A Series of Miniature Wire Spring Relays

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The BF, BG, BJ, and BL miniature wire spring relays have recently been added to the family of AF, AG, AJ, AK, AL, and AM wire spring relays. The miniature series has been developed for use in central office equipment to be compatible with printed wiring board mounting and semiconductor devices. A description of the development, features, and performance of the BF miniature wire spring relay is presented along with a brief comment on the BG, BJ, and BL types. Production has been started on the miniature types and a number of codes have been issued for various projects.

I. INTRODUCTION

The Western Electric Company has recently started production of the BF miniature wire spring relay (Fig. 1) and its variations. It is the intent of this paper to describe in some detail the background and course of development for these families of relays.

Two basic pressures have been responsible for a growing demand for miniature relays in the telephone plant. The first of these is the modern trend toward miniaturization. Because of the premium on space in the telephone plant, there has been increased effort to put more equipment into less volume. This has been directly responsible for a need for smaller components, and relays are one of the major building blocks of telephone systems.

The second pressure for miniature relays has come from the large scale introduction of semiconductor devices. These devices are generally small and mounted on printed wiring boards. However, for many circuit functions and for interfaces with existing equipment, relays are needed. Equipment designers have found it both difficult and impractical to use large relays in conjunction with printed wiring boards and small components such as diodes and transistors. This has resulted in a demand for a miniature relay which can be mounted compatibly with the semiconductor devices on printed wiring boards.

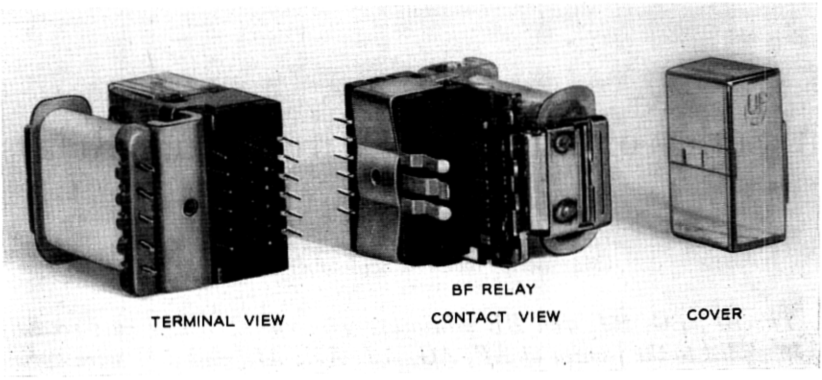

Fig. 1 — BF miniature wire spring relay.

Thus, we see a large and continuing demand for miniature relays of all types. For use in telephone equipment which is mounted on customer premises, such as key telephone systems, the MA and MB miniature relays have been developed.[1] For some other general areas of application, specific requirements and objectives have led to the development of miniature wire spring relays. In telephone central offices, it is important to be able to conduct relay and circuit tests using the relay itself. It is also desirable in this environment that relays be maintained in those rare instances when such action is necessary. Generally speaking, in central offices there are skilled craftsmen available with experience in the maintenance of the large wire spring relays (Fig. 2).[2] Considering these factors, and the outstanding performance which has been demonstrated by the large wire spring relay over the past several years, the development of a miniature wire spring relay was undertaken. It was the intent of this development to make use of all of the experience that has been gained from the manufacture and use of the large wire spring relay.

II. OBJECTIVES

Taking into consideration the factors discussed above, seven basic objectives evolved for the design of miniature wire spring relays as follows:

(*i*) To provide in a miniature relay the proven outstanding performance of the large wire spring relay.

(*ii*) To provide large margins for manufacture, long operating life, and high reliability.

(*iii*) To use established manufacturing techniques as far as possible.

(*iv*) To provide a broad range of operating characteristics for both general purpose and special purpose application.

(*v*) To provide a relay that can be maintained and tested in the field as well as allow for circuit testing.

(*vi*) To provide for mechanically secure printed wiring board mounting with adaptability to hard wiring.

(*vii*) To provide a design capable of being manufactured at a low unit cost.

The following sections of this paper will describe the design and its capabilities, and thus show how these objectives have largely been met. Throughout the text, comparisons will be made to the large wire spring relay which is now accepted in the Bell System as the standard building block relay.

III. MECHANICAL DESIGN

There are many similarities between the large[2] and miniature wire spring relays in the design of the actuating mechanisms and wire

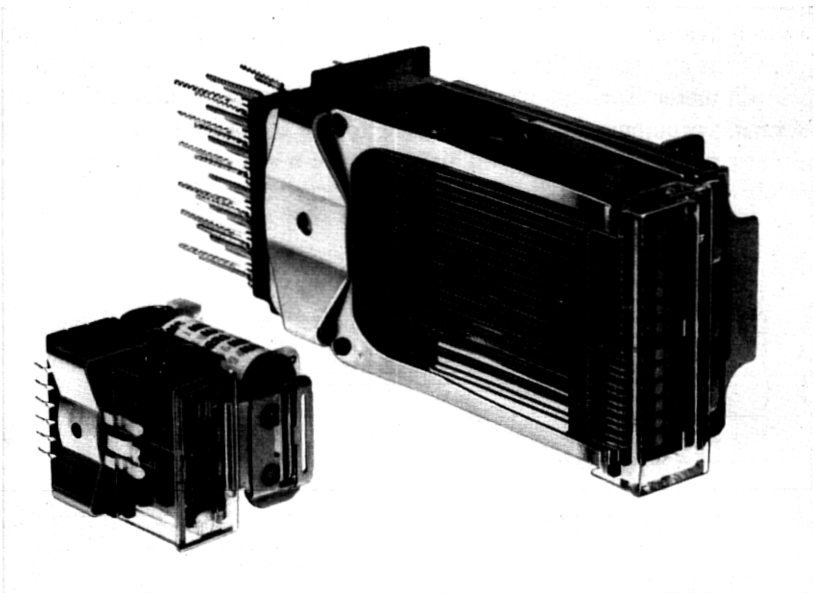

Fig. 2 — Comparison of BF relay (left) and AF relay (right).

mountings. However, as the result of experience with the large relay, and because of the necessity of miniaturization, there are also numerous differences.

In any relay where the movable springs operate in the same plane, such as the wire spring types, it is extremely difficult to adjust individual springs for contact force or closure point. In the large (AF) relay, the need for contact force adjustment has been eliminated by the use of low-stiffness springs with large predeflection bends as shown in Fig. 3. This results in minimizing the effect of dimensional variations in; (*i*), the spacing A between fixed and movable wires; (*ii*), the angle B between the movable wire and mounting block; (*iii*), the pre-tension bend C and; (*iv*), the "Z" shape D of the contact tip that bridges the operating card. Since the ratio of the summation of all of these variables to the large predeflection bend permitted by the low-stiffness spring is small, these variations have small effect on contact force and it does not have to be adjusted.

Spring stiffness varies inversely as the cube of the spring length, and directly as the fourth power of the diameter. Thus, as the springs are made shorter, there is a rapid increase in spring stiffness which must be compensated for by a reduction in diameter. With the allowable spring length in the miniature wire spring relay it would be necessary to use movable springs 0.006 inch in diameter to achieve the same stiffness as the springs of the large wire spring relay. It was felt that 0.006-inch diameter springs would present unreasonably difficult manufacturing problems, so it was decided to use 0.009-inch springs in the miniature wire spring relay. This results in a spring stiffness approximately 4 times that of the springs in the large relay. To compensate for

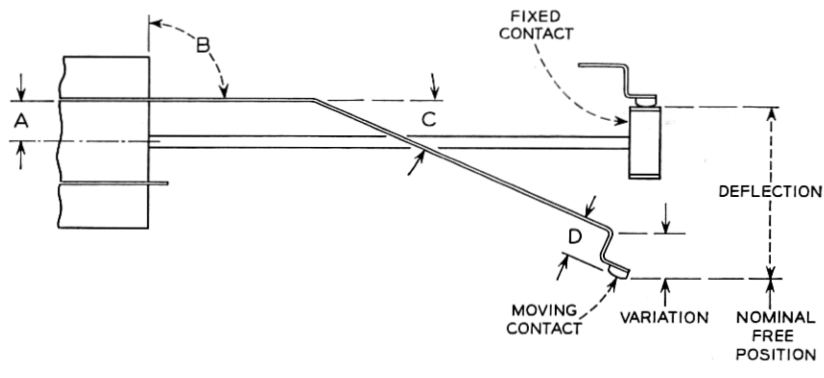

Fig. 3 — AF relay movable twin wire deflection.

