Nov. 1, 1955 O. M. MARQUARDT 2,722,589

METHOD AND APPARATUS FOR UNIFORMLY HEATING INTERMITTENTLY MOVING METALLIC MATERIAL

Filed Nov. 30, 1950 2 Sheets-Sheet 1

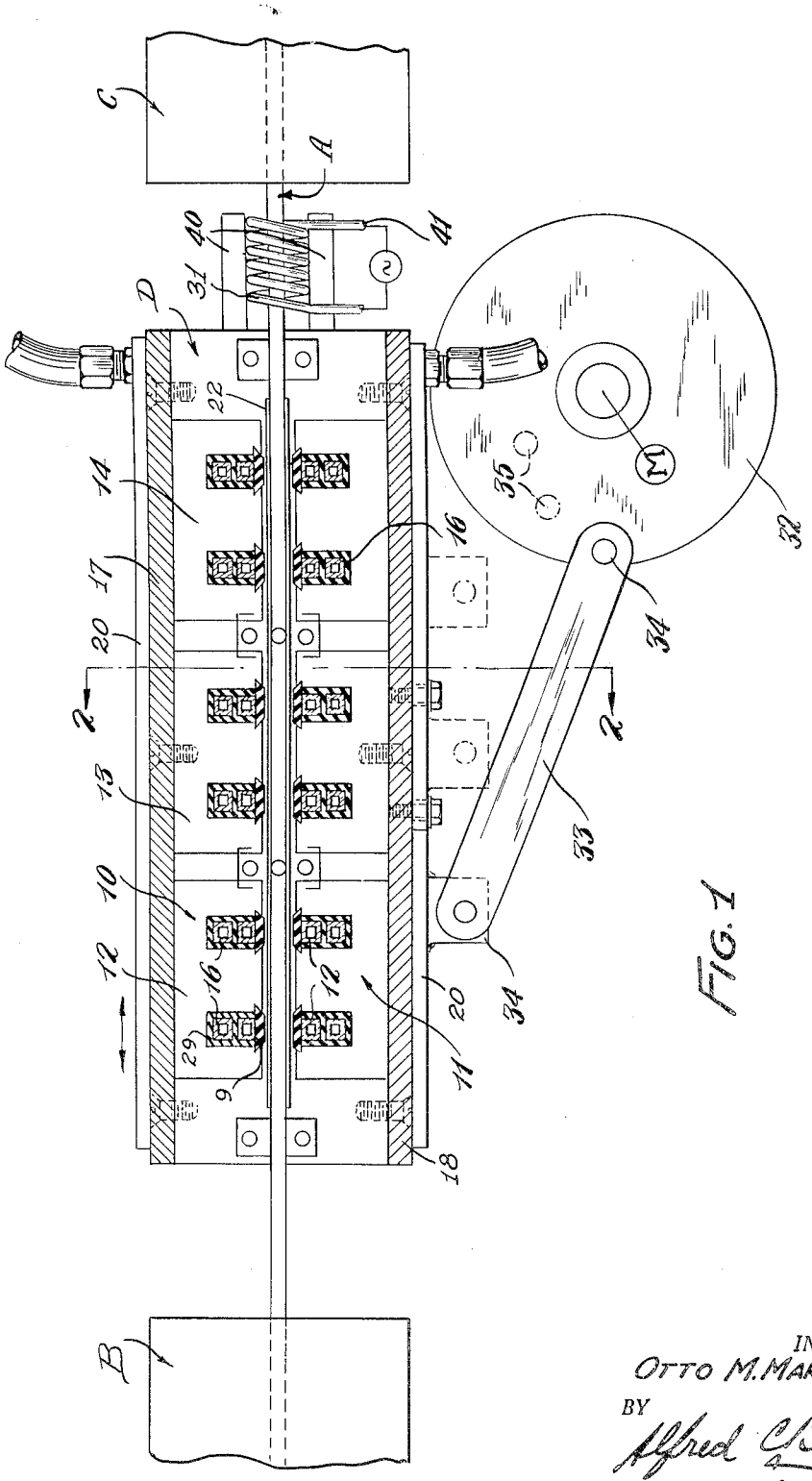


FIG. 1

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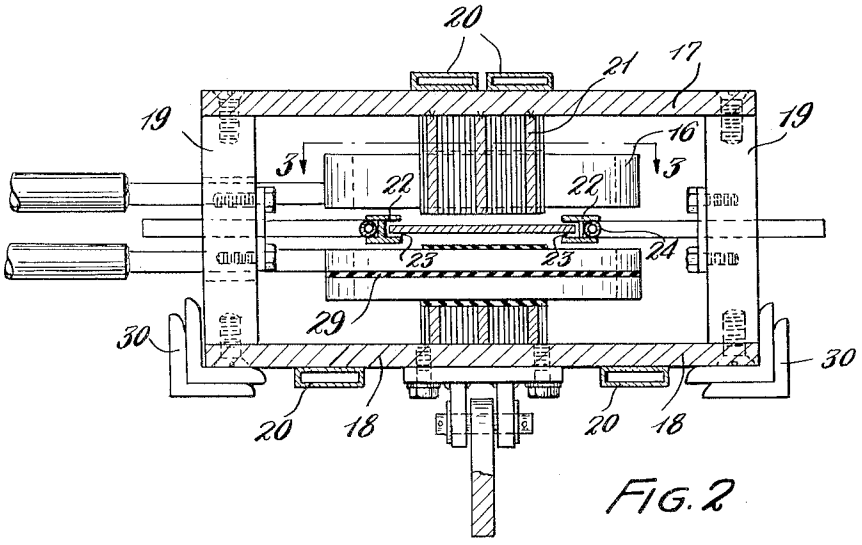


FIG. 2

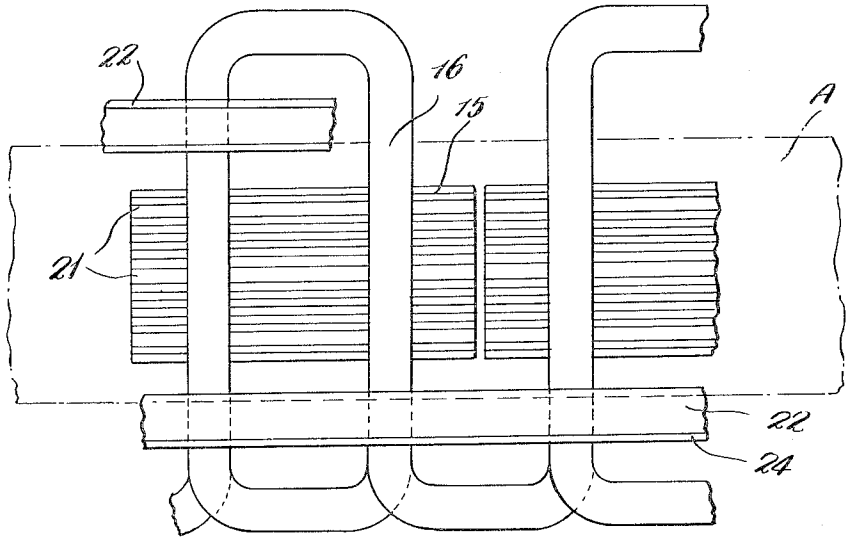


FIG. 3

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2,722,589

Patented Nov. 1, 1955

2,722,589

METHOD AND APPARATUS FOR UNIFORMLY HEATING INTERMITTENTLY MOVING METALLIC MATERIAL

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Application November 30, 1950, Serial No. 198,459

6 Claims. (Cl. 219—10.61)

This invention pertains to the art of high-frequency induction heating and, more particularly, to a method and apparatus for uniformly heating, by a heater that has an inherent nonuniform heating pattern, a portion of an elongated member which must be intermittently advanced past the heater.

The invention is particularly adaptable to heating to a forging temperature an end portion of a metallic strip, which end, when heated, must be advanced at spaced intervals into a punch or forge and, for the forging operation, must be heated uniformly over its entire length.

In the art of high-frequency induction heating, it has been quite difficult in the past to uniformly heat metallic articles of certain conventional cross-sectional shapes. One of these shapes has been flat metallic strip. With flat strip, the tendency is for either the center of the strip to heat or for the edges of the strip to heat and this tendency may shift in the course of heating as the temperature of the strip passes through the Curie-point temperature. This shift of heat pattern is particularly true where the high-frequency inductor is in the form of a helix with the strip passing axially through the helix. Composite inductors have been provided, one part of which is adapted to heat the edges and the other part of which is adapted to heat the center. The heating of edges and center cannot take place at the identical points of the strip and, therefore, a uniform continuous movement of the strip has been required if uniform heating is to be obtained.

