Wire Straightening and Molding for Wire Spring Relays

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(Manuscript received January 19, 1954)

The basic design of the wire spring relay departs from conventional relay design in many ways. Translation of some of these design departures into commercial relay manufacture has necessitated the development of new machines and new methods because those available were incapable of producing to the new design requirements. Two developments in this category involved the straightening of large quantities of small diameter wire and the molding of a multiplicity of straightened wire inserts into phenolic resin blocks. The manner in which these developments were reduced from problems to practice is the subject of this paper.

PART I — AUTOMATIC WIRE STRAIGHTENING

Ordinarily wire is received from suppliers on spools or reels. In the spooling operation a spiral bend is placed in the wire which persists when it is unspooled. For use as a wire spring in the wire spring relay this spooling bend must be removed if the wire is to be positioned with the precision required for the desired functioning of the relay. It is necessary, also, to have the wire free of bends if automatic manufacturing methods are to be employed. For these reasons, it is important that the nickel silver and silicon copper wire used in the wire spring relay be straightened as the initial operation in the manufacture of wire block assemblies or "combs" for these relays.

Wire straightening can be accomplished by cold working the wire under controlled conditions until sufficient stress has been built up, particularly at the surface, to make the wire resist bending efforts. The degree of straightness required is governed, of course, by the desired performance of the comb in the operation of the wire spring relay. For the 0.0226-inch nickel-silver wire used in the twin wire comb this has been established, for example, as a deviation not exceeding 0.010-inch from absolute straightness measured at the contact end of the comb, i.e. 2⅝-inches from its anchorage point in the phenol resin block. This degree of straightness is satisfactory also for the automatic manufacture of relay combs in which a multiplicity of straightened wires are guided into a molding die and positioned so accurately that they can be permanently imbedded in phenolic resin to the close dimensional limits necessary for ultimate assembly into relays.

EXPERIMENTAL WORK

Wire Straightening

The original experimental work on wire straightening was done at the Bell Telephone Laboratories to aid in establishing the feasibility of a wire spring relay design. After eliminating other approaches it was decided to straighten the wire in a motor-driven machine by pushing the wire through carefully oriented dies in a rotating head. The wire produced in this manner was known to have a twist but was adequate for making model parts. Subsequently, Western Electric development engineers made a survey of available commercial wire straightening machines. A machine was purchased which, while not intended for straightening wire of the small diameters used in wire spring relays, was capable of modification. Among the important things learned from the operation of this machine were first, it is preferable to push instead of pull wire through the rotating die head because of interference at the puller due to twist in the straightened wire; second, much of the twist can be removed from the straightened wire by spinning the spool of raw wire counter to the direction of the driven die head; and third, it appeared that a simpler approach than spinning the spool of raw wire would be to pass the wire through a second straightening head rotated in the opposite direction from the first. On the basis of these observations, a Hawthorne-designed experimental straightening machine was constructed. This machine featured two die heads independent of each other and counter rotating in operation. Five individual sets of die blocks, with provision for spacing adjustment as found on the rotary die holder of the commercial straightener, were retained in each head. Subsequently, this experimental machine was used for an extended series of tests to determine such things as the optimum spacing between individual dies, the proper offset from the center line of the head for each die, the best ratio of opposing head speeds, and the maximum rate of wire feed with respect to the rotational speed of the die holder head required to produce straight wire in the diameters employed in the wire spring relay.

Since it had become evident by the time this study was well advanced that a multiple head machine would be required, a second experimental machine was built. This machine, Fig. 1, designed with the driving mechanism and spacing allowances considered necessary for an automatic multiple head straightener, had only one double head capable of straightening a single wire. A major change, to be discussed later, was replacement of the five adjustable die blocks in each head by a pair of opposing die blades contoured to provide a wire passage space between them identical to the predetermined path previously forced upon the wire by the five die sets. These die blades were retained by a spindle keyed to the drive mechanism. To accommodate the double head feature, a rotating unit consisting of two spindles coupled together was employed. Much of the remaining experimental work, such as optimum rotational speed of the spindles, the effect of different configurations of the die blade wire path surfaces, rate of wire feed, etc. was performed with this machine. Except for minor changes it became the prototype for the automatic multiple head machines constructed later.

Straightened Wire Storage

In contrast to the manual operations needed to assemble the springs and phenol fibre insulators of U- and Y-type relay spring pile-ups, it was planned from the beginning to mold straightened wire into phenolic resin by automatic means so that unit assemblies would be obtained for

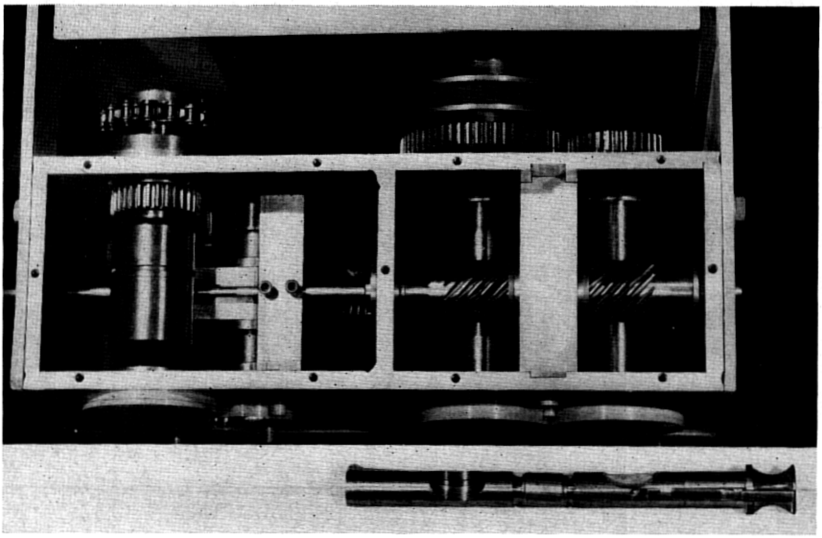

Fig. 1 — Experimental machine with one double head, prototype of 24 and 30 double head wire straightening machines.

the wire spring relay. The labor economy of the latter procedure is obvious. To implement this plan it was necessary that straightened wire be available at the molding press in the quantities required to prevent loss of molding time. To be successful it was important that interruptions to the regular recurrence of molding cycles, such as rethreading the multiplicity of wires into molding dies, be kept to a minimum.

The original planning envisioned a battery of single strand wire straighteners operating continuously to make relatively long lengths of straightened wire. How to store this wire between the wire straightener and the molding press presented the real problem. An early attempt toward a solution involved winding straightened wire on 36-inch diameter reels until sufficient length had been accumulated for eight hours' molding time. These reels would be mounted ahead of the molding press as shown in Fig. 2, and changed at the end of each eight hour shift.