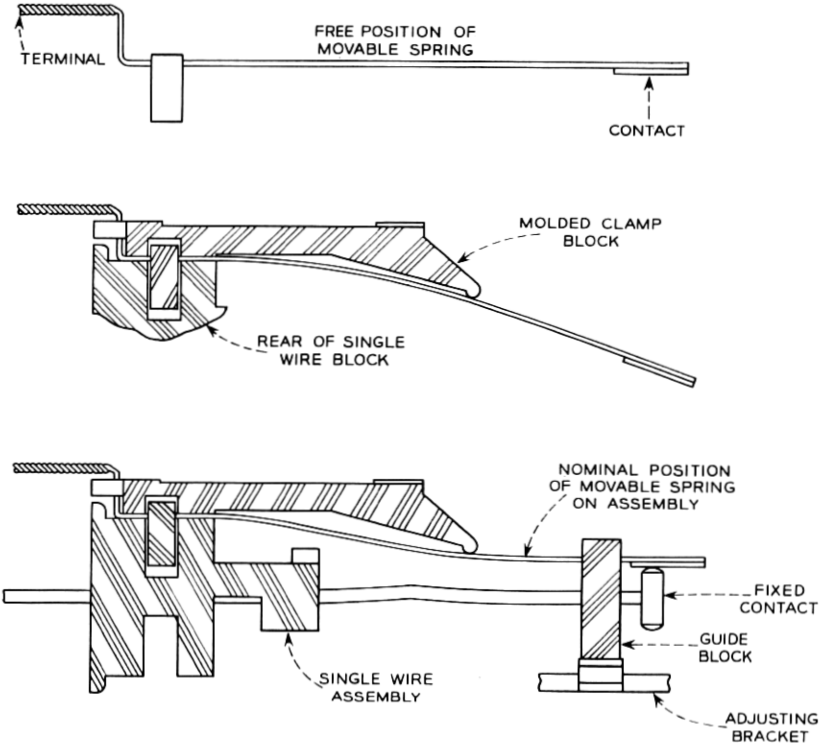

Fig. 4 — Miniature wire spring relay movable twin wire deflection.

this increase in stiffness it was necessary to use a different deflection system to minimize the effects of possible variations. This deflection scheme is illustrated in Fig. 4. The upper portion of the figure shows the profile of the movable twin wires in the unassembled condition. The phosphor bronze wires are molded in a phenolic block with terminals formed on one end and with contacts welded to the opposite end. No pretension bend is applied to the straight springs prior to assembly. In the relay, as shown in the center section of the figure, the twin wires are deflected downward by a molded clamp block which also clamps the wires against the rear portion of the single wire block. This results in two advantages: first, all of the wires are clamped in the same plane at their point of emergence from the pile-up. Thus, any variability in their angle to the pile-up is reduced to essentially zero. Secondly, by deflecting the wires with a molded block, which can readily be held to close tolerances, variations in predeflection bend are minimized. With predeflection bends, variations from wire to wire result from differences in wire diameter, yield strength and modulus, and deflection by means of a molded clamp block negates these effects. As shown in the bottom of the figure, when the twin wire contact is brought into engagement with the fixed contact, the spring is deflected upward to develop the desired contact force. No "Z" bend at the tip of the spring is required in the miniature relay since the operating card has been placed in front of the contacts instead of to the rear as is done in the large relay. This deflecting block technique has one additional advantage in that it results in the terminals of the fixed and movable springs being separated to a greater degree for wiring purposes.

The movable twin wire blocks, which in a full position relay have 12 individual phosphor-bronze springs that are paired for 6 contact positions, can be molded in a continuous process. The contact assembly used for the make contacts and for the break contacts are identical. For break contact use, the movable springs are assembled upside down to that shown in the figure.

The single wire or fixed contact assemblies are very similar to those used in the large relay. A molded block in the front provides guidance for the movable twin wires. The front of the fixed wire block is tensioned against an adjusting bracket so that bending the adjusting bracket will move the fixed contacts up or down. This provides an adjustment for the contact closure points.

As in the large (AF type) wire spring relay the contacts are of the card release or permissive actuation type.[3] That is, when open, the movable contacts are tensioned against a molded actuating card and they are permitted to close against the fixed contacts by motion of the card (Fig. 5). In the unoperated position, the movable make (normally open) contacts are tensioned against the card and the movable break (normally closed) contacts are tensioned against the fixed contacts. When the card moves, as the relay is operated, the make contacts are permitted to move against the fixed contacts and lose contact with the card. At about the same time, which varies according to coding, the opposite surface of the card makes contact with the break contacts and lifts them off the fixed contacts. When the relay is released the card moves in the opposite direction and the procedure is reversed. The width of the operating card bar determines the sequence of make and break contacts. By having different widths across the card break-before-make and make-before-break (continuity) transfer contact combinations are obtained as shown in Fig. 5.

The actuating card is linked to the relay armature by two tabs that

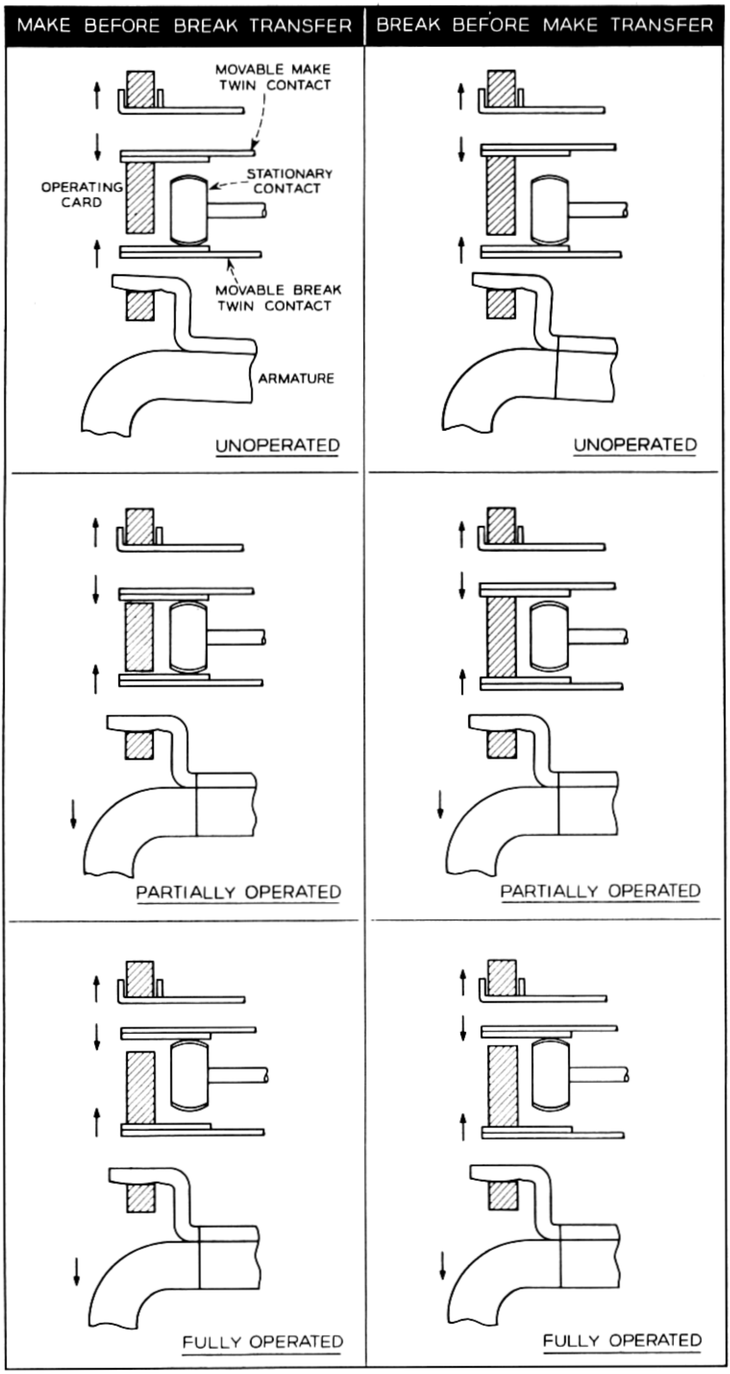

Fig. 5 — BF relay contact sequence operation.

engage mating tabs on the armature. In this manner, the armature can pull the card from the unoperated to the operated position. Since the movable contacts springs are tensioned against the card it is necessary to provide an additional spring which is generally known as a balance spring to move the actuating card from the operated to the unoperated position on release of the relay. The balance spring must develop sufficient force to overcome the forces of the make contacts in the unoperated position and reliably hold the card-contact spring-armature combination in the unoperated position. Conversely, the balance spring must not provide a load to the armature that exceeds the magnet capability.