Transverse flux inductors have been employed for the heating of strip. Such inductors take their name from the fact that the flux is forced directly through the strip from the core of one inductor to the core of a second inductor. Such inductors, however, tend to heat narrow transverse bands on the strip. Therefore, in order to obtain uniform heating, the strip must be moving forward relative to the inductor at a uniform rate. Also, the inductor should have a strip positioned therein over substantially its entire length for proper electrical loading. Another problem with high-frequency induction heating of strip to be fed into forges and the like has been that the inductor itself must be spaced from the press. This is to allow clearance for the dies of the press and, also, to prevent stray flux fields from causing undesirable circulatory currents in the metal of the press. On the other hand, it is impossible to let the heated piece hang free between the inductor and the punch press due to the rapid cooling of the piece at the elevated temperatures and sagging due to its weight. This cooling on thin strip can be as high as 100 degrees per second.

The present invention attempts to make use of transverse-type induction heaters for uniformly heating a periodically or intermittently moving or advancing workpiece such as strip or bar or wire. For the purposes of convenience, the workpiece upon which the present invention is operable will be termed generally "strip."

In accordance with the present invention, the portion of the strip to be heated and the inductor are moved in an oscillatory or reciprocatory manner continuously relative to each other during the heating cycle so that, to all intents and purposes, the inductor sees the strip as though it was progressively moving relative thereto. The amount of reciprocation of the inductor, if transverse flux inductors are employed, is such as to at least span the distance between the narrow portions which would heat if the relative movement were not employed. When the portion to be forged has reached the desired temperature, it is advanced to the punch or forge, cut off and the strip is then retracted to bring the remaining portion of the strip back into the inductor. In some instances, the radiation and temperature loss of the strip due to its advancing from the inductor to the punch may be excessive. In this event, the entire inductor which forms a radiation-preventing housing for the strip may be advanced as far as possible toward the press along with the strip to prevent the temperature losses of the strip.

In view of the above, it is an object of the present invention to provide a new and improved method for uniformly heating, using an inductor having a relative nonuniform heat pattern, a portion of a metallic strip which is advancing intermittently through the inductor, which method comprises oscillating the inductor and strip relative to each other during the heating operation; and, when the heating operation is completed, advancing the strip rapidly through the inductor to where it is to be used.

Another object is the provision of a new and improved method of the type referred to wherein the strip and inductor are moved continuously relative to each other until the desired portion of the strip is heated to the desired temperature. The strip and inductor are then advanced in the same direction but the strip to a greater distance than the inductor so that the inductor may prevent radiation from the strip for a portion of its travel from furnace to forge or press.

Still another object of the invention is the provision of a new and improved apparatus for uniformly heating the portions of intermittently advancing metallic strip comprising the combination of a transverse flux inductor, a feeder for intermittently advancing the strip past the inductor and means for continuously oscillating or reciprocating the inductor relative to the strip during the heating operation.

Still another object is the provision of apparatus of the type referred to wherein the inductor and the means for reciprocating the inductor relative to the strip are, in turn, mounted for reciprocation in a direction longitudinally of the strip.

The invention may be embodied in practical form in a number of different physical arrangements of parts and inductors. For the purposes of better illustrating the invention, a single preferred embodiment will be described in this specification and illustrated in the attached drawing which is a part hereof, and wherein:

Figure 1 is a side view, partly broken away, showing apparatus constructed in accordance with the present invention and which is capable of carrying out the method of the present invention;

Figure 2 is a sectional view on the line 2—2 of Figure 1; and

Figure 3 is a fragmentary sectional view taken approximately on the line 3—3 of Figure 2.

Referring now to the drawings wherein the showing is for the purposes of illustrating the invention only, the figures show a flat metallic strip A being intermittently advanced from right to left into a forge press B by a feeder

mechanism C and with a high-frequency induction heating unit D disposed intermediate the feeder and the forge for the purpose of heating the strip to a forging temperature.

