June 28, 1960

J. J. MOYNIHAN
APPARATUS AND METHOD FOR MAKING
LAMINATED FERROMAGNETIC CORES

2,942,511

Filed Aug. 4, 1953

3 Sheets-Sheet 1

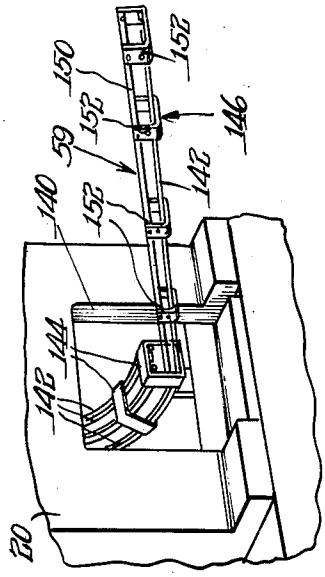


Fig. 3

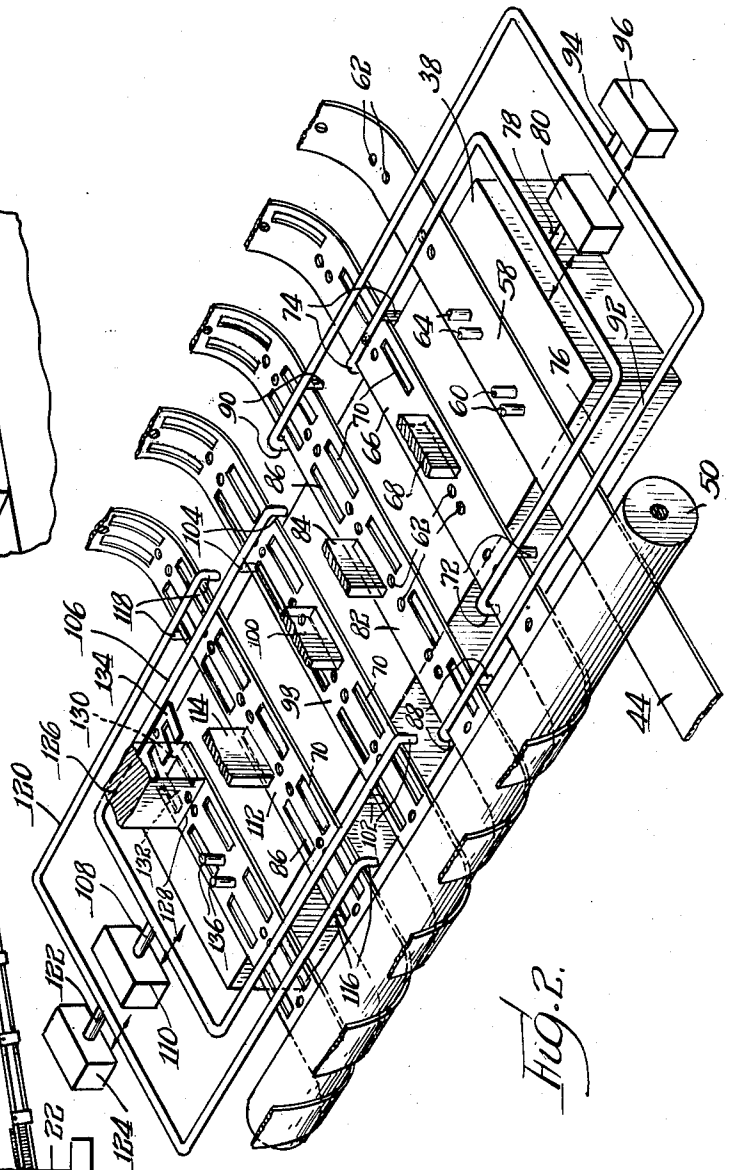


Fig. 2

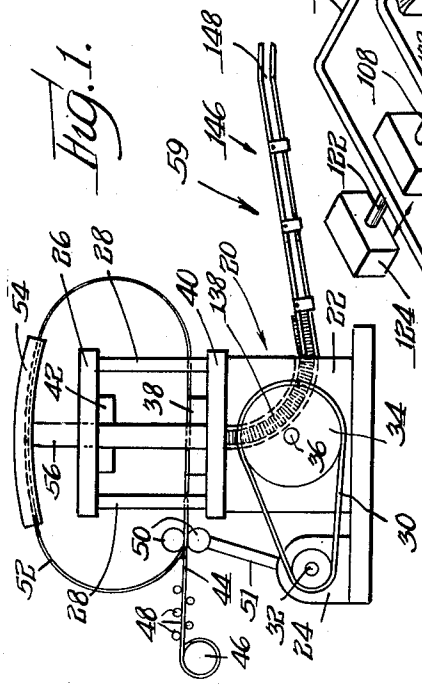


Fig. 1

INVENTOR.
John J. Moynihan
BY:
Olson & Trexler
attys.

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Fig. 4.

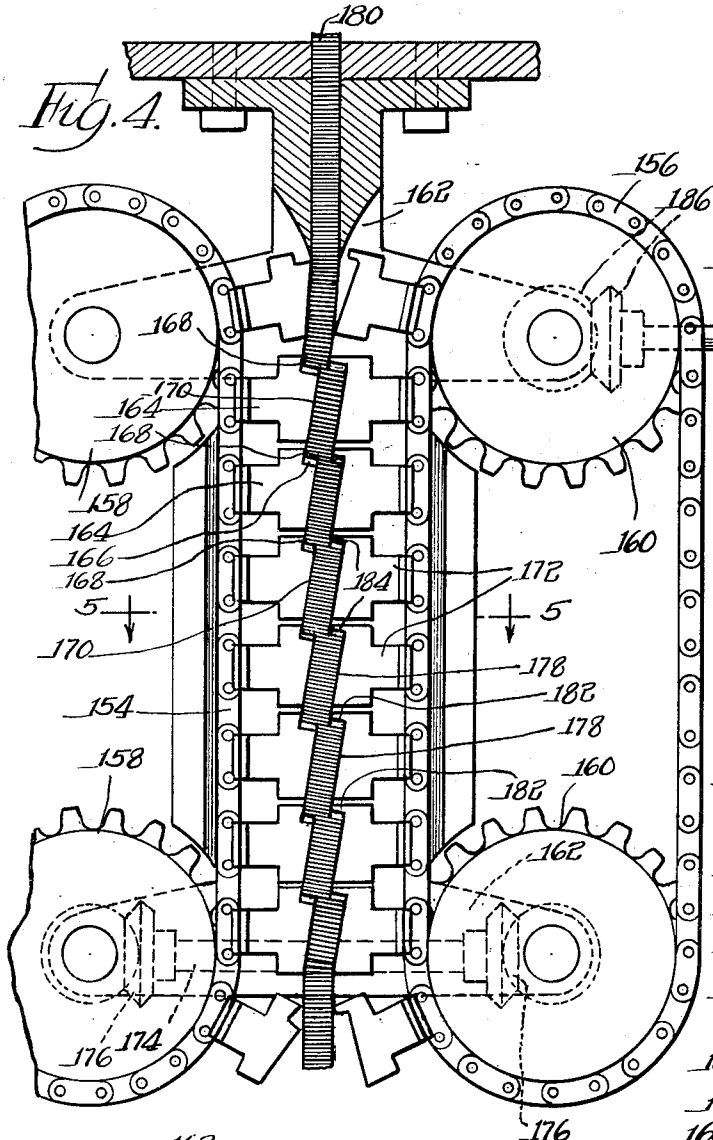


Fig. 5.