Also part of the mechanical design is a cover spring and cover for the contact assembly. As indicated by its name the cover spring is a three-legged spring that performs the function of holding the cover in place. The cover, which is molded of transparent styrene acrylonitrile encloses the contact springs and contacts. This protects the contacts from dirt or dust and mishandling and any fumes that might be generated by the coil.

The contact pile-up, which includes the fixed wire contact blocks, the movable wire contact blocks, the deflecting blocks, balance spring and cover spring, is held together with a clamp spring. The clamp spring is similar to that used on the AF relay except for the tip that engages the core. In the case of the miniature relay, these tips are "J" shaped and hook into notches in the core. All of the parts of the relay are shown in Fig. 6.

IV. MAGNETIC DESIGN

The magnetic circuit consists of a "J" shaped core and an "L" shaped armature made of 0.080-inch thick low carbon steel. The armature and core are held in a modified end-on arrangement by means of a stainless steel hinge spring. Two pins are extruded from the armature and act as rivets to secure the hinge and a clamping bracket to the armature. The clamping bracket provides the tabs which link the actuating card to the moving armature.

Initially, the core was designed with a square end as shown in Fig. 7(a). Early life tests indicated that there was some slight sliding motion between the core and armature on operate. This slight sliding motion caused a rapid deterioration in the chromium plating on the two parts. As a result it was proposed to put an angular surface on the core and armature as shown in Fig. 7(b). This arrangement, although

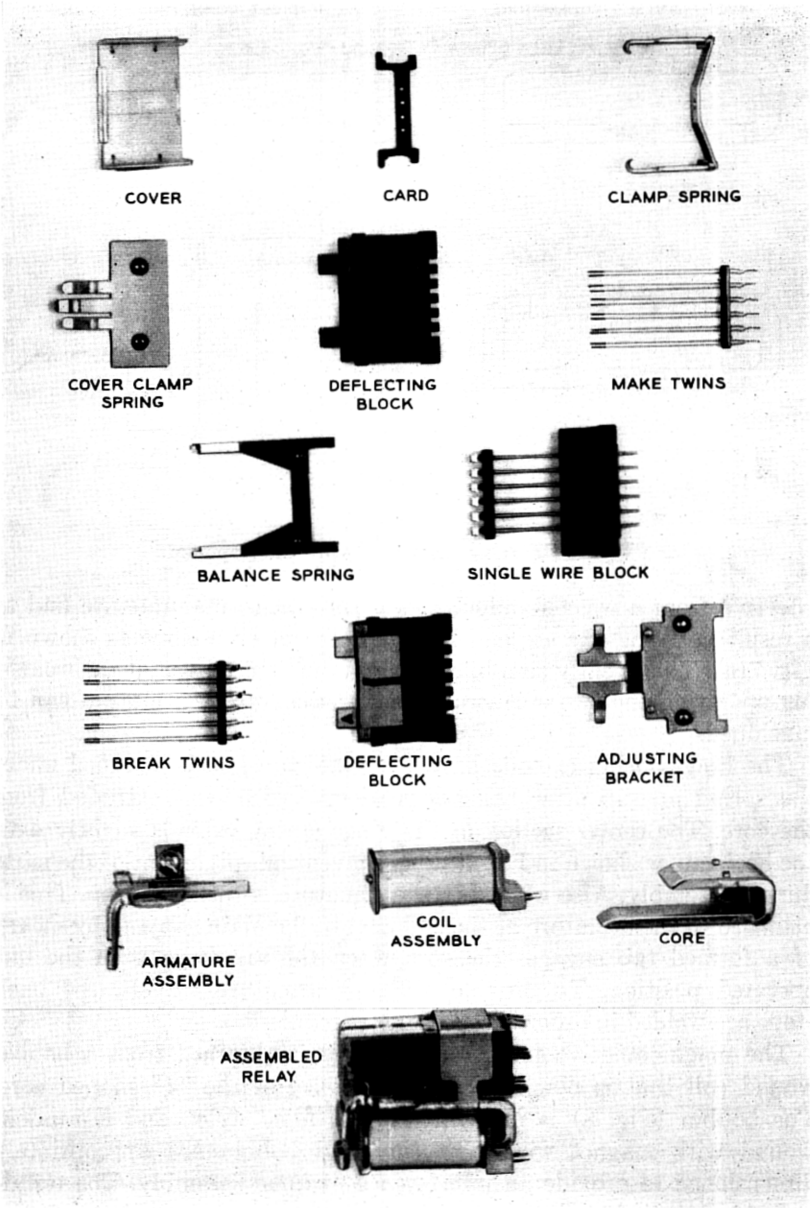

Fig. 6 — BF relay parts.

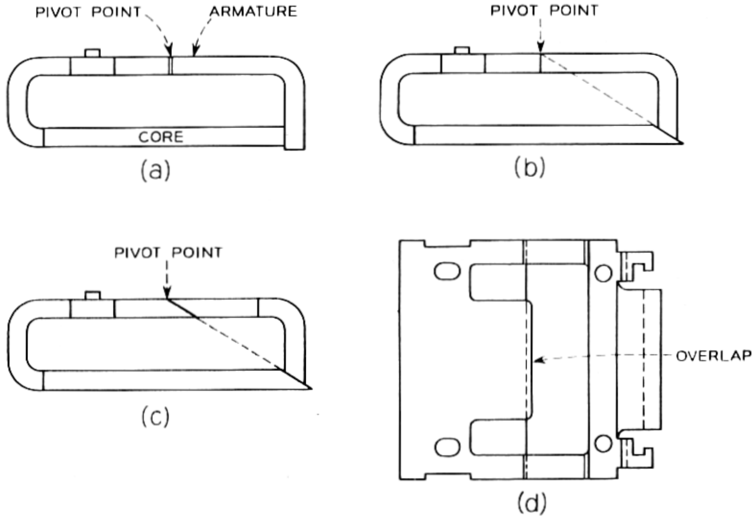

Fig. 7 — BF relay armature—core development.

effective from a wear standpoint, was difficult to manufacture and as a result both the operate and heel gap are cut on a slope as shown in Fig. 7(c). This greatly simplifies manufacture since by a single broaching operating the two surfaces on either the core or armature can be machined.

The hinge spring extends back over the core and is clamped under the spring pile-up after being located on two dowels extruded from the core. The center section of the hinge spring extends slightly over the heel gap as shown in Fig. 7(d) to prevent misalignment of the parts during assembly. Also welded to the armature is the back stop. This is attached to the armature at the end next to the main gap and by means of a formed tab engages the core when the armature is in the unoperated position. To provide different armature travels, the back stops are welded in different positions as required.

The magnetomotive force for the relay is obtained from a bobbin wound coil that is placed over the long leg of the "J" shaped core. The bobbin (Fig. 8) is made from glass-filled nylon and is random wound with magnet wire. The core and bobbin are appropriately dimensioned to provide an interference fit upon assembly. The terminal end of the bobbin is arranged to support a maximum of 5 terminals; thus, it is possible to have two separate windings with one of the two tapped. Lead-in grooves are provided to guide the magnet wire from the terminals to the winding area of the bobbin without an unncessary risk of crosses or shorts.

V. CONTACTS

Much experience has been gained on various relays and in particular on the large wire spring relay with the use of various contact materials and contact geometries. The efficient field performance of the large relay has demonstrated that palladium contacts give the best all around performance on a switching device. Therefore, palladium is being used for both the fixed and moving contacts on the miniature relay.

Because of experience which has been obtained with palladium contacts where insulating polymers[4] form on the contacts when they are operated without current, a thin layer of gold is being used on the fixed palladium contact. It has been demonstrated on the large relay that a layer of gold on one of the two palladium contacts effectively suppresses the formation of polymers.[5] For manufacturing convenience, it appears to be more practical to put the gold on the fixed contact of the minature relay. As a result, the fixed contact of a fully-equipped miniature relay is made up of a 5-layer sandwich with gold on the two outer surfaces, palladium as the next inner layer on each side, and a base of nickel. This contact block is percussively welded[6] using a low-voltage process to the ends of the single wires of the relay. It has been demonstrated in the large relay that the use of percussive welding to attach a fixed contact results in a high degree of dimensional control.