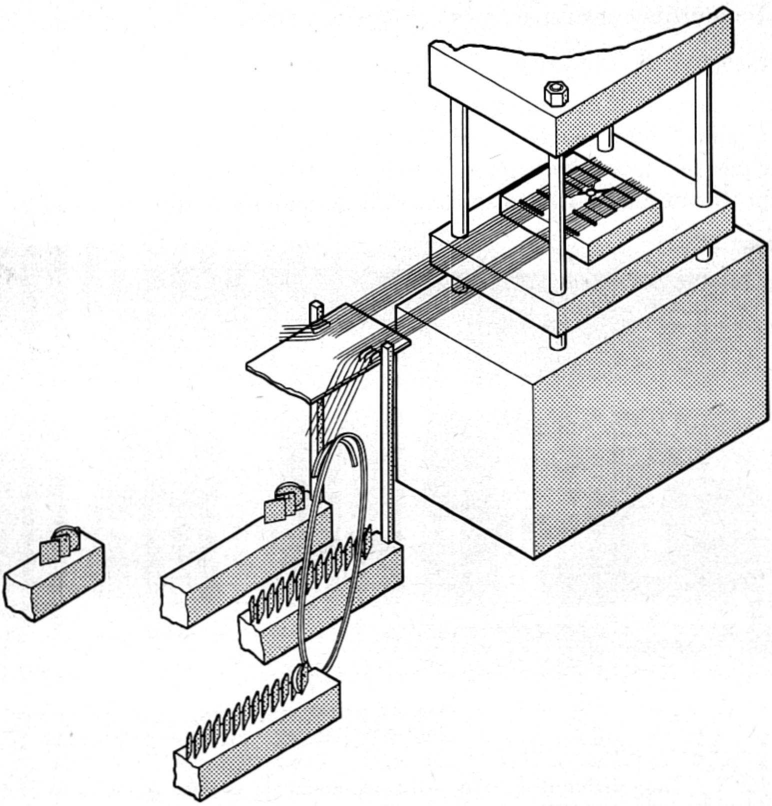

Fig. 2 — Sketch showing handling of straightened wire on storage reels.

Initial efforts indicated that this procedure was practicable. However, a new shipment of nickel silver wire revealed that, while not detectably different from previous shipments, the new wire took a permanent set on the 36-inch reels thereby making it unusable at the molding press. Principally because of the incipient possibility of straightened wire acquiring a set when not stored on flat surfaces, this reel approach was abandoned. Another effort consisted of providing a multiplicity of straight storage tubes, of either metallic or plastic material, into one end of each of which an eight hour supply of a single strand of wire was pushed by the wire straightening machine and from the other end of which a molding press would withdraw its requirement of wire (Fig. 3). This was found unworkable because often the wire straighteners were unable to push the required length of wire into the tubes due to the lead end becoming snarled from twist in the wire. It was decided, finally, to discard the idea of continuously straightening and storing wire in favor of placing multiple head machines adjacent to the molding presses and operating them only as required. This meant increasing the straightening machine investment because intermittent operation of the straighteners necessitated more wire straightening facilities. A compensating factor was the elimination of investment in storage facilities. It was found that interrupting the continuous operation of the straightening heads had no detectable effect on the characteristics of the straightened wire. Accordingly, multiple head automatic wire straighteners are now placed adjacent to the molding press and operated at a speed slightly greater than the wire consumption of the molding dies. Automatic control of the length of a partial loop of wire extending from the wire straightener assures an adequate supply of wire at the molding press. The ultimate length of continuous straightened wire available to the molding press by this arrangement is governed only by the length of raw wire on the spool and is sufficient for many operating shifts.

AUTOMATIC MULTIPLE HEAD WIRE STRAIGHTENER

Both 24- and 30-double head automatic wire straighteners have been built by the Western Electric Company. The 24-double head straighteners are used in making combs for the AF, AG and AJ type general purpose wire spring relays and the 30-double head machines for the 286, 287 and 288 type multi-contact relays. In practice the phenol resin molding operation is accomplished in four-cavity dies with the cavities arranged symmetrically about the center of the die. Thus two forward cavities face the wire straightener with the remaining two cavities in tandem. When making the twelve wire single comb of general purpose

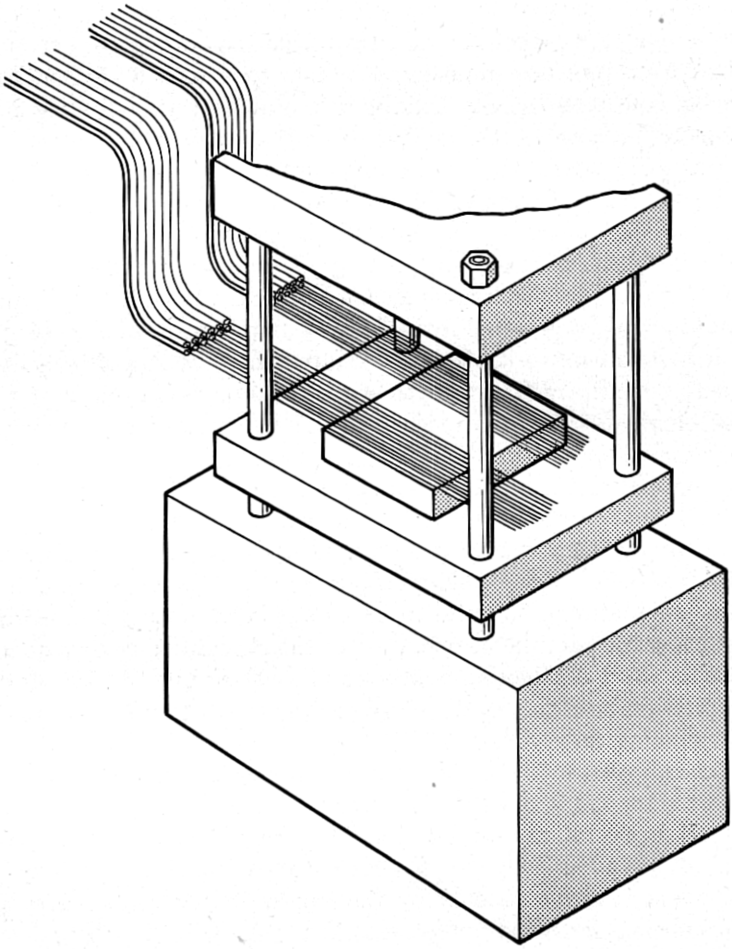

Fig. 3 — Sketch showing method of handling straightened wire from storage tubes.

relays, half of the wires from the 24-double head straightener are guided into each forward cavity. When the twenty-four wire twin wire comb is being made, on the other hand, the entire production of a 24-double head straightener is guided into each forward cavity and two wire straighteners are necessary for each molding press.

The 30-double head straighteners are arranged similarly when the fifteen wire single wire comb and the thirty wire twin wire comb of the multi-contact relay are being molded.

WIRE SUPPLY

One spool of raw wire is cradled in the wire straightener, Fig. 4, for each wire required in the molded comb. There are three sizes of wire straightened, 0.0200 and 0.0226-inch diameter wire for the twin wire comb of multi-contact and general purpose relays, respectively, and 0.0400-inch diameter wire for the single wire comb of both relays. The smaller wires are nickel silver while the 0.0400-inch wire is a silicon-copper alloy. All three wires are in the hard temper range.

Originally the wire was pulled from the spools by the drive (pusher) roll of the wire straightener. However, the pulling force required varied widely from spool to spool. The result was an unequal rate of wire feed through the straightening heads. To avoid this, a capstan with an individual pulley adjustment for each wire was added to the machine. This capstan, in addition to pulling the wire from the supply spools, meters the amount of wire fed into the straightener. An occasional adjustment of individual capstan pulleys is all that is necessary now to assure production of straightened wire at a uniform rate from every head.

WIRE STRAIGHTENING MECHANISM

Fig. 5 shows the wire straightening mechanism. Some of the spools of raw wire are visible to the right below the 24 wires, in this instance, being pulled from the capstan pulleys by the grooved shaft mounted just inside the machine housing. This shaft has 24 grooves, one for each wire, which mate with twelve spring tensioned twin grooved wobble rolls underneath to provide the means for pushing the wires through the straightener heads. Both the grooved shaft and the twelve mating rolls are power driven. The wires are pushed through the tubes to the left of the grooved shaft which guide them to the spindles in the straightening heads. These heads, arranged in two vertical rows, make it possible for a common spiral geared drive shaft to rotate all 24 heads at identical speed. This arrangement, however, causes twelve of the heads to rotate clockwise and twelve to rotate counterclockwise. The opposite twists produced in the upper and lower wires under this circumstance are corrected for by the double head arrangement in which the second set of heads rotate counter to the first set.