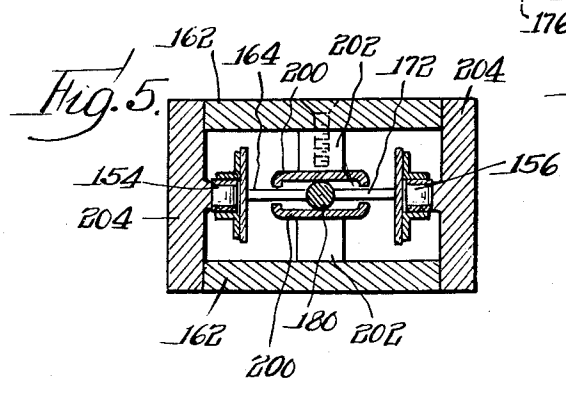


Fig. 6.

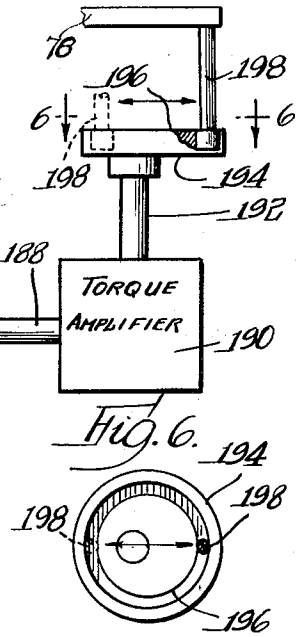
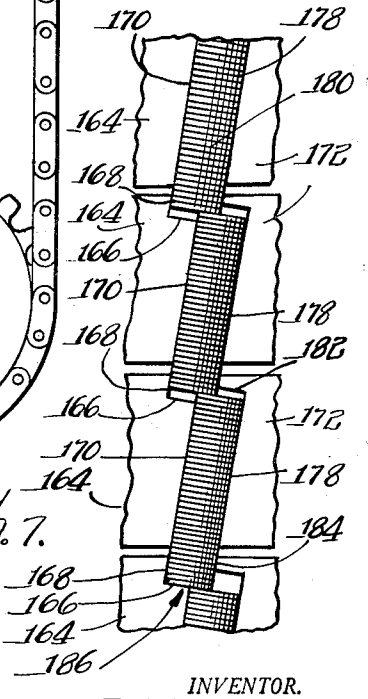


Fig. 7.



INVENTOR.

John J. Moynihan

By: Olson & Trexler

Attys.

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Fig. 8.

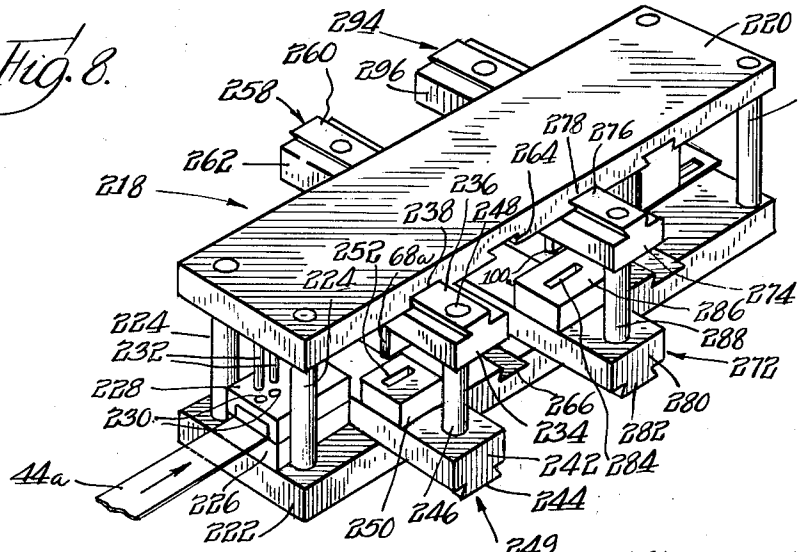


Fig. 9.

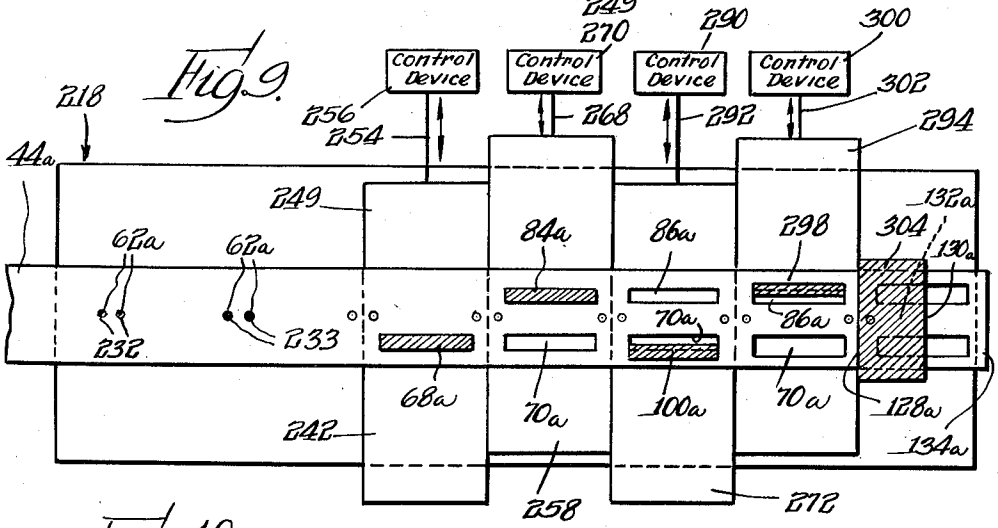


Fig. 10.