The movable contacts are solid palladium and are welded longitudinally to the phosphor-bronze movable wires. The contact metal is

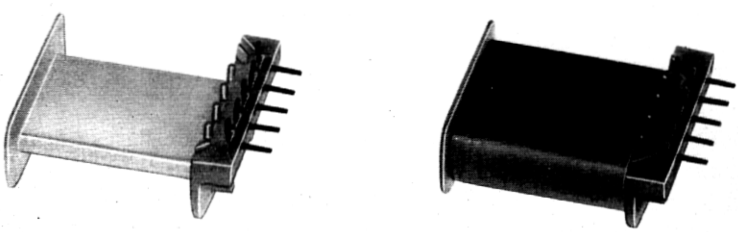

Fig. 8 — BF relay coil bobbin (left) and coil assembly (right).

long enough to bridge both the fixed contact and the operating card. By this technique, dimensional variation in the height of the contact as it affects contact gauging is minimized. It will also be seen later that this is of major importance in the maintenance of the relay. In order to insure uniformity of the mating points of the two contacts in the miniature relay, the fixed contact surface is cylindrical. This helps to minimize the possibility of open contacts caused by dust or small particles of insulating material which may stick to the contacts. Fig. 9 shows the size of the fixed and movable contacts and their relative orientation.

In miniaturizing the relay, it was necessary to have closer spacing of the movable wires than is used in the large relay. This has forced some reduction in the volume of precious metal. As a result, the miniature wire spring relay has only 2/3 of the erodible volume of the large relay. This results from the movable contacts being only 2/3 as wide as the movable contacts on the large relay. In other respects the dimensions are similar.

VI. PARTS STANDARDIZATION AND CODING

By variation of some parts, many different codes can be achieved in the BF miniature relay. Regardless of code, however, the same basic parts are used and the same basic number of pieces must be used to assemble a complete relay. A variety of codes is achieved by using different coils, varying the number of movable contacts, both make and break, varying the number of fixed contacts and using different operating cards.

The same coil bobbin is used for all coil resistances and windings. For a single wound coil only two terminals are used on the bobbin and coil resistance from 16 to 3400 ohms with a fully-wound coil can be achieved by variations in wire size. Double-wound coils with four terminals on the bobbin are used for other codes, and finally a fifth terminal can be attached to the bobbin to provide a tap for one winding if required.

Both the movable twin wires and the fixed single wires are molded in continuous strips as shown in Fig. 10 in a process similar to that used for the large relay. The long strips of contact assemblies are then cut apart and contacts provided as needed for various codes. The movable twin contact assemblies for both make and break contacts are symmetrical and the same details can be used for either purpose. When a twin wire block is coded for less than a full complement of contacts, the contact springs are clipped-off approximately 1/16 inch from the phenolic block on the contact and terminal sides. Typical assemblies of coded twin wire blocks are shown in Fig. 11. It is necessary to leave a short length of wire in the unused positions since the clamp blocks bear on the twin wires in the assembly as shown in Fig. 4.

In the single wire blocks all six wires are always provided on the contact side. This provides constant tension against the adjusting bracket as well as support for the front molded section for the wire guide slots. Contacts, however, are not welded to the ends of the wires in those positions that will not be used in a particular code. In order to minimize the use of the expensive palladium contact material, the contact block welded to the tip of the single wires can have contact metal on either side or both sides depending on the mating contacts being used. For mounting and wiring purposes, which will be discussed later, the terminal ends of all unused contacts are removed from the single wire block. Samples of several coded single wire assemblies are shown in Fig. 12.

The final part which contributes to coding of relays is the actuating card. By providing different widths for the actuating bar of the card, different sequences of contact actuations can be obtained. By using a relatively wide bar a break-before-make (EBM) transfer contact can

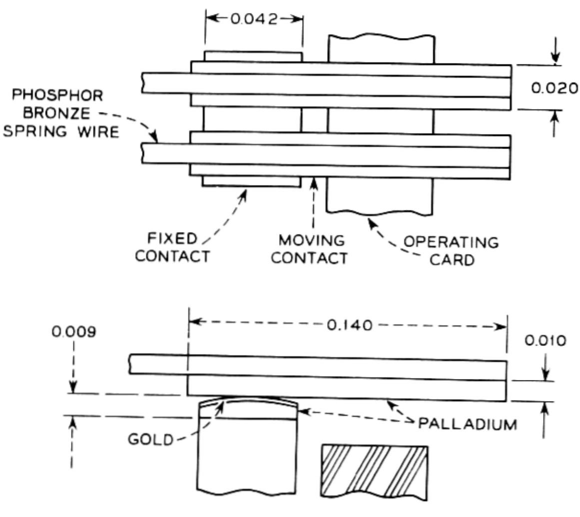

Fig. 9 — BF relay contact configuration.

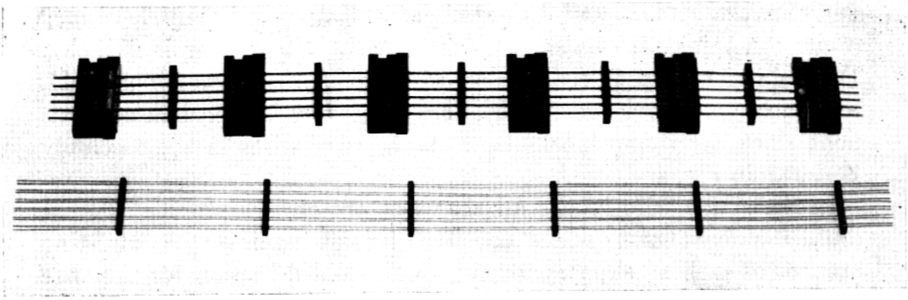

Fig. 10 — BF relay movable twin wire molded ladder (bottom) and fixed single wire molded ladder (top).

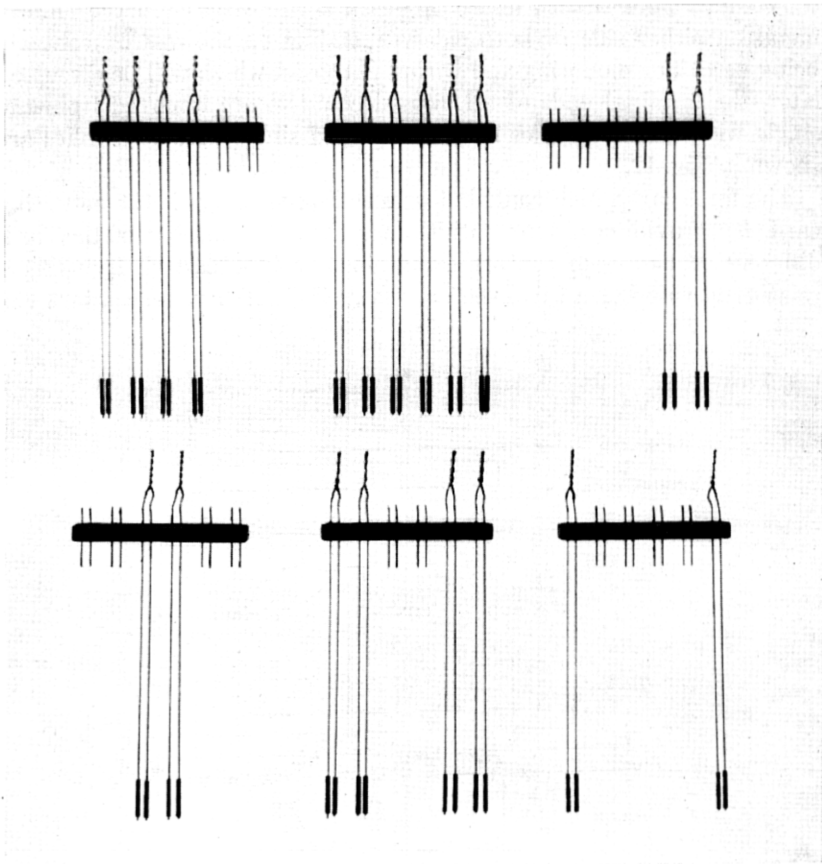

Fig. 11 — BF relay typical coded movable twin wire assemblies.

be achieved (see Fig. 5) and by using a relatively narrow bar a make-before-break (EMB) continuity transfer contact can be obtained. Also, by having different widths to the bar across the card, these different contact sequences can be obtained on the same relay.

