and to each other provides that when a yoke **94** moves, the yoke **130** moves in the opposite direction. Thus, when the yoke **94** moves upwardly, the yoke **130** moves downwardly at the same speed and vice versa. Further, since as above-mentioned, the yoke **130** is provided with a mass substantially the same as the combined mass of the yoke **94** and the winding head assemblies **48, 50**, momentum of the yoke **94** and the assemblies **48, 50** is always balanced by the momentum of the yoke **130**. Or, in other words, the product of the combined mass of the yoke **94** and the assemblies **48, 50** and the velocity at which they are traveling is at all times equal to and in an opposite direction of the product of the mass of the yoke **130** and its velocity.

Obviously, the mechanism of this counter balancing portion of the apparatus above described could be modified in several respects. For example, the combined mass of the yoke **94** and the assemblies **48, 50** would not necessarily need to be substantially the same as the mass of the yoke **130** so long as the product of the combined mass times the velocity of the yoke **94** and the assemblies **48, 50** is kept equal to the product of the mass of the yoke **130** times its velocity. Thus, for example, the yoke **130** could have a mass one-half of that of the combined mass of the yoke **94** and the assemblies **48, 50** so long as the crank pin **156** of the crank **136*a*** was spaced from the axis of rotation of the crank **136*a*** one-half the distance between the axis of rotation of the crank **136** and its crank pin **156**. Other modifications in the weight of the mass of the yokes and the positioning of the crank pins **156** from the axes of rotation of the cranks **136, 136*a*** could be made; however, in each of these different embodiments, both of the cranks **136** must rotate at the same speed.

A further limitation to high speed operation of prior art gun-type winding machines has been the expansion of certain parts of the machine which become heated by frictional heat due to the high speed operation and for which no allowance has been made in the design of the machine. The apparatus above-described makes such allowance by providing that the bores **110, 120** and the openings **116** and **117** in the yoke **94**, the guide member **118**, the bottom **26** of the drive compartment **24** and guide element **34** are out-of-round and elongated in the specific direction shown by the exaggerated drawing of FIGS. 5 through 7. This structure allows for the lateral expansion of the yokes **94** and **130**. These yokes, because of their mass and high speed movement along the guide rods **112**, **114** are the two parts of the assembly above-described which cause an expansion problem at the speed that the above structure is operated. Thus, allowing for the lateral expansion of the yokes **94**, **130** during operation solves the expansion problem. By means of the elongated bores **110** and **120** and the openings **116**, **117**, the guide rod **112** is moved away from the guide rod **114** in a direction of a line drawn perpendicular to and through the centers of the rods **112** and **114**. Thus, when the body portion **96** of the yokes **94** and **130** expand, the guide rods are adapted to move laterally apart accommodating for this expansion. Further, by the elongation of the bores **110** in the same direction, the expansion of the yoke **94** adjacent to the ears **100** and **102** is also accommodated. Thus, the expansion of the yokes **94** and **130** does not cause any binding between the yokes, the assemblies **48**, **50** and the guide rods **112**, **114** during the operation of the apparatus.

The apparatus of this invention, while above-described in relation to a gun-type stator winding machine, is capable of wide application for converting rotary motion into reciprocal motion. In this wide application the structure which minimizes the vibration caused by the reciprocal motion and the structure which makes allowance for the expansion of the yokes **94**, **130** due to the frictional heating thereof are also widely applicable. Further, however, the structure is uniquely applicable to gun-type stator winding machines and allows high speed operation thereof. The unique drive means by which each of the yokes **94**, **130** and the barrel cam **160** is driven by a common shaft **132** and the means by which the assemblies **48**, **50** are rotationally actuated by a single barrel cam **160** are also uniquely applicable to winding machines. This structure provides a structure simple in construction for driving multiple winding head assemblies **48**, **50** by a common shaft **132**. This same structure is applicable to winding machines having more than two winding head assemblies **48**, **50**, for example, by merely elongating the yoke **94** to accommodate any number of winding head assemblies in two parallel rows extending on opposite sides of an elongated barrel cam, the same structure could be used to actuate a plurality of winding head assemblies **48**, **50**.

While there have been described above the principles of this invention in connection with specific apparatus, it is to be clearly understood that this description is made only by way of example and not as a limitation to the scope of the invention.

What is claimed is:

1. A stator winding apparatus comprising a frame, a first elongated gun-type winding head assembly having a first longitudinal axis, means for mounting said first assembly on said frame for movement in the direction of said first axis, a second elongated gun-type winding head assembly having a second longitudinal axis in spaced, parallel relationship with said first axis, means for mounting said second assembly on said frame for movement in the direction of said second axis, a yoke, means for drivingly securing said yoke to said first and second assemblies, means for mounting said yoke on said frame for movement in the direction of said axes, a shaft and first and second cranks, means for rotatably mounting each of said cranks and shaft on said frame, said cranks respectively having separate and spaced apart axes of rotation, means for drivingly connecting both of said cranks to said shaft, said cranks each having a crank pin respectively spaced from said axes of rotation, a counterweight, said yoke having a slot therein extending transversely of said first and second assemblies, said crank pin of said first crank being positioned in said slot, said crank pin of said second crank being operatively connected to said counterweight, said cranks having a fixed rotational relation with said shaft, said crank pins being substantially 180° out of identical rotational relation with said shaft, a barrel cam, means for rotatably mounting said barrel cam on said frame between said assemblies, means for drivingly connecting said barrel cam to said shaft, first and second cam, followers respectively operatively connected to said barrel cam on opposite sides thereof, means for mounting said first cam follower on said frame for slidable movement with respect to said frame and said first assembly transversely of said first assembly, a first rack secured to said first cam follower, means for mounting said second cam follower on said frame for slidable movement with respect to said frame and said second assembly transversely of said second assembly, a second rack secured to said second cam follower, each of said assemblies including a splined rod portion and a gear positioned on said rod portion, said gear mating with said rod portion whereby said gears are prevented from rotating independently of said rod portion, said rod portion being slidably movable in said gear in the direction of said assembly axis, said gears being respectively operatively geared to said first and second racks whereby the rotation of said shaft moves said cam followers in reciprocal motion thereby respectively rotating said assemblies alternately in opposite directions as said assemblies reciprocate in the direction of said axes.

