A New Multicontact Relay for Telephone Switching Systems

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The trend in new telephone switching systems toward faster operation, longer life and lower cost, indicates a need for faster and more capable control circuits. This paper describes a new high speed wire spring multicontact relay designed primarily for these applications. The basic unit contains 30 make-contact pairs. Two variations of the new design provide relays of 60-contact capacity. They are mechanically and electrically interchangeable with all crossbar system multicontact relays.

INTRODUCTION

In a modern dial telephone central office, many thousands of momentary intraoffice control connections are made daily between the various parts of the switching equipment. For example, in the No.5 crossbar system, seven major types of connectors[1] are used to associate markers[2] with other common control circuits, and with the switching frames, for brief intervals, to assist in setting up the talking connection. Connectors are required to simultaneously close a large number of circuit paths, as many as 240 in the trunk link connector. The earlier flat spring type multicontact relays[3] used for this purpose provide large blocks of contacts per relay and provide an economical means for common or multiple wiring.

The trend in new improved switching systems toward longer life, faster operation, lower cost and reduced maintenance, indicates a need for faster and more reliable connector circuits. This paper describes a new multicontact relay, designed primarily for these applications. It is a wire spring relay incorporating the improved manufacturing processes and many of the design features of the new general purpose wire spring relay.[4] The basic unit, Fig. 1, for use in new equipments, is a high speed 30-contact pair relay, with wiring terminals arranged for horizontal multiple connections.

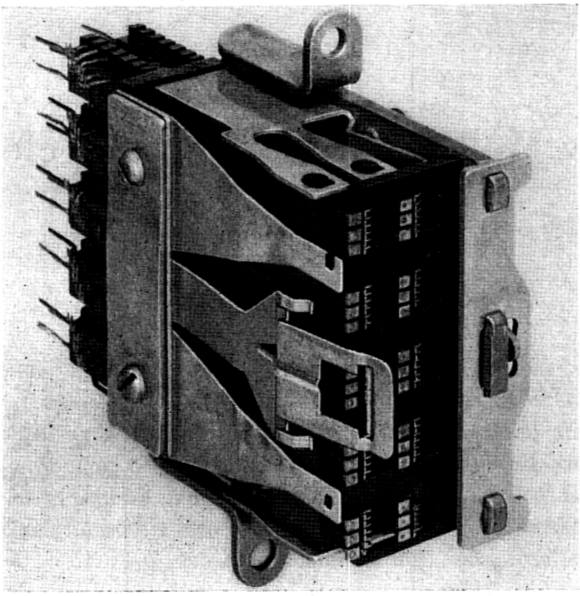

Fig. 1 — New 30-contact relay with contact cover detached.

This development also includes two modifications of the new wire spring relay for replacement use and for additions in existing crossbar equipments. They are 60-contact pair relays, each consisting of two 30-contact units attached to a common mounting bracket. They are completely interchangeable with existing crossbar system multicontact relays. When a new improved relay is developed, it is almost invariably necessary to continue in manufacture and carry in merchandise stock, small demand codes of the old relays for many years. In this case, however, manufacture of the old multicontact relays will be discontinued and all future needs will be supplied by the new product.

OBJECTIVES AND REQUIREMENTS

At the start of the project, all requirements from the standpoint of operating performance, circuit design and equipment use, were prepared in detailed form. The principal design objectives are summarized as follows:

Electrical and Mechanical

1. Operate and release times as fast as economically possible.
2. Forty year life, or 200 million operations, with no adjustment necessary during the first 100 million operations.

3. No contact chatter.
4. No false actuation due to armature rebound.
5. No magnetic or vibrational interference.
6. 120-ohm and 275-ohm coils, to work with equipment already in use.

Equipment

1. Lower manufacturing costs.
2. Reduced mounting space.
3. Terminal arrangement for multiple wiring same as at present, or equivalent from a wiring standpoint.

Maintenance

1. Contact failures due to dirt or insulating films should be substantially equal to and preferably less likely than in the present relay.
2. No contact locking due to contact erosion.
3. Contacts should be replaceable in the field.
4. Coil winding should be replaceable in the field.
5. Field adjustment should be reduced to a minimum.

Replacement Relay

The design objectives also included modification of the new relay, if possible, to replace multicontact relays in existing crossbar equipments.

Design History

During the early stages of this development, considerable effort was directed toward improving the present flat spring multicontact relay. Later, many experimental models were constructed, to investigate other flat spring, and wire spring designs, and several contact actuating methods. The most favorable designs of flat and wire spring multicontact relays were compared, and their differences were resolved by an analysis of manufacturing tolerances and their effect on performance and cost. Preliminary estimates of initial cost were only slightly in favor of the wire spring design. However, the wire spring relay offered significant advantages in (1) higher speed, longer life, less chatter, (2) better manufacturing control of tolerances, (3) less maintenance, and (4) possibilities of future cost reductions as further improvements are made in mechanized methods of manufacture.

DESCRIPTION OF THE NEW RELAY

General

Stationary single wire and moving twin wire spring subassemblies are arranged in alternate layers attached to the core and mounting

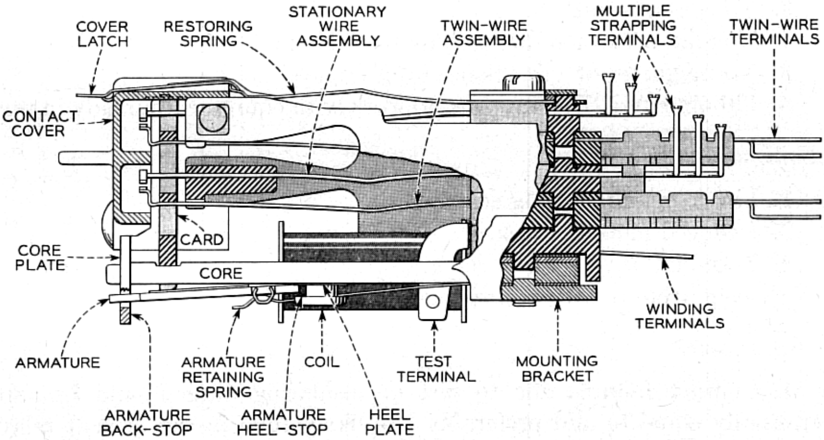

Fig. 2 — Top view of relay showing location of parts.