DIE BLADES AND SPINDLES

Inside each head is a removable spindle for retaining a pair of contoured wire straightening die blades. The spindles are suitably keyed

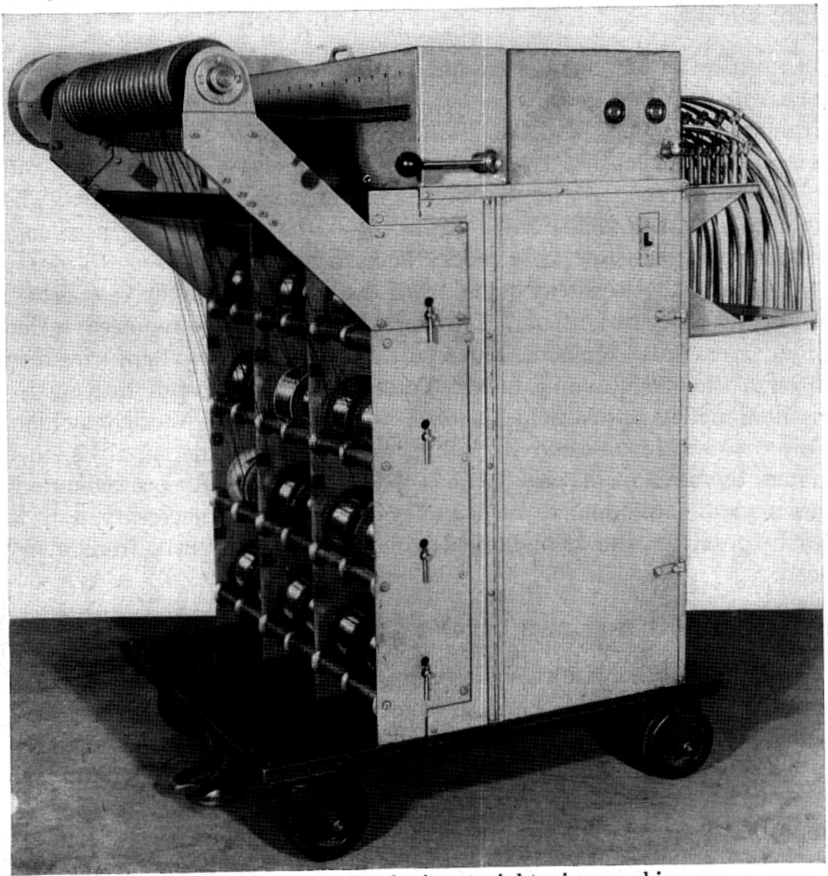

Fig. 4 — 24 double head wire straightening machine.

to the heads to assure rotation. To conform to the double head design two spindles, joined by a loose coupling, are used. This is illustrated in Fig. 6 which also pictures two sets of die blades removed from the spindle slot. The space between each pair of contoured die blades as positioned for the photograph shows clearly the path of the wire during its transit of the rotating heads.

The die blades maintain the same spacing, offset and length that constituted the desired wire path through the five individually adjusted sets of die blocks of the early straightening machines. The continuity of a die blade is accomplished simply by bridging what had been air spaces between the individual die elements and removing enough metal to prevent wire contact in the bridging sections.

The die blades are used not only to conserve space but also to minimize die costs. The latter is accomplished by making them from inexpensive sheet metal on a punch press and discarding them as soon as wear has destroyed their usefulness for wire straightening. Unlike the individual die blocks used in the previous rotary head straighteners, it is not necessary to groove these die blades to direct the flow of wire through the head. There is a slot milled into each spindle to hold the die blades as shown in Fig. 6. The walls of these slots guide the wire and limit its sideways movement in much the same manner as the grooves in the individual die blocks. The actual thickness of the die blade was established as slightly more than that of the diameter of the largest wire to be straightened for wire spring relay combs. Thus, one slot of uniform width is milled into each spindle allowing interchangeability of spindles regardless of the diameter of the wire to be straightened.

Wire in its transit through the die blades is flexed and burnished to the extent required to produce the desired degree of straightness. It is not rotated during the straightening operation but may acquire twist and even a spiral threadlike burnished appearance from rotation of the die blade surfaces.

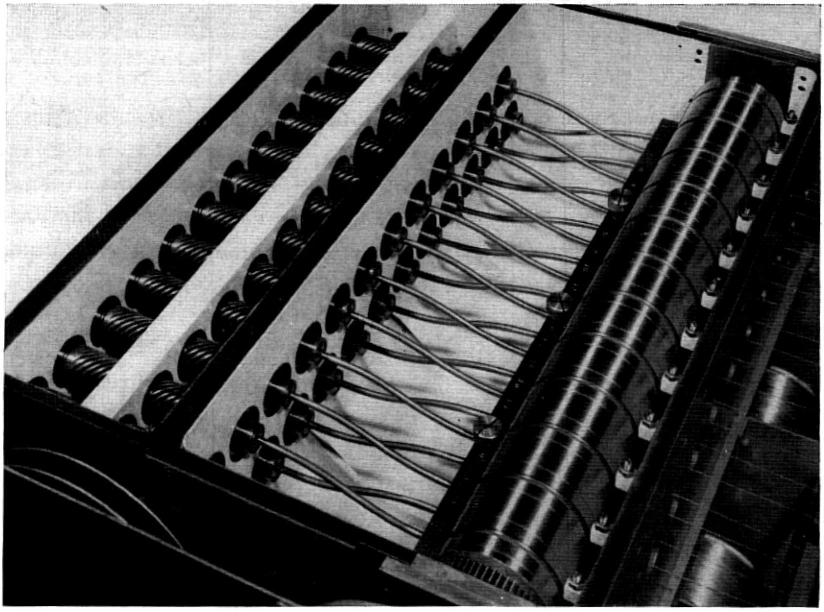

Fig. 5 — Straightening mechanism of 24 double head wire straightening machine.

OBSERVATIONS ON WIRE STRAIGHTENING

The straightening operation affects some physical properties of the wire. Tensile strength is reduced about 10 per cent while elongation is increased around 50 per cent. The diameter of the straightened wire is usually from 0.5 to 1.0 per cent greater than that of the raw wire with commensurate loss in wire length. Both straightness and twist appear to be dependent in large part upon the contours of the die blades. Thus far these contours have been determined by trial and error on the adjustable die block straightener, although general relationships, especially with respect to wire size, are becoming evident. It is expected that further study and experience will establish bases on which contours can be calculated with accuracy.

Twist imparted to the wire by the rotating action of the spindle has been found difficult to measure. What is referred to as twist is actually

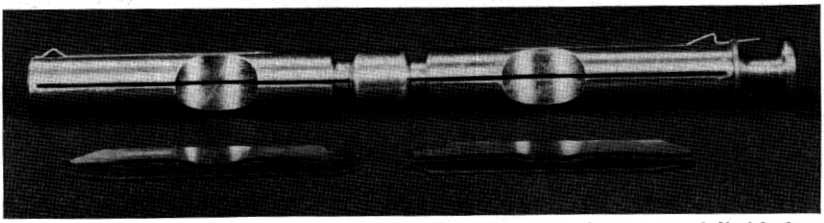

Fig. 6 — Double spindle showing slots and complement of two sets of die blades.

radial distortion of the wire about its longitudinal axis resulting from partial release of internal stresses remaining in the wire after straightening. Further release of internal stresses may occur when the wire ends of the twin wire comb are formed before welding, in which event mislocation of contacts will result, Fig. 7. This is objectionable from the standpoint both of subsequent manufacturing operations and of relay performance. The internal stresses are caused by the crank action applied to the wire surface while it is passing between the die blades in the rotating spindles. Internal stress which is not apparent until after its release, as by forming, has been designated as "residual twist".