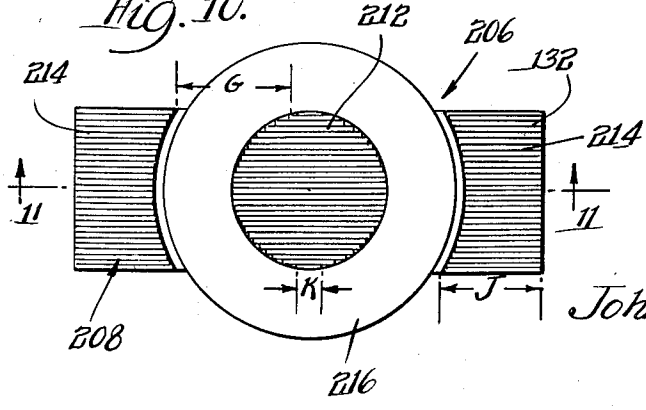
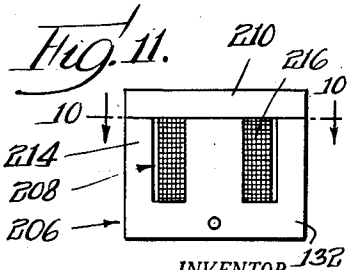


Fig. 11.



INVENTOR.
John J. Moynihan
BY:
Olson & Trexler
attys.

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APPARATUS AND METHOD FOR MAKING LAMINATED FERROMAGNETIC CORES

John J. Moynihan, Chicago, Ill., assignor to M & F Associates, St. Joseph, Mich., a limited partnership

Filed Aug. 4, 1953, Ser. No. 372,363

17 Claims. (Cl. 83—29)

This invention is concerned with an apparatus for and a method of making laminated ferromagnetic cores for small transformers, magnets, and the like.

Ferromagnetic cores for small transformers and the like operating at power and audio frequencies generally are made by stamping laminations from sheet steel and stacking them together. The cores are E-shaped with an I bar lying across the ends of the legs of the E and parallel to the back so that the resulting core is symmetrical. To conserve material in manufacture, the E-shaped laminations are blanked out in confronting pairs with the ends of their legs contacting one another. The material stamped out to form the windows in the core thus serves as the laminations forming the I bar of each core, and no material is wasted except for that stamped out to form holes for guides in a punch press and often later serving as bolt holes for holding the laminations together or for mounting the magnets. The laminations so produced are generally known as scrapless E and I laminations.

Heretofore all of the laminations going into one magnet core generally have been identical so that the central leg of the E-shaped core generally has been square in cross section, while the other two legs, the back, and the I bar generally have had a rectangular cross section equal to one half the cross section of the central leg. This maintains the flux density, and hence the core losses uniform throughout the core.

As fully set forth in my copending application Serial No. 372,213, filed of even date herewith and entitled "Ferromagnetic Core," I propose the provision of a ferromagnetic core for small transformers and the like made up of stacked E and I laminations wherein the central leg of the core is cylindrical. The provision of a cylindrical center core leg results in substantial savings in copper and iron.

The provision of a cylindrical core leg permits the use of a cylindrical coil winding. Due to its contour or shaping, a round coil turn is about 9% shorter than a square coil turn embracing the same cross sectional core area. Thus the round coil turn requires 9% less, by weight, of copper; and inasmuch as resistance varies directly with length, each round coil turn has approximately 9% less resistance than an equivalent square coil turn. A cylindrical coil thus has approximately 9% less resistance than an equivalent rectangular coil. If it is desired only to maintain the coil resistance within certain maximum limits, to thereby limit power and heat losses, advantage may be taken of the foregoing, in my invention as set forth in the aforesaid copending application, to reduce the wire size, thereby to effect a further saving, by weight, in the copper required. A reduction in wire size of one half size or gage increases the resistance, for any given length, approximately 12%. Considering that with my invention a coil length of 9% less is employed there would result, with a decrease in wire size of one half size or gage, an apparent or anticipated increase in resistance of approximately 3%.

However, the use of smaller wire permits more turns

per layer in the coil. This leads to fewer and thinner layers. The fewer and thinner layers reduces the mean diameter of the coil so that for a given total number of turns (as compared with conventional practice) less over-all length of wire is required, resulting in a resistance decrease due to this factor of approximately 3%; so that the final resistance value of the completed or composite coil will be approximately the same as in the conventional construction. Over all, the combination of the foregoing factors referred to, including the permissible use of smaller wire, and the decreased length thereof for equivalent performance, results in a saving of copper by weight, as compared with a conventional coil, of approximately 26%.

The smaller physical size of the coil when wound in a cylindrical configuration is accompanied by shorter magnetic paths allowing a reduction in the amount of steel necessary to construct a core.

An object of this invention is to provide means for and a method of producing a laminated ferromagnetic core having a cylindrical center leg.

As fully pointed out in my aforesaid pending application, the windows in succeeding laminations must be relatively shifted toward and away from one another in order to form the cylindrical center leg. More specifically, the windows are farthest apart in the center of a stack of laminations making up a core, and move progressively closer together in succeeding laminations moving out toward the top and bottom of the stack. In order to form a substantially circular cylindrical core, rather than an elliptical or other non-circular core, it is necessary that the windows move relatively toward and away from one another in accordance with the thickness of the laminations. More specifically, in working from the center lamination out toward the top and bottom of a core stack, the window of each succeeding lamination must move closer together a distance commensurate with the thickness of the lamination and its position in the stack. The shifting distance cannot be exactly predetermined, as stock thickness may vary. More particularly, I prefer to make core laminations from strip stock, and the thickness of a strip may vary from end to end of the strip.

An object of this invention is to provide apparatus for and a method of automatically forming windows in different locations in different laminations so that the stacked laminations will produce a circular center leg.

More specifically, it is an object of this invention to provide means and methods for automatically shifting the window position in different laminations in accordance with the stock thickness.

At the center of a core stack, a lamination lies substantially along a diameter. The window space for admitting the coil winding therefore can be at a minimum. Each succeeding lamination moving out from the center of the stack is a chord of the coil winding and the window space moves farther and farther away from the diameter of the circle and eventually approaches a tangent. The window width in the outer laminations therefore must be greater than in the center laminations. The change in window width is in accordance both with the position of a lamination in a stack and the stock thickness. In order to use a minimum of the ferromagnetic stock, I use a novel modification of the scrapless E and I laminations, the I being equal in width to the minimum window width. Additional material must be removed from certain other laminations to provide the wider windows.

It therefore is an object of this invention to provide means and methods for progressively removing additional metal from the E laminations to provide wider windows in accordance with a predetermined pattern.

A more specific object of this invention is to remove additional material from the E-shaped laminations to provide progressively wider windows in accordance with the stock thickness.