plate, as shown in Fig. 2. The wire spring assemblies form two rows, each containing 15 make contacts. Each contact pair consists of moving twin contacts on separate twin wires, associated with a single stationary contact. The stationary springs are supported close to the contacts by arms extending from the bracket. A detailed view of all parts and subassemblies for a 30-make contact relay is shown in Fig. 3. Moving contacts are pretensioned by relatively large pre-deflections as shown in Fig. 4. The method used in flat spring multicontact relays to obtain contact force is illustrated for comparison. It is apparent that contact force obtained by the "buckle" method depends on operating stud length and therefore is subject to change due to wear. The new pretensioned wire springs are supported and actuated by a single molded phenolic card by the "card release" method as illustrated in Fig. 5. In the unoperated position, the card is held against the core by a restoring spring, which also supplies the force to open all contacts. In the operated position, the armature supplies the force to move the card, releasing the twin wires and closing all contacts. This method of actuation has some important advantages:

1. Contact force is essentially independent of gauging and wear.

2. The effects of wear at points in the relay which affect gauging are compensating to some degree, and therefore tend to minimize changes in gauging.

3. Dimensional variations controlling contact separation and armature travel are reduced, making possible shorter armature travel, faster

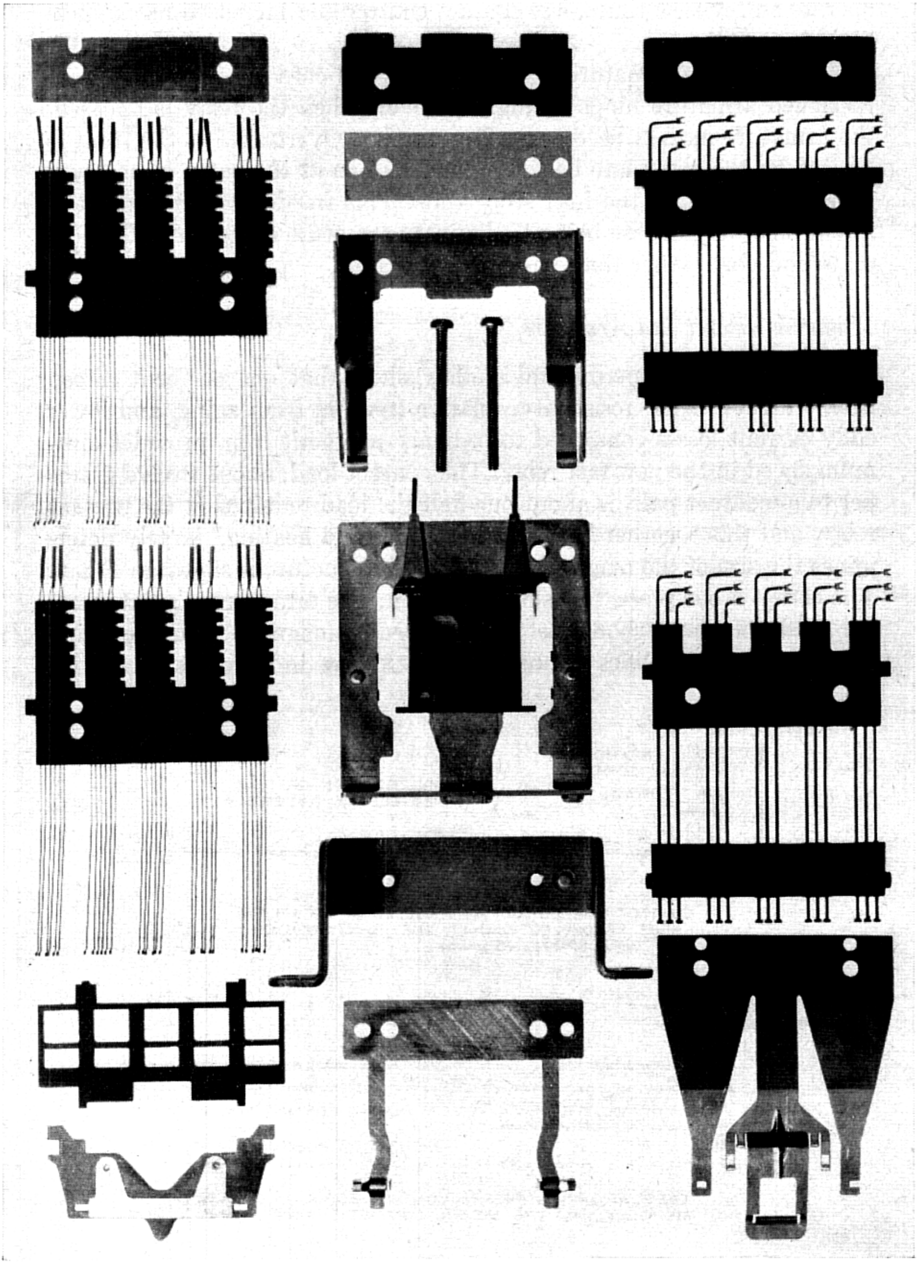

Fig. 3 — Parts of the new 30-contact relay.

operate and release times, less contact chatter and increased mechanical life.

Normally, the armature is held against the card by the lightly pretensioned armature hinge spring. However, when the relay is released, the armature motion becomes quite complex. Overtravel at the front is limited by the core plate backstop, and motion at the back, or heel sections, is limited by the heel stop studs. This freedom of movement is intentional, its purpose being to dissipate armature energy into the core plate and core rather than back into the card.