A rough approximation of the amount of residual twist in wire can be obtained by measuring what has been termed "apparent twist". Apparent twist is the amount of visible rotation at the end of a wire after leaving the straightener. It can be measured in degrees of rotation per foot of wire straightened. When the apparent twist is low, usually the residual twist also is low. A working range for permissible apparent

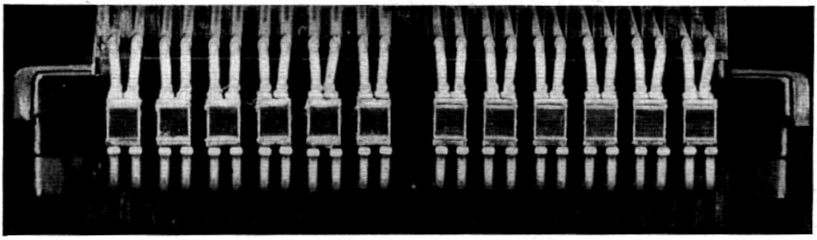

Fig. 7 — Photograph showing the affect of residual twist in the upper set of wires as compared to freedom from residual twist in the lower wires.

twist has been established which has been successful generally in maintaining acceptable limits on residual twist.

There are three variables which largely control the quality of straightened wire. The first is the physical properties of the wire itself. Although a shipment of wire may, on the basis of the sampling method employed, meet specification requirements limiting physical and chemical characteristics, an occasional spool or part spool of wire can be expected which will be enough outside limits to cause unsatisfactory straightness and unmanageable residual twist.

The second variable affecting straightness and twist in wire processed on multiple head machines lies in small differences between the rotating head assemblies. While all critical dimensions of the die blades, spindles, and spindle housings are held to close tolerances, it is possible to obtain an accumulation of dimensional deviations in some spindle assemblies of such magnitude as to cause appreciable difference in wire twist and sometimes in wire straightness. It has been necessary, therefore, to provide means for balancing such dimensional variations.

The third variable is wear on working surfaces of the die blades. Continued sliding of wire over die blade surfaces eventually produces grooves which decrease offset and increase clearance in the wire path. It has been found in general that, as the die blades wear, twist decreases until it eventually reverses direction. Simultaneously, straightness may improve to a critical point from which it rapidly deteriorates. Accordingly, replacement of die blades must be made before wear has rendered them ineffective.

CONCLUSIONS

Satisfactory performance of the multi-head wire straightening machines described has been demonstrated during the pilot plant period of wire spring relay manufacture. Further refinements in the means for controlling known variables must be made, however, to assure the reliability demanded of heavy duty mass production machines.

Part II — Automatic Molding of Wire Spring Relay Block Assemblies

Parallel with the effort directed toward development of wire straightening facilities, an investigation was undertaken by Western to develop automatic facilities for molding an array of straightened wires into small plastic blocks spaced at specified intervals. These blocks were designed not only to hold the wires securely and to locate them accurately but also to insulate them from each other electrically. The design engineers at Bell Telephone Laboratories had decided, after evaluation of the physical properties of available plastic molding materials, that a thermosetting phenolic type resin would best provide the characteristics needed for wire spring relay block assemblies. Proceeding on this information, Western Electric development engineers reviewed the merits of molding methods adaptable to embedding a multiplicity of inserts, wires in this instance, into phenolic resin. Such economic factors as molding time and material cost were balanced against molding problems like shrinkage and flow characteristics. It appeared from this review that transfer molding offered the most favorable possibilities. It appeared also that the shortest practicable molding cycle might be achieved by preforming the phenolic resin material, preheating these preforms electronically and automatically feeding them into the molding die. Further study of the molding problems indicated that molding presses for this purpose would have to be specially designed, particularly if multicavity dies were to be used. The special design features, such as wider spacing between the tie rods, provision of an electronic preform heater, and microtiming devices, are discussed later as they become pertinent to the description of the machines finally adopted.

AUTOMATIC MOLDING MACHINE

Hydraulic molding presses appeared to offer the most advantages for this job. Essentially, these consist of two opposed hydraulic rams mounted vertically; the lower and more powerful ram providing the force required to close and hold closed the split die employed and the upper ram providing the force needed to transfer the phenolic resin in a softened or plastic state into the die cavities.

Unusually wide spacing between the tie rods of the press had to be provided to accommodate the complex progressive die required to make the molding operation automatic. This die had to be designed not only to mold resin in multiple cavities but also to remove the plastic cull, index the molded blocks, and shear the completed assemblies. Provision had to be made, in addition, for mounting an electronic preform heater and for space to install an appropriate conveyor from the heater to the plastic transfer point of the die. These features were incorporated into an experimental prototype machine, shown in Fig. 8, operated under laboratory conditions. Adjustable microtiming devices were engineered into this machine to control the sequence of operations precisely and automatically.

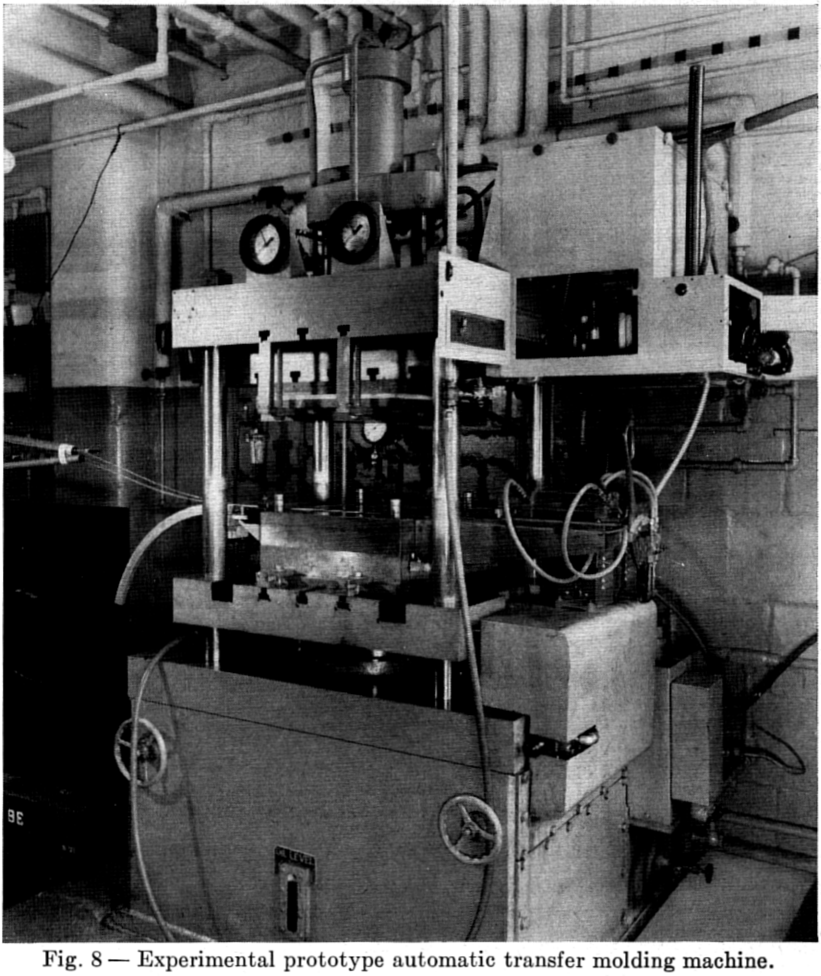

Fig. 8 — Experimental prototype automatic transfer molding machine.