The flat metallic strip A shown may be of steel or other material of either high or low carbon or alloy. Other cross-sectional shapes could also be employed. This strip is generally a continuous length fed from a coil (not shown) if it is of such a small thickness that it can be coiled, or from an ordinary rack if it is such a thickness that it cannot be coiled. It is preferred that if strip is fed from a roll, the feeder mechanism be preceded by a welding unit so that the tail end of one coil of strip may be welded to the leading end of another coil of strip so that there will be continuous lengths of strip fed to the forge.

The forge is more or less conventional and forms no part of the present invention but may include a pair of mating dies which are adapted to be forcefully closed on the heated portion of the strip to suitably shape it. The forge may also include a cut off for the strip, which cut off will generally precede the forging operation. In operation, the strip A then is advanced intermittently into the forge, cut off and then forcefully shaped to the desired configuration.

The strip is advanced by the feeder mechanism C which again forms no part of the present invention and may be of any conventional construction. As shown, it is spaced a substantial distance from the forge B.

The induction-heating unit D includes a pair of generally identical high-frequency inductor assemblies **10**, **11** mounted in spaced, parallel relationship on opposite sides of the strip A. As the assemblies are identical in construction, only the assembly **10** will be described in detail and like numerals will be used to designate like parts in the assembly **11**.

The inductor assembly **10** is comprised of three (there may be more or less) identical aligned inductor elements **12**, **13** and **14**. Each inductor element **12**, **13**, **14** is comprised of a stack of thin, magnetically-permeable laminations **15** having the plane thereof perpendicular to the plane of the strip and parallel to the line of movement thereof. The magnetically-permeable laminations **15** are interleaved by three cooling laminations **21** formed of a material of high heat conductivity, such as copper. The strip-adjacent side of each stack of laminations has a pair of transverse slots in which a two-turn winding of an electrical conductor **16** is disposed. Each turn of the conductor, as shown, is insulated from the other and from the laminations by insulation **29**. An insulating-retainer strip **9** extends across and closes the lower end of the transverse slot to retain the winding therein. This strip **9** may be retained in position by any suitable means but is shown as having its edges extending into grooves in the walls of the slots. While a two-turn winding is shown, obviously more or less turns could be employed. The windings of each inductor element can be connected in electrical parallel relationship with each other; but, preferably, they are connected in electrical series relationship so that the direction of the current in each slot from one end of the inductor unit to the other will alternate as shown by the plus (+) and minus (—) signs in Figure 1. The arrangement is shown more clearly in Figure 3. As stated, the inductor assembly **11** is generally identical in construction to the inductor assembly **10** and the slots in the laminations of the inductor assembly **11** are preferably disposed directly opposite the slots of the laminations of the inductor elements **12**, **13** and **14**. The direction of the current in the windings of the inductor assembly **11** are in the same direction as that of the winding of the inductor assembly **10**. The effect is that the flux caused by current flow in the conductors will flow transversely through the strip A and generate high-frequency, high-density, electric currents to flow in the strip A.

The inductor assembly **10** is fastened to an upper supporting plate **17** formed of an electrically-conductive and heat-conductive material such as copper. The cooling laminations **21** are brazed to this plate to provide effective heat transfer to the plate. The inductor assembly **11**, in a like manner, is fastened to a lower supporting plate **18** of like material.

Both plates **17** and **18** have copper tubes **20** brazed to the outer surfaces thereof. Cooling water may be circulated through the tubes **20** to remove any heat which may be generated in the laminations **15** and conducted to the plates **17**, **18** through the cooling laminations **21**.

The plates **17**, **18** are held in fixed, spaced relationship by a pair of side members **19** preferably formed of an electrically-insulating material. Screws are shown as holding the members **17**, **18** and **19** in assembled relationship. The length of the members **19** controls the spacing between the inductor assemblies **10**, **11** and, therefore, the clearance between the strip A and the strip-facing surfaces of the inductor assemblies.

As shown, the ends of the legs of the laminations are spaced and the strip A extends through this space.