Theoretically, it is possible to have 3^6 or 729 different operating cards, i.e., with either an EMB, EBM or a BM (nonsequenced) set of contacts in each of the six positions. This is a prohibitive number of molded cards to provide tooling and controls, therefore, eight different cards have been standardized for use in miniature relays. Whenever an early contact of either the make or break variety is required on a relay, all positions of that relay will have one early contact. This is possible since when a circuit designer specifies a simple make or a

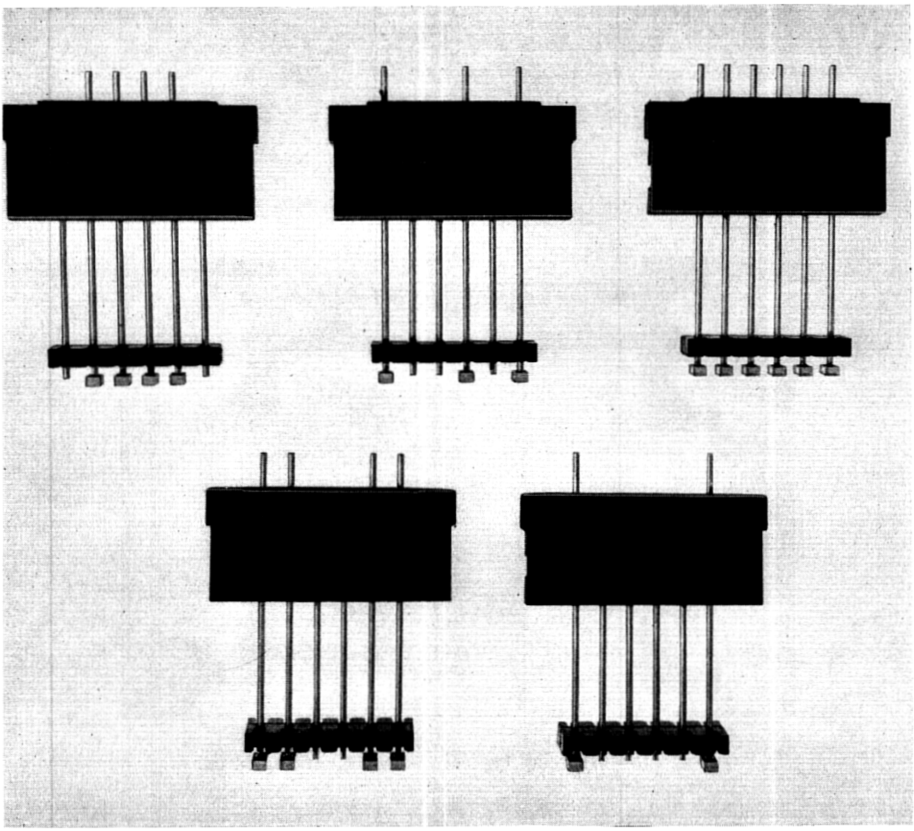

Fig. 12 — BF relay typical fixed single wire contact assemblies.

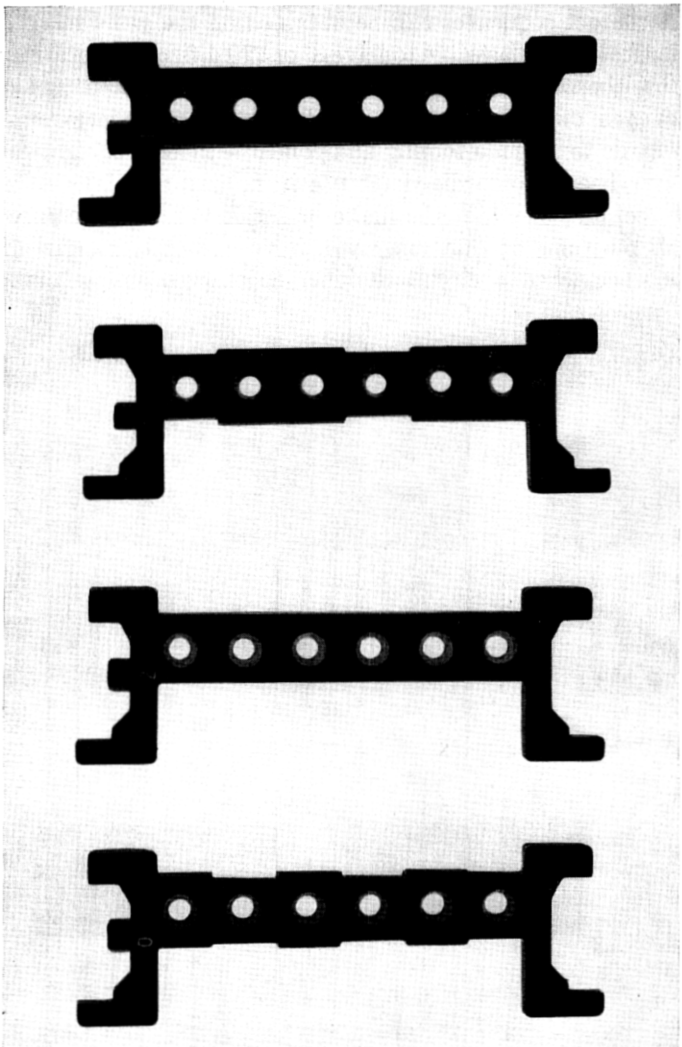

Fig. 13 — BF relay typical molded operating cards.

simple break contact, he is not concerned with where in the stroke of the relay it operates. Also, a sequence transfer can always be used in place of a nonspecified sequence transfer. Samples of several coded actuating cards are shown in Fig. 13.

VII. ASSEMBLY AND ADJUSTING

The pile-up of the BF miniature relay is designed so that the various parts are either keyed or doweled together successively on assembly. The base for the contact pile-up is the magnet core which has two dowels which locate the armature assembly and the adjusting bracket. The armature assembly is located only in a sideways direction by these dowels. The magnet coil is normally energized when the armature is assembled to the core so as to produce a minimum heel air gap between the armature and core, and the dowel holes in the hinge spring are slotted to allow the armature to assume its natural position. The adjusting bracket on top of the hinge spring has close fitting holes to locate it in both directions.

The contact assembly is built up on top of the adjusting bracket. This bracket has two dowels which serve to locate the lower deflecting block. The deflecting block in turn has an inner grove which locates the break twin wire assembly. The opposite side of the molded section of the break twin wire assembly serves to locate the single wire block by means of another groove. In the top of the single wire block, the balance spring is located by appropriate projections. Similar to the break twin wire assembly, the make twin wire assembly and deflecting block are keyed to the single wire block by means of grooves. On top of the make contact deflecting block, grooves locate the cover clamp spring and the relay clamp spring. When all of the parts are stacked in the proper order, the clamp spring is snapped into place over the pile-up to securely lock it in its proper position.

After the pile-up is assembled and clamped, the movable make and break contacts are spread apart by means of a spacer or wedge and the operating card is inserted. It is held in place as described earlier by lugs on the armature clamp bracket and the balance spring.

After assembly there are three adjustments that may be made to assure that a particular relay meets its requirements. The armature travel may be adjusted by bending the armature backstop lug. This adjustment is only required if the armature backstop detail is inaccurately welded to the front of the armature. The twist tabs on the front of the adjusting bracket are bent to position the single wire block.

By moving the single wire block either up or down in this fashion, the closure points for the make and break contacts can be varied relative to the single contacts. This allows for adjustment of the point of make or break of the moving contacts in the stroke of the armature. The third adjustment that can be performed on the finished relay is that of balance spring tension. Three different balance springs are provided for the relay. However, since a relay may have anywhere from one to six movable make contacts, it is sometimes necessary to adjust the tension in the balance spring after assembly to the specified range. It is impractical to have a balance spring for each contact combination since in addition to the variation in relay contact load, it is difficult to accurately control the pretension bends in the balance spring to the point where no adjustment is required.

VIII. PERFORMANCE

As indicated earlier the broad objective in the design of a miniature wire spring relay was to achieve as far as possible the good performance that has been demonstrated by the large wire spring relay. Therefore, in evaluating the performance of the BF relay, the large AF type wire spring relay has been used for comparison. Tests and evaluations have been made of all of the various performance characteristics of the BF relay. These studies have been conducted both on model shop samples in the course of development and production samples as they became available. In the following paragraphs, the major aspects of the relays performance will be described and discussed.

8.1 *Load and Pull Characteristics*

Fig. 14 shows a typical set of load and pull curves[7] for a BF relay with six early-make-break transfer contacts. The travel of the operating card is plotted on the abscissa and the load and pull at the operating card is plotted on the ordinate. Actually, two load curves are shown; one as measured with the relay armature moving in the operate direction and the second as the relay is released. The load curve begins at approximately 0.033 inch of travel with a load of approximately 60 grams which is the force holding the armature against its backstop. There is then a gradual build-up to approximately 80 grams at which point a very rapid change in load takes place. This rapid change is the result of the operation of the early-make contacts and takes place between 0.022 and 0.018 inch of travel in this particular case. From this point, the load again increases gradually to approximately 0.012

inch of travel at which point the break contacts open causing a rapid increase in load until the travel is reduced to 0.008 inch. From this point, until the armature strikes the core the load build-up is again quite gradual and ends with a maximum load of approximately 270 grams. The release load curve closely parallels the operating curve but is slightly lower. The difference between the operate and release curve is a measure of the mechanical hysteresis or friction of the structure. It can be seen from the curve that in the case of the BF relay this hysteresis is quite small.