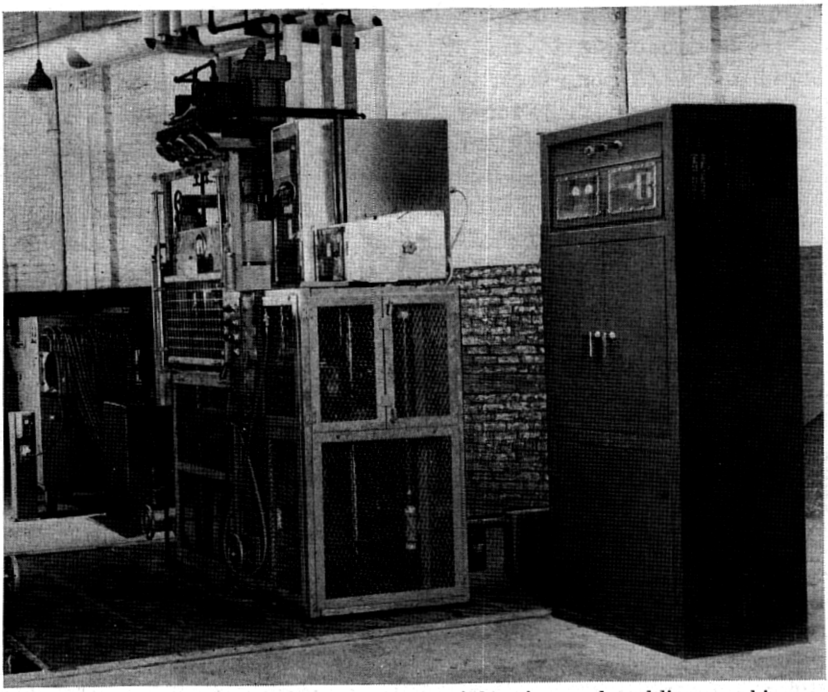

Fig. 9 — Typical installation of wire straightening and molding machines.

The final embodiment of the molding machine is shown in Fig. 9. The wire straightener included in the photograph is positioned a short distance from the molding machine to allow straightened wire to form a partial loop between the two. This permits the wires to leave the straightener at a constant speed from a fixed position and to enter the die at intervals controlled by the molding cycle and move vertically with the opening and closing motions of the lower half of the die. The straightening machine is started and stopped by an electrical control which assures the desired size partial wire loop at all times.

PHENOLIC RESIN PREFORMS

To operate on an automatic basis, it is important to have the molding compound in such form that it can be handled easily and that the charges are of uniform weight and size. This is done by compressing the bulky granular compound as received from suppliers into small carefully dimensioned cylinders or "preforms". Mechanical presses, capable of turning out preforms in multiple at each stroke, are used at Hawthorne for this purpose. To obtain uniformly low water content in these preforms, it is necessary to store them in an air conditioned chamber for a three week period to assure attaining equilibrium conditions.

PREFORM HEATING

An electronic preform heater is a means of increasing molding machine production by shortening the time the phenolic resin must be retained in the molding die during each cycle. This is done by adding to the preform, just before it enters the die, much of the heat required to plasticize the resin. Thus, as one charge of compound is being molded in the die cavity, another is being preheated as part of the molding cycle. The amount of preheat that can be permitted is limited by the extent to which heat induced chemical reaction can be tolerated outside the molding cavity and varies with the size and contour of the die cavity. The rate at which the preform is heated influences its consistency at a given temperature.

A feed mechanism has been provided to convey the preform from a magazine to the electronic heater and thence to the die. This mechanism consists of a horizontal guide plate extending between the two grids in the upper part of the press. The preform is pushed along this guide plate by a metal bar mounted on endless roller chains at each side of the guide plate. In operation, a preform from the magazine is pushed to a position between the electrodes of the dielectric heater. The push bar is then backed away a small distance so that it will not interfere in the inductive field. Upon completion of the preheating operation, the push bar shoves the heated phenolic preform to and beyond a drop off position above the open end of the transfer cylinder of the molding die. The conveyor continues to operate until the push bar has removed a new preform from the magazine and loaded the heater in preparation for the next cycle.

PRESS CONTROLS

The electrical controls or "brain" of the production unit are housed in a cabinet adjacent to the molding machine. The operation of the press, the electronic heater, the feed mechanism and the pneumatic device on the die are all coordinated into precise sequences by micro-adjustment of these controls, Fig. 10. Any operational sequence or length of cycle desired can be established for repetitive manufacture. On the other hand, the press and the electronic heater can be placed on manual control at any time.

THE MOLDING DIE

Experimental Work

No attempt will be made to discuss the many ideas on mold design which were conceived, evaluated and either discarded or improved in arriving at the designs now employed. The investigation was undertaken

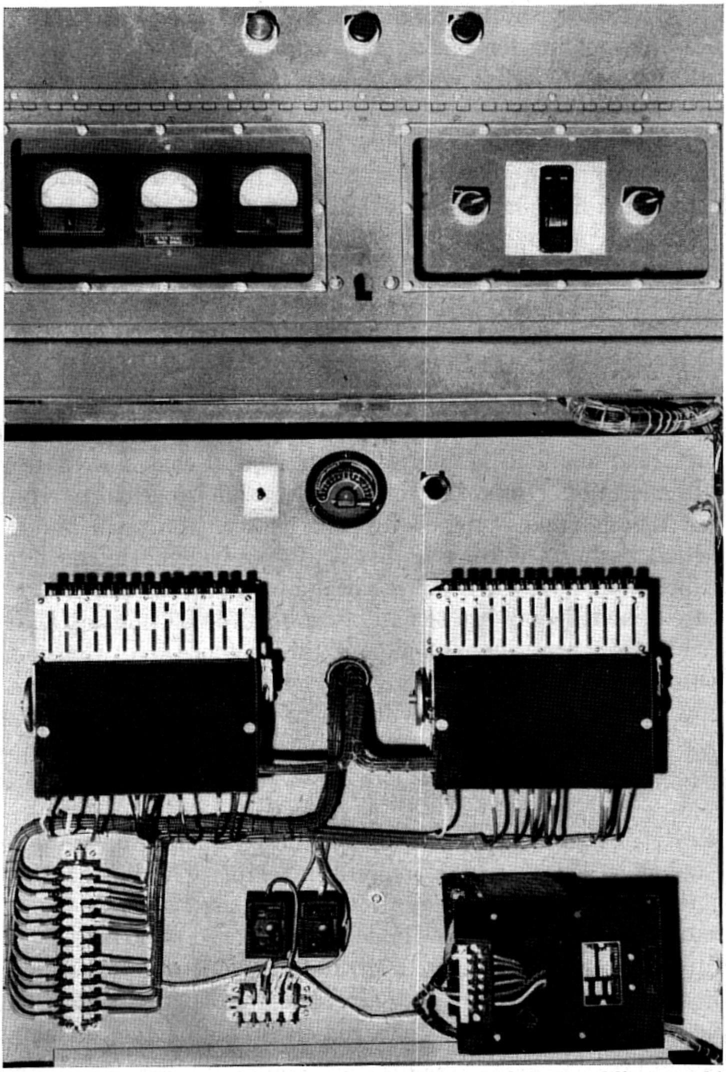

Fig. 10 — Cycle timing and electronic heater controls for molding machine.