Magnetic Circuit and Armature

Analytical and experimental studies[5] show that one per cent silicon iron, with its higher resistivity, relative freedom from aging, and lower eddy-current losses compared to ordinary magnetic iron, provides optimum speed in the new fast relay. The contact load, about twelve grams per twin contact pair, is about one-half the load required in the present relay, and this together with winding space and heating,[6] largely determines the size of the magnet. The magnetic structure is shown in Fig. 6. The core is a one piece "E"-shaped section. The armature is a flat member made of low carbon steel having specific magnetic characteristics. This material simplifies manufacture, resulting in a cost saving with

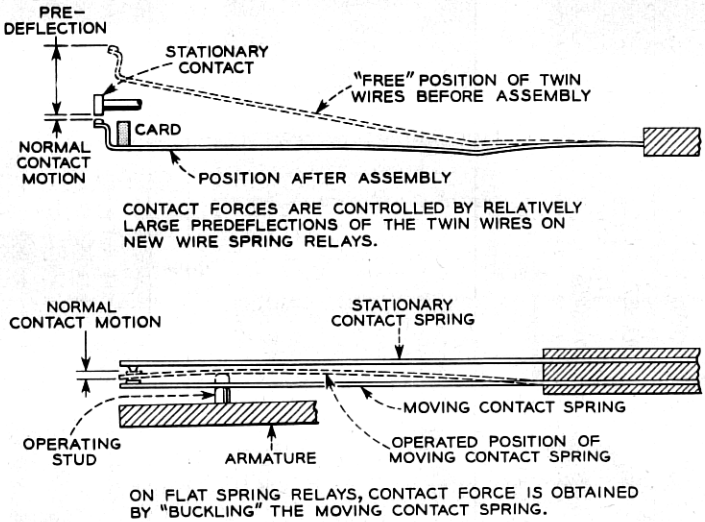

Fig. 4 — Development of contact forces in wire spring and flat spring multicontact relays.

no appreciable penalty in performance. The armature has adequate sections to carry the flux, optimum poleface area and lowest possible mass. Two small rectangular holes in the armature locate the base of the card in the horizontal direction only. The card is located vertically by the restoring spring as illustrated in Fig. 1. Fast release is obtained by a nonmagnetic separator strip, welded to the face of the armature. This strip also provides a smooth supporting surface for the molded card. Negligible wear at this critical point contributes materially to long life and stable adjustment of this relay.

A cellulose acetate filled coil[7] is assembled to the center leg of the core. A nonmagnetic core plate, illustrated in Fig. 7, is then forced over the three core legs to hold them in alignment. The center hole in the core plate also functions as an armature backstop and permits a certain amount of overtravel of the armature when the relay is released.

Coil Assemblies

For circuit reasons, 120-ohm and 275-ohm coil resistances used in the old relays are required in the new relays. Nominal power savings which ordinarily would result due to an improved magnet and reduced load, are therefore sacrificed in the new relays in favor of increased speed. More than half of the new relays are expected to be used in circuits requiring maximum speed of operation and will, therefore, have 120-ohm

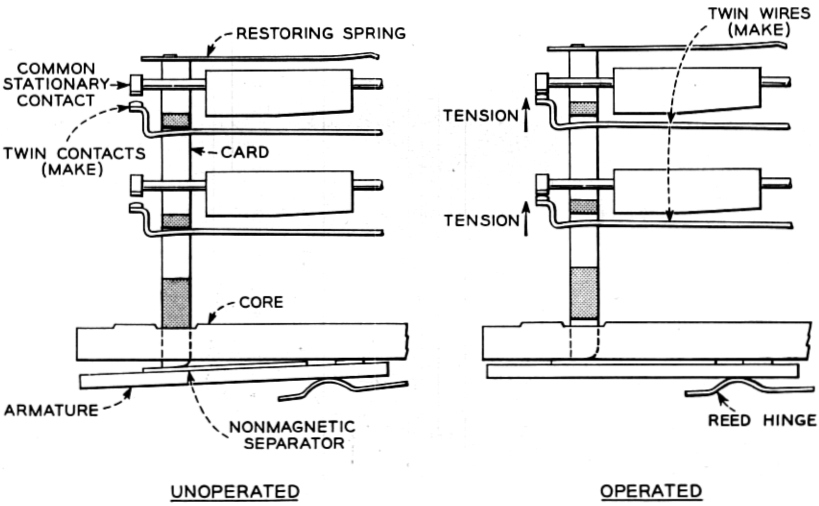

Fig. 5 — Principal of contact operation.

coils. In normal operation, these relays are not energized continuously, but operate only for short intervals while a talking circuit is established. The design provides for replacement of a coil winding in the field, but this is not expected to be necessary except in rare cases.

Molded Wire Spring Subassemblies

Wire spring subassemblies for a 30-contact relay are shown in Fig. 8. The two single wire subassemblies differ only in their terminal arrangement. The twin wire subassemblies are identical. Therefore only three basic molded parts are required which supply all needs for all new production relays. The wire spring sections are molded in continuous ladders[8] as in the general purpose relay. Spring bending, contact welding and coining[9] and terminal forming for solderless wrapped connections,[10] are performed in automatic tools developed by Western Electric Company engineers. A comparison of the wire spring parts used in two new 30 make relays and the corresponding parts of a 60-make flat spring relay, is shown in Fig. 9. This illustrates the reduction in parts and simplicity of wire springs compared with flat springs. Seven types of subassemblies are used in the twelve layers required for an equivalent flat spring relay.