Also plotted on the figure are four typical pull curves for different values of ampere turns. The 135 NI curve is the lowest of the four that does not fall below the load curve at the point of maximum travel. Thus, it can be concluded that any value of ampere turns less than 135 will not result in any motion of the armature. The 135 NI curve,

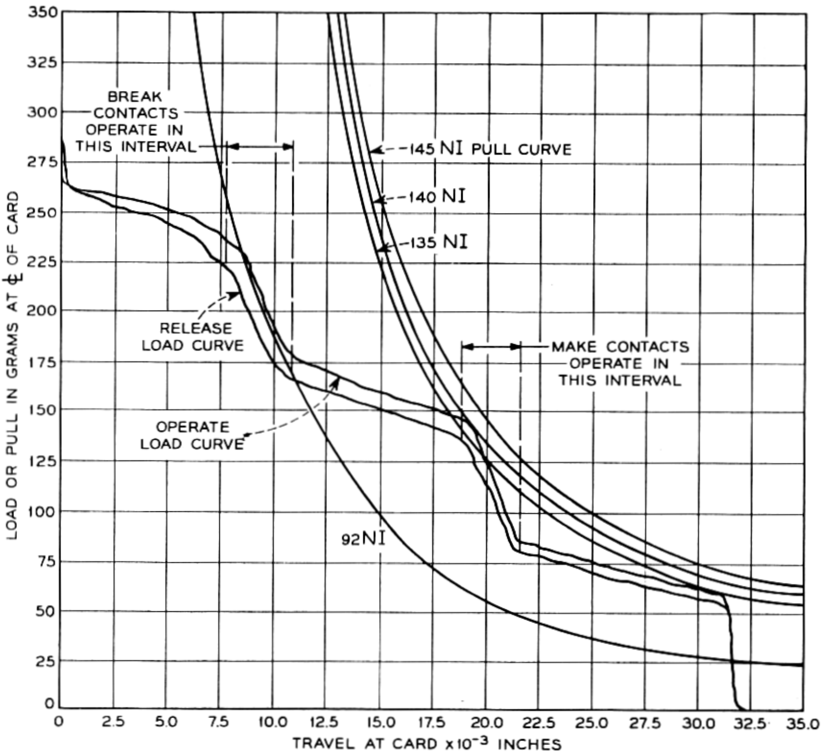

Fig. 14 — Typical BF relay load and pull curves with six early-make-break transfer contacts.

however, intercepts the load curve at approximately 0.020 inch of travel. Thus, the application of 135 NI to this relay will result in hesitation of the armature at this point in the stroke. The 140 NI curve just passes above the load curve over its entire length. Thus, the just-operate current of this relay is that current which is equivalent to 140 NI. For margin in operating, it is customary to specify a test value somewhat higher than the just-operate value; for example, in the order of 145 NI. Also plotted is a 92 NI curve which has more than sufficient pull to hold the relay operated once the armature is in contact with the core. Thus, a hold current equivalent to 92 NI would prevent this typical relay from releasing.

8.2 *Speed of Operation and Release*

The operate time of a relay structure is a function of the load, the armature air gap, and the applied power. Fig. 15 shows the operate time of three typical BF relays. The upper curve is a long travel 6 transfer contact relay with the operate time plotted versus coil input power. The second curve is slightly below the 6 transfer contact curve and indicates the effect of contact load. Long travel for the relay armature is required when the transfer contacts are of the sequenced variety such as EMBs or EBMs. The third and lowest curve in the figure is for a short travel two transfer contact relay. The only difference between the latter two curves is that with the short travel relay no assured sequence exists in the transfer contacts. This typical curve shows that with a lightly loaded short travel relay the operate time

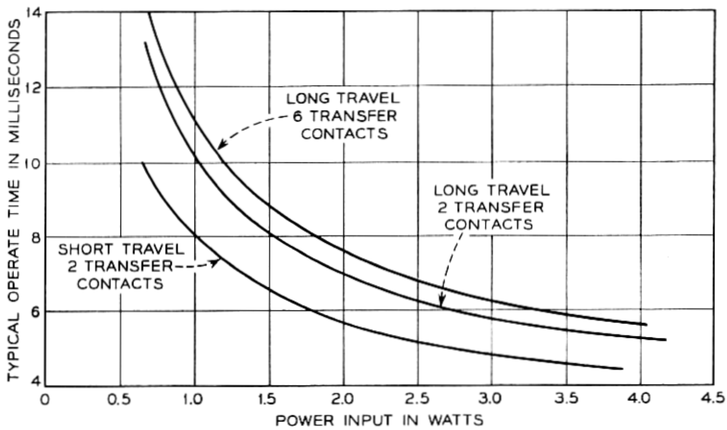

Fig. 15 — Typical operate time curves for BF relays.

will be in the order of 4.5 milliseconds with 3.5 watts input to the coil; while a long-travel heavily-loaded relay will have an operate time in the order of 11 milliseconds with 1 watt input to the coil.

Fig. 16 shows typical release time measurements for a BF relay. The two principle factors affecting the release time of the BF relay structure is the contact load and the presence of a magnetic separator in the armature-core air gap. BF relay codes are divided into two classes: one group has a 0.003-inch nonmagnetic separator in the air gap when the relay is operated, and the other group has only the chromium plating on the armature and core in the operated gap. Fig. 16 shows a very substantial difference in the release time for the two types of relays. With no magnetic separator the release time varies from approximately 15 to 10.5 milliseconds depending on the contact load while the relay with a 0.003-inch nonmagnetic separator varies from 5.3 to 4.7 milliseconds release time.

8.3 *Power Limitations*

The minimum operate power using optimum coils for the BF relay is 400 milliwatts when operating 6 early-break-make contacts and 170 milliwatts when operating 1 make contact. The maximum power that can be used to achieve maximum speed is dependent upon the coil heating characteristics.[8] In telephone switching systems, relay coils

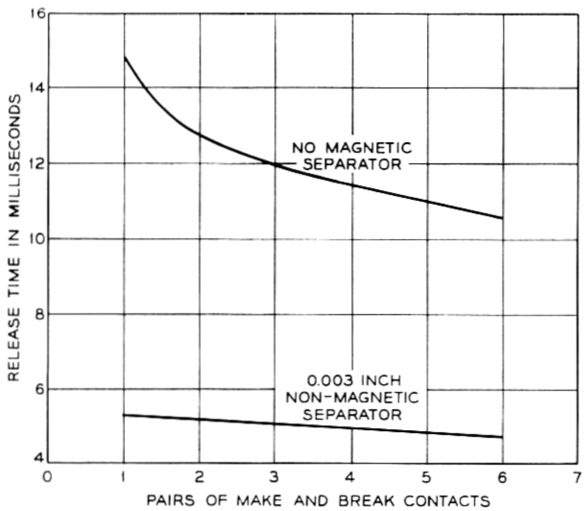

Fig. 16 — Typical release time curves for BF relays.

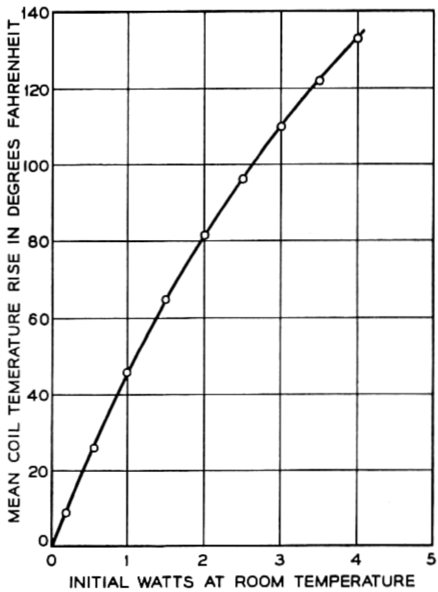

Fig. 17 — Typical heating curve for a BF relay coil assembly.

are designed to withstand an exposure to 360°F for a maximum of 48 hours of cumulative exposure. They also shall withstand an indefinite exposure to 225°F. The temperatures referred to are the mean winding temperatures. Fig. 17 shows a typical BF relay coil heating curve where input power at room temperatue is plotted versus change in mean coil temperature.

For this particular coil, an initial power input of 4 watts results in a temperature rise of approximately 135°F. To maintain a maximum temperature of 225°F at an ambient temperature of 100°F, there would be a maximum 125°F temperature rise. From the curve a 125°F rise will result from 3.6 watts of initial power.