Other and further objects and advantages of the present invention will be apparent from the following description when taken in connection with the accompanying drawings wherein:

Fig. 1 is a side view, somewhat schematic in nature, of a punch press constructed and operated in accordance with the principles of my invention;

Fig. 2 is a perspective view of the punching layout;

Fig. 3 is a perspective view showing a part of the stacking chute;

Fig. 4 is a side view of the mechanism for relatively shifting the stock and dies in accordance with the stock thickness;

Fig. 5 is a horizontal sectional view taken along the line 5—5 of Fig. 4;

Fig. 6 is a horizontal view partially in section taken along the line 6—6 of Fig. 4 and showing the shifting cam;

Fig. 7 is an enlarged, detail view of a portion of Fig. 4;

Fig. 8 is a perspective view illustrating a modified arrangement of the apparatus;

Fig. 9 is a plan view of a punching arrangement accompanying the apparatus of Fig. 8;

Fig. 10 is a view taken in section along the line 10—10 of Fig. 11 illustrating the core produced; and

Fig. 11 is a sectional view taken along the line 11—11 of Fig. 10.

Referring now in greater particularity to the figures, and first to Fig. 1, it will be seen that my invention incorporates a punch press **20**. The punch press is shown somewhat schematically since it may be of a conventional type. A standard O.B.I. (open back inclined) type press may be used, but I prefer to use the type known commercially as a Henry and Wright due to the more accurate alignment of punches and dies.

The punch press **20** includes the usual base **22** and a motor **24** driving the head **26** mounted on the connecting rods **28** by means of a belt **30** passing over a pulley wheel **32** on the motor shaft and over a pulley wheel **34** on a drive shaft **36**. The drive shaft **36** carries a suitable weighted flywheel, and is connected through suitable gearing to the connecting rods **28**. A die block **38** is mounted on the bolster or table **40** carried by the base **22**, and suitable punches are carried by a block **42** on the head **26**.

Ferromagnetic stock in the form of a strip **44** is fed from a roll **46** between a set of idler support rollers **48** and a pair of pressure, feed rollers **50** over the die block **38**. The rollers **50** are driven from the motor **24** by any suitable means such as a belt **51** and pulley arrangement in timed relation to the operation of the punch press. In order to perform the multiplicity of punching operations necessary I provide a multiplicity of punches and cooperating dies past which the strip is fed. The punches and dies may be arranged in a straight line and the strip may be fed straight past them. This takes a rather large punch press, however, and I prefer to arrange the punches and dies side by side as the physical space requirements are thereby reduced and a smaller punch press can be used. In order to feed the strip stock successively past the laterally arranged punches and dies, I loop the stock over the top of the machine several times as illustrated at **52** so that the stock is fed between the rollers **50** and through the punch press **20** several times. Channel-shaped guides **54** are supported above the head **26** by suitable supporting brackets **56** secured to the table **40**. The stamped laminations are fed in stacked arrangement from the punch press by a stacking chute **59** supported by any suitable supporting structure (not shown).

In Fig. 2 the strip **44** is shown as it is fed the multiplicity of times between the rollers **50** and over the die block **38**, the lowermost roller **50** and the punch press having been omitted for clarity of illustration. The punches are shown only in part and it will be understood that they are affixed in any known or suitable manner to the block **42** mounted on the head **26**.

On the first pass of the strip through the punch press, as illustrated at **58**, a pair of cylindrical perforating dies **60** punches apertures **62** in the strip for guide purposes. Pilots **64**, having rounded noses, enter the apertures **62** properly to locate the portion **58** of the strip **44** after the holes **62** have been punched therein, suitable apertures being provided in the die block **38** for cooperation with the punches **60** and the pilots **64**. On the second pass or loop **66** of the strip **44** through the punch press, a rectangular punch **68** and cooperating aperture in the die block **38** shear a rectangular section from the strip to form a rectangular aperture **70**. The rectangular section forms the I bar of a core and may drop into a receptacle beneath the punch press, or preferably is fed from the punch press through a stacking chute similar to the chute **59** which is used for stacking the E-laminations as they are produced. The loop **66** is guided laterally by pairs of depending guide members **72** and **74** engaging the edges of the strip adjacent the edges of the die block **38**. The depending guide members **72** and **74** are carried at the end of a U-shaped member **76** having a connecting rod **78** extending into a control unit **80**. The control unit **80** as will be hereinafter pointed out includes suitable mechanism for longitudinally shifting the connecting rod **78** and thereby laterally shifting the strip portion **66** by means of the depending guide members **72, 74**. The distance the strip is shifted is in accordance with a predetermined pattern and with the thickness of the strip as will be apparent.

On the next pass or loop of the strip **44** through the punch press, this portion of the strip being indicated at **82**, a second rectangular punch **84** shears a rectangular section from the strip to provide a rectangular aperture **86** parallel to each rectangular aperture **70**. The apertures **86** are coextensive with the apertures **70** and are spaced equidistant from the center line of the strip. The lateral position of the strip portion **82** is controlled by pairs of depending guide or positioning members **88** and **90** similar to the members **72** and **74**. The members **88** and **90** are carried adjacent the ends of a U-shaped member **92** having a connecting rod **94** extending into a control apparatus or mechanism **96** similar to the control **80**, but shifting the strip in the opposite direction.

On the succeeding pass or loop through the punch press, this portion of the strip being identified by the numeral **98**, the outer edges of the apertures **70** may or may not be shaved according to the intended position in the finished core of the lamination being produced. In the illustrative embodiment of Fig. 2 the outer edge is shown as being shaved by a rectangular punch **100**, and it will be understood that the amount of metal removed by this die will vary from one point to another in the strip according to a predetermined pattern.

The lateral position of the strip portion **98** is determined by pairs of depending guide members **102** and **104** similar to those heretofore disclosed and carried at the ends of a U-shaped member **106**, conveniently arranged on the opposite side of the punch press from the members heretofore shown and described, although it will be understood that it can be arranged on either side. A connecting rod **108** connects the U-shaped member **106** to a control device **110** similar to the controls **80** and **96** previously referred to.

On the fifth loop or pass of the strip **44** through the punch press, this portion of the strip being identified with the numeral **112**, the apertures **86** may be shaved or enlarged similarly to the apertures **70** in the previous portion. The rectangular punch **114** is shown as shaving or enlarging the outer edge of the rectangular apertures **86** to the same size as the apertures **70**, the shaved apertures **70** and **86** being symmetric about the central axis of the

strip. The lateral position of the strip portion **112** is controlled by pairs of depending guide members **116** and **118** on the ends of a U-shaped member **120**. A connecting rod **122** connects the member **120** to a control device **124** similar to those heretofore shown and described.

On the final pass or loop of the strip **44** through the punch press, a rectangular punch **126** parts the strip at **128** and **130** to cut off the end of the strip into a pair of similar E-shaped laminations. The punch **126** punches certain of the E-shaped laminations **132** through the die block into a stacking chute, while the remaining E-shaped laminations **134** fall from the edge of the die block into a suitable receptacle, or preferably into another stacking chute.