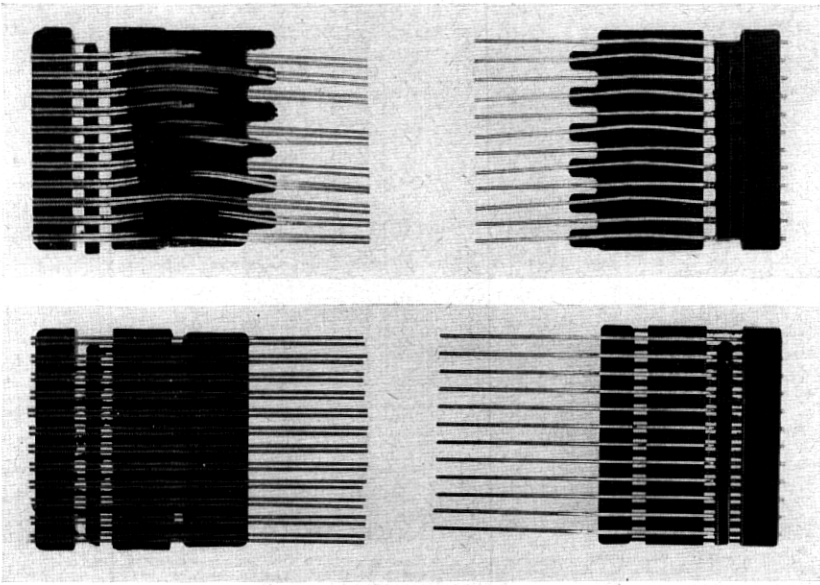

Fig. 11 — Cutaway sections of resin blocks showing inadequate versus adequate wire supports in molding die.

with no significant experience in molding closely spaced arrays of small diameter wires into phenolic resin. The initial effort demonstrated convincingly, Fig. 11, that small diameter wires cannot be embedded in resin by high pressure molding techniques without the liberal use of wire supports. These are needed to prevent individual wires from being deformed by the pressure of the plastic as it is forced into the cavity. One fundamental observed in die design subsequently was to keep all wire spans inside die cavities as short as possible.

As expected, early studies demonstrated that lack of cross sectional symmetry caused combs to have a marked tendency to warp. While warping could be reduced by increasing the time the resin was retained in the molding cavity, this partial solution was unsatisfactory from the standpoints both of warpage and product cost. Accordingly, every effort was made, consistent with relay design requirements, to depart as little as possible from symmetrical die cavity design and where symmetry could not be achieved, to attempt to distribute the resin mass uniformly on each side of the center line of the wires.

The importance of symmetry, together with the desire to keep molding flash to a minimum, influenced Western development engineers to design the earlier experimental die cavities with the wire inserts centered at the

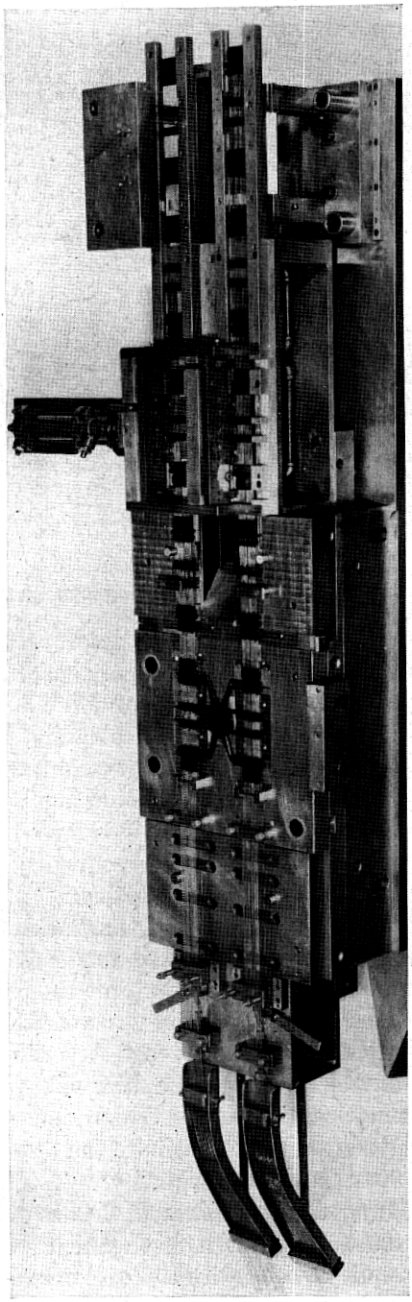

Fig. 12 — Lower half of typical automatically operated four cavity die.

die parting line. In the course of die development work it became apparent that reduction in both die cost and die construction time could be effected in some instances by confining the grooves for locating and supporting the wire array to one half of the die cavity. This type of design had the added advantage of eliminating annoying problems relating to precise registration of the upper and lower die halves during the molding operation.

The design of the die cavities now used for high production molding represents development work based on such considerations as those outlined above. The die cavities are similar but not the same for both twin and single wire combs. They differ in the location of the parting line which is flush with the top of the wire array in the twin wire comb die and principally at the center line in the single wire comb. The latter arrangement was dictated by two considerations, (1) Use of a U shaped groove in one half the die cavity for a wire as large as 0.040-inch diameter, resulted in excessive molding flash and (2) The chance of obtaining completely filled fins on both sides of the forward block was enhanced by centering the wires.

THE DIE

Fig. 12 shows the lower half of the complex automatically operated four cavity die which was evolved from simple single cavity hand loaded units. That this evolution may not be completed is indicated by the fact that the section of the die operated by the air cylinder shown at the top of the photograph and intended to remove molding flash from the wires is no longer used. Much better flash removal is effected by blasting the combs with ground walnut shells after the molding operation has been completed. The operation of the automatic die, as related to the manufacture of single wire combs containing twelve 0.040-inch silicon copper wires, will be described under five sub-heads in the same sequence as the progression of the wire array through the five sections of the die. Similar progressive operations are performed in making twin wire combs. The die consists of an upper half attached immovably to the head of the press and a lower half mounted on a hydraulic ram which raises and lowers to close and open the die.

WIRE GUIDING

The single wire comb die uses one 24-double head wire straightener. Fig. 13 shows how twelve continuous strands of wire from the straightener are guided to the required spacing in each comb array. Spring ten-

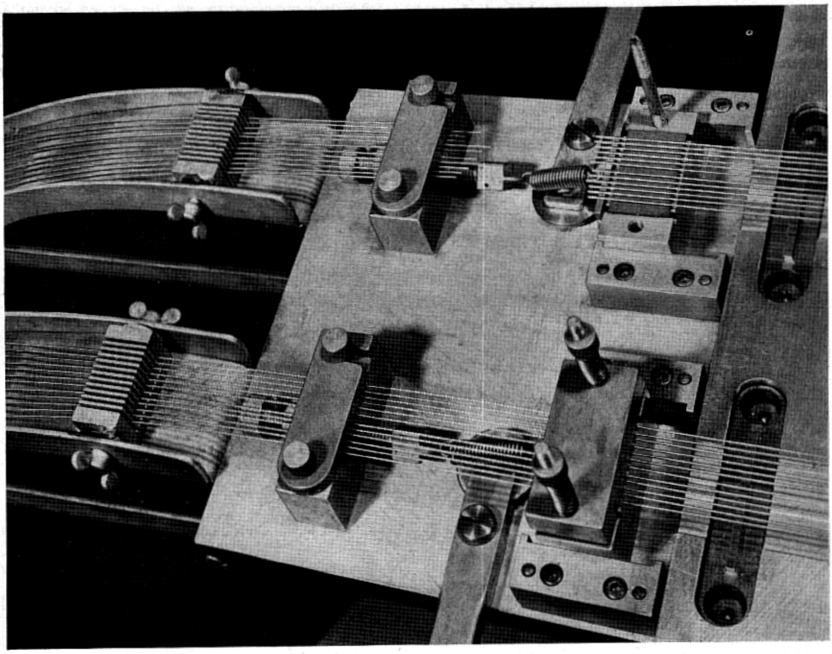

Fig. 13 — Wire guide section of automatic die.

sioned sliding blocks with spring loaded felt cleaning pads hold the wires taut during the operations that follow.