8.4 *Contact Performance*

The use of the wire spring technique produced in the BF relay all of the proven advantages of the large wire spring relay with regard to contact performance.[2] These include such things as full twin action in the movable springs, card release actuation to prevent contact locking, cylindrical surface on one of the contacts to minimize the effective contact area that contaminants can occupy to affect contact performance. Also, the BF relay makes use of palladium contacts for both the fixed and movable members to take advantage of the long experience in the Bell System of the use of this material. In addition, one of the contact members has a 0.001-inch thick gold layer to minimize the formation of polymers.

8.5 *Life*

Life studies have been conducted on the BF relay and have shown that the mechanical life of the moving parts is at least 200 million operations. This life is limited by operating card and armature backstop wear. Replacement of the card and readjustment of the armature backstop can probably extend this life. Generally speaking, the electrical life of the contacts is determined by factors outside of the relay such as the size and inductance of the load and whether contact protection is employed. With a non-inductive load or with optimum contact protection on an inductive load, the contact life will be equal to or greater than the mechanical life of the relay. A subsequent paper will describe the development of contact protections specifically for use with miniature relays.

8.6 *Stability*

BF relays have been subjected to shock, vibration, temperature change and humidity tests to determine their stability in shipment and in use. The shock and vibration tests have used levels of severity that have been established by various military specifications for normal shipping conditions. The temperature and humidity tests have used levels of severity which have proven satisfactory for many years in the Bell System. These exposures are as follows:

Shock —30G 11-millisecond pulses with six shocks in each direction of each of the three mutually perpendicular axes or the relay.

Vibration —Cycled from 10 to 55 to 10 Hz in one minute with an amplitude of 0.060 inch peak-to-peak. Cycled for a period of two hours in each of the three mutually perpendicular axes.

Temperature—Tempreature cycles of from $-40°$F to $+140°$F.

Humidity —Six days of exposure at 90 percent relative humidity and 85°F followed by six days at 120°F dry.

When relays were exposed to this full sequence of shock, vibration, temperature, and humidity, changes in relay contact operate points of less than 0.001 inch were measured. This small change is as good as or better than that observed on AF type relays.

8.7 *Magnetic Interference*

On some older type relays, magnetic interference results when several relays are mounted in close proximity of each other. By the nature of the armature and core design of the miniature relay it was not expected that any significant magnetic interferences would result in BF relays. To establish this, a study was conducted with nine BF relays mounted in a square 3×3 pattern. Horizontally the relays were spaced 0.2 inch apart and vertically 0.15 inch apart. In this array, operation of the eight outer relays had a maximum affect on the center relay of 2 percent on the operate current and 5 percent on the release current. With normal manufacturing and using margins this amount of interference presents no difficulty.

IX. SPECIAL PURPOSE DESIGNS

Up to this point the discussion has all centered about the BF miniature wire spring relay. Early in the design it was recognized that by relatively minor modification, three other types of miniature relays could be produced. The magnetic structure of the BF relay has the capability of operating more than 6 transfer contacts. As a result, the BJ type relay (Fig. 18) has been developed with a maximum of 12 transfer contacts. This relay uses almost all of the same parts as the

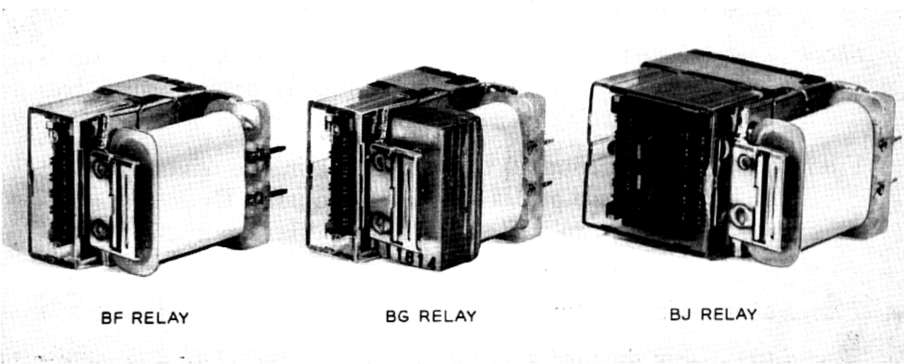

Fig. 18 — BJ relay (right), BG relay (center), BF relay (left).

BF relay. For the 12 transfer contacts, 4 twin wire assemblies and 2 single wire assemblies identical to those used in the BF relay are required. Three new parts are required for the BJ type and these are: a new cover, a larger clamp spring, and an adjusting and spacer block to separate the two levels of contacts.

By reducing the length of the coil and bobbin, copper washers can be placed on the core to provide a slow release capability for the relay. When copper washers with a short coil are used, the relay is known as the BG type (Fig. 18).

Similar to the large wire spring relay, if a semi-permanent magnetic material is used for the core and armature, a magnetic latching relay will result and this is known as the BL type. The BL relay is identical to the BF in appearance. Subsequent papers will describe the details of both the slow release and magnetic latching types of relays.

In the design of the miniature relay, it was necessary to make some sacrifices in sensitivity to achieve the small size. This has resulted in a hardship in some applications where it is necessary to work a relay in conjunction with long subscriber loops or with low current semiconductor devices. As a result a slightly larger relay has been designed and proposed for manufacture for those applications where maximum sensitivity is required. This proposal uses the same contact and pile-up parts as the BF relay but has a slightly larger core and armature to provide the increased sensitivity. It will therefore, require a slightly larger mounting area.

X. FIELD TESTING AND MAINTENANCE

As indicated earlier, the BF type relay has been designed primarily for use in telephone central office equipments. In such an environment, a relay is expected to have a long and relatively trouble-free life. However, on those occasions when relay maintenance is necessary, it is expected that they can be repaired or adjusted either in place or locally. Also, for circuit testing, it is often useful to use the relay as a test point in the circuit. In telephone central offices there normally are skilled craftsman available to perform both circuit testing and relay maintenance functions. As a result, the ability to perform all of the essential field testing and relay maintenance functions has been built into the BF relay.

Under field testing there are three major functions to be performed:

(*i*) *Contact Insulating*—For circuit testing it is often useful to the maintenance man to be able to insulate a contact to isolate a portion of a circuit. Since the twin contact of the BF relay is smooth and continuous from the contact area out over the operating card to the tip, it is possible to insert a small piece of lint free parchment paper between the fixed and movable contacts to effectively insulate them from each other.

(*ii*) *Armature Blocking*—To study circuit performance in the course of testing, it is often useful to block a relay armature in either the operated or unoperated position. The BF relay has its armature in the front and uncovered. It is thus possible to insert a simple plastic wedge-shaped tool between the armature and core to hold the relay unoperated, or between the armature backstop and the core to hold the relay in the operated position.

(*iii*) *Contact Test Points*—When the relay is blocked either operated or unoperated, or when contacts are insulated, as well as in normal performance, it is often desirable to be able to test for battery or ground conditions on relay contacts. With the BF relay cover removed, a test pick can be touched to either the make or break movable contact springs to test for potential conditions. The fixed contacts are behind the operating card, but to allow for testing, a series of holes has been provided in the movable card. These holes are located so that a test pick can be inserted to touch the end of the fixed contact.

The foregoing comprises the principal circuit testing functions that are performed on the relay. In addition to these, there are five principal relay maintenance functions which can be performed if required:

(*i*) *Contact Cleaning*—As described under contact insulating, a piece of parchment paper moistened with an appropriate solvent can be inserted between the fixed and movable contacts and moved back and forth to effectively clean the two contact surfaces.

(*ii*) *Operating Card Replacement*—In long life applications, it may sometimes be necessary to replace the relay operating card. Being of plastic, this card will probably wear more than the various metal parts. With the cover removed, a replacement card can be installed with the use of rather simple tools that have been developed.

(*iii*) *Armature Travel Adjustment*—With wear, it may be necessary in some cases to adjust the armature travel of the relay in order to keep it within its operating requirements. The backstop which is welded to the armature provides an adjustment slot. The use of a screw driver twisted in the slot will change the armature travel and thus compensate for wear.

(*iv*) *Contact Gauging Adjustment*—To permit the readjustment of the pick-up points of the make or break contacts, two twist tabs are provided at the front of the relay to change the position of the single wire contacts. By twisting the two tabs, the fixed or single contacts can be moved either up or down thus changing the point in the armature stroke where contacts either open or close.

(*v*) *Back Tension Adjustment*—Due to wear on relatively long life relays it may sometimes be necessary to adjust the armature balance spring tension. In the BF relay the balance spring is accessible from the front and can be adjusted with a spring-bending tool.