It will be understood that the strip **44** is fed stepwise through the punch press **20** so that the strip is stationary each time that the head **26** descends. To this end, the belt **51** and pulley mechanism for driving the feed rollers **50** incorporates an intermittent motion mechanism (not shown) of suitable or conventional type such as a Geneva mechanism. Suitable pilots **136** are provided on the block **42** carried by the head for cooperation with the apertures **62** of the strip **44** in its last loop or pass through the punch press in order to position the strip properly for cutting off of the E-shaped laminations by the punch **126**. Other pilots may be provided on the head block for longitudinal positioning of the strip in its intermediate loops. These pilots must be narrow relative to the holes **62** to cooperate with the holes as the strip is shifted laterally, or must be shiftable laterally with the strip. Such pilots have been omitted from the drawings for clarity of illustration.

The stacking chute **59** for the E-shaped laminations **132** is shown in perspective in Fig. 3. The stacking chute **59** extends from beneath the die block in a continuous curve **138** as illustrated in Fig. 1 and exits through an aperture **140** (Fig. 3) in the side of the punch press **20**. The stacking chute through the curved portion thereof comprises four longitudinal struts **142** joined together by rectangular braces **144**. The braces hold the struts a proper distance apart to allow the E-shaped laminations to slide therethrough broadside. The abutting of adjacent laminations against one another keeps them from tipping over. After leaving the curved portion **138** the stacking chute is provided with a straight inclined section **146** curving into a substantially horizontal section **148**. The lower two of the longitudinal struts **142** are continued through the sections **146** and **148**. The upper pair of the struts **142** is terminated and a pair of longitudinal struts **150** at an intermediate height is joined to the continued struts **142** by U-shaped connectors or brace members **152**. The stacking chute is supported inside the punch press and outside thereof by any suitable means (not shown). The laminations in the stacking chute being free to move relative to one another to a limited extent act very much the same as water in a tube. The weight of newly sheared laminations pushes on the laminations already in the chute and feeds the laminations down through the chute along the curved portion **138** and then upwardly in the inclined straight section **146** and to some distance from the punch press where they readily can be removed for assembly into individual ferromagnetic cores. This action of the laminations in the chute makes it unnecessary for the punch **126** to push the laminations through the chute. Such pushing on the part of the punch would place undue reactive forces on the punch and on the head and would dull the punch.

It will be understood that a similar stacking chute may be used for feeding the E-shaped laminations **134**, and a slightly modified stacking chute may be used for feeding the rectangular laminations stamped out by the punches **68** and **84**. Such chutes have been omitted from the drawings to maintain the greatest possible clarity in the drawings.

The mechanism for laterally shifting the various loops or portions of the strip **44** relative to the punches is shown in Figs. 4–7. This mechanism includes a pair of endless link chains **154** and **156** trained over sprocket wheels **158** and **160** arranged in vertical pairs and rotatably mounted on a pair of suitable brackets **162** depending from the bolster or table **40**.

The sprocket chain **154** carries a plurality of support members **164** each of which is substantially T-shaped in configuration with the stems of the T's connected to alternate links. The heads of the T's are provided with shoulders **166** having short tapered surfaces **168** above them and relatively long tapered surfaces **170** beneath them, adjacent supports **164** nearly abutting on the straight reaches of the chains and the surfaces **168** and **170** of adjacent supports forming nearly continuous surfaces.

The opposite chain **156** carries a plurality of positioning members **172** confronting the support members **164**, the chains being suitably synchronized by means such as a cross shaft **174** interconnecting bevel gears **176** meshing with bevel gears affixed to the lowermost sprockets **158**, **160** for rotation therewith. The positioning members **172** are provided with inclined surfaces **178** parallel to the inclined surfaces **170** of the support members and spaced therefrom a distance equal to the diameter of a circular slug **180** punched from the strip **44** by the punches **60**. Shoulder portions **182** overlie the inclined surfaces **178** and are spaced above the shoulder portions **166** of the support members. Short inclined surfaces **184** above the shoulder portions **182** form substantially continuous surfaces with the inclined surfaces **178** of the adjacent positioning members.

The chains are driven by the slugs **180** as will be brought out more fully hereinafter and act through suitable connections such as bevel gears **186** and a drive shaft **188** to drive a torque amplifier **190**. The torque amplifier may be of any type known in the art and requires a very low input torque for driving an output shaft **192** in synchronism with the input shaft **188**. The output shaft **192** controls one or more of the various control devices **80**, **96**, **110**, and **124** by any suitable means such as a cam **194** mounted on the end of the drive shaft **192** and having a cam track **196** receiving a cam follower **198**. The cam follower **198** may be connected directly to one of the connecting rods **78**, **94**, **108**, **122** to move these rods as indicated by the double ended arrows, for example, the connecting rod **78** as shown in Fig. 4. All of the control devices are operated in accordance with the movement of the chains **154** and **156** and to this end may include followers similar to the follower **198** engaging with cams similar to the cams **194**, all of the cams being driven in synchronism by any suitable or conventional means such as gearing and shafting. The gearing and shafting have been omitted from the drawings as this or any equivalent structure may be conventional and would tend to confuse the drawings without adding anything useful to the disclosure.

The strip **44**, and consequently the slugs **180** stamped therefrom, are quite thin, and when the thickness of the strip varies, the increment is exceedingly small. Impractically precise measurements would be necessary to control the lateral shifting of this strip if the strip were shifted directly in accordance with the variations of thickness in the strip. The mechanism disclosed in Figs. 4–7 and heretofore described multiplies the incremental variations. The slugs **180** rest at some point along the vertical reaches of the chains **154** and **156** on the shoulder **166** of one of the support members **164**. This is illustrated in detail at **186** in Fig. 7. If the strip thickness happens to be of a particular value, some of the slugs will rest directly on the shoulder **166** of the support member **164** directly above the one providing the support illustrated at **186**. In general, however, the thickness will be such that the top of one of the slugs will not be substantially coplanar with the shoulder **166** of the next higher support member, and the next higher support member therefore will serve only to position the slugs. A disjoined column of slugs equal in height to several support mem-

bers therefore will be supported at the position indicated at **186**. The vertical reaches of the chains are made sufficiently long that somewhere the top surface of a slug will come out coplanar with one of the shoulders **166** so that that shoulder **166** also will support a column of slugs. This coplanar alignment is somewhat along the same lines as a vernier wherein different units of length line up every so often.

The slugs **180** pass through an aperture in the table or bolster **40** and are supported in a column by suitable side guides **200** (Fig. 5) supported by spacers **202** mounted on the brackets **162**. The side guides **200** support the column laterally throughout its length, and back-up members **204** are provided behind the chains **154** and **156** along the vertical reaches thereof to assure linearity of the reaches. As each slug is stamped from the strip it advances the sprocket chains **154** and **156** a distance in accordance with the thickness of the slug. Since the vernier-like action of the slugs and support members causes a large number of slugs to be supported as a continuous column, it is the total thickness of a large number of slugs that determines the total travel of the sprocket chains, and hence the rotation of the cam **194**. The cam **194** (and similar cams in all of the control devices) are formed so as to shift the strip portions laterally in accordance with a predetermined pattern so as to produce a round core leg. The movement of the chains in accordance with the thickness of the slugs engrafts upon this predetermined pattern a function of the thickness of the strip so that the strip portions are shifted laterally in accordance both with the predetermined pattern and with the thickness of the strip. A substantially perfect circular cross section of the central leg of the core thus is insured.