2. A stator winding apparatus comprising a frame, two elongated gun-type winding head assemblies each having a longitudinal axis, means for respectively mounting each of said assemblies on said frame for movement in the direction of said axes, first and second yokes, means for respectively mounting said yokes on said frame for independent movement in the direction of said axes, means for drivingly securing said first yoke to both of said assemblies, a shaft and first and second cranks, means for rotatably mounting said cranks and shaft on said frame, said cranks having separate axes of rotation, means for operatively connecting both of said cranks to said shaft, each of said cranks having a crank pin respectively spaced from said axes of rotation, said crank pins being operatively connected to said yokes, respectively, said crank pins being substantially 180° out of identical rotational relation with said shaft, said cranks having a fixed rotational relation with said shaft, whereby the rotation of said shaft causes the rotation of both of said cranks and the movement of said yokes axially of said assemblies in opposite directions, said first yoke having means respectively providing expansion clearance with said assemblies, said frame also having means for cooperating with said last-named means, to allow for expansion of said yokes in a direction transverse to said axes.

3. The stator winding apparatus of claim **2** wherein said frame has two spaced apart guide rods disposed substantially parallel to each other and to said assemblies, said first and second yokes each having two spaced apart apertures therein, said guide rods being positioned in said apertures respectively, said yokes being slidably movable axially of said rods, and wherein said cooperating means comprises means on said frame providing an expansion clearance between one of said guide rods and said frame, said last-named clearance extending in a direction transverse to said one guide rod and away from the other of said guide rods.

4. The stator winding apparatus of claim **3** wherein said first yoke has a second pair of spaced apart apertures therein, said assemblies being positioned in said second apertures, said second apertures being enlarged in the direction of a line drawn transversely of and intersecting the axes of said assemblies, said apertures providing an expansion clearance located intermediate said assemblies when said first yoke is at an ambient temperature.

5. The stator winding apparatus of claim **2** further comprising a barrel cam and two cooperating cam followers, means for rotatably mounting said barrel cam on said frame, means for operatively connecting said barrel cam to said shaft, means for mounting said cam followers on said frame on opposite sides of said barrel cam for slidable movement with respect to said frame and said assemblies, said assemblies each including a splined rod portion and a gear positioned on said rod portions, said gears respectively mating with said rod portions whereby said gears are respectively prevented from rotating independently of said rod portions, said rod portions being respectively slidably movable in said gears in the directions of said axes, two racks respectively secured to said cam followers, said gears respectively being operatively geared to said racks whereby the rotation of said shaft moves said followers in reciprocal motion thereby simultaneously rotating each of said assemblies alternately in opposite directions as said assemblies reciprocate in the direction of said axes.

6. The stator winding apparatus of claim **5** wherein said frame has two spaced apart guide rods disposed substantially parallel to each other and to said assemblies, said first and second yokes each having two spaced apart apertures therein, said guide rods being positioned in said apertures respectively, said yokes being slidably movable axially of said rods, and wherein said cooperating means comprises means on said frame providing an expansion clearance between one of said guide rods and said frame, said clearance extending in a direction transverse to said one guide rod and away from the other of said guide rods.

7. The stator winding apparatus of claim **6** wherein said first yoke has a second pair of spaced apart apertures therein, said assemblies being positioned in said second apertures, abutting members secured to both of said assemblies on opposite sides of said first yoke thereby securing said first yoks to said assemblies, said second apertures being enlarged in the direction of a line drawn transversely of and intersecting the axes of said assemblies, said second apertures providing an expansion clearance located intermediate said assemblies when said first yoke is at an ambient temperature.

8. The stator winding apparatus of claim **7** wherein said assemblies and first yoke have a combined mass substantially equal to the product of the mass of said second yoke the ratio of the velocity of said second yoke to the velocity of said assemblies in the direction of said axis.

9. The stator winding apparatus of claim **8** wherein said shaft and one of said cranks are positioned on the same axis and have the same axis of revolution, said one crank being secured to said shaft; and further comprising a first gear coaxially secured to said shaft, a second gear positioned on the same axis as said other crank and being secured to said other crank, said first and second gears having respectively the same axes of revolution as said shaft and other crank, and a third gear operatively coupling said first and second gears.

10. An apparatus comprising a frame, two spaced-apart and parallel elongated guide rods connected to said frame, a member having two spaced-apart bores therein, said rods being positioned in said bores thereby mounting said member to said frame, said member being movable in relation to said frame in the longitudinal direction of said rods, one of said rods being secured to said frame, first means for permitting the other of said rods to move toward and away from said one rod in a direction transverse thereto, and second means for reciprocally driving said member in the longitudinal direction of said rods.

11. The apparatus of claim **10** further comprising an elongated element mounted to said frame, said element being movable with respect to said frame in the longitudinal direction of said rods, said element being drivingly secured to said member; and wherein said first means includes openings in said frame and said member which are elongated in the direction of a line drawn transversely of said rods.

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