Terminals of the single wire subassemblies are formed for multiple wiring, and therefore differ in length and configuration. An improved

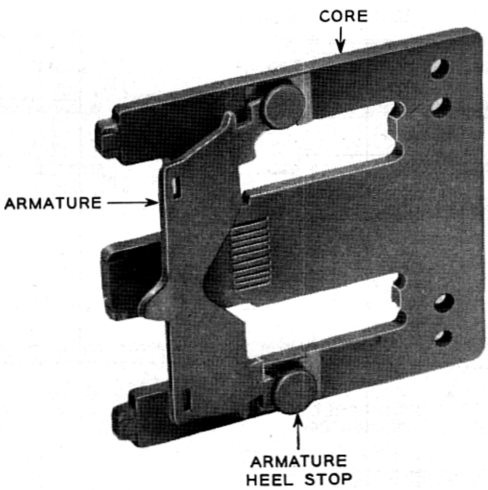

Fig. 6 — Magnetic structure of the new relays.

form of open wire multiple strapping has been developed for use with this terminal arrangement. It consists of bare wires held together in ladder form by means of phenolic plastic blocks molded successively in a continuous process. Fig. 10 shows relays with ladder type horizontal strapping soldered to the single wire terminals. The usual cable with new solderless wrapped connections is used on the twin wire terminals. Fig. 10 also illustrates the accessibility of multiple connections provided by locating them off to one side in the clear area between cable groups.

Contacts

All contacts in the new wire spring relays are palladium having a volume of contact material suitable for forty years life. This is equivalent to about 200 million operations for relays in high usage circuits. Contacts are easily visible, readily cleaned and may be insulated for test purposes.

Contacts may be replaced in the field if necessary using Bell System field welding equipment.[11] Suitable tools and electrodes have been developed to permit use of this equipment on all wire spring relays.

Assembly and Adjustment

The relay pile-up is securely fastened by two high tensile screws and a spring compliance member. Laboratory tests show that a pile-up of

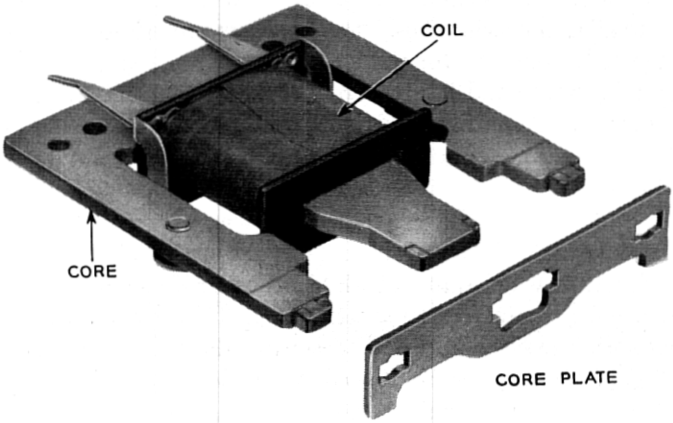

Fig. 7 — Core legs are held in alignment by the core plate, which is forced on the ends after the coil is assembled.

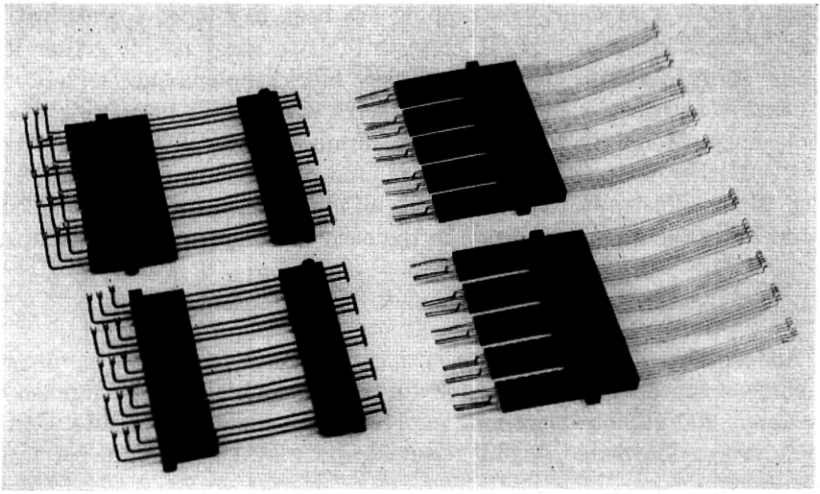

Fig. 8 — Molded wire assemblies for a 30-contact relay.

this design will remain tight under widely varying atmospheric conditions.

In the design of the new relay considerable attention was given to manufacturing control of tolerances, with reduced assembly and adjustment costs as an objective. The molding process provides dowels for aligning the four layers of contact springs, trunnion supports to locate the single wires, and control grooves in the single wire subassemblies to align the twin wires. These features provide accurate registration for mating contacts, for the location of wire subassemblies relative to other relay parts and for the pretensioned restoring spring which in turn locates the actuating card in relation to the operating contacts. The card determines contact separation of all twin moving contacts in relation to their respective single stationary contacts. Due to these controls, and because the pre-deflected twin wire springs require no adjustment of contact force, no factory adjustments are anticipated except on relays which fall outside acceptable limits for back tension or contact gauging (or follow) as assembled. If necessary, therefore, the restoring spring may be adjusted to control the armature back tension. Contact gauging may be controlled if required by independent mass adjustment of the single wire contact rows. Fig. 11 shows this operation being performed by bending the bracket arm using a tool designed for this purpose. The mass adjustment feature is expected to simplify field maintenance practice.