The function of the foregoing apparatus possibly will be more fully understood with reference to a transformer or similar core produced thereby. A transformer **206** is shown in Figs. 10 and 11 and includes a plurality of the E-shaped laminations, for instance, the laminations **132**, stacked together to form a core **208** in cooperation with a stack of the I bars or laminations **210**, the latter being arranged across the ends of the legs of the E. As will be seen with reference to Fig. 10, the width K of the laminations of the center leg **212** varies from a maximum at the center of the stack to a minimum at the top and bottom of the stack so as to provide a central leg which is substantially circular in cross section. At the same time the width J of the end legs **214** varies from a minimum at the center to a maximum at the top and bottom of the stack. The window width G is non-uniform due to the fact that the lamination at the center of the core lies along a diameter of the coil while the remaining laminations are chordal relative to the coil. Accordingly, the window width G varies from a minimum at the center of the core stack to a maximum at top and bottom. The coil **216** readily will be seen to be round wound or cylindriform in configuration leading to the substantial savings in copper as earlier set forth.

Following the above brief description of the ferromagnetic core, a further summary of the operation of the invention might prove enlightening. The function of the entire mechanism shown in Fig. 4 is to integrate continuously the thickness of the stock passing through the tools. This integration results in rectilinear motion of the cam follower **198**, and hence of the various connecting rods as **78**, **94**, etc. The return or extent of motion of the cam follower is an arbitrary function of the sum of the thicknesses of the material of the individual scrap pieces punched out by the tools. The function is arbitrary inasmuch as it is dependent on the shape of the cam track, as well as on the integrated thickness.

The necessity for an integrating thickness measuring device to control the rotation of the cam arises from the normal variation in the gage of the stock being used as raw material. For example, #24 gage electrical sheet is .025" thick with a mill tolerance on thickness of plus-or-minus .003". If a stacked core is desired to be one inch in total thickness, and the material is running exactly to gage, there will be forty laminations in the stack. If the material runs light to the limit of the mill tolerance, there will be forty-five laminations in the stack. Conversely, if the material runs maximum heavy, there will be thirty-five laminations in the stack. There is no way of avoiding this mill variation. Thus, if height is relied on as a criterion, the number of laminations in the stack must vary. If the number of laminations is relied on as a criterion, the stack will be of an improper height.

With the height as criterion as is the case throughout this exemplary embodiment of my invention, not only the number but also the planform of the individual laminations must change with the variations in thickness. Therefore, it is impossible to predetermine a schedule of positions for the variable tool element based on the number of strokes taken by the press following the inception of a given forming operation or sequence of operations. Such a schedule would, if based on normal gage of material, result in an elliptical cross section of the middle leg of the core. With light gage stock, the major axis of the ellipse would be the diameter of the circle in the normal gage schedule and would be parallel to the surface of the laminations. With heavy gage stock, the minor axis of the ellipse would be the normal gage diameter and similarly oriented. The thin gage material would be inadequate for the design flux density, while the thick gage material would not permit slipping the prewound coil over the middle leg.

Members **164** and **172** are so formed, and the total active length of the chain members in engagement with the slugs is so designed, that a relatively large column of slugs is used as an integrating column at any given time, thereby completely avoiding or at least minimizing "jumps" in the advance of the shaft **188** due to possible incommensurability of the gage of the material referred to the pitch of the chain.

As will be appreciated, the last or upper-most slug in the column tends to control the lateral shifting of the tool relative to the sheet stock. However, if reliance were placed solely on the thickness of an individual punching, measurements would have to be impractically precise. The use of a column of slugs effectively gives a multiplication of slug thickness, thereby avoiding the necessity of impractically extreme precision. Several slugs can be taken in the columns without leading to error, since the thickness of the strip stock varies gradually, not suddenly. The height of the column is not a factor in the motion of the cam or other control elements. However, the height is important in allowing the number of shoulders **166** to be made sufficiently large so that if the pitch of the chains (and shoulders) is incommensurable with the thickness of the slugs, there will be a minimum of lost motion when the support of the column shifts from one shoulder to another. The important thing is that the last slug punched forms the top of a column of uncertain effective height. Thus, the column is always lowered a distance equal to the thickness of the slug forced on to the top of the column.

In the illustrative embodiment of my invention heretofore set forth, the various cooperating punches and dies are laterally disposed relative to one another and the strip is passed through the punch press a plurality of times. The punches and dies are positioned relative to the strip by laterally shifting the strip. The laminations also can be formed by arranging the punch and die sets in a line and thereby passing the strip in a straight line through the punch press. Likewise, the strip and punch and die sets can be relatively located by laterally shifting the punch and die sets while maintaining the strip laterally fixed. Apparatus embodying the principles of my invention in this manner is shown in Figs. 8 and 9.

The apparatus includes a sub-press **218** comprising a punch holder **220** and a die shoe **222** which will be

mounted on the head and bolster of the punch press as will be understood. Guide rods **224** extend between the punch holder and die shoe to insure proper alignment thereof at all times.

At the entering end of the sub-press **218** there is provided a supporting block **226** for supporting the strip stock **44***a*. It will be understood that the strip **44***a* is fed by means similar to those heretofore described in timed operation with the reciprocation of the punch press and the consequent relative movement of the punch holder and die shoe toward and away from one another. A strip guide **228** is positioned on top of the block **226** and is channel-shaped in configuration to guide the strip laterally. The guide **228** is provided with a pair of apertures **230** in its upper surface providing passage for a pair of cylindrical punches **232** for punching pilot holes **62***a* in the strip as indicated in Fig. 9. The slugs stamped from the strip to form the apertures **62***a* are used for controlling the lateral position of the punches and dies by means of an apparatus similar to that shown and described in Figs. 4–7. The apertures **62***a* cooperate with pilots **233** for properly positioning the strip throughout the ensuing punching operations as will be apparent hereinafter.

A punch carrier **234** is mounted on the punch holder **220** for transverse movement relative thereto by means of a dovetail slide **236** fitting in a dovetail slot **238** in the under side of the punch holder. The punch carrier **234** carries a rectangular punch **68***a*. A movable die carrier **242** is mounted on the die shoe **222** for movement transversely thereof by means of a dovetail slide **244** on the carrier **242** and a dovetail guideway (not shown) in the die shoe. The punch carrier **234** and die carrier **242** are joined together for movement transversely of the sub-press **218** by means of guide rods **246** fixed in one of the carriers, for instance the die carrier **242**, and reciprocable through an aperture **248** in the other carrier. The punch carrier **234** and die carrier **242** along with the guide rods **246** and the punches and dies carried thereby form a movable sub-press tool **249**.