ANCHORING

Because phenolic resin does not wet and, therefore, does not bond with most metals, mechanical means must be used to prevent the wires from turning in the resin block of the finished combs. This precaution is necessary because wire wrapping tools are employed in wiring relays into equipment. The wrapping tool puts a torque on the wire which may, if the wire is not securely anchored, turn it in the resin block. Any movement, obviously, will mislocate the contact welded onto the wire and cause maladjustment of the relay. To mechanically prevent turning, a section of each half of the die is provided with accurately spaced mating blade inserts, Fig. 14, which press flat lands or "anchors" on the wire each time the die is closed. When the wires are indexed subsequently these anchors are located on that portion of the wire embedded in the resin.

MOLDING

Dies with four cavities are used for all comb molding operations. The cavities are located around the plastic transfer area as illustrated in Fig. 15. Above the transfer area a cylindrical opening extends vertically through the upper die half to permit passage of the transfer ram. By closing the die, the transfer area is enclosed except for small orifices leading to each of the four cavities. The heated preform is dropped into the center of the transfer area ahead of the transfer ram. This ram, operated by hydraulic pressure and heated by contact with the hot die, forces or transfers much of the heat softened resin through the orifices and into the die cavities. The resin residues which are left in the passages between the ram and the cavity gates upon completion of the molding cycle are called runners. The heat of the die, approximately 360°F., further softens the plastic resin enabling the pressure of the ram to force it into intimate contact with all die cavity surfaces. Continued application of heat and pressure hardens or cures the resin by the process of polymerization, after which it is permanently infusible.

To successfully operate on an automatic basis, the cluster of wire, plastic blocks, ram slug, and runners must be removed from the molding cavity. This is complicated in the single wire comb because the plastic block at the contact end of the wires has very thin fin sections

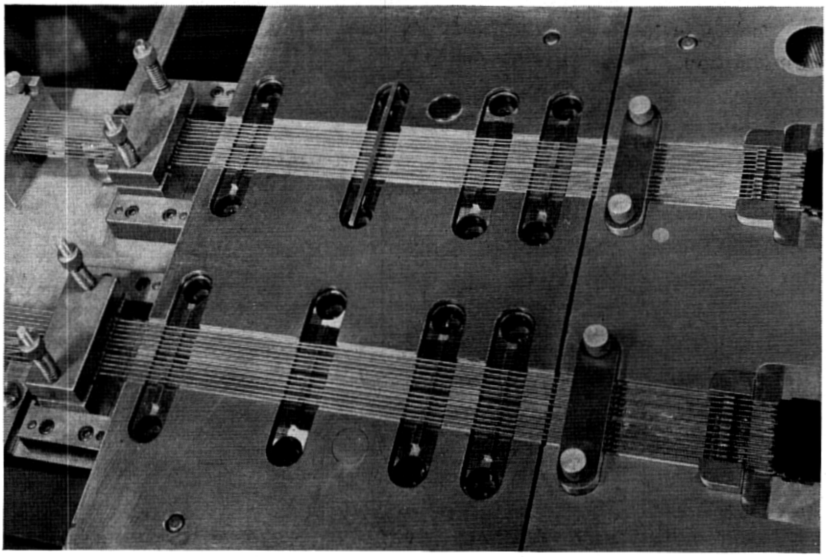

Fig. 14 — Anchoring section of automatic die.

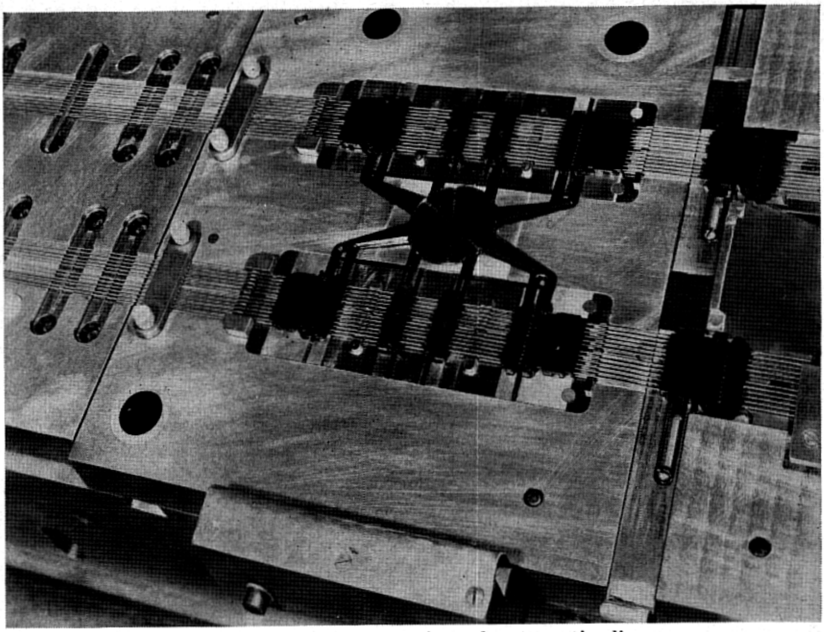

Fig. 15 — Molding section of automatic die.

projecting into both halves of the die cavity. These fins, used to guide the mating twin contact wires in the finished relay, must be held to close limits dimensionally and are thin to the point of fragility. To insure satisfactory removal of the resin blocks from the upper half of the die while simultaneously retaining them in place in the lower half when the die is opened, spring loaded ejector pins in the upper die half push down against the cured blocks. The ejector pins operate until the wire-resin cluster has been ejected from the upper die. Subsequently they are retracted by contact with reset pins which butt against the lower die half when the die is closed. The openings in the die half which accommodate these ejector pins serve as air vents when the resin is entering the cavity. To prevent the plastic cull, i.e., the resin slug and associated runners, from breaking off and damaging the die on the next molding cycle, the pressure of the transfer ram is maintained on the slug until the upper die surface has been cleared.

The hydraulic ram bearing the lower die half continues to withdraw until the lower ejector pins can function. These ejector pins are more numerous and more complex in design than those in the upper die half because, in addition to ejecting the resin blocks from the die cavities, they aid in guiding the progression of wire inserts through the die and in locating the incoming wires in the die cavities. The operation of this ejection or "knock-out" consists of freeing the wires and resin blocks from the die cavities and then moving the newly molded cluster horizontally from the lower die cavity. When the die surface has been cleared by this indexing operation, compressed air is blasted across the die to remove loose molding flash which might be present. With the completion of the indexing operation, the ejector pins are restored to their original position by spring pressure. As a precaution, reset pins are provided in case this spring pressure should be inadequate.