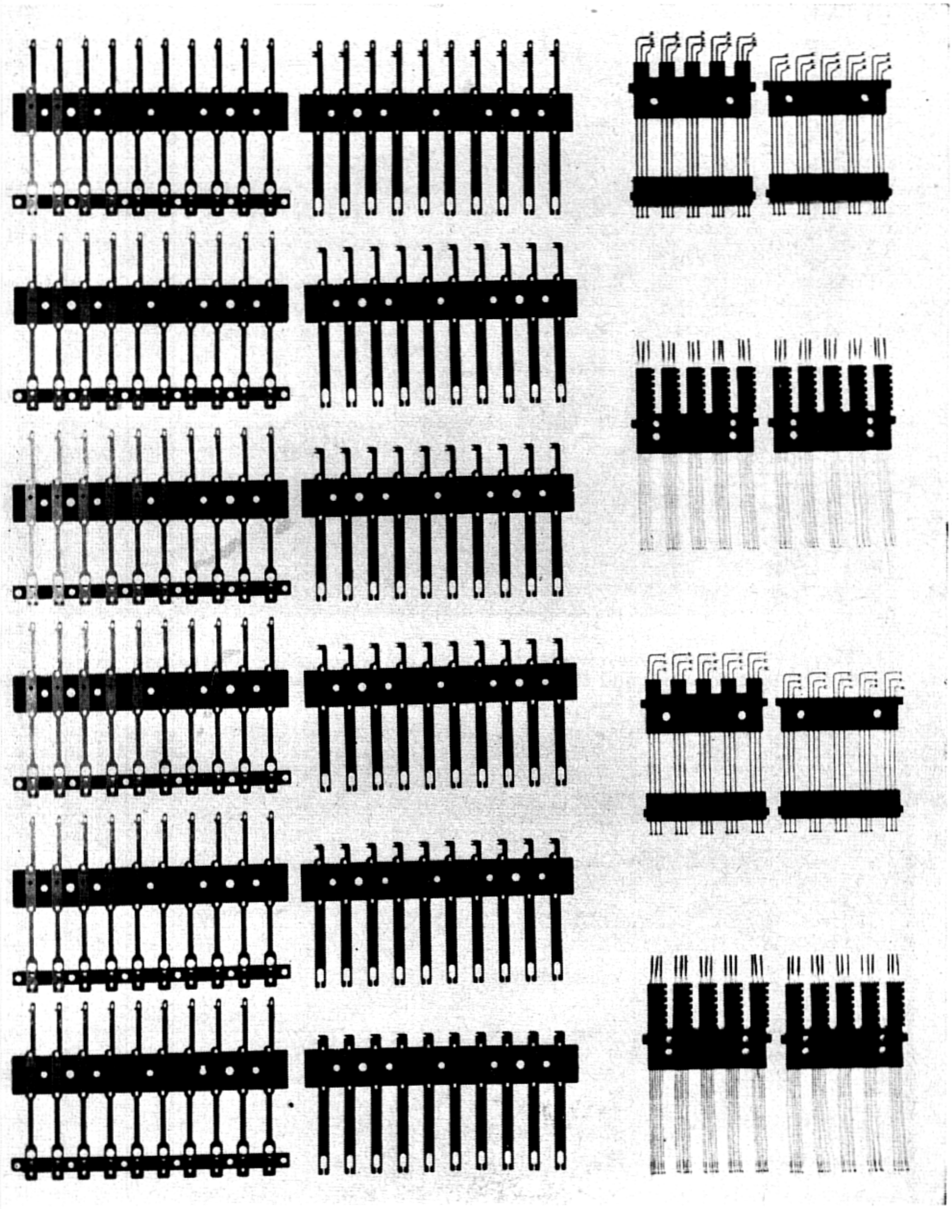

Fig. 9 — A comparison of molded wire assemblies for a 60-contact replacement relay with the corresponding flat spring relay parts.

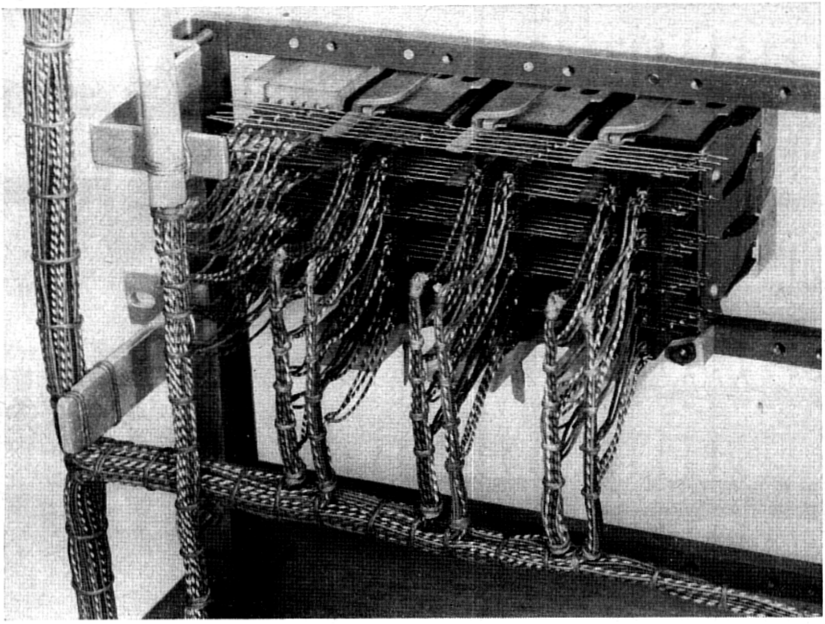

Fig. 10 — New 30-contact relays showing multiple wiring by the new ladder type strapping method, and the new solderless wrapped cable connections.

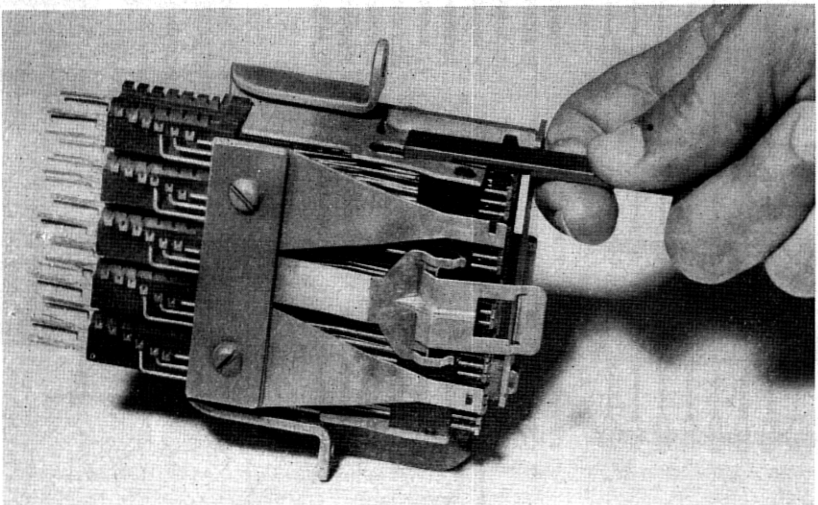

Fig. 11 — New 30-contact relay showing method of mass adjusting stationary contacts.