The die carrier **242** carries a die **250** having a rectangular aperture **252** therein aligned with the punch **68***a* for punching rectangular shaped I bars from the strip **44***a*. The movable sub-press tool **249** is connected by means such as a connecting rod **254** to a control device **256** such as that shown and described with regard to the previous embodiment of my invention. This control device shifts the sub-press tool **249** transversely of the sub-press in accordance with a predetermined pattern and in accordance with the thickness of the strip stock **44***a*. The punch **68***a* forms rectangular apertures **70***a* in the strip stock **44***a* similar to the rectangular apertures formed in the stock in the first embodiment of my invention.

A second sub-press tool **258** similar in construction to the sub-press tool **249** and having a cooperating rectangular punch **84***a* and rectangular die aperture (not shown) is mounted for movement transversely of the sub-press **218**. This mounting is similar to that heretofore described and includes a dovetail slide **260** on the punch carrier **262** fitting in a dovetail guideway **264**, and a dovetail slide (not shown) on the die carrier (not shown) fitting in a dovetail guideway **266** in the die shoe **222**. The sub-press tool **258** is controlled in lateral position relative to the strip **44***a* by a connecting rod **268** and a control device **270** similar to those heretofore set forth. The rectangular punch **84***a* of the second sub-press tool **258** stamps another I bar strip and leaves a rectangular aperture **86***a* which is of the same size as the rectangular aperture **68***a* and is symmetrical about the center line of the strip **44***a* therewith.

A sub-press tool **272** substantially identical with the tool **249** is mounted in the sub-press **218** adjacent the tool **258**. The tool **272** includes a punch carrier **274** mounted by means of a dovetail slide **276** and guideway **278**, and a die carrier **280** mounted by means of a dovetail slide **282** and guideway (not shown). The punch carrier **274** carries a rectangular punch **100***a* aligned with a rectangular aperture **284** in a die **286** carried by the die carrier **280**. Rods **288** maintain the punch carrier and die carrier in properly aligned relation. A control device **290** similar to those heretofore disclosed operates through a connecting rod **292** laterally of the strip **44***a* to cause the punch **100***a* to shave a section of metal from the stock to enlarge each aperture **70***a* in accordance with a predetermined pattern and in accordance with the thickness of the strip stock.

A further sub-press tool **294** similar to those heretofore described is similarly mounted by means of dovetail slides and guideways and includes a punch carrier **296** (Fig. 8) carrying a punch **298** (Fig. 9). It will be understood that there is also a die carrier mounting a die having a rectangular aperture therein for receiving the punch **298**. A control device **300** is connected to the sub-press tool **294** by means of a connecting rod **302** to shift the tool laterally of the strip for shaving or enlarging each of the apertures **86***a* so that the apertures **86***a* and **70***a* are of the same size and symmetrical about the center of the strip **44***a*, at any given transverse section of strip **44***a*.

A parting punch **304** is carried by the punch holder **220** near the discharge end thereof and cooperates with a rectangular opening in a parting die carried by the die shoe **222** for parting the strip into pairs of E-shaped laminations **132***a* and **134***a* along the lines **128***a* and **130***a* in the same manner as previously described with regard to the first embodiment of my invention.

It will be understood that suitable stacking chutes can be, and preferably are, placed beneath the die chute **222** and supporting bolster (not shown) for automatically stacking the E-shaped and I-shaped laminations. Suitable stripper plates, of various designs commonly used, are incorporated in the various sub-presses.

By the practice of my invention as herein disclosed it is possible automatically to fabricate laminated ferromagnetic cores for transformers and the like, these cores being of the type fully disclosed and claimed in my copending application "Ferromagnetic Core," Serial No. 372,213, filed of even date herewith. According to my invention, the windows in the E-shaped laminations are automatically determined in size according to their intended position in a finished stack of laminations making up a ferromagnetic core.

Two particular embodiments of my invention have been shown and described. It will be understood that these two embodiments are by way of illustration and are not by way of limitation. Other embodiments are possible and come within the scope of my invention insofar as they fall within the spirit and scope of the appended claims.

I claim:

1. Apparatus for making ferromagnetic core laminations comprising means for feeding ferromagnetic sheet stock means having a thickness and corresponding in extent to a plurality of core laminations along a predetermined path, means along said path for forming pairs of elongated parallel openings in said sheet stock means, means for varying the spacing between successive pairs of openings in accordance with a predetermined pattern and a thickness of said stock, and means for operating said feeding means, said forming means, and said varying means in timed relation.

2. Apparatus for making pairs of E and I shaped ferromagnetic core laminations comprising means for feeding ferromagnetic sheet stock means having a finite thickness and corresponding in extent to a plurality of pairs of E and I shaped laminations along a predetermined path, means along said path for removing rectangular sections of stock of uniform size to form the I-shaped laminations and to form the interior of said E-shaped laminations, means for varying the spacing between the openings left by the removal of said stock in accordance

with a predetermined pattern and the thickness of said stock, means for enlarging the openings left by the removal of said stock in accordance with a predetermined pattern and the stock thickness, and means for separating the stock at intervals to form E-shaped laminations.

3. Apparatus for making ferromagnetic core laminations comprising means for feeding a strip of ferromagnetic stock along a predetermined path, means at a first station along said path for forming a succession of elongated openings in said strip spaced apart longitudinally of said strip, means at a second station along said path for forming a succession of second elongated openings coextensive with and parallel to said first openings and laterally spaced therefrom, the openings defining the interior portions of pairs of confronting E-shaped laminations, means for relatively varying the position of said strip and said forming means laterally of the openings for varying the spacing between successive pairs of first and second openings according to a joint function of the thickness of said stock and a predetermined pattern, and means for severing the strip at intervals to form a plurality of E-shaped laminations.

4. Apparatus for making ferromagnetic core laminations comprising means for feeding a strip of ferromagnetic stock along a predetermined path, means at a first station along said path for forming a succession of elongated openings in said strip spaced apart longitudinally of said strip, means at a second station along said path for forming a succession of second elongated openings coextensive with and parallel to said first openings and laterally spaced therefrom, the openings defining the interior portions of pairs of confronting E-shaped laminations, means for relatively varying the position of said strip and said forming means laterally of the openings for varying the spacing between successive pairs of first and second openings according to a joint function of a predetermined pattern and the thickness of said stock, means for enlarging certain successive pairs of the first and second openings to achieve a mutual relationship between edges of the resulting openings according to a predetermined pattern, and means for severing the strips at intervals to form a plurality of E-shaped laminations.