With apparatus of this type, difficulty is sometimes experienced with the magnetic field pulling the metallic strip, if it is of a magnetic material, into actual physical engagement with the laminations. This is undesirable. Also, it is necessary, with the construction of the type described, that the strip itself be accurately aligned relative to the inductor. In the embodiment shown, guides **22** extend the length of the inductor in the space between the two inductors and have a channel **23** formed on their facing surfaces into which the edges of the strip A may extend and be guided thereby. It is preferred that these guides be formed of a nonmagnetic material in order that the amount of heating by hysteresis in the guides may be held down to a minimum. The guides may take a number of different forms of construction but, in the embodiment shown, they are made up of a number of flat steel strips welded or brazed together about a hollow copper tube **24** to form a channel member. Water may be circulated through the tube **24** for the purposes of cooling the guides.

Referring now specifically to Figure 3, it will be noted that the thickness of the stack of laminations is considerably less than the width of the strip A while, at the same time, the conductor **16**, in forming the winding between one transverse slot and the other, extends beyond the edges of the strip A. With such a construction, the evenness of the heat pattern may be accurately controlled by increasing or decreasing the thickness of the stack of laminations. Thus, if the strip tends to heat too much in the center, the thickness of the stack of laminations may be increased. If the edges tend to heat too much, the thickness of the stack of laminations may be decreased. It has been found that the guides have little effect on the heating of the edges. They are non-magnetic and they have a relatively small transverse width compared with the width of the strip.

The heating unit D shown also includes what may be termed a preheating unit in the form of a helical inducing coil **31**. This coil **31** is positioned at the end of the unit D adjacent the strip feeder C and is supported in position by a pair of spaced arms **40**, **41** fixed to the member **19**. The coil **31** preferably has an axial cross-sectional shape which is substantially rectangular and the strip A passes through this coil before entering the space between the inductor assemblies **10**, **11**. The coil **31** may be connected electrically in series or in parallel with the coils of the inductors **10**, **11** or it may be separately energized as shown. The coil **31** has the characteristic, with thin strip, that if the strip is allowed to remain stationary in the coil, the strip will heat to the Curie point and not beyond, regardless of the amount of power supplied to the coil or the length of time that the strip remains therein.

The use of such a coil greatly contributes to obtaining an increased uniformity of final temperature of the

strip as it emerges from the induction-heating unit 10 to be forged into the heating unit D. The coil 31 is capable of heating the entire strip entirely across its width uniformly to the same temperature at or near the Curie point. Thus, the inductors 10, 11 need only raise the temperature from the Curie point to the forging temperature and it has been found that a far greater uniformity of temperature over the entire width of the strip can be obtained.

In the embodiment shown, the conductors 16 of one inductor are disposed opposite the conductors 16 of the other inductor. Corresponding conductors 16 of each inductor have the current flowing therein in the same direction such that the flux in the laminations will tend to pass directly from one stack of laminations to the other; that is to say, transversely through the strip A. Normally, with such a construction, heating of the strip, assuming that the strip is not moving continuously in one direction relative to the inductor, as is usually the case, will occur between the opposed conductors 16 and transversely across the strip and along the edges intermediate the transverse heated portions. Obviously, with such an arrangement, it would be impossible to obtain a uniformly heated length of strip which is so necessary for forging operations; and, yet, in the particular field to which this invention applies, the strip cannot be continuously progressively moved relative to the inductor because of the intermittent use of heated strip by the forge B.

In accordance with the present invention, the induction-heating unit is continuously moved relative to the strip even though the strip may be relatively stationary to an observer. Thus, the inductor unit D is continuously moved or reciprocated in a direction parallel to the longitudinal length of the strip A and, accordingly, the induction-heating unit D is suitably supported on a rack 30 for such movement. In the embodiment shown, the rack has longitudinally extending ways and the housing has correspondingly shaped surfaces to slide in the ways.

Suitable means are provided for the purpose of oscillating or reciprocating the induction-heating unit D. In the embodiment shown, a crank and connecting rod arrangement are shown consisting of a connecting rod 33 pivoted at one end to a lug 34 fastened to the bottom side of the induction-heating unit and at the other end pivoted on a crank pin 34 of a crank member 32 which, in this instance, is a disk rotated about an axis by a motor M through a variable-speed mechanism (not shown). As shown, the crank pin 34 may be mounted in a threaded opening 35 on the disk and a plurality of such openings are provided located at varied distances from the axis of rotation of the disk so that the amount of movement of the induction-heating unit D may be controlled. Other types of mechanism may be employed for reciprocating the unit D.