Replacement Type Relays

Future replacements of flat spring multicontact relays in existing crossbar equipments for maintenance reasons require a slightly modified form of the new relay, capable of complete interchangeability. As these relays are commonly used in connector circuits, operate and release times must be comparable with older type relays in order to avoid circuit interference. This was accomplished in the new wire spring relay with only minor changes in design and in the manufacturing process.

As illustrated by Fig. 12, the interchangeable or replacement relay consists essentially of two 30-contact units assembled on a common mounting bracket having the same vertical mounting centers as the 60-contact flat spring relay. Since horizontal mounting space required by the new relay has been reduced, the 60-contact wire spring unit may also be used to replace 30-, 40- and 50-contact flat spring multicontact relays. The model shown in Fig. 12 has terminals arranged for horizontal multiple wiring. In another variation of the replacement relay all terminals are arranged for cable wiring.

Modifications necessary to slow down the new relays for replacement use are (1) longer armature travel, requiring a different card; (2) an armature of larger mass — although this is a different piece part it has the same contour as the armature for the fast relay and may be punched in the same tool setup; (3) a core of low carbon steel in place of the one per cent silicon iron used in the high speed relay; (4) a leakage reluctance shunt element shown in Fig. 13 to by-pass a portion of the total magnetic flux; and (5) coil windings having resistances of 120 and 275 ohms as required for circuit reasons, but having the number of turns calculated for slower speed consistent with reliable operating capability.[12]

Relay Performance

Measurements have been made on laboratory-built models carefully prepared and adjusted to simulate extreme ranges of manufacturing tolerances, and more recently, on representative samples of pre-production relays. Although some of the performance characteristics studied will be determined accurately only after long-term use in the field, it has been possible by designed experiments and comparative tests, to obtain a fair appraisal of relay capability. These tests and measurements indicate that design objectives stated earlier in this paper have been substantially achieved.

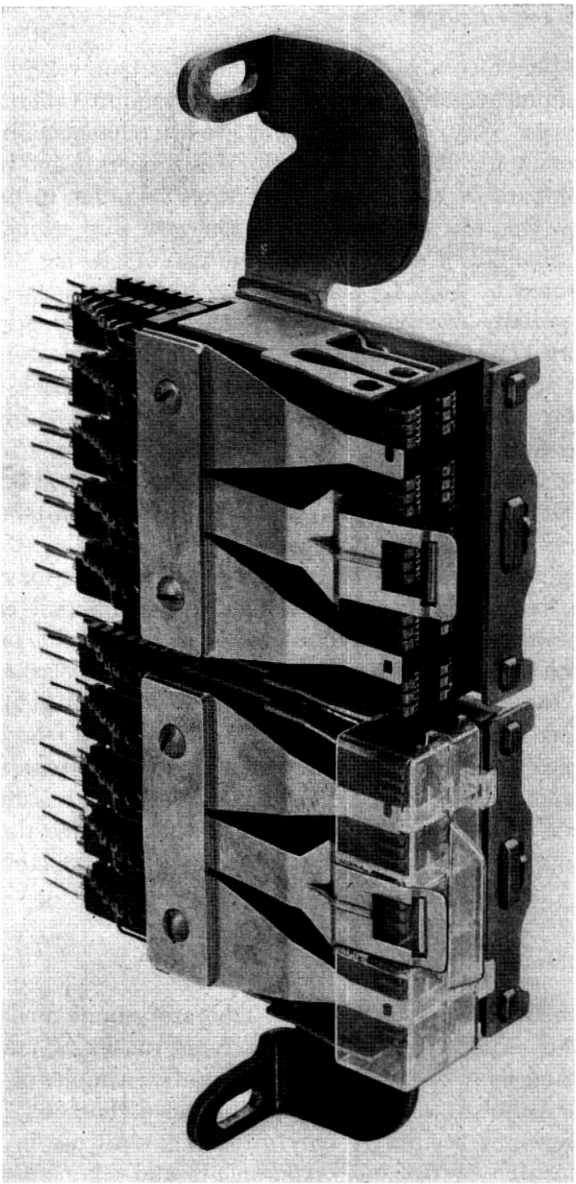

Fig. 12 — A 60-contact replacement relay with one contact cover detached.

Load and Pull Characteristics

Load and pull curves are measured under essentially static conditions. Spring load and armature motion are both observed at the center line of the card. They are measured and simultaneously recorded in chart form in a modification of a tensile testing machine.[13] A typical load and pull chart is shown in Fig. 14. The abscissa shows armature motion, as the armature moves the card and the spring load, through a distance of 0.030 inch to the operated position, and back again. The ordinate shows spring load on the armature on both operate and release, and also the magnetic pull which is developed in the armature for various numbers of ampere turns in the winding.

The load and pull chart provides a comprehensive picture of over-all relay performance. For example, starting from the released position, the force or back tension, holding the card against the core is about 140 grams. Following the upper curve, the spring load increases slowly as the armature moves toward the core, until the first contacts make at a load of about 200 grams. The load increases rapidly as the remaining contacts are closed until the last contacts are closed at about 650 grams. Further travel of the armature to the operated position increases the spring load to a final value of about 700 grams. As the armature is allowed to return to the original position, the lower curve is traced. The area between the two curves is a measure of mechanical hysteresis, or friction, in the relay. This energy loss is a very small fraction of the spring load at all values of armature travel.