5. Apparatus for making ferromagnetic cores as set forth in claim 4 wherein the means for varying the spacing between successive pairs of first and second openings and means for enlarging certain of the openings comprise means for laterally shifting the strip in accordance with a joint function of predetermined patterns and the thickness of said stock.

6. Apparatus for making ferromagnetic core laminations as set forth in claim 4 wherein the means for varying the spacing between successive pairs of first and second openings and for enlarging certain pairs of said openings comprises means for shifting the opening forming means and the enlarging means laterally of the strip in accordance with joint functions of predetermined patterns and the thickness of said stock.

7. Apparatus for making ferromagnetic core laminations as set forth in claim 4 wherein the strip is fed along a straight path and the first and second opening forming means and the opening enlarging means are spaced longitudinally along said path.

8. Apparatus as set forth in claim 4 wherein the first and second opening forming means and the opening enlarging means are disposed laterally of one another and the strip is fed past the opening forming and enlarging means in a series of loops.

9. Apparatus for making ferromagnetic core laminations comprising a punch press, means for feeding a strip of ferromagnetic stock through said punch press, a cooperating punch and die carried by said punch press for stamping a first series of I-shaped sections from said strip to form I laminations, a second cooperating punch and die carried by said punch press for stamping a second series of rectangular sections from said strip to form additional I laminations, the openings left in the strip by punching out the first and second series of laminations providing a series of pairs of openings of equal size in said strip, said pairs of openings being coextensive and parallel and forming the interior portions of pairs of confronting E laminations, means for relatively shifting said strip and both of said cooperating punches and dies to vary the spacing between said openings in accordance with a joint function of a predetermined pattern and the thickness of said stock, further cooperating punch and die means carried by said punch press for enlarging certain of said openings in accordance with a predetermined pattern, shearing means carried by said punch press for severing the strip at intervals to form a plurality of E-shaped laminations, and further including means for automatically stacking E-shaped laminations in accordance with the sequence in which they are formed.

10. Apparatus for making ferromagnetic core laminations comprising means for feeding a strip of ferromagnetic stock along a predetermined path, means at a first station along said path for forming successive elongated openings in said strip and spaced longitudinally of said strip, means at a second station along said path for forming a succession of elongated openings coextensive with and parallel to the first mentioned openings and laterally spaced therefrom, the openings defining the interior portions of pairs of confronting E-shaped laminations, means at another station along said path for removing slugs from said strip, means for arranging a plurality of said slugs in a column as they are stamped from said strip, means operable in accordance with the increment in height of said column for relatively varying the position of said strip and said forming means laterally of the elongated openings for varying the spacing between successive pairs of first and second openings according to the thickness of said strip, and means for severing the strip at intervals to form a plurality of E-shaped laminations.

11. Apparatus for working sheet material comprising means for feeding sheet material, material working means past which said sheet material is fed, means for locating said material working means in predetermined position, means for removing sections from said sheet material, means for locating said section removing means in predetermined position, a pair of endless chains having confronting, substantially vertical reaches, cooperating carriers on said endless chains confronting one another in pairs along said substantially vertical reaches and receiving the sections removed from said sheet material for driving said chains, and means controlled by the movement of said chains for relatively shifting said sheet material and said material working means for controlling the portions of the sheet material to be worked in accordance with the thickness of said sheet material.

12. Apparatus as set forth in claim 11 wherein the cooperating carrier means includes pairs of confronting members on the opposite chains, the members on one chain having a supporting shoulder near the top thereof, an underlying inclined surface and an overlying inclined surface substantially parallel to one another, and the members on the other chain having an overlying shoulder, an inclined surface extending outwardly beneath said shoulder, and a surface above said shoulder substantially parallel to the underlying surface, the inclined surfaces of opposite members being substantially parallel and spaced in accordance with the distance across the sections removed from the sheet material, and the shoulders on opposite members being vertically spaced apart a distance at least as great as the thickness of a plurality of the sections removed, the sections removed thereby being supported by one of the shoulders of the first mentioned members and on one another.

13. Apparatus as set forth in claim 12 wherein the means for relatively shifting the material working means and the sheet material includes power multiplying means.

14. The method of forming ferromagnetic cores which

comprises forming pairs of elongated apertures in a strip of ferromagnetic sheet stock to define the internal outlines of pairs of confronting E-shaped laminations, varying the spacing between successive pairs of openings in accordance with a predetermined pattern and the thickness of said stock, enlarging certain of said openings in accordance with a predetermined pattern and a thickness of said stock, cutting off the stock at intervals to form E-shaped laminations, stacking the laminations to form E-shaped core portions having circular center legs, and arranging the material removed from the strip in stacks of I-shaped laminations across the ends of the legs of the E-shaped core portions to complete the cores.

15. Apparatus for making pairs of E and I shaped ferromagnetic core laminations comprising means for feeding ferromagnetic sheet stock means having a finite thickness and corresponding in extent to a plurality of pairs of E and I shaped laminations along a predetermined path, means along said path for removing rectangular sections of stock to form the I-shaped laminations and to form the interior of said E-shaped laminations, means for varying the spacing between the openings left by the removal of said stock in accordance with a predetermined pattern and the thickness of said stock, means for enlarging the openings left by the removal of said stock in accordance with a predetermined pattern and the stock thickness, and means for separating the stock at intervals to form E-shaped laminations.

16. Apparatus for making ferromagnetic core laminations comprising a punch press, means for feeding a strip of ferromagnetic structure through said punch press, a cooperating punch and die carried by said punch press for stamping a first series of I-shaped sections from said strip to form I laminations, a second cooperating punch and die carried by said punch press for stamping a second series of rectangular sections from said strip to form additional I laminations, the openings left in the strip by punching out the first and second series of laminations providing a series of pairs of openings of equal size in said strip, said pairs of openings being coextensive and parallel and forming the interior portions of pairs of confronting E laminations, means for relatively shifting said strip and both of said cooperating punches and dies in accordance with a predetermined pattern and in accordance with the thickness of the stock, further cooperating punch and die means carried by said punch press for enlarging certain of said openings in accordance with a predetermined pattern and in accordance with the thickness of the stock, and shearing means carried by said punch press for severing the strip at intervals to form a plurality of E-shaped laminations.

17. Apparatus for making ferromagnetic core laminations comprising means for feeding ferromagnetic sheet stock means having a thickness and corresponding in extent to a plurality of core laminations along a predetermined path, means along said path for forming successive sets of paired non-overlapping openings, the number of paired openings in a set being equal to at least one, any excess of paired openings beyond one being overlaid on the first pair of openings formed in said sheet stock means so as to effect enlargement of each of the openings in said first pair of openings, means associated with at least one of said paired openings forming means to vary the spacing between successive pairs of openings in accordance with a predetermined pattern and in accordance with the thickness of the sheet stock means, and means for parting said sheet stock means to produce pieces each having no more than one set of said paired non-overlapping openings.

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