In the heating of thin metallic strip, the heat radiation which occurs at forging temperatures is very rapid. Obviously, there must be some space between the exit end of the inductor unit D and the forge B even when the inductor unit is advanced the maximum amount toward the forge unit B. With a normal and conventional intermittent advancement of the strip A by the strip feeder C, it will be appreciated that there would always be a free end of the strip A projecting beyond the end of the inductor unit D and, in the time required between the feed movements, this projecting end would cool to an extent which cannot be tolerated if the strip is to be at the maximum temperature when it enters the forging die. The invention, accordingly, contemplates that the strip feeder C will advance the strip A into the forge the required distance and, when the end of the strip has been cut off of a cut-off mechanism in the forge B, the strip feeder mechanism will then act to draw the free end of the strip A back into the inductor unit D where the heating of the entire end of the strip may be continued so that, when the strip is again advanced, the entire end of it which is to go into the forge B will be at the maximum and desired forging temperature.

A preferred embodiment of the invention has been described in order to more fully explain the aspects of the invention. It would be appreciated that other embodiments will also come within the scope of the invention. For example, but without limitation, the transverse slots of the laminations could extend longitudinally of the strip and the inductor assembly could be oscillated transversely to the length of the strip and then, when it is time to feed a strip to the forge, the entire induction-heating unit B could be oscillated in a longitudinal direction.

It would be appreciated that other modifications will occur to those skilled in the art upon a reading and understanding of this specification. It is my intention to include such modifications and alterations even though they differ radically in appearance from the described preferred embodiment so long as such modifications and alterations come within the scope of the appended claims.

Having thus described by invention, I claim:

1. The method of uniformly heating intermittently moving metallic strip with a heater unit which inherently has a nonuniform heating pattern which comprises advancing said strip intermittently through said heating unit and simultaneously and continuously oscillating said heating unit relative to said strip in the plane of movement thereof and out of phase with the intermittent advancing of said strip.

2. The method of uniformly heating predetermined lengths of intermittently advancing metallic strip material with a heating unit which has an inherently nonuniform heating pattern which comprises intermittently advancing said strip and continuously oscillating said heating unit relative to said strip in the plane of movement thereof and out of phase with the intermittent advancing of said strip.

3. The method of uniformly heating predetermined lengths of intermittently advancing metallic strip material with a high-frequency transverse flux-type heating unit which tends to heat a plurality of generally rectangular patterns on said strip which comprises intermittently advancing said strip and continuously oscillating said unit relative to said strip in the plane of movement thereof a distance at least equal to the distance between the side of said rectangular heating pattern.

4. The method of claim 3 wherein the strip is magnetic and is first heated to the Curie point before being subjected to the heating action of the transverse flux unit.

5. Apparatus for uniformly heating intermittently moving metallic strip with a heater unit which inherently has a nonuniform heating pattern comprising, in combination, a high-frequency induction-heating unit of the transverse flux type, means for intermittently feeding an elongated workpiece past said heating unit at predetermined intervals and other means for continuously reciprocating the heating unit along the line of movement of said workpiece and out of phase with the intermittent feeding of said workpiece whereby to provide uniformly heated lengths of strip material.

6. Apparatus for uniformly heating predetermined lengths of intermittently advancing metallic strip material with a heating unit which has an inherently nonuniform heating pattern comprising, in combination, a heating unit comprised of high-frequency inductors positioned in close-spaced relationship to the workpiece and lying in the general plane of the surface of said workpiece, means for intermittently advancing said workpiece along the line of movement past said inductor and other means for reciprocating the heating unit in the plane of said strip out of phase with such intermittent advancing thereof whereby to uniformly heat the strip to an elevated temperature.

(References on following page)

References Cited in the file of this patent

UNITED STATES PATENTS

1,912,214	Northrup	May 30, 1933
2,202,758	Denneen et al.	May 28, 1940
2,274,072	Kersting	Feb. 24, 1942
2,326,163	Patterson	Aug. 10, 1943

2,401,899	Bierwirth et al.	June 11, 1946
2,414,362	Denneen et al.	Jan. 14, 1947
2,441,940	Rohdin	May 18, 1948
2,448,011	Baker et al.	Aug. 31, 1948
2,480,287	Crowe	Aug. 30, 1949
2,495,055	Crowe	Jan. 17, 1950
2,504,815	Detuno et al.	Apr. 18, 1950