The pull curves show ampere turns necessary to assure operation of

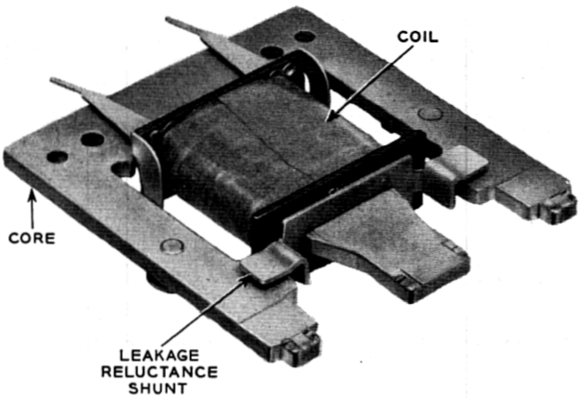

Fig. 13 — Core assembly for replacement type relays showing leakage reluctance shunt.

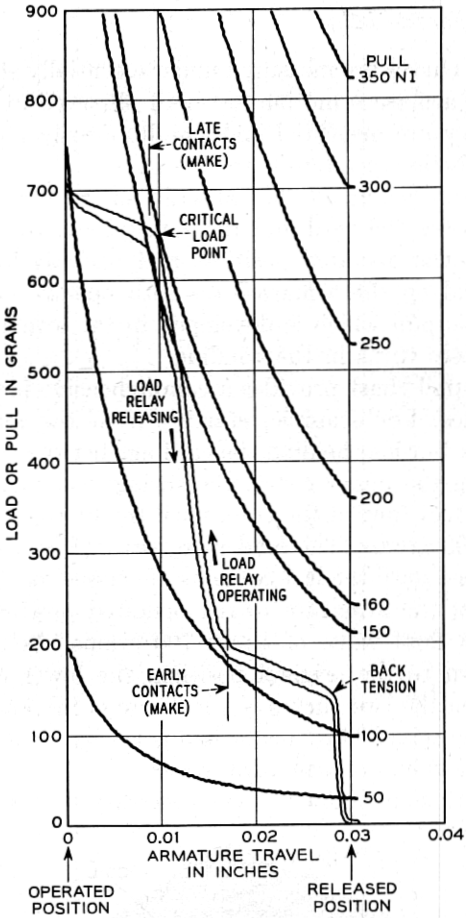

Fig. 14 — Typical load and pull characteristics of a 30-contact fast relay.

the relay. The maximum ampere turns required are determined by the "critical load point." This occurs at 0.010 inch armature travel and about 650 grams. Under static conditions, therefore, 160 ampere turns would be required for complete operation. Circuit uses for these relays do not include nonoperate, hold, or release requirements. This information could however be obtained from the pull curves in a similar manner.

Operate and Release Speed

The new high speed multicontact relay operates two to three times as fast as its predecessor, the flat spring type relay. Operate and release

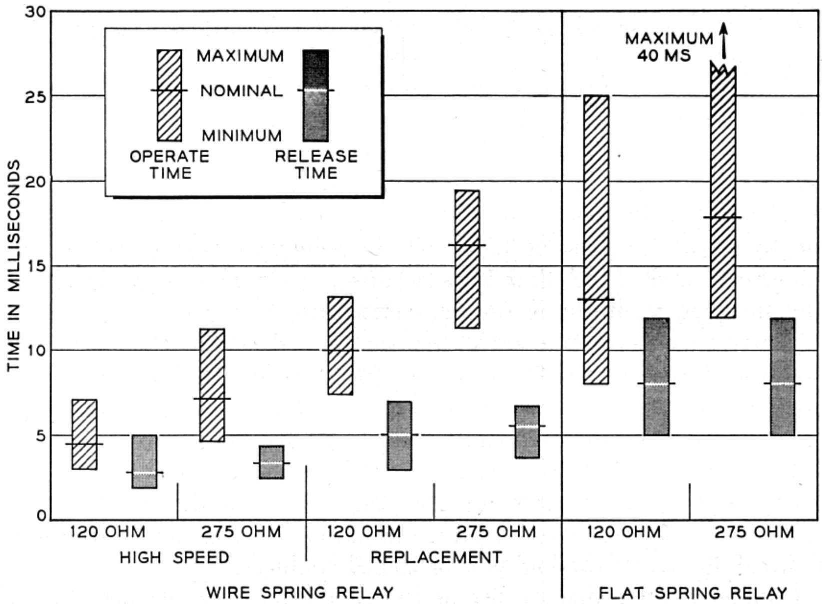

Fig. 15 — Comparison of operate and release times of wire spring versus flat spring multicontact relays.

times are shown in Fig. 15. The improved performance of the new relays is shown by nominal operate and release values, and also by greatly reduced spread, or difference between minimum and maximum values, as compared with corresponding data for flat spring relays.

Minimum operate times of the replacement and existing flat spring relays are comparable. It will be noted however, that operate and release time spreads are much less in the new relay. This generally should improve the operation of existing crossbar circuits as new relays are used for replacements or additions.

Contact Performance

As speed increases, relays and other switching mechanisms become more susceptible to false operation of contacts. It is obvious also that faster operation adds to life requirements and therefore extends the period or increases the number of operations during which trouble-free contact performance must be provided. For these reasons, extensive studies were made of chatter, unprotected erosion, and locked contacts as applied to the new multicontact relay. Additional longer range tests are planned to study protected contact erosion and susceptibility to open contact failures.

When contacts of the new high speed relay are operated, initial chatter does not normally exceed 0.1 millisecond. There is no shock chatter caused by spring vibration due to impact of the armature with the core or backstop. There is no chatter caused by hesitation of the armature in its travel at the point where it picks up the contact load. This is due largely to the low mass of 0.020 inch diameter twin wires, the low mass and short travel of the actuating mechanism, the type of card operation, and the rigid mounting of the relay structure.