COOLING AND CULL REMOVAL

The next operations are those of cooling the plastic to minimize warpage and removing the cull. Because the larger plastic block of the single wire comb has surface irregularities on one side and is smooth on the

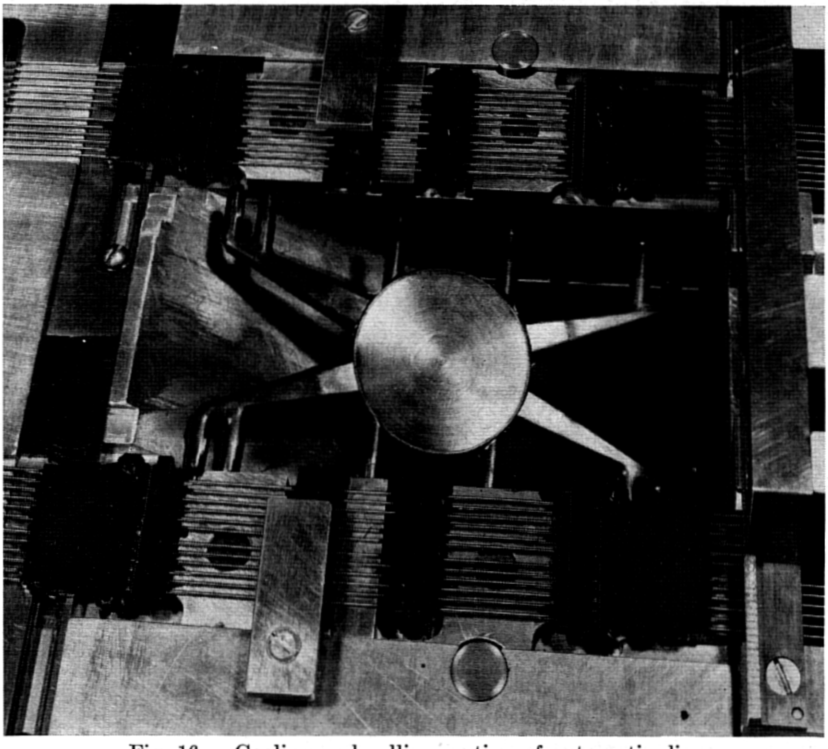

Fig. 16 — Cooling and culling section of automatic die.

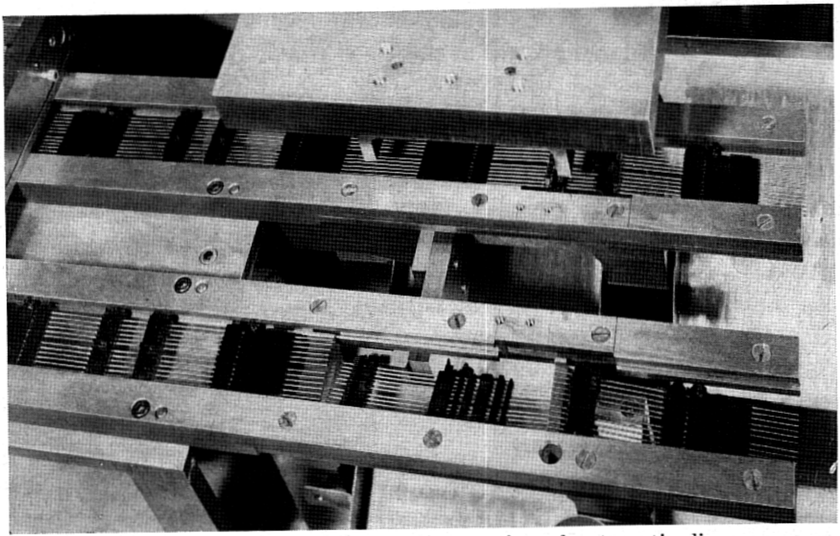

Fig. 17 — Indexing and shearing section of automatic die.

other, there is some tendency for it to warp upon cooling. To prevent this, when the die is closed the plastic embedded wire assemblage is clamped against spring loaded steel pads operating between water cooled plates and retained in this position during the next molding cycle. The closing of the die also causes the cull to be sheared off, Fig. 16. This waste material slides down a chute for removal from the press. A locating stop is built into this section of the die to establish the proper spacing for inserting a new progression of wires through the die should such action become necessary as when wire from new spools must be placed in the dies. This locating stop can be used also as a check at any time to determine whether the parts are being indexed the proper distance.

INDEXING AND SHEARING

The mechanism for indexing the continuous strands of wire through the die is located beneath and parallel to tracks built into the last die section to accommodate and guide them. It is driven by a timer controlled pneumatic cylinder to which feed heads are attached by a yoke. The feed heads reciprocate on rails beneath the guide track and transmit their motion to the ladderlike train of assemblies by a spring loaded dog which engages the resin blocks on the forward stroke. The return stroke is carried out after the press is closed.

The last operation performed by the die is that of shearing the wire in the molded assembly to form individual combs. One set of opposing shearing details for each line of molded assemblies is adjustably mounted on the base plate of the lower die half, Fig. 17. When the die is closed, the upper details butt against the upper die plate thereby forcing the cutting shears upon the wire. To reduce the force required, the cutting blades are so tapered that they cut each wire in succession.

Upon termination of the cutting operation, the parts fall free of the guide rails into chutes leading to the front of the press, thus completing the molding operation.

CONCLUSION

The original objective of embedding a multiplicity of straightened small diameter wires in phenolic resin blocks (Fig. 18) on a commercial basis has been accomplished. These wire spring relay parts are being produced at low cost to the required dimensional accuracy in automatic molding machines.

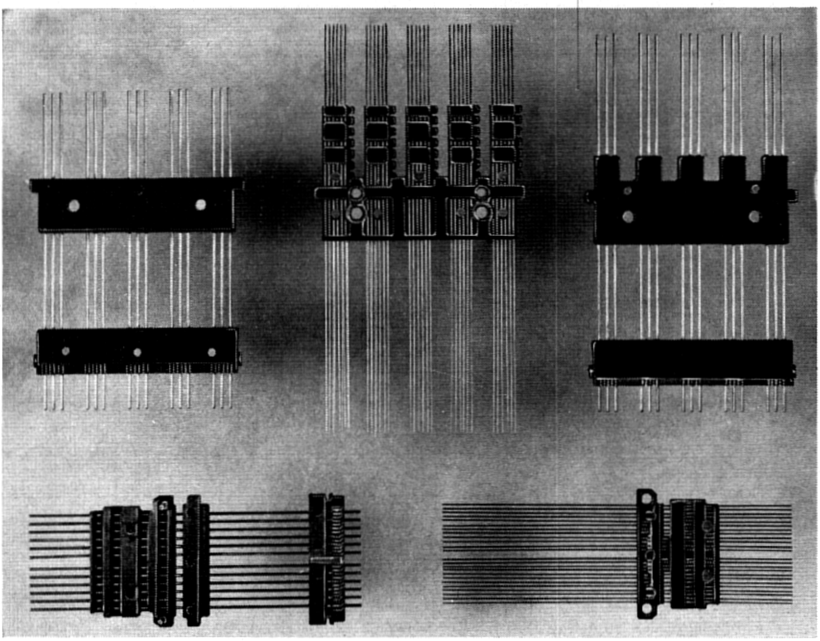

Fig. 18 — Wire block assemblies as manufactured for wire spring relays.

ACKNOWLEDGMENT

The authors wish to acknowledge the many contributions of fellow engineers to the development work which they have reported. These engineers include; in the wire straightening study, C. Paulson, A. E. Swickard, L. L. Mazza and the late N. K. Engst; and in the molding investigation, F. A. Schultz.