Most of these maintenance and testing features are possible in a relatively simple manner since the contacts and armature air gap of the relay are exposed. The contacts are normally covered with a transparent plastic cover. This cover is designed so that it will remain securely in place during the shipping and handling of the relay but can be readily removed with the fingers. It will be noted that a number of the maintenance and test functions require access to the contacts or contact area of the relay; thus, the cover must be readily removed when required. Special or new testing or adjusting tools have been designed to perform all of the functions described above and are available for the central office craftsman's use.

XI. MOUNTING AND WIRING

The BF relay is designed to be mounted on a printed wiring board with all of the terminals mass soldered to circuit paths. The terminal spacing is sufficient to allow for economical printed wiring board manufacture and the soldering can be performed by conventional mass soldering techniques. The relay occupies 1.081 square inches of space on a printed wiring board. Generally speaking, the minimum distance between two relays on a board is limited by the circuit paths on the wiring side rather than by the area occupied by the relay on the apparatus side. The terminals are of sufficient length to be used on both 1/16 and 3/32-inch printed wiring boards. Thus, the relay can be mounted on circuit boards in conjunction with other miniature devices such as semiconductor units.

When the relay is mounted, the core comes in direct contact with the printed board and a tapped hole is provided in the core for mounting security. It is recommended that a screw always be used to support the relay. In this fashion, strains are avoided on the soldered joints at the terminals. On a relay with a maximum complement of springs, the soldered connections do provide sufficient strength to support the relay, but even in such an application, the use of the screw is recommended for reliable mechanical strength of mounting. On relays with less than a full complement of contacts, all unused terminals are eliminated. Thus, there will be terminals on the back of the relay only in the active positions. This is done to provide the maximum flexibility in the design of the printed circuit board to which the relay is mounted.

An adapter has been designed for the relay to provide terminals for hard wiring by solderless wrapping techniques. This adapter is basically a small printed wiring board with solderless wrapped terminals inserted in it. The adapter has found great use in bread board circuits for experimental use but has not been applied in any production unit.

Equipment designers in various systems are finding many different ways of incorporating miniature relays into their units. The different equipment arrangements have resulted from different needs and are related to the other apparatus devices being used. Figs. 19, 20, and 21 show three typical equipment arrangements for miniature wire spring relays. Fig. 19 shows the line unit from the ESS 101 system. This unit has four line circuits per printed wiring board arranged for plug-in mounting. There is one BF type relay in each line circuit mounted in conjunction with other miniature components such as transformers,

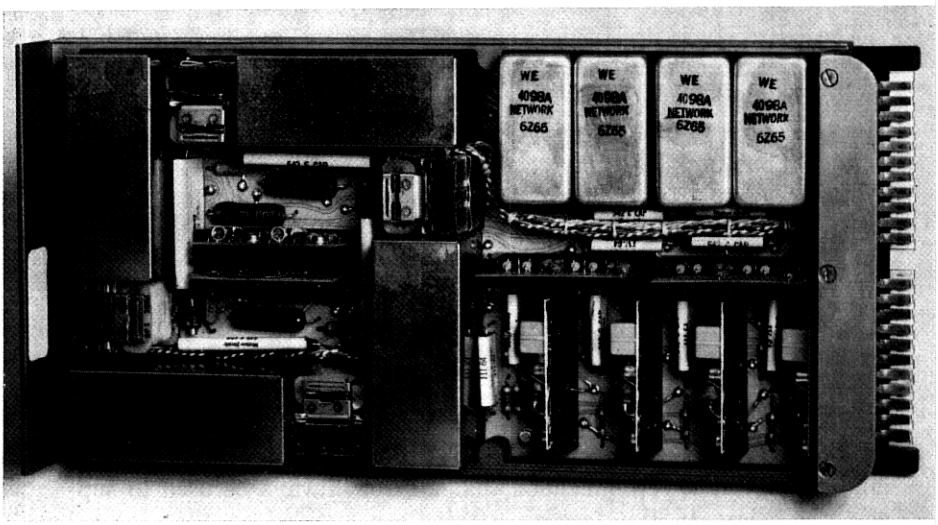

Fig. 19 — ESS 101 line circuit package with BF relays.

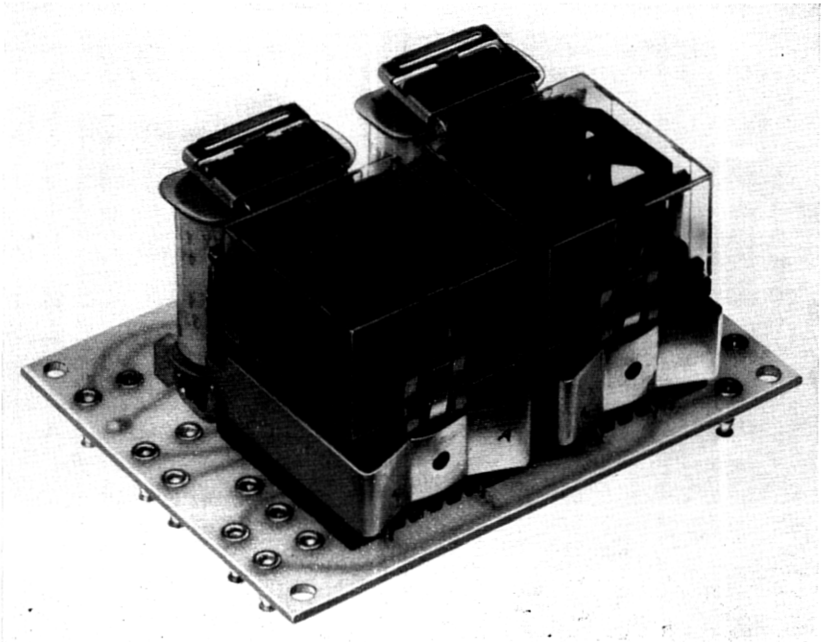

Fig. 20 — TD-3 radio alarm circuit relay unit with BJ relays.

networks, resistors, capacitors, etc. Fig. 20 shows a relay unit from the TD-3 radio alarm circuit. This unit has two BJ type relays mounted on a small board with terminals for hard wiring. This is basically a small adapter board but does provide on the wiring side for some interconnection between the two relays. Fig. 21 shows a relay board from the TSPS No. 1 system. In this unit, there are four BF type relays mounted on a plug-in board. The wiring side of this board makes provision for some interconnection between the relays with the outside connections being made on a plug-in basis. In an application of this type the number of relays on the board is limited by the printed circuit path geometry and the available number of connector positions.

XII. CONCLUSION

Up to this time, the production of BF and other miniature wire spring relays has been very small compared to the production of the AF and other standard wire spring relays. This production has been limited by the rate of introduction of the new projects which are using

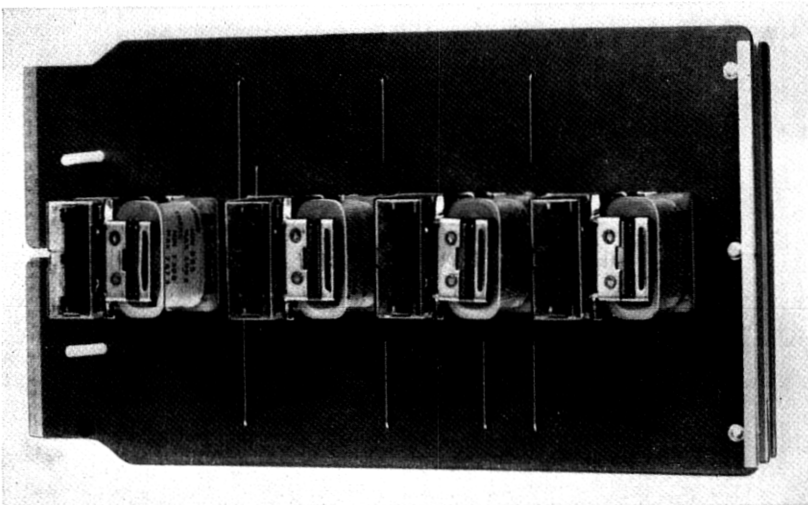

Fig. 21 — TSPS relay unit with BF relays.

the miniature wire spring relays. As of July, 1966, 31 different miniature wire spring relays had been coded for use in 12 projects. Also, work is in progress to apply these relays in other projects where there is a need for miniaturization.

XIII. ACKNOWLEDGMENT

In preparing this paper, I am acting as spokesman for numerous people who have contributed to the design, test, and manufacture of the BF relay. In particular, credit is due to A. L. Jeanne for the mechanical design and to A. K. Spiegler for the magnetic design. The development and the preparation of this paper has all been with the direction and encouragement of H. M. Knapp. Finally, the smooth introduction of the BF relay into production has been made possible by the cooperation of the Western Electric Company engineering staff at the Columbus Works.

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