Electrical erosion of contact material is reduced in the new relay, because of the reduction in chatter. For this reason, the contact size provided is expected to be adequate for all normal use for the life of the relay, and contact maintenance should be greatly reduced.

Locked contacts are substantially eliminated in the new relay by the single card release method of operation. Static and dynamic forces associated with the restoring spring and card system are powerful enough to break loose any random pair of locked contacts.

Contact failures due to dirt or the formation of insulating films on the contacts are difficult to check in laboratory tests. Long-term accelerated tests are necessary, with a large test sample, under carefully controlled dust conditions. Many precautions were taken in the design to minimize failures from this source, as follows: (1) a dust cover, Fig. 16, encloses the contacts, but does not enclose the coil; (2) the cover partially segregates the contacts in groups of three pairs of contacts, reducing air movement in the vicinity of the contacts; (3) palladium contact material is used on all relays; (4) twin contacts are coined — the rounded surface reduces the area in contact, effectively restricts the area which may trap lint or other foreign matter, and increases contact pressure; (5) card release actuation and wire springs with large predeflections insure that no appreciable loss of contact force will occur due to age or erosion; and (6) twin contacts are attached to completely independent wires.

Rebound chatter is another form of false operation which occurs in the form of contact reclosures caused by rebound of the armature after striking the backstop when the relay is released. Fundamental studies were made of rebound behavior in relay structures[14] and various models were constructed and measured. As a result there is no rebound chatter in the new high-speed wire spring relay within the range of normal adjustment. A comprehensive survey was made to determine the probability of reclosures due to rebound, in relays having limiting adjust-

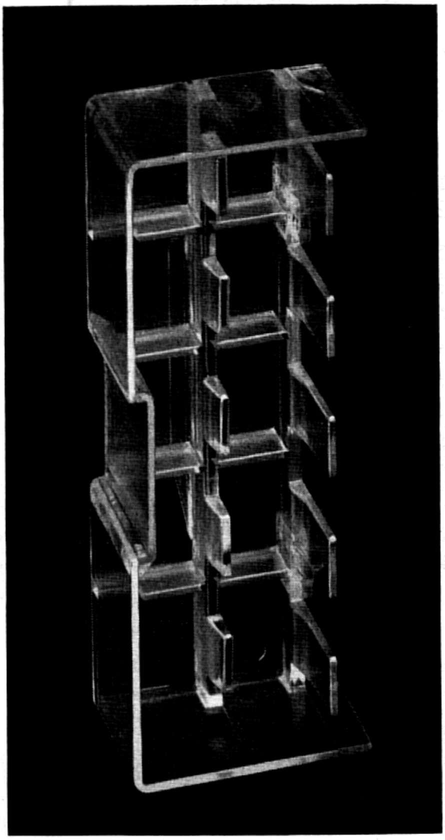

Fig. 16 — Contact cover for the new relays showing compartments in which contacts are grouped.

ments. The probability of reclosures exceeding one millisecond duration is estimated as one in 28,000 relays. This grade of performance is due primarily to: (1) an armature having low travel and the lowest possible mass; (2) an armature suspension designed to dissipate rebound energy into the core plate and core rather than into the actuating card; and (3) a stiff mounting bracket to reduce the natural amplitude of core vibration due to armature impact on operate and on release.

Life

Less than 5 per cent of the new multicontact relays will be required to operate more than 100 million times in crossbar systems during an estimated life term of forty years. Life tests show that no readjustment should be necessary during the first 100 million operations. The tests also indicate that not more than a small percentage of relays will require readjustment prior to an estimated maximum life of 200 million operations. In extreme cases, still greater life may be obtained if required, by replacing the molded card. This is an inexpensive part and replacement is easily accomplished.

Stability

When the new relays are exposed to extreme temperature and humidity cycles, the greatest change in contact separation is, in general, about 0.004 inch, and only a small percentage of relays are likely to be used in this manner. Tests indicate that changes of this magnitude leave adequate margin for 100 million operations before readjustment is necessary.

For economy, most equipment is shop assembled and wired on a frame basis, and shipped complete, ready for installation as equipment units. It is important, therefore, that apparatus units should be capable of withstanding physical shock far in excess of normal usage. Design features in the new relay which provide an adequate margin of safety in this respect are: (1) a rigid mounting bracket; (2) the wire spring pile-up is attached securely to the bracket with two specially heat treated steel screws; (3) the cover is held in place by the bending moment of an embossed section of a spring clip with a force many times greater than the compressive force of a single spring; and (4) guard surfaces molded in the cover prevent twin wires from leaving their respective guide notches in the single wire combs.

Excessive shocks during shipment have, at times, damaged flat spring relays by bending their brackets. The new relays have been subjected to shocks of similar magnitude without damage.

Magnetic Interference

Under certain marginal conditions, a relay may be affected by leakage flux from adjacent relays entering its magnetic circuit, and changing its operate and release values. Tests show that interaction is negligible between the new relays and also between new and old type relays when they are used in adjacent positions.

CONCLUSIONS

The new 30-contact relays provide faster operate and release times, longer life, improved contact performance, reduced maintenance, and greater adaptability in new circuit and equipment units than previous multicontact relays. The new relays also require less vertical and horizontal space in new equipments. As a result of these improvements, substantial savings are expected when these relays are used. The design includes many features which permit the use of mechanized manufacturing processes, which, in turn provide better control of tolerances. For these reasons, lower initial costs are expected as manufacturing and assembly methods continue to improve.

The new 60-contact relays are completely interchangeable with all codes of flat spring multicontact relays in existing crossbar equipments, and in addition, they provide superior performance, longer life and reduced maintenance. Therefore, manufacture of the flat spring multicontact relays will be discontinued as soon as new relay production becomes adequate for all